Time	Cavaniglia	Spadolini 001	Spadolini 002	Spadolini 101	Spadolini 102	Spadolini 103	Spadolini 104	Spadolini 105	Spadolini 106	Spadolini 107	Spadolini 108	Spadolini 109	Spadolini Ground Floor	Sala della Scherma	Polveriera	Sala Arco	Palazzina 7
Monday, March 27																	
09:00-10:00	*Opening ceremony*																
10:00-10:45	Keynote 1: *Nader Engheta*																
10:45-11:15									*Coffee Break*								
11:15-12:00	Keynote 2: *Rashaunda Henderson*																
12:00-12:45	Keynote 3: *Marco Di Renzo*																
12:50-14:00									*Lunch*								
14:00-16:00	SW1: *History of Electromagnetics and Antennas*	CS46: *RIS Modelling, Design and Characterization for 6G networks*	CS41: *Recent advances in communication antennas: from ground to satellite*	CS27: *INTERACT Propagation measurements and modelling for 6G and beyond*	CS7: *Antenna and Array Technologies for 6G and Beyond*	CS44: *Reconfigurable and Programmable Metamaterials*	CS2: *Advances in Electromagnetic Diagnostics, Therapeutics and Biomedical Sensors*	CS30: *ISAP session: Recent Advances in Asian Antennas and Propagation Research*	CS21: *Fundamental challenges and novel methodologies in the next-generation computational electromagnetics*	CS40: *Recent Advances in 2-D Leaky-Wave Antennas*	CS38: *Quantum Electromagnetics - From Photonics to Quantum Computing*	M06: *Innovative Approaches for Antenna Measurement*		SW3: *Active Array Antennas*	SW7: *Metrological Traceability Workshop*		
16:00-16:30									*Coffee Break*								
16:30-18:30	SW1b: *History of Electromagnetics and Antennas (continued)*	CS46b: *RIS Modelling, Design and Characterization for 6G networks (continued)*	CS12: *CEM methods applied to radio astronomy*	CS27b: *INTERACT Propagation measurements and modelling for 6G and beyond (continued)*	CS7b: *Antenna and Array Technologies for 6G and Beyond (continued)*	CS19: *EuMA-EurAAP session: Towards 6G leveraging Smart EM Environment and Holographic MIMO – Network and Hardware perspective*	CS24: *Implantable antennas and intra-body wave propagation*	CS43: *Recent Advances on Propagation Research and Its Impact on Localizations*	CS21b: *Fundamental challenges and novel methodologies in the next-generation computational electromagnetics (continued)*	CS40b: *Recent Advances in 2-D Leaky-Wave Antennas (continued)*	CS38b: *Quantum Electromagnetics - From Photonics to Quantum Computing (continued)*	P08: *Body Propagation, Sensing and EMC*		SW3b: *Active Array Antennas (continued)*	SW7b: *Metrological Traceability Workshop (continued)*		
18:30-20:00													*Welcome Drink*				
Tuesday, March 28																	
09:00-10:40		CS47: *Shape and control of electromagnetic fields through reflective and transmissive surfaces*	CS17: *Emerging Beam-Steering Antenna Solutions for Satellite and Terrestrial Communications including 5G+*	CS36: *Propagation for Smart Mobility Scenarios*	CS53: *Wide-Scanning Antenna Array Concepts for Millimetre-Wave Applications*	CS50: *Synthesis, Optimization, and Design of IoT antenna systems*	E01: *Inverse Problems and Imaging for biomedical applications*	CS45: *Remote-sensing of marine litter at microwave and millimetre-wave frequencies*	CS33: *Multiscale and Multiphysics Techniques for Electromagnetic Imaging*	CS14: *COST CA18223 (SyMat): Applications of Metamaterials with higher symmetries*	CS1: *Advances in and Applications of the Methods of Analytical Regularization in Electromagnetics*	A29: *Antennas for 5G/6G Communication Systems*		SW9: *Disruptive Innovations: the Roadmap of European Funding Agencies*	IW1: *Tracking and Pointing Performance Verification Using an Airborne Positioner(QuadSAT)*		WG MEAS: *EurAAP Measurement WG meeting*
10:40-11:00									*Coffee Break*								
11:00-12:40		CS47b: *Shape and control of electromagnetic fields through reflective and transmissive surfaces (continued)*	CS17b: *Emerging Beam-Steering Antenna Solutions for Satellite and Terrestrial Communications including 5G+ (continued)*	CS36b: *Propagation for Smart Mobility Scenarios (continued)*	A03: *Antennas for 5G Systems I*	CS50b: *Synthesis, Optimization, and Design of IoT antenna systems (continued)*	M02: *Dosimetry, Exposure and SAR Assessment*	A19: *Antennas for Vehicular Communications*	CS33b: *Multiscale and Multiphysics Techniques for Electromagnetic Imaging (continued)*	CS14b: *COST CA18223 (SyMat): Applications of Metamaterials with higher symmetries (continued)*	CS1b: *Advances in and Applications of the Methods of Analytical Regularization in Electromagnetics (continued)*	A33: *Antennas with Innovative Manufacturing Techniques*		SW9b: *Disruptive Innovations: the Roadmap of European Funding Agencies (continued)*	IW3: *Simulation Measurement Capabilities at Emerson & Cuming AC (ECAC)*		RoE: *EurAAP RoE meeting*
12:40-13:30									*Lunch*								
13:30-15:00		PA1: *Poster Session on mmWave Antennas I*		PA2: *Poster Session on mmWave Antennas II*		PA3: *Poster Session on Array Design and Technology*		PE1: *Poster Session on Electromagnetics I*		PM1: *Poster Session on Measurements*		PP1: *Poster Session on Propagation*					AMTA: *AMTA Europe meeting*
15:00-16:20		*Invited Speakers: Buon Kiong Lau and Dennis Lewis*	*Invited Speakers: Ekaterina Shamonina and Filippo Capolino*														
16:20-16:40									*Coffee Break*								
16:40-18:20		CS15: *Electromagnetic modelling and design of reconfigurable intelligent surfaces*	M01: *Material Characterisation and Nondestructive Testing*	CS49: *Spectrum management for 6G communications: research challenges under the electromagnetic propagation perspective*	A27: *Antenna for 5G Systems II*	CS8: *Antenna Design for Wireless Power Transmission/ RF Energy Harvesting*	A15: *Implantable Antennas*	A28: *Sub-6 Antennas for 5G systems*	A08: *Advanced Array Design Techniques*	CS5: *AMTA session: Satellite Antenna Measurements*	A10: *Innovative Lens Antennas I*	CS13: *Characteristic Mode Analysis for Next Generation Systems and Technologies*			IW6: *On antenna value in the telecommunication industry: Information Theory and EM (Huawei)*		SW4: *Small antennas for societal development goals*
Wednesday, March 29																	
09:00-10:40		A07: *Leaky Wave Antennas I*	CS16: *Emerging Antenna Technologies of Beam Manipulation for Beyond 5G and Space Applications*	CS37: *Propagation research at the cross-road of telecommunication, space systems, remote-sensing and meteorology: A tribute to Frank Silvio Marzano*	P01: *mmWave and THz propagation measurements*	CS48: *Small antenna techniques for large-scale of integration*	P03: *Imaging, detection and estimation*	A22: *Antenna Design and Technologies*	E05: *Optimization and machine learning for EM design*	CS3: *AMTA session: Advanced Measurement Techniques for 5G and Beyond*	CS51: *Unconventional electromagnetic phenomena in wave propagation and beam focusing*	A30: *Innovative Antenna Designs I*		SW5: *Effectively Addressing the Challenges to Uncertainties Induced by Modern Environment and Positioning Systems in Electromagnetic Compatibility and Antenna Measurements*	IW4: *From Component to mission.... Simulation as Must -Have for Aerospace & Defense Industry (Ansys)*	Perspectives I: *The Evolution of Smart Wireless Environments (I)*	
10:40-11:00									*Coffee Break*								
11:00-12:40		A23: *Leaky Wave Antennas II*	CS16b: *Emerging Antenna*	CS37b: *Propagation research at the*	A20: *Mm-wave Phased Arrays*	CS48b: *Small antenna techniques for*	CS29: *Inversion in Antennas and*	P05: *Localization and imaging*	E02: *Computational Electromagnetics*	CS3b: *AMTA session: Advanced*	CS51b: *Unconventional electromagnetic*	E13: *EM computing and optimization*		SW5b: *Effectively Addressing the*	IW5: *Uncertainty Quantification with TICRA Tools (Ticra)*	Perspectives II: *The Evolution of*	

			Technologies of Beam Manipulation for Beyond 5G and Space Applications (continued)	cross-road of telecommunication, space systems, remote-sensing and meteorology: A tribute to Frank Silvio Marzano (continued)		large-scale of integration (continued)	Scattering and Applications		1	Measurement Techniques for 5G and Beyond (continued)	phenomena in wave propagation and beam focusing (continued)			Challenges to Uncertainties Induced by Modern Environment and Positioning Systems in Electromagnetic Compatibility and Antenna Measurements (continued)		Smart Wireless Environments (II)	
12:40-13:30	Lunch																
13:30-15:00		PA4: *Poster Session on Antennas for Health Applications*		PA5: *Poster Session on Antennas for Space Applications*		PA6: *Poster Session on Antenna Design I*		PE2: *Poster Session on Electromagnetics II*		PM2: *Poster Session on Measurements II*		PP2: *Poster Session on Propagation II*				Perspectives III: *The Evolution of Smart Wireless Environments (III)*	CM-SIG: *Characteristic Modes Special Interest Group*
15:00-16:20		*Invited Speakers: Cathryn Mitchell and Piero Angeletti*	*Invited Speakers: John L. Volakis and Thomas Kürner*														
16:20-16:40	Coffee Break																
16:40-18:20		A04: *Reflectarrays*	CS9: *Antenna solutions for broadband satellites and constellations*	E04: *Frequency-selective surfaces*	P02: *Evaluation of mmWave and THz channels*	CS23: *Human RF Exposure to Present and Future Wireless Communication Systems*	CS11: *Biomedical Microwave Techniques and Devices: from Diagnosis to Treatment*	A12: *RFID Antennas*	E03: *Computational Electromagnetics 2*	CS6: *AMTA Session: UAV-based Antenna and Field Measurements*	A11: *Innovative Lens Antennas II*	A32: *Technologies for Antenna Systems I*		ESR: *Exhibitors and Sponsors Reception*	WG PROP: *EurAAP Propagation WG meeting*	IW7: *Novel Antenna and Architecture for Future 6G Wireless Communication and Sensing (Huawei)*	SW8: *Women in Antennas and Propagation (WiAP) workshop*

Thursday, March 30

09:00-10:40		CS18: *Emerging Technologies for Reflectarrays and Transmitarrays*	CS42: *Recent advances in sub-millimeter wave antenna systems for radio-astronomy and space exploration*	CS20: *Frontiers in Propagation and Wireless Channel Modeling — Assembly 2*	A02: *Antennas for mm-Wave Applications*	CS22: *Future trends of RFID systems and applications*	CS52: *Use of base materials not intended for RF applications and eco-friendly materials*	E09: *Theory and Design of Metasurfaces*	P07: *Simulations and modeling of long range links*	CS4: *AMTA session: Post Processing Techniques in Antenna Measurements and Recent advances in Robotic Antenna Measurements*	A17: *Reconfigurable Antennas*	E14: *Imaging, Inverse Design and Optimization*		SW11: *Quantum Electromagnetics for Antennas and Propagation*	SW10: *Stand on the IEEE Antennas & Propagation Standards*	IW8: *Radio channel modelling and emulation for NTNs and for terrestrial sub-THz links (Keysight)*	
10:40-11:00	Coffee Break																
11:00-12:40		CS18b: *Emerging Technologies for Reflectarrays and Transmitarrays (continued)*	CS42b: *Recent advances in sub-millimeter wave antenna systems for radio-astronomy and space exploration (continued)*	CS20b: *Frontiers in Propagation and Wireless Channel Modeling — Assembly 2 (continued)*	A09: *Sub-mm wave and Terahertz Antennas*	A13: *Wireless Power Transfer Antennas*	CS52b: *Use of base materials not intended for RF applications and eco-friendly materials (continued)*	A01: *Fundamental Research on Antennas I*	CS25: *Innovative Metasurface Applications for Next-Generation Antenna Systems*	CS4b: *AMTA session: Post Processing Techniques in Antenna Measurements and Recent advances in Robotic Antenna Measurements (continued)*	E07: *Inverse problems and radar imaging*	A34: *Technologies for Antenna Systems II*		SW11b: *Quantum Electromagnetics for Antennas and Propagation (continued)*	IW2: *Antenna Design and Test Considerations for Future 5G/6G Wireless Communication (ETS Lindgren)*	IW9: *Antenna Array Design & Coverage Analysis of Private Wireless Networks (Dassault)*	WG SA: *EurAAP Small Antenna WG meeting*
12:40-13:30	Lunch																
13:30-15:00		PA7: *Poster Session on Antenna Design II*		PA8: *Poster Session on Antenna Systems*		PE3: *Poster Session on Electromagnetics III*		*Poster Session: Best Paper Awards*									
15:00-16:20		*Invited Speakers: Jeff Guerrieri and Jun-Ichi Takada*	*Invited Speakers: George V. Eleftheriades and Yang Hao*														
16:20-16:40	Coffee Break																
16:40-18:20		E11: *Applications of Metasurfaces*	A18: *Antenna for Satellite Systems*	CS26: *Innovative Research on Millimeter-Wave and THz Radio Propagation Towards Beyond 5G and 6G*	A05: *Reflectarrays and Transmittarrays*	E06: *EM theory 1*	A21: *Antennas for Health Applications*	P04: *Channel simulations, measurements and emulation*	E10: *Modelling and simulation of metasurfaces*	CS34: *Novel Antenna Measurement Techniques and Data Analysis*	A25: *Fundamental research on Antennas II*	E15: *Analysis, desing and application of metasurfaces*		SW10b: *Stand on the IEEE Antennas & Propagation Standards (continued)*	*Student Paper Award*	ESoA: *ESoA WG Meeting*	

Friday, March 31

09:00-10:40		CS31: *Metagratings, Sparse metasurfaces, and beyond-homogenization design schemes*	A06: *Reflector systems*	CS35: *Plastic Based Antennas: a Real Alternative*	M03: *MM-Wave, THz and Quasi-Optical antenna measurement*	A14: *Wearable Antennas*	A24: *Antennas for Imaging Systems*	P06: *Detection and estimation*	M04: *Data Acquisition, Imaging Algorithms and Measurement Post-Processing*	CS32: *mmWave and THz channel sounding for Beyond 5G communications*	A16: *Aditive Manufacturing Antennas*	A35: *Innovative Antenna Designs II*		SW2: *Material and RCS Measurements*	SW6: *Antenna-Enabled Systems: An Inter-Society Perspective*		
10:40-11:00	Coffee Break																
11:00-12:40		CS39: *Radio propagation characterizations and channel modelling for RIS and sub-THz channels*	CS10: *Antennas for Radio Astronomy*	CS35b: *Plastic Based Antennas: a Real Alternative (continued)*	A31: *Antennas for Emerging applications*	M05: *General antenna measurements and other topics*	E08: *EM theory 2*	E12: *Reconfigurable metasurfaces for 5G and beyond*	CS28: *Inverse Problems for Electromagnetics*	CS32b: *mmWave and THz channel sounding for Beyond 5G communications*	A26: *Innovative Array Designs*	P09: *Medium- and Long-Range Propagation Measurements and Analyses*		SW2b: *Material and RCS Measurements (continued)*	SW6b: *Antenna-Enabled Systems: An Inter-Society Perspective (continued)*		
12:40-13:50		*Closing Ceremony*															
14:00-17:00	Short Courses																

Monday, March 27

Monday, March 27 10:00 - 10:45

Keynote 1: Nader Engheta

Room: Cavaniglia

Chairs: Sana Salous (Durham University, United Kingdom (Great Britain)), Sergei Tretyakov (Aalto University, Finland)

Prof. Nader Engheta, University of Pennsylvania, USA

Metastructures as Computing Machines

In order to structure and control waves, we need materials. By judiciously engineering material media, one can manipulate and tailor waves to achieve novel functionalities. One of the interesting thrusts in exploring the utility of structuring waves is in ultrafast computing. Can one envision specially designed metamaterials that can function as analog computing machines? The answer to this question is indeed "yes". In recent years, we have been exploring how such metamaterials and metasurfaces can be designed and constructed in order to provide wave-based, material-based, ultrafast analog computation. We have shown, theoretically and experimentally, how such metastructures can solve integral and differential equations, can invert matrices and can indeed achieve optimization when waves enter into them. In this talk, I will give an overview of our recent work in this area, will discuss some of the results, will explain physical insights into their functionalities, and finally will forecast possible future research directions in this field.

Monday, March 27 11:15 - 12:00

Keynote 2: Rashaunda Henderson

Room: Cavaniglia

Chairs: Sana Salous (Durham University, United Kingdom (Great Britain)), Sergei Tretyakov (Aalto University, Finland)

Prof. Rashaunda Henderson, University of Texas at Dallas, USA

Millimeter Wave Integration and Packaging Strategies Using Antenna-in-Package

Affordable and high performance front end modules (FEMs) have been identified as key research challenges for next generation millimeter wave communications. While the design of active components and sub-systems has been explored by many research groups, there is still a need to provide integration and packaging strategies that can meet system requirements and not inhibit the performance obtained at the wafer level. This poses challenges on the front-end modules (FEM) to deliver innovative packaging solutions which can fulfill the FEM integration requirements to maximize performance. Antenna-in-package (AiP) is a key technique that will enable the realization of 6G FEMs. The talk will discuss AiP solutions from a multi-disciplinary research team and will highlight the design, modeling, and characterization of planar antennas integrated into enhanced quad flat no-lead (eQFN) packages in WR8 and WR5 frequency bands. Further, the design, modeling, and simulation results of chip-to-package transitions, transmission line structures, and antenna feed elements are discussed. The simulated bandwidth and gain of the integrated antennas is compared with their standalone versions. To facilitate accurate design of the antennas and packaging transitions, high frequency material characterization has been conducted to obtain dielectric properties of the over mold materials. A workflow to characterize fatigue failure under board level vibration will be introduced with simulation results indicating the potential locations of solder failure under vibration. Validation of simulation results is conducted using fringe projection to directly measure the vibration mode when a printed circuit board is under vibration.

Monday, March 27 12:00 - 12:45

Keynote 3: Marco Di Renzo

Room: Cavaniglia

Chairs: Sana Salous (Durham University, United Kingdom (Great Britain)), Sergei Tretyakov (Aalto University, Finland)

Research Director Marco Di Renzo, Paris-Saclay University - CNRS and CentraleSupelec, France

Intelligent Surfaces for Wireless Communications: Living at the Interface of Electromagnetic and Communication Theories

In wireless communications, the term intelligent surface is referred to a planar metamaterial structure that is capable of generating an arbitrary current density distribution, so as to ensure the highest flexibility in generating a specified electromagnetic field and in shaping the propagation of the electromagnetic waves in large-scale networks. This presentation is aimed to report the latest research advances on analytical modeling, evaluating the ultimate performance limits, and optimizing intelligent surfaces for application to wireless communications, with focus on the synergies between electromagnetic and communication theories.

Monday, March 27 14:00 - 16:00

SW1: History of Electromagnetics and Antennas

Organized by: Ari Sihvola (Aalto University, Finland); Arthur D. Yaghjian (Concord, MA, USA)

Room: Cavaniglia

14:00 ***The Discovery of Electromagnetism by Hans Christian Ørsted 203 Years Ago***

Olav Breinbjerg (ElMaReCo, Denmark)

In 1820 Hans Christian Ørsted (1777-1851), then a professor of natural philosophy at the University of Copenhagen and later a founder and the first president of the Technical University of Denmark, observed from systematic experiments that electricity and magnetism are related. He thus discovered an entirely new natural science that he termed electromagnetism; a science that became of paramount importance for the understanding of Nature and for technologies developing the modern society. This paper reviews Ørsted's epoch-making discovery through his own writings published between 1820 and 1830.

14:20 ***Electromagnetism Before Maxwell: From Ørsted to Weber***

Ovidio Mario Bucci (University of Naples Federico II, Italy)

This presentation summarizes the main stages of the development of Electromagnetism before Maxwell, from Ørsted's discovery of the magnetic effect of currents, through the Ampere's development of electrodynamics and Faraday's discovery of electromagnetic induction, until the development of Weber's electrodynamics. The emphasis is on the conceptual evolution that led, from one side, to the unification under a coherent, mathematically sound theory of all known electromagnetic phenomena within the Newtonian paradigm of instantaneous action at distance, from the other side to lay the foundation for the Maxwell's revolution, which definitely changed such paradigm.

14:40 ***After Ørsted's Discovery: Johan Jacob Nervander and the Quantification of Electric Current***

Ari Sihvola (Aalto University, Finland)

This presentation focuses on the developments in electromagnetism after Ørsted's discovery in 1820. In particular, the principles to measure and quantify the electric current are given attention. Schweigger, Poggendorff, Nobili, and Pouillet contributed to the development of the galvanometer. The article puts special emphasis on the researches of Johan Jacob Nervander, whose "tangent bussol", presented to L'Institute de France in Spring 1834, and later published in Annales de Chimie et de Physique, was an important development in the instrumentation of electrical engineering.

15:00 *Maxwell's Derivation of the Lorentz Force from Faraday's Law*

Arthur D Yaghjian (Electromagnetics Research Consultant, USA)

In a brief but brilliant derivation that can be found in Maxwell's Treatise and traced back to his 1861 and 1865 papers, he derives the force on a moving electric charge subject to electromagnetic fields from his mathematical expression of Faraday's law for a moving circuit. Maxwell's derivation in his Treatise of this force, which is usually referred to today as the Lorentz force, is given in detail in the present paper using Maxwell's same procedure but with more modern notation.

15:20 *The History of the Watson Transformation in Electromagnetics and in Particle Physics*

Piergiorgio L.E. Uslenghi (University of Illinois at Chicago, USA)

When Marconi succeeded in sending a radio signal across the Atlantic Ocean, the scientific world was surprised, because with the equipment at his disposal no signal should have been detected. The ionospheric layers which provided a duct for the signals were not discovered until 1924, by Appleton in the UK and by Breit and Tuve in the USA. Marconi was an experimenter and a businessman with little theoretical background; had he been a better theoretician, he may not have attempted the experiments which led to his receiving a share of the Nobel Prize in Physics in 1909 (this is a rare example of ignorance paying off). Among the many descriptions of Marconi's efforts, the book Thunderstruck by Eric Larson (New York: Random House, 2006) is particularly informative and entertaining. The success of Marconi's experiments let to a flurry of studies on the propagation of electromagnetic waves over a spherical Earth. Among these early studies, the works of Poincaré and Nicholson in 1910 are noted.

The advent of radar during and after World War II provided a new impetus to the study of scattering of electromagnetic waves. In particular, the scattering by a conducting cylinder or by a conducting sphere may be described exactly in terms of infinite convergent series of Bessel functions of integer order (for the cylinder) or half-integer order (for the sphere). These series converge slowly when the product of the wavenumber k times the radius a of the scatterer is large compared to one, ka»1. In 1918, G.N. Watson had published a paper (Proc. Roy. Soc. London, vol. 95) in which he considered the terms of the infinite series as poles along the real axis of a complex plane, replaced the poles with a contour integral which he then deformed into a new contour. His approach leads to an asymptotic result in terms of a contour integral evaluated by saddle point (optical reflection by the scatterer) plus poles in the complex plane (creeping waves around the scatterer), thus providing a nice physical interpretation of the scattering phenomenon. The technique, which can be extended to coated bodies, became known as the Watson Transformation; it was popularized by Sommerfeld in his book Partial Differential Equations in Physics (New York: Academic Press, 1947) and let to many investigations in the 1950s and 1960s, before the advent of digital computers diminished its importance.

The Watson Transformation was employed by Tullio Regge in a different realm of theoretical physics: the nonrelativistic study of the analytical properties of the scattering matrix for strong interactions between elementary particles, by introducing the concept of a complex angular momentum. Regge was born in Turin, Italy in 1931, studied at both the Polytechnic and the University of Turin, spent research periods at Rochester and Princeton, and died near Turin in 2014, while Professor Emeritus of Physics at the Polytechnic. His first two papers appeared in Il Nuovo Cimento in 1958 and 1959. Regge poles phenomenology led to many papers in the 1960s, and to Regge candidacy for the Nobel Prize in Physics. Succinct accounts of Regge's achievements have been published recently (Atti Acc. Sc. Torino, vol. 149, pp. 17-34, 2015; ibid., vol. 152, pp. 61-75, 2018).

This author is grateful to Prof. Stefano Selleri of the University of Florence for suggesting this historical study of the Watson Transformation, several years ago.

Monday, March 27 14:00 - 16:00

CS46: RIS Modelling, Design and Characterization for 6G networks

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France), Gabriele Gradoni (University of Nottingham, United Kingdom (Great Britain))

14:00 ***System Level Analysis of Computational Channel Characterization Using Compressive Surfaces***

Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain)); Muhammad Ali Babar Abbasi (Queen's University Belfast & The Institute of Electronics, Communications and Information Technology (ECIT), United Kingdom (Great Britain)); Thomas Fromenteze (University of Limoges & Xlim Research Institute CNRS, France); María García Fernández and Guillermo Alvarez Narciandi (Queen's University Belfast & University of Oviedo, United Kingdom (Great Britain)); Rupesh Kumar and Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain))

Direction of arrival (DoA) estimation plays a crucial role in channel characterization and is a critical step to execute the necessary beam-shaping operations needed from antennas present within the wireless environment. Conventional DoA estimation frameworks rely on array-based topologies, making use of the phase difference information between the individual channels to retrieve the DoA data. Recently, the idea of computational imaging has been shown to offer a promising solution to conventional raster-scan-based techniques. The application of computational imaging to the channel characterization problem is intriguing. Yet, a system level of knowledge of the design parameters, which are key to understanding the development of compressive surfaces for computational DoA estimation, is far from comprehensive. In this paper, we demonstrate different techniques to synthesize spatio-temporally incoherent field patterns, a key requirement for computational DoA estimation, and provide a study of the different system level parameters needed to design such antennas.

14:20 ***Modeling the Mutual Coupling of Reconfigurable Metaurfaces***

Marco Di Renzo (Paris-Saclay University / CNRS, France); Vincenzo Galdi and Giuseppe Castaldi (University of Sannio, Italy)

In [1], the authors introduced a circuits-based approach for modeling the mutual coupling of reconfigurable surfaces, which comprise sub-wavelength spaced passive scattering elements coupled with electronic circuits for enabling the reconfiguration of the surface. The approach is based on a finite-length discrete dipole representation of a reconfigurable surface, and on the assumption that the current distribution on each thin wire dipole is a sinusoidal function. Under these assumptions, the voltages at the ports of a multi-antenna receiver can be formulated in terms of the voltage generators at a multi-antenna transmitter through a transfer function matrix that explicitly depends on the mutual coupling and the tuning circuits through the mutual impedances between every pair of thin wire dipoles. In [1], the mutual impedances are formulated in an integral form. In this paper, we show that the mutual impedances can be formulated in a closed-form expression in terms of exponential integral functions.

14:40 ***Design of a Dual Polarization Reconfigurable Intelligent Surface at 26.0 GHz for 5G Applications***

Philippe Ratajczak (Orange Innovation, France)

In this paper, the design of a reconfigurable unit cell intended to form a Reconfigurable Intelligent Surface (RIS) is presented at mm-waves frequency. The proposed solution to control the reflection phase coefficient of this cell and of the resulting RIS is based on varactors diodes allowing to achieve a continuous independent control of the two orthogonal polarizations.

15:00 ***RIS Dynamic Control Strategies in Smart EM Environments for 6G Networks***

Giacomo Oliveri (University of Trento & ELEDIA Research Center, Italy); Arianna Benoni (ELEDIA Research Center, Italy); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Marco Salucci (ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

The concept of Reconfigurable Intelligent Surfaces (RISs) is attracting a considerable academic and industrial interest in view of their potential adoption in 6G networks. Nevertheless, several important challenges still need to be addressed from the technological and methodological viewpoint to enable the deployment and effective exploitation of RISs. This is specifically relevant concerning the surface dynamic control algorithms to be implemented for a successful integration of RISs in existing

wireless environments. In this framework, the objective of this work is to illustrate the recent advances and emerging solution strategies for RIS configuration and adaptation in next generation networks.

15:20 ***Impact of Channel Models on Performance Characterization of RIS-Assisted Wireless Systems***

Vahid Jamali (Technical University of Darmstadt, Germany); Walid Ghanem (Friedrich-Alexander-University Erlangen-Nuremberg, Germany & Huawei Munich Research Center, Germany); Robert Schober (University of British Columbia, Canada); H. Vincent Poor (Princeton University, USA)

The performance characterization of communication systems assisted by large reconfigurable intelligent surfaces (RISs) significantly depends on the adopted models for the underlying channels. Under unrealistic channel models, the system performance may be over- or under-estimated which yields inaccurate conclusions for the system design. In this paper, we review five channel models that are chosen to progressively improve the modeling accuracy for large RISs. For each channel model, we highlight the underlying assumptions, its advantages, and its limitations. We compare the system performance under the aforementioned channel models using RIS configuration algorithms from the literature and a new scalable algorithm proposed in this paper specifically for the configuration of extremely large RISs.

15:40 ***Intelligent EM Modeling of RIS-n***

Matteo Albani, Enrica Martini and Stefano Maci (University of Siena, Italy)

The new paradigm of smart radio environment (SRE) is analyzed here from the perspective of intelligent electromagnetics (EM) models. The enabling technology of metasurface-based intelligent surfaces (IS) is categorized here by using the synthetic notation RIS-n, where n counts the number of "R"-type functionalities embedded in the IS: Reflecting IS (RIS-1), Reflecting-Reconfigurable IS (RIS-2) Receiving-Repeating-Reconfigurable IS (RIS-3), Receiving-Regenerating-Repeating-Reconfigurable IS (RIS-4). For increasing n, RIS-n possess an increasing level of complexity, environmental impact, power consumption and costs, but a decreasing level of densification and standardization requirement. The deployment of RIS-n in SRE is reviewed considering the new challenges that the RIS-n technology implies when implemented through metasurfaces. Special emphasis is given to efficient ray-model for both Fresnel and far zone coverage, where the scattered field from polygonal contoured RIS-1 or RIS-2 is represented in terms of few rays. The latter formulation can be conveniently used in a ray-tracer to speed-up dramatically the calculation of the field coverage.

Monday, March 27 14:00 - 16:00

CS41: Recent advances in communication antennas: from ground to satellite

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Gangil Byun (Ulsan National Institute of Science and Technology (UNIST), Korea (South)), Ick-Jae Yoon (Chungnam National University, Korea (South))

14:00 ***SWARM CubeSat: Smart mmWave Active Radio Module on a 2U CubeSat Platform for Ground-Space LEO Communication Networks***

Dohyun Kim, Gyoungdeuk Kim, Hoyong Kim, Eunyoung Park, Nohgyeom Ha, Myeongha Hwang and Sangkil Kim (Pusan National University, Korea (South))

This paper describes the preliminary design of Smart mmWave Active Radio Module (SWARM) CubeSat and its planar patch antenna array for mmWave communication. The proposed SWARM CubeSat is built on 2U CubeSat frame (10×10×20 cm3) while the antenna array is mounted on a facet of a CubeSat. The proposed active antenna array is operating at the K/Ka bands and it has circular polarization to compensate the high attenuation of mmWave. The proposed antenna array consists of parasitic

patch loaded truncated microstrip patch antennas. General design procedure and specifications of electrical system of the 2U SWARM CubeSat, such as power system, and RF front-end, are discussed.

14:20 ***Fabry-Perot Cavity Antenna with Lateral Metallic Walls***

Seong Ju Kim and Dongho Kim (Sejong University, Korea (South))

Fabry-Perot cavity (FPC) antennas are well known for their high-gain feature using simple cavity resonance, which only a single feeding element can feed. However, their aperture efficiency is limited despite the antenna size increase due to leaking waves through lateral openings. To solve this problem, we propose a new method to improve aperture efficiency by blocking the openings with optimum feeding locations. Consequently, our antenna shows about 64 % aperture efficiency in a bore sight direction. Our idea is verified by simulation and experiment.

14:40 ***Sequentially-Fed Rhombus Patch Subarrays for Wide-Angle Circular Polarization***

Wootaek Kang and Tae Heung Lim (Ulsan National Institute of Science and Technology, Korea (South)); Ikmo Park (Ajou University, Korea (South)); Gangil Byun (Ulsan National Institute of Science and Technology (UNIST), Korea (South))

This paper proposes sequentially-fed rhombus patch subarrays for wide-angle beamforming with circular polarization. The proposed antenna consists of three rhombus patches arranged in rotational symmetry, and each patch is sequentially fed by aperture coupling. The rhombus patches are squeezed within a hexagonal-shaped substrate having an aperture size of a half wavelength for symmetric beam shapes in both U- and V-planes without grating lobes. The proposed antenna has fractional impedance and axial ratio bandwidths of 8.23% and 2.2%, respectively, and maintains a high realized gain of greater than 3.4 dBic and an axial ratio of less than 4.4 dB within the target angular range.

15:00 ***Lightweight and Low-Profile Ferrite Core Loaded Military VHF/UHF Communication Antenna***

Mee-Su Lee, Wonkyo Kim and Geonyeong Shin (Chungnam National University, Korea (South)); Hyun Kim and Chang-Hyun Lee (LIG Nex1 Company Ltd., Korea (South)); Ick-Jae Yoon (Chungnam National University, Korea (South))

A low-profile, lightweight military VHF/UHF communication antenna loaded with ferrite cores for integrated mast is presented herein. The proposed antenna takes the form of a grounded split ring resonator that enables a loop current distribution that is desired for efficient radiation at a low-profile design. The ferrite core part within the metal configuration is covered by a PC housing whose electromagnetic effect is also encountered in the full-wave EM simulations. The ferrite core part only weights 14.3 kg. The proposed antenna satisfies the minimum operating frequency of 30.8 MHz with a VSWR < 3.5 criterion at a given small electrical size ka of 0.34 and shows a maximum gain over -10 dB in every operating frequencies over than 500 MHz.

15:20 ***Design of a Light Weight Deployable Mesh Reflector Antenna for Satellite Applications***

Changhyeon Im (Hongik University, Korea (South)); Minsu Hwang (University of Hongik, Korea (South)); Changseong Kim, Seul-Gi Park, Kihun Kim and Sungkyun Park (Hanwha Systems, Korea (South)); Hosung Choo (Hongik University, Korea (South))

In this paper, we investigate the optimal mesh structure to minimize the weight of the reflector antenna while maintaining antenna performances. Various shapes of meshes are designed to have the same weight per unit area, and the reflectivity is simulated. To predict the antenna performance of the reflector to which the mesh shape is applied, effective lossy conducting surfaces with the same reflectivity are derived. In the simulation results, 33.95 dBi of the antenna gain and 1.5 degree of HPBW are obtained with a hexagonal mesh surface. As a result of comparing to the other mesh surfaces, the hexagonal mesh surface exhibits highest antenna gain with the same weight per unit area.

15:40 ***5G/6G Reconfigurable Intelligent Surface Supporting Multiple Pairs of Polarization and Scattering Modes***

Hogyeom Kim and Jungsuek Oh (Seoul National University, Korea (South))

This study proposes a novel polarization/ scattering modes-selectable reconfigurable intelligent surface (PS-RISs) based on a liquid crystal (LC) for enhancing millimeter-wave (mmWave) 5G link connectivity. With the introduction of a gamma-shaped stacked bias layer and a sandwiched air gap, the controllability in polarization conversion, scattering/absorption, and the corresponding loss/phase shift can be achieved simultaneously maintaining high isolation between two polarized waves. The proposed PS-RIS can overcome the polarization mismatch by introducing multiple pairs of polarization states of the reflected waves toward the receiver. In addition, to reconfigure the radar cross-section, scattering modes can be implemented by biasing each unit cell whose reflection phase difference is 180° again near the cells. In the measurements, the maximum aperture efficiency of 26 % and a reliable link connectivity were confirmed where 10 dB higher power was received compared to non-line-of-sight scenario.

Monday, March 27 14:00 - 16:00

CS27: INTERACT Propagation measurements and modelling for 6G and beyond

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 101

Chairs: Marina Barbiroli (University of Bologna, Italy), Sana Salous (Durham University, United Kingdom (Great Britain))

14:00 ***Min-Path-Tracing: A Diffraction Aware Alternative to Image Method in Ray Tracing***

Jérome Eertmans (UCLouvain, Belgium); Claude Oestges (Université Catholique de Louvain, Belgium); Laurent Jacques (University of Louvain, Belgium)

For more than twenty years, Ray Tracing methods have continued to improve on both accuracy and computational time aspects. However, most state-of-the-art image-based ray tracers still rely on a description of the environment that only contains planar surfaces. They are also limited by the number of diffractions they can simulate. We present Min-Path-Tracing (MPT), an alternative to the image method that can handle diffractions seamlessly, while also leveraging the possibility to use different geometries for surfaces or edges, such as parabolic mirrors. MPT uses implicit representations of objects to write the path finding challenge as a minimization problem. We further show that multiple diffractions can be important in some situations, which MPT is capable to simulate without increasing neither the computational nor the implementation complexity.

14:20 ***Measurement-Based Analysis of Multi-Band Assisted Beam-Forming at mmWave in Industrial Scenarios***

Diego Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany); Alexander Ebert (Technische Universität Ilmenau, Germany); Reiner S. Thomä (Ilmenau University of Technology, Germany)

The mmWave and sub-THz bands are foreseen as candidates to achieve the data-rate demands in the beyond 5G and 6G wireless communication networks. The co-existence of multiple radio interfaces at several bands enables data fusion and the utilization of the similarities and differences on propagation and system properties for communication and sensing applications. MmWave radio interfaces rely on directive beams that require high training overhead for beam steering. Sensors in the network infrastructure and co-located radio interfaces at sub-6 GHz and mmWave can be used to assist the beam-forming process at mmWave. In the resent paper we investigate the performance of multi-band assisted beam-forming in an industrial environment. We empirically demonstrate from real-world measurements that even in NLOS, the direction of the beams estimated at sub-6 GHz can be used to established a link at mmWave.

14:40 ***Performance and Challenges of Ray Tracing-Assisted Device Discovery for Terahertz Communications***

Tobias Doeker (Technische Universität Braunschweig, Germany); Mate Boban (Huawei Technologies Duesseldorf GmbH, Germany); Thomas Kürner (Technische Universität Braunschweig, Germany)

In this paper, a novel device discovery approach based on ray tracing simulations is presented. For device discovery, ray tracing can provide a rough estimation of the desired angle of departure and angle of arrival, followed by a fine beam alignment through measurements. Compared to an iterative approach, the proposed approach results in a reduced number of measurement steps needed for device discovery. Furthermore, the influence of the 3D environmental model on the performance of the ray tracing-assisted device discovery approach is analyzed with respect to the room dimensions and the furniture in the room. An equation to calculate the inaccuracy of the predicted angle of departures and angle of arrivals due to the model is given. Finally, the results show that the proposed approach is faster in case the blocking furniture covers less than 1.5% of the area.

15:00 ***MIMO Channel Characterization at MmWave Bands for Typical Indoor Environments***

Sana Salous and Amar Al-Jzari (Durham University, United Kingdom (Great Britain))

In this paper, multiple-input multiple-output (MIMO) dual polarized channel measurements with 2x2 antenna configurations are carried out in a conference room and an office with 6 GHz bandwidth at 56, 62, and 70 GHz. The channel characteristics, including power delay profile (PDP), power angle profile (PAP), root mean square delay spread (RMS DS), and angular spread (AS) are estimated and analyzed. The impact of polarization on the channel parameters and the frequency dependency of the delay and angular spreads using the 3GPP model are investigated. In addition, based on the ITU model, the predicted RMS DS and AS as a function of the room size are studied.

15:20 ***Impact of Facade Details on Radio Propagation at 28 GHz***

Marjolijn Kleijer (Eindhoven University of Technology, The Netherlands); Gerhard Steinbock and Bengt-Erik Olsson (Ericsson AB, Sweden); Martin Johansson (Ericsson Research, Sweden); A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

Channel modeling tools, such as ray-tracers, require geometrical information of the environment. Usually, this geometrical information consists of smooth 3D models. These models are obtained by extruding building footprints from commercially available digital maps. However, with the evolution of mobile networks and the use of higher frequencies, small-scale geometric details are becoming increasingly important. This contribution investigates if the typically used diffuse scattering models are sufficient to mimic these small-scale geometric variations or if more detailed geometrical models are needed. A ray-tracing tool is used to simulate the channel with a 3D model of various levels of details. Comparison between simulations and corresponding measurements indicate that typically used diffuse scattering models mimic scattering from facades not well enough. More details, such as windows, should be included in the 3D models or an improved facade scattering model is required to more realistically model the scattering observed from a facade.

15:40 ***Machine Learning-Based Line-Of-Sight Prediction in Urban Manhattan-Like Environments***

Nicola Di Cicco (Politecnico di Milano, Italy); Simone Del Prete, Silvi Kodra, Marina Barbiroli, Franco Fuschini, Enrico M. Vitucci and Vittorio Degli-Esposti (University of Bologna, Italy); Massimo Tornatore (Politecnico di Milano & University of California, Davis, Italy)

This paper considers the problem of predicting whether or not a transmitter and a receiver are in Line-of-Sight (LOS) condition. While this problem can be easily solved using a digital urban database and applying ray tracing, we consider the scenario in which only few high-level features descriptive of the propagation environment and of the the radio link are available. LOS prediction is modelled as a binary classification Machine Learning problem, and a baseline classifier based on Gradient Boosting Decision Trees (GBDT) is proposed. A synthetic ray-tracing dataset of Manhattan-like topologies is generated for training and testing a GBDT classifier, and its generalization capabilities to both locations and environments unseen at training time are assessed. Results show that the GBDT model achieves good classification performance and provides accurate LOS probability modelling. By estimating feature importance, it can be concluded that the model learned simple decision rules that align with common sense.

Monday, March 27 14:00 - 16:00

CS7: Antenna and Array Technologies for 6G and Beyond

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 102

Chairs: Y. Jay Guo (University of Technology Sydney, Australia), Richard W Ziolkowski (University of Arizona, USA & University of Technology Sydney, USA)

14:00 ***Hybrid Design Technique for Reflectarrays and Transmitarrays: Concept and Validation***

Qi Luo (University of Herfordshire, United Kingdom (Great Britain)); Steven Gao (Chinese University of Hong Kong, China); Wei Hu (Xidian University, China); Mingyang Dong (CETC, China); Xuexia Yang (Shanghai University, China)

This paper presents our recent research progress in developing beam-steering reflectarrays and transmitarrays with a reduced number of elements. To achieve this objective, a hybrid design method that mixes different types of elements including microstrip patches and dielectric lenses into one aperture is developed. The advantage of this design method is that the total number of elements in the aperture can be reduced while promising beam-steering performance is maintained. To validate this hybrid design method, one reflectarray and one transmitarray are designed and simulated. The simulation results show good beam-steering performance with promising radiation patterns. As proof of concept, multiple passive prototypes were fabricated and measured as demonstrators. A good agreement between the simulation and measurement results is obtained. The present hybrid design method is scalable and can be extended to the design of active arrays.

14:20 ***A Reconfigurable Feed Network Splitter to Apply Progressive Phase for Steerable Antenna Arrays***

James R Henderson (Queen Mary University of London & Plextek, United Kingdom (Great Britain)); Yang Hao (Queen Mary University, United Kingdom (Great Britain))

A reconfigurable antenna feed network splitter, designed to apply phase shift within an antenna array for beamsteering applications, is presented. Different configurations are selected providing from -180° to 180° of relative phase shift at each 1:2 split in a corporate feed network. This alternative approach to steering planar antenna arrays without the requirement for complex, lossy phase shifters at every element offers the potential to realise large, passive antenna arrays for future 6G communication systems where low-cost, high-performance systems exhibiting low power consumption is important. The concept has been fabricated and measurements using zero-ohm resistor links, as ideal switches, provide good correlation with simulation. Reconfigurability is also demonstrated using PIN diodes to dynamically switch between different configurations at a reduced frequency, as a result of the device package capacitance, although the fabricated design still provided the expected relative phase shift within 9.6° demonstrating its capability in a reconfigurable antenna array.

14:40 ***Compact End-Fire Arrays: From Theory to Directivity and Gain Maximization***

Alessio Tornese (Université Grenoble Alpes & CEA Leti, France); Antonio Clemente (CEA-Leti, France); Christophe Delaveaud (CEA-LETI, France)

End-fire arrays are among the best candidate for high directivity and compact dimensions. Several solutions for the synthesis of superdirective arrays have been proposed in the literature. However, what is called a "superdirective" array suffers inevitably from high losses and very poor radiation efficiency. More appealing is the joint optimization of directivity and efficiency, or the intrinsic gain, of the antennas. This paper set side by side the directivity and gain optimization methods based on the Spherical Wave Expansion (SWE) theory. The synthesis of superdirective and supergain end-fire arrays is proposed when Huygens sources, which attain the highest level of directivity, or simple bent dipoles are selected as elements of the array. On behalf of the spherical modal expansions, the results obtained for different optimizations of the two arrays are examined.

15:00 ***Risley Prism-Inspired Beam Steering Reflectarray Antenna***

Chenfeng Yang, Gengbo Wu and Chi Hou Chan (City University of Hong Kong, Hong Kong)

A novel compact beam steering reflectarray system is introduced in this paper. The antenna is composed of a feed waveguide and two metasurfaces with the same phase gradients. The waveguide is integrated into the metasurfaces to reduce the overall system thickness. In analogy with the beam scanning principle of the Risley prism, the generated beam direction is steerable by rotating the two metasurfaces independently. The proof-of-concept antenna achieves a maximum simulated scanning angle of 40°. The presented beam steering approach will provide a new path for future satellite communications.

15:20 *Electrically Small CP Unidirectional WPT and Comm Antennas for Amalgamation into a Retrodirective Reconfigurable Intelligent Surface (RRIS) System*

Wei Lin (The Hong Kong Polytechnic University, Hong Kong); Richard W Ziolkowski (University of Arizona, USA & University of Technology Sydney, USA)

This paper presents a circularly polarized wireless power transfer (WPT) and communication antenna system for amalgamation into a retrodirective reconfigurable intelligent surface (RRIS) system. The dual CP antenna system consists of two crossed electrically small Egyptian axe dipoles (EADs), two crossed capacitively loaded loops (CLLs), and a delayed loop feeding structure. RHCP (LHCP) Huygens radiation patterns are realized by one (the other) of two orthogonal excitations of the same radiator. Good isolation is observed (< −15 dB) between its transmitting and receiving ports. The dual CP rectenna/antenna system is designed to operate at 915 MHz in the free industrial, scientific and medical (ISM) band.

15:40 *Flexible 6G Antenna Systems Based on Innovative Lenses Combined with Array Antennas*

Astrid Algaba-Brazález (Ericsson Research (Sweden)); Hairu Wang and Pilar Castillo-Tapia (KTH Royal Institute of Technology, Sweden); Lars Manholm and Martin Johansson (Ericsson Research, Sweden); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this article, we propose an innovative concept to realize flexible and cost-effective array antenna systems for next generation communication systems. The idea is to tailor the performance of an antenna array to different use case scenarios by applying a customized dielectric lens placed in front of the array. By combining a lens with an array we can improve certain performance properties of the antenna system and adapt it for unique site locations and requirements. Moreover, the lens may also act as a radome, providing mechanical protection from environmental conditions. This study consists of exploring the possibilities of using a lens to increase the gain of the antenna in certain directions: scanning range close to broadside (from 0° to 30°), and extreme scanning ranges (from 60° to 80°).

Monday, March 27 14:00 - 16:00

CS44: Reconfigurable and Programmable Metamaterials

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 103

Chairs: Vincenzo Galdi (University of Salerno, Italy), James Rains (University of Glasgow, United Kingdom (Great Britain))

14:00 *Space-Time-Coding Digital Metasurfaces for Advanced Field Manipulations*

Massimo Moccia and Giuseppe Castaldi (University of Sannio, Italy); Lei Zhang (Southeast University, China); Vincenzo Galdi (University of Sannio, Italy); Tie Jun Cui (Southeast University, China)

Space-time-coding digital metasurfaces are emerging as a powerful and versatile platform for advanced field manipulations in the joint space-frequency-polarization space and for overcoming some fundamental limitations in linear and time-invariant electromagnetic systems. Here, we provide a compact overview of results from recent and ongoing research in this field, ranging from harmonic beam-steering/shaping to non-reciprocal effects.

14:20 ***Noise-Adaptive and Task-Specific Coherent Illuminations with a Programmable-Metasurface Imager***

Chenqi Qian (CNRS, France); Philipp del Hougne (CNRS, Univ Rennes, France)

We study the impact of noise on the end-to-end optimization of multi-shot single-detector meta-imagers with respect to a specific information-extraction task. Latency constraints and noise can severely limit the total amount of information that can be extracted from the scene. Therefore, the ability to predominantly extract task-relevant information is a strong advantage. Considering dynamic metasurface antenna (DMA) hardware in a prototypical object-recognition task, we observe remarkable performance improvements over conventional meta-imaging with random DMA configurations. Moreover, we analyze the learned sequence of scene illuminations and discover intuitively understandable trends in its dependence on latency constraints and the noise level.

14:40 ***Experimental Study of Channel Estimation Algorithms for General IRS Applications***

Yueheng Li and Lucas Giroto de Oliveira (Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany); Mohamad Basim Alabd, Xueyun Long and Sven Bettinga (Karlsruhe Institute of Technology, Germany)

An intelligent reflecting surface (IRS) is a promising antenna array concept capable of realizing flexible electronically steerable beamforming. Depending on the location of the feeding antenna, IRS applications can be classified as either nearfield or farfield types. Using the IRS operating at 28 GHz, both application types are analyzed and compared in this paper. On the IRS testbed, channel estimation algorithms, including beam training and IRS unit channel state information (CSI) estimation, are implemented and analyzed for both application types. The results of the measurements indicate that the aforementioned algorithms are adaptable to both IRS application types. In addition, the IRS coding patterns designed using the estimated CSI at each IRS unit outperform the pre-designed patterns for beam training when constructing the wireless communication link. This paper provides evidence that IRS-based theoretical algorithms can be implemented in practice.

15:00 ***Intelligent Omni-Metasurface for Full-Space Wireless Coverage and Signal Enhancement***

Qi Hu, Kui Tang, Ke Chen and Yijun Feng (Nanjing University, China)

We propose an intelligent omni-metasurface that can be flexibly switched among transmission mode, reflection mode, and duplex mode to provide dynamic control over forward, backward, and even full-space electromagnetic waves. By adaptively applying coding patterns optimized by genetic algorithm to the metasurface aperture, the wireless coverage can be extended into full-space with significant regional signal enhancement. As the exemplary demonstration, through-wall and reflected signals at mobile user terminals at forward and backward locations are obviously enhanced with a maximum of 9.9 dB and 16.9 dB, respectively. Therefore, the proposed approach is beneficial for assisting indoor communications and even bringing outdoor wireless coverage indoors, which may have potentials in next-generation wireless communication systems.

15:20 ***Reconfigurable Metasurface Antennas Based on Varactor Diodes***

Joaquín García Fernández (WAVE UP SRL & University of Siena, Italy); Francesco Caminita (Wave-Up SRL, Italy); Cristian Della Giovampaola (Wave Up srl, Italy); Enrica Martini and Stefano Maci (University of Siena, Italy)

Radiation control of modulated metasurface antennas by means of tunable capacitances is studied in this work. Two reconfigurable topologies are presented, each of them performs beam-scanning controlled by the bias voltage of varactor diodes. The study commences from a single-layer metasurface antenna whose modulation period is actively changed, being extended to a double-layer design with scan angle dictated by a single parameter. Numerical results are reported, demonstrating the versatile control of the leaky-wave aperture field, as well as the good performance in terms of beam shape and field of view.

15:40 ***Fully-Addressable Varactor-Based Reflecting Metasurface with Dual-Linear Polarisation for Low Power Reconfigurable Intelligent Surfaces***

James Rains and Jalil ur Rehman Kazim (University of Glasgow, United Kingdom (Great Britain)); Anvar Tukmanov (BT, United Kingdom (Great Britain)); Lei Zhang, Qammer H Abbasi and Muhammad Ali Imran (University of Glasgow, United Kingdom (Great Britain))

This work explores the performance of a 1-bit dual-linear polarised varactor-based metasurface design at sub-6 GHz. A modified particle swarm optimisation algorithm was utilised to determine the element geometry resulting in minimum reflection loss and phase error, and maximum cross-polarisation isolation. Unit cells may be individually addressed and with independent polarisation control over 3.3 to 3.7 GHz. A prototype consisting of an arrangement 48 x 16 unit cells has been fabricated for deployment in a reconfigurable intelligent surface-aided wireless communication channel sounding campaign.

Monday, March 27 14:00 - 16:00

CS2: Advances in Electromagnetic Diagnostics, Therapeutics and Biomedical Sensors

T04 Biomedical and health / Convened Session / Antennas

Room: Spadolini 104

Chairs: Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal), David O. Rodriguez-Duarte (Politecnico di Torino, Italy)

14:00 ***A Methodology for Evaluating Image Resolution in Experimental Breast Microwave Imaging***

Tyson Reimer and Stephen Pistorius (University of Manitoba, Canada)

Breast microwave sensing (BMS) is a potential method for breast cancer detection. While radar-based imaging methods have been applied in patient studies, the evaluation of radar-based imaging methods has been limited. Image quality metrics, which aim to quantitatively describe the quality of an image, have been generally limited to descriptors of image contrast. Contrast is only one aspect of image quality - the traditional image quality aspects of image resolution, noise, contrast resolution, accuracy, and artifacts have not been fully addressed in the BMS literature. This work describes methodologies and quantitative metrics for evaluating spatial resolution in BMS. These methods have been applied to evaluate the quality of images produced by the delay-and-sum, delay-multiply-and-sum, and optimization-based radar reconstruction methods. The spatial resolution of images produced by the DAS and DMAS beamformers was found to be (1.95 +/- 0.15) cm and by the ORR algorithm to be (1.65 +/- 0.15) cm.

14:20 ***Novel Antenna for Microwave Breast Screening: Minimizing Surface-Wave Crosstalk***

Milad Mokhtari and Milica Popović (McGill University, Canada)

The crosstalk between sensing elements of microwave-based breast imaging systems has been widely explored in the literature. In single-substrate sensor arrays, the main source of crosstalk are the surface waves propagating at the interface of the substrate and the biological tissue. In this paper, we first report on the analysis of the existing surface waves for a shielded unidirectional antenna array next to the human breast. Then, we present a novel antenna array operating in 3.1-5.1 GHz, followed by a more complex design with hexagonal metallic walls, advantageous for the suppression of the surface waves. The results indicate that the reduction in the crosstalk is significant and worth the trade-off of the design complexity.

14:40 ***Field Intensity Shaping for Biomedical Applications: Preliminary Results with Linear Superposition of Focused Patterns***

Martina Teresa Bevacqua and Sabrina Zumbo (Università Mediterranea di Reggio Calabria, Italy); Tommaso Isernia (University of Reggio Calabria, Italy)

In this contribution, the aim is to design the complex excitations feeding a biomedical array applicator such to ensure uniform and maximum field intensity distribution inside a given region of interest, while keeping it under control in some other regions. This issue is relevant in several applications, including hyperthermia treatment planning and magnetic resonance radiofrequency shimming. To this end, the idea of superimposing single focused patterns for field intensity shaping is further developed and discussed. In particular, a smart procedure based on the minimization of the nuclear norm is introduced and discussed for the determination of linear superposition coefficients. Note that this procedure is also relevant in satellite and radio communications, as well as in antenna array synthesis theory.

15:00 ***Electronically Scanned Active Sensor Array for the Imaging of Compressed Breast***

Nooshin Valizade Shahmirzadi, Jimmy Nguyen, Romina Kazemivala, Natalia Nikolova and Chih-Hung Chen (McMaster University, Canada)

We present an active sensing array for microwave imaging of the breast in the frequency range from 3 GHz to 8 GHz. This array is composed of printed slot antennas integrated with low-noise amplifiers (LNAs). The proposed active array is designed to interface with an array of mixer chips to provide an electronically scanned sensing array with intermediate frequency (IF) switching, thus overcoming the limitations of the current RF-switched arrays employed in tissue imaging. The IF-switched architecture allows for the multiplexing of 16×16 (256) IF sensing ports. The performance of the active sensor array is verified by both simulation and measurement.

15:20 ***Harmonisation of Measurement Method and Reporting Method of Dielectric Properties of Tissues***

Julian Bonello (University of Malta, Malta); Daniela M. Godinho (Instituto de Biofísica e Engenharia Biomédica - Faculdade de Ciências - Universidade de Lisboa, Portugal); Andrea Mula (University of Malta, Malta); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal); Emily Porter (University of Texas at Austin, USA); Lourdes Farrugia (University of Malta, Malta)

The dielectric properties of biological tissues are very important for the improvement and emergence of medical devices which make use of microwaves. While various studies have reported the dielectric properties of biological tissues, a significant variation can be observed between data from one study to another. Such variations are problematic when accurately modelling the medical scenario. Harmonising lab practices as well as utilising the same platform for data analysis will allow for better comparison across the different dielectric studies. Finally a recently developed data/metadata repository is proposed. This will allow for better comparison of data from different dielectric centres.

15:40 ***Development of Mechanically and Dielectrically Realistic Breast Models for Microwave Therapy and Healing Simulations***

Maria C. T. Gonçalves (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal); Michael R. Haberman (The University of Texas at Austin, USA); Emily Porter (University of Texas at Austin, USA); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal)

Simulations performed with computational breast models with realistic tissue properties, such as dielectric and mechanical properties, can provide relevant information regarding the cosmetic outcome of microwave therapy, and surgery on a personalized basis. Although the dielectric properties of breast tissues are well characterized, the mechanical properties reported in the literature, namely the Young's moduli, encompass a wide range of values. In this work, we propose the extraction of the Young's modulus from breast ultrasound elastography exams, which enables the integration of mechanical with dielectric properties in breast models. We present the framework developed to this end and an application example. Our framework allowed us to obtain an indication of the Young's modulus of the tissue present in the ultrasound elastography exam. Although preliminary, these results indicate that it is possible to acquire quantitative and personalized information from conventional ultrasound devices without burdening physicians with extra examination. This framework is flexible and allows to realistically model several breast tissues with different Young's moduli.

Monday, March 27 14:00 - 16:00

CS30: ISAP session: Recent Advances in Asian Antennas and Propagation Research

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 105

Chairs: Hiroyuki Arai (Yokohama National University, Japan), Hang Wong (City University of Hong Kong, Hong Kong)

14:00 ***3D Absolute Gain Pattern Measurements Within a Strip Region Using a New Multi-Cut Fresnel Field to Far-Field Cylindrical Transformation***

Masanobu Hirose (7G aa Co., Ltd., Japan); Satoru Kurokawa (National Institute of Advanced Industrial Science and Technology, Japan); Kota Nishimura and Takeshi Sugiyama (Photonic Edge Inc., Japan)

We have proposed a new multi-cut Fresnel-field to far-field transformation in the cylindrical scanning to overcome the error of an absolute gain pattern in a single-cut plane by using a single-cut near-field to far-field transformation. Because the multi-cut method requires the measurements on a several parallel cut-plates, we can obtain the 3D absolute gain pattern in a strip region between the several-cut planes. Therefore, the multi-cut method makes it possible to obtain the absolute gain patterns for any type of antennas and can be obtained the peak absolute gain if the peak exists between the multi-cut planes. We demonstrate the effectiveness of the multi-cut method by simulations and the preliminary results using a EO probe at 76.2 GHz.

14:20 ***Machine-Learning-Based Optimization Method for Wideband Metasurface Antenna***

Peiqin Liu, Zijue Shan and Zhi Ning Chen (National University of Singapore, Singapore)

A machine-learning-based optimization method is proposed for the design of wideband metasurface antenna. The artificial neural network (ANN) algorithm is utilized to build an accurate and efficient neural network model for the optimization of antenna geometry parameters. The proposed metasurface antenna evolves from the Mosaic antenna with uniform patch cells. By dividing the patch cells into fractional pieces, the impedance bandwidth of the proposed antenna is improved. In the proposed neural network, the input data is the target reflection coefficients of the metasurfaces antenna, and the neural network predicts the geometry of patch pieces that satisfy the target performance. A prototype antenna is fabricated and measured to verify the design strategy. Measurement results show that the |S11|<-10-dB impedance bandwidth of the proposed antenna is 32.3% or ranging from 4.98 GHz to 6.90 GHz. Compared to the original Mosaic antenna, the impedance bandwidth of the proposed metasurface antenna improves by 21.5%.

14:40 ***Measurement of Multipath Waves at 160 GHz and 300 GHz in an Indoor Conference Room***

Mitsuki Nakamura, Satoshi Suyama, Koshiro Kitao and Takahiro Tomie (NTT DOCOMO, INC., Japan); Minoru Inomata, Wataru Yamada, Nobuaki Kuno and Motoharu Sasaki (NTT, Japan)

In this paper, we measured path loss and direction of arrival of multipath in sub-terahertz wave bands of 160 GHz and 300 GHz in an indoor conference room. The measurement used a directional antenna for the transmitting (Tx) and receiving (Rx) antennas. The horizontal and vertical directions of the Tx antenna were changed by half power beam width, and the Rx antenna was rotated by 360 degrees horizontally while changing the angle of elevation. Measurements were carried out at two Rx antenna points. It was found that the arrival of the multiple waves reflected from wall and ceiling are observed and those path losses are about 10 dB to 30 dB larger than the free space path loss at 160 GHz and 300 GHz.

15:00 ***Reconfigurable Dual-Layer Unit Cell Based Beam Steering Transmitarray***

Xuan Wang, Peiyuan Qin and Y. Jay Guo (University of Technology Sydney, Australia); Kamal Gupta (Australian Department of Defence, Australia)

A beam steering transmitarray utilizing reconfigurable dual-layer unit cells is presented in this paper. Two PIN diodes are used on each array unit cell to achieve a 1-bit phase change with a high transmission. Compared to other electronically reconfigurable transmitarrays employing multi-layer unit cells with metal vias, the developed transmitarray has a much simpler configuration, which is beneficial to larger aperture designs in high frequency bands. To validate the unit cell design concept, a transmitarray prototype at 13 GHz is designed. The measured peak gain is 18.4 dBi, and 2-D beam steering performances are ±50° and ±40° in E- and H-planes, respectively.

15:20 ***Design of a Ka-Band High-Gain Waveguide Rotman Lens Beamformer for Far-Field Wireless Power Transfer***

Soo Young Oh, Dohyeon Kim, Won Ryeol Lee, Ha Young Hong, Hong Soo Park and Sun K. Hong (Soongsil University, Korea (South))

In this paper, we present a high-gain Ka-band Rotman lens beamformer that can be utilized for retrodirective beamforming in millimeter-wave wireless power transfer. Rotman lens beamformers can offer relatively simple and low-cost retrodirective beamforming due to their passive, true-time-delay nature. The proposed Rotman lens is based on a waveguide platform and is capable of generating 9 beams over a steering range of $\pm 20^0$, with a maximum gain of 28dBi.

15:40 ***Measurement and Characterization for Terahertz Metasurfaces***

Yat Sing To, Quan Wei Lin, Hang Wong and King Tung Lo (City University of Hong Kong, Hong Kong)

This paper investigates and demonstrates measurement for terahertz metasurfaces using the far-field scanning technique. A THz coding reflective metasurface with reconfigurable beam functions is utilized as the measured prototype. The radiation patterns of the metasurface under test are obtained with a stable gain of 23 dBi and minimal beam direction deviation over the operating frequencies ranging from 0.28 to 0.31THz, and the simulated and measured results of the metasurface radiation patterns made a good agreement.

Monday, March 27 14:00 - 16:00

CS21: Fundamental challenges and novel methodologies in the next-generation computational electromagnetics

T09 EM modelling and simulation tools / Convened Session /

Room: Spadolini 106

Chairs: Luis Landesa (Universidad de Extremadura, Spain), Francesca Vipiana (Politecnico di Torino, Italy)

14:00 ***Radiation Efficiency Estimation of Lossy Geodesic Lens Antennas Based on a Ray-Tracing Technique***

Pilar Castillo-Tapia and Shiyi Yang (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

Here, we propose a generalized ray-tracing (RT) model to accurately compute the radiation patterns and radiation efficiency of lossy non-rotationally symmetric geodesic lens antennas. The RT model uses geometrical optics to obtain the ray paths from the source to the aperture, ray tube theory to calculate the field amplitude distribution, and Kirchhoff's diffraction formula to compute the radiation pattern. Losses in geodesic lenses are mainly produced by the finite conductivity and roughness of the metallic plates. These losses are added to the calculation of the radiation pattern to estimate the radiation efficiency of the antenna. To demonstrate the accuracy of the proposed RT model, a geodesic half-Maxwell fish-eye lens is designed. Radiation patterns, scan losses, and radiation efficiency are calculated. These results agree well with those computed by full-wave simulations.

14:20 ***Novel Test Integral Quadrature Scheme for the Method of Moments***

Javier Rivero and Francesca Vipiana (Politecnico di Torino, Italy); Donald Wilton (University of Houston, USA); William Johnson (Private Consultant, USA)

An extensive literature exists on the efficient and accurate evaluation of the double surface integrals that arise in the Method of Moments. Most papers have focused on the evaluation of the inner (source) integral with the idea that once that integral is evaluated, the test (outer) integral's integrand is sufficiently smooth that it should be much easier to integrate numerically. However, that affirmation is not always true. Here, we propose an integration scheme that improves the numerical evaluation of the test integral without affecting the treatment of the source integral. The method is numerically validated for static and dynamic kernels in the reaction integrals arising in electric field integral equations.

14:40 ***Design of Energy Selective Surface Guided by Theory of Characteristic Modes***

Zihao Ning (Nanjing University of Science and Technology, China); Mengmeng Li (Nanjing University of Science and Technology & Communication Engineering, China); Dazhi Ding (Nanjing University of Science and Technology, China); Chao-Fu Wang (National University of Singapore, Singapore)

A characteristic mode (CM) guided design of high-performance energy selective surface (ESS) is presented in this paper. Due to the nonlinear nature of loading diodes, the ESS can provide a passband for the low-intensity radiation field (LIRF) and a stopband for the high-intensity radiation field (HIRF). The design of the ESS is guided by the theory of characteristic modes (TCM), investigated by analyzing an equivalent circuit model, and then verified using field-circuit cosimulation. The results confirm that the transmitted power decreases remarkably at input power levels above 15 dBm. Such a property offers great potential as a protective screen for electronic devices from HIRF.

15:00 ***Origami Basis Functions for the h-Refinement in the MoM Solution of Curvilinear Surfaces***

Luis Landesa (Universidad de Extremadura, Spain); Jorge A. Tobon Vasquez (Politecnico di Torino, Italy)

We propose a new set of basis functions, Origami basis functions, which can model folded triangles. That basis functions are similar to RWG basis functions and have been built using the same constraints that RWG basis. With these new basis functions, we can model curvilinear surfaces increasing accuracy when a non-fine mesh is used or when h-refinement or its adaptive algorithm version is applied. This set of basis functions is very useful in h-refinement problems where curvature correction is included in the process of refining meshes.

15:20 ***Full Analytic Evaluation of Galerkin Matrix Elements of Electromagnetic Operators for Parallel-Planes Geometries***

Elizabeth Bleszynski (Monopole Resesarch, USA); Marek Bleszynski, Dr (Monopole Resaearch, USA); Thomas Jaroszewicz (Monopole Research, USA)

We present results of a complete analytic evaluation, in the static limit, of matrix elements of electromagnetic operators for the RWG basis functions supported on two parallel planes. Our method employs Laplacian representation of Green's function, which allows converting surface integrals to integrals over triangles perimeters. By using scaling properties of the resulting double line integrals, we are able to express them in terms of functions involving only logarithms and square-roots, and depending on a few parameters representing geometry of the triangles' edges. The obtained formulae can be used for sufficiently non-parallel and for exactly parallel edges, but become numerically unstable for nearly parallel edges. We were able to represent some of the contributions in numerically stable forms. However, such a treatment of the remaining expressions is quite complex and will be the subject of future work. .

15:40 ***Derivation of Canonical Equivalent Circuits for Multiresonant FSSs with Cross Polarization***

Raúl Rodríguez-Berral (Universidad de Sevilla, Spain); Francisco Mesa (University of Seville, Spain); Francisco Medina (University of Sevilla, Spain)

We extend our previous formulation for frequency-selective surfaces to the general case with cross polarization and derive the

topology and circuit elements of the equivalent two-port network. A canonical Foster representation of the network, together with semi-analytical formulas for all circuit elements, could be obtained by using the resonant current profiles as basis functions for the unknown surface current at the FSS metallizations. For comparison purposes, we have also implemented a standard method of moments (MoM) for the analysis of this structure. A very good agreement has been obtained between the MoM results and the values calculated from the proposed frequency-dependent Foster network for both the co- and cross-polar components, thus validating the proposed procedure.

Monday, March 27 14:00 - 16:00

CS40: Recent Advances in 2-D Leaky-Wave Antennas

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 107

Chairs: Paolo Baccarelli (Roma Tre University, Italy), Davide Comite (Sapienza University of Rome, Italy)

14:00 ***Linearized Multimodal Transfer-Matrix Approach Applied to 2-D Periodic Leaky-Wave Antennas***

Federico Giusti (University of Siena, Italy); Qiao Chen (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Matteo Albani (University of Siena, Italy); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

The linearized Multimodal Transfer-Matrix Approach (MMTMA) is a systematic hybrid solution to efficiently compute the dispersion analysis of two-/three-dimensional 2-/3-D general periodic structures. This approach linearizes the nonlinear eigenvalue problem associated with 2-D/3-D periodic structures, avoiding the search for complex wavenumber solutions (both the phase and/or attenuation constants) in the complex plane. Here, MMTMA is explained and used for the Bloch analysis of a 2-D periodic leaky-wave antenna.

14:20 ***Shaped Beam Synthesis with Peripherally Excited Phased Arrays***

Alexander Mackay and George V. Eleftheriades (University of Toronto, Canada)

The Peripherally Excited phased array has been studied as a useful device for scanning a beam through two dimensions, with a simple structure and reduced number of phase shifters. The antenna uses peripheral sources to excite waves in a leaky cavity, which radiate directive scanning beams. This work investigates how using input amplitude control as a degree of freedom allows for the synthesis of shaped beams. Through a simple model of fields in the cavity, a linear system of equations can be constructed and solved for a desired aperture excitation. Examples of binomial and Chebyshev beams, scanned and at broadside show good agreement between theory and simulation.

14:40 ***Near-Field Links with Obstructed Line of Sight via Bessel Beams***

Konstantinos D. Paschaloudis (Université de Rennes, CNRS, IETR, France); Ravel C. M. Pimenta (Aix-Marseille Université, France); Gabriel Soriano (Aix-Marseille University, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

The generation and propagation of Bessel beams between two apertures with obstructed line-of-sight at microwave frequencies is studied herein. Both the transmitting and receiving apertures are based on leaky radial waveguides consisting of an array of metallic patches over a grounded dielectric substrate. The present work focuses in the case where an axially aligned metallic obstacle is placed between the two launchers to validate the self-healing feature of Bessel beams. Obstacles with different radius are considered and their effect in the power efficiency studied. A limit for the radius' scatterer is defined up to which the self-healing property of the generated Bessel beam is valid.

15:00 ***Efficient Integral Equation Approach for the Modelling of Glide-Symmetric Structures***

Martin Petek, Javier Rivero and Jorge A. Tobon Vasquez (Politecnico di Torino, Italy); Guido Valerio

(Sorbonne Université, France); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Francesca Vipiana (Politecnico di Torino, Italy)

For the design of advanced microwave and antenna components, efficient and accurate electromagnetic methods are required. In this work, we present a technique to fast simulate mirror- and glide-symmetric periodic structures. More concretely, a novel Green's function is proposed which allows to reduce the computational domain to one half of the unit cell. Full dispersion diagrams are computed for metallic glide- and mirror-symmetric structures with three stages of mesh refinement. The results converge with the meshing and agree well with conventional eigenmode analyses.

15:20 ***Dielectric Bull-Eye Leaky Wave Antenna with Broadside Radiation Pattern***

Tomas Lira (Pontificia Universidad Católica de Valparaíso, Chile); Francisco Pizarro (Pontificia Universidad Catolica de Valparaiso, Chile); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain); Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain)

This article presents a new configuration of the Bull-Eye leaky wave antennas by replacing metal rings with dielectric rings. The periodic surface is composed of double concentric dielectric rings used for generating a broadside pencil beam. A parametric study of the effect of the height t of the rings is first presented analysing the dispersion characteristic for both the TE and the TM leaky-modes supported by the cylindrical rings. Afterwards, two antenna designs made with different values of t are presented with results obtained by full-wave simulations. The selected final design exhibits a high-gain symmetrical broadside pencil beam and it is prepared to be manufactured by simple cost effective 3D printing technology.

15:40 ***Creating Sharp Nulls at Broadside Using a 2-D Leaky-Wave Antenna with a Vertical Dipole Source***

Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy); Alessandro Galli (Sapienza University of Rome, Italy); David R. Jackson (University of Houston, USA)

A two-dimensional leaky-wave antenna (2-D LWA) is one that uses a cylindrically propagating leaky wave to form a narrow beam, which is usually a pencil beam at broadside when a horizontal dipole source is used. When excited with a vertical dipole source, however, a null at broadside is instead produced, which might be beneficial for some applications. This peculiar feature is scarcely investigated in the literature and a preliminary analysis is here reported. Relations between the half-power beamwidth and the half-power nullwidth of the beams radiated by 2-D LWAs are found and demonstrated through numerical results.

Monday, March 27 14:00 - 16:00

CS38: Quantum Electromagnetics - From Photonics to Quantum Computing

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 108

Chairs: Nicola Anselmi (University of Trento, Italy), Amir Boag (Tel Aviv University, Israel)

14:00 ***Maxwell-Schrodinger Hybrid Simulation for Analyzing Control and Readout of Transmon Qubits***

Thomas E. Roth (Purdue University, USA); Samuel T. Elkin (Indesign LLC, USA)

The control and readout of a transmon qubit through applied microwave pulses is a key capability in operating many quantum technologies. Currently, the design of microwave pulses for these purposes is done through simple theoretical or numerical models that do not account for how the transmon modifies the applied microwave field. In this work, we present the formulation and discretization of a self-consistent semiclassical model that solves the Schrodinger equation describing qubit dynamics in tandem with a one-dimensional wave equation describing transmission line dynamics. Numerical results are presented using this

Maxwell-Schrodinger method to characterize the control and readout of a transmon qubit. We show that our method matches simple theoretical predictions in relevant operating regimes and also look at situations where simplified models break down. In the future, our method can be used to explore these broader operating regimes to search for more effective control and readout protocols.

14:20 ***Operative Approach to Quantum Electrodynamics in Dispersive Dielectric Objects Based on a Polarization Modal Expansion***

Carlo Forestiere and Giovanni Miano (University of Naples Federico II, Italy)

We present an operative approach to the macroscopic electromagnetic response of a finite-size dispersive dielectric object in unbounded space, in the framework of quantum electrodynamics using the Heisenberg picture. The approach is based on a Hopfield-type model, but it does not rely on an explicit diagonalization of the Hamiltonian. The proposed approach greatly simplifies the formulation of the problem, allows a full-wave analysis, and significantly reduces the computational burden for objects with sizes of the order up to min{c0/[ωsqrt[|χ(ω)|]} where χ(ω) is the susceptibility of the dielectric.

14:40 ***Classical Emulation of Quantum Light: From Few Photons to Bright States***

Dmitri Mogilevtsev (Institute of Physics, National Academy of Sciences of Belarus, Belarus); Amir Boag (Tel Aviv University, Israel); George Hanson (University of Wisconsin-Milwaukee, USA); Alexander Mikhalychev (IPNASB, Belarus); Svetlana Vlasenko (B. I. Stepanov Institute of Physics of the National Academy of Sciences of Belarus, Belarus); Samaneh Pakniyat (University of California Davis, USA); Gregory Slepyan (Tel Aviv University, Israel)

We show the way to emulate classically a number of fundamental quantum mechanical experiments, such as Hong- Ou-Mandel interference, phase measurements with NOON states, and "ringing revivals" in Jaynes-Cummings model using coherent states with a large number of photons. We also show that certain classes of bright non-classical states can be efficiently emulated by our technique independently of the average photon number of those states.

15:00 ***On a Boundary Element Method Modeling the Optical Response from Nanoparticle-On-Mirror Constructs***

Xuezhi Zheng (Katholieke Universiteit Leuven, Belgium); Christos Mystilidis (KU Leuven, Belgium); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)

This work reports a Boundary Element Method (BEM) that predicts the optical response from a Nanoparticle-on-mirror (NPoM) structure which consists of a metallic NP and a mirror with an extremely thin gap (from a fraction of 1 nm to a few nm's) in between. The modeling accounts for the finite compressibility of the electron gas in the metals of the structure by using the nonlocal hydrodynamic model (HDM). A system of Boundary Integral Equations (BIEs) is derived to describe the interaction of light with the NPoM structure and is further solved by the BEM. The numerical implementation is benchmarked against a generalized T-matrix method. Good quantitative agreements are observed.

15:20 ***Analysis and Synthesis of Phased Antenna Arrays Through Quantum Computing***

Luca Tosi (ELEDIA Research Center, Italy); Nicola Anselmi (University of Trento, Italy); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

The analysis and synthesis of phased array (PA) antennas are addressed and reformulated in a Quantum Computing (QC) framework by adopting the Quantum Fourier Transform (QFT) to perform fundamental calculations as an alternative to the classical discrete Fourier transform (DFT). Numerical results obtained by simulation of quantum devices are also presented to support the proposed methodology.

15:40 ***On the Design of Unconventional Optical Phased Array Antennas***

Nicola Anselmi (University of Trento, Italy); Andrea Melloni and Francesco Morichetti (Politecnico di Milano, Italy); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Andrea Massa

(University of Trento, Italy)

The design of unconventional optical phased array architectures suitable for implementation within photonic integrated circuits, is addressed. Starting from a set of free-space-optics beam pattern requirements, thinned array layouts are optimized using a multi-objective approach with the double goal of minimize the array architecture complexity, while controlling the radiation pattern side lobes and main lobe beam width. A numerical example is reported showing an illustrative design of the proposed method.

Monday, March 27 14:00 - 16:00

M06: Innovative Approaches for Antenna Measurement

T10 Fundamental research and emerging technologies / / Measurements

Room: Spadolini 109

Chairs: Amedeo Capozzoli (Università di Napoli Federico II, Italy), Marc Dirix (Antenna Systems Solutions, Spain)

14:00 ***Analysis of the Feed Absorber Fences in Compact Antenna Test Ranges and Their Impact on Quiet Zone Metrics***

Vince Rodriguez (NSI-MI Technologies & University of Mississippi, USA); Branko Lj Mrdakovic (WIPL-D, Serbia); Anil Tellakula (NSI-MI AMETEK, USA); Daniël J Janse van Rensburg (NSI-MI Technologies & Nearfield Systems Inc, USA); Mark Ingerson (NSI-MI AMETEK, USA)

Compact Antenna Test Ranges (CATR) are one of the workhorses of antenna measurements. Ideally, a plane wave is generated by the parabolic reflector at the quiet zone (QZ). The purity of the plane wave is affected by the pattern of the feed and the termination of the reflector. The feed pattern has to be broad enough to minimize the amplitude taper across the QZ. But a broad beam antenna will cause direct illumination of the QZ from the feed, creating an interference ripple on the QZ fields. Recently a high order MoM approach was used the field distribution on the QZ. In this paper the absorber fence that is used to minimize the direct illumination of the QZ from the feed is analyzed. Traditional fences are analyzed for different absorber loadings, from a heavily loaded to lighter loaded absorber. In addition a differently shaped absorber fence is analyzed.

14:20 ***Validation of a Two-Antenna Interferometer for Space Domain Awareness***

Simon Henault, Jean francois Guimond and Kathia Levis (Defence Research and Development Canada, Canada)

A simple land survey method is introduced and demonstrated to determine the reference points of two antennas used as an interferometer for space domain awareness. This method includes the determination of the interferometer baseline orientation through the observation of the Polaris star and can be used in the absence of existing survey markers. A new low- cost flat panel antenna feed was also modified to provide dual-circular polarization on a 4.6 m Cassegrain antenna to track low-Earth orbit satellites and obtain interferometry measurements along with an existing 9.1 m antenna. Phase measurements were validated against precision ephemeris data of satellites NEOSSat and SCISAT.

14:40 ***Near-Field Diagnosis of an X-Band Telemetry Antenna Using Infrared Thermography***

Adrien Laffont and Stéphane Fauré (Anyfields, France); Michele Del Mastro, Quentin Lamotte, Jacek Bhatker and Maxime Romier (Anywaves, France); Daniel Prost (Anyfields, France)

This paper presents an example of antenna diagnosis using a measurement device based on infrared thermography. Infrared thermography measurements allow to obtain, in less than one minute, a high resolution near-field mapping of the electric field radiated by the antenna under test. In this study, such measurements are performed on an X-band telemetry antenna and allow to quickly identify manufacturing defects by comparing the measurements with numerical results.

15:00 ***Antennas for Railway Applications: Comparison Between Scaled Mock-Up and Real Locomotive Measurements***

Muhammad Ehtisham Asghar and Christian Bornkessel (Technische Universität Ilmenau, Germany); Philipp Clauder (Funkwerk Systems GmbH Koelleda Thueringen, Germany); Tobias Nowack (Technische Universität Ilmenau, Germany); Jens Köcher and Uwe Stöpel (Funkwerk Systems GmbH Koelleda Thueringen, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

This paper presents and compares real locomotive and scaled mock-up antenna measurements to investigate the reliability of scaled model measurements and to evaluate the impact of the locomotive chassis on performance of the installed antennas. Three different operational frequencies and two distinct mounting positions at the center and front of the locomotives were selected for comparison. Fair comparability between patterns is observed with a similarity factor above 64%. The deviations between patterns arise from different geometries and installed superstructures. However, the results reveal coherent findings, particularly the significant impact of locomotive chassis, roof geometries, and superstructures onthe radiation patterns. This impact becomes more pronounced at higher frequencies. Moreover, the front position results show strong distortions in patterns compared tothe center position. The results imply that when analyzing the installed locomotive antenna pattern beside the chassis, the impact of superstructures and the impact of the mounting position must be carefully considered.

15:20 ***Efficient Phased Array Radiation Pattern Evaluation for 5G and SatCom On-The-Move (SOTM) Applications***

Mostafa Alazab Elkhouly (Fraunhofer Institute for Integrated Circuits IIS, Germany & Technische Universität Ilmenau, Germany); Ali Eltohamy and Peter Große (Technische Universität Ilmenau, Germany); Markus Landmann (Fraunhofer Institute for Integrated Circuits IIS, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

In satellite communications, it is becoming challenging to provide the tracking performance which is required for Non-Geostationary Orbit (NGSO) constellations with the traditional Satellite Communications (SatCom) On The Move (SOTM) terminal structure which employs bulky parabolic antennas. On the other hand, in terrestrial networks, the single omni- directional communication with User Equipment (UE) does not provide enough throughput to fulfill the need for higher speed connections. As a consequence, manufacturers started to invest in developing new terminals which use phased array antennas to enable beamforming to increase the directivity and null the interference in terrestrial networks and to provide rapid tracking performance as well as seamless handovers in SOTM. In this paper, we propose a methodology to measure a large number of beam patterns of a phased array antenna in a more time efficient approach compared to traditional antenna measurement methods.

15:40 ***Broadband Evolutionary Optimisation of a Free Form Contour Defined Serrated Edge Compact Antenna Test Range***

Marc Dirix (Antenna Systems Solutions, Spain); Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain))

Modern evolutionary optimization techniques when used with efficient parallelized electromagnetic simulation algorithms provide a very effective strategy for the design of high-performance compact antenna test ranges that can be readily tailored to address specific measurement needs. This paper extends the authors previous studies to include far more general serrated edge reflector designs than have previously been considered that, for the first time, not only refine the serration profile, but also the envelope of the projected outline of the offset parabolic reflector. This paper presents results that illustrate the utility of this approach examining and comparing fully broadband optimized predicted CATR quiet-zone performances.

Monday, March 27 14:00 - 16:00

SW3: Active Array Antennas

Organized by: Mauro Ettorre (MSU, USA and CNRS IETR, France); Daniele Cavallo (TU Delft, The Netherlands); Bart Smolders (Eindhoven University of Technology, The Netherlands)

Room: Sala della Scherma

14:00 - Welcome introduction (Mauro Ettorre, MSU, USA and CNRS IETR, France)

14:10 - Active antennas for telecom space applications from GEO to LEO - Challenges and enabling concepts (Jean-Philippe FRAYSSE, Thales Alenia Space, France)

14:40 - Challenges for active array antennas (Stefania Monni, TNO, The Netherlands)

15:10 - Wavelength-level wireless coordination in distributed phased arrays using spectrally-sparse signals (Jeffrey Nanzer, Michigan State University, USA)

Monday, March 27 14:00 - 16:00

SW7: Metrological Traceability Workshop

Organized by: Jeff Guerrieri (NVLAP/NIST)

Room: Polveriera

14:00 - Metrological Traceability Introduction (Jeff Guerrieri, NVLAP/NIST)

14:20 - Rydberg Atom-Based Sensors (Christopher Holloway, NIST)

15:20 - Discussions

Monday, March 27 16:30 - 18:30

SW1b: History of Electromagnetics and Antennas (continued)

Organized by: Ari Sihvola (Aalto University, Finland); Arthur D. Yaghjian (Concord, MA, USA)

Room: Cavaniglia

16:30 *Beating the Spread: Localized Waves and Non-Diffracting Beams*

Richard W Ziolkowski (University of Arizona, USA & University of Technology Sydney, USA)

A historical review of the various non-separable space-time localized wave solutions of the acoustic wave equation, Klein-Gordon equation and Maxwell's equations will be given. These solutions will be contrasted with the frequency domain non-diffracting beams, e.g., Bessel beams. The analysis techniques and the technologies to launch them will also be described. Focused wave modes (FWMs) were introduced 40 years ago in the seminal paper [1]. They were the first electromagnetic localized waves reported. Their provocative properties, i.e., they are electromagnetic (EM) pulses that are localized in space and time and did not disperse as they propagated, unleashed a flurry of activity into examining their properties and their extensions to related classes of solutions. Because the original vision of FWMs was to represent a photon, i.e., a packet-like solution of Maxwell's equations that was localized and had no decay as it propagated, and because their discovery occurred during the Star Wars era, many of the original efforts associated with LWs emphasized directed energy concepts. In fact, it was for these reasons that the nomenclature of the time was associated with "weapons" related terms, i.e., EM Missiles [2]; acoustic and EM Bullets [3]; and acoustic (ADEPTs) and electromagnetic (EDEPTS) directed energy pulse trains [4]. In fact, I would normally describe these pulses to general audiences as "photon torpedoes", one of the futuristic weapons systems of the starship Enterprise of Star Trek fame. Other classes of LWs also began to appear at the time: the so-called diffraction-free or non-diffracting Bessel beams [5] and non-diffracting X waves [6]. They have since evolved into "flying doughnuts" [7], [8] and "diffraction-free space-time light sheets" [9]. A variety of approaches to developing localized waves also unfolded, e.g., [10], [11]. Many of these solutions and their generation methods will be discussed and are detailed in depth in the reference texts [12], [13].

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16:50 *Integral Equations for Stratified Media Problems: From Radio Propagation over Ground to Terahertz Graphene Antennas*

Juan R Mosig (Ecole Polytechnique Federale de Lausanne, Switzerland); Krzysztof Michalski (Texas A&M University, USA)

In this paper, we sketch the history of the development of the mixed potential integral equations for stratified media, in the frame of the Sommerfeld formulation. The analytical formulations, the required Green's functions and the development of discretization algorithms are discussed from a historical perspective. Two classic, almost canonical, problems are discussed in detail: the Sommerfeld half-space problem and the microstrip antenna problem. The paper concludes with some remarks about numerical techniques and with hints about the extension of the theory to recent topics, like Terahertz graphene antennas and metasurface-based structures.

17:10 *From Archimedes Burning Mirror to James Webb Space Telescope: A Journey from the Ancient past to the Renaissance and the Present*

Yahya Rahmat-Samii (University of California, Los Angeles (UCLA), USA)

Antennas are the most important engineering devices dealing with the electromagnetic waves in both receive and transmit modes. Among very diverse configurations of antennas perhaps reflector antennas (mirrors) have seen the most unique and exotic applications. They provide the highest gain, widest bandwidth, and best angular resolutions at the lowest costs. The primary role of a reflector antenna (mirror) is to confine or radiate most of the electromagnetic energy including light over its aperture into a focal plane in receive mode or radiate to the far fields for communication or energy transfer in transmit mode. Majority of reflector antennas use classical conic sections, the parabola, ellipse, hyperbola, and sphere, to either focus or efficiently radiate electromagnetic waves at a wide range of frequencies covering low, microwave, mm-wave, THz, optical and beyond. Reflector antennas are typically categorized according to radiation pattern types, reflector surface types, and feed types.

Archimedes is credited with using parabolic reflectors to focus the Sun's heat on attacking Roman ships in order to set them on fire. At the close of the Renaissance optical mirrors of many kinds resulted in many astronomical discoveries using designs such as Gregorian, Cassegrain and other folded optics configurations. It was not until WWII era that reflector antennas in non-optical regimes received much attention particularly for RADAR applications. Satellite communications including earth observation systems and the current interests in using Cubesats have significantly influenced the developments of exotic designs including offset, shaped, deployable, multi-beam reflector antennas. Many heavenly objects are not only observable in visible light but also emit radiation at radio wavelengths. Apart from observing energetic objects such as pulsars and quasars, radio telescopes are capable of observing other astronomical objects: galaxies, nebulae, black holes, and even radio emissions from planets. The first radio emissions detected by Jansky at Bell Labs in the 1930s were from the Milky Way Galaxy. Inspired by Jansky's work, in 1937, Grote Reber built the first 9.5-m radio telescope. Since then giant reflector antennas have been built with super resolution capabilities. Most recently we have witnessed the flawless deployment of 6.5m James Webb Space Telescope (JWST) operating primarily at infra-red frequencies. JWST is for sure going to revolutionize our current understanding of the universe addressing the following questions: (a) How did it all start? (b) Are we alone? (c) How is our universe evolving?

In this plenary talk, the development of reflector antennas (mirrors) from Archimedes Burning Mirror (200 BC) to James Webb Space Telescope (2021) is reviewed in a concise and novel fashion. This author was so fascinated by a typical shape of a reflector antenna that when he designed the winning IEEE Antennas and Propagation Society Logo many decades back he used a rendition of a reflector antenna in the logo artwork. His logo design now appears on thousands of publication materials related

to the IEEE AP-S publications, symposia flyers and books, etc.

17:30 ***Beam Frame Representations: A New Local Spectrum Alternative to the Plane Wave and Green's Function Representations***

Ehud Heyman (Tel Aviv University, Israel)

Beam summation methods have long been utilized for modeling wave propagation in complex environments due to their unique properties, combining (i) local resolution of the (real or induced) source distributions; (ii) asymptotically uniform spectral representation; and (iii) algorithmic ray-based structure. We use the generic term "beam waves" for both the frequency-domain and the time-domain formulations, where the propagators are iso-diffracting Gaussian beam (ID-GB) or iso-diffracting pulsed beams (ID-PB), respectively.

So far, beam summation methods were mainly a source-based approach: The beam-waves were used only for spectral expansion of the source, and then as propagators. The beam frame is a new concept where a properly constructed phase-space set of beams constitutes a frame everywhere in the propagation domain, and thus can be used for local expansion not only of the sources but also of the medium. This transforms the problem of tracking waves in complicated media into a local-spectrum diagrammatic formulation where the same beam-set is used to expand both the source, the medium, and the local interaction of the field with the medium.

17:50 ***A Brief History of Ray Methods from Ancient to Modern Times and Their Impact on Electromagnetic Engineering Applications***

Prabhakar Pathak (The Ohio State University, USA)

This paper briefly reviews a few of the major steps in the evolution of ray concepts and methods from about 700 B.C. to the present. Some applications of the modern ray methods to solving complex high frequency (or electrically large) problems are later summarized; they clearly illustrate the distinct advantages of ray methods not available in other methods.

Monday, March 27 16:30 - 18:30

CS46b: RIS Modelling, Design and Characterization for 6G networks (continued)

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France), Gabriele Gradoni (University of Nottingham, United Kingdom (Great Britain))

16:30 ***Indoor Factory mmWave Channel Characterization Using Transmitting-RIS Antenna***

Alfred Mudonhi (CEA Leti and Universite Catholique de Louvain & Universite Grenoble-Alpes, France); Gloria Makhoul (CEA-LETI & Université Grenoble Alpes, France); Marina Lotti (University of Bologna, Italy & CEA Leti, France); Antonio Clemente (CEA-Leti, France); Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France); Claude Oestges (Université Catholique de Louvain, Belgium)

In this paper we present a channel measurement characterization in the millimiter wave in Indoor Factory environment, exploiting beamforming capabilities provided by a 400 elements Transmitting RIS antenna. The results in terms of channel gain and delay spread according to the phase distribution on the unit cells are presented. The synthesis of Power Delay Profile over a 120° scanning angle is discussed and compared with the one obtained by Virtual Array.

16:50 ***Test of 5G System in the Reverberation Chamber at mm-Wave***

Davide Micheli (Telecom Italia - TILAB, Italy); Riccardo Diamanti (Telecom Italia, Italy); Luca Bastianelli (Università Politecnica delle Marche, Italy); Emanuel Colella (CNIT, Parma, Italy); Valter Mariani Primiani (Polytechnic University of Marche, Italy); Franco Moglie (Università Politecnica delle Marche, Italy); Andrea Allasia (Telecom Italia S.p.A., Italy); Maurizio Crozzoli (Telecom Italia, Italy); Michele Colombo (Nokia Networks Italia, Italy)

The performance of a real fifth generation base station was studied by using a reverberation chamber as a real life propagating environment. Preliminary tests were conducted in order to define 5G base station operation conditions at mm-wave and emulated scenarios where reconfigurable intelligent surface(s) (RISs) will successively be tested. Measurements campaign was carried out under the H2020 European project RISE-6G and a collaboration program between TIM S.p.A., Nokia and Università Politecnica delle Marche.

17:10 ***Electromagnetics-Based Channel Model of Reconfigurable Intelligent Surfaces***

Ondřej Franek (Aalborg University & APMS Section, Denmark)

Motivated by recently growing interest in reconfigurable intelligent surfaces (RIS), we introduce a channel model of communication between two arbitrarily positioned end devices assisted by a RIS, where all three devices are characterized using off-the-shelf electromagnetic simulation software. The communication between the devices is assumed to occur via planar electromagnetic waves. This approach correctly represents the electromagnetic coupling between the RIS elements, and also allows the user to choose additional complex weights for path loss between the devices. The user is given a scattering or impedance matrix that exposes all ports of the involved devices, including the RIS element ports, which can be used to optimize the RIS performance for various goals.

17:30 ***Design of Reconfigurable Intelligent Surfaces at mmWave with Application to 5G/6G***

Jean-Baptiste Gros, Luca Santamaria, Vladislav Popov, Mikhail Odit, Vladimir Lenets, Xhoandri Lleshi, Ayoub Toubal, Youssef Nasser and Geoffroy Lerosey (Greenerwave, France)

This paper describes the process to design and prototype a Reconfigurable Intelligent Surface (RIS) operating at mmWave. The design process includes the basic, i.e. single, unit cell to the full characterization of the RIS. The prototyped RIS is then demonstrated in a full setup as first 5G/6G access point extender operating at this frequency. The prototype is first of its kind developed by the cutting-edge technology of Greenerwave

17:50 ***A Phase-Space Ray Tracing Method for Smart Electromagnetic Environments***

Sergio Terranova (Nottingham University, United Kingdom (Great Britain)); Martin Richter, Neekar Mohammed, Gabriele Gradoni and Gregor Tanner (University of Nottingham, United Kingdom (Great Britain))

Reconfigurable intelligent surfaces got an increasing amount of attention recently for their capability to provide remarkable performance enhancements in the actual and next 6G generation wireless systems. These programmable metasurfaces can control the EM propagation and achieve the desired wavefront by tuning the local reflection phase of its elements. Accurately estimation of the EM propagation in the RIS-assisted radio channel represents a challenge and becomes crucial for Telecom operators for the management and the optimized allocation of the radio resources. In this context, the authors propose the use of a ray-tracing method operating in the phase-space setting, the Dynamical Energy Analysis (DEA), as a radio planning tool. The leading characteristics of DEA are discussed highlighting the motivations that make it a suitable tool for these purposes. Moreover, some preliminary results of the RIS integration within the DEA algorithm will be presented in some numerical examples.

18:10 ***Do Linear Cascaded Models of RIS-Parametrized Wireless Channels Violate Wave Physics?***

Antonin Rabault (CNRS, France); Philipp del Hougne (CNRS, Univ Rennes, France)

Because the linear input-output relation of a linear scattering system depends, in general, in a non-linear manner on the scattering system's structural parameters, we question the rationale behind the use of cascaded models of RIS-parametrized wireless channels that impose by construction a linear dependence of the wireless channel on the RIS configuration. Using a physics-compliant end-to-end channel model, we demonstrate the importance of reverberation-induced long-range mesoscopic correlations \textit{under rich-scattering conditions} that yield a clearly non-linear RIS-parametrization of the wireless channel. We further show that neglecting these correlations can yield quantitatively and qualitatively incorrect performance predictions. Our results imply that important envisioned 5G and 6G deployment scenarios of RISs at sub-6~GHz or millimeter-wave frequencies (e.g., machine-type communication in smart factories) should not be planned and evaluated using the common linear cascaded models of how the wireless channel is parametrized by the RIS.

Monday, March 27 16:30 - 18:30

CS12: CEM methods applied to radio astronomy

T09 EM modelling and simulation tools / Convened Session /

Room: Spadolini 002

Chairs: Pietro Bolli (INAF - Osservatorio Astrofisico di Arcetri, Italy), Maria Kovaleva (Curtin University, Australia)

16:30 ***Performance of the VGOS Radio Telescope with As-Built Feed and Geometry Using Electromagnetic Simulations***

Mariet Venter (South African Radio Astronomy Observatory, South Africa); Óscar García-Pérez and Félix Tercero (IGN Spain, Spain); Jose-Antonio López-Pérez (IGN Spain & Yebes Observatory, Spain); Sias Malan and Philip Mey (South African Radio Astronomy Observatory, South Africa)

This paper reports on electromagnetic simulations performed of the as-built VGOS (VLBI Global Observing System) 13.2-metre Radio Telescope at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). Specifically, the telescope performance with a measured quadruple-ridge flared horn (QRFH) and with actual surfaces and alignment from photogrammetry, are presented from 2-14 GHz. The results are compared to an ideal Gaussian feed where the effects of the struts and primary reflector panel gaps are also characterised. The manufactured QRFH meets the specification of 50% aperture efficiency over the whole observing band and produces a minimum intrinsic cross-polarisation (IXR) of better than 15 dB. Photogrammetry results at 34° elevation indicate that the telescope is structurally very rigid. The maximum main beam error within the -20 dB contour ranges between only 0.47 and 2.11% across frequency.

16:50 ***Effect of Noise in Embedded Element Pattern Measurements on Mutual Impedance Matrix Extraction***

Maria Kovaleva (Curtin University, Australia); Karl Warnick (BYU, USA)

In a situation when antenna ports are inaccessible for a direct measurement of scattering parameters, embedded element pattern transformation equations can be solved via numerical optimization to extract information about the array mutual impedance matrix. Our goal is to analyze the sensitivity of the impedance matrix extraction to uncertainty in the measured radiation patterns. By varying the noise in the element patterns, we can determine the accuracy of the method in practical situations where the element patterns are not known precisely. If the measured pattern SNR is 40 to 60 dB, representing high quality measured patterns, the error in a mutual impedance matrix does not exceed 5 to 0.5 Ohm. This technique will find its application in radio astronomy and mm-wave systems.

17:10 ***Galileo EMT Software Applied to SKA-Low***

Mirko Bercigli (IDS Ingegneria Dei Sistemi S. p. A, Italy)

Since 2017, the commercial Computer-Aided Engineering (CAE) tool Galileo EMT (ElectroMagnetic Toolkit) has been thoroughly used in various phases of numerical analysis that have supported the construction of one prototype station of the SKA-Low

telescope. This work contains a summary of the activities carried out starting from the analysis at the single element antenna level up to the simulations of the latest version of the array prototype AAVS2. Particular emphasis is placed on the peculiarities of the SKA-Low station making the analysis and the performances evaluation challenging for a general-purpose tool like Galileo EMT.

17:30 ***Characteristic Modes Analysis of Mutually Coupled Log-Periodic Dipole Antennas***

Georgios Kyriakou (INAF Arcetri Astrophysical Observatory & University of Florence, Italy); Pietro Bolli (INAF - Osservatorio Astrofisico di Arcetri, Italy); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy)

Characteristic Modes Analysis (CMA) is a widely used method with recent progress in multi-antenna systems. We employ this method to characterize the mutual coupling phenomenon between two SKALA4.1 antennas, the low-frequency array elements of the future radiotelescope Square Kilometer Array (SKA-Low). The CMA accuracy is first validated at the lowest frequency range of interest with respect to a standard Method of Moments (MoM) solution by decomposing the single antenna into its characteristic modes. We then examine critical frequencies of a two-antenna system in modal decomposition, and characterize those responsible for the radiated electric field spurious spectral features owing to the mutual coupling. We connect these modes to first-order coupling of single antenna CMA modes, by using the eigenvalue data of both single- and two- antenna simulations.

17:50 ***How Electromagnetic Models Can Improve Astronomical Observations in the Square Kilometre Array Radio Telescope***

Maria Grazia Labate, Alice Pellegrini, Mark Waterson and Robert Laing (SKA Observatory, United Kingdom (Great Britain))

The Square Kilometer Array is an ambitious project aiming to tackle some of the most fundamental scientific questions of our time and revolutionize our understanding of the Universe. The SKA is made up of two world-leading complementary radio telescopes on two continents, and will cover a very wide frequency range from 50 MHz up to 15 GHz+. These telescopes represent a game-changer for radio astronomy and, to achieve the science goals, precise prediction and knowledge of the telescopes' performance and behavior are essential. This contribution provides insights into the importance of electromagnetic models in prediction, support, and verification of astronomical observations with the Square Kilometer Array.

18:10 ***Modelling of MFAA Candidate Arrays Using a New Solver Based on Localised Solutions***

André S Conradie and Matthys M. Botha (Stellenbosch University, South Africa)

A new local solution-based iterative scheme for the method of moments (MoM) analysis of large-scale antenna arrays, such as those envisaged for the mid-frequency aperture array (MFAA) part of the Square Kilometre Array (SKA) telescope, is presented in this paper. Localised sub-problems, one associated with each array element, are solved iteratively. Global coupling is incorporated in these local problems through a direct-coupling approximation of non-local currents. The local problem matrices are excitation and iteration independent, hence they can be computed and inverted once and then reused to solve for multiple excitation vectors. Rapid convergence, which is practically independent of excitation, is demonstrated. The method's localised nature renders it ideally suited to parallelisation.

Monday, March 27 16:30 - 18:30

CS27b: INTERACT Propagation measurements and modelling for 6G and beyond (continued)

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 101

Chairs: Marina Barbiroli (University of Bologna, Italy), Sana Salous (Durham University, United Kingdom (Great Britain))

16:30 ***A Ray-Tracing and Deep Learning Fusion Super-Resolution Modeling Method for Wireless Mobile Channel***

Zhao Zhang, Danping He, Xiping Wang, Ke Guan and Zhangdui Zhong (Beijing Jiaotong University, China); Jianwu Dou (ZTE Corporation, China)

Deterministic channel modeling could precisely achieve mobile channel description, however with defects of equipment and time consuming. In this paper, we proposed a novel super resolution (SR) model for cluster characteristics prediction. The model is based on deep neural networks with residual connection. A series of simulations at 3.5 GHz are conducted by a three-dimensional ray tracing (RT) simulator in diverse scenarios. Cluster characteristics are extracted and corresponding data sets are constructed to train the model. Experiments demonstrate that the proposed SR approach could achieve better power and cluster location prediction performance than traditional method. Channel impulse response (CIR) is reconstructed based on cluster characteristics, which could match well with the multipath component (MPC). The proposed method can be used to efficiently and accurately generate big data of mobile channel, which significantly reduces the computation time of RT-only.

16:50 ***Angle-Resolved THz Channel Measurements at 300 GHz in a Shopping Mall Scenario***

Alper Schultze, Ramez Askar and Michael Peter (Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany); Wilhelm Keusgen (Technische Universität Berlin, Germany); Taro Eichler (Rohde & Schwarz, Germany)

This paper presents first results of channel measurements conducted at 300 GHz in an shopping mall scenario. For understanding the radio channel's behaviour in such scenarios within the sub-THz and THz domain, a measurement campaign in the atrium of a large company building was carried out. Angle-resolved channel impulse responses were analysed with regards to channel parameters such as delay and angular spread. A novelty of this work is the analysis of mentioned parameters with regards to synthetic beamwidth of the receiver and various signal-to-noise ratio (SNR)conditions. The analysis shows that with a decreasing receiver (RX) antenna directivity and an increasing SNR the number of multipath components increases rapidly.

17:10 ***Sub-THz Outdoor Urban Measurements and Multipath Propagation Characteristics***

Juyul Lee, Jae-Joon Park, Kyung-Won Kim, Heon Kook Kwon and Myung-Don Kim (ETRI, Korea (South))

This paper investigates sub-THz measurement-based multipath propagation characteristics. The measurements were collected in an outdoor urban environment at frequency of 159 GHz considering both LoS and NLoS link scenarios. With a rotationally-scanning directional antenna setup and a wideband sounder (5-GHz bandwidth), both spatial and temporal multipath power distributions were investigated. By comparing the multipath dispersion characteristics to the associated frequency-extrapolated 3GPP model parameters, which is valid only up to 100 GHz, we found that the delay spread and the angular spread statistics in the 3GPP model deviated from our 159-GHz measurement data.

17:30 ***Wideband Elliptical Arrays for DoA and ToA Estimation in Multipath Environments***

Alejandro Ramírez-Arroyo (University of Granada, Spain); Antonio Alex-Amor (Universidad San Pablo-CEU, Spain); Pablo Padilla (University of Granada, Spain); Juan Valenzuela-Valdés (Universidad de Granada, Spain)

In this paper, we present a phase-mode method for the estimation of time-of-arrival (ToA) and direction-of-arrival (DoA) in smart wireless channels via concentric elliptical arrays with wideband characteristics. The method can be efficiently applied in line-of-sight (LoS) and non-line-of-sight (NLoS) radio environments including multipath components. It generalizes former developments based on wideband circular arrays, as circular and linear geometries are particular cases contained in this approach. In addition, it allows for the implementation of quasi-arbitrary array patterns formed by the superposition of elliptical arrays with different geometries (size, eccentricity, rotation). Finally, some simulations and experimental results in the millimeter-wave range are carried out to illustrate the correct performance of the wideband method.

17:50 ***Space-Time Dense Multipath Components Modeling at mmWaves in Indoor Industrial Environments***

Frederic Munoz (CEA LETI & University of Grenoble-Alpes, France); Gloria Makhoul (CEA-LETI & Université Grenoble Alpes, France); Davy P Gaillot (University of Lille, France); Claude Oestges (Université Catholique de Louvain, Belgium); Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France)

In this paper we present a characterization and model of specular and dense multipath component in the millimeter wave channel for industrial scenarios. The results are obtained from a channel measurement campaign covering the 26-30 GHz band and employing virtual array. Two different high resolution algorithms, SAGE and RiMAX, have been employed, then beamforming on the dense component is used to obtain their angular distribution. The results are compared in terms of large scale parameter fitting

18:10 ***Measurement of the V2I Channel in Cell-Free Vehicular Networks with the Distributed MaMIMOSA Channel Sounder***

Eric P. Simon (IEMN CNRS UMR8520, France); Pierre Laly (University of Lille, France); Joumana Farah (Lebanese University, Faculty of Engineering, Lebanon); Emmeric Tanghe (Ghent University, Belgium); Wout Joseph (Ghent University/IMEC, Belgium); Davy P Gaillot (University of Lille, France)

In this paper, we present a small, yet realistic, vehicular cell-free massive MIMO (multiple-input multiple-output) architecture deployed at the University of Lille in a typical suburban environment under both Line-of-Sight (LOS) and obstructed LOS (OLOS) shadowing conditions. The radio channels were acquired with a distributed RF-over-Fiber (RoF) upgrade of the real-time channel sounder MaMIMOSA. The system operates at 5.89 GHz with an 80 MHz bandwidth, which corresponds to the ITS frequency band offered by the ITS-G5 and C-V2X technologies. Four omnidirectional receive antennas were placed on the roof of a van moving at a speed of 25 km/h. The propagation channel was measured for various transmit antenna configurations, ranging from co-located antennas to fully distributed antennas. The measurement results show a significant gain in the signal-to-noise ratio (SNR) as well as a more uniform coverage and smaller delay spread values with the distributed scenarios compared to the centralized ones.

Monday, March 27 16:30 - 18:30

CS7b: Antenna and Array Technologies for 6G and Beyond (continued)

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 102

Chairs: Y. Jay Guo (University of Technology Sydney, Australia), Richard W Ziolkowski (University of Technology Sydney, USA & University of Arizona, USA)

16:30 ***Optimizing Multibeam Feed Networks for Antenna Arrays with Independent Beam Steering and Low Sidelobes***

Y. Jay Guo and He Zhu (University of Technology Sydney, Australia); Jinhong Yuan (University of New South Wales, Australia); Charles Guo (UNSW, Australia)

In this paper, a new method for synthesizing the generalised joined coupler (GJC) matrix is reported. The GJC matrix serves as a feed network to support arrays with independently steerable multibeams. The synthesis method aims to optimise the joined couplers according to the beam pattern requirements and then the multibeams can be steered independently by tuning the phase shifters. Numerical results demonstrate the effectiveness of the method. An experimental prototype verifies the feasibility

in producing steerable low sidelobe multibeams by employing a Nolen-like GJC matrix.

16:50 ***Satellite Antenna Technologies Enabling 5G Mobile Direct Services***

Nelson Fonseca (European Space Agency, The Netherlands); Bingen Cortazar Unzaga (ESA, The Netherlands); Alberto Mengali (European Space Agency, The Netherlands); Ewelina Ryszawa (ESA, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Pantelis-Daniel Arapoglou (European Space Agency, The Netherlands); Stefano Cioni (European Space Agency & ESTEC, The Netherlands); Alberto Ginesi (ESA/ESTEC, The Netherlands)

5G and beyond 5G communication networks ambition to provide connectivity "anywhere, anytime". This global reach is simply not feasible using only terrestrial networks, which provides interesting opportunities for non-terrestrial networks, including space (from LEO to GEO systems) and atmospheric satellites (e.g. balloons, high altitude platforms). Mobile direct services are of particular interest and pose clear challenges to achieve an adequate sizing of the space segment, all the more so when addressing handheld devices, with very unfavorable link budgets, for continuity of service beyond the reach of terrestrial networks. This paper summarizes some of the main findings of an internal ESA 5G Task Force, with particular focus on the satellite antenna technologies required to enable 5G mobile direct services. The discussion covers both applications in the sub-6 GHz band (FR1) and in the millimetre-wave band (FR2).

17:10 ***140-170GHz Integrated Core-Shell Lens Antenna Front-End for High-Speed Communications***

Nick van Rooijen, Rik Bokhorst, Juan Bueno, Marco Spirito, Nuria LLombart and Maria Alonso-delPino (Delft University of Technology, The Netherlands)

This work presents the current development towards a 140-170GHz integrated front-end for a Fly's Eye architecture. This architecture proposes to combine quasi-optical beamforming with broadband millimeter-wave transceivers to realize a single base station capable of providing Tbit/sec capacity in dense environments (stadiums, football fields, conference centers…). The proposed front-end is composed of a core-shell shell leaky-wave lens antenna integrated on a fused-silica package with MMICs covering the 140-170GHz band. In this contribution, the antenna prototype, the front-end transmitter architecture, the packaging and flip-chip interconnects are discussed using preliminary simulated performances. We expect an antenna directivity >32dBi and a gain >30dBi. A stand-alone antenna prototype and flip-chip assembly test structures are currently being developed to assess the technology performance at these high frequencies.

17:30 ***Millimeter-Wave Single RF Channel Front-End with Stackable Planar Antenna for Multi-Oriented, Extremely Low-Power Gigabit Wireless Connectivity***

Junho Park (Kreemo Inc., Korea (South))

This paper proposes a single RF channel antenna front-end that efficiently generates a directive beam in three orthogonal directions for multi-oriented, millimeter-wave gigabit wireless communication. The low-power OOK architecture featuring a single TRX channel is proposed to mitigate the issues of significant power consumption and heat dissipation from RF components in the conventional RF beamforming architecture. The dual sub-array AiP is also proposed to minimize coupling between TX and RX paths and maximize beam coverage by symmetrically arranging the two sub-arrays. In addition, to further improve the beam coverage, the symmetrically stackable planar antenna (SPA) technology is introduced in order to be able to form the beam towards the endfire direction. The proposed dual sub-array AiP is fully integrated with the RF transceiver and modem compliant with IEEE 802.15.3e standard, which demonstrates a data rate of 1.1 Gb/s in three orthogonal directions at a distance of 60cm.

17:50 ***Metasurface Antenna Enabling Dual Polarization Operation in Ka-Band***

Ravikanth Thanikonda, Marco Faenzi, Alberto Toccafondi, Enrica Martini and Stefano Maci (University of Siena, Italy)

This paper is aimed to propose a novel design strategy and fabrication of a dual polarized metasurface (MTS) based aperture by the concept of inward and outward surface wave (SW) duplexing. The design is indeed based on the illumination sharing of the radiating aperture by an inward, edge excited coherent SW phase front and an outward directed SW, launched from the aperture center. While the latter provides a broadside right-hand circularly polarized (RHCP) broadside beam by interaction

with a spiral unwinding counter-clockwise impedance boundary conditions (IBC), the inward propagating SW interacts with a specular azimuthal IBC phase progression, thus enabling a left-handed circularly polarized (LHCP), where a concentric triaxial feed scheme is adopted. This simple solution has the advantage of maintaining the low profile without power handling detriment or over-complicating the feeding structure or the aperture modulation layout.

18:10 ***Millimeter-Wave Reflector Antenna with Integrated Sub-6 GHz Conformal Patches for 5G/6G Applications***

Jose-Manuel Poyanco (University Carlos III of Madrid, Spain); Alfonso Fernández Durán (Nokia Spain, Spain); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

In this work, the integration of conformal patch antennas in a reflector is proposed as a solution for a dense multi-band antenna. The patch antennas are used to cover sub-6 bands whilst the reflector operates in the millimeter frequency range. One of the key aspects of the design is the definition of the thickness of the substrate of the conformal patches as a multiple of 0.5lambda0 at the millimeter wave frequency to produce in-phase reflections. A proof of concept covering 28 GHz and two sub-6 bands has been manufactured and measured showing the viability of this solution to be used in 5G terminals.

Monday, March 27 16:30 - 18:30

CS19: EuMA-EurAAP session: Towards 6G leveraging Smart EM Environment and Holographic MIMO – Network and Hardware perspective

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 103

Chairs: Roberto Flamini (Huawei Technologies, Italy), Renato Lombardi (Milan Microwave Competence Center, Italy)

16:30 ***Performance Evaluation of Electromagnetically Large Antenna Arrays for 6G Communications***

Giacomo Bacci and Luca Sanguinetti (University of Pisa, Italy)

Modern multiple antenna communication systems are almost exclusively designed under the assumption of locally plane wavefronts over antenna arrays. This is known as the far-field approximation, which is soundly justified at sub-6 GHz frequencies and over sufficiently long transmission ranges. However, it breaks down when higher carrier frequencies are used. Since the wavelength reduces and the transmission range tends to be short, the wave curvature over the array is no longer negligible and arrays operate in the so-called radiative near-field region. The aim of this work is to show that the classical far-field approximation may have a profound impact on the the rates when operating in the 30 GHz bands (and above). The analysis is carried out for a single-cell network with a deterministic line-of-sight channel model that captures key fundamental aspects of the radiative near-field. Maximum ratio (MR) and minimum mean square error (MMSE) combining schemes are considered.

16:50 ***Fully Reconfigurable Holographic Antenna for Next-Gen Wireless Communication Systems***

Cristian Della Giovampaola (Wave Up srl, Italy); Francesco Caminita (Wave-Up SRL, Italy); Nicola Bartolomei (Wave Up srl, Italy); Stefano Maci (University of Siena, Italy)

This work describes a novel type of electronically reconfigurable 2D scanning holographic antenna to be used as part of a smart repeater for next-generation communications systems in Ka band. The antenna is able to scan the beam in both azimuth and elevation by relying solely on the electronic control of PIN diodes on top of the radiating aperture, avoiding the use of phased shifters, which would significantly increase the power consumption of the device. Experimental results showed excellent agreement between simulations and measurements, and highlighted good scanning performance in terms of coverage, side lobe level and cross-polar discrimination.

17:10 ***The Smart EM Environment Paradigm - from the Idea Towards the Implementation***

Marco Salucci (ELEDIA Research Center, Italy); Giacomo Oliveri and Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Lorenzo Poli (ELEDIA Research Center, University of Trento, Italy); Arianna Benoni, Pietro Da Rù and Francesco Zardi (ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

The Smart Electromagnetic Environment (SEME) is a revolutionary paradigm that is expected to become a fundamental pillar in the design of next generation wireless communication systems. It is based on the disruptive idea that the environment should be regarded, differently from the past, as an additional degree-of-freedom (DoF) to improve the overall Quality-of-Service (QoS), rather than an uncontrollable obstacle to the propagation of electromagnetic (EM) waves. This work summarizes the basic concepts and ideas on which the SEME is founded, surveying some of its most recent implementations and envisaging some future trends in this emerging research area, as well.

17:30 ***Maximum-Likelihood User Localization in Active-RIS Empowered mmWave Wireless Networks***

Georgios Mylonopoulos (Consorzio Interuniversitario Delle Telecomunicazioni & University of Cassino and Southern Latium, Italy); Luca Venturino (Universita' degli Studi di Cassino e del Lazio Merdionale & Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT), Italy); Stefano Buzzi (University of Cassino and Lazio Meridionale/CNIT, Italy); Carmen D'Andrea (Università di Cassino e del Lazio Meridionale, Italy & Consorzio Nazionale Interuniversitario per Le Telecomunicazioni (CNIT), Italy)

This paper considers the user localization problem in a multi-user and single-cell scenario with an active reconfigurable intelligent surface (RIS), and assuming line-of-sight (LOS) links operating at millimeter wave (mmWave) carrier frequencies. For the considered scenario, the maximum likelihood (ML) estimator for the user location and antenna array orientation is presented, along with several sub-optimal lower complexity estimation strategies. Closed-form formulas for the Cramér Rao Lower Bounds (CRLB) are also given. Numerical results show the effectiveness of the proposed estimation strategies, as well as the gains granted by the use of an active RIS, especially when the direct LoS link between the base station and the mobile device is obstructed.

17:50 ***LoS MIMO-Arrays vs. LoS MIMO-Surfaces***

Marco Di Renzo (Paris-Saclay University / CNRS, France); Davide Dardari (University of Bologna & CNIT, Italy); Nicolò Decarli (CNR - IEIIT, Italy & WiLab/CNIT, Italy)

The wireless research community has expressed major interest in the sub-terahertz band for enabling mobile communications in future wireless networks. The sub-terahertz band offers a large amount of available bandwidth and, therefore, the promise to realize wireless communications at optical speeds. At such high frequency bands, the transceivers need to have larger apertures and need to be deployed more densely than at lower frequency bands. These factors proportionally increase the far-field limit and the spherical curvature of the electromagnetic waves cannot be ignored anymore. This offers the opportunity to realize spatial multiplexing even in line-of-sight channels. In this paper, we overview and compare existing design options to realize high-rank transmissions in line-of-sight channels.

18:10 ***On Highly Spaced Antennas for Locally Distributed MIMO***

Silvia Mura and Marouan Mizmizi (Politecnico di Milano, Italy); Damiano Badini (Huawei Technologies Italia, Italy); Roberto Flamini (Huawei Technologies Italy, Italy); Christian Mazzucco (Huawei Technologies, European Research Center, Italy); Umberto Spagnolini (Politecnico di Milano, Italy)

The persistent increase in frequency leads to a growing demand for efficient antenna arrays with large apertures capable of generating pencil beams. New technologies have been proposed to meet these requests, e.g., holographic multiple-input multiple-output (MIMO) and distributed MIMO. However, these solutions might have practical limitations, such as the channel state information acquisition for holographic MIMO, or have prohibitive deployment costs for distributed MIMO. This paper proposes using a fully digital array with few highly spaced antennas (beyond the conventional spacing), namely locally distributed MIMO (LDMIMO). The results demonstrate the benefit of the proposed solution. In particular, the advantage over holographic

MIMO is remarkable. With LDMIMO, achieving the same spatial selectivity of holographic MIMO with 40x fewer elements is possible. The same gain is reached during the beam-sweeping procedure for the initial access, where LDMIMO allows a 40x faster operation compared to holographic MIMO.

Monday, March 27 16:30 - 18:30

CS24: Implantable antennas and intra-body wave propagation

T04 Biomedical and health / Convened Session /

Room: Spadolini 104

Chairs: Sema Dumanli (Bogazici University, Turkey), Ali Khaleghi (NTNU, Norway & OUS, Norway)

16:30 ***Vertebrae Transmission Probe Testing - Preliminary Bone Measurements***

Paul M Meaney (Dartmouth College, USA); Viktor Mattsson and Robin Augustine (Uppsala University, Sweden); Tomas Rydholm (Fridagymnasiet, USA); Helena Brisby (Sahlgrenska University Hospital, Sweden)

We are developing a new transmission-based probe for assessing vertebrae strength via the differences between the dielectric properties of normal and osteoporotic bone. Probes are open-ended coaxes that fit into the pedicle canals made before implanting screws to secure the supporting instrumentation. Screws pull out because of bone weakness, can inflict many complications. Moving towards actual clinical trials, we have already validated the approach on different liquids with varying dielectric properties. In this study, we assess actual animal bone samples as a precursor to human investigations. We exploit the fact that the trabecular bone is considerably different on opposite sides of the growth plate of long bones such as the femur - somewhat mimicking differences between normal and osteoporotic bone. For these experiments, we show that the properties of the distal and proximal sections are considerably different and present opportunities to exploit them in a diagnostic setting.

16:50 ***Overview of Medical Implant Antennas***

Ali Khaleghi (NTNU, Norway & OUS, Norway); Sema Dumanli (Bogazici University, Turkey); Ilangko Balasingham (NTNU, Norway)

Antenna miniaturization for integration with small implants for sensing, wireless powering, and communication is a multi-parameter design task. The implanted antenna performance is governed by the antenna size, operating frequency, surrounding and subsequent biological tissues, antenna encapsulation, the electronics and metal objects nearby the antenna, implant depth, and the electromagnetic radiation source defined by the antenna geometry. The antenna performance can be characterized in terms of impedance matching, bandwidth, antenna near-field, far-field radiation pattern, efficiency and gain, and the specific absorption rate (SAR). This paper reviews the design steps for miniaturized implant antennas, the frequency dependency of biological tissues, and EM modeling and simulation tools to support the design. Examples of miniaturized implant antennas are provided for application in the cardiac, gastric, and brain.

17:10 ***Study of an Ingestible Antenna Detuning in a Porcine Model Ex Vivo: Methodology and Experimental Demonstration***

Erdem Cil (University of Rennes 1, France); Icaro V Soares (Institut d'Électronique et des Technologies du Numérique & Université de Rennes 1, France); David Renaudeau (Inrae, France); Ronan Sauleau (University of Rennes 1, France); Denys Nikolayev (Institut d'Électronique et des Technologies du Numérique (IETR) - UMR CNRS 6164, France)

As an ingestible antenna travels through the gastrointestinal tract, the environment surrounding the antenna continuously changes. Varying electromagnetic properties of gastrointestinal tissues lead to antenna detuning during this travel. This paper demonstrates the detuning encountered by ingestible antennas in the gastrointestinal tract with an ex vivo study in a porcine

model. Four dipole antennas and a patch antenna are used for this demonstration. The magnitude and the phase of the reflection coefficient in different gastrointestinal tissues are measured and presented. Moreover, the results of the ex vivo study are compared with measurements conducted in homogeneous liquids mimicking the electromagnetic properties of the gastrointestinal tissues. It is shown that the differences between the magnitude and the phase values obtained in different tissues are greater in the porcine model. The results indicate the importance of performing ex vivo or in vivo characterization of ingestible antennas to validate their robustness against electromagnetic changes.

17:30 ***Flexible Terahertz Antenna Arrays Based on Graphene for Body-Centric Wireless Communication***

Abdoalbaset Abohmra (Glasgow University, United Kingdom (Great Britain)); Hasan Abbas (University of Glasgow, United Kingdom (Great Britain)); Akram Alomainy (Queen Mary University of London, United Kingdom (Great Britain)); Muhammad Ali Imran and Qammer H Abbasi (University of Glasgow, United Kingdom (Great Britain))

For Body-Centric Wireless Communication, a hybrid terahertz (THz) antenna array design with a three-layer structure (gold, graphene, and flexible substrate) is being investigated. Graphene and gold are the two main radiation elements employed in this design. Graphene is used to increase efficiency, whereas conventional metal (gold) is used with sufficient thickness for fabrication and measurement. When combined, these two materials provide design flexibility by manipulating shape and structure and can assist in addressing certain fabrication and measurement problems. Using an ungrounded coplanar waveguide feed (UCPW), the micro-fabricated structure provides a simulated efficiency of 98% at the resonant frequency of 0.84 THz. Because the cost of micro-fabrication has decreased considerably due to recent technical advances, the results of this study demonstrate that highly efficient THz antennas can be achieved for widespread applications, including wearable applications, with the help of 2D materials.

17:50 ***Radiation Performance of Antennas Implanted in Small Animals for Neuroengineering***

Mingxiang Gao (EPFL, Switzerland); James Rosenthal (Swiss Federal Institute of Technology (EPFL), Switzerland); Kangling Wu (EPFL, Switzerland); Zvonimir Sipus (University of Zagreb, Croatia); Stephanie Lacour (University of Cambridge, United Kingdom (Great Britain)); Anja K. Skrivervik (EPFL, Switzerland)

Wireless data communication could improve the performance and reliability of biomedical implants used in fundamental neuroscience research by removing infection-prone transcutaneous cabling. The small size of common research animals like mice and rodents, however, presents an additional challenge in the design of implantable antennas due to the resonance effects of the host body. In this work, we demonstrate how the far-field radiation performance of an antenna implanted in a rat cadaver is impacted by the electrically small size of the rat's body. We further discuss design strategies for developing implantable antennas in small animals in order to obtain robust wireless link budgets for the considered size and energy constrained wireless implantable systems.

18:10 ***Wireless Power Transfer System Design Using Zero-Index Metamaterial for Implantable Medical Devices***

Tarakeswar Shaw (Indian Institute of Engineering Science and Technology, Shibpur, Howrah, West Bengal, India); Bappaditya Mandal (Uppsala University, Uppsala, Sweden); Debasis Mitra (Indian Institute of Engineering Science & Technology, Shibpur, India); Pramod K B Rangaiah (Researcher & Uppsala University, Sweden); Mauricio D Perez (Uppsala University, Sweden & National Technological University, Argentina); Robin Augustine (Uppsala University, Sweden)

This paper presents a novel metamaterial (MTM) integrated, highly efficient approach to designing a wireless power transfer system (WPT), particularly for implantable devices. The proposed implantable WPT system has been constructed by utilizing the radiating principle of the antenna. To design the system, a simple biocompatible circular slot antenna has been constructed on a flexible substrate to use as an implantable receiving (Rx) element. A simple circular patch antenna is designed in air environment to utilize as a transmitting (Tx) element outside the human body for WPT system. Further, the novel zero-index property of the MTM is utilized to enhance the proposed system's power transfer efficiency (PTE). Finally, the prototypes are fabricated, and

measurements are performed in a skin-mimicking gel that is equivalent to the human skin tissue. The measured and simulated result confirms the feasibility of the proposed concept by improving the PTE due to the use of MTM

Monday, March 27 16:30 - 18:30

CS43: Recent Advances on Propagation Research and Its Impact on Localizations

T07 Positioning, localization & tracking / Convened Session /

Room: Spadolini 105

Chairs: Christian Gentner (German Aerospace Center (DLR), Germany), Wei Wang (Chang'an University, China)

16:30 ***Tensor Based Channel Parameter Estimation for Positioning Applications***

Yuzhe Sun, Wei Wang and Jiahui Chai (Chang'an University, China); Yue Lv (Chang‘an University, China)

This paper deduces a variational bayesian method for complex tensors based on mean field theory in MIMO-OFDM systems, which realizes automatic determination of tensor rank and applies CP decomposition of tensors to practical measurements through the tensor space structure. In this method, the channel harmonics are firstly estimated, and then used to implement the angle positioning method. To the end, the estimated harmonic errors and positioning errors are analyzed, confirming the achievability of this method.

16:50 ***Recursive UE Localization for a Multi-RIS-Assisted Wireless System in an Obstacle-Dense Environment***

Sibo Zhao (Tongji University, China); Yuan Liu and Linlong Wu (University of Luxembourg, Luxembourg); José Rodríguez-Piñeiro, Xuefeng Yin and Jingxiang Hong (Tongji University, China)

Accurate user equipment (UE) localization in obstacle-dense environment is quit challenging due to the insufficiency of line-of-sight (LoS) links. However, the reconfigurable intelligent surface (RIS) is potential to offer alternative RIS-assisted LoS links to refine the localization results. In this paper, a recursive localization scheme is proposed based on an iterative RIS selection strategy with the help of the prior knowledge of the propagation environment. And numerical results based on geometry-based channel simulator in typical urban environment exhibit the improvement of localization accuracy.

17:10 ***Indoor Multipath Channel Modeling Effects on UHF-RFID Localization with Synthetic Arrays***

Andrea Motroni, Glauco Cecchi, Alice Buffi and Paolo Nepa (University of Pisa, Italy)

This paper aims at experimentally demonstrating the performance enhancement of passive UHF-RFID (Radio Frequency IDentification) localization systems based on synthetic array approach with appropriate propagation channel modeling in multipath environment. A measurement setup in a relatively controlled indoor environment is built to create a two-ray propagation channel where a metallic reflector contribution superimposes to the LOS (Line Of Sight) path. Localization error reduces when an appropriate channel model is retrieved. Furthermore, multipath proves to be exploitable to enhance localization performance with respect to LOS scenarios since more information can be extracted from the tag backscattered signal. A potential field of application resides in autonomous robots for item grasping, where even small localization improvements may determine the success of an object picking task.

17:30 ***User Tracking with Multipath Assisted Positioning-Based Fingerprinting and Deep Learning***

Markus Ulmschneider and Christian Gentner (German Aerospace Center (DLR), Germany)

Multipath assisted positioning schemes allow localizing a user with a single physical transmitter by treating multipath components (MPCs) as line-of-sight signals from virtual transmitters. The user position and the locations of the transmitters can be estimated jointly with simultaneous localization and mapping (SLAM). While such approaches are promising, they are computationally complex. To reduce this complexity, multipath assisted positioning schemes based on SLAM may be combined with fingerprinting, where the fingerprints are features of the wireless radio channel. Within this paper, we present such an approach, where a deep neural network (DNN) is trained on data from a multipath assisted positioning scheme to predict the user position and its uncertainty from channel information. A Kalman filter can then accurately and efficiently track the user. We show that the positioning performance is improved by a factor of 1.5 while the computational complexity is crucially lower compared to multipath assisted positioning-based SLAM.

17:50 ***Measurement-Based Channel Characterization Using Virtual Array with Directional Antenna***

Mengting Li, Fengchun Zhang and Wei Fan (Aalborg University, Denmark)

Obtaining accurate channel characteristics is essential for wireless communication system design and protocols. Directional scan sounding (DSS) achieved by rotating a directional antenna with a turntable, and virtual antenna array (VAA) based sounding achieved by moving the antenna to the pre-designed locations are both popular methods to characterize static radio channel environments. However, the beam-width of the employed directional antenna limits the angular resolution of DSS. The conventional VAA usually employs an omni-directional antenna which limits its application in millimeter wave bands due to the low antenna gain. In this work, VAA scheme based on directional antennas is presented to characterize the spatial-temporal profiles and omni-directional pathloss of the channels. This scheme can provide high angular resolution and improve the SNR in the measurements simultaneously. Indoor channel measurements at 28 GHz with four different link distances were conducted to verify the effectiveness of the directional antenna based VAA scheme.

18:10 ***Distributed Measurement Framework for UWB Communications, Localization, and Sensing***

Martin Schmidhammer, Christian Gentner and Siwei Zhang (German Aerospace Center (DLR), Germany); Francisco Jurado Romero (German Aerospace Center, Germany); Fabian de Ponte Müller (German Aerospace Center DLR, Germany); Stephan Sand (German Aerospace Center (DLR), Germany)

Radio measurements are essential for the development of next generation wireless networks, which are expected to be multi-functional and handle a massive number of devices. Therefore, we present a flexible modular measurement framework based on ultra-wideband devices, which allows to measure the radio channels in widely distributed networks. In order to deploy a large number of network nodes, we have developed a memory-based synchronization and ranging protocol, that improves particularly the temporal efficiency compared to state-of-the art ranging methods. The proposed modular framework is applied to a measurement campaign at an urban intersection measuring the radio channels between a meshed network of 16 static and one mobile node. Based on these measurements, we evaluate the proposed ranging procedure and show to achieve a mean distance estimation error of less than 0.3 m between static nodes, and of less than 1 m for an exemplary trajectory of the mobile node.

Monday, March 27 16:30 - 18:30

CS21b: Fundamental challenges and novel methodologies in the next-generation computational electromagnetics (continued)

T09 EM modelling and simulation tools / Convened Session /

Room: Spadolini 106

Chairs: Luis Landesa (Universidad de Extremadura, Spain), Francesca Vipiana (Politecnico di Torino, Italy)

16:30 *Investigations on the Low-Frequency Stability of Inverse Surface Source Field Transformations Based on the Electric Field Integral Operator*

Bernd Hofmann (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany); Francesco P. Andriulli (Politecnico di Torino, Italy); Simon B Adrian (Universität Rostock, Germany)

The low-frequency stability of inverse surface source field transformations based on the electric field integral operator (EFIO) together with the boundary element method (BEM) is investigated. In order to overcome the observed breakdown, we study a stabilization scheme based on quasi-Helmholtz projectors. This scheme incorporates a self-adaptive normalization and a stabilized right-hand side (RHS) evaluation which are found of critical importance to determine all fields accurately as shown by the simulation of different inverse surface source reconstructions.

16:50 *Tear and Interconnect DDM with Efficient Multibranch-Multiresolution Preconditioner for the Simulation of Highly Complex Realistic Problems*

Víctor Martín (Universidad de Extremadura, Spain); Diego M Solís (University of Pennsylvania, USA); David Larios (Universidad de Extremadura, Spain); Jose M. Taboada (University of Extremadura, Spain); Luis Landesa (Universidad de Extremadura, Spain); Fernando Obelleiro (University of Vigo, Spain); Francesca Vipiana (Politecnico di Torino, Italy)

In this work we present the combination of a high scalability implementation of the multibranch-multiresolution preconditioner with the domain decomposition method for the electromagnetic analysis of non-conformal complex problems with different levels of multi-scale features. A numerical experiment will be shown to illustrate the great flexibility of this approach for the solution of large multi-scale objects.

17:10 *Design of Meta-Lenses Using Perfect Electric Conducting Spheres and Optimization Methods*

Felipe Vico (Universidad Politécnica de Valencia, Spain); Miguel Ferrando-Bataller and Eva Antonino-Daviu (Universitat Politècnica de València, Spain); Marta Cabedo-Fabrés (Universidad Politécnica de Valencia, Spain)

In this paper we present a method to design lenses based on perfect electric conducting spheres located in free space. The method consist of applying an optimization method to find the best location of the spheres in a plane to maximize certain goal function. The goal function consist of maximizing the total field in a particular point (the focal point). The method uses spherical harmonics centered on each sphere to represent the scattered field produced by the set of all spheres. We present results of particular designs.

17:30 *A Potential-Based Surface Operator for Modeling Lossy Conductors from DC to High Frequencies*

Shashwat Sharma and Piero Triverio (University of Toronto, Canada)

Surface integral equation methods are appealing for the electromagnetic modeling of lossy conductors due to their ability to model the skin effect with only a surface mesh. However, they can be hindered by a lack of accuracy and numerical stability down to DC. We propose a new method based on electromagnetic potentials, rather than fields, which can accurately model lossy conductors from exactly DC to very high frequencies. Unlike existing potential-based methods, the proposed formulation involves deriving a surface operator for each object to model field penetration inside its volume, but does not significantly increase the number of unknowns compared to field-based methods. The accuracy of the proposed technique is verified numerically for structures representative of applications such as high-speed interconnects and electrically small antennas.

17:50 *Numerical Noise in Analytical Evaluation of MoM Integrals*

Denis Tihon and Christophe Craeye (Université Catholique de Louvain, Belgium)

In the Method of Moments (MoM), the evaluation of near-field interactions is a numerically complex task due to the singularity

of the free-space Green's function. Recently, an analytical evaluation method has been proposed to evaluate these interactions. While being theoretically exact, the method deals with recursive formulas that can be ill-conditioned in specific cases when dealing with finite machine precision. In this work, we study the numerical stability of the method. We show that large errors can appear when one edge of the basis function (BF) is nearly parallel to the testing function (TF), and vice-versa. The error depends on the relative distance between the BF and the TF, their polynomial order and their relative orientation. Asymptotic behaviours are extracted from the numerical experiments for the different cases considered.

18:10 ***Ultrafast Channel Estimation and Optimization with Reconfigurable Intelligent Surfaces: A Hybrid Classical-Quantum Computing Model***

Charles Ross (University of Illinois at Urbana-Champaign, USA); Qi Jian Lim (University of Illinois Urbana-Champaign, USA); Gabriele Gradoni (University of Nottingham, United Kingdom (Great Britain)); Zhen Peng (University of Illinois at Urbana-Champaign, USA)

The reconfigurable intelligent surface (RIS) based on discrete meta-surfaces with tunable elements has been widely studied in wireless communication and electromagnetics communities. Researchers have devoted substantial efforts to investigating large-scale optimization algorithms to achieve desired channel conditions. This is particularly challenging in low-complexity RIS architectures without sensing capabilities. We have proposed a novel hybrid classical-quantum computing model that enables the possibility of ultrafast optimization adapting to multipath wireless environments. The performance of the proposed work is demonstrated in representative wireless propagation scenarios.

Monday, March 27 16:30 - 18:30

CS40b: Recent Advances in 2-D Leaky-Wave Antennas (continued)

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 107

Chairs: Paolo Baccarelli (Roma Tre University, Italy), Davide Comite (Sapienza University of Rome, Italy)

16:30 ***Improving Performance of Metasurface-Based Beam-Steering 2D-Leaky Wave Resonant-Cavity Antennas***

Maira I Nabeel (University of Technology Sydney & NUST, Australia); Muhammad Usman Afzal (School of Electrical and Data Engineering University of Technology Sydney, Australia); Dush Thalakotuna and Karu Esselle (University of Technology Sydney, Australia)

This paper presents a design strategy to improve the radiation performance of the metasurface-based beam-steering resonant-cavity antenna (RCA). The antenna system uses phase-gradient metasurfaces (PGMs) placed within the RCA's near-field. The concept is referred to as near-field meta-steering, an efficient beam-steering solution yielding low-profile and planar antenna systems for on-the-move connectivity applications. The PGMs of these antennas have arrays of cells, designed using infinite periodic boundary conditions and plane-wave propagation. While in PGM, the periodicity does not exist in one of the lateral directions. Placing these surfaces in the near-field region of the RCA, deteriorates the antenna system's performance, including gain in the desired direction and shift in the operating frequency. It has been observed that the spacing between the PGMs should be set to 0.25λ from the RCA while spacing between PGMs itself should be less than 0.25λ to have the highest gain at the operating frequency.

16:50 ***Tuneable Millimetre-Wave Leaky Wave Antenna Based on Air-Bridged Schottky Diodes***

Evangelos Vassos, Ioannis Gerafentis, Savvas Chalkidis and Alexandros Feresidis (University of Birmingham, United Kingdom (Great Britain))

A novel beam-steering antenna based on air-bridged Schottky diodes is proposed for emerging millimetre wave technologies such as 5G/6G. The primary radiating structure is a metasurface-based leaky-wave antenna (LWA), including a tuneable high impedance surface (HIS) ground plane. The HIS phase variation is accomplished by varying the capacitance of air-bridged Schottky diodes embedded into the periodic elements of the HIS. The proposed antenna operates at 43.5 GHz with a continuous beam scanning of 20°. The fast (in the order of ns) and continuous beam steering are the key advantages of the proposed metasurface-based antenna. Simulations have been carried out using CST Microwave Studio to evaluate the performance of the beam-steering antenna.

17:10 ***Complete Open-Stopband Suppression in 1D Periodic Metasurface Leaky Wave Antennas***

Federico Giusti, Stefano Maci and Enrica Martini (University of Siena, Italy)

A novel and general approach for completely suppressing the open-stopband effects using anisotropic one-dimensional periodically modulated metasurfaces is here presented. By eliminating this stopband behavior, the anisotropic modulated leaky wave antenna is able to scan from backward end fire to forward end fire without any frequency regions of high attenuation. A closed-form solution for the complex spatial harmonics is found, proving the general validity of this approach. Also, the dispersion analysis of the macroperiodic unit cell is performed using anisotropic impenetrable and penetrable homogenized impedance models, and the accuracy of this latter is corroborated with a spectral ad-hoc method of moments.

17:30 ***Micromachined Modulated Metasurface Antennas in the Sub-THz Range***

Olivier De Sagazan (University Rennes 1, France); Xavier Morvan (Université de Rennes 1, France); Laurent Le Coq (University of Rennes 1 & IETR, France); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

Modulated metasurface antennas have sprung up in recent years as an attractive solution to generate directive beams with low-profile structures. These features makes them excellent candidates to overcome the high propagation losses in sub-terahertz wireless links or for Earth observation missions in the sub-millimeter wave regime with compact platforms. Nonetheless, the use of conventional substrates beyond 100~GHz impairs the antenna efficiency due to the high dielectric losses. This paper presents a metal-only solution that exploits micro-machining to overcome the aforementioned limitation. A structure made of pillars is fabricated by deep reactive ion etching (DRIE) to engrave a Si wafer that is subsequently metallized by sputtering Ti/Au. The photo-lithographic process used for patterning guarantees the accuracy needed in this frequency band. A sub-THz antenna prototype has been fabricated and tested, yielding a measured directivity of 30.9 dBi at 240~GHz.

17:50 ***Contactless Excitation of Leaky-Wave Antennas***

Kan Wang, Mohamed K. Emara, Tom Smy and Shulabh Gupta (Carleton University, Canada)

A simple technique to enable a contactless excitation of a millimeter-Wave (mmWave) slot array Leaky-Wave Antenna (LWA) is proposed and demonstrated using full-wave simulations at 30~GHz. It consists of a broadside coupled input section which can feed the input port of a LWA without any physical contact with the antenna. The frequency beam-scanning property of the resulting structure is demonstrated numerically showing a minimal effect on its performance compared to the LWA with a direct port excitation. This paves a way for an electro-mechanically tunable LWA array suitable for mmWave frequencies.

18:10 ***Fast Near-Field Antenna Measurement Setup Using a Reconfigurable Leaky-Wave Probe***

Mahdi Behdani and Sean V Hum (University of Toronto, Canada)

The data acquisition process in a near-field antenna characterization setup can be greatly accelerated by deploying a reconfigurable antenna as a field-scanning probe. Recent advanced in wide-angle steerable leaky-wave antennas can enable electronic interrogation over a wide range of plane wave directions. This in turn contributes to the accuracy in predicting the tangential near-fields of an antenna under test (AUT) over the interrogation plane. By applying regularization to the captured transmission coefficients of the interrogation process, the tangential electric fields of the AUT are reconstructed. Then, the equivalent magnetic currents of these fields have been used to find the far-field radiation pattern of the AUT through a NF-FF transformation.

Monday, March 27 16:30 - 18:30

CS38b: Quantum Electromagnetics - From Photonics to Quantum Computing (continued)

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 108

Chairs: Nicola Anselmi (University of Trento, Italy), Amir Boag (Tel Aviv University, Israel)

16:30 ***Multimodal Emission and Scattering of Quantum Light***

Gregory Slepyan (Tel Aviv University, Israel); Dmitri Mogilevtsev (Institute of Physics, National Academy of Sciences of Belarus, Belarus); Ilay Levie and Amir Boag (Tel Aviv University, Israel)

We consider the scattering of multimodal quantum light by the perfectly conducting cylinder and its emission by quantum two-element phased array antenna. For the scattering description, we use the well-known classical numerical technique based on the characteristic modes adapted to the quantum light. The method is applicable to cylinders of arbitrary cross-section and size relative to the wavelength. It is shown that the antenna emission and scattering are accompanied by the transformation of the quantum-statistical properties of light (the second-order far field correlation function becomes directional and the multimodal entanglement is created. The obtained results are promising for applications in various branches of quantum technologies.

16:50 ***Antenna Radiation Properties from a Quantum Perspective***

Alfonso Gonzalez Jimenez (Universidad Carlos III Madrid, Spain); Enderson Falcón-Gómez (University Carlos III of Madrid, Spain); Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain); Isabel Carnoto Amat (University Carlos III Madrid, Spain); Luis Enrique García Muñoz (Universidad Carlos III de Madrid, Spain)

We present for the first time the analysis of an actual antenna radiating coherent states from a quantum perspective. Using Quantum Electrodynamics, we show different lights states such as Fock states and the coherent states. The radiation produced by a classical current is associated with Glauber or coherent states. We use a λ/2 dipole for showing this quantum radiation properties. Finally, we show that the interest of studying the quantum radiation properties of an antenna is based on generating Schrödinger superposition states. This will generate a new paradigm for applications such as cryptography, computation, and communication.

17:10 ***Nonlinear Elements in Traveling-Wave Parametric Amplifiers for Dispersive Qubit Readout***

Michael Haider and Yongjie Yuan (Technical University of Munich, Germany); Christian Jirauschek (Technische Universit¨at München, Germany)

In this paper, we present models for the nonlinearity of different nonlinear elements for superconducting Josephson traveling-wave parametric amplifiers. Such devices are typically used as a first-stage readout amplifier for superconducting qubits in a cryogenic quantum computing environment. The nonlinear coefficients of different designs are evaluated as functions of an externally applied bias field, taking into account direct and external pumping schemes. Finally, we present results of the total gain for two different nonlinear transmission lines, one that is embedded with single Josephson junctions operating in four-wave mixing mode with direct pumping, and an externally pumped SNAIL-based amplifier operating in the three-wave mixing regime with a corresponding constant external flux bias. The gain is evaluated using a quantum circuit model including substrate losses and chromatic dispersion.

17:30 ***Collective Photon Emission and Photon Propagation in Layered Photonic Environments***

Mads A. Jørgensen (Technical University of Denmark, Denmark); Ehsan Amooghorban (Shahrekord University, Iran); Sanshui Xiao, Nicolas Stenger and Martijn Wubs (Technical University of Denmark, Denmark)

We present results of our theoretical research on collective emission of photons (super- and subradiance) and photon propagation in photonic environments.

Just like the single-atom emission, collective emission depends on the photonic environment. For quantum emitters in layered media, we study whether surface plasmons can enhance collective emission, especially for emitters at distances smaller than an optical wavelength.

A common approximation in quantum optics is the rotating-wave approximation in the light-matter interaction. We show that in general multi-atom emission rates depend on the approximation, but exceptions exist. Interatomic interactions induced by the electromagnetic field are given by the classical Green tensor, but only when not making the rotating-wave approximation.

As a final example of quantum electromagnetics, we describe photons propagating through a layered medium with alternating loss and gain, so-called loss-compensated media. There is no analogous compensation of the quantum noise associated with loss and gain media.

17:50 ***Engineering Super-Resolution Antenna Array by Quantum Integer Programming***

Qi Jian Lim (University of Illinois Urbana-Champaign, USA); Zhen Peng (University of Illinois at Urbana-Champaign, USA)

Eavesdropping on communication networks involves malicious sensors intercepting information broadcasted from transmitters. One main factor that contributes to the risk of eavesdropping is the unintended radiation energy away from the intended receivers. In this paper, we proposed a quantum integer programming approach for super-resolution antenna array processing. The key idea is to map the antenna array excitations onto a discrete energy minimization model, which would then be optimized using quantum annealing. The results of this study demonstrated beam resolution improvement when compared to traditional phase array beamforming for several complex beamforming scenarios, including a single main lobe at a normal angle, a single main lobe at an oblique angle, and finally multiple main lobes at oblique angles. Our proposed method would improve the physical layer security of wireless communications against eavesdroppers close to the intended receivers.

Monday, March 27 16:30 - 18:30

P08: Body Propagation, Sensing and EMC

T04 Biomedical and health / / Propagation

Room: Spadolini 109

Chairs: Sandra Costanzo (University of Calabria, Italy), Christophe Roblin (Telecom Paris - Institut Polytechnique de Paris & LTCI - Institut Mines-Télécom, France)

16:30 ***Ear-To-Ear Propagation Model - Comparison of Free-Space and On-Body Gain Formulations***

Jonas Ørnskov Nielsen (Technical University of Denmark, Denmark); Søren Helstrup Kvist (GN Hearing A/S, Denmark); Kaj Bjarne Jakobsen (Technical University of Denmark, Denmark)

Two different formulations of the antenna far-field used to evaluate the on-body path gain at 2.45 GHz through a ray-based ear-to-ear propagation model are compared. The free-space far-field formulation does not take field coupling to the human body in the on-body far-field into account, whereas the on-body formulation does. The simulations are compared with a reference full-wave simulation. It is expected that the on-body formulation should improve the accuracy of the propagation model since it takes the field-to-body coupling into account in the on-body far-field. It is found that the results of the comparative study are aligned with expectations. The path gain that results from the use of the on-body far-field formulation is closer to the reference path gain in the band of interest, i.e., around 2.45 GHz.

16:50 ***Ear-To-Ear Propagation Model - Antenna Radiation Pattern Optimization***

Jonas Ørnskov Nielsen (Technical University of Denmark, Denmark); Søren Helstrup Kvist (GN

Hearing A/S, Denmark); Kaj Bjarne Jakobsen (Technical University of Denmark, Denmark)

A highly sophisticated ray-based propagation model is used to find the optimal on-body radiation pattern for an ear-to-ear link. The propagation model allows for a rapid evaluation of the path gain given the antenna radiation patterns. The radiation patterns are represented by the spherical wave expansion (SWE) since they are easy to handle in the computer and in addition the expansion coefficients separate one antenna from another. Furthermore, the SWE produces physically realizable radiation patterns. The procedure to obtain the optimal radiation patterns is formulated as evolution-based optimization. It is found that the optimal gain pattern directs the power in the directions of the geodesic paths traced by the model that lead from one ear to the other. This is in accordance with expectations. The optimized path gain is -35.0 dB which is obtained with lossless antennas with a minimum sphere of 0.2 λ0.

17:10 ***Determining Ablation Zones Using Microwave Transmission Measurement***

Mohamed Lamhamdi, Ali Esmaeili, Kiyan Layes and Tim-Jonas Wechler (University of Applied Science RheinMain, Germany); Andreas Brensing (Hochschule RheinMain, Germany); Bernd Schweizer (RheinMain University of Applied Sciences, Germany); Georg Rose (OVGU, Germany)

In this paper, a measurement method is presented that determines the propagation of the heat front that is generated during microwave ablation (MWA) for monitoring purposes. A measurement setup is implemented that emulates an MWA scenario and consists of a microwave emitter in the ISM band at 2.45 GHz via a slot applicator. These microwaves are transmitted through a phantom body with two different materials, Triton X-100 70% and Triton X100 30%, representing warm and cold tissue of liver. The transmitted wave is received via a bowtie dip antenna. The transmitted power is 10 dBm. The radial extent of the hot zone is changed from 5 mm up to 20 mm in 5 mm steps using a sliding device on top of the phantom body. The changes in time delay between the emitted and received wave are detected.

17:30 ***A Novel Biosensor for Non-Invasive Blood Glucose Measurement Based on Double Square Complimentary Split Ring Resonator***

Esraa Elsayed Mansour (Egypt-Japan University of Science and Technology (E-JUST), Egypt); Mohamed Ismail Ahmed (Electronics Research Institute, Egypt & PSATRI, King Saud University, Egypt); Ahmed Sayed Ahmed Abdelhamid Allam (Egypt-Japan University of Science and Technology (E-JUST), Egypt); Ramesh K. Pokharel (Kyushu University, Japan); Adel Bedair (Egypt-Japan University of Science and Technology, Egypt)

Planar microwave sensors are considered a promising solution to measure blood glucose levels non-invasively. A novel metamaterial microwave biosensor is presented, consisting of a double square complementary split-ring resonator (CSRR) over the frequency range (0-7 GHz). This unique structure is novel in this application. The main concept of the proposed sensor is the concentrated, confined electric field over the sensing region, which results in sensitivity enhancement. The double CSSR sensor is theoretically studied, numerically modeled using Computer Simulation Technology (CST). The sensor's sensitivity is illustrated through simulation in the range of 40-500 mg/dL. In-vitro, experiments are held using de-ionized water glucose solutions within the clinical diabetic range. Results show a high sensitivity performance up to 0.0056 dB/(mg/dL). Hence, our sensor ensures the capability of monitoring the glucose changes either for hypo (40 mg/dL) or hyperglycemia (500 mg/dL) cases non-invasively.

17:50 ***Circular DGS Resonator for Non-Invasive Sensing of Diabetes***

Hala M. Marzouk (Egypt-Japan University of Science and Technology, Egypt); Anwer Sayed Abd El-Hameed (Electronics Research Institute); Ahmed Sayed Ahmed Abdelhamid Allam (Egypt-Japan University of Science and Technology (E-JUST), Egypt); Adel Bedair (Egypt-Japan University of Science and Technology, Egypt)

A millimeter wave-defected ground structure (DGS) resonator is introduced for noninvasive blood glucose concentration detection. The unloaded sensor is designed to operate at 16 GHz. The sensing process is carried out by measuring the variations in the resonant frequency, and S-parameters phase and magnitude. The planned resonator is justified by time domain and frequency domain measurements. Several glucose solution concentrations are considered through experiments from 0 to 1000 mg/dL, providing high sensitivity of 1.4 dB/ (100mgdL-1) and a quality factor of 61.08. Three volunteers assisted to check the potential sensor sensitivity by measuring their blood glucose levels. The actual permittivity of the human body affects the measurements and shifts down the frequency from 16 GHz to 5 GHz, while in simulation the frequency of the loaded sensor is moved to 12 GHz. The presented sensor reveals high sensitivity levels in both simulations and measurements.

18:10 ***Electromagnetic Susceptibility of Implantable Medical Devices: An Experimental Assessment***

Robert A. Urbina and Manuel Pérez (Pontificia Universidad Javeriana, Colombia); Maria Patricia Barajas Salamanca, Zenaida Cucaita Vergara and Javier Leonardo Araque Quijano (Universidad Nacional de Colombia, Colombia); E. F. Pineda (National University of Colombia, Colombia)

Electromagnetic waves can cause electronic devices to malfunction unintentionally. Implantable medical devices must be specially designed to be immune to radio frequency interference. Measuring the electric field around an IMD is one approach to determine whether it might malfunction. This paper presents an experimental set-up that emulates the conditions of a medical device implanted inside a human body. Using an electric field probe for liquids, the field around the IMDs is measured. As result, the heat maps around the IMDs are shown, which allows us to infer that at frequencies of 850 MHz there is no reason to consider that the device may have malfunctioned.

Monday, March 27 16:30 - 18:30

SW3b: Active Array Antennas (continued)

Organized by: Mauro Ettorre (MSU, USA and CNRS IETR, France); Daniele Cavallo (TU Delft, The Netherlands); Bart Smolders (Eindhoven University of Technology, The Netherlands)

Room: Sala della Scherma

16:30 - Building High Performance Affordable SATCOM and wideband SATCOM using silicon chips (Gabriel Rebeiz, UCSD, USA)

17:00 - Current developments on Ka-band wide-angle scanning AESAs (Benoit Lesur, SAFRAN, France)

17:30 - Panel discussion (Mauro Ettorre, MSU, USA and CNRS IETR, France; Daniele Cavallo, TU Delft, The Netherlands; Bart Smolders, Eindhoven University of Technology, The Netherlands)

Monday, March 27 16:30 - 18:30

SW7b: Metrological Traceability Workshop (continued)

Organized by: Jeff Guerrieri (NVLAP/NIST)

Room: Polveriera

16:30 - Re-establishment of the NIST On-axis Gain Service with BIPM (Joshua Gordon, NIST)

17:10 - Establishing a Traceability Path (Dennis Lewis,The Boeing Company)

17:50 - Conclusion & Discussions

Monday, March 27 18:30 - 20:00

Welcome Drink

Room: Spadolini Ground Floor

Tuesday, March 28

Tuesday, March 28 9:00 - 10:40

CS47: Shape and control of electromagnetic fields through reflective and transmissive surfaces

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: Antonio Clemente (CEA-Leti, France), Ronan Sauleau (University of Rennes 1, France)

9:00 ***Synthesis of Transmitarrays for Far- and Near-Field Shaping Using Convex Optimization***

Francesco Foglia Manzillo (CEA-LETI, France); Marie Defives (CEA-Leti University Grenoble-Alpes Grenoble, France)

A unified mathematical framework for the analysis and synthesis of the near and far field radiated by a transmitarray antenna is presented. The far-field co-polar component and a scalar near-field component are expressed as formally identical, convex functions of the phases of the transmission coefficients of the transmitarray cells. Far-field and near-field shaping problems are thus solved using the same iterative convex optimization algorithm, based on semidefinite relaxation. The robustness and effectiveness of this phase-only synthesis procedure in handling diverse pattern constraints is numerically demonstrated with the optimization of a shaped-beam transmitarray and a near-field focusing one. The accuracy of the near-field model is proved by comparison with full-wave simulations.

9:20 ***Evaluation of a Dual-Circularly-Polarized Reflective Metasurface as a Plane Wave Generator in Ka-Band***

Álvaro F. Vaquero (Universidad de Oviedo, Spain); Daniel Martinez-de-Rioja (Universidad Politécnica de Madrid, Spain); Manuel Arrebola (Universidad de Oviedo, Spain)

In this work, a reflective metasurface is designed to generate a dual-circularly-polarized uniform plane wave at Ka-band (31 GHz). The metasurface is designed using a Phase-Only Synthesis with the generalized Intersection Approach. The design considers tight constraints in both amplitude and phase of the radiated near field. The synthesized phase-shift distribution is also used to convert the dual-linearly polarized incident field into a dual-circularly polarized reflected field. The unit-cell of the metasurface is based on two stacked layers of three parallel dipoles, adjusted cell by cell to provide the synthesized phase distributions with less than ±1º of phase error. Preliminary results show the generation of a uniform plane wave in an area equivalent to 82.8% of the metasurface aperture size, revealing the possibility of generating dual-circularly-polarized uniform plane waves using metasurfaces with a simple design process.

9:40 ***A 2-Bit Circularly Polarized Reconfigurable Reflectarray Based on Crossed-Bowtie Elements***

Fan Wu (Southeast University, China)

Circularly polarized (CP) electronically reconfigurable reflectarray with higher than one bit of phase agility has not been thoroughly investigated. Some of the fundamental challenges lie in achieving decent element bandwidth, low insertion loss as well as simplicity in the biasing circuit. Using crossed-bowtie-based elements with PIN diodes assisted reconfigurability, a 2-bit wideband high-efficiency tunable CP reflectarray is designed and presented. The proposed reconfigurable element achieves a wide 2-bit operating bandwidth of 22% while maintains a low insertion loss of smaller than 1.5 dB. The fabricated 16×16 two-dimensional beam-scanning reflectarray experimentally demonstrates a peak gain of 25 dBic, an aperture efficiency of 35% and a scan loss smaller than 3 dB at the scanning angles of ±60°.

10:00 ***Smart Antennas 2.0***

Filiberto Bilotti (ROMA TRE University, Italy); Mirko Barbuto (Niccolò Cusano University, Italy); Michela Longhi (University of Rome "Tor Vergata", Italy); Alessio Monti (Roma Tre University, Italy); Davide Ramaccia (RomaTre University, Italy); Luca Stefanini (Roma Tre University, Italy); Alessandro Toscano (University Roma Tre (IT), Italy); Stefano Vellucci (Niccolò Cusano University, Italy)

Reconfigurable metasurfaces, characterized by electromagnetic properties that can be controlled in both space and time, allow conceiving a new generation of smart antennas, whose intelligence is brought by the physical layer rather than by the connected signal processing modules, as it happens for conventional smart antennas. In particular, by combining either stand-alone or array antennas with reconfigurable metasurfaces, we can enhance the antenna functionalities, enabling cognitive and awareness capabilities, as well as a dynamic control of both radiating and electrical properties. The fundamental bricks of this idea will be presented and discussed, considering the examples of single monopole radiators and planar antenna arrays.

10:20 ***Random Ising Hamiltonian Model of Metasurfaces in Complex Environments***

<u>Gabriele Gradoni</u> (University of Nottingham, United Kingdom (Great Britain)); Sergio Terranova (Nottingham University, United Kingdom (Great Britain)); Qi Jian Lim (University of Illinois Urbana-Champaign, USA); Charles Ross and Zhen Peng (University of Illinois at Urbana-Champaign, USA)

The optimisation of Reconfigurable Intelligent Surfaces (RIS) requires tractable channel models that are electromagnetic compliant. We incorporate the effect of multipath fading in an impedance-based model of wireless communication links assisted by RIS. The fading originating from complex propagation environments is captured by a statistical model based on wave chaos theory: The random coupling model. We show that the so obtained MIMO transfer matrix configures as a Sherrington-Kirkpatrick Hamiltonian with generalised complex-valued Hopfield couplings. For both SISO and MIMO systems, we perform numerical Montecarlo simulations that elucidate the transition to Gaussianity, as parameterised by the average environment losses and RIS line-of-sight channel strengths. Finally, we discuss a research roadmap that includes: i) Retrieving the transmission matrix of complex environments from random coupling fluctuation; ii) Studying of the relation between channel hardening and the onset of a spin-glass phase for small size RIS. Achieved results are important for smart environment design.

Tuesday, March 28 9:00 - 10:40

CS17: Emerging Beam-Steering Antenna Solutions for Satellite and Terrestrial Communications including 5G+

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Karu Esselle (University of Technology Sydney, Australia), Mohsen Sazegar (Kymeta Corporation, USA)

9:00 ***Scan Performance of Low Cost Ka-Band Patch-Based Array***

<u>Rod Waterhouse</u> (Pharad LLC, USA)

In this paper we present a probe-fed stacked patch antenna configuration that can operate over the entire Ka-band and arrays of these elements that can be scanned to beyond 60 degrees. The antenna technology is potentially low cost and is compatible with silicon integration techniques.

9:20 ***Achieving Wide-Angle Mechanical Beam Steering in Ka-Band with Low-Profile Transmit-Array Antennas***

Sergio Matos (ISCTE-IUL / Instituto de Telecommunicações, Portugal); Álvaro F. Vaquero and Manuel Arrebola (Universidad de Oviedo, Spain); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Nelson Fonseca (European Space Agency, The Netherlands)

Beam scanning and high gain are fundamental requisites for antennas operating at millimeter wave, where many 5G and satellite-on-the-move applications are emerging. Mechanical beam steering using Transmit-arrays (TAs) has been proposed as a viable alternative to the more costly and complex electronic-based solutions. As a spatially fed array, TAs operate with a minimal focal length, distance between the primary source and the radiating aperture, which impacts on the overall size of the antenna. The focal length also limits the maximum scanning range that can be achieved through a linear displacement of the primary source parallel to the aperture (a common mechanical scanning approach using TAs). In this work, an iterative method for optimizing the unit cells distribution in the aperture for low F/D (focal length over aperture ratio) is presented. This approach allows extending the scanning range of the common unifocal TA phase distribution. To validate the proposed method, a TA with F=50 mm and in-plane dimensions 195x145 mm (F/D = 0.34) operating at Ka-band (30 GHz) was designed. The full-wave results show that this antenna as a 3 dB scanning range of [-59º,59º], with a maximum gain of 26.3 dBi at 30 GHz and SLL < -11.7 dB.

9:40 ***Calibrated Design of Beam-Steerable Antennas Fed by Varactor-Based Phase Shifters***

Yuan Yuan (The University of Adelaide, Australia); Shengjian Jammy Chen (Flinders University, Australia & The University of Adelaide, Australia); Christophe Fumeaux (The University of Adelaide & School of Electrical and Electronic Engineering, Australia)

An accurate calibration procedure is proposed for a single-feed beam-steerable antenna controlled by varactor-based phase shifters working in differential pairs. The calibration is based on the performance curve of every phase shifter measured from dedicated sampling points on the circuit. A fast selection algorithm based on multi-objective optimization is employed to obtain the control voltages for all differential phase shifter pairs. The final control voltages for a particular beam configuration are validated and fine-tuned on-board at the sampling points. To verify the effectiveness of this procedure, calibrated null-scanning of an 1 X 4 array is demonstrated. The calibrated array can realize null-scanning from -30 degree to 30 degree with a null-depth smaller than -21 dB and a null-position tolerance less than 2.5 degree from 4.75 to 5.25 GHz. These experimentally validated results suggest that the proposed calibration procedure is accurate for beam-scanning arrays fed by varactor-based phase shifters.

10:00 ***Multihyperuniform Disorder and Its Application on Shared-Aperture Phased Antenna Arrays***

Orestis Christogeorgos (Queen Mary University of London, United Kingdom (Great Britain)); Ernest Okon (University of Bedfordshire, United Kingdom (Great Britain)); Yang Hao (Queen Mary University, United Kingdom (Great Britain))

The main design strategy for shared-aperture antenna arrays usually involves the stacking of patch arrays operating at different frequencies on a multilayer setup. This implies that a sophisticated feeding network needs to be designed for each stacked array and in several cases proper Frequency Selective Surfaces (FSS) need to be employed, which will be invisible for certain design frequencies and will alter the propagation characteristics of the radiated wave for other frequencies. These designs although promising are rather complex, difficult to be generalized and in most cases reach up to tri-band operation. Here, we formulate the mathematical model behind the generation of a multiple element aperiodic distribution, the multihyperuniform disordered, which has been found in several natural processes. We employ this type of disordered distribution in order to overcome the bandwidth limitations of periodic distributions and design shared aperture antenna arrays for ultra-wideband unidirectional emission applications.

10:20 ***Multi-Beam Continuous Transverse Stub Antenna Enabled by a Reflecting Luneburg Lens at Ka-Band***

Christos Bilitos (University of Rennes, France); Ronan Sauleau (University of Rennes 1, France); Enrica Martini and Stefano Maci (University of Siena, Italy); David González-Ovejero (Centre National

de la Recherche Scientifique - CNRS, France)

This paper presents a low-profile multi-beam antenna for broadband operation at Ka-band. The structure at hand consists of two vertically stacked parallel plate waveguides (PPWs) of circular shape. The bottom PPW houses a reflecting Luneburg lens (RLL), whereas the top one accommodates a continuous transverse slot (CTS) array. The RLL's graded index (GRIN) profile serves to address the rays along curvilinear paths such that, after reflection at a metallic rim, they emerge collimated in the top PPW. The rotational symmetry of the RLL's medium allows one to generate multiple planar wavefronts with arbitrary directions by introducing a number of sources in the bottom layer. The slotted plate in the top layer produces pencil beams, whose pointing angle is dependent on the angle between the direction of the planar wavefronts and the slots. This metal-only, low-profile antenna achieves 2D scanning, by beam switching, at Ka-band with over a 17.1% fractional bandwidth.

Tuesday, March 28 9:00 - 10:40

CS36: Propagation for Smart Mobility Scenarios

T05 Aircraft (incl. UAV, UAS, RPAS) and automotive / Convened Session /

Room: Spadolini 101

Chairs: Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany), Danping He (Beijing Jiaotong University, China)

9:00 ***Parametric Study of Radio Propagation in Railways Based on Ray-Tracing Simulations***

Jorge Elizalde (Ikerlan & BRTA, Spain); Aitor Arriola (IKERLAN, Spain); Marti Roset (Comsa, Spain); Jérôme Härri (EURECOM, France); Igor Lopez (Construcciones y Auxiliar de Ferrocarriles (CAF), Spain); Marvin Straub (Alstom, Germany)

In this work the RF propagation has been characterized first for a 5G Wireless Train Backbone, based on a parametric simulation model of a train. Different parameters have been changed to study their effect on the RF propagation. According to these results, some recommendations are made. The antenna propagation has also been studied in a model for the Wireless Consist Network

9:20 ***Parametrization and Validation of the Geometry-Based Stochastic Channel Model for Train-To-Train Communication***

Paul Unterhuber and Michael Walter (German Aerospace Center (DLR), Germany); Thomas Kürner (Technische Universität Braunschweig, Germany)

The future of railway transport aims at more flexible train composition with virtually coupled train sets (VCTSs), automatic train operation, and autonomously driving trains. The train-to-train (T2T) communication is one major technology which is enabling those future railway concepts. Hence, the development of the next generation of communication standards takes into account railway communication. The development of standards and equipment for wireless communication requires a profound knowledge of the propagation conditions in railway environments and for moving trains. For safety critical applications the time-variant behavior of the propagation channel has to be considered. Therefore, we propose a geometry-based stochastic channel model (GSCM) and show the parametrization for an open field environment. The proposed and parametrized GSCM enables the development and testing of communication standards for T2T communication.

9:40 ***Performance and Reliability of 5G Communications for USV-UAV Critical Applications***

Kang Xue (TongJiUniversity, China); José Rodríguez-Piñeiro, Yuning Yu, Jingxiang Hong and Xuefeng Yin (Tongji University, China); Xie Shunqin (Institute of Electronic Engeneering, China Academy of Engineering Physics, China)

With the development of fifth generation (5G) and 5G and beyond (B5G) mobile communications, unmanned vehicles are gaining attention. In critical applications, such as rescue operations, cooperative operation between unmanned vehicles, like unmanned aerial vehicles (UAVs) and unmanned surface vehicles (USVs), is required. In order to implement these applications, reliable communications between the vehicles become necessary In this paper, based on propagation results obtained by measurements, we evaluate the communications performance between a USV and a UAV, considering metrics like the Block Error Rate (BLER), the end-to-end delay, the throughput and the packet loss ratio. The results show that in order to satisfy the reliability requirements for critical communications established by the 3rd Generation Partnership Project (3GPP), the Modulation and Coding Scheme (MCS) index needs to be carefully optimized. The obtained results are of great importance to evaluate whether current 5G deployments can support critical communications for UAV-USV communications.

10:00 ***Narrowband UAV Air-To-Ground Channel Measurement and Modeling in Campus Environment***

Yue Lv (Chang'an University, China); Wei Wang and Yuzhe Sun (Chang'an University, China)

Unmanned aerial vehicle(UAV) air-to-ground(A2G) wireless communication is a fundamental technology for integration of UAV in the intelligent transportation system(ITS), where accurate analysis and modeling of UAV to vehicle wireless channel are of great importance for communication algorithm development. In this paper, the multi-link channel measurements are carried out in low altitude with UAV vertical flying over a semi-urban environment. Based on the measurement data at 2.4 GHz and 5.9 GHz, the large scale and small scale channel parameters are investigated in the non line-of-sight(NLoS) and obstructed line-of-sight(OLoS) conditions, respectively. The value of the path loss as a function of the elevation angle and distance is proposed. Then, the shadow fading(SF) and fast fading are statistically analyzed for comprehensively describing the channel fading behaviors. Our results will be useful for the modeling of low altitude A2G propagation channels, and the performance analysis of UAV-enabling A2G communication systems for future intelligent transportation.

10:20 ***Non-Stationarity Analysis of Vehicle-To-Vulnerable Road Users Channel in Critical Scenarios***

Ibrahim Rashdan and Stephan Sand (German Aerospace Center (DLR), Germany); Suying Jiang and Wei Wang (Chang'an University, China); Giuseppe Caire (Technische Universität Berlin, Germany)

Direct vehicle-to-vulnerable road users (V2VRU) communication can prevent accidents by providing 360 degree awareness and improving detection, localization, and tracking of both vehicles and VRUs. Having a realistic channel is a prerequisite for developing a reliable V2VRU communication system. In order to parameterize a geometry-based stochastic channel model (GSCM), it is important to determine the length of local quasi-stationarity regions. Therefore, in this work, the non-stationarity of the V2VRU channel is analyzed by estimating the generalized local scattering function (GLSF) and its collinearity based on the channel measurement data. The estimated stationarity distance is presented for the three most critical accident scenarios in urban environment. We find that the observed rapid fluctuations of the stationarity distance are mainly caused by the sudden change in the Doppler domain at the collision point, strong multipath, and the blockage of the line of sight by parked vehicles.

Tuesday, March 28 9:00 - 10:40

CS53: Wide-Scanning Antenna Array Concepts for Millimetre-Wave Applications

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 102

Chairs: Daniele Cavallo (Delft University of Technology, The Netherlands), Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

9:00 ***Wideband Planar Printed Aperture on a Triangular Lattice for Millimeter Wave Applications***

Rick Kindt (Naval Research Laboratory, USA); Bradley T Binder (The Office of Naval Research, USA)

This paper presents a Planar Ultra-wideband Modular Antenna (PUMA) array that operates up to millimeter-wave frequencies. The dual-polarized planar aperture is tuned for operation over a wideband frequency range (8 GHz to 40 GHz) with elements optimally spaced on a triangular lattice for grating-lobe-free scans in visible space with minimal element counts. Infinite array modeling simulations are discussed and validated with measurements on prototype aperture hardware.

9:20 ***Reconfigurable Transmitarrays at Ka-Band with Beam-Forming and Polarization Agility***

Antonio Clemente and Reda Madi (CEA-Leti, France); Francesco Foglia Manzillo (CEA-LETI, France); Maciej Smierzchalski (ATOS, France); Jacques Reverdy (CEA, France); Ronan Sauleau (University of Rennes 1, France)

This paper presents transmitarray-based antenna solutions for SATCOM transmit (Tx) user terminals at Ka-band. We propose a new electronically-reconfigurable unit-cell structure which combines a 2-bit phase control with circular polarization agility. Six p-i-n diodes are integrated into the proposed unit-cell implemented by stacking two half-wavelength periodic structures: a reconfigurable phase-shift module and a switchable linear-to-circular polarization converter. The two structures, developed on a standard PCB stack-up, are separated by an optimized air gap. A 576-element square transmitarray with 3456 integrated p-i-n diodes has been designed, optimized, and fabricated. To enhance the advantages of this innovative architecture, its performance is compared to the one of our previous transmitarray demonstration based on a random sequential combination of 576 vertically- and horizontally-polarized 2-bit reconfigurable unit-cells. To the best of our knowledge, this represents the first demonstration of transmitarray with two stacked reconfigurable functionalities.

9:40 ***Wide-Angle Scanning Coupled Dipole Antenna Array for Heterogeneous mm-Wave Communication Networks***

Michael Fischer (Ulm University, Germany); Christian Waldschmidt and Tobias Chaloun (University of Ulm, Germany)

A novel design of a coupled dipole antenna array for terrestrial and non-terrestrial mm-wave communication networks is presented. This antenna is optimized for large scanning capabilities up to 60° in all planes across a large frequency range. A total frequency range from 18.4GHz to 31.0 GHz is covered, including the downlink and uplink frequency bands for K/Ka-band SatCom as well as for mm-wave 5G radio access. With its scalable design and wide application scenario, this antenna overcomes the issue of having to design and optimize dedicated antennas for each single application. In a simulative investigation, the antenna showed an excellent performance with transmission coefficients to the co-polarized Floquet-mode in free space of −0.5 dB in the E-plane at the maximum scanning angle. Furthermore, it maintains a cross-polarization suppression of more than 20 dB over most of the frequency range and scanning angles.

10:00 ***High Gain Linearly Polarized 1D Beam Scanning Array Antenna Based on Gap Waveguide Technology***

Viktor Mattsson and Sebastian Ekman (Satcube AB & Chalmers University of Technology, Sweden); Ashraf Uz Zaman (Chalmers University of Technology, Sweden); Lukas Nystrom (Satcube AB, Sweden)

This paper presents a feed network for a high gain array antenna capable of 1D beam scanning up to 60 degrees without grating lobes. The feed network uses a layered design where the use of gap waveguide technology enables the layers to be assembled without good electrical contact. Each layer constitute one section of a vertical corporate feed network ending in a horizontal series feed, allowing for a compact design and integration of electronic components inside the antenna. To enable this, a periodic pin structure has been designed together with two vertical power dividers, one in ridge gap waveguide and one from microstrip to ridge gap waveguide. The structure is designed for Ka-band at 27.5-30 GHz and results show a 10 dB return loss bandwidth of 10 %. The array size is 40x8 elements which fits in a volume of 59.2x242.9x13.1 mm, while the boresight realized gain is 28 dBi.

Tuesday, March 28 9:00 - 10:40

CS50: Synthesis, Optimization, and Design of IoT antenna systems

T03 Wireless LANs, IoT and M2M / Convened Session /

Room: Spadolini 103

Chairs: Jaume Anguera (Ignion & Universitat Ramon Llull, Spain), Miloslav Capek (Czech Technical University in Prague, Czech Republic)

9:00 ***Conformal In-Body Bolus Antenna for Precision Goat Farming***

Jasper Goethals (Ghent University & IMEC, Belgium); Denys Nikolayev (Institut d'Électronique et des Technologies du Numérique (IETR) - UMR CNRS 6164, France); Gunter Vermeeren (Ghent University, Belgium); Wout Joseph (Ghent University/IMEC, Belgium); Matthew Philpott and Eli Clement (ENT Studios, Belgium); Margot Deruyck (Ghent University - IMEC, Belgium)

Precision livestock farming has seen an increased interest in the past years. To enable this technology, solid ground work needs to be done to roll-out the system. One major pillar of the ground work is the sensor to base station communication link. In this work, we present an in-body conformal bolus antenna to improve the wireless capability of the sensor nodes, as well in efficiency as in performance. Throughout the paper, we explain the design choices we made based on the state of the art theoretical background that is developed in the recent years concerning in-body antennas. The proposed antenna has a gain of -37.2 dBi. The antenna is well matched to the 50 Ohm system and has a bandwidth of 20 MHz.

9:20 ***On Small Antennas with Circular Polarization, Bandwidth Estimates and Design Considerations***

Lars Jonsson (KTH Royal Institute of Technology, Sweden); Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France)

Circular polarization is an essential feature for small antennas designed to connect with satellite navigation systems. Here, a Q-factor optimization problem constrained with a circular polarization radiation requirement is formulated and solved. The constrained problem is shown to be solvable as fast as calculating the Q-factor bound without the constraint. Two antenna models are designed to assess the bounds. One aims for bandwidth, and the other for circular polarisation. The well-known relation between the Q-factor and the available bandwidth is used to evaluate the designs. The circularly polarised antenna is close to the bound and has a wide field of view. The Q-factor bound provides insight into desirable antenna positions on the small device.

9:40 ***Compact Folded Meander-Line Harmonic Tag Antenna for Insect Tracking***

Arjun Kumar (University of Twente, The Netherlands & Bennett Uinversity, India); Anastasia Lavrenko (University of Twente, The Netherlands)

This article proposes a new single layer folded meander-line harmonic tag implemented on a thin flexible substrate. The proposed prototype consists of two asymmetric modified meander-line dipoles that are matched to a low-voltage Schottky diode to generate second harmonic frequency at 5.8GHz when illuminated by a fundamental frequency of 2.9GHz. The proposed tag achieves fractional bandwidth of 1.67% at the fundamental frequency with compact size of 0.14λo x 0.12λo. The proposed tag antenna has the gain of 2.09dBi at 2.9GHz and 1.38dBi at 5.8GHz.

10:00 ***Reconfigurable Antenna Booster Element for Multiband Operation in IoT Devices with an SP4T***

Elena García and Aurora Andújar (Ignion, Spain); Joan Pijoan (Universitat Ramon Llull, Spain); Jaume Anguera (Ignion & Universitat Ramon Llull, Spain)

The increase of the IoT (Internet of Things) puts pressure on device's dimensions and energy costs. This is challenging to embed an antenna into such a small device as 70 mm x 65 mm. For this purpose, a further step is taken by optimizing the area required for the integration of a wireless transmission system using the development of smart adaptive networks so that a single antenna system is capable of transmitting at different frequency bands. To validate the procedure, a reconfigurable architecture with a single SP4T (Single-Pole 4-Throw) operating at 698 MHz - 960 MHz and 1710 MHz - 2170 MHz is designed and built with a non-resonant element called an antenna booster element. This procedure opens the window to facilitate the design of tunable antenna solutions systems for IoT designers requiring a multiband operation.

10:20 ***Reconfigurable Multiband Antenna Booster Element Under Metallic Environment for IoT Applications***

Alejandro Fernández and Aurora Andújar (Ignion, Spain); Jaume Anguera (Ignion & Universitat

Ramon Llull, Spain)

A passive matching network cannot match a device for more than one specific scenario. For this reason, a new approach capable of matching an Internet of things (IoT) device at 698-960 MHz and 1710-2170 MHz for two different environments, free space and on top of a metallic plate, is presented. The proposed method uses an SP4T (Single Pole 4 Throw) switch to provide good impedance matching in both environments. The multiband reconfigurable matching network can mitigate the frequency shifting created by the metallic environment. To validate it, a prototype is implemented and tested in both environments. By using the reconfigurable architecture, total efficiency is maximized in both free-space and on-metal plate cases. The total efficiency is increased by 3 dB for the on-metal condition compared to a passive solution where a single matching network is used for both cases.

Tuesday, March 28 9:00 - 10:40

E01: Inverse Problems and Imaging for biomedical applications

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / / Electromagnetics

Room: Spadolini 104

Chairs: Rossella Gaffoglio (Fondazione LINKS, Italy), Giovanni Leone (University of Campania, Italy)

9:00 ***Study of the Effect of Fibroglandular Tissue in Tumor Detection Using Microwave Breast Imaging***

Raquel A. Martins (Instituto de Telecomunicações/Instituto Superior Técnico, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal)

We perform a study to evaluate the effect that fibroglandular tissue has on tumor detection in radar-based microwave imaging (MWI). MWI relies on the contrast between the dielectric properties of healthy and malignant tissues, which may be as low as 10%, thus hindering tumor identification. Here, we performed measurements on a dry MWI setup, in the 2-5 GHz frequency range, to scan anthropomorphic breasts with two fibroglandular tissues, and a tumor placed at different distances from the fibroglandular. Imaging results showed that tumor identification in MWI is highly influenced by the volume and shape of the fibroglandular tissue. Indeed, we find that in most cases the tumor cannot be distinguished with common image metrics because it is indistinguishable from the fibroglandular. Yet, we verify that there are changes in the magnitude of the confocal algorithm, which may open the opportunity to machine learning techniques to detect it.

9:20 ***MammoWave Breast Imaging Device: An International and Multicentric Clinical Investigation***

Navid Ghavami (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Daniel Álvarez Sánchez-Bayuela (University Hospital of Toledo, Servicio de Salud de Castilla - La Mancha, Toledo, Spain); Lorenzo Sani, Alessandro Vispa and Alessandra Bigotti (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Mario Badia (UBT - Umbria Bioengineering Technologies, Italy); Lorenzo Papini (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Giovanni Raspa (UBT - Umbria Bioengineering Technologies, Italy); Soumya Prakash Rana (London South Bank University, United Kingdom (Great Britain)); Cristina Romero Castellano (Hospital Virgen de la Salud, Toledo, Spain); Daniela Bernardi (Humanitas Research Hospital, Milan, Italy); Alberto Tagliafico (University of Genoa, Italy); Massimo Calabrese (IRCCS Ospedale Policlinico San Martino, Genoa, Italy); Mohammad Ghavami (London South Bank University, United Kingdom (Great Britain)); Gianluigi Tiberi (London South Bank University, United Kingdom (Great Britain) & UBT - Umbria Bioengineering Technologies, Italy)

This work presents the first multicentric, single arm, prospective study to evaluate the ability of MammoWave, a microwave imaging prototype in breast lesions detection. This study was the first breast microwave imaging study during which both symptomatic and asymptomatic subjects were recruited. MammoWave output consists of a selection of microwave images' features, determined prior to the beginning of the trials, to quantify images' non-homogenous behavior. Our results on 382 breasts show a sensitivity of 82% using a statistical significance of $p<0.05$, indicating MammoWave's ability in distinguishing breasts with and without radiological findings. This prospective clinical trial may pave the way for introducing microwave imaging into clinical practice, for assisting in identification of breast lesions in asymptomatic women of all ages, without safety limitations.

9:40 ***Brain Stroke Microwave Imaging via an Efficient Implementation of the CSI-FEM Algorithm***

Valeria Mariano (Politecnico di Torino, Italy); Lucas Banting (University of Manitoba, Canada); Jorge A. Tobon Vasquez (Politecnico di Torino, Italy); Ian Jeffrey and Joe LoVetri (University of Manitoba, Canada); Francesca Vipiana (Politecnico di Torino, Italy)

Microwave imaging of the human head for stroke detection is demonstrated using the finite-element contrast source inversion method with enhanced discretization of the contrast-source variable. The linear basis functions used in the new discretization lead to a simple implementation of higher accuracy compared to discretizations wherein the contrast source variable is assumed to be constant over each tetrahedron of the 3D finite-element mesh. These advantages are particularly important for stroke imaging because of the highly inhomogeneous nature of the human head. Results using synthetic data obtained from a realistic numerical model of the head show promise for stroke detection.

10:00 ***Combined MR and Microwave Imaging - Prototype and Phantom Experiments***

Paul M Meaney, Shireen Geimer, Grace Player and Timothy Raynolds (Dartmouth College, USA); Xiaoyu Yang (Quality Electrodynamics, USA); Keith D. Paulsen (Dartmouth College, USA)

We are developing a microwave breast imaging system that can operate simultaneously in a magnetic resonance imaging system. Being able to directly register the two image sets allows us to exploit the excellent spatial resolution of MR with the more specific nature of the recovered dielectric properties. This fused imaging configuration could ultimately obviate the need for invasive contrast agents such as gadolinium. The integrated system consists of a substantially slimmed down microwave illumination tank integrated with a custom 3-channel MR coil for improved signal-to-noise ratio. The microwave apparatus has been designed to minimize the overall height and be compatible with the MR environment - specifically, material choice and cross-system signal coupling. We demonstrate our new imaging tank and present results from initial breast-like phantom experiments. These results are a major step towards integration, implementation of our 3D soft prior imaging algorithm and ultimately patient exams.

10:20 ***Radar-Based Imaging Through StrokeWave Device: Preliminary Experimental Results***

Navid Ghavami (Umbria Bioengineering Technology (UBT), United Kingdom (Great Britain)); Mario Badia (UBT - Umbria Bioengineering Technologies, Italy); Lorenzo Sani (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Giovanni Raspa (UBT - Umbria Bioengineering Technologies, Italy); Daniel Álvarez Sánchez-Bayuela (University of Castilla - La Mancha & University Hospital of Toledo, Spain); Alessandro Vispa, Alessandra Bigotti and Lorenzo Papini (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Mirco Cosottini (University of Pisa, United Kingdom (Great Britain)); Mohammad Ghavami (London South Bank University, United Kingdom (Great Britain)); Gianluigi Tiberi (London South Bank University, United Kingdom (Great Britain) & UBT - Umbria Bioengineering Technologies, Italy)

This paper presents for the first time preliminary measurement results obtained using an innovative microwave brain imaging device, named StrokeWave. Brain strokes are the world's second largest cause of death and the largest cause of adult disability, and their correct timely detection is vital for increasing patient's chance of survival. The StrokeWave prototype introduced here employs only two antennas which operate without matching medium, and uses a radar backpropagation algorithm based on the Huygens' principle. We present results obtained through both a cylindrical phantom and the head of a patient with hemorrhagic stroke who participated in our first round of clinical trials. Our measurement results indicate the capability of the algorithm in detecting and localizing the dielectric contrast, paving the potential for brain stroke detection and classification.

Tuesday, March 28 9:00 - 10:40

CS45: Remote-sensing of marine litter at microwave and millimetre-wave frequencies

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 105

Chairs: Joao M. Felicio (Instituto de Telecomunicações, Portugal), Nelson Fonseca (European Space Agency, The Netherlands)

9:00 ***Spaceborne Radar Observations and Laboratory Wavetank Experiments for Tracking Ocean Microplastics***

Christopher Ruf, Madeline Evans, Yulin Pan and Yukun Sun (University of Michigan, USA)

A new approach to the imaging of microplastics from space is presented. Spaceborne radar measurements of ocean surface roughness are used to infer the reduction in responsiveness to wind-driven roughening caused by the presence of surfactant tracers of the microplastics. On a global scale over monthly time scales, time lapse images derived from the satellite radar observations reveal seasonal changes in the microplastic mass density within the major ocean basin gyres which appear to be related to seasonal changes in ocean circulation patterns. On smaller spatial and temporal scales, weekly time lapse images near the mouths of major rivers reveal episodic bursts of microplastic outflow from the river into the sea. The physical relationship between the presence of surfactants and the suppression of ocean surface roughening caused by winds has been investigated via a series of controlled wave tank experiments.

9:20 ***Investigating the Backscatter of Marine Plastic Litter Using a C- and X-Band Ground Radar, During a Measurement Campaign in Deltares***

Morgan D Simpson (University of Stirling, United Kingdom (Great Britain)); Armando Marino (The University of Stirling, United Kingdom (Great Britain)); Peter de Maagt (European Space Agency, The Netherlands); Erio Gandini (ESA - European Space Agency, The Netherlands); Anton de Fockert (Deltares, The Netherlands); Peter Hunter, Evangelos Spyrakos, Andrew Tyler and Trevor Telfer (University of Stirling, United Kingdom (Great Britain))

Here, we exploit the use of a C- and X-band radar to understand the capabilities of radar for detecting and monitoring marine plastics. Our results show that backscattering differences in C- and X-band between ‘clean' water and test water filled with plastics can be detected in some conditions (based on statistical analysis). With C- and X-band detecting statistical differences in 20 / 67 and 48 / 68 cases respectively. We also find that the difference in backscattering is dependent on the size and shape of the plastic object, as well as the wave conditions in which the plastic is moving. This work provides key information on the capabilities of radar for detecting marine plastic litter and provides details which can be used for future planning in regard to tackling remote sensing of marine plastic pollution.

9:40 ***Thruster Plume Influence on AIS Antennas Onboard Kineis Satellites for Maritime Monitoring***

Vincent Laquerbe and Rémi Fragnier (CNES, France); Naomi de Méjanes (ISAE-SUPAERO, France); Mathieu Albinet (Kineis, France)

This paper presents a numerical analysis of the RF impact of the thruster on the maritime traffic monitoring payload of the Kineis smallsats. The satellite consists in a 16U class cubesat and comprises a 6-monopoles AIS antenna working at 160 MHz, placed around an hexagon structure and facing earth. It is shown that the plasma created by the thruster modifies significantly the electrical characteristics of the closest monopoles while having no impact on the furthest ones (impedance mismatch and modification of the radiation pattern).

10:00 ***Detection of Low Permittivity Floating Plastic Sheets at Microwave Frequencies***

Tomás Soares da Costa (ULisboa - Instituto Superior Técnico & Instituto Telecomunicações, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Mario Vala (Instituto de Telecomunicações de Portugal, Portugal); Nuno R. Leonor (Polytechnic Institute of Leiria (IPL) & Instituto de Telecomunicações (IT), Leiria, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Paulo Marques (ISEL-IT Lisboa, Portugal); Antonio A Moreira (IST - University of Lisbon & Instituto de Telecomunicações/ Lisbon, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal); Sergio Matos (ISCTE-IUL / Instituto de Telecommunicações, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Nelson Fonseca and Peter de Maagt (European Space Agency, The Netherlands)

Microwaves are surfacing in remote sensing as a viable or complementary technology to optical techniques for the detection and monitoring of floating plastic litter, given their advantages in, e.g., Earth observation missions. There is a limited number of studies that analyze the detection of low permittivity plastics in a systematic manner. To contribute to this topic, we evaluated the microwave response of a few typical floating targets in two scenarios, one with near-static water and the other with waves. We present an interesting example of target in this paper, which involves very low amount of material - stretched and crumpled plastic sheets. The results, obtained for different transmit and receive polarization combinations, indicate a strong, distinct response of the plastic sheets, in both cases. The study shows that, at least under the tested conditions, microwave radar may be sensitive to very low amount of plastic, through an indirect detection process.

10:20 ***On the Feasibility of Using Passive mm-Wave Imaging for Marine Litter Detection at the W-Band***

Mario Vala (Instituto de Telecomunicações de Portugal, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Tomás Soares da Costa (ULisboa - Instituto Superior Técnico & Instituto Telecomunicações, Portugal); Nuno R. Leonor (Polytechnic Institute of Leiria (IPL) & Instituto de Telecomunicações (IT), Leiria, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Paulo Marques (ISEL-IT Lisboa, Portugal); Antonio A Moreira (IST - University of Lisbon & Instituto de Telecomunicações/ Lisbon, Portugal); Sergio Matos (ISCTE-IUL / Instituto de Telecommunicações, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Nelson Fonseca and Peter de Maagt (European Space Agency, The Netherlands)

Large research effort is appearing in the literature on remote detection of plastic marine litter, using optical instruments, and lately microwaves. We present here a feasibility study of passive mm-wave imaging (PMMWI) for the same goal. Several measurements were taken in a controlled pool environment both in static and agitated water conditions using a W-band radiometer to assess the influence of plastic on the radiometric response. Different sized plastic bottles and concentrations were studied to verify its influence on the results provided by the radiometer. For each measurement, references of still water were taken to correct eventual errors due to equipment drifts in terms of gain and noise. Preliminary results show that it is possible to detect differences in the radiometers output voltage when plastic is present or the water is agitated or both and, thus, PMMW imaging seems to be a promising technology for remote detection of floating plastics.

Tuesday, March 28 9:00 - 10:40

CS33: Multiscale and Multiphysics Techniques for Electromagnetic Imaging

T09 EM modelling and simulation tools / Convened Session /

Room: Spadolini 106

Chairs: Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy), Rosa Scapaticci (CNR-National Research Council of Italy, Italy)

9:00 ***Measuring Hemodynamic Parameters in Humans with Wearable RF Sensing Leveraging MRI Information***

Bart R Steensma, Alexander Raaijmakers and Nico van den Berg (University Medical Center Utrecht, The Netherlands)

We developed a wearable setup based on radio-frequency sensing (RFS) to detect hemodynamic parameters such as stroke volume and left ventricular volume in humans. EM simulations were used to demonstrate the possibility of measuring changes in stroke volume with RFS and to investigate the spatial sensitivity of the antenna. A Valsalva manoeuvre was used to provoke changes in stroke volume, which were observed with RFS and in real-time cine MRI acquisitions in 5 healthy controls.

9:20 ***Use of Compressive Sensing in Efficient Mutiscale Stochastic-Based Inverse Profiling of Multilayered Subsurface Targets***

Maryam Hajebi (University of Hormozgan, Iran); Ahmad Hoorfar (Villanova University, USA)

A multiresolution electromagnetic inverse scattering algorithm is proposed for reconstruction of multiple objects buried in a multilayered media, using limited amount of data. For tackling this highly nonlinear and ill-posed problem, it is required to combine different inverse profiling modalities. The proposed algorithm starts with using the total variation minimization (TVM) method to locate the objects and roughly estimate their borders. Then, an iterative multi-scale approach (IMSA) is implemented to confine the investigation domain (ID) to the detected objects regions, step by step. Using this approach, the resolution can be enhanced without increasing the number of unknowns. As the inverse solver, the robust stochastic optimization technique of Covariance Matrix Adaption Evolution Strategy (CMA-ES) is utilized in each step. The presented numerical results indicate the efficiency of the proposed algorithm in quantitative profiling of multiple objects, using limited amount of data.

9:40 ***Metrological Contributions to Magnetic Resonance-Based Electric Properties Tomography***

Alessandro Arduino and Luca Zilberti (INRIM, Italy)

Magnetic resonance-based electric properties tomography (EPT) is a quantitative imaging technique that, starting from acquisitions performed with a magnetic resonance scanner, aims at producing a map of the distribution of the electric properties at radiofrequency within a human subject. All the EPT implementations proposed in the literature deal with the problem of noise amplification. This makes the noise in the retrieved maps a major issue for EPT development. Indeed, in order to make EPT results really quantitative in the strict sense of measurement science, it is fundamental to find a way to evaluate the actual uncertainty with which the electric property values are retrieved in each pixel. In this paper, a method based on Helmholtz-EPT that estimates at the same time the conductivity and its uncertainty in each pixel is proposed. The method is applied to acquisitions of a heterogeneous phantom and possible applications of the uncertainty map are shown.

10:00 ***A Multifrequency Electromagnetic Imaging Approach for the Detection of Brain Injuries***

Valentina Schenone, Alessandro Fedeli, Claudio Estatico, Igor Bisio, Fabio Lavagetto, Andrea Sciarrone, Matteo Pastorino and Andrea Randazzo (University of Genoa, Italy)

Stroke diagnostics may benefit from an early detection and a continuous monitoring of the disease, which is possible thanks to the application of electromagnetic imaging systems. However, the inverse problem that should be tackled to retrieve a quantitative microwave image of the dielectric properties of the head tissues presents many challenging points, i.e., ill-posedness, non-linearity, and weak stroke response. In the framework of Lebesgue-space methods with adaptive exponent functions, the present paper proposes the adoption of a simultaneous processing of multifrequency data. Initial results coming from a numerical assessment with a detailed three-dimensional phantom of the human head are presented and discussed, analyzing the case of a simulated hemorrhagic event.

10:20 ***Dual-Band Phase-Encoded Linear Sampling Method Imaging from Limited Apertures***

Matthew J Burfeindt and Hatim Alqadah (US Naval Research Laboratory, USA)

The phase-encoded linear sampling method (PELSM) is a qualitative inverse scattering algorithm that can achieve high-fidelity imaging of conducting targets from limited multistatic synthetic apertures. In this paper, we propose a dualband enhancement to the PE-LSM in order to simultaneously achieve the benefits of two frequency scales. Leveraging both high and low frequencies mitigates azimuthal aliasing in wide imaging scenes and also improves robustness to motion error in the synthetic aperture. We demonstrate improved performance using simulated data.

Tuesday, March 28 9:00 - 10:40

CS14: COST CA18223 (SyMat): Applications of Metamaterials with higher symmetries

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 107

Chairs: Stavros Koulouridis (University of Patras, Greece), Francisco Mesa (University of Seville, Spain)

9:00 ***Analysis and Design of Wideband Artificial Dielectric Flat Lenses***

Caspar Coco Martin and Daniele Cavallo (Delft University of Technology, The Netherlands)

This work describes the analysis and design of wideband flat lenses based on artificial dielectric layers. Planar lenses based on metasurfaces or resonant elements are typically narrowband, due to the phase wrapping over the period of 2π that is strongly frequency dependent. On the contrary, true-time-delay (TTD) planar lenses, which do not resort to phase discontinuities, can achieve large bandwidths, at the cost of increased volume. Here, artificial dielectric layers are employed to design wideband TTD lenses with low profile and low reflection. A design procedure is presented, as well as an analysis approach based on a combination of ray tracing, physical optics, and equivalent transmission lines of artificial dielectric layers.

9:20 ***Air-SIW Unit Cell with Glide-Symmetric Structures***

Cleofás Segura-Gómez and Angel Palomares-Caballero (dept. of Signal Theory, Telematics and Communications, University of Granada (CITIC-UGR), 18071 Granada, Spain); Antonio Alex-Amor (dept. of Information Technology, Universidad CEU San Pablo, 28668 Boadilla del Monte (Madrid), Spain); Carlos Molero and Pablo Padilla (dept. of Signal Theory, Telematics and Communications, University of Granada (CITIC-UGR), 18071 Granada, Spain)

This paper presents an air-SIW unit cell which is composed of contactless unit cells and periodic structures that modify the phase constant. The contactless unit cells are located on both sides of the waveguide to confine the propagating field into the air-SIW. The proposed unit cell which has a double-mushroom with off-center via generates a stopband between 26.5 GHz and 47.3 GHz up to a gap size of 0.1 mm. Two types of elements which modify the phase constant in the air-SIW unit cell have been analyzed. First, three slots on both broad sides of the waveguide are introduced, and later, single-mushrooms. The application of glide symmetry to theses elements are studied. Glide symmetry produces a larger operating bandwidth while maintaining linearity in the phase constant and producing a phase shift of 32º in 3.9 mm length at 40 GHz regarding an air-SIW unit cell without periodic structures.

9:40 ***Multimodal Transmission-Matrix Analysis of Microstrip Lines with Symmetric and Glide-Symmetric Periodic Loads***

Guido Valerio (Sorbonne Université, France); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); David R. Jackson (University of Houston, USA)

We perform a dispersive analysis of periodic microstrip lines by means of the multimodal transmission-matrix method by simulating a single unit cell. Transmission matrices involving one or more higher-order modes are used and the results are compared with the analysis of a large number of unit cells and with a commercial eigensolver. The use of higher-order modes is found to be relevant in geometries with strong asymmetric cross sections as happens in glide-symmetric microstrip lines.

10:00 ***Hybrid Glide Symmetries and Printed Periodic Surfaces for Leakage & Mutual Reduction on Slotted Antennas Fed by Groove Gap Waveguide***

Panagiotis Petroutsos and Stavros Koulouridis (University of Patras, Greece)

We present the implementation of a hybrid multilayer planar linear slot array antenna, operating at ka-Band. We expect to combine the advantages of high-efficiency metal Groove Gap Waveguide (GWW) feedings with slotted array antennas and metamaterials printed on a Printed Circuit Board (PCB). We implement hybrid glide symmetric holes to achieve the compatibility of the two above technologies and reduce energy leakage. Also, the integration of periodic Electromagnetic Band Gap (EBG) surfaces in printed technologies offers advantages due to manufacturing feasibility, low cost, and low compactness. In our proposed antenna, we develop periodic structures of the EBG Mushroom-type, to reduce the mutual coupling between the parallel slot array antennas. Consequently, the antenna directivity is enhanced by 1.2dB, and the power level of sidelobes is reduced by a factor of 5.4dB. The impedance bandwidth of 8.4% covers the frequency range from 38.21GHz to 41.50GHz, providing a peak gain of over 20dB.

10:20 ***All-Metal THz Leaky-Wave Antenna with Suppressed Open Stopband***

Dejian Zhang (Tsinghua University); Davide Comite (Sapienza University of Rome, Italy); Xiaojiao Deng and Xiaoping Zheng (Tsinghua University, China); Paolo Baccarelli (Roma Tre University, Italy); Paolo Burghignoli (Sapienza University of Rome, Italy)

A half-annular corrugated all-metal leaky-wave antenna is designed based on asymmetric unit cells. The adoption of two non-identical perturbations of the metallic profile (i.e., of the groove) for each unit cell is applied to demonstrate the capability of suppressing the open stopband and thus improving the radiative performance when scanning through broadside. The use of trapezoidal grooves, which provide an asymmetric perturbation with respect to the propagation direction of the guided mode, is also considered for the same purpose. An in-house method-of-moments code is implemented and optimized to study the dispersion behavior of the relevant leaky modes, whereas the radiative performance is analyzed by full-wave simulations to validate the scanning behavior of the proposed antenna. The results show that, thanks to the one-sided configuration and a quasi-flat nonzero attenuation constant, a linear scanning behavior and almost constant gain through broadside can be achieved at terahertz frequencies with all-metal compact structures.

Tuesday, March 28 9:00 - 10:40

CS1: Advances in and Applications of the Methods of Analytical Regularization in Electromagnetics

T10 Fundamental research and emerging technologies / Convened Session / Electromagnetics

Room: Spadolini 108

Chairs: Mario Lucido (University of Cassino and Southern Lazio, Italy), Alexander I. Nosich (IRE NASU, Ukraine)

9:00 ***A Regularized Analysis of the Scattering from a PEC Split Ring***

Fulvio Schettino and Christian D amata (University of Cassino and Southern Lazio, Italy)

In this paper, an accurate and efficient method for the analysis of the scattering by a conducting split ring is presented. By means of a conformal mapping the problem is first transformed to the analysis of a rectangular patch, and then formulated in the spectral domain as a system of Electric Field Integral Equations. The solution is obtained by means of Galerkin's method with expansion functions reconstructing the expected physical behavior of the unknown at edges, thus achieving the regularization of the problem, as proved by the error decaying.

9:20 ***Natural Mode Resonances in the Plane Wave Scattering from an Infinite Thin Resistive Plate with***

a Circular Hole

Mario Lucido (University of Cassino and Southern Lazio, Italy)

In this paper, the natural mode resonances of an infinite thin resistive plate with a circular hole excited by an impinging plane wave are analyzed. By using the generalized boundary conditions and introducing suitable unknowns related to the azimuthal harmonics of the effective surface current density, the problem is formulated as an infinite set of independent one-dimensional dual integral equations in the Hankel transform domain. The discretization and analytical regularization of such integral equations are achieved by means of the Helmholtz-Galerkin technique. Once the unknowns are reconstructed, the resonance frequencies are readily individuated by the peaks of the total scattering cross-section.

9:40 ***MAR Algorithm for Cylindrical Luneburg Lens Equipped with Conformal Graphene Strip***

Iryna O. Mikhailikova (V. N. Karazin Kharkiv National University, Ukraine); Sergii V. Dukhopelnykov (V. N. Karazin Kharkiv National University & Universite de Rennes 1, Ukraine)

We consider the characteristics of THz antenna made of circular layered dielectric rod, which mimics the Luneburg lens, decorated with conformal microsize graphene strip. The strip has arbitrary angular size and location and its surface impedance is characterized with the quantum Kubo theory. We build mathematically accurate algorithm, which uses the method of analytical regularization (MAR) based on explicit inversion of the static part of the problem, that has mathematically guaranteed convergence. We study the frequency dependences of the total scattering and absorption cross-sections of this scatterer in wide range from zero to 10 THz. This analysis supports the presence of the broadband electromagnetic-jet effect of lens-like dielectric rod and the resonances on the moderate-Q plasmon modes of graphene strip.

10:00 ***A Semi-Analytical Approach for the Design of Reconfigurable All-Dielectric Metagratings with Phase-Change Material Constituents***

Nikolaos L. Tsitsas (Aristotle University of Thessaloniki, Greece); Stavroula Foteinopoulou (University of New Mexico, USA)

We present a semi-analytical approach, based on a volume-integral equation method employing entire-domain expansion functions, for the calculation of the transmission response of all-dielectric two-component metagratings embedded in air. The presented approach can efficiently treat metagratings with high permittivity inclusions and is able to delineate the transmission contributions of the individual available Bragg diffracted channels. We utilize the capabilities of this method to design metagratings for reconfigurable beam splitting which relies on the high-refractive index shift between amorphous and crystalline phases of newly developed dielectric phase transition alloys. We further analyze the salient characteristics of Fano features present in the transmission responses of the crystalline-state metagrating and discuss the pertinent principles to guide the design of related practical systems for beam splitting. These principles further underline the need for transmission information within each Bragg channel and hence the merit of the semi-analytical approach presented here.

Tuesday, March 28 9:00 - 10:40

A29: Antennas for 5G/6G Communication Systems

T02 Mm-wave and THz cellular / / Antennas

Room: Spadolini 109

Chairs: Astrid Algaba-Brazález (Ericsson AB, Sweden), Jose Luis Masa-Campos (Universidad Autonoma de Madrid, Spain)

9:00 ***Impact of Inter-Cell Interference on Sum-Rate-Based Array Layout Design for Massive MIMO***

Noud Kanters and Andrés Alayón Glazunov (University of Twente, The Netherlands)

Irregular, sparse array antennas deployed at base stations (BSs) in massive MIMO systems have been shown to yield a higher sum rate compared to conventional uniform half-wavelength spaced arrays. However, these results have been obtained for single-cell models, i.e., in the absence of inter-cell interference (ICI). In this paper, we propose an interference-region-extended single-cell model and we investigate the impact of ICI on array layout design. First, we show that sum rate gains achieved by irregular, sparse array antennas disappear in scenarios with ICI. Instead, uniformly spaced arrays yield the highest sum rates in these scenarios. Second, we show that sum rate gains of irregular arrays can be recovered and in some cases even increased compared to the single-cell scenario through coordinated beamforming.

9:20 ***Dual-Polarized Patch Antenna of Large Frequency-Tuning Range at mm-Wave Frequency Bands***

Quangang Chen and Juha Ala-Laurinaho (Aalto University, Finland); Alexander Khripkov (Huawei Technologies LTD, Finland); Janne Ilvonen (Huawei Technologies Oy (Finland) Co. Ltd, Finland); Resti Montoya Moreno (Huawei Technologies Finland, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

In this paper, we present a dual-polarized frequency-reconfigurable patch antenna working at millimeter wave frequency bands for 5G applications. A square patch is surrounded by four metallic L-shaped walls. Four ideal varactor diodes are placed between the corners of the square patch and L-shaped walls. Frequency tunability is achieved by adjusting the capacitances of the varactor diodes. Two 50 Ω probes are used to feed the square patch which can excite two orthogonal polarizations. Operating frequency can vary from 23 GHz to 45 GHz with a 10-dB return loss when the capacitance decreases from 0.05 pF to 0.005 pF. The isolation between two polarizations is better than 13 dB over the operating frequency bands. Cross-polarization level is lower than -15 dB. In addition, the quality factor of varactor diodes is studied to demonstrate the influence on antenna efficiency.

9:40 ***Shaped-Beam Subarrays for Equi-Power Urban Area Coverage with Modularity and Low Cost***

Changxu Zhao (Delft University of Technology, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands); Antoine Roederer (Technical University of Delft, The Netherlands); Yanki Aslan (Delft University of Technology, The Netherlands)

Design of millimeter-wave arrays for base stations operating in dense urban environment is investigated. Innovative designs for linear subarrays with shaped beam patterns for hybrid beamforming are proposed. The number of elements and element spacings in the subarrays are optimally selected based on a pattern matching technique. The subarrays are designed and verified in series edge-fed slotted substrate integrated waveguide technology at 26 GHz. A novel phase shifter unit is proposed to reduce the subarray width for grating lobe-free beam steering in the plane orthogonal to the sub-array axis. Infinite array simulations are performed to observe the coupling effects on the subarrays.

10:00 ***Millimeter-Wave MIMO Antenna with Decoupling Structures for Isolation Enhancement***

Oludayo Sokunbi and Ahmed A Kishk (Concordia University, Canada)

MIMO antenna of 4 elements with decoupling structures is presented for millimeter-wave applications. The antenna consists of radiating elements and decoupling structures such as defective ground plane and metasurfaces individually or combined. First, an optimized defected ground surface (DGS) is introduced to improve the isolation over 60-75 GHz (22%) bandwidth with an inner edge separation of 0.55 mm (0.13λ) at 70 GHz. Furthermore, metasurface realized by split ring resonators at 0.6λ from the antenna elements improved the isolation of the 4 elements by a maximum of 25 dB. The proposed antenna's gain, efficiency, and surface currents are compared to the initial 4 elements to verify the proposed decoupling technique for MIMO applications.

10:20 ***New mmWave Pattern Reconfigurable Tightly Coupled Array for Photonic Integrated Base-Station Applications***

Saeed Haydhah, Jordan Joseph and Ahmed A Kishk (Concordia University, Canada); John Zhang (Concordia, Canada)

The new pattern reconfigurable Tightly Coupled Array of 92.7*33.15*0.15 mm^3 at 28 GHz is proposed. A 5 GHz impedance matching bandwidth is achieved. Using three ports to feed the array, three radiation patterns are possible. The available radiation patterns are directed to the front end-fire, or tilted to the right or left sides of the array. The array gain is 8.3 dBi or 7 dBi for front end-fire or tilted beams, respectively. The antenna is proposed for photonic integrated base-station applications.

Tuesday, March 28 9:00 - 10:40

SW9: Disruptive Innovations: the Roadmap of European Funding Agencies

Organized by: Stefania Monni (TNO, The Netherlands); Stefano Maci (University of Siena, Italy)

Room: Sala della Scherma

9:00 - Welcome Introduction

9:05 - European Space Agency funding opportunities for innovations in RF technology (Piero Angeletti, Head of the Radio Frequency Payloads and Technology Division at European Space Agency - ESA)

9:35 - European Innovation Council funding opportunities for game changing innovations in 2023 (Stela Tkatchova, European Innovation Council Program Manager for Space Systems)

10:05 - 2023 Electronic Components & Systems Strategic Research and Innovation Agenda (Patrick Cogez, Technical Director AENEAS)

Tuesday, March 28 9:00 - 10:40

IW1: Tracking and Pointing Performance Verification Using an Airborne Positioner(QuadSAT)

Room: Polveriera

Tuesday, March 28 9:00 - 10:40

WG MEAS: EurAAP Measurement WG meeting

Room: Palazzina 7

Tuesday, March 28 11:00 - 12:40

CS47b: Shape and control of electromagnetic fields through reflective and transmissive surfaces (continued)

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: Antonio Clemente (CEA-Leti, France), Ronan Sauleau (University of Rennes 1, France)

11:00 ***Conformal Electromagnetic Skin for 5G Applications***

Michele Beccaria and Andrea Massaccesi (Politecnico di Torino, Italy); Agnese Mazzinghi (University of Florence, Italy); Angelo Freni (Università degli studi Firenze, Italy); Paola Pirinoli (Politecnico di Torino, Italy)

In this communication, some preliminary numerical results on a curved passive smart electromagnetic skin working at millimeter waves are presented. The reflective surface is designed to enhance the performance of 5G network and is supposed to be mounted on street or stop light poles instead of the facade of a building. If the curvature can affect the surface re-radiating feature, and therefore it has to be taken into account in its design, this choice presents some advantages as the reduced visual impact and the possibility to rotate the surface around the supporting pole. The obtained results are promising and worthy of further investigation.

11:20 ***On the Comparison Between Local and Optimized Approach for the Design of a Beam-Tilting Metasurface***

Federico Giusti, Enrica Martini, Stefano Maci and Matteo Albani (University of Siena, Italy)

A numerically efficient tool based on the optimization of surface field harmonics for the design of three-layer beam-tilting metasurfaces is compared with a design approach based on a local approximation. In the first approach, a certain number of evanescent Floquet modes are introduced through an optimization procedure aiming at minimizing the real part of the sheets surface impedance. In the second one, the sheet impedance profiles are derived analytically based on the uniform problem that locally matches the structure. The two techniques have been applied to design three different beam-tilting metasurfaces, and the resulting structures have been analyzed with a full-wave code in order to assess and compare their accuracy. Numerical results show the superior performance of the optimization approach with respect to the local approach in terms of capability to design highly-efficient reflectionless wide-angle anomalous beam-tilting metasurfaces.

11:40 ***Slimmed 6G Transmit Reconfigurable Intelligent Surface (RIS) Unit Cells Electromagnetically Tailoring Effective Cell Gap of Liquid Crystal***

Jaehoon Kim and Jungsuek Oh (Seoul National University, Korea (South))

This study presents a transmit reconfigurable intelligent surface (TRIS) unit cells (UCs) with slimmed liquid crystal (LC) electromagnetically tailoring effective cell gap to control the LC with empirical values of voltage. Prior LC-based transmit-type UCs require higher voltage values and thicker cell gaps even for the narrow phase tuning range. To overcome this limit, we propose a complementary electric-inductive-capacitive (cELC) topology. Two coupled-cELC resonators are designed in the different layers and positioned to be laterally offset to each other. This can increase the effective height of LC leading to improved insertion loss and phase linearity. The proposed UC successfully achieved 135° of phase tuning range by employing a slimmed single-layer LC with 0.18 mm cell gap, which is three times thinner than those used in the previous studies. Additionally, a gain of 15.2 dBi and beam scanning range of ±40° is attained by 14×14 (5λ0×5λ0 at 77 GHz) TRIS array.

12:00 ***A Passive Multibeam Metasurface Antenna***

Faris Alsolamy (University of Michigan Ann Arbor, USA); Nacer Chahat (NASA-JPL, Caltech, USA); Goutam Chattopadhyay (NASA-JPL/Caltech, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

Recently, the mode conversion capabilities of metasurfaces have been exploited to design cylindrical vector (radially-polarized) beam antennas, and orbital angular momentum (OAM) antennas. Motivated by these developments, we use mode-converting metasurfaces to design passive MIMO metasurface antennas. The MIMO antenna consists of a mode-converting metasurface atop a rectangular cavity that is fed by multiple waveguides. The metasurface itself comprises a cascade of electric sheets separated by dielectric spacers. The impedance profiles of the electric sheets are optimized such that each waveguide feed excites a specified beam. The excited beams are orthogonal to ensure isolation between the feeds. Furthermore, the proposed MIMO antennas can be used to design future MAB (multiple azimuth beams) SAR imaging systems.

Tuesday, March 28 11:00 - 12:40

CS17b: Emerging Beam-Steering Antenna Solutions for Satellite and Terrestrial Communications including 5G+ (continued)

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Karu Esselle (University of Technology Sydney, Australia), Mohsen Sazegar (Kymeta Corporation, USA)

11:00 ***Ku-Band SATCOM User Terminal with Complete Beam Steering Using a Shared Aperture Metasurface for Full-Duplex Operation***

Mohsen Sazegar (Kymeta Corporation, USA); Ibrahim Nassar (Kymeta, USA); Chris Eylander, Amin Momeni, Brad Eylander and Ryan Stevenson (Kymeta Corporation, USA)

A SATCOM user terminal with full-duplex capability in shared aperture and high efficiency is presented in this work. The antenna is designed using a metasurface aperture operated through holographic beam forming. To cover the entire Ku receive and transmit bands, three sub-arrays are integrated into the metasurface resulting in a Tripleband Metasurface Aperture (TMA). The TMA is manufactured using traditional flat panel display technology with liquid crystal as the tunable dielectric, which provides the reconfigurability needed for beam steering, polarization, and frequency switching. The circular aperture, 82cm in diameter, provides a gain of up to 36dBi and 35dBi in receive and transmit bands, respectively. A wide scan range of ±75° in 2D and fast tracking (~30°/sec) is demonstrated. Furthermore, an integrated multi-WAN 3G & LTE provides seamless connectivity between satellite and terrestrial networks.

11:20 ***Beam-Steering Antenna Technologies for Space-Related Applications***

Khushboo Singh (University of Technology Sydney, Australia & Macquarie University, Australia); Dush Thalakotuna, Karu Esselle, Foez Ahmed and Mst Nishat Yasmin Koli (University of Technology Sydney, Australia)

A dramatic growth of the satellite terminal market up to a cumulative total of billions of US dollars by 2030 has been predicted by market analysts. Perhaps motivated by these predictions and based on own customer feedback, established geostationary-orbit (GEO) satellite operators are investing in new high-throughput technologies and new satellite operators have committed billions of dollars to low-earth-orbit (LEO) and medium-earth-orbit (MEO) satellite constellations. The beam-steering antenna is the most challenging and expensive subsystem in the ground segment of a modern satellite communication (SATCOM) terminal. New innovative beam-steering methods are required to meet the demands of the many new high-volume markets, such as low cost, low power consumption and aesthetically appealing shape. This paper outlines the challenges and briefly reviews some disruptive antenna beam-steering methods that are commercially available or being developed for the next generation of SATCOM terminals.

11:40 ***Advances in 8T8R Antenna Design***

Martin Zimmerman (1909 N LARRABEE STREE UNIT A & CommScope, USA); Björn Lindmark (Commscope, Sweden)

In the Mobile Wireless field, there has been much development done on beamforming antennas, with a radio vendor focus on increasing the number of transceivers from 8 up to 64. However there has been very little work on improving the actual antenna, with it typically being assumed that it consists of a panel array adhering to certain basic parameters. This paper examines some efforts to look at alternate antenna types with the goal, of providing new or improved functionality that will work with off-the-shelf 5G radios.

12:00 ***Enabling Multibeam Technologies in Space and on Ground for OneWeb Future Systems***

Sara Mugnaini and Ben Allen (OneWeb Communication Ltd, United Kingdom (Great Britain)); David Alexander (OneWeb Communication Llc, USA); Ed Totten and Carol Marsh (Celestia-UK, United Kingdom (Great Britain))

In this paper, we introduce the delivery of 5G services by means of a LEO satellite communication system consisting of around 600 satellites providing global coverage. The satellite constellation is complimented by a ground network of gateways and user terminals. Satellites are assumed to host a regenerative communication payload with beam hopping capability. The gateway antenna system is assumed to provide multi-beams for serving several satellites simultaneously. We discuss the design trade-offs of these antenna systems in terms of key trade-offs and 5G service provision over such a system.

12:20 *Compact Full Metal Continuous Transverse Stub Antenna for Ka Band Satellite Communications*

Ravikanth Thanikonda (University of Siena, Italy); Jorge Ruiz-García (University of Michigan, USA); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Enrica Martini and Stefano Maci (University of Siena, Italy)

In this article, a fully metallic low-profile metasurface (MTS) antenna is designed and numerically investigated in Ka-Band. The antenna design is composed of three stacked parallel plate waveguides of circular shape, these three plates are separated with equal distances by making it into two sections. The feed of the system is a planar lens working in reflection positioned in the bottom, and radiating Continuous Transverse stub high gain antenna is sitting above. A scanning beam is produced in the upper hemisphere as a result of the relative rotational movement between the two sections, which produces a phase gradient throughout the radiating part. The radiating aperture is created by etching slots in the upper wall of a corrugated parallel plate waveguide, this solution will provide us with almost frequency and scan-independent active impedance, and radiation efficiency, Tapering efficiency is increased by tapering the radiating slot width.

Tuesday, March 28 11:00 - 12:40

CS36b: Propagation for Smart Mobility Scenarios (continued)

T05 Aircraft (incl. UAV, UAS, RPAS) and automotive / Convened Session /

Room: Spadolini 101

Chairs: Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany), Danping He (Beijing Jiaotong University, China)

11:00 *Outage Probability Modeling with Human Blockage for Mobile VLC Systems*

Yue Yin (BUPT, China); Pan Tang and Jianhua Zhang (Beijing University of Posts and Telecommunications, China); Guangyi Liu, Liang Xia and Xiaoqian Wang (China Mobile Research Institute, China); Hu Zheng (Beijing University of Posts and Telecommunications, China)

In this paper, we analyze and model the outage probability (OP) caused by human blockage for mobile VLC systems. First, we generate a realistic human moving trajectory and calculate the OP with variable human heights and widths. Then, the OP is analyzed from three dimensions, i.e., human height, human width, and transceiver distance. When the human height increases from 1.50 m to 2.05 m, OP increase can reach 2.09 dB. When the human width increases from 0.3 m to 0.8 m, OP increase can reach 4.59 dB. With the transceiver distance increasing by 1.4 m, the increase of OP can reach 5.47 dB. A three-dimensional OP model is further proposed as a function of human height, human width, and transceiver distance. The small root mean square error (0.0094) between the model and the simulated data indicates that our proposed model has the goodness of fit to the simulated data.

11:20 *5G-Positioning for Traffic Safety and Intelligent Intersections*

Mehdi Ashury, Jan Matthias Nausner and Christoph F Mecklenbräuker (TU Wien, Austria)

Fifth generation (5G) of mobile communications enables precise location estimates due to large time-bandwidth products of 5G waveforms and large aperture antenna arrays. In this contribution we discuss and evaluate two hyperbolic approaches to 5G positioning for vehicular applications, namely Friedlander's method and Chan's. These may improve the reliability and robustness for position estimates in rural road scenarios compared to estimates from automotive sensor data only. Here, we report on the impact of multipath propagation and cellular network deployment geometry on estimation accuracy and the underlying optimization algorithm has been investigated. Furthermore the results indicate the system requirements for an estimation accuracy for vehicular applications.

11:40 ***Measurement and Modeling of Vehicular Millimeter Wave Radar Signal in Expressway Environment***

Hongyu Duan, Danping He, Ke Guan and Zhangdui Zhong (Beijing Jiaotong University, China); Yihua Ma (ZTE Corporation & State Key Laboratory of Mobile Network and Mobile Multimedia Technology, China)

With the gradual development of autonomous driving technology, the cost of traditional road test is becoming higher and higher. The mainstream approach of autonomous driving test has been transferred to the accurate and efficient simulation test system based on typical environment. Millimeter wave (mmWave) radar is an important part of autonomous driving and integrated sensor system. This means that the foundation of the future autonomous driving environment simulation system needs the real mmWave vehicular radar signal propagation mechanism. In this paper, the vehicular mmWave radar signal in the expressway environment is measured, and ray-tracing (RT) simulation is conducted according to the measurement configuration. The electromagnetic (EM) parameters is calibrated through the Radar Cross section (RCS). The signal propagation characteristics are researched, and a hybrid channel model is established with RT, which effectively increases the simulation efficiency and serves for future autonomous vehicle driving test.

12:00 ***Modeling the Drone-To-Drone Communications Channel for Urban Environments***

Dennis Becker, Uwe-Carsten G. Fiebig and Lukas Marcel Schalk (German Aerospace Center (DLR), Germany)

Preventing mid-air collisions between autonomously flying drones in urban airspace will be a crucial task for the future Urban Air Mobility. Especially in dense urban scenarios, the direct information exchange between drones based on Drone-to-Drone communications is a promising technology for enabling reliable collision avoidance systems. In order to design and validate respective communication systems, accurate knowledge about the specific underlying propagation characteristics is inevitable. Therefore, we performed a wideband channel sounding measurement campaign with two flying drones in urban scenarios and investigated the channel propagation conditions. In this work, we present a geometrical-statistical architecture to model the D2D communications channel for urban environments. It considers the identified propagation effects from our measurements and shall serve as a basis to incorporate further statistics from our measurements. We show its feasibility by comparing the preliminary channel model results with our measurements. Further investigation of the measurement data will refine model.

12:20 ***Measurement-Based Wideband Maritime Channel Characterization***

Michiel Sandra, Guoda Tian, Aleksei Fedorov, Xuesong Cai and Anders Johansson (Lund University, Sweden)

Maritime communication is one of the 5G vertical domains and is attracting more attention. Advanced channel models that accurately characterize the wideband maritime propagation channels are essential for the development of modern maritime communication technologies. To this end, we measured the propagation channel at 5.6 GHz with a sailing boat, capturing the channel with a bandwidth of 250 MHz, both in the harbor and the open sea. Based on the measurement results, we evaluated the Rician K-factor, coherence bandwidth and path loss. We concluded that in the maritime environment various types of power delay profiles can occur, and that the Rician K-factor and coherence bandwidth can vary significantly within a short period of time.

Tuesday, March 28 11:00 - 12:40

A03: Antennas for 5G Systems I

T02 Mm-wave and THz cellular / / Antennas

Room: Spadolini 102

Chairs: Luis Jofre (Universitat Politecnica de Catalunya, Spain), Ioan E. Lager (Delft University of Technology, The Netherlands)

11:00 ***A 29 GHz Dual-Polarized Reconfigurable Intelligent Surface with 2-Dimensional Wide Scanning Range***

Jun Hwa Oh (Samsung Research & Samsung Electronics Co., Korea (South)); Jun Gi Jung (Samsung Electronics, 34 Seongchon-gil, Seoul Korea, Korea (South)); Sang Hyuk Wi (Samsung Research, Samsung Electronics, Korea (South)); Yuntae Park (Samsung Research, Korea (South))

This paper presents a reconfigurable intelligent surface (RIS) to control the direction of the reflected wave independently in each orthogonally dual-polarized incident wave for deploying millimeter wave RIS-aided wireless communications. A designed 1-bit controlled reflective unit cell is used for both vertical and horizontal polarization. The proposed alignment technique enables overall size reduction of RIS efficiently and also provides secure 2-dimensional (2-D) operation of each polarization without performance degradation. In addition, dummy patterns are designed for a wide scanning range. Furthermore, a RIS prototype that includes a 40 × 40 array of dual-polarized unit cells, an Arduino microcontroller, and a DCDC converter is designed and fabricated. The measurement is performed using a customized antenna holder that helps to accurately measure the 2-D spherical coordinate while changing the reflected angle from −30° to +30°. By confirming the measurement and simulation match well, the validity of the proposed RIS was proven.

11:20 ***Self-Diplexing Antenna Operating at Sub-6 GHz and Milimeter Wave Frequencies***

Hassan Naseri Gheisanab (University of Quebec, INRS, Canada); Peyman Pourmohammadi, Noureddine Melouki and Amjad Iqbal (University of Quebec INRS, Canada); Tayeb Denidni (INRS, Canada)

A low-profile self-diplexing antenna supporting sub-6 GHz and mm-wave frequencies is introduced for the first time. The design process starts with cutting a Substrate Integrated Waveguide (SIW) cavity into two equal parts. One part is taken into consideration for the proposed antenna in a way that a small part of the cavity is selected for mm-wave operation (28 GHz), and the rest is assigned for microwave operation (4.8 GHz). A capacitive slot brings the microwave frequency to the desired band (4.8 GHz). The mutual coupling among the ports is less than -30 dB and the measured gains show 5.3 and 8 dBi for lower and higher bands, respectively. It should be mentioned that independence of frequencies is another advantage of the proposed structure. Therefore, such an antenna is a suitable alternative for traditional dual-band antennas.

11:40 ***Dual-Band and Dual-Polarized Reflectarray for Intelligent Reflecting Surface Applications in Millimeter-Wave 5G***

Felipe Cordente, Eduardo Martinez-de-Rioja and Ana Arboleya (Universidad Rey Juan Carlos, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain)

In this work, a dual-band and dual-polarized reflectarray is proposed for passive Intelligent Reflecting Surface (IRS) applications in millimeter-wave 5G. The reflectarray unit-cell has a dual-layer configuration, where the printed elements on each layer are designed to provide the required phase shifts at a different operating frequency (lower layer elements for 28 GHz and upper layer elements for 39 GHz). A 20 cm x 20 cm reflectarray panel has been designed to produce a collimated beam in dual-linear polarization at the 28 GHz and 39 GHz bands simultaneously. The proposed concept can be applied to design passive IRS panels with dual-band operation, which can be used to improve coverage of dead zones or avoid obstacles that block direct communication links in millimeter-wave 5G networks.

12:00 ***Experimental Evaluation of 28 GHz Multi-Sector Base Station Antenna Consist of Yagi-Uda Antennas Assuming Indoor Office Environment***

Yuki Inoue (NTT DOCOMO, INC., Japan); Yasuko Kimura (NTT DoCoMo, Inc., Japan); Hiroyuki Arai (Yokohama National University, Japan)

In the beyond 5G and 6G mobile communication systems more higher frequency bands will be used such as millimeter waves and terahertz waves. Since propagation loss increases in the higher frequency band, an efficient way to cover indoor areas with a limited number of base stations is to place base stations on the ceiling and switching the branch of high-gain multi-sector antennas to realize an omni-directional coverage area. There are some proposals about multi-sector antennas with beam switching. However, there is not much measurement evaluation with multi-sector antenna in indoor environments. In this paper,

we present experimental evaluation assuming indoor office environment using a 28 GHz band multi-sector base station antenna consist of Yagi-Uda antennas in a shielded room.

12:20 ***Reconfigurable Antenna Array for 5G Small Cells***

Maymouna Dabbous (Université Côte d'Azur, France); Philippe Le Thuc (Université Côte d'Azur, CNRS, LEAT, France); Aliou Diallo (Universite Côte d Azur, France); Robert Staraj (Université Côte d Azur, France); Jean Marc Ribero (Université Côte d'Azur & CNRS, LEAT, France); Assane Ngom (Universite Côte d Azur, France)

In this paper, the design of an antenna array for small 5G base stations, also called "small cells", operating in the 26 GHz millimeter band is proposed. Based on a single feeding circuit, this structure has dual polarization and diversity in radiation pattern. Simulated results show a maximum gain of 8.9 dBi and a maximum HPBW of 64° for this structure.

Tuesday, March 28 11:00 - 12:40

CS50b: Synthesis, Optimization, and Design of IoT antenna systems (continued)

T03 Wireless LANs, IoT and M2M / Convened Session /

Room: Spadolini 103

Chairs: Jaume Anguera (Ignion & Universitat Ramon Llull, Spain), Miloslav Capek (Czech Technical University in Prague, Czech Republic)

11:00 ***High Encoding Capacity Chipless RFID Tag***

Milan Polivka and Milan Svanda (Czech Technical University in Prague, Czech Republic)

In this letter, we introduce the concept of a novel chipless RFID tag with high encoding capacity, which is based on the principle of sub-band frequency shift coded (SB-FSC) techniques to increase the number of bits per each individual resonator. The tag consists of an array of N variable-length microstrip line resonators, each with up to M = 9 notches (corresponding to digits 0-9), which in total encodes N × log2M bits/tag, and a pair of microstrip resonators serving as a frequency reference. A 60 × 80 mm2 proof-of-concept tag is demonstrated with 13 + 2 resonant microstrip elements (for GTIN-13 code) with high quality factor backed by a metallic plate, thus providing 43 bits/tag. The tag operates in the frequency range from 1.4 to 4.2 GHz with a coding density 36.7 bits/λ2/GHz at the center frequency. The concept enables the integration of chipless RFID technology with the GS1 standards.

11:20 ***On-Body Antenna Optimization Method Based on Spherical Wave Function Channel Modeling***

Hendrik Jäschke (Institute of Microwave and Wireless Systems, Leibniz University Hannover, Germany); Dirk Manteuffel (University of Hannover, Germany)

A method for antenna optimization of an on-body antenna based on antenna de-embedding and channel modeling using spherical wave functions is presented. This method is validated by comparison with an analytically derived solution. Therefore, maximum transmission coefficients and optimal antenna gains are calculated for comparison. The results obtained by both computations are identical within a small tolerance range. This demonstrates applicability of the optimization proposed method for practical applications.

11:40 ***Low Profile Pattern Reconfigurable ESPAR for UAVs in IoT Applications***

Francesco Positano (Université Côte d'Azur, LEAT, CNRS, France); Luca Santamaria (Greenerwave, France); Robert Staraj (University Cote d'Azur, CNRS, LEAT, France); Leonardo Lizzi (University

Côte d'Azur, CNRS, LEAT, France)

A 6 direction pattern reconfigurable Electronically Steerable Parasitic Array Radiator (ESPAR) system is proposed to work at 5.075 GHz, in the C-Band dedicated to unmanned aerial vehicles. This single fed antenna can switch among 6 directive beams across the whole azimuth plane, thanks to the coupling with its parasitic elements. The directional reconfiguration is enabled by changing reactive loads on each parasitic element. The proposed antenna is light weight, low profile and high gain in each directive state. Measurements on a static single beam configuration and simulated results on the reconfiguration circuit are presented to confirm the effectiveness of the design principles.

12:00 ***Degrees of Freedom and Characteristic Modes***

Mats Gustafsson and Johan Lundgren (Lund University, Sweden)

Degrees of freedom of an antenna system quantify how many beams can be used in a communication system. In this paper, a scattering-based formulation of characteristic mode analysis is used to determine the degrees of freedom of arbitrary-shaped objects. It is shown that the number of characteristic modes which are close to resonance can be estimated by the average shadow area of an object.

12:20 ***Design of an FR-4 Metamaterial Surface Improving 24 GHz-Antenna Signal Strength***

Junghyun Cho, Jiyeon Jang and Yejin Lee (Incheon National University, Korea (South)); Yejune Seo (Inchoen National University, Korea (South)); Jaewon Koh (Incheon National University, Korea (South)); Jaume Anguera (Universitat Ramon Llull, Spain); Sungtek Kahng (Incheon National University, Korea (South))

This paper presents an effective and cost-saving method to improve the signal strength of a 24 GHz-antenna which is adopted to short-range radars and RF sensors. An FR-4 metasurface is used to heighten the flux density of the wave from the single patch instead of the power-divider array antenna. As in motion sensing applications at the frequency, the RX antenna receives the wireless power from the TX, which reveals the transmission ratio becomes greater with the metasurface than without it by around 7 dB. A possibility is given that FR-4 the cheap and lossy substrate is handled to be useful and it is inexpensive to realize the EM lensing structure.

Tuesday, March 28 11:00 - 12:40

M02: Dosimetry, Exposure and SAR Assessment

T04 Biomedical and health / / Measurements

Room: Spadolini 104

Chairs: Christian Bornkessel (Technische Universität Ilmenau, Germany), Francesca Mioc (Consultant, Switzerland)

11:00 ***User Exposure in mmW Bands: Impact of Age, Textile and Body Curvature***

Giulia Sacco (Institut d'Électronique et des Technologies du numéRique (IETR), CNRS (UMR 6164)); Maxim Zhadobov (Institut d'Électronique et des Technologies du numéRique (IETR), CNRS)

With the upcoming deployment of 5G and B5G, new frequencies, absent from the natural electromagnetic (EM) spectrum, have been proposed for wireless communications. In this study, we investigate the variations of the human body exposure in real conditions at 26 GHz and 60 GHz as a function of age, textile presence, and local body curvature radius. The analysis revealed that aging induces variations of the averaged absorbed power density within 10%. At 26 GHz, the variations reach 41.5% in presence of a textile for the averaged absorbed power density and 72.3% for the peak absorbed power density when the curvature radius is of 1 mm.

11:20 ***Exposure Change at Two Mobile Radio Base Stations Due to Upgrading with 5G***

Christian Bornkessel, Tobias Struck and Lisa-Marie Schilling (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

Radio frequency exposure measurements in the surroundings of two mobile radio base stations were performed before and after their upgrade to 5G to investigate exposure changes. The measurements were carried out in Berlin, and a 5G Dynamic Spectrum Sharing (DSS) base station and a 5G massive MIMO base station were investigated. At the first base station, a previous UMTS system was replaced by a DSS system with unchanged total transmission power. The maximum possible exposure at five out of six measurement points remains unchanged. At the second base station, a 5G massive MIMO antenna technology was additionally installed to an existing mobile radio system. Here, maximum possible exposure increases of 6 to 11 dB. A parallel recording of the 5G instantaneous exposure at the massive MIMO station shows that the exposure without provoking traffic load and at low traffic load exploits only 5-10% of the maximum exposure.

11:40 ***Exposure Estimation of mm-Waves Using Screen-Printed Metasurfaces***

Johan Lundgren (Lund University, Sweden); Marzieh Zabihipour (Linköping University, Sweden); Daniel Sjöberg (Lund University, Sweden); Isak Engquist (Linköping University, Sweden); Mats Gustafsson (Lund University, Sweden)

Validation and characterization of radiating devices operating in, and near, the mm-Wave regime often require near-field evaluations. In this work, we present an alternative to commonly used electromagnetic near-field scanning techniques to rapidly image the incident power density. Our technique revolves around a metasurface that efficiently converts the incident electromagnetic radiation to heat which is imaged by an infrared camera. The metasurface design is demonstrated for single and dual linear polarization at 12.8 GHz and 28 GHz. It is manufactured using screen printing of a carbon-silver mixture on a PET substrate. At 12.8 GHz a single element is illuminated using an open-ended waveguide. At 28 GHz simultaneous measurement of several spatial points over the aperture of a standard gain horn antenna at 28 GHz is measured, demonstrating the possibility of real-time near-field measurements over larger regions.

12:00 ***Numerical Dosimetry for Human Tissues in Presence of Wireless 5G Millimeter-Wave Devices Using an Equivalent Surface Impedance Boundary Condition Model***

Abdelrahman Abdallah Ijjeh and Soukaina Mifdal (Université Cote d'Azur, France); Marylène Cueille (University of Nice Sophia Antipolis CNRS, France); Jean-Lou Dubard (UCA, LEAT, France); Michel Ney (IMT Atlantique, France)

In lossy dielectrics (e.g., human tissues) the skin effect plays a major role in Electromagnetic (EM) waves propagation as frequencies increase. This skin effect indicates that EM-waves decay exponentially as they penetrate good conductors, and they practically vanish as they traverse a distance of few skin depths. Moreover, in such media, the effective EM-waves' wavelengths become very short, leading to a big increase in their electric size. Consequently, huge number of cells is necessary to represent such problem (e.g., numerical dosimetry). This article investigates the use of an equivalent Surface Impedance Boundary Condition (SIBC) to replace the 3D lossy dielectric object. This SIBC envelope excludes its interior form the computational domain, thus, one can use larger mesh sizes (e.g., one tenth of free-space wavelength). This leads to an enormous computational gain as compared to 3D discretization of the lossy dielectric and offers the capability for simulating large computational problems.

12:20 ***Evaluation of the Influence of the Measuring Person on the Assessment of Mobile Radio Exposure with an Isotropic Measurement Probe***

Thanh Tam Julian Ta, Anna-Malin Schiffarth and Dirk Heberling (RWTH Aachen University, Germany)

An accurate exposure measurement is important to verify compliance with exposure safety limits. The presence of the measuring person can cause reflections on that person, which can affect the measured exposure and lead to misinterpretation of the actual exposure. Therefore, the influence of the measuring person on the exposure measurement with an isotropic probe is evaluated for wireless communication standards GSM, LTE and 5G in the sub-6 GHz frequency range and 5G in frequency range 2. For measurement-based investigation, measurements were carried out with and without a person. The results show an influence of the person on measured field strengths when examining individual measuring points. Usually, the local maximum field strength

in a measurement volume is determined for exposure measurements. By comparing the maximum measured field strength of the comparative measurements, smaller influences of the measuring person results, which can nevertheless lead to a false evaluation of the actual exposure.

Tuesday, March 28 11:00 - 12:40

A19: Antennas for Vehicular Communications

T05 Aircraft (incl. UAV, UAS, RPAS) and automotive / / Antennas

Room: Spadolini 105

Chairs: Carlo Bencivenni (Gapwaves AB, Sweden), Simona Bruni (IMST GmbH, Germany)

11:00 *Novel Low-Loss Coaxial Slot Array Based on Gap Waveguide Technology for E-Band Automotive Radar Applications*

Abbas Vosoogh (Gapwaves AB, Sweden); Abolfazl Haddadi (Gapwaves AB, Gothenburg, Sweden); Carlo Bencivenni (Gapwaves AB, Sweden)

This paper presents a novel ultra-thin slotted array antenna for automotive radar applications operating at E-band. A low-loss air-filled coaxial waveguide transmission line based on multilayer waveguide (MLW) technology is formed by vertically stacking three unconnected thin metal plates. The proposed antenna element consists of two series-fed columns of 6 slots which are combined with a power divider. In order to prevent any possible field leakage due to the air gaps between the layers, a periodic textured structure is used in the top and bottom layers. The desired patterns are fabricated by using chemical etching technique which is a fast and low-cost manufacturing process suitable for mass-production. The design, numerical simulations and experimental validation of the proposed antenna are presented in the frequency band from 76 to 81 GHz. The proposed coaxial MLW slot array antenna provides the advantages of low-loss, low-profile, low-cost and mass-production capability at millimeter-wave frequencies.

11:20 *Automotive RADAR Planar Antenna Optimization Based on Conformal Transformation Optics*

Coen van de Ven (University of Twente & Gapwaves AB, Sweden); Abolfazl Haddadi (Gapwaves AB, Gothenburg, Sweden); Andrés Alayón Glazunov (University of Twente, The Netherlands)

Wide Beam slotted waveguides typically suffer from a ripple on the radiation pattern. Due to the limited thickness of the outer wall of the waveguide, which acts as the ground plane, it is not possible to shape this ground plane to reduce this ripple. Conformal transformation optics presents a solution to virtually add a deformation without needing to change the physical shape of the ground plane. Transverse magnetic polarized waves can not follow arbitrary conformal transformations. This paper introduces an rescaling method to increase the possible transformations which can be done for transverse magnetic polarized waves. Numerical computations have shown promising results, i.e. a reduction of the farfield ripple from 1.92 dB to 0.64 dB at a half-power beam-width of 112 degree at 77 GHz.

11:40 *Dual-Band, Slant-Polarized MIMO Antenna Set for Vehicular Communication*

Rasool Keshavarz (University of Technology Sydney, Australia); Dan Winson (Zetifi, Australia); Justin Lipman (University of Technology, Sydney (UTS), Australia); Mehran Abolhasan and Negin Shariati (University of Technology Sydney, Australia)

Slant-polarized MIMO antennas are able to improve the performance of mobile communication systems in terms of channel capacity. Especially, the implementation of MIMO configurations for automotive applications requires to consider high gain, wideband, low-profile and affordable antennas in the communication link. In this work design, simulation and measurement of a new dual-band slant-polarized MIMO antenna with HPBW of around 90 deg are presented. Then, four replicas of the proposed antenna set are placed at four different poles (North, South, West and East) to cover 3600 around the vehicle as an omnidirectional pattern. In the real scenario, the proper antenna set is selected to communicate with the intended user. Each

slant MIMO antenna set consists of two inclined (45deg) low band (700 to 900 MHz) and two inclined high band (1.7 to 2.7 GHz) log-periodic antennas. The measured gain of LB and HB antennas are 7 dBi and 8 dBi, respectively.

12:00 ***Low-Cost 3D Printed Circularly Polarized Lens Antenna for 5.9 GHz V2X Applications***

Weronika Kalista, Krzysztof Nyka, Luiza Leszkowska and Lukasz Kulas (Gdansk University of Technology, Poland); Mateusz Rzymowski (Gdansk University of Technology & WiComm Center of Excellence, Poland)

This paper presents design and realization of a circularly polarized antenna consisting of a linearly polarized patch antenna and a 3D printed lens, at the same time performing the functions of wave collimator and a polarizer. The antenna is dedicated for 802.11p systems, as a part of road infrastructure, with operation bandwidth 5.85 - 5.925 GHz. Its realised gain and axial ratio at center frequency 5.9 GHz are 14.0 dBi and 2.17 dB respectively. The lens provides approximately 6% bandwidth with axial ratio below 3 dB. The proposed antenna is easy to design and fabricate and can be realized with the use of low-cost materials.

12:20 ***A Wideband Automotive 4x4-MIMO 5G Antenna System with Decoupling Circuit for a Single Shark Fin Cover***

Mirco Hardman (Universität der Bundeswehr München, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany)

For the fifth generation of mobile services (5G) compact solutions of 4x4 MIMO antenna systems are required fitting into mounting positions with small volume requirement. Herein we present a new set of four individual MIMO antennas which are arranged in a line of 19.5 cm length which can be integrated into one single shark fin antenna cover. The three larger antennas cover a frequency range from 617 MHz to 960 MHz (low band) and the four antennas cover the frequency range between 1.7 GHz to 6 GHz (high band). For increased performance in low band, antennas are connected via single-stage low-loss decoupling and matching circuits. With that, transmission factors of less than -14dB and reflection factors of -10dB are typically obtained in low band, while at band limits transmission factors of -11dB and reflection factors of -6 dB are not exceeded.

Tuesday, March 28 11:00 - 12:40

CS33b: Multiscale and Multiphysics Techniques for Electromagnetic Imaging (continued)

T09 EM modelling and simulation tools / Convened Session /

Room: Spadolini 106

Chairs: Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy), Rosa Scapaticci (CNR-National Research Council of Italy, Italy)

11:00 ***Wideband Dielectric Properties Reconstruction from MR Acquisitions***

Flavia Liporace and Marta Cavagnaro (Sapienza University of Rome, Italy)

The growing use and development of medical techniques based on the application of electromagnetic fields (EMF) has increased the necessity of an accurate reconstruction of the dielectric properties of human tissues. These properties in fact represent the response of the biological system when it is exposed to an external EMF. Given the complexity and the heterogeneity of human tissues, it is required to use in-vivo data that are specific for each subject. Since traditional techniques are not able to reach this aim, an alternative method based on MR is here considered. In this work a model is proposed for the reconstruction of dielectric properties of biological tissues from MR acquisitions. The proposed dielectric model is wideband, specific, and applicable in vivo and can be used for those medical techniques that need a precise dielectric characterization of the subjects.

11:20 *Microwave Tomographic Imaging of Shoulder Injury*

Sahar Borzooei (University of Nice Sophia Antipolis, France); Claire Migliaccio (Université Côte d'Azur, CNRS, France); Pierre-Henri Tournier (Sorbonne University, France); Victorita Dolean (University of Nice Sophia Antipolis, France); Christian Y. Pichot (Université de Côte d'Azur, CNRS, LEAT, France)

One of the most challenging shoulder injuries is rotator cuff tear that increases with aging and particularly happens among athletes. This tears cause pain and highly affect the functionality of the shoulder. The motivation of this work is detecting these tears by microwave tomographic imaging. This imaging method requires the solution of an inverse problem based on a minimization algorithm, with successive solutions of a direct problem. We make use of parallel computation from the domain decomposition method and domain-specific language with the open source FreeFEM solver. Results demonstrate the possibility to detect tendon tear in a simplified shoulder model

11:40 *Enhancement of Dual-Mode Microwave-Ultrasound Imaging of an Experimental Breast Phantom Using Radial Basis Functions*

Lucas Banting, Hannah C Fogel, Colin Gilmore, Ian Jeffrey and Joe LoVetri (University of Manitoba, Canada)

An inter-iteration processing technique, in which pulse basis contrast source inversion reconstructions are projected onto a set of chosen basis functions, is applied to a microwave imaging scenario in which ultrasound prior information, obtained from a dual-mode microwave-ultrasound imaging system, is used as a background model. Choosing a set of radial basis functions is shown to improve image quality for an experimental phantom tumour detection problem. Results suggest additional work into customizing the chosen basis for joint ultrasound and microwave biomedical breast imaging.

12:00 *Deep Learning Enhanced Microwave Imaging for Brain Diagnostics*

Darko Ninković (University of Belgrade, Serbia); Álvaro Yago Ruiz (CNR, National Research Council, Italy); Marta Cavagnaro (Sapienza University of Rome, Italy); Branko Kolundzija (University of Belgrade, Serbia); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Marija Nikolic Stevanovic (School of Eletrical Engineering, University of Belgrade, Serbia)

Permittivity reconstruction of head tissues has an essential role in the application of microwave imaging for brain stroke diagnostics. In this paper, we propose a deep learning enhanced microwave imaging approach for estimating permittivities of tissues inside the head assuming that only the outer boundary of the head is known. The approach first retrieves the inner domain boundaries and then determines the permittivity of each domain. The first task is performed by a U-Net neural network trained to predict the inner boundaries based on the qualitative images obtained using the first order solution computed via truncated singular value decomposition. Then, the permittivities of the domains inside the head are iteratively estimated using the distorted Born iterative method. An assessment of the approach with a simplified but realistic head model consisting of two homogeneous tissues is provided.

12:20 *Multimodal Tissue-Mimicking Breast Phantoms for mm-Wave and Ultrasound Imaging*

Alessia Cannatà, Simona Di Meo, Giulia Matrone, Simone Morganti and Marco Pasian (University of Pavia, Italy)

Multimodal tissue-mimicking breast phantoms represent a useful instrument to validate the experimental imaging systems, as biological samples are not always available for the testing. In the context of cancer detection, multimodal imaging approaches are gaining increasing interest as they could provide complementary data about the investigated tissues. The aim of this work is to provide a brief review on the characterization of dielectric, mechanical and acoustic properties of breast phantoms and to prove that it is possible to design a tissue-mimicking material able to emulate different physical properties (i.e., real and imaginary part of the dielectric permittivity, Young's modulus, ultrasound wave speed and attenuation) of the corresponding human tissues.

Tuesday, March 28 11:00 - 12:40

CS14b: COST CA18223 (SyMat): Applications of Metamaterials with higher symmetries (continued)

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 107

Chairs: Stavros Koulouridis (University of Patras, Greece), Francisco Mesa (University of Seville, Spain)

11:00 ***Discussion on Forward and Backward Modes in Periodic Bounded Structures***

Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Raúl Rodríguez-Berral (Universidad de Sevilla, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

We discuss forward and backward modes in bounded periodic structures. First, it is shown that the conventional definition of the phase velocity can incorrectly identify the forward/backward nature of modes. Therefore, we propose an alternative definition of the phase velocity for modes in bounded periodic structures and demonstrate that this definition correctly identifies the nature of modes in a one-dimensional periodic corrugated parallel plate waveguide. The proposed phase velocity is analyzed through simulations with commercial software and a circuit model.

11:20 ***Mode Analysis of Groove Gap Waveguide Loaded with Glide Symmetric Corrugations for TWTs***

Nelson Castro (University Carlos III of Madrid, Spain); Miguel Saavedra-Melo and Filippo Capolino (University of California, Irvine, USA); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

The design of three groove gap waveguide slow wave structures for traveling wave tube (TWT) applications at the mm-wave regime is presented and analyzed in terms of dispersion diagram, phase velocity and interaction impedance. The proposed structures consist of a groove gap waveguide loaded with periodic corrugations with different configurations including glide symmetry. The effect of the use of glide symmetry is discussed and the parameters for the potential application in TWTs are evaluated. A significant increase of the relative bandwidth of approximately 34\% is observed when glide symmetry is used in the structure.

11:40 ***Funneling Electromagnetic Waves with PTD Symmetric Metastructures***

Kristy Hecht and Mario Junior Mencagli (University of North Carolina at Charlotte, USA)

This paper investigates a new class of metastructures for funneling electromagnetic energy within arbitrary narrow channels. This class is based on structures that are invariant under the Parity Time-reversal Duality (PTD) transformation. Such structures produce zero backscattering under the illumination of a plane wave at normal incidence for all incident polarizations. These reflectionless and arbitrary polarizations features are exploited to design metastructures for concentrating electromagnetic energy within subwavelength channels. Numerical results of the proposed metastructures are also discussed.

12:00 ***A Leaky Wave Antenna Made of Two TLs with Exceptional Point Degeneracy***

Nathaniel Furman (University of California, Irvine, USA); Albert Herrero-Parareda (University of California Irvine, USA); Filippo Capolino (University of California, Irvine, USA)

We show for the first time the concept of a second-order exceptional point of degeneracy (EPD) in a leaky wave antenna (LWA) coupled to a passive waveguide. The LWA system is modeled as a transmission line (TL) with a shunt conductance representing distributed radiation, coupled to a second lossless and gainless TL. This system allows for an EPD with five degrees of freedom. The LWA working at an EPD frequency is exceptionally sensitive to system's perturbations. Here we focus on the case that is fully passive, with loss representing radiation, but also the PT symmetric case, where the coupled TL has distributed gain, will be discussed during the presentation.

12:20 ***Multimodal Analysis of Glide-Symmetric Dielectric/Magnetic Structures***

Ludovica Tognolatti (Roma Tre University, Italy); Francisco Mesa (University of Seville, Spain); Paolo Baccarelli and Giuseppe Schettini (Roma Tre University, Italy); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this contribution, we propose the use of the multimodal transfer matrix approach to investigate two-dimensional dielectric and magnetic periodic structures that possess glide symmetries. This method allows for the calculation of the attenuation constant in bandgaps, leaky structures, and material losses. In addition, this method enables a fundamental understanding of the operation of periodic structures. The method is also used to explain the differential response produced by dielectric/magnetic glide symmetries.

Tuesday, March 28 11:00 - 12:40

CS1b: Advances in and Applications of the Methods of Analytical Regularization in Electromagnetics (continued)

T10 Fundamental research and emerging technologies / Convened Session / Electromagnetics

Room: Spadolini 108

Chairs: Mario Lucido (University of Cassino and Southern Lazio, Italy), Alexander I. Nosich (IRE NASU, Ukraine)

11:00 ***Complex Eigenvalues of Two-Dimensional Slotted Metallic Elliptic Cavities***

Elena Vinogradova and Paul Smith (Macquarie University, Australia)

Highly accurate calculations of the complex eigen-values of natural TM- and TE-oscillations which may be excited in a two-dimensional (2D) elliptic cavity with a variably located longitudinal slit are reported. The algorithm is obtained by regularisation of the integral equations obtained from the single-and double-layer potential representations, respectively. The final form is a Fredholm matrix equation of second kind. Its solution is obtained by the truncation method which rapidly converges as the truncation order increases. The high accuracy of the method is assessed by comparison with the eigenvalues for the closed cavity computed from exact solutions in terms of special functions. A novel study of the evolution of the complex eigenvalues and the corresponding modes as a longitudinal slit of increasing width is opened is reported.

11:20 ***Completeness and Regularization Techniques for Wiener-Hopf Problems with Discontinuous Layers***

Vito Daniele (Polythechnic of Turin, Italy); Guido Lombardi (Politecnico di Torino, Italy)

Scattering and radiation by buried multiple objects in multilayered media is of great interest in a vast variety of electromagnetic applications. In this work, we present a general methodology to analyze the complex scattering problems with the capability of semi-analytical method in spectral domain, which allows physical interpretation of the problem and asymptotics estimation of field behavior. The method is based on the combination of the Wiener-Hopf technique, completeness and regularization techniques.

11:40 ***Infrared Diffraction Radiation from Two In-Line Dielectric Rods Covered with Graphene***

Dariia O. Herasymova (Institute of Radio-Physics and Electronics NASU, Ukraine)

We analyze the terahertz and infrared range diffraction radiation (DR) of a modulated beam of electrons flowing near two graphene-covered dielectric nanorods. In our treatment, we assume that the velocity of the charged particles beam is fixed and use the Kubo formalism and resistive-type boundary conditions for the graphene cover description. To satisfy the boundary conditions, we apply the separation of variables in the local coordinates and the addition theorem for the cylindrical functions. This transforms the DR problem to a Fredholm second-kind matrix equation for the field expansion coefficients. As a result,

the scattering and absorption characteristics and the near and far field patterns are determined with controlled accuracy. The obtained data show the resonance effects related to the excitation of the plasmon supermodes of four different classes of symmetry. Our work could be used in design of elementary cells of dielectric laser accelerators.

12:00 ***Flat Superscatterer Based on Split Ring Resonators***

Anna Mikhailovskaya (Tel Aviv University, Israel); Konstantin Grotov Grotov (ITMO University, Russia); Dmytro Vovchuk (Tel Aviv University, Israel); Dmitry Dobrykh (ITMO University, Russia & Tel Aviv University, Israel); Pavel Belov (ITMO University, Russia); Pavel Ginzburg (Tel Aviv University, Israel)

Increasing scattering cross-sections of subwavelength structures is an important challenging problem. There are several bounds used to assess scattering cross-sections with Chu-Harrington and Geyi criterions being the most frequently used ones. Here we demonstrate a device, which overcomes those bounds by an order of magnitude. Our strategy to increase a scattering cross-section of a subwavelength device is resonance cascading. In this case, many resonances of a structure are designed to interfere with each other at nearly the same frequency. This concept is realized within a 2D array of near-field coupled split-ring resonators. Their positions and orientations were optimized with an aid of a genetic algorithm, which allowed them to boost performances quite significantly, compared to a standard parametric optimization. This flat superscatterer can be employed as passive electromagnetic beacons, used to increase the radar visibility of small airborne targets, making them subject to reliable traffic monitoring.

Tuesday, March 28 11:00 - 12:40

A33: Antennas with Innovative Manufacturing Techniques

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 109

Chairs: Manuel Arrebola (Universidad de Oviedo, Spain), William Whittow (Loughborough University, United Kingdom (Great Britain))

11:00 ***Single-Fed Additively Manufactured Conical Horn Antenna with Circular Polarization for Millimeter-Wave Applications***

Benedikt Micha Dorbath (Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany); Konstantin Lomakin (Friedrich-Alexander University, Germany); Tim Pfahler (Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany); Jan Schür (Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany); Martin Vossiek (LHFT, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany)

We present a circularly polarized conical horn antenna fed by a standard WR19 waveguide. The antenna was additively manufactured and electroplated with a thin copper layer. The performance of the fabricated conical horn antenna is specified by a measured realized gain of 11 - 13.5 dBi over the entire frequency band of interest from 40 - 50 GHz for circular polarization. The measured reflection coefficient for this frequency range is less than −16.5 dB. The axial ratio of the manufactured antenna remains below 3 dB. An axial ratio of less than 5 dB is reached over the entire Q Band. This circularly polarized antenna design, in combination with the flexibility of additive manufacturing and electroplating, can be integrated conveniently with other components and can satisfy various demands for the gain and main lobe width, as well as both left-hand or right-hand circular polarization by slight changes to its geometry.

11:20 ***3D Printing Technique for a New Efficient Production Method of mm-Wave Antennas***

Alexander Vorobyov (CSEM & Center Suisse d'Electronique et de Microtechnique SA, Switzerland); Ignacio Montesinos-Ortego (TTI, Spain); Samuel Unterhofer (CSEM, Switzerland); Belen Galocha (Universidad Politecnica de Madrid, Spain); Manuel Sierra-Castañer (Universidad Politécnica de

Madrid, Spain)

This paper presents the 3D printed metallic planar slotted antenna array operating at 94GHz. A reliable and cost-effective additive manufacturing method has been optimized for high printing resolutions. The prototyped antennas were characterized, and performance was compared with the theoretical estimation.

11:40 ***Development of 3D Printed Metallic Lenses***

Deepak Shamvedi (University of Dundee, United Kingdom (Great Britain)); Paul O'Leary (Supervisor, Ireland); Ramesh Raghavendra (SEAM, Ireland)

The research presented in this paper reports, for the first time the development of a 3D printed metallic lens for mm-wave applications, fabricated using Direct Metal Laser Sintering (DMLS). The metallic lens has been designed, simulated, and fabricated for use at E-band. The paper studies the focusing effect of both a 3D Plano-concave and a Bi-concave metallic lenses, and focusses towards development of metallic lenses, through 3D printing. Furthermore, the paper also highlights design and manufacture challenges of such 3D printed lenses. Potential applications include horn antennas with an in-built metallic lens, as an alternative to parabolic reflectors or dielectric lens horn antennas for 5G applications.

12:00 ***Fully 3D-Printed Hemispherical Dielectric Resonator Antenna for C-Band Applications***

Jakub Przepiorowski (Technological University Dublin & Antenna and High Frequency Research Centre, Ireland); Irina Munina (Trinity College Dublin, Ireland); Max James Ammann (Technological University Dublin, Ireland); Daniel Trimble (Trinity College Dublin, Ireland)

This paper investigates the 3D printing of a hemispherical dielectric resonator antenna (DRA) on a ground plane made from a 3D printed conductive material. The DRA is designed to operate in the C-band (3700 - 4200 MHz) and is intended for satellite communication (SATCOM) applications. The proposed antenna prototype achieved a 10 dB bandwidth of 12.2% with an average and peak gain of 4.69 dBi and peak gain of 5.39 dBi respectively.

12:20 ***Additive Manufacturing in 316L Steel for Microwave Waveguide Components in the Ka-Band***

José Rico-Fernández, Álvaro F. Vaquero and Manuel Arrebola (Universidad de Oviedo, Spain)

This paper evaluates additive manufacturing technique of Laser Powder-Bed Fusion for metallic-only waveguide microwave components made in 316L stainless steel. The validation is carried out by the design, manufacture and test of simple microwave waveguide components, such as rectangular and 90º twist waveguides. Furthermore, horn array antennas are introduced and experimentally validated in 316L steel and AlSi10Mg aluminum alloy manufactured through additive manufacturing. Finally, a combination of presented designs is presented in order to achieve a 4x4 planar horn array design, which is manufactured and experimentally validated. The overall results show good agreement and therefore, corroborate that Additive Manufacturing through Laser Powder-Bed Fusion technique is a promising manufacturing method to produce metal-only solutions for microwave waveguide components reaching monolithic prototypes.

Tuesday, March 28 11:00 - 12:40

SW9b: Disruptive Innovations: the Roadmap of European Funding Agencies (continued)

Organized by: Stefania Monni (TNO, The Netherlands); Stefano Maci (University of Siena, Italy)

Room: Sala della Scherma

11:00 - The EU Research and Innovation Programme 2021-2027: MSCA Doctoral Networks (Gergana Simenova - Arida, European Research Executive Agency Program Manager)

11:30 Panel discussion

Tuesday, March 28 11:00 - 12:40

IW3: Simulation Measurement Capabilities at Emerson & Cuming AC (ECAC)

Room: Polveriera

Tuesday, March 28 11:00 - 12:40

RoE: EurAAP RoE meeting

Room: Palazzina 7

Tuesday, March 28 13:30 - 15:00

PA1: Poster Session on mmWave Antennas I

/ / Antennas

Rooms: Spadolini 001, Spadolini 002

Chairs: Sergio Matos (ISCTE-IUL / Instituto de Telecommunicações, Portugal), Julien Sarrazin (Sorbonne Université, France)

Fabrication of SENTENNA with Hand Grip Sensing Based on MEMS Technology for 5G Mobile Application

Thi Quynh Hoa Nguyen (Jeonbuk National University, Korea (South) & Vinh University, Vietnam); Jeong-Ung Yoo and Hae-Won Son (Jeonbuk National University, Korea (South)); Donggu Im (Chonbuk National University, Korea (South)); Jung-Mu Kim (Jeonbuk National University, Korea (South))

We propose the MEMS antenna with user hand grip sensing functionality for 5G mmWave phased antenna system. The built-in device is called "SENTENNA" which stands for SENsor and anTENNA. The SENTENNA is fabricated based on MEMS technology on two Borosilicate substrates. The top metal patch fabricated on the Borosilicate glass acts as a radiation patch of antenna and an electrode of capacitance sensing simultaneously. The proximity-coupled microstrip patch antenna of SENTENNA is designed and fabricated to operate at 28 GHz and capacitance variation on the patch is measured at 1 MHz. The performance of the designed SENTENNA is evaluated by HFSS simulation and experimental.

Optimizing Antenna Beamforming with Quantum Computing

Annalise Stockley (University of Durham, United Kingdom (Great Britain)); Keith Briggs (BT Group, United Kingdom (Great Britain))

We consider beamforming with large-scale antenna arrays in which the elements can transmit only in one of a small number of phase-shifts. This creates a hard optimization problem, namely the maximization of the ratio of two Hermitian quadratic forms. We show how the maximization problem can be rigorously solved by reformulating it as a sequence of quadratic minimization problems. These minimization problems can be solved exactly with integer linear programming when sufficiently small. When they are large there is essentially no good classical solution method, but we show that they can be solved using quantum computers of the annealing type.

Additively Manufactured Endfire Bifilar Helix Antenna for E-Band

David Panusch (Friedrich Alexander Universität Erlangen-Nuermberg, Germany); Jing Shi (Friedrich-

Alexander-Universität Erlangen-Nürnberg, Germany); Konstantin Lomakin (Friedrich-Alexander University, Germany); Gerald Gold (FAU Erlangen-Nürnberg, Germany)

In this work, an additively manufactured endfire bifilar helix antenna with a center frequency of fc = 66 GHz employing a novel transition from bifilar helix to E-band waveguide is presented. This novel transition enables a higher bandwidth of the antenna and also tuning of the antenna matching. Measurements suggest a B20dB ≈ 5.2 GHz and of B15dB = 16 GHz respectively. An axial ratio below AR<3.15dB is achieved over the entire E-Band and even AR < 2 dB within B20dB in main lobe direction. The realized linear polarization gain ranges at Glp 11 dBi with a circular polarization gain of Gcp 12 to 13dBi was measured. Hence, measurements suggest general feasibility of the proposed bifilar helix antenna for mmWave applications due to the small form factor of the antenna and the circular polarization. Those applications in future could be satellite systems or future 6G infrastructures.

Travelling-Wave Design of Corner-Cut Serpent Array Antenna in 275 GHz Band

Jihoon Kim, Yoshiki Sugimoto, Kunio Sakakibara and Nobuyoshi Kikuma (Nagoya Institute of Technology, Japan)

A travelling-wave serpent array is designed in 275 GHz band. A single element is analyzed in terms of corner angle. Chebyshev tapering with 25 dB side-lobe level (SLL) is applied. Remained power in the array is considered to design the correct radiated power distribution. The maximum gain is 16.3 dBi and the SLL was 23.7 dB, while the main beam was tilted about -9° at 275 GHz. The bandwidth of gain drop was appeared as 260 to 285 GHz, and beam tilting angle by the frequency was from -17° to -4° at that range.

Impact of the Asymmetric Signal Routing on the Wideband Spatial Behavior of Large Modular Phased Arrays

Duccio Delfini, Nuutti Tervo, Marko E Leinonen and Aarno Pärssinen (University of Oulu, Finland)

Phased arrays have typically equal lengths for all antenna paths. This paper compares three phased array architectures for 5/6G applications. The first two arrays present unequal-length feeding networks, while the third array is the corporate-fed one. The first array is fed from the center, while the second is fed from the side. The impacts of the unsymmetrical feeding network on the bandwidths are analyzed and compared to the corporate-fed array. We show that side-fed arrays present higher bandwidths for higher steering angles, while center-fed arrays work better in the boresight direction. Moreover, side-fed arrays can also be better than corporate-fed ones for large steering angles, making them a good alternative to reduce the footprint of the feeding networks. Finally, we illustrate that if the feeding point can be varied as a function of the desired steering angle, the broadband performance of the array can be optimized for different steering angles.

A Uniplanar Low-Sidelobe Periodic Leaky-Wave Antenna Based on a Metamaterial-Inspired Substrate Integrated Waveguide

Maria - Thaleia Passia and Traianos Yioultsis (Aristotle University of Thessaloniki, Greece)

We analyze and design a uniplanar and low-sidelobe periodic leaky-wave antenna (PLWA), suitable for millimeter-wave 5G applications. The antenna is synthesized by etching a non-uniform pattern of transverse slots on the top plane of a metamaterial-inspired substrate integrated waveguide (SIW). Uniplanar complementary split-ring resonators (CSRRs) substitute the conventional metalized via holes, to construct the CSRR SIW. The CSRR SIW is uniplanar and presents a low-loss, low-cost and easy-to-fabricate alternative for millimeter-wave communications. The proposed CSRR-SIW-based PLWA features low sidelobes, high gain and a beam-scanning ability. The antenna performance is similar to PLWAs implemented using the conventional SIW. The proposed design is also accompanied by a considerably simpler fabrication process, hence rendering the CSRR-SIW PLWA an appealing choice for 5G applications.

Shared-Volume Millimeter-Wave Substrate Integrated Step Horn Antennas and Arrays

Weiguang Song and Zhenxiang Yi (Southeast University, China); Jin Zhang (Aalborg University, Denmark); Kun Zhao (Aalborg University, Denmark & Sony, Sweden); Lei Wang (Heriot-Watt University, United Kingdom (Great Britain))

Two shared-volume substrate integrated step horn antennas and arrays are proposed in this paper. Two horn antennas exciting the top and the front apertures share a substrate integrated waveguide (SIW) volume assembled into by using five layers of printed circuit boards (PCB). Both the two antennas have a wide bandwidth from 24 to 30 GHz with reflection coefficients below −10 dB. The top and front apertures contribute together to the radiation in the θ-plane, resulting in an increased space coverage efficiency. Moreover, a linear broadside array with eight antenna units is investigated to obtain the beam scanning property. Simulation results demonstrate that the radiation beams of the eight-unit array in both directions can steer continuously from −45◦ to +45◦ with scanning loss less than 3 dB. The antenna unit and array proposed in this paper are promising for millimeter-wave communication systems on mobile devices.

Connected Arrays of Slots with Reduced Number of Active Controls: Efficiency, Matching and Radiation Pattern Agility

Christos Monochristou (University of Rennes 1, France); Shang Xiang (Lund University, Sweden); Mark Holm (Huawei Technologies (Sweden) AB, Sweden); Ronan Sauleau (University of Rennes 1, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

Sparse arrays attract a lot of interest due to their potential to significantly simplify phased arrays while maintaining their agile operation. However, the majority of studies concern numerical synthesis techniques and little attention is paid to the practical implication of such arrays. The present work analyzes finite x infinite sparse configurations of connected arrays by full-wave simulations to evaluate their performance in terms of array efficiency, optimal lattice and radiation pattern quality. The proposed study also takes into account the mutual coupling among the array elements and the appropriate termination of the inactive elements to boost the array performance.

A Multi Beam Slot Array Antenna Fed by Contact-Less Multi-Layered 4×8 Buttler Matrix Using Gap Waveguide Technology for 60GHz Fixed Wireless Access Applications

Seyed Ali Razavi (Graduate University of Advanced Technology, Kerman, Iran); Ashraf Uz Zaman (Chalmers University of Technology, Sweden)

A multi beam antenna design based on gap waveguide technology is presented. In the proposed antenna a 8×10 slot array is used as the antenna aperture, however the beam forming network consists of a multi layered 4×8 Buttler matrix realized using both ridge and groove gap waveguide technologies. The proposed structure is composed of five unconnected layers which can be simply assembled using screws and guiding pins without any need of electrical contact in accordance with the contact-less assembly feature of gap waveguide technology. The designed antenna shows proper radiation performance including low side lobes and flat gain response which can be applied for access points in fixed wireless communications operating at 60GHz. Also the S11 remains below -10dB for the input ports within the frequency range of 59-64GHz. The simulated gain for the array is 25dBi at bore sight and 22 dBi when the ±45º beam is excited

Design Methodology for Wideband Bowtie Patch Antenna for 5G mmWave Applications

Abolfazl Azari (Microwave and Antenna Group (MAG), Ecole Polytechnique Fédérale de Lausanne (EPFL) & K N Toosi University of Technology, Iran); Anja K. Skrivervik (EPFL, Switzerland); Hadi Aliakbarian (K. N. Toosi University of Technology, Iran)

Millimeter wave (mmWave) frequencies has become a research area of interest in recent years because of providing broad available bandwidth and thus higher data rates. Wideband mmWave antenna is one of the important development areas in wireless communication systems. Conventional planar bowtie antennas have a limited impedance bandwidth. This contribution presents a design method for wideband bowtie patch antennas targeting mmWave frequencies, based on the combination of patch antennas and bowtie antennas. The proposed method is illustrated with the design of a dual polarized antenna element that can be a good candidate for mmWave wireless technologies such as 5G, radar and satellite communications.

Millimetre-Wave Multiple-Input-Multiple-Output Antenna Frontend for Beyond 5G Applications

Richard Darren Fabianczyk (Aberystwyth, United Kingdom (Great Britain)); Shaker Alkaraki (Queen Mary University Of London, United Kingdom (Great Britain)); Muhammad Aslam (University of West of Scotland, United Kingdom (Great Britain)); Qammer H Abbasi (University of Glasgow, United Kingdom

(Great Britain)); David Andrew Evans (Aberystwyth University, United Kingdom (Great Britain)); Syeda Fizzah Jilani (Aberystwyth University & Queen Mary University of London, United Kingdom (Great Britain))

This paper presents a millimeter-wave (mm-wave) multiple-input multiple-output (MIMO) antenna for the fifth-generation (5G) networks and beyond. The proposed antenna frontend aims to deliver a high gain and bandwidth, planar configuration for a compact assembly, and high isolation for the MIMO operation. The top layer is comprised of a modified T-shaped radiating patch integrated with a coplanar waveguide (CPW) feed. The partial ground is comprised of six ring-slots as the defective ground structures (DGS) in a symmetrical triangular formation at optimized positions. The results show an impedance bandwidth in the range of 24.5-38.4 GHz with a maximum gain of 6.19 dBi at 36.75 GHz. The 2×2 MIMO assembly is presented with a lower mutual coupling and transmission coefficient below -20 dB. The performance of the proposed MIMO antenna is on merit to support various mm-wave wireless applications such as cellular phones and indoor base stations for 5G and beyond.

Decoupling Design for MIMO Antenna Array in Joint Communication and Sensing System

Zizhen Zhang and Zhirun Hu (University of Manchester, United Kingdom (Great Britain))

Beamforming algorithms have been applied to millimeter wave joint communication and sensing systems. Applying weight-beamforming algorithms to the transmit and receive beams can reduce the self-interference of the system while maintaining the integrity of the beam. Considering that there are still some limitations of beamforming algorithms in JCAS systems, this paper proposes a design method for antenna arrays applied to JCAS systems from the perspective of antenna array layout, which can directly reduce the coupling between transmit and receive antenna arrays. The results show that the designed antenna array layout can enhance the decoupling between the antenna arrays, thus reducing the system self-interference.

Highly Omnidirectional Monopole-Like Radiation with SIW Slot Antenna in Ka-Band

Yang Cai and Peng Mei (Aalborg University, Denmark); XianQI Lin (University of Electronic Science and Technology of China, China); Shuai Zhang (Aalborg University, Denmark)

A monopole-like radiation pattern with high omnidirectivity in Ka-band is generated by substrate integrated waveguide (SIW) slot antenna. Two pairs of symmetric slots are designed to facilitate the radiation of two out-of-phase elements based on the fundamental TM11 mode in SIW cavity, leading to the cancellation of electromagnetic (EM) fields in the broadside direction, thus yielding a monopole-like radiation pattern. Moreover, four metal vias are properly positioned to improve the impedance matching. Simulation results show a highly omnidirectional radiation pattern in azimuth plane (θ = 54◦) and a deep null (<-95 dB) in broadside, and the realized gain is 1.81 dBi at 28.86 GHz.

Multibeam Antenna System Based on Reconfigurable Reflectarray for 5G mm-Wave Applications

Philippe Ratajczak (Orange Innovation, France)

In this paper, an antenna multi-beam system based on reconfigurable reflectarray antennas is proposed for mm-waves applications. In order to control more than the 2 beams provided by a single dual polarization system, 4 structures are associated to manage up to 8 independent beams. A preliminary design based on passive reflectarrays is presented to analyze the achievable performance of such system. To validate this first step, the antenna system is under manufacturing and will be tested. A reconfigurable unit cell is presented for the final transformation into a reconfigurable antenna system.

Multi-User Shadowing Investigation at 28 GHz for 5G Mobile Communication Systems

Igor Syrytsin, Peiye Liu and Shuai Zhang (Aalborg University, Denmark)

In this paper, the multi-user measurement has been done at 28 GHz with the handset antenna array for purpose of studying the user blockage. The measurement has been done in the anechoic chamber with one active and 3 passive users. The passive users are oriented in 6 different setups and the base station probe horn antenna has two different angles in order to replicate the most critical real life scenarios. It has been found that presence of multiple users will increase the overall handset antenna gain by adding multiple reflections, scattering and diffractions. In order to increase the power in the shadow region when the user is pointing away from the base station an extra one to three different scan angles on the handset can be added in order to gain 10 dB.

Demonstration of Low-Complexity D-Band Extension of Fiber X-Haul for 5G and Beyond Infrastructure

Ronis T. Maximidis, Christos Vagionas and Sotirios Soukaras (Aristotle University of Thessaloniki, Greece); Zhongxia Simon He (SINOWAVE, Sweden); Konstantina Kanta, Panagiotis Toumasis and Giannis Giannoulis (National Technical University of Athens, Greece); Dimitrios Apostolopoulos (National Technical University of Athens & Institute of Communication and Computer Systems, Greece); George Kalfas (Aristotle University of Thessaloniki & Center for Interdisciplinary Research and Innovation, Thessaloniki, Greece); Agapi Mesodiakaki (Aristotle University of Thessaloniki (AUTH) & Center for Interdisciplinary Research and Innovation, Thessaloniki, Greece); Marios Gatzianas (Aristotle University of Thessaloniki & Center for Interdisciplinary Research and Innovation, Thessaloniki, Greece); Hercules Avramopoulos (National Technical University of Athens, Greece); Amalia N. Miliou and Nikos Pleros (Aristotle University of Thessaloniki, Greece)

This work presents a seamless integration of a wireless D-band transmission link to a fiber network. The D-band wireless transmission is performed by utilizing recently developed direct up-/down- conversion and high gain flat EBG antennas, thus resolving the issue of high complexity and cost of the optical heterodyne mixing adopted until now for the generation of the D-band signals in fiber-wireless implementations. More specifically the transmission of a baseband signal up to 12.5Gb/s as well the transmission of QAM modulated IF signals with up to 256QAM 900Mbaud format are successfully demonstrated validating the potential of D-band link to become the next "last mile" wireless extension of mobile networks

Periodic EBG Mushroom Unit Cells for Leakage & Sidelobes Reduction in Hybrid Multilayered Antenna Based on Gap Waveguide Technology

Panagiotis Petroutsos and Stavros Koulouridis (University of Patras, Greece)

We propose a hybrid multilayer slot array antenna based on Gap Waveguide Technology for mm-Waves wireless systems. The hybrid antenna structure consists of a metal Ridged Gap Waveguide feeding network, backed by a metallic layer from resonant cavities, while the radiation plane is etched on a PCB. The novelty of the above proposal focuses on the implementation of printed periodic EBG structures of inverted or no-inverted "Mushroom" type on the radiation layer. The utilization of EBG structures contributes to reducing the level of the sidelobes. Secondly, the integration of periodic surfaces on the same radiating layer provides a more compact structure, as compared to other methods, which use corrugation slots. In addition, the periodic structure of inverted mushroom cells avoids any leakage due to any gap between the cavity and the radiation layer. Finally, the presented antenna covers an impedance bandwidth from 37.90GHz to 39.83GHz, providing a gain of 23.3dB.

Efficient mm-Wave Antenna-On-Chip Through Effective Illumination of Integrated Artificial Magnetic Conductor

Yiyang Yu and Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)

Artificial magnetic conductors (AMC) employed underneath the antenna-on-chip (AoC) can provide the in-phase reflection as well as the isolation from the lossy silicon substrate. The gain of an AMC-backed AoC is proportional to the AMC area. However, the relatively large AMC cannot be illuminated effectively due to the limited space in the stack-up. This means the AMC-backed AoC cannot achieve its optimum performance. In this paper, we propose to resolve this issue through custom-designed coupling enhancement structures (CESs), which enable the energy coupling from the well-illuminated unit cells (in the center) to the less or non-illuminated unit cells (at the peripheries). Compared to a conventional AMC, the proposed CES-based AMC enhanced the AoC gain by 3.5 dBs and radiation efficiency by 23% at 94 GHz. The fabricated prototype of the proposed AMC-backed AoC demonstrated a gain of 9.8 dBi which was 25 times greater than an AoC without AMC.

Performance Evaluation of a Circularly Polarized Circular Loop Antenna Printed on GaAs, InP, and 4H-SIC Substrates in the Q/V Band Frequencies

Rawad Asfour, Salam Khamas and Edward Ball (University of Sheffield, United Kingdom (Great Britain))

In this paper, the performance of an on-chip circularly polarized circular loop antenna has been evaluated using three various dielectric substrates in the Q/V band. To this end, Gallium Arsenide, GaAs, Indium Phosphide, InP, and Silicon Carbide, 4H-SIC, substrates are used with dielectric constants of 12.94, 12.4, and 6.52, respectively. The simulation results demonstrate impedance matching at 43 GHz, 44 GHz, and 45 GHz for 4H-SIC, GaAs, and InP, respectively. On the other hand, an axial ratio (AR) of less than 3 dB has been achieved in all cases with different bandwidths and frequency bands depending on the dielectric constant of each material. Moreover, the simulation results demonstrate a left-hand circularly polarized, LHCP, wave. Furthermore, the gain, radiation efficiency, and radiation pattern for the three configurations have been compared with each other. The antenna has been designed using Computer Simulation Technology (CST).

Photonic-Integrated mm-Wave On-Chip Antenna Design for Opto-Electronics Applications

Ryan Gold, Saeed Haydhah and Ahmed A Kishk (Concordia University, Canada); John Zhang (Concordia, Canada)

A new multi-element on-chip mmWave antenna at 24 GHz is proposed using Silicon Photonics (SiP) technology. The antenna includes a coplanar patch antenna, a Bowtie antenna, and a slot antenna. The achieved -10 dB impedance bandwidths are 4.45, 2, and 0.9 GHz for the coplanar patch, the Bowtie, and the slot, respectively. The obtained realized gains are 2.1, 2.8 and -1.4 dBi for the coplanar patch, the Bowtie, and the slot, respectively. The size of the proposed antenna is 730.731 mm^3. The coplanar patch and the slot provides omnidirectional radiation patterns, while the Bowtie provides a directional pattern. The coupling between the coplanar patch and the slot is high, enabling the inter-chip communications.

Tuesday, March 28 13:30 - 15:00

PA2: Poster Session on mmWave Antennas II

/ / Antennas

Rooms: Spadolini 101, Spadolini 102

Chairs: Stavros Koulouridis (University of Patras, Greece), Cristina Yepes (University of Siena, Italy)

Millimeter-Wave Switched-Beam Grid-Array Antenna

N Nasimuddin (Institute for Infocomm Research, Singapore); Yijun Zhou (I2R, Singapore); Xianming Qing (Institute for Infocomm Research, Singapore)

An electronic switched-beam grid-array antenna (GAA) at 28.0 GHz is investigated. The proposed antenna panel includes of a sixteen-port GAA integrated with RF switching circuit that consists of five RF switches and a separate control panel. The sixteen beams can be electronically switched/steered with a beam coverage of ±22 degrees and measured antenna gain of around 14.0 dBi at 28.0 GHz.

A Broadband Coaxial to Stripline Transition for Millimeter-Wave LTCC Circuit Applications

Maryam Sadeghi and Dawood Shekari Beyragh (University of Calgary, Canada); Ammar Kouki (École de Technologie Supérieure, Canada); Mohammad S. Sharawi (Polytechnique Montreal, Canada); Mohamed Helaoui and Fadhel Ghannouchi (University of Calgary, Canada)

This paper proposes a broadband coaxial to stripline transition for 5G millimeter-wave (mm-wave) band using low temperature co-fired ceramic (LTCC) technology. The proposed structure is specifically designed for Surface-Mount-Device (SMD) coaxial connectors. A back-to-back configuration has been designed and fabricated using a 5-layer LTCC stack and two SMD mini-SMP connectors. Measurements were carried out between 100 MHz and 34 GHz and the results show good agreement with the simulations, with a loss better than 0.7dB for a single transition over the entire range of the operating frequency.

Broadband Characteristics of Integrated Si Lens Antennas at 220-330 GHz

Kimmo Rasilainen, Jiangcheng Chen and Mostafa Jafari Nokandi (University of Oulu, Finland);

Markus Berg (University of Oulu & Excellant LTd., Finland); Marko E Leinonen, Timo Rahkonen and Aarno Pärssinen (University of Oulu, Finland)

Directive, high-gain wireless links are needed to achieve practically feasible communications distances at sub-THz frequencies. This work investigates the operation of an integrated Si lens antenna that is fed by an on-chip antenna connected to a power detector, and the lens is working in receive mode. The antenna is studies using both simulations and over-the-air measurements. The simulated and measured results are in good agreement, and the proposed antenna design is a viable candidate for use in more advanced, higher functionality 6G applications.

A Novel Heatsink Attached mm-Wave Active Patch Antenna with Adjustable Frequency and Cooling

Feza Turgay Çelik and Yanki Aslan (Delft University of Technology, The Netherlands)

In this study, the thermal management problem of the modern communication systems with small array sizes is addressed. A novel dual-functional active antenna design strategy is introduced for adjustable frequency of operation and cooling extension at millimeter-wave bands. The concept is based on placing different types of heatsinks on the same patch antenna. The electromagnetic and thermal behavior of the proposed heatsink structures are presented via simulations. Reconfigurable operation at 24, 26, and 28 GHz frequencies with 23 to 28 degrees of extra cooling in the chip as compared to the conventional patch is achieved.

Effect of Left-Handed Grip on Coverage of Quasi-Omnidirectional Millimetre Wave 5G Handset Antenna

Mark Megarry (Queens University Belfast, United Kingdom (Great Britain)); Christopher P Larmour (Queen's University Belfast, United Kingdom (Great Britain)); Muhammad Ali Babar Abbasi (Queen's University Belfast & The Institute of Electronics, Communications and Information Technology (ECIT), United Kingdom (Great Britain)); Neil Buchanan (Queens University Belfast, United Kingdom (Great Britain)); Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain))

This paper investigates the impact of a left-handed grip on the coverage of a handset featuring three antenna arrays operating in the n257 frequency band 26.5 GHz - 29.5 GHz. Beam steering is implemented using multi-bit phase shifters while the handset is held with a left-handed grip. Results are compared to a right-handed grip, and a handset in free space. For a left-handed grip, beam steering increased the coverage region (in which gain is greater than 0 dBi) from 23.8% to 57.7% through the use of 3-bit phase shifters. Similarly, coverage increased from 24.7% to 61.0% for a right-handed grip. This paper also investigates the benefit of increasing the number of bits available to the multi-bit phase shifters and results show performance improvement begins to plateau around 3 bits. From the data collected in this paper, a right-handed grip provides better coverage than a left-handed grip for the simulated scenario.

A Bandwidth-Enhanced Substrate Integrated Waveguide Cavity-Backed V-Band Antenna Using Double-Sided Complementary Annular Slots

Ching-Wen Chiang and Yen-Cheng Kuan (National Yang Ming Chiao Tung University, Taiwan); Chung-Tse Michael Wu (Rutgers University, USA)

This work presents a 64-GHz substrate integrated waveguide (SIW) cavity-backed antenna, whose bandwidth is extended through the complementary multiple annular slots on the front and back sides of the SIW cavity, respectively. A perturbed TE210 mode with two broadside radiation patterns in opposite directions can be observed under the double-sided slots. A Rogers RO4003C substrate is used to manufacture this antenna through a printed circuit board process. With the -10-dB S11 criteria, the measured impedance bandwidth is 3.2 GHz. The measured realized gains at 64 GHz in the two broadside directions are 6.4 dBi and 3.4 dBi, respectively. Furthermore, an over-the-air experiment with a QPSK modulation signal was conducted to validate the double-sided radiation.

Higher Spatial Harmonic Leaky Wave Antenna Design Based on Meandering Microstrips

Pratik V Vadher, Giulia Sacco and Denys Nikolayev (IETR UMR 6164, Univ Rennes, CNRS 35000 Rennes)

A Leaky Wave Antenna (LWA) design with high scanning rate (the ratio of beam scanning range and bandwidth) is proposed in this work. The antenna is based on a periodic meandering microstrip line operating in K-Band with continuous beam scanning from backward-to-forward direction in the elevation plane. The height of the transverse lines is varied periodically in the unit cell to increase the electrical length. Hence, the antenna operates in higher spatial order which increases the scanning rate. The final antenna shows a scanning range in the elevation plane from −40° to 45° in the frequency range from 20.6 GHz to 24.6 GHz corresponding to a scanning rate of 21.25 °GHz−1. The antenna performance is compared to other leaky wave antenna designs in similar frequency ranges showing notable increase in the scanning rate with very less impact on gain while maintaining low profile.

Folding the Feeding Network of a Millimeter-Wave Circularly Polarized Printed Antenna Array

Ahmad Jabri, Youssef Tawk and Joseph Costantine (American University of Beirut, Lebanon)

This paper discusses the effects of folding the feeding network of printed antenna arrays operating in the Ka-band range of the spectrum. More specifically, the impact of single- and double-folded topologies on the radiation behavior of a 10-element antenna array is investigated and analyzed herein. Such impact is assessed in terms of impedance matching, circularly polarized realized gain, and axial ratio bandwidth. The proposed double-folded design features an impedance bandwidth between 26 GHz and 34 GHz while preserving circular polarization between 28.9 GHz and 30 GHz. The proposed design also achieves a maximum realized gain of 13.6 dBic, a half-power beamwidth of 11^0, and a cross-polarization level of 14.31 dB along the direction of maximum radiation.

Effects of an IC Chip on an Antenna-IC Transition at 100 GHz

Jan H. S. Bergman, Kaisa Ryynänen, Juha Ala-Laurinaho and Kari Stadius (Aalto University, Finland); Jussi Ryynänen (Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

This paper investigates the challenges and limitations an IC chip places for modeling a mm-wave antenna system. A compact differential antenna-IC transition suitable for antenna array applications at 100 GHz is presented. Challenges related to including the chip in the antenna design process are evaluated by analyzing the transition through EM simulations. The importance of the correct excitation method in the simulations is discussed, and different excitation port types and their locations are compared. Additionally, the effects of differently modeled IC chips, for example a simple silicon slab or partially metallic chip, are studied. Finally, recommendations for the combined antenna and IC chip simulations are given.

Dual-Polarized SIW-Based Fabry-Perot Leaky-Wave Antenna for Diversity and Radar Applications

Iram Shahzadi (The University of Edinburgh, United Kingdom (Great Britain)); Davide Comite (Sapienza University of Rome, Italy); Maksim Kuznetcov (Heriot Watt University, United Kingdom (Great Britain)); Paolo Burghignoli (Sapienza University of Rome, Italy); Paolo Baccarelli (Roma Tre University, Italy); Alessandro Galli (Sapienza University of Rome, Italy); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

A Current and next-generations of communication systems demand for high-data rates devices with enhanced coverage and compact dimensions for different applications. We present here a dual-polarized, differentially fed, metasurface leaky-wave antenna for dual-polarized full-duplex and Radar applications. The design is based on a slotted substrate-integrated waveguide designed to excite two orthogonal polarizations using differential feeding. The antenna is constituted by a partially reflective surface placed on the top of a dielectric substrate and it operates around 24 GHz, providing satisfactory impedance matching, isolation greater than 40 dB, and maximum realized gain of the order of 17 dBi. The proposed antenna is also capable of providing sum and difference radiation pattern when excited with 180◦ and 0◦ phase shift across two opposite ports, respectively.The null depth is about -28dB

Design, Implementation and Demonstration of Waveguide Components for OTA Power-Combining in W-Band

Mehrnoosh Mazhar Sarmadi (Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany); Mathis Schmieder (Fraunhofer Heinrich Hertz Institute, Germany); Michael Peter (Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany); Dirk Schwantuschke

(Fraunhofer Institute for Applied Solid State Physics, Germany); Wilhelm Keusgen (Technische Universität Berlin, Germany)

This paper reports the design, simulation and implementation of waveguide components including a power divider, an antenna feeder and a sector horn antenna array. The prototype design parameters apply to the W-band, i.e. 75-110 GHz, but can be scaled for other frequency bands associated with waveguides with the same 2:1 aspect ratio. These components are designed for an Over-The-Air (OTA) power-combining setup, which will be expanded to include a Rotman lens module for beam switching. An OTA transmission experiment is carried out with the aforementioned components to examine the performance at a system level.

Design of a Gap Waveguide Based Unit Cell for 1-D Beam Scanning Application at W-Band

Mu Fang (Chalmers University of Technology & Chalmers, Sweden); Jian Yang and Ashraf Uz Zaman (Chalmers University of Technology, Sweden)

In this paper, we present a 1-D scanning slot array unit cell column based on ridge gap waveguide technology which can be a good candidate for wide scanning antenna applications at 100GHz. A parametric analysis of the proposed model is organized to demonstrate the merits and potential performance. Simulated data in terms of H-plane pattern and impedance bandwidth as well as the scanning characteristics has been investigated for the unit cell column of slot array. Also, design concerns regarding manufacturing issues and corresponding mechanical challenges have been taken into account while doing the electromagnetic design. The chosen unit cell which consists of a column of slot array works with 6-16% impedance bandwidth and achieves a scanning up to ± 60° in one dimension.

Dual Mode Monopulse Conical Horn Antenna for 5G Millimeter-Wave Band Applications

Asrin Piroutiniya and Mohamad Hosein Rasekhmanesh (Universidad Autónoma de Madrid, Spain); Jose Luis Masa-Campos (Universidad Autonoma de Madrid, Spain); Jose Luis Jose Luis Calero Rodríguez (Universidad Autónoma de Madrid, Spain); Jorge A Ruiz-Cruz (Universidad Autonoma de Madrid & Escuela Politecnica Superior, Spain)

A dual mode monopulse network at K-band is presented for 5G space applications. This network consists of two mode converters from rectangular to circular waveguide. The first converter excites the 〖TE〗_11^cir mode and the second excites the 〖TE〗_01^cir mode in a circular waveguide, both from the 〖TE〗_10^rec mode of nominal WR-28 rectangular waveguide sections. This mode converter network is then integrated into a conical horn antenna to radiate the sum and difference patterns associated to each excited mode inside its feeding circular waveguide. This integration process is detailed to properly avoid the propagation of other higher order modes as well as mode mutual coupling. The simulated results such as reflection coefficient, pattern and directivity of final structure are presented. The monopulse antenna system provides up to ±11° range per beam in the angular of arrival detection of 5G satellite applications at millimeter-wave band for high data rate operation.

The Design of the Tapered Slot Antenna Array for 5G Photonic-Integrated Base-Stations

Saeed Haydhah, Qingnan Li, Conrad Bizier-Stern and Ahmed A Kishk (Concordia University, Canada); John Zhang (Concordia, Canada)

A new mmWave Tapered Slot Antenna is designed at 38 GHz for the 5G base-station applications. The antenna is designed on the Aluminum Nitrite substrate such that it is photonically integratable. The single-element TSA shows wide bandwidth of operation from 28.5 to 45 GHz, with a peak gain of 12 dBi, and a minimum radiation efficiency of -0.75 dB. The transition Grounded-Coplanar-Waveguide-to-microstrip line, and the transition microstrip-to-slot-line are used, and they show good impedance matching and very low insertion losses. The single-element TSA is extended to 1\times8 linear array which shows a very wide bandwidth of operation, and an increase in the gain by 4.7 dB due to the array factor.

Fabry-Perot Resonant Cavity Antenna with Tunable Superstrate for Beam Steering Millimeter-Wave Applications

Hussein Attia (King Fahd University of Petroleum and Minerals (KFUPM), Saudi Arabia)

This work presents a novel beam-steerable microstrip millimeter-wave antenna. The antenna is constructed using a single-layer

metamaterial superstrate, arranged on top of a wideband patch antenna in the form of a Fabry-Perot resonant cavity (FPRC). The superstrate comprises dual-array of square patches; each array consists of 9X3 square unit cells. The dual-array unit cells are placed on both sides of a parasitic patch printed on the top layer of the superstrate. By varying the electrical length of the unit cells using electronic switches controlled with DC bias, the proposed antenna achieves beam steering at -20◦ and +20◦. Other beam directions can be achieved by changing the switching schemes of the electronic switches. The proposed FPRC based on a single patch antenna exhibits an acceptable peak gain that ranges from 7 to 9.7 dB throughout the whole operating impedance bandwidth from 29 GHz to 35.3 GHz and for different switching schemes.

An Intriguing Relation Between the Power Consumption and Number of Antenna Elements in Multi-Beam Phased Arrays

Natasha Birari and Yanki Aslan (Delft University of Technology, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands)

An improved system-level power consumption model (PCM) for 5G base station multi-beam phased-array transmit architectures is developed. Using this model, it is shown that an optimum number of antenna elements of the array exists with respect to the total power consumption. The proposed model is benchmarked against a recent study which is shown to underestimate the total power consumed in analog and digital antenna systems by 37% and 126% respectively.

Tuesday, March 28 13:30 - 15:00

PA3: Poster Session on Array Design and Technology

/ / Antennas

Rooms: Spadolini 103, Spadolini 104

Chairs: Marta Arias Campo (IMST GmbH, Germany), Jose I Herranz-Herruzo (Universitat Politècnica de València & APL - iTEAM, Spain)

Application of Spread-Spectrum Techniques to a Time-Modulated Metasurface Illuminated by Non-Harmonic Signals

Karim Kouny, Rémi Fragnier and Vincent Laquerbe (CNES, France)

This paper focuses on the behavior of a time modulated cell illuminated with non-harmonic incident waves. Spread-spectrum techniques are applied to optimize its response to realistic signals. Simulations were carried out using CST Microwave Studio for both unit cell and a regular array of 8x8 elements.

Simulations of N-Way, Series Power Dividers

Haim Matzner (HIT-Holon Institute of Technology, Israel)

CST Microwave Studio simulations of N-way, un-equal, symmetric, microstrip series power dividers are proposed. The dividers are constructed from quarter wavelength transmission line sections and 90 degrees quadrature hybrids. For simplicity we have simulate microstrip dividers on air substrate, where the distances between output ports are one wavelength. 1:2, 1:3, 1:4 and 1:5 dividers are presented, where the output amplitudes were optimized to approach binomial distribution at the center frequency of 2 GHz. Moreover, 1:3 divider on FR4 substrate is presented, and an array antenna of 3 microstrip elements fed by this divider was simulated, showing sidelobes reduction as expected. The typical amplitude deviation from the binomial distribution at 2 GHz is less than 0.1 dB, and the phase error between adjacent output ports is 10 degrees approximately.

Phase-Only Beam Broadening for Array Antennas

Lior Maman, Shlomo Zach and Amir Boag (Tel Aviv University, Israel)

Two beam broadening techniques for active electronically scanned array (AESA) antennas using phase-only control are proposed. As a preliminary step, the problem dimensionality is reduced from five to only two variables. The first method is suitable for various applications and involves an efficient optimization of phase tapering. The second technique is more specific for radar AESAs typically transmitting pulse trains used for coherent integration. Here, time dependent phase modulation is employed to effectively produce amplitude tapering resulting in beam broadening.

Phased Array Scattering-Cross-Section Reduction Based on Hybrid Scattering Cancellation Technique

Peng-Fa Li and Shi-Wei Qu (University of Electronic Science and Technology of China, China)

A novel hybrid scattering cancellation approach to reduce scattering cross section (SCS) of phased arrays is proposed in this paper, which not only makes use of cancellations between antenna mode and structural mode scattering fields, but also achieves cancellation of scattering field from different array elements. An 8 x 8 planar microstrip phased array is constructed to validate the concept. By optimizing element loads utilizing particle swarm optimization algorithm, the proposed phased array realizes very impressive SCS reductions of 8.3 dB and 20 dB with respect to its conventional counterpart and the equal-sized metallic plate, respectively, with a balanced radiation performance.

An Ultrawideband Interwoven Spiral Array with Improved Polarization Characteristics

Yunus E Taskir (ASELSAN Inc. & Istanbul Technical University, Turkey); Mustafa Kuloglu (Aselsan Inc., Turkey); Serkan Şimşek (Istanbul Technical University, Turkey)

A compact ultrawideband (UWB) tightly coupled array unit cell with improved circular polarization (CP) is proposed. Previous studies have obtained impedance bandwidth of 10:1 on a ground plane by increasing mutual coupling between array elements by using self-complementary square spiral elements having interweaved arms. However, the axial ratio (AR) of these structures is more than 3-dB in the entire frequency band, thus their use in applications requiring CP is limited. In this study, the interweaved arms of the modified periodic unit cell were resistively loaded. Hence, while achieving both size reduction and improved CP performance, antenna gain is maintained. Simulated AR is less than 3-dB over almost the entire 0.38 - 1.18 GHz frequency band. Simulated voltage standing wave ratio (VSWR) remains below 2.2 in the 0.1 - 1.25 GHz frequency range.

A Dual-Linear Polarization VHF Probe for Spherical Near-Field Measurement Based on a Wideband Superdirective Antenna Array

Rémi Fragnier, Gwenn Le Fur, Vincent Laquerbe and Romain Contreres (CNES, France); Frederic Munoz (CEA LETI & University of Grenoble-Alpes, France); Serge Bories (CEA, France); Jean-François Pintos (CEA-LETI, France)

This paper presents the analysis and design of a dual-linear polarized VHF antenna based on a superdirective parasitic array of three magneto-electric antennas. The proposed antenna has been designed to work as a compact VHF near-field probe in CNES measurement facilities. The optimization process is detailed and a focus is made on maximizing the operating bandwidth. The proposed antenna exhibits superdirective properties over a 9% fractional bandwidth.

A Beamforming Network for 5G/6G Multibeam Antennas Using the PCB Technology

Giulia Buttazzoni and Giovanni Schettino (University of Trieste, Italy); Alessandro Fanti and Elena Marongiu (University of Cagliari, Italy); Nicola Curreli (Italian Institute of Technology, Italy); Fulvio Babich and Massimiliano Comisso (University of Trieste, Italy)

This paper presents the design of a 4x4 Blass matrix for enabling beamforming operations in a four-element uniform linear antenna array (ULAA) operating at 3.5 GHz, corresponding to the first frequency band reserved for the forthcoming fifth and sixth generation (5G/6G) systems. To obtain a simple and inexpensive device, the proposed feeding network, which provides to the ULAA beam pointing capabilities towards four different directions, is entirely implemented using printed circuit board technology. The design procedure is realized adopting an extended iterative mathematical framework accounting for losses control and providing the pointing angles and the matrix coefficients. The performance of the conceived architecture is numerically investigated through full-wave simulations. The versatility, low losses, and low price of the developed microstrip

network makes it suitable for both 5G/6G air/terrestrial femtocell base stations and Internet of Things (IoT) cluster-head sensors/actuators.

CPW-Fed Transparent Antenna Array Using Metal Mesh

Yu Yao and Bingxue Wu (The University of Sheffield, United Kingdom (Great Britain)); Yu Shao (Chongqing University of Posts and Telecommunications, China); Jiliang Zhang (Northeastern University, China); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

Increasing the deployment density of the indoor base stations is a way to deal with the problem of low transmission efficiency of high-frequency communication indoors in the future. To reduce the space occupation and virtual influence of the indoor base station, a coplanar waveguide (CPW)-fed transparent antenna array (TAA) is proposed. The TAA is comprised of 4 CPW-fed antenna units and a standard glass substrate. The gain is improved by array structure to 7.6 dBi. The transparency of the antenna achieves 80%. It achieves more than 90% efficiency. The TAA operates at the bands of 2.12-2.5 GHz.

Wideband Phased Array System at K-Band for Satellite Down-Link Applications

Bo Shi and N Nasimuddin (Institute for Infocomm Research, Singapore); Francois Chin (Institue for InfoComm Research, Singapore); Xianming Qing (Institute for Infocomm Research, Singapore)

This paper presents a wideband electronically steerable circularly polarized receive phased array antenna system at K-band (17.7 GHz to 20.2 GHz) for satellite downlink applications. A scalable 64-element antenna array module in a multi-layered PCB is designed using a dual-polarized proximity-fed square-ring patch radiator with stacked circular-ring patch as the antenna element. For circular polarization (CP) radiation, the two feeds are excited orthogonally in 90° out of phase. To enhance CP performance, each 2 × 2 antenna subarray is excited in a sequentially rotated manner with one Rx beamforming chip. The 64-element array module with aperture size of 60mm × 60mm demonstrates a measured 12.5° half-power beam width, around 22 dBic antenna gain and less than 2.5 dB axial ratio across the frequency band. The beam can be steered to ±60° in all planes without grating lobes. Furthermore, to demonstrate the scalability, a 256-element phased array is prototyped and measured.

Performance Evaluation of Implementing LCVM Beamformer for Cylindrical Antenna Array in Smart Array Antenna Applications

Somayeh Komeylian (Ryerson University, Canada); Christopher Paolini (San Diego State University, USA)

Array signal processing provides a capability for steering the mainbeam toward the direction of desired signals as well as for directing ideal nulls toward interference signals. Indeed, array signal processing techniques significantly enhance the accuracy and resolution of received signals by overcoming multipath fading and maximizing the SIR. This work has a major contribution to implementing the LCMV beamforming technique for the cylindrical antenna array for achieving high resolution and accuracy of received signals. The implementation of the LCMV beamforming technique for the cylindrical antenna array yields an excellent efficiency of about 90%, as well as a high value of SIR of 2.25 (dB). The cylindrical antenna array has been implemented for the passive WiFi Radar with the IEEE 802.11x frames. In this scenario, the time domain evaluation of the cylindrical antenna array has verified that the maximum amplitude of voltage increases to 800 (volt) in the IEEE 802.11x frames.

Integrated Antenna Module for 5G Applications

Zunnurain Ahmad (Infineon Technologies AG, Germany); Khai Yuan Chang (Infineon, Germany); Heinrich Heiss and Hans-Dieter Wohlmuth (Infineon Technologies AG, Germany)

This work presents an antenna integrated module operating in the 28 GHz frequency band. The module comprises of a 2x2 antenna array integrated with a beamforming transceiver chip operating in the 24 - 30 GHz range. The beamformer transceiver chip has in total eight transceiver channels and it excites four vertical and four horizontal polarizations in the dual polarized patch antennas array. A maximum EIRP of 35 dBm is achieved with this module in each polarization. The module can be cascaded to form a larger array for base station applications.

Analysis of Non-Canonical Body-Conformal Arrays with Polarization Decomposition

Icaro V Soares (Institut d'Électronique et des Technologies du Numérique & Université de Rennes 1, France); Pratik V Vadher (IETR, CNRS & University of Rennes 1, France); Anja K. Skrivervik (EPFL, Switzerland); Giulia Sacco (IETR - CNRS, France); Denys Nikolayev (Institut d'Électronique et des Technologies du Numérique (IETR) - UMR CNRS 6164, France)

Conformal phased arrays can be found in many applications due to their ability to fit tridimensional surfaces and, thanks to their scanning performance, can excel planar arrays. However, most of the previously proposed analysis methods can be applied only to canonical cases and do not consider the effects of polarization. Therefore, this paper presents a closed-form formulation for analyzing antenna arrays conformal to arbitrary surfaces, evaluating the effects of the polarization components on the overall radiation performance. Besides, an on-body array conformal to the human torso surface is analyzed as a case study, and its beam scanning performance is evaluated with the developed in-house code. Finally, an amplitude tapering methodology is proposed to switch off shadowed elements and redistribute the power to the operational ones. After applying this tapering strategy, the results show that the maximum directivity is maintained, and a significant reduction in the side lobe levels is achieved.

Common-Mode Loss Mitigation of a Differentially Fed Eight-Port On-Antenna Power Combining Patch Implemented in a Scanning Phased Array

Timothee Le Gall (University of Bordeaux, France); Anthony Ghiotto (Bordeaux INP, France); Stefan Varault, Gwenael Morvan and Bruno Louis (THALES Defence Mission Systems, France); Gregoire Pillet (Thales Research and Technology, France)

On-antenna power combining is an emerging topic of high interest, especially for active electronically scanned arrays (AESA), where high power amplifiers (HPA) are directly connected to a multiport antenna. Compared to other on-circuit power combining technics, improved efficiency, higher radiated power, smaller associated monolithic microwave integrated circuits (MMIC) and enhanced heat dissipation are achieved. This technic can be used in addition to spatial power combination within an array, to further improve the radiated power. However, several of these multiport antennas result in a common-mode parasitic effect, only occurring when the beam is steered, which reduces the radiated power. This paper exposes this phenomenon through infinite array simulations and explains its origin. Several ways to avoid this problem are finally proposed.

A Filtering Dipole Antenna Design with Bandwidth Enhancement for 5G

Feza Turgay Çelik (Delft University of Technology, The Netherlands); Sulayman Joof and Kamil Karacuha (Istanbul Technical University, Turkey)

The present study proposes a dipole filtering antenna with wide-band characteristics for communication. The filtering is achieved by employing parasitic elements and wide- band characteristic is obtained by reshaping the dipole and using specially designed balun. One radiation null is optimized at the higher band limit for sharp transition from pass band to stop band via two half-rectangular ring resonators. Furthermore, the antenna is operating between 2.6 and 5 GHz bandwidth and maximum realized gain of 8.39 dBi. The |S11| is less than -10 dB in the required band. The simulation results and evolution of the design procedure are presented.

On Site Calibration of AESA Using Two Probes

Matteo Ciattaglia (Leonardo)

The first calibration of active phased arrays is usually performed in factory using Near Field facilities. In most cases, the calibration can be repeated on site using built in calibration networks, reference measurements performed during the factory tests or expensive equipment. This paper explores a calibration technique that does not need factory reference measurements and that is based on on-site measurements from two external probes.

Synthesis of Isophoric Sparse Arrays with Good Directivity and Low Number of Radiators

Daniele Pinchera and Marco Donald Migliore (University of Cassino, Italy)

In this paper, we discuss a synthesis method for generating equal-amplitude (isophoric) sparse arrays with good directivity and a low number of radiators. The approach is based on three phases: in the first, a layout with a low number of radiators is generated (the excitations of this array will not be identical); in the second, the geometry is modified in order to obtain an isophoric layout; in the third, the array is refined to improve the directivity. Each one of the steps is realized by employing convex programming techniques, thus being very efficient from a numerical point of view.

Sparse Hemispherical Arrays with Hierarchical Low Discrepancy Sequence Sampling

Payam Nayeri (California Polytechnic State University, USA); Randy Haupt (Haupt Associates, USA)

Sparse spherical arrays have grating lobes due to large element spacings. Aperiodic spacing can reduce the grating lobes, however random approaches typically increase the average sidelobe level. This paper explores the use of a deterministic hierarchical random-like distribution based on the low-discrepancy Van der Corput sequence. Array pattern results are presented for hemispherical arrays with element spacings larger than one wavelength and we show that this approach removes the grating lobes while allowing one to add or remove elements without needing to recalculate positions.

Design of Unequally Spaced Antenna Arrays with Minimum Sidelobe Power via Quasi-Newton Method

Katarina Vodvarka (University of Zagreb, Croatia); Maja Jurisic Bellotti and Mladen Vucic (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia)

In this work, design of unequally spaced antenna arrays with uniform excitation is considered. The design is based on numerical optimization of array's sidelobe power. The corresponding optimization problem is nonconvex and highly nonlinear. Therefore, we consider the Quasi-Newton method for its solving. Such an approach allows the application of versatile objective functions. This is illustrated in the design of linear and planar arrays. Resulting beam patterns exhibit high beam efficiency and low sidelobe level.

DOA Estimation for Cylindrical Antenna Arrays Using Cramer-Rao Lower Bound Analysis

Jiahao Wang, Peizhuo Yang and Koen Mouthaan (National University of Singapore, Singapore)

The estimation of the directional of arrival (DOA) for receiving cylindrical antenna arrays is presented. The analysis uses the Cramer-Rao lower bound (CRLB), which provides the best unbiased estimation for minimizing the residual noise. First, the CRLB for conformal surfaces is derived. Then the method is applied to case studies to gauge the difference in the performance of the cylindrical array compared to a flat array. The presented approach will help designers of cylindrical conformal arrays to optimize the antenna performance.

A Dual-Circularly Polarized Gap Waveguide-Based Linear Array Antenna for 60 GHz-Band

Davood Zarifi (University of Kashan, Iran); Ali Farahbakhsh (Graduate University of Advanced Technology, Iran); Ashraf Uz Zaman (Chalmers University of Technology, Sweden)

This paper deals with the design of a dual-circularly polarized (CP) linear array antenna based on gap waveguide for 60 GHz band. The radiating array is based on dual-slot fed cavities with septum polarizers to achieve both left hand circular polarization (LHCP) and the right hand circular polarization (RHCP) radiations. The simulated input reflection coefficient and gain of the proposed linear array antenna are below -10 dB and higher than 18.1 dB from 58 to 62 GHz, respectively. Also, the AR is less than 3 dB over the operating bandwidth.

Estimation of Active Standing Wave Ratio in Finite Size Phased Array - Example for a Ka-Band SatCom Application

Marc Thevenot (XLIM-University of Limoges, France); Cyrille Menudier (XLIM Université de Limoges, France); Benoît Lesur and Anael Lohou (Safran Data Systems, France); Julien Lintignat (XLIM UMR 7252 Université de Limoges/CNRS, France); Bruno Barelaud (Université de Limoges, CNRS, XLIM, France); Christophe Melle and Alain Karas (Safran Data Systems, France)

Phased array for Satcom applications are based on high-level specifications. By using a Active Electronically Scanned Array (AESA), it is mandatory to predict and analyze the energy consumption while the radiating elements are directly connected to the amplifier stage of the beamformer integrated circuits. This work details a design in Ka-band for such an application with a wide-angle beamsteering (θ0=70°). An analysis of the active reflection coefficients in a 256-elements finite size array is proposed without the need for a full-wave simulation.

Fast Radiation Pattern Synthesis and Optimization of Monopole Circular Antenna Array

Samuel Travnicek, Jan Kracek and Pavel Hazdra (Czech Technical University in Prague, Czech Republic)

The synthesis and optimization of the radiation pattern of a monopole circular antenna array are described. The method is fast and effective since it employs impedance and radiation pattern matrices, which relate elements of the array, precalculated in a full-wave electromagnetic simulator. A simple excitation by only the central element is used, and the other elements are reactively loaded. The desired radiation pattern of the array is obtained by optimization of the reactive loads. A particular example is given for a circular array of 25 monopole elements.

Bidirectional Monopole Antenna Array with Minimized Ground Plane for WLAN Applications

A. Baris Gok, Francesca Benassi and Diego Masotti (University of Bologna, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy)

This paper proposes a new design of printed monopole antenna array with minimized ground plane for WLAN applications. To decrease the ground plane dependence of monopole antenna, different and smaller configuration of ground planes have been constructed. Simulations of the 2-by-2 monopole antenna array with optimized size of ground plane show that antenna performance is improved bidirectionally with miniaturization of ground structure and this has been verified by the measurements. The results show that the unique shape of ground structure provides an increase of the antenna gain by 1.75 dB and a decrease of side lobe level by 5.30 dB.

Spectral Floquet-Spatial Modulations Devoted to Strongly Coupled Periodic Arrays: Metasurfaces, Dense Massive MIMO, Reconfigurable-Intelligent-Surfaces (RIS), 5G and 6G Uses

Bilel Hamdi (UClouvain, Belgium); Taoufik Aguili (ENIT, Tunisia)

In this paper, we propose a spectral modulation technique with its spatial equivalent to studying the coupled largely finite and infinite periodic arrays, useful for 5G and 6G applications (e.g., reconfigurable smart surfaces for 6G systems). Various forms of spectral and spatial modulations are presented. The sum of these modulations based on their large spatial periods allows the estimation of the total large array response (and to control their beam orientation in any desired direction) in the presence of a large number of elements (e.g., dense massive MIMO). The decomposition into sub-arrays where each of them has its own modulation character is demonstrated based on the Floquet analysis (steering the beam of each modulation zone independently of the other neighboring zones is possible in the same panel structure). Various numerical methods use these modulation properties in their kernels, including the MoM-GEC

Tuesday, March 28 13:30 - 15:00

PE1: Poster Session on Electromagnetics I

/ / Electromagnetics

Rooms: Spadolini 105, Spadolini 106

Chairs: Jan Kracek (Czech Technical University in Prague, Czech Republic), Agostino Monorchio (University of Pisa & CNIT, Italy)

Field and Array Factor of a VLF Dipole Antenna Array Located in an Anisotropic Ionosphere

Huiran Zeng (Xidian University, China); Qiaobo Xiong (Wuhan Ship Communication Research Institute, China); Tong He (Zhejiang Laboratory, China); Li Kai (Zhejiang University, China)

With the increasing importance of contemporary very low frequency (VLF: 3-30 kHz) space-borne propagation systems in applications such as underwater communications and navigation, it is important to study the radiation field of a space-borne VLF dipole antenna array in an anisotropic ionosphere. In this paper, the radiation field of a VLF dipole antenna array in an anisotropic ionosphere is investigated. The effect of ionospheric parameters on the radiation field of a VLF dipole antenna as well as the variation law of the electric field of a VLF dipole antenna array with different propagation angles are explored. The effect of the number of array elements and spacing on the field distribution of an array is analyzed. The results show that the multiple-element antenna array, the overall field strength increases when the spacing of the space-borne VLF dipole antenna array is short. If the spacing increases, the phenomenon of interference will occur.

Reconfigurable Intelligent Surfaces Aided Wireless Communications with Electromagnetic Interference

Saber Hassouna (University of Glasgow, United Kingdom (Great Britain)); Muhammad Ali Jamshed (James Watt School of Engineering University of Glasgow Glasgow G12 8QQ UK, United Kingdom (Great Britain)); Masood Ur-Rehman, Muhammad Ali Imran and Qammer H Abbasi (University of Glasgow, United Kingdom (Great Britain))

Controlling the electromagnetic signals' features of scattering, reflection, and refraction is possible using reconfigurable intelligent surfaces (RIS). In this study, we examined the data rate performance utilizing a codebook technique to produce a set of pre-designed phase shift configurations for the RIS elements. This arrangement has previously been investigated without taking into account electromagnetic interference (EMI), which consists of the inescapable incoming waves from outside sources. We analyzed the system model considering the EMI for single-user SISO wideband communication system. We developed the power method to get a high-quality optimized configuration for the RIS besides using the old water pouring algorithm to fairly allocate the power for all orthogonal frequency division multiplexing (OFDM) subcarriers. Communication performance is significantly impacted by electromagnetic interference, particularly as the RIS becomes bigger.

Low-Loss All-Metallic Gap Waveguide-Based Bandpass FSS for Broadside mmWave Applications

Wai Yan Yong (University of Twente, The Netherlands); Abolfazl Haddadi (Gapwaves AB, Gothenburg, Sweden); Andrés Alayón Glazunov (University of Twente, The Netherlands)

This paper presents a bandpass frequency selective surface (FSS) radome based on an all-metallic gap-waveguide (GW) operating at broadside for the mmWave band. The proposed GW-based FSS uses conventional cross-dipole slots and a dual-GW cavity over three distinct metallic layers. The top and bottom layers consist of cross-dipole slots, whereas the middle layer consists of a dual-GW cavity and cross-dipole slots. The proposed GW-based FSS provides a stable broad bandpass, from 26 - 30GHz, in the broadside direction for both transverse electric (TE) and transverse magnetic (TM) polarisations. A prototype of the designed 20 x 20 GW-based FSS finite array was manufactured and measured with an insertion loss of 0.6 dB. A good agreement between simulations and measurements is shown at broadside directions. The proposed GW-based FSS offers an excellent low-insertion-loss and cost-effective solution to fully metallic bandpass FSS radomes.

A Dual-Band Line-To-Circular Broadband Reflective Polarization Converter Based on Metasurface

Wenjuan Shu, Enyang Wang and Jian-ying Li (Northwestern Polytechnical University, China)

In this paper, a single-layer dual-band linear-to-circular reflector is presented. The converter is composed of a U-shaped metal sheet with the middle part wider than the sides for dual-band operation. The unit enables a stable response of 60° to oblique incidence angles in both frequency bands. Under normal incidence, the converter effectively converts x/y linearly polarized (LP) waves to orthogonal circularly polarized (CP) waves at 13.86-21.51 GHz (43.3%) and 27.56-35.98 GHz (26.5%). The proposed metasurface has the advantages of simple planar structure, broadband and high angular stability, making it suitable for satellite communication and polarization conversion devices.

Analysis of the Interlayer Coupling Impact on the Impedance and Transmission of a 3-Layer Unit Cell

Embedded on a Radome

Pablo Camacho and Mohammad S. Sharawi (Polytechnique Montreal, Canada)

On designing multilayer metamaterials, the interlayer coupling is initially neglected. This happens because there isn't a general methodology to analyze it. This work describes a procedure to study the coupling impact on an active 3-layer unit cell's performance. It shows that by relating the unit cell's simulation and its theoretical ABCD parameters, one can find the actual layers impedance. We compare those values with the ones of a method that neglects the coupling. In the researched unit cell, the comparison shows that the coupling decreases the top/bottom layer's impedance up to j270 [Ohms] while it makes the middle layer's impedance a function of the other ones. Additionally, this reduces the unit cell's achievable transmission region from 360 degrees to 300 degrees. This analysis allows having an accurate characterization of the unit cell impedance and transmission.

Effect of Frequency and Load on Efficiency of Inductive Wireless Power Transfer Systems

Arianna Ginette Amaya Colina (nok9 AB, Sweden); Buon Kiong Lau (Lund University, Sweden); Laurens Swaans (nok9 AB, Sweden); Mats Forsman (Saab Aeronautics, Sweden)

Wireless charging of smartphones using inductive wireless power transfer (IWPT) has become very popular. However, the efficiency of IWPT systems can decrease substantially when the transmitting and receiving coils are not closely coupled. One popular approach to mitigate the efficiency degradation is to utilize higher frequency. However, the higher efficiency is only achieved at a specific range of load resistance, which may not be feasible in real applications. In this work, we analyze the effect of frequency and load variations on the power transfer efficiency of a typical two-coil IWPT setup, based on a numerical model. The results show that lower frequency systems are favored for low load resistances, and vice versa for high load resistances. For example, when the coils' inductance is 20uH and the load resistance is below 3.4 ohms, then operation at lower frequencies is recommended even when the coupling factor is as low as 0.1.

Efficient Application of Electromagnetic Technique with Dielectric and Magnetic Materials for the Development of Broadband Microwave Absorber

Anshika Verma (Indian Institute of Technology, Roorkee, India); Naina Narang (GITAM University, India); Dharmendra Singh (IIT Roorkee, India); Ghanshyam Das Varma (Indian Institute of Technology Roorkee, India)

Nowadays, with the advancements in technology, electromagnetic (EM) radiation emanating from electronic and wireless devices is becoming a major concern. In this regard, the demand of an efficient absorber is increasing. Currently, the reported absorbers have narrow bandwidth and large thickness. However, obtaining the broadband response with the compactness of the structure is still a challenging task. Therefore, this paper has attempted to solve the problem of development of broadband microwave absorber by developing dielectric and magnetic materials with the application of electromagnetic (EM) technique. The proposed design involves simple hydrothermal and ball milling methods for the preparation of materials. Further, multilayering technique was also used to obtain the broadband response with the advantage of having less thickness. The result provides 98.83% of fractional bandwidth of the double-layer absorber which is quite acceptable at 2.2 mm thickness. This compact absorber with optimized dimensions can be potentially utilized for stealth applications.

Nonlinear FDTD Simulation of Optical Thin Films with Intensity-Dependent Drude-Lorentz Parameters

Joao Guilherme Nizer Rahmeier, Tom Smy and Shulabh Gupta (Carleton University, Canada)

Nonlinear optical materials drawn a lot of attention when integrated into metasurfaces for full-optical control of the surface response. Although several methods for modeling this materials are proposed in the literature, most of them have limitations on being non-dispersive and of instantaneous response. In this paper, we present the integration of an extended Drude-Lorentz model that captures the local intensity response of nonlinear materials while being dispersive and allowing for inertial response via a low-pass filtering process. This method is integrated into standard FDTD method and the ADE for the Drude-Lorentz model is extended via local intensity-dependent parameters. A numerical demonstration shows the response for a thin film of nonlinear material, where the parameters across the sample are time-varying with respect to the local intensity. Therefore, showing direct feedback of the field profile to the nonlinear response of the material, which is critical when incorporating such films in resonating structures.

Metasurface with Unequal Spacing Unit-Cells Based Antenna for Linear and Circular Polarizations

N Nasimuddin and Michael Chia (Institute for Infocomm Research, Singapore)

A metasurface based on unequal spacing between the rectangular-ring unit cells is proposed for a broadband, low profile, circularly polarized (CP), and linearly polarized (LP) antenna design. This can be used for 5G New Radio and GNSS applications in navigation and telemetry on drone which uses remote sensing radar/lidar for aerial survey mapping. The antenna structure comprises of a stacked-metasurface based on unequal-spacing between the 7×7-unit cells, a radiating rectangular-patch, and a near diagonal line probe feed. A metasurface is considered using rectangular-loop 7×7-unit cells array with unequal-spacing's in x- and y-directions and it is placed above a rectangular-radiator to realize a wide CP bandwidth for GNSS applications. Our antenna reaches a 3dB axial ratio of 25.3% (1.38 GHz - 1.78 GHz) with CP (3-dB axial ratio) bandwidth of 15.8% (1.51 GHz - 1.77 GHz) and gain of greater than 8.5 dBic.

A Novel High-Order Spectral Element Method for the Analysis of Cylindrical Waveguides Filled with Complex Anisotropic Media

Raul Oliveira Ribeiro (Pontifical Catholic University of Rio de Janeiro, Brazil); Jose R Bergmann (PUC-Rio, Brazil); Fernando Teixeira (The Ohio State University, USA); Guilherme Simon Rosa (Pontifical Catholic University of Rio de Janeiro, Brazil)

We present an improved formulation of the spectral element method in cylindrical coordinates for analyzing electromagnetic fields in waveguides filled with complex (non-reciprocal and non-Hermitian) anisotropic media. Our method obtains accurate results with a small number of elements and degrees of freedom (DoFs) when compared with ordinary finite-element approaches. For this, we use high-order expansion functions in which the internal nodes of each element are defined by the zeros of the completed Lobatto polynomial. The convergence analysis demonstrates the absence of the Runge effect as the expansion order increases. Numerical results show that our technique is efficient and accurate for modeling cylindrical waveguided geometries filled with complex media.

A 2-Bit Programmable Dual Linearly-Polarized Metasurface Structure Element

Lihao Zhu (Xidian University, China); Jiaqi Han (China); Guanxuan Li, Xiangjin Ma, Dexiao Xia and Long Li (Xidian University, China)

This paper proposes a novel shared-aperture dual linearly-polarized 2-bit programmable metasurface structure element. Two orthogonally placed dipoles, each equipped with two pin diodes and parasitic patches, are used to realize the 2-bit phase shift in the respective polarization direction. A cross-over structure is introduced into the element to ensure high cross-polarization discrimination (XPD). The reflection coefficients and XPD under the +45° polarized incidence are analyzed. The maximum insertion loss is 2.4 dB and the XPD of the element in the four states is all above 54 dB. The electromagnetic response validates that the element is an excellent candidate for dual-linearly polarized metasurface with high efficiency and little crosstalk.

Performance Analysis of Mm-Wave Wearable Antennas for Visually Impaired Aid

Alicia Flórez Berdasco (University of Oviedo, Spain); Jaime Laviada and María Elena de Cos Gómez (Universidad de Oviedo, Spain); Fernando Las-Heras (University of Oviedo, Spain)

The evaluation of the performance of several wearable antennas for helping visually impaired people by means of radar technology, is presented. The antennas have been designed ad hoc for this application in the 24.05 to 24.25 GHz unlicensed frequency band. Based on Synthetic Aperture Radar (SAR) techniques, a simulation for each antenna has been performed in short distance to obtain an electromagnetic image of the target. In order to assess the quality of the electromagnetic images, an error metric has been applied, so that the behavior of the antennas is analyzed and compared for this application.

Dual-Polarized SIW Slot Antenna Using ENZ Metamaterial for 5G and mmWave Applications

Amir Jafargholi (University College London, United Kingdom (Great Britain)); Romain Fleury (EPFL, Switzerland)

This paper presents a broadband dual-polarized substrate integrated waveguide (SIW) slot antenna. It is analytically shown that

by decreasing the permittivity of a dielectric-loaded slot antenna, the resulting bandwidth increases significantly, where the widest bandwidth can be achieved when the permittivity of the dielectric approaches near zero. To demonstrate this idea, a rectangular SIW slot is loaded by arrays of thin wires to realize epsilon-near-zero (ENZ) metamaterials (MTM), which consequently resulted in a simple, single-layer, compact and cost-effective structure. The measured impedance bandwidth (|S11|<-10 dB) of 13.6%, covering the millimetre wave (mmWave) frequency range of 22.6 GHz to 25.9 GHz is achieved. The radiation efficiency is higher than 80%, providing at least 9.5 dBi gain through the entire frequency band.

Simultaneous Reflectionless Transient Excitation of Modes Using Virtual Critical Coupling for a Single-Channel Resonant Microwave Cavity

Théo Delage (Laboratoire LAPLACE, Université Fédérale de Toulouse, France); Valentin Mazières (ISAE SUPAERO, France); Olivier Pascal (Université de Toulouse - UPS INPT CNRS, France); Jerome Sokoloff (Université de Toulouse, UPS, INP & CNRS, France)

In this paper, we propose to extend the application of our time domain method for the extraction of S-matrix zeros from a single-channel cavity. The first step consists in measuring the S-parameters of a multimodal cavity in order to extract the complex frequencies of several modes to be excited under virtual critical coupling. Then, overcoupled resonances are identified from this measurement in order to apply the method on relatively isolated resonances (weak modal overlapping regime). We show the simultaneous excitation of several modes under virtual critical coupling.

An Active Frequency Selective Surface with a PIN Diode Switching Mechanism

Chao Gu and Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain)); Dmitry E Zelenchuk (Queen's University of Belfast, United Kingdom (Great Britain)); Simon Cotton (Queen's University, Belfast, United Kingdom (Great Britain)); Raymond Dickie (Queens University Belfast, United Kingdom (Great Britain))

This paper presents an active frequency selective surface design based on slot arrays. A novel biasing technique is described for switching the PIN diode on and off. The bandpass response can be switched between transmitting and reflecting modes. The biasing layer is printed on one layer, whereas the slot is printed in halves on both layers, separated by a substrate. The DC bias lines allow independent control of each row of the active frequency selective surface (AFSS). The resultant AFSS has low insertion loss of 0.45 dB at 2.5 GHz and high reflectivity when the PIN diodes are switched off and on, respectively.

High Resolution Near-Field SAR Imaging with Non-Uniform Measuring Interval and Low-Sampling Recovery Method

Hien The Pham and Ic Pyo Hong (Kongju National University, Korea (South))

In this paper, we study the method to enhance the azimuth resolution for near-field synthetic aperture radar (SAR) imaging using a low cost frequency modulated continuous wave (FMCW) radar to form the 2-D shape of the object located at a near-field distance. In terms of SAR image reconstruction, While the range resolution is dependent on the bandwidth, the azimuth resolution is determined by the aperture length. In this paper, to improve the azimuth resolution while maintaining the image quality, we measure the target on a wider aperture length at a non-uniform spacing of measurement points. Additionally, to avoid the ghost area on the image result caused by the sidelobe effect, a low-sampling approximation method is studied. A simulation was conducted to verify the efficiency of the proposed method.

Improved Dichroic FSS for Broadband and Large Incidence Angle Applications with Isolated Grating Lobes

Roberto Garrote, Miguel Salas-Natera and Ramón Martínez (Universidad Politécnica de Madrid, Spain)

This paper presents an improved model of dichroic surface, triple band operation, dual reflection, and single transmission. The reflection of the K-Band is obtained using a novel miniaturized element. Ka-Band is achieved with a resonant ring, these two elements have equal admittance in X-Band, so applying transmission line theory, separating both layers lambda by 4 we obtain the passband at 8GHz. With the novel element we can reduce the unit cell size of by at least 14% for a square lattice and 24% if

a triangular lattice is employed, further analysis is done comparing with canonical elements.

Reconfigurable Intelligent Surface Design Using PIN Diodes via Rotation Technique - Proof of Concept

Samara Gharbieh (CEA-Leti Minatec, Grenoble, France); Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France); Antonio Clemente (CEA-Leti, France)

In this paper, we present the design of a reconfigurable intelligent surface (RIS) operating in the Ka-band and in reflection mode; thus, it is a reflectarray antenna. The reflectarray unit cell has a relatively simple structure with four metal layers. In order to achieve the electronic phase control of the unit cell, two p-i-n diodes were integrated. The alternation of the diodes states will create a rotation in the current distribution on the top of the reflecting patch, and thus a 1-bit phase shift resolution is obtained. The unit cell performances present 1.5 dB losses over the studied band. The designed unit cell is then used in the synthesis of reflectarray antennas. For this purpose, an in-house synthesis tool is developed to optimize the reflectarray analytically. Furthermore, a reflectarray is designed and its theoretical results are compared to a full-wave simulation.

High-Order Free-Spurious 2.5D Finite Element Approximations of Electromagnetic Problems

José Gil (Universidad Politécnica de Madrid, Spain); Alfonso Gómez García (Universidad de Extremadura, Spain); Miguel A. González de Aza (Universidad Politecnica de Madrid, Spain); Rafael Gómez Alcalá (University of Extremadura, Spain); Jesus Garcia (Universidad Politecnica de Madrid, Spain); Jesús Rubio (University of Extremadura, Spain)

Axisymmetric antennas constitute an interesting group of devices which provides good performance and symmetric radiation pattern. Examples are conical horn antennas, focused with convex lenses and/or charged with dielectric materials. In the formulation of the problem, we must introduce the behavior of the azimuthal component, projecting the physical problem onto a bi-dimensional one, making possible a very fast parametric study and optimization of the antenna. It is surprising that most of commercial codes do not include this kind of tool. This is an old issue but the great interest of such technique recommends a review of the formulation adding higher-order approximations and a strategy to avoid the apparition of spurious modes when the order of the basis functions augments. To show the usefulness of this approach, a conical diel-core horn has been optimized by adding a double-convex lens.

Tuesday, March 28 13:30 - 15:00

PM1: Poster Session on Measurements

/ / Measurements

Rooms: Spadolini 107, Spadolini 108

Chairs: Dirk Heberling (RWTH Aachen University, Germany), Laurent Le Coq (University of Rennes 1 & IETR, France)

Non Destructive Technique to Characterize the Permeability of Material in the Microwave Range: Evaluation and Analysis of the Measurement Uncertainties

Thibault Charlet (CEA CESTA, France); Muriel Sesques, Guillaume Cartesi and Genevieve Maze-Merceur (CEA, France)

We present in this paper the characterization of a magneto-dielectric layer and the associated uncertainties. A non-destructive and non-contact technique has been developed to determine the microwave characteristics of a layer of material covering an object. The method is based on a reflection measurement and assumes that one of the radioelectric characteristics is known. The measured signal, reflected at the surface of an object, is compared to a numerical calculation taking as input variable the desired microwave characteristic, and then this one is determined by solving an inverse problem. To obtain the desired characteristic with

a good accuracy, the uncertainties of the numerical calculation and the measurement must be low. The first step is the evaluation of the uncertainties, then their calculation, and finally their analysis, possibly their reduction.

Microwave Profiling Inside Wood Beams Using Computed SAR Images

Mohamed Adel Ezzat Elqunawy Radwan, Yana Salchak, Noor Albadri, Hugo G Espinosa and David V Thiel (Griffith University, Australia)

Microwaves are used to non-destructively assess the uniformity of structural wood beams. The near-field radiation penetration from a surface-mounted cavity-backed slot antenna depends on the conductivity and permittivity of the wood, but it cannot be predicted from the antenna impedance alone. The Specific absorption rate (SAR) is typically used to estimate the power absorbed by living tissues and can be determined by numerical modelling. In this paper, SAR analysis was used to image microwave radiation inside isotropic wood beams with a square cross-section with a density ranging from 60 to 1000 kg/m3. The wood beams were imaged with and without defects.

K-Band Microwave Breast Imaging: Two-Dimensional Scanning of Tissue Phantoms

Jochen Moll (Goethe University Frankfurt am Main, Germany); Duy Hai Nguyen (Ericsson Antenna System Germany GmbH, Germany); Jonathan Stindl and Teresa Slanina (Goethe University Frankfurt, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany)

This paper aims at K-band microwave breast cancer detection in the frequency range from 15 to 25 GHz. An experimental case study has been performed with newly developed elliptical monopole antennas that were connected to a two port vector network analyzer. Measurements have been recorded on a tissue mimicking phantom using two-dimensional scanning. It was demonstrated here that malignant inclusions hosted in a matrix of fatty tissue can be accurately detected by the analysis of transmission measurements.

Dielectric Material Characterization of Traffic Objects in Automotive Radar Applications

Sevda Abadpour, Mario Pauli and Marius Kretschmann (Karlsruhe Institute of Technology, Germany); Philip Aust (Mercedes-Benz, Germany); Hasan Iqbal (Continental, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)

A safe and comprehensive experimental verification of automotive radars is a significant challenge in the development process of autonomous driving technology. This challenge is an inevitable part of testing, whether in simulation or conventional real-road testing. In order to rely on software-in-the-loop (SIL) modeling and simulation, the test environment have to be modeled as realistic as the real test environment. One step in more realistic test environment modeling is characterizing the electromagnetic properties of the environmental materials in automotive radar frequency bands. Therefore, studying the radar reflectivity and scattering of traffic objects is one of the critical tasks for more realistic test environment modeling. This paper demonstrates a free-space measurement setup for dielectric material characterization based on the measured scattering parameters. In this procedure, deterministic tests are conducted to investigate the scattering parameters of the different traffic materials and calculate the effective dielectric constant using Muller's algorithm and their angle-dependent

Effect of Magnitude and Phase of Millimeter-Wave Images on Classification Accuracy

Rahul Sharma and Rupesh Kumar (Queen's University Belfast, United Kingdom (Great Britain)); Bhabesh Deka (Tezpur University, India); Vincent Fusco and Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

Millimetre-wave (mmW) reconstructed images are of complex-valued in nature, suggesting that they contain both magnitude and phase. It is known that from the phase aspect of the reconstructed images, meaningful feature information can be extracted about the imaged objects, which in turn, is beneficial to solve computer vision problems such as classification. To this end, a comparative study is shown in this paper wherein two Convolutional Neural Network (CNN) models are considered: one trained with magnitude aspect of mmW reconstructed images, and the other is trained with both the magnitude and the phase aspects of mmW reconstructed images. After training, when these two models are tested, a higher classification accuracy is obtained in the performance of the classification model trained with both the magnitude and phase information of mmW images, as compared to

the other model.

Conductive Adhesives at Microwave Frequencies: Silver-Filled vs. Graphite-Filled

Davor Bonefačić (University of Zagreb, Croatia)

Performance and applicability of silver-filled and graphite-filled conductive adhesives in the frequency band from 1 to 6 GHz is experimentally examined. To test the possibility of repairing damaged transmission lines and circuits, and replacing missing ones by means of conductive adhesive, a section of microstrip line and a rectangular patch antenna were painted by using both adhesives under test. The sliver filled adhesive performed well while the graphite-filled adhesive did not give good results in this test. Further test showed that graphite-filled adhesive can be used only for gluing conductive parts, not for replacing missing portions of the conductor.

Emulation of Realistic Satellite Constellations for GNSS Receiver Testing in Virtual Environment

Syed Naser Hasnain (Technische Universität Ilmenau, Germany); Aidar Khakimov (Technische Universitaet Ilmenau, Germany); Uwe Stehr (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

Automotive navigation is key for modern traffic, which necessitates robust satellite navigation receivers. Distributed antenna arrays can be advantageous with their beam- and null-steering capabilities, however, testing them in the field is resource-intensive and non-repeatable. Therefore, evaluating them in virtual electromagnetic environments is reasonable prior to scheduling field-operational tests. Thereby the challenge arises that the angles-of-arrival of satellite signals deviate from those of their corresponding antennas due to the fixed orbital rotation of satellites and mechanical limitations of physical antenna placements. This discrepancy creates an unrealistic satellite constellation, eventually affecting directions-of-arrival estimation of incident signals which is crucial for interferer suppression. A Matlab tool was implemented to locate satellites near desired transmitter positions and numerically alter their orbital parameters to minimize their angular deviation from respective transmitters. Employing the tool, a realistic virtual satellite constellation with less than 1 degree deviation was emulated and experimentally verified for the test facility.

A Tethered Power Supply Concept for Large-Scale UAV-Based Antenna Near-Field Measurements

Stefan Punzet (Technical University of Munich & Chair of High-Frequency Engineering (HFT), Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

Unmanned aerial vehicles (UAVs) gain popularity in the antenna measurement domain. Measuring the near field (NF) of large-scale antennas or antenna arrays can take up to several hours. In contrast, the non-stop flight time of a battery powered UAV is commonly limited to the order of tens of minutes. In order to overcome this limitation, the concept and implementation of a tethered power supply for UAVs are presented. The resulting non-stop flight time allows for faster and denser sampling of the antenna under test (AUT) NF without the corresponding start and land maneuvers for replacing the battery. Detailed electromagnetic interference (EMI) measurements, as well as a fallback battery power solution for safe and reliable operation of the UAV are presented.

Validated E-Field Measurement Setup for SAR Estimation in Human Phantom Model

Manuel Pérez, Robert A. Urbina and Cristian O. Duran (Pontificia Universidad Javeriana, Colombia); Gabriel F. Martinez and Andres Gallego (Universidad Nacional de Colombia, Colombia); Arturo Fajardo (Pontificia Universidad Javeriana, Bogota, Colombia); Carlos I. Páez-Rueda (Pontificia Universidad Javeriana, Colombia); Javier Leonardo Araque Quijano (Universidad Nacional de Colombia, Colombia)

This paper describes the validation of an experimental E-field and Specific Absortion Rate (SAR) measurement setup for RF exposure assessment in a human flat phantom model. The requirements of standards related to RF dosimetry were taken into account for the integration of the experimental setup. From the various test cases tackled, we present results on the accuracy and precision of the E-field probe tracking system, and the comparison of measured E-field/SAR hot maps with simulations, which

presented good agreement.

Surviving the Fire: Shallow Underground Radio Communications in Natural Disasters

Arslan A Nizami, Hugo G Espinosa and David V Thiel (Griffith University, Australia)

Current wireless communications technology is vulnerable to major weather events caused by climate change. A buried antenna is resilient during and after fires, floods and strong winds. A low power, 2.4GHz transmitter in a resonant slot cavity buried 10cm between the surface was measured and modelled as a vertically polarized wave at the surface. The technique offers promise for short distance communications during and after fire, flood and storm events.

Calibration Schemes for Probes for Breast Tissues Dielectric Properties Characterization

E Fernandez-Aranzamendi (Universidad Carlos III de Madrid, Peru & Universidad Católica San Pablo, Peru); Manuel Alejandro Condori Huayna, Patricia Castillo and Ebert G San Roman Castillo (Universidad Católica San Pablo, Peru); Vicente Gonzalez-Posadas (Universidad Politecnica de Madrid, Spain); Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)

Currently, medical technology has great interest in the development of solutions based on using radiofrequency and electromagnetics techniques. This technology is non-invasive, low-cost and portable. However, the main bottleneck is associated to the correct dielectric characterization of biological tissues. Their variability depending on either the applied pressure, temperature or position makes a difficult task to have a correct estimation of those electrical properties. A study of the effects of the pressure is presented in this paper. The method used was based on the open circuit coaxial probe under a pressure variation from 0 up to 69.71 kPa in a frequency range of 1-8 GHz is shown. The results showed a pressure range under which tissues do not suffer important alteration providing reliable results in the tissue electrical characterization.

Experimental Setup for the Characterization of a Quasi-Optical Link Between Two Pulsed Photoconductive Antennas

Huasheng Zhang, Juan Bueno, Paolo Sberna, Nuria LLombart and Andrea Neto (Delft University of Technology, The Netherlands)

Photoconductive antennas (PCAs) are promising candidates for millimeter-resolution security imaging systems. In the past, our group investigated their properties under pulsed laser illumination both in transmission and reception. A transmitting PCA was well characterized and validated by the power measurement. For a receiving PCA, the model of a Quasi-Optical (QO) link between a transmitter and a receiver was analyzed but was not measured. In this work, we present a reflector-based QO link used for the measurement. We use bow-tie based PCAs as examples, and measured the radiated power of the transmitter. The procedures to measure the detected current of the receiver is described and the measurement is ongoing.

Novel Ultra-Thin Meta-Material Absorber for Potential Use in Compact Anechoic Chamber

Amit Kumar Baghel (AVENIDA DE ARTUR RAVARA 4 1ESQ & IT AVEIRO, Portugal); Marco Anacleto (Instituto Telecomunicações, Portugal); Nuno Borges Carvalho (Universidade de Aveiro, Portugal & Instituto de Telecomunicacoes, Portugal); Pedro Pinho (UA - Universidade de Aveiro & IT - Instituto de Telecomunicações, Portugal)

In this paper, the authors have proposed a novel ultra-thin meta-material absorber (MTA) characterized from 1 to 12 GHz. The MTA is designed and the physics of the same is studied. To show the utility of the MTA as the future material for the conventional chambers, a compact chamber (CC) measuring (L × B × H): 0.4 × 0.4 × 0.3 m3 is designed. The radiation pattern of the monopole antenna having a resonating frequency at 3 GHz is used to compare the CC performance with the MTA lining. From the 3D-radiation pattern and simulated gain of the antenna, it is observed that the CC with the MTA lining can produce the same results as the free space. This solution open direction to use the MTA as the potential absorbing material for future chambers, which require antenna characterization for the frequency band, i.e., 1-12 GHz.

Tuesday, March 28 13:30 - 15:00

PP1: Poster Session on Propagation

/ / Propagation

Rooms: Spadolini 109, Spadolini Ground Floor

Chairs: Vittorio Degli-Esposti (University of Bologna, Italy), Davy P Gaillot (University of Lille, France)

Predicting the Line-Of-Sight Existence Using Radio Channel Properties and Relative Antenna Locations

Katsuyuki Haneda (Aalto University, Finland); Rachana Desai (Rapidminer, Finland)

Existence of the line-of-sight (LoS) in a radio link is an important feature determining radio link and localization performance. This study explores relationship between multi-dimensional nature of radio channel properties such as delay and angular spreads and link pathloss with the LoS existence along with the relative antenna geometry of the two communicating devices in an attempt to predict the LoS existence. A non-linear classification method of the decision tree is trained by extensive wideband double-directional channel sounding data in a microcellular environment. It was found that the BS-MS link distance and link pathloss were most influential features in predicting the LOS existence. While the use of less influential features of delay and angular spreads led to 75 % accuracy due to not being able to find the exact pattern across different MS routes. We thereby demonstrate the usefulness of incorporating geometrical knowledge of the link to predict the LoS state, despite not using a map of the cellular site, in addition to using channel parameters.

Bird Protection Zones in a Wind Park by Ka-Band Radar Surveillance: Field Results from the Wind Testing Site WINSENT

Moritz Mälzer (Goethe University Frankfurt am Main, Germany); Marcel Burhenn (HÜBNER GmbH & Co. KG, Germany); Sebastian Beck (Goethe-University Frankfurt, Germany); Ashkan Taremi Zadeh (Goethe University Frankfurt, Germany); Jochen Moll (Goethe University Frankfurt am Main, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany); Daniel Huebsch (HÜBNER GmbH & Co., Germany); Andreas Nuber (Wölfel Engineering GmbH + Co. KG, Germany); Michael Werner and Stefan Kaminsky (Kaminsky Naturschutzplanung GmbH, Germany)

In this paper, we report on a newly developed 34 GHz radar system and its field application in the wind energy testing site WINSENT on the Swabian Alb (Germany). The envisaged sensor system addresses the early detection of birds for a bird-friendly wind turbine operation. In this way, wind turbines could be adaptively controlled to reduce the collision risk of endangered species. Besides the description of the radar sensor and its characterization in the laboratory, we also demonstrate the system implementation using three Ka-band radar units. Bird detection results are presented along with a synchronized camera-based validation.

Sidelobe Suppression by Optimizing Receiver Positions via PSF-Based Multi-Objective Optimization

Guanying Sun and Carey Rappaport (Northeastern University, USA)

A method for sidelobe suppression in Advanced Imaging Technology (AIT) system is developed using the PSF-based multi-objective optimization. Two metrics for measuring image quality of the PSF are proposed and defined as the objective functions of the optimization problem. In order to find a satisfactory solution, we introduce another metric to select the desired solution from the numerous Pareto-optimal solutions. Numerical experiments are conducted to verify the effectiveness of the proposed method. The results show that the optimized receiver design by the optimization method generates better images with less and weaker sidelobes, compared with the uniform receiver design. Our method can be easily extended to other scenarios in electromagnetic imaging for sidelobe suppression.

Leaves Permittivity Estimation at 2.2 GHz for the Development of Propagation Models in Citrus Plantations

Ricardo Robles Enciso, Leandro Juan-Llacer and Jose-Maria Molina-Garcia-Pardo (Universidad

Politécnica de Cartagena, Spain)

The massive use of sensors and actuators expected in Agriculture 4.0 will require a large deployment of wireless systems in agricultural environments. The planning of these radio communication systems is carried out using computer tools that incorporate propagation models. In this sense, it is necessary to propose propagation models for specific agricultural environments according to the type of plantation. In some of these models the trees are replaced by a layer medium, in which the electrical properties of leaves are specified in terms of their relative permittivity. This work presents permittivity measurements on citrus leaves, using a device based on a microwave cavity resonant method. Measurements were performed on shredded leaves inside a sealed Pyrex tube. At 2.2 GHz, the estimated values of the real and imaginary parts of the dielectric constant for lemon and oranges fresh leaves were 23.26 and 7.26, and 19.73 and 7.05, respectively.

Excess Attenuation Detection in Satellite Communication Channel Measurements with Deep Learning Architectures

Anargyros J. Roumeliotis, Maria Kaselimi, Apostolos Z. Papafragkakis, Athanasios D. Panagopoulos and Nikolaos D. Doulamis (National Technical University of Athens, Greece)

In this paper a robust methodology for detecting excess attenuation events in satellite communication links is thoroughly investigated and described. The scope is to distinguish the existence of large excess attenuation values in the next future time-steps based on data from previous time-steps. Deep learning architectures, such as encoder-decoder and traditional paradigms are investigated and tested using experimental data from ALPHASAT campaign in Athens and Lavrion, in Greece, at Ka and Q frequency bands. Specifically, artificial neural networks with convolutional and gated recurrent units are examined. Results of the deep learning techniques for the in excess attenuation's event detection in the four datasets are very promising.

A Refined Path Generation Pipeline for Radio Channel Propagation Modeling

Niklas Vaara, Pekka Sangi, Juha Pyhtila, Markku Juntti and Janne Heikkilä (University of Oulu, Finland)

Ray tracing is a widely used approach for deterministic modelling of radio channels. We present our path generation pipeline, which combines environment discretization-based propagation path search with path refinement, which outputs validated paths fulfilling the Fermat's principle of the least time. We propose a novel gradient descent-based solution for refinement. Whole pipeline is implemented as GPU computations using NVIDIA CUDA and OptiX ray tracing engine, and experimental results show efficacy of the approach.

Automated Breast Tissue Classification Through Machine Learning Using Dielectric Data

Daniel Álvarez Sánchez-Bayuela (University of Castilla - La Mancha & University Hospital of Toledo, Spain); Eliana Canicattì (University of Pisa, Italy & RaSS, CNIT, Italy); Mario Badia (UBT - Umbria Bioengineering Technologies, Italy); Lorenzo Sani and Lorenzo Papini (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Cristina Romero Castellano, Paul Martín Aguilar Angulo, Rubén Giovanetti González, Lina Marcela Cruz Hernandez and Juan Ruiz Martín (University Hospital, Toledo, Spain); Navid Ghavami (Umbria Bioengineering Technology (UBT), United Kingdom (Great Britain)); Gianluigi Tiberi (London South Bank University, United Kingdom (Great Britain) & UBT - Umbria Bioengineering Technologies, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)

In recent years, new technologies focused on dielectric principles have been developed for medical applications. Conductivity and permittivity of biological tissues have been described to vary among benign and malignant tissues, so many efforts are being made to implement new systems based on safe low-power microwaves able to capture these inhomogeneities for medical imaging. However, such conductivity and permittivity parameters are being investigated for several different applications. The dielectric characterization of tissues in vivo during surgeries or via excised tissue may offer clinicians new tools for optimizing hospital routines in the diagnostic pathway. This work presents the application of several Machine Learning (ML) approaches to dielectric data gathered from excised breast tissues using a novel open-ended coaxial probe.

Analysis of Varying Car Geometry Accuracies for Ray Tracing Simulations in Urban V2V Scenarios

Enes Aksoy (Technische Universität Berlin & Huawei Munich Research Center, Germany); Haroon

Khan and Yun Chen (Huawei Technologies Duesseldorf GmbH, Munich Research Center, Germany); Leszek Raschkowski and Lars Thiele (Fraunhofer Heinrich Hertz Institute, Germany); Slawomir Stanczak (Technische Universität Berlin & Fraunhofer Heinrich Hertz Institute, Germany)

Fifth Generation (5G) communications are envisioned to be an important part of future vehicle to vehicle (V2V) communications. Therefore, the characterization of V2V channels is a growing research area. Several different methods, such as ray tracing are used for the channel modeling. In this context, the geometries for the ray tracing simulations are key to obtain correct channel models. This paper focuses on the car geometries for urban scenarios, since they are one of the most important objects in urban environments. Car models with different accuracies are used, to perform ray tracing simulations, in order to assess the effect of the car accuracies on the simulations. It can be observed, that low poly car models provide the best trade-off between computational complexity and simulation accuracy for ray tracing simulations. So the computational complexity is significantly reduced, while the simulation results are changing between 5% to 15%, depending on the scenario.

Statistical Modelling of the Delay Spread of the WBAN Channel Considering Room Geometry and Material Characteristics

Badre Youssef (Télécom ParisTech-Institut Mines-Télécom & LTCI, France); Christophe Roblin (Telecom Paris - Institut Polytechnique de Paris & LTCI - Institut Mines-Télécom, France)

This communication presents the development of Delay Spread statistical models of the WBAN (Wireless Body Area Network) indoor channel taking into account parametrically the geometry and the material characteristics of the rooms within the framework of a scenario-based approach in the UWB (Ultra Wide Band) context. The study is performed in the 1st UWB sub-band $\Delta f = [3.1, 4.8]$ GHz and restricted to the stationary (time-invariant) channel, the subject being motionless. The models are derived from statistical samples obtained thanks to a homemade simplified Ray-Tracing code. The trends of the simulations were compared to the behavior of the Delay Spread of the "classic" indoor channel observed in several experimental studies (for different frequency bands), which confirmed the reliability and consistency of our approach. The models extracted from a set made up of several categories of premises present a very satisfactory goodness of fit for the three considered radio links.

Nanosatellite SAR Preliminary System Design for New Zealand Maritime and Terrestrial Remote Sensing

Simone Mencarelli, Andrew C M Austin and Michael J Neve (The University of Auckland, New Zealand)

The potential of nanosatellite radar sensors for illegal fishing vessel detection in the coastal waters and imaging on the land of New Zealand is investigated. It was found that for a sensor in Low Earth Orbit at an altitude of 500~km, with an antenna compatible in width with the longest side of a 3-U CubeSat, i.e., 0.3~m and a length of 2~m and a peak transmitted power of 200~W; adequate detection performance can be obtained over a swath of up to 60~km at an incidence angle of 36° using an ambiguous acquisition mode. Alternative solutions for different looking angles, but smaller swaths are also found to be viable. A design method and the resulting imaging performance for a land non-ambiguous imaging mode are also presented.

Map Based RNN Model for Proactive Prediction of Received Power Distribution in an Indoor Area

Motoharu Sasaki and Naoki Shibuya (NTT, Japan); Kenichi Kawamura (NTT Corporation, Japan); Nobuaki Kuno, Minoru Inomata, Wataru Yamada and Takatsune Moriyama (NTT, Japan)

This paper presents a proactive prediction method for received power distribution using GRU (Gated Recurrent Unit), which is one type of RNN (Recurrent Neural Network), as deep learning. In addition to the 50 most recent RSSI (Received Signal Strength Indicator) data acquired approximately every 0.1 seconds as input data, the distance and LoS/NLoS between transmitter and receiver at the prediction target position were used as a map data. As an output data, the median, 5%, and 95% values of RSSI after 5 seconds were predicted. The output data was derived using 50 points (about 5 seconds) of RSSI data. We used RSSI data of 5.6GHz band wireless LAN measured in an indoor environment for training data and validation data. With the proposed method, the RMSE (Root Mean Squared Error) for the validation data is approximately 1.4 dB.

Compact Metamaterial Antenna for Angular Localization of Radio-Frequency Sources

Abdelwaheb Ourir (Institut Langevin ESPCI Paris CNRS, France); Mohamed Kamoun (Huawei

France, France); Arnaud Tourin (Laboratoire Ondes et Acoustique (LOA), France); Mathias Fink (ESPCI PSL Paris, France); Julien de Rosny (CNRS, ESPCI Paris, PSL Research University, France)

Localization of radio-frequency sources is commonly carried out by adjusting the radiation patterns of phased arrays to scan a specific region. This task could be difficult and expensive to implement in some frequency regimes of the last generation of communication systems. We present an alternative to the classical Radio-frequency angular localization based on a single port compact metamaterial antenna. We use a finite periodic array of sub-wavelength (=6) resonators for the design of this antenna. We show that the proposed antenna is able to achieve several complex radiation patterns over a specific narrow frequency band. We implement numerical methods to estimate the direction of a target antenna by taking benefits of the complex frequency signatures over this band. We demonstrate experimentally in the microwave regime that a single port antenna made of a finite array of metamaterial resonators can be used to retrieve the incident direction.

A Study of Building Map Representation for Delay Spread Estimation Model Using Machine Learning

Keiji Yoshikawa, Tatsuya Nagao, Kazuki Takezawa, Satoshi Ito and Takahiro Hayashi (KDDI Research, Inc., Japan)

To emulate propagation channels with high accuracy, it is important to model spatiotemporal characteristics in addition to propagation loss for each environment. Machine learning has been proposed as a propagation loss model for each environment. However, for accurate estimation of spatiotemporal characteristics, it is necessary to consider weak incoming waves. Therefore, it is effective to use images that represent a larger area, however, the computation time increases with the data size. To reduce computation time, this paper proposes an input image that represents the area around the transmitter and receiver in polar coordinates. The proposed image densely represents the area near the transmitter/receiver, which has a large impact as a feature, and sparsely represents the distant area, which has a small impact, thus reducing the data size while maintaining accuracy. Simulation evaluation shows that the proposed method can reduce computation time to about 33% without degrading estimation accuracy.

Evaporation Duct Channel Model for Flat Sea

Sebastian Kudera, Angela Doufexi and Geoffrey Hilton (University of Bristol, United Kingdom (Great Britain))

The evaporation duct is a natural phenomenon that occurs over large bodies of water. Caused by the rapid decrease of the refractive index, evaporation ducts are important for radio communications due to their ability to enhance the signal strengths of propagated electromagnetic waves. This paper presents a channel model for evaporation ducting for a flat sea. A novel way of approximating modified refractivity is proposed based on nonlinear regression analysis. The model introduces the ability to use water's true relative permittivity. Simulation results confirm that seawater is a good conductor. The simulated Path Loss when water's permittivity is modelled lies within 0.1 dB of the perfectly conducting surface. Simulation results are compared to the free propagation software PETOOL. When the distance between the receiver and the transmitter is above 40 km, the path loss is 10 to 20 dB lower compared to PETOOL due to more accurate modified refractivity profiling.

Performance of Free Space Optical Links: A Case Study for Pakistan

Umair Ahmed Korai and Mirza Ehsan (Mehran University of Engineering and Technology, Pakistan); Lorenzo Luini (Politecnico di Milano, Italy); Roberto Nebuloni (Ieiit - Cnr, Italy)

A case study for 5G/6G network free space optical (FSO) links affected by fog is reported. Twenty years of visibility data for some major cities of Pakistan were acquired from the Pakistan Meteorological Department. The visibility data consists of three daily measurements collected at 05:00, 08:00, and 17:00 Pakistan standard time (PKT). The data are used to calculate the availability of a 1550 nm FSO link, for each city. Results highlight large differences among the six locations, due to the different climatic conditions. Lahore has the worst performance: in that case, an FSO backhaul link shorter than 150 m would achieve an availability of 99.5%. Whereas, Peshawar has the best performance for the said availability.

Assessment of Prediction Accuracy of the ITU-R P.530 Model in 73 GHz and 83 GHz Frequency Bands

Pavel Valtr, Pavel Pechac, Martin Fencl and Vojtech Bares (Czech Technical University in Prague, Czech Republic)

The attenuation statistics is calculated from a unique dataset containing measurements collected at a sampling rate of 1 minute for one year from 33 full-duplex microwave links operating in the 73 GHz and 83 GHz frequency bands. Link lengths range from 100 m to 4 km. The measured values differ by up to 6 dB from the ITU-R model predictions. The results suggest that the ITU-R P.530 recommendation to limit the distance factor to a maximum level of 2.5 should not be used in estimating short link attenuation.

Tuesday, March 28 13:30 - 15:00

AMTA: AMTA Europe meeting

Room: Palazzina 7

Tuesday, March 28 15:00 - 16:20

Invited Speakers: Buon Kiong Lau and Dennis Lewis

Room: Spadolini 001

Chairs: Amedeo Capozzoli (Università di Napoli Federico II, Italy), Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

15:00-15:40 Invited Speaker: **Buon Kiong Lau**

Title: **"Design Challenges and Opportunities in Car Antenna Systems"**

Abstract: For many years, car antennas simply imply protruding wires on car bodies that are used for receiving broadcast radio signals. In recent years, many more antenna systems are packed into cars to support new applications and services, including GNSS, Wi-Fi, LTE, SDARS, long/mid/short-range radar, etc. These antennas are challenging to design due to a wide variety of design requirements and constraints. To make things worse, industrial designers want antennas to disappear from the car body altogether. In this talk, I will overview the evolution of car antennas and how the design of these antennas become increasingly challenging. I will then introduce some recent innovations in car antenna design to address the challenges in different use cases. As a representative example of an interesting research problem that benefits from an innovative approach, I will detail the systematic design procedure of a Vehicle-to-Everything (V2X) antenna system that can provide the required line-of-sight coverage, despite being a hidden antenna solution. Going higher up in frequency, I will also introduce our recent design of a 79 GHz series-patch array, which is intended for future cars' multiple-input multiple output (MIMO) radar.

15:40-16:20 Invited Speaker: **Dennis Lewis**

Title: **"Recent Advances in Robotic Antenna Measurements"**

Abstract: Traditional antenna test facilities are typically designed with a specific measurement application in mind, and as a result these facilities tend to be comprised of single fixed measurement geometry. However, modern antenna measurement ranges employing multi-axis robotic positioners provide a near limitless degree of re-configurability in terms of measurement types and scan geometries. This drives an ongoing need to evaluate each unique setup and application. This previously unimaginable flexibility offers new opportunities for the improvement of safety, measurement quality and reduction of measurement uncertainties. These new robotic systems are capable of acquiring large amounts of special data allowing for the implementation of advanced post processing techniques. Model based Systems Engineering and development (MBSE/MBD) approaches can be employed to dramatically reduce the time, effort and cost associated with the test development and validation phases of a given program. MBSE tools can also be used to optimize test configurations to greatly reduce measurement uncertainties and simulate measurements. This presentation provides an overview of how these engineering techniques are being harnessed during the implementation of a new dual multi-axis robotic antenna test system.

Tuesday, March 28 15:00 - 16:20

Invited Speakers: Ekaterina Shamonina and Filippo Capolino

Room: Spadolini 002

Chairs: Filiberto Bilotti (Roma Tre University, Italy), Ariel Epstein (Technion - Israel Institute of Technology, Israel)

15:00-15:40 Invited Speaker: **Ekaterina Shamonina**

Title: **"Wireless Power Transfer via Magnetoinductive Waves"**

Abstract: The concept of magnetoinductive (MI) waves was introduced two decades ago in the context of the emerging field of metamaterials as slow waves that can propagate by virtue of magnetic coupling between individual meta-atoms. Changing the resonant frequency of the meta-atoms and the coupling between them, the dispersion of MI waves can easily be tailored enabling a large variety of applications of MI waves ranging from near-field guiding and imaging to superdirective antennas. In this talk we focus on wireless signal and power transfer in magnetoinductive structures. We look at a variety of scenarios, including power splitting and guiding, switchable unidirectional signal transfer, wireless power transfer in the presence of radiation, in the presence of a conducting environment, or via coupled evanescent magnetoinductive waves.

15:40-16:20 Invited Speaker: **Filippo Capolino**

Title: **"Applications of Exceptional Points of Degeneracy in RF"**

Abstract: We discuss an important class of degeneracies that occur when two or more eigenstates of a system fully coalesce. Such exceptional degeneracies happen in circuits, resonators, and multimode waveguides. These exceptional points degeneracies (EPDs) involve the polarization states and occur in a surprisingly large number of systems, like fully passive systems or in systems that include gain elements.

We provide various experimental verifications of the occurrence of EPDs in circuit resonators and waveguides. We discuss possible applications in antennas, antenna arrays, oscillators, delay lines, etc. Important applications are in extreme sensitivity for sensing, extreme tunability, purity and robustness of oscillation in circuit oscillators, very high-power generation, etc.

We discuss how EPDs are useful to conceive highly sensitive sensors. Indeed, it has been apparent that resonant frequencies in a system with EPD are extremely sensitive to a perturbation. Therefore, the detection of a large frequency shift in a resonator or in an oscillator is an indicator of an applied physical, chemical or biological perturbation. Systems of EPDs can be realized using gain and loss (usually referred as EPDs induced in PT symmetric systems), time modulation of a component, etc. We will provide the experimental demonstration of such extremely sensitive systems.

Tuesday, March 28 16:40 - 18:20

CS15: Electromagnetic modelling and design of reconfigurable intelligent surfaces

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: Marco Di Renzo (Paris-Saclay University / CNRS, France), Giacomo Oliveri (University of Trento & ELEDIA Research Center, Italy)

16:40 ***On the Design of Reconfigurable Passive Skins Towards a Smart EM Environment for Next***

Generation Wireless Communications - Challenges, Solutions, and Trends

Giacomo Oliveri (University of Trento & ELEDIA Research Center, Italy); Lorenzo Poli (ELEDIA Research Center, University of Trento, Italy); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Marco Salucci and Francesco Zardi (ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

Reconfigurable passive electromagnetic skins (RP-EMSs) are considered one of the fundamental technologies to implement the "Smart EM Environment" paradigm in next generation wireless communications. Despite their popularity and the already demonstrated successful applications of such a technology, several challenges still need to be addressed concerning the design, optimization, control, and implementation of cost-effective and efficient RP-EMSs. A review of the most recent advances and trends in this framework will be discussed in this work.

17:00 ***A Cylindrical, Metasurface-Based, Azimuthally-Symmetric Beam-Shaping Shell***

Chun-Wen Lin (University of Michigan - Ann Arbor, USA); Richard W Ziolkowski (University of Arizona, USA & University of Technology Sydney, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

A cylindrical beam-shaping shell that transforms the field of a displaced (off-center) coaxial feed to a narrow radiated beam is presented. The displaced coaxial feed is characterized using the mathematical properties of Hankel functions, whereas the concentrically-cascaded, cylindrical metasurfaces comprising the shell are modeled using the multimodal wave matrix theory. The scattering properties of the feed and metasurfaces are combined to synthesize the beam-shaping shell. The symmetry of the device allows control over the beam direction via azimuthally displaced feeds.

17:20 ***Reconfigurable Surfaces for Wireless Communications***

Marco Di Renzo (Paris-Saclay University / CNRS, France)

Reconfigurable surfaces have recently attracted the interest of researchers in wireless communications. In this paper, we overview the potential applications of reconfigurable surfaces in wireless communications and discuss their design requirements for emerging wireless applications.

17:40 ***Link Budget Estimations for Millimeter-Wave Links via Anomalous Reflectors***

Sergei Kosulnikov and Francisco S. Cuesta (Aalto University, Finland); Xuchen Wang (Karlsruhe Institute of Technology, Germany); Ana Díaz-Rubio (Universitat Politècnica de València, Spain); Sergei Tretyakov (Aalto University, Finland)

High-frequency (millimeter-wave) wireless communications require the use of directive, high-gain antennas, as otherwise the achievable length of the communication link quickly decreases with increasing frequency. In order to provide necessary space coverage, anomalously reflecting and reconfigurable intelligent surfaces can be possibly used. In this presentation, we will discuss our recent results on analytical estimations of the link budget in the presence of such reflectors. Using the concept of macroscopic reflection coefficients, it is possible to come to very simple analytical expressions for the far field and set it into the form of a generalized Friis formula. The analytical results are validated by numerical simulations of a particular realization of an anomalous reflector for the millimeter-wave frequency band.

18:00 ***Space-To-Surface Wave Conversion and Beam Steering Using a Single Metasurface for Smart Radio Environments Applications***

Talha Arshed, Enrica Martini and Stefano Maci (University of Siena, Italy)

This work presents a three-part planar modulated metasurface (MTS) that couples and re-transmits the incoming broadband electromagnetic waves in frequency-dependent angular directions. MTS is divided in three sections. The first section (receiver) of MTS receives the space wave at a set angle and efficiently converts it into a surface wave. The second section (transition) gradually changes the phase velocity of the surface wave guiding it to the third section (transmitter), which radiates it into free space with broadband. For the proposed task, the MTS is synthesized using modulated transparent impedance model, which

allows the necessary control of phase constant (dispersion) and leakage constant (efficiency) throughout the structure. The synthesized impedance profile of the MTS is then realized using metallic patches placed on a grounded dielectric slab. This metasurface is useful for application in smart radio environments.

Tuesday, March 28 16:40 - 18:20

M01: Material Characterisation and Nondestructive Testing

T10 Fundamental research and emerging technologies / / Measurements

Room: Spadolini 002

Chairs: Michael J Havrilla (Air Force Institute of Technology, USA), Dirk Heberling (RWTH Aachen University, Germany)

16:40 ***Tomographic Reconstruction of the Index of Refraction Using Radar at 15 GHz***

Dominik Rhiem (Fraunhofer-Institut für Hochfrequenzphysik und Radartechnik FHR, Germany); André Froehly and Patrick Wallrath (Fraunhofer FHR, Germany)

In this paper, we present a method for processing tomographic radar data with subsequent imaging. The imaging method we used is the averaged multiplicative algebraic reconstruction technique, which is commonly used for tomography purposes. We applied this technique to data measured at 15 GHz to reconstruct the index of refraction of an object. The results of this reconstruction are presented in this paper. Finally, we have developed a simple method that aims at correcting for signal paths which have been deflected due to refraction.

17:00 ***In-Situ Monitoring of Grouted Joints Using a SFCW Radar: Initial Results of an Installation Inside a 3.6 MW Offshore Wind Turbine***

Thomas Maetz (Goethe University Frankfurt, Germany); Manfred Hägelen and Rainer Jetten (IMST GmbH, Germany); Johannes Käsgen (Fraunhofer Institute for Structural Durability and System Reliability LBF, Germany); Marcel Wiemann (University of Siegen, Germany); Marco Jackel (Fraunhofer Institute for Structural Durability and System Reliability LBF, Germany); Jonas Kappel (University of Siegen, Germany); Jochen Moll (Goethe University Frankfurt am Main, Germany); Peter Kraemer (University of Siegen, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany); Holger Huhn (WindMW Service GmbH, Germany)

Many offshore wind turbines with a monopile as foundation structure use grout, a special form of concrete, to connect the monopile and the transition piece. The use of stepped-frequency continuous wave (SFCW) radar with frequencies from 100 MHz to 2 GHz is proposed for in-situ monitoring of this grouted joint. Network analyzer measurements are performed on improved grout-filled TEM horn antennas. A procedure for installing the antennas and radar systems offshore is described. Three SFCW radar systems are installed in a turbine at the Meerwind Ost offshore wind farm north of the island Heligoland. The first measurement results of these systems are presented.

17:20 ***Anthropomorphic Multi-Tissue Head Phantom for Microwave Imaging Devices Testing***

Cristina Origlia, Martina Gugliermino, David O. Rodriguez-Duarte, Jorge Tobon and Francesca Vipiana (Politecnico di Torino, Italy)

This paper describes the realization of a versatile anthropomorphic multi-tissue head phantom for testing microwave imaging devices, employing mixtures featuring readily available, not harmful, and stable components. Considering that the evaluation of devices, such as medical ones, might require the variation of the tissues' characteristics for their assessment, the manufacturing approaches the issue using both unalterable and adjustable components. For the former, we reproduce the tissues using flexible

and solid compounds made with proper proportions of urethane rubber and graphite powder, while for the latter, water and triton X-100. The anatomical structures of the tissues are faithfully rendered using 3D-printed molds and assembled without additional intermediate plastic layers. The materials' dielectric properties are measured via an open-ended coaxial probe method, investigating the frequency range of 0.5-2 GHz. The final prototype fits the nominal dielectric values in the literature, presenting stability and replicability, demonstrating its validity as a multi-purpose test object.

17:40 *Ethylene Glycol Based Phantoms for High-Loss and Malignant Tissue at Microwave Frequencies*

Klementina Vidjak (Sapienza, University of Rome, Italy); Laura Farina (Endowave Ltd, Ireland); Giuseppe Ruvio (Endowave Ltd., Ireland); Martin O'Halloran (National University of Ireland, Galway, Ireland); Marta Cavagnaro (Sapienza University of Rome, Italy)

This work presents the dielectric properties of different mixtures of distilled water and ethylene glycol in the frequency range 0.5-8 GHz and at 25 °C. The measured dielectric properties are fitted to Debye and Davidson-Cole relaxation models depending on the percentage of ethylene glycol in the mixtures. The relationship between model parameter values and mixture types are found. Dielectric properties of mixtures at 2.45 GHz are compared with those of high-loss tissues and tumors found in literature suggesting them to be used as liquid phantoms.

18:00 *Measurement of the Plasma Density Using Stationary Method in Cavity*

Fatemeh Sadeghikia and Mohammad reza Dorbin (Aerospace Research Institute, Iran); Jalil A. Rashed-Mohassel (School of Electrical and Computer Engineerimg College of Engineering & University of Tehran, Iran); Hajar Jaafar (Universiti Teknologi MARA, Malaysia)

In this paper a new measuring method for the measurement of the plasma density using stationary method in a cavity is presented.

Tuesday, March 28 16:40 - 18:20

CS49: Spectrum management for 6G communications: research challenges under the electromagnetic propagation perspective

T01 Sub-6GHz cellular / Convened Session /

Room: Spadolini 101

Chairs: Gianmarco Baldini (Joint Research Centre - European Commission, Italy), Doriana Guiducci (European Communications Office, Denmark)

16:40 *Spectrum Challenges for 6G Satellite*

Frank Zeppenfeldt (European Space Agency, The Netherlands)

Satellite communications is currently undergoing major changes: on one hand the technological progress enables the use of higher frequency bands, at the other hand the pressure from other users increases to gain access to satellite spectrum. The paper will address a number of scenarios for satellite communications that are related to spectrum sharing and the evolution of regulations, set in the context of the World Radio Conference 2023.

17:00 *Clutter Loss Characteristics at the Line-Of-Sight and Non-Line-Of-Sight Boundaries in High Base Station Environments*

Ho-Yu Lin, Hideki Omote and Akihiro Sato (Softbank Corp., Japan); Shoma Tanaka (SoftBank Corp., Japan); Sho Kimura (Softbank Corp., Japan); Takaya Yamazato (Nagoya University, Japan)

High-Altitude Platform Station (HAPS) is a new mobile communication platform for ultra-wide coverage areas and disaster-resilient networks. HAPS can provide mobile communication services directly to smartphones from an altitude of 20 km via an Unmanned Aerial Vehicle (UAV). In this paper, we focus on the propagation loss at high elevation angles in urban and suburban areas. The proposed model can correct Recommendation ITU-R P.2108 using shielding building heights as the urban structure is proposed. If the shielding building heights are defined, it is important to clarify the relationship between the ground antenna height and the shielding building heights.In this paper, we carried out field measurement using a helicopter and clarified the propagation loss characteristics of the ground antenna height from below to above the roof (shielding building).

17:20 ***Building Wireless Systems of the Next Decade and Beyond***

Aleksandar Damnjanovic (Qualcomm Technologies Inc, USA); Tingfagn Ji (Qualcomm Technologies Inc., USA); Yu Zhang (Qualcomm Technologies, Inc., USA); Luigi Ardito (Qualcomm Inc., Italy)

As the deployment of 5th generation (5G) mobile networks is ramping up, and enhancements, referred to as 5G Advanced are being considered in 3GPP standards, the requirements for new 6G technology are staring to emerge. The requirements are driven not only by the new use cases and enhanced experiences associated with the existing services, but also available spectrum and challenges associated with the propagation characteristics of new spectrum and incumbent services. In addition to enhanced communications services, the technology suitable for wireless systems of the future, needs to enable ubiquitous sensing service, provide pervasive access, and meet social sustainability goals. This paper describes our vision for the technologies and spectrum required to meet above challenges and be foundation of the future wireless systems for the next decade and beyond.

17:40 ***Monte Carlo Modelling of mmWave 6G Systems for Shared Spectrum Deployments***

Arturas Medeisis (Vilnius Gediminas Technical University, Lithuania); Peter Faris (European Communications Office, Denmark)

The evolving 6G systems will push the mobile spectrum frontier well into mmWave and THz bands, i.e., from 24 GHz to 275 GHz. This calls for a better understanding of future spectrum sharing and coexistence scenarios that involve mobile systems in those frequency ranges. The European regulatory establishment has started addressing such studies with initial focus on 5G mobile systems sharing in 26 GHz band. This paper takes a further step by modelling the evolving 6G systems across a wider mmWave range of 26-71 GHz. The paper discusses radio wave propagation prediction in mmWave bands and uses Monte Carlo simulations to estimate the probability of interference between mobile and fixed systems under different assumptions. In particular, the paper shows the importance of terrain elevation modelling in future spectrum sharing studies.

18:00 ***Fading Channel Identification Based on Convolutional Neural Network with General Linear Chirplet Transform***

Gianmarco Baldini (Joint Research Centre - European Commission, Italy); Fausto Bonavitacola (Energy Security, Distribution and Markets Unit, Joint Research Centre, EC, Italy)

This paper proposes the application of Deep Learning and Convolutional Neural Networks (CNN). The classification of the fading channels is an important function in wireless communications as it contributes to the spectrum awareness of a wireless communication system. This paper proposes an approach based on the transformation of the RF one dimensional signal (e.g., the amplitude component of the signal) to an image using the General Linear Chirplet Transform (GLCT). The results show that the combination of GLCT with CNN is able to outperform the direct application of the CNN, not only on the original one dimensional signal but also on the combination of the spectrogram and CNN as proposed in literature. The approach is applied to a data set of RF weather radar signals generated by the authors, where different fading conditions are created.

Tuesday, March 28 16:40 - 18:20

A27: Antenna for 5G Systems II

T02 Mm-wave and THz cellular / / Antennas

Room: Spadolini 102

Chairs: Ahmed A Kishk (Concordia University, Canada), Ashraf Uz Zaman (Chalmers University of Technology, Sweden)

16:40 *E Band High Gain Antenna for 5G Backhauling Systems*

Carmine Mustacchio (CEA-LETI & Universita della Calabria, Italy); Luigi Boccia and Emilio Arnieri (University of Calabria, Italy); Giandomenico Amendola (Università della Calabria, Italy)

An E band Cassegrain switched beam high gain antenna for 5G backhauling systems is proposed in this article. The targeted antenna is able to realize beam-switching operations and it is fed by a 7x7 array of Magneto-electric dipoles, with every element capable of providing a steering of ±0.33 degrees, through the beam switching operation. This antenna was thought to use beam switching for compensating small boom movements, which are estimated to be within ±1 degrees in both azimuth and elevation planes. The average gain within the band of interest is higher than 52 dBi. The proposed solution is based on a Cassegrain reflector fed through a feed array implemented by cavity-backed magneto-electric dipoles. This type of illuminator can be designed to have a gain and beam shape well suited for a feed array configuration thus being a valid alternative to classical feed array configurations based, for example, on horn antennas.

17:00 *Single Layer Antenna Based on Gap Waveguide Technology with Dual-Circular Polarization for 60-GHz Band*

Ali Farahbakhsh (Graduate University of Advanced Technology, Iran); Davood Zarifi (University of Kashan, Iran); Ashraf Uz Zaman (Chalmers University of Technology, Sweden)

A dual-circularly polarized antenna element based on E-plane groove gap waveguide (GGW) for 60 GHz applications is presented in this work. The simulated return loss of the antenna is better than -10 dB for both polarizations in the working frequency bandwidth of antenna covering from 58 GHz to 62 GHz. The axial ratio of the proposed antenna is better than 2.5 dB in the whole bandwidth. The simulation results prove that the proposed antenna element is a good candidate to design larger array with dual circular polarization for different wireless applications at millimeter wave frequency range.

17:20 *Planar Quasi Log Periodic Dipole Antenna for Millimeter Wave 5G Band*

Anton Venouil (Aix-Marseille University (AMU), France); Matthieu Egels and Philippe Pannier (IM2NP, France); Mohammed Benwadih and Christophe Serbutoviez (CEA, France)

This article present the design and measurement of a planar quasi log periodic antenna covering the first millimeter band of 5G (24.25 GHz - 28.4 GHz). The antenna is conceived using HFSS and realized using laser etching on Taconic RF-35 substrate. A modification of the topology is applied to obtain a vialess antenna. The proposed antenna is easier to manufacture than most 5G antenna available with comparable results. The antenna present an measured average gain of 6.85 dB over the first millimetric 5G band.

17:40 *The Design of a New Vivaldi Linear Array for 5G Photonic-Integrated Base-Station Applications*

Saeed Haydhah, Mesrob Arsenien and Ahmed A Kishk (Concordia University, Canada); John Zhang (Concordia, Canada)

A new 1*8 linear array of Vivaldi elements is proposed for 5G photonic-integrated base-stations. The array is designed at 28 GHz on the Aluminum Nitrite substrate. The array has a size of 33.89*70*0.15 mm^3, with a bandwidth from 23.4 to 31 GHz, and a peak gain of 14.3 dBi. The radiation pattern of the antenna is unidirectional. The cross-polarization level is reduced sharply in this work; the reduction in the yz-plane is achieved by more than 20 dB. The performance of the antenna array when connected to a high-power photodiode is also investigated. The used transition from the Grounded-Coplanar-Waveguide to microstrip line is used for the photodiode connection requirements.

18:00 *High Performance 60 GHz Beamforming Antenna Array for 5G and Beyond Industrial Applications*

Abdul Jabbar and Qammer H Abbasi (University of Glasgow, United Kingdom (Great Britain)); Zhibo Pang (Forskargrand 7 & ABB Corporate Research, Sweden); Muhammad Ali Imran and Masood Ur-

Rehman (University of Glasgow, United Kingdom (Great Britain))

A compact and high-performance beamforming array antenna is designed for 60 GHz Industrial, Scientific, and Medical (ISM) band industrial applications. The proposed 16-element array provides peak realized gain of 16.5 dBi and half power beamwidth of 7° at 61 GHz (with realized gain greater than 15 dBi in the achieved band of 57-64 GHz). Radiation efficiency is greater than 70% in the band. The side-lobe levels are less than -10 dB in E and H planes, with extremely low cross polarization levels. Since the design of a low loss and wideband feed network is a challenging task at mmWave bands, therefore the junction lengths and chamfered transitions of the power divider are carefully optimized to achieve enhanced array performance, and a thorough analysis is presented. Moreover, an accurate antenna connector model is co-simulated and analyzed, which significantly affects antenna performance at millimeter-wave bands. Measured and simulated results show good agreement.

Tuesday, March 28 16:40 - 18:20

CS8: Antenna Design for Wireless Power Transmission/RF Energy Harvesting

T03 Wireless LANs, IoT and M2M / Convened Session /

Room: Spadolini 103

Chairs: Sotirios Goudos (Aristotle University of Thessaloniki, Greece), Paolo Rocca (University of Trento & ELEDIA Research Center, Italy)

16:40 ***Advanced Reconfigurability of Frequency-Diverse Radiators for Both Localization and Powering***

Enrico Fazzini (Università di Bologna, Italy); Diego Masotti (University of Bologna, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy); Tommaso Tiberi (University of Bologna, Italy)

In this work an effective and feasible procedure for real-time focusing of Frequency Diverse Arrays (FDAs) is proposed, to be exploited for intentional far-field Wireless Power Transfer (WPT) applications. The array layout relies on a circular symmetric transmitting architecture where the frequency diversity is applied by rings. This solution represents one of the best in terms of focused area dimension and therefore able to support precise powering applications. Through a software control able to manage the multifrequency excitation a preliminary localization phase for the collection of targets data position is performed, followed by a precise and energy-aware powering phase, enabling a real-time and capillary WPT system.

17:00 ***Unconventional Array Design for Efficient Wireless Power Transmission***

Nicola Anselmi (University of Trento, Italy); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Arianna Benoni (ELEDIA Research Center, Italy); Lorenzo Poli (ELEDIA Research Center, University of Trento, Italy); Andrea Massa (University of Trento, Italy)

The design of unconventional arrays for far-field wireless power transmission (WPT) is addressed. The architecture complexity of conventional arrays is reduced proposing an irregular tiled architecture that allows to reduce the number of transmit modules while affording an efficient power transfer. The beam collection efficiency is maximized through the optimization of the irregular tiling layout and of the amplification coefficients, and by assuring a full aperture coverage with the tiles shapes.

17:20 ***A Planar Distributed Receiver Coil Antenna Array to Encapsulate Vertical and Lateral H-Fields for Drone Wireless Charging***

Vivek Kumar Srivastava, Ananth Bharadwaj Madduluri and Ashwani Sharma (Indian Institute of Technology Ropar, India)

This paper presents a planar distributed receiver coil antenna array to harvest all the magnetic field components generated by a conventional transmitter for drone charging applications. For this purpose, four anti-parallel turn coils are placed on four arms of the drone to harvest lateral field components along with a conventional circular Rx coil that harvests vertical magnetic field. A DC combining technique is proposed for combining the output voltages induced in each receiver coil to avoid destructive superposition of responses. An EM simulator is used to analyze the potential of harvesting lateral fields by the proposed anti-parallel turn coils. Later, the anti-parallel turn coils' positions are determined based on the maximum voltage induced in these coils. The system is further verified using an experimental setup, and the results prove a significant enhancement of output voltage. Thus, proving the potential of the proposed Rx coil antenna suitable for drone charging applications.

17:40 ***Wideband mmWave Wireless Power Transfer: Theory, Design and Experiments***

Chaoyun Song and Lei Wang (Heriot-Watt University, United Kingdom (Great Britain)); Zhensheng Chen (KU Leuven, Belgium); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium); Yi Huang (University of Liverpool, United Kingdom (Great Britain))

A new type of wireless power transfer system is presented with wideband mmWave transmitters and rectennas. The proposed system transmits a beam formable and beam steerable signal by exploiting the inherent frequency-dispersive nature of a passive leaky wave antenna, thereby eliminating the need for an active phased array and other costly control methods. Multiple nodes can be wirelessly powered simultaneously by using a wideband mmWave rectenna to harvest the frequency scanning signals. A 24-34 GHz rectenna was designed in a highly integrated fashion and has been tested to show its high conversion efficiency of >50% at the frequency and power levels of interest. We have presented a system demonstration for remotely charging diverse nodes at > 1 m distance using the proposed system with feedback control. Our work has showcased the passive beamforming and multi-node tracking of the mmWave WPT system using significantly reduced cost and complexity.

18:00 ***Modified Bow-Tie Antenna Design Using Artificial Hummingbird Algorithm for Wireless Power Transfer IoT Applications***

Achilles D. Boursianis (Aristotle University of Thessaloniki, Greece); Maria S. Papadopoulou (International Hellenic University & Aristotle University of Thessaloniki, Greece); Aikaterini I. Griva, Vasileios P. Rekkas, Lazaros Alexios Iliadis, Sotirios Sotiroudis and Panagiotis D. Diamantoulakis (Aristotle University of Thessaloniki, Greece); Thomas Lagkas (International Hellenic University, Kavala Campus & South-East European Research Centre, Greece); Panagiotis Sarigiannidis (University of Western Macedonia, Greece); Sotirios Goudos (Aristotle University of Thessaloniki, Greece); Christos Christodoulou (The University of New Mexico, USA); George K. Karagiannidis (Aristotle University of Thessaloniki, Greece)

The advent of the Internet of Things has allowed the re-usability of established techniques combined with emerging technologies. In the TERMINET project, several key-enabling technologies in an IoT ecosystem are explored. The smart farming paradigm is one of the realistic use cases of the project, in which Wireless Power Transfer, assisted by an Unmanned Aerial Vehicle, will be demonstrated as a proof-of-concept, to deliver energy in wireless sensor networks. In this work, we provide a feasible solution of a rectifying antenna module in a rectenna system, which operates in the Wi-Fi 2.4 GHz frequency band. The proposed antenna is optimized by utilizing the Artificial Hummingbird Algorithm. Numerical results demonstrate excellent performance of the proposed antenna, in terms of the key characteristics of reflection coefficient, input impedance, realized gain, and efficiency.

Tuesday, March 28 16:40 - 18:20

A15: Implantable Antennas

T04 Biomedical and health / / Antennas

Room: Spadolini 104

Chairs: Sema Dumanli (Bogazici University, Turkey), Gaetano Marrocco (University of Rome Tor Vergata, Italy)

16:40 ***Fully Printed Electrically Small Antenna-On-Package for Wireless Electrocardiogram System***

Jiajun Li and Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)

In this paper, we present an antenna-on-package (AOP) design for a compact wireless Electrocardiogram (ECG) system. The proposed electrically small antenna (ESA) (ka=0.67 at 2.45GHz), inspired by a traditional inverted F type antenna, has been realized on a 3D printed compact cylinder with a ra-dius and height of 12mm each. The cylindrical substrate has been designed (made hollow from one side) to house the driv-ing electronics, thus qualifying this to be an AoP. The antenna has been realized through printing of silver paste, as the fully printed process ensures low cost. The ground plane is folded underneath the radiator to minimize the effect of the human body. As an ESA, it has decent performance in free space, with bandwidth of 87MHz, gain of 2.6dBi and radiation efficiency of 92%.

17:00 ***Ultra-Miniaturized Camera Integrated Antenna for Wireless Capsule Endoscopy***

Muhammad Qamar (Queen Mary University of London, United Kingdom (Great Britain)); Kamil Yavuz Kapusuz (Ghent University & IMEC, Belgium); Muhammad Usman Ejaz (Antenna Group, EECS, Queen Mary University of London, United Kingdom (Great Britain)); Mohamed Thaha and Akram Alomainy (Queen Mary University of London, United Kingdom (Great Britain))

The wireless capsule endoscopy requires a high resolution camera and compact wideband antenna systems that yield high performance at low manufacturing cost and allow easy integration of components into a capsule. Therefore, a novel ultra-miniaturized wideband meandered antenna along an annular ring substrate is proposed that enables straightforward integration between the camera and capsule wall. It contains two rings of microstrip lines on two dielectric layers. By exciting microstrip lines and judiciously positioning their resonance frequencies, all the MedRadio in the [401-457]MHz bands are covered. Numerical results exhibit an overlapping impedance bandwidth of 251MHz (57.8%) and stable radiation performance across the operating bandwidth with a minimum realized gain of -42dBi, and efficiency of 0.02% for different body tissues. Hence, this innovative design paves the way for a new generation of cost-effective, high-performance, and directly integrated antenna systems that efficiently exploit the area in the capsule.

17:20 ***Implant Antenna Reconfigured by Engineered Skeletal Muscle Tissue***

Cagla Karabulut, Ahmet Bilir, Macit Lacin and Sema Dumanli (Bogazici University, Turkey)

Synthetic biology opens new research opportunities for a brand-new generation of sensing systems and devices. With advancements in this area, it is now possible to realize living devices that can undertake sensing at a molecular level. This work presents a novel bio-hybrid implant that can achieve molecular sensing and wireless communication. The implant consists of an in-body antenna and skeletal muscle tissue. The skeletal tissue is engineered to contract in the presence of molecules of interest. The implant antenna is designed around the engineered tissue to be mechanically deformed as the contraction takes place. This deformation changes the resonance behavior of the implant antenna, which is detected by an on-body antenna. The proposed sensing system is novel in integrating engineered living cells with an implant antenna for wireless real-time monitoring of chemicals in-vivo as well as a novel in the utilization of skeletal muscle tissue for bio-sensing.

17:40 ***Semi-Implantable Antenna Integrated into a Medical Needle***

Federica Naccarata, Nicoletta Panunzio, Marco Di Cristofano, Giulio Tufi, Francesca Ciafrei, Monica Cinelli, Federico Delle Fave, Cristina Magnante and Gaetano Marrocco (University of Rome Tor Vergata, Italy)

Peripheral venous/arterial catheters are among the most used devices in hospitals to inoculate fluids or to perform medical tests. These devices are invasive and not immune to risks. Namely, the insertion of a catheter can frequently lead to Catheter-Related Bloodstream Infection. The diagnosis is currently based on qualitative clinical observation of the insertion site and, rarely, by temperature monitoring with expensive infrared thermography. The cannula equipped with temperature-sensing capability and wireless communication connectivity could enable periodic remote monitoring of the insertion site at lower costs. This paper describes a method to equip the polymeric cannula with an antenna and a battery-less RFID IC, that is provided with an integrated temperature sensor. The resulting Smart Cannula is fully biocompatible and leaves unperturbed the lumen of the blood vessel. Numerical simulations and preliminary tests demonstrated a reliable communication link with a hand-held, or fixed reader at the bedside, up to 35-50 cm.

18:00 ***Maximum Radiation Efficiency of an Implantable Antenna: The Role of High-Order Modes***

Jakub Liška (Czech Technical University in Prague, Czech Republic); Mingxiang Gao (EPFL, Switzerland); Lukas Jelinek and Miloslav Capek (Czech Technical University in Prague, Czech Republic); Anja K. Skrivervik (EPFL, Switzerland)

A combination of two numerical techniques of computational electromagnetics, namely, method of moments and vector spherical wave expansion, is used to show performance limitations on the radiation efficiency of implantable antennas and to efficiently resolve computation difficulties imposed by the interaction of an electrically small radiator with its host body. The results computed for ideal and realistic radiation sources prove the significantly limited performance of implantable antennas. The role of substructure characteristic modes decomposition in the formulation of this fundamental limit is explained.

Tuesday, March 28 16:40 - 18:20

A28: Sub-6 Antennas for 5G systems

T01 Sub-6GHz cellular / / Antennas

Room: Spadolini 105

Chairs: Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain), Silvio Hrabar (University of Zagreb, Croatia)

16:40 ***A Wideband Dual-Polarized Filtering Antenna for Multi-Band Base Station Application***

Xuekang Liu (University of kent, United Kingdom (Great Britain)); Benito Sanz-Izquierdo (University of Kent, United Kingdom (Great Britain)); Haiwei Zhang (Huawei Technologies Ltd, China); Steven Gao (Chinese University of Hong Kong, China)

A dual-polarized filtering antenna with wide impedance bandwidth and good rejection level at n78 and n79 bands is realized in this paper. By deftly exciting the inherent radiation nulls of the dual-coaxial-fed dipole antenna, good out-of-band rejection levels can be achieved in both the lower frequency band and the n79 band. Then, by replacing the ordinary dipole arms with split loop resonators, new adjustable radiation null can be obtained in the n78 band. The effective length of the split loop resonator can be changed to conveniently alter this radiation null. A prototype of the proposed design was made and tested. The fabricated prototype achieves a wide impedance bandwidth of 52% (1.69- 2.87 GHz) which can cover established 1.71-2.69 GHz LTE bands. Besides, the proposed antenna realizes good gain suppression levels at the n78 and n79 bands. The tested mutual coupling between its differential input ports is lower than -40 dB.

17:00 ***A Triple-Mode Dual-Polarized Metasurface Antenna for 5G Terminal Applications***

Long Qian and Xiaodong Chen (Queen Mary University of London, United Kingdom (Great Britain)); Hanyang Wang (Huawei Technologies, United Kingdom (Great Britain)); Hai Zhou (Huawei Technology (UK), United Kingdom (Great Britain)); Meng Hou (Huawei Technologies CO., LTD, China)

This paper presents a triple-mode dual-polarized metasurface antenna with high isolation for fifth-generation (5G) terminal applications. The proposed antenna consists of a 4 × 4 nonuniform metasurface radiator and a cross-shaped feeding probe. Based on the theory of characteristic modes (TCM), the resonance potential of the different characteristic modes (CMs) is discussed for the proposed nonuniform metasurface radiator. By combining the differential-fed scheme, three pairs of degenerate modes can be excited to realize wide impedance bandwidth. Meanwhile, the independent tuning characteristics for the three resonances are also achieved. The simulated results show the proposed dual-polarized antenna with a low profile of 1.8 mm can cover 3.3-4.2 GHz with 45 dB isolation, which is promising to be applied to 5G mobile devices.

17:20 ***Planar Beamforming Networks for Producing Multiple Independently Steerable Beams***

He Zhu (University of Technology Sydney, Australia); Charles Guo (UNSW, Australia); Y. Jay Guo (University of Technology Sydney, Australia)

This paper presents a design of multibeam beamforming networks (BFNs) using planar microstrip circuit. The multibeam BFNs, which are based on the generalized joined coupler matrices, can produce multiple independently steerable beams using one feed network. Key to the BFN design is a mixture of one-section and two-section branch-line couplers, which are able to realize a wide range of coupling coefficients. The theoretical analysis on a 3 × 8 is conducted first, and then an electromagnetic model is designed and simulated using microstrip lines. Finally, the BFN is fabricated, tested, and employed to feed an 8-element linear array, demonstrating its capability of producing three steerable beams.

17:40 ***A Dual-Slant-Polarized In-Band Full-Duplex (IBFD) Antenna System with Four Isolated Channels***

Yuenian Chen (University of Technology Sydney, Australia); Can Ding (University of Technology Sydney (UTS), Australia); He Zhu (University of Technology Sydney, Australia); Ying Liu (Xidian University, China); Y. Jay Guo (University of Technology Sydney, Australia)

An in-band full-duplex (IBFD) antenna system having four ports with good self-interference cancellation (SIC) is presented in this paper, in which three types of coupling need to be suppressed simultaneously. They are the cross-polarization coupling between the two ports of the same antenna, the co-polarization coupling between adjacent antennas, and the cross-polarization coupling between adjacent antennas. The three types of couplings are defined as A- type, B- type, and C-type coupling, respectively. In this work, a novel isolation feed network is firstly proposed to deal with coupling A. Then, the B- and C-couplings are also well suppressed in a double-antenna system thanks to the combined decoupling structures. The resultant isolation between any two of the four ports is > 39 dB from 3.3 to 3.9 GHz. The radiation patterns of the four ports are very similar and stable, which makes it an excellent candidate for 5G sub-6 GHz IBFD applications.

18:00 ***Circularly Polarized Magneto-Electric Dipole with Axial Ratio Enhancement***

Khalid AlMegbel (University College London & King Abdulaziz City for Science and Technology (KACST), United Kingdom (Great Britain)); Kin Fai Tong (University College London, United Kingdom (Great Britain))

In this paper, we propose a new circularly polarized circular magneto-electric dipole antenna. The proposed antenna has a wide impedance bandwidth of 66.66% from 3.0 to 5.4 GHz, high stable gain with maximum gain of 9.3 dBi at 4.0 GHz and wide 3-dB axial ratio bandwidth of 44% from 3.5 to 5.35 GHz. The radiating element is smaller in size by 35% while maintaining a high stable gain, and wide 3-dB axial ratio bandwidth. To improve the 3-dB axial ratio, we introduced a pair of rectangular slots on the electric dipoles that can adjust the four ME-dipole modes for reducing the size of ground reflector. The antenna is designed on a RT/duroid® 5880LZ filled PTFE substrate with thickness of 1.27 mm and �r =2, tanδ = 0.0027.

Tuesday, March 28 16:40 - 18:20

A08: Advanced Array Design Techniques

T09 EM modelling and simulation tools / / Antennas

Room: Spadolini 106

Chairs: Simone Genovesi (University of Pisa, Italy), Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

16:40 ***On Realized Gain-Optimal Feeding Coefficients of Antenna Arrays***

Albert Salmi and Anu Lehtovuori (Aalto University, Finland); Ville Viikari (Aalto University & School of

Electrical Engineering, Finland)

The feeding coefficients maximizing the realized gain are often solved from an eigenvalue problem. We derive an alternative method for obtaining the optimal feed coefficients in this paper and show that it gives the same solution. The derived method obtains the coefficients from a direct equation. We compare the realized gain obtained with the optimal feeding coefficients to the case where the elements are progressively phased. The examples show that with optimal feeding coefficients the realized gain can be improved in cases where the mutual coupling is high, edge-element effect is strong, or the embedded element patterns are unequal. Also, an example demonstrates that circularly polarized realized gain can be improved in dual polarized array by feeding the elements with optimal coefficients.

17:00 ***Design-Oriented Fast Analysis of Low Profile Patch Antennas with Shorting Wires***

Alfonso Gómez García (Universidad de Extremadura, Spain); Jesús Rubio (University of Extremadura, Spain); Miguel A. González de Aza and Jesus Garcia (Universidad Politecnica de Madrid, Spain); Yolanda Campos-Roca and Rafael Gómez Alcalá (University of Extremadura, Spain); Juan F. Izquierdo (Universidad de Extremadura, Spain); José Gil (Universidad Politécnica de Madrid, Spain)

This work proposes a fast and versatile full wave analysis procedure for coaxial probe-fed microstrip antennas loaded with shorting vias. The method, based on a hybrid finite element and modal analysis, characterizes in isolation the shorting pins and the probe feeding by generalized scattering matrices in terms of cylindrical modes. The analytical connection of these matrices makes it possible to obtain a fast and rigorous simulations for different number and distributions of pins, and location of the probe feeding, providing a suitable tool for design purposes.

17:20 ***Considerations for Mutual Coupling and Mutual Radiation Resistance of Array Antenna***

Nakato Kojima (Mitsubishi Electric Corporation & Kamakura Works, Japan); Koichi Miyazaki (MELCO, Japan)

In this paper, the mutual impedance and mutual radiation resistance of an array antenna are expressed and compared using the field expansion in terms of vector spherical harmonics. It is demonstrated that if the element fields are rotationally symmetric and the field expansion coefficients are real, the mutual radiation resistance is the real component of the mutual impedance. \ Furthermore, under the assumption that the current shapes are not affected by mutual coupling, the first-order approximation of the array gain, which explicitly incorporates the mutual impedance matrix, is derived. Also, the first-order approximation of the array directivity, which explicitly includes the mutual radiation resistance matrix, is derived. Both the expressions have similarities. However, the major difference is that the array directivity includes the Kronecker product of the conjugate of the input current and the input current whereas the array gain does not.

17:40 ***Design and Optimization of Slotted Arrays by Power Synthesis Approach***

Davide Guarnera (University of Reggio Calabria Mediterranea, Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy); Loreto Di Donato (University of Catania, Italy); Andrea Francesco Morabito (University Mediterranea of Reggio Calabria, Italy); Tommaso Isernia (University of Reggio Calabria, Italy); Gino Sorbello (University of Catania, Italy)

In this paper, we present a method for the design and optimization of slotted arrays capable of radiating a maximally focused beam in a given direction by controlling sidelobe level. The pattern synthesis problem is reduced to a convex optimization problem by using the optimal power pattern synthesis approach. The optimization algorithm is implemented by interfacing an in-house developed code with an electromagnetic CAD. Two design examples are provided to show effectiveness of the proposed method, namely a linear polarized (LP) and a circular polarized (CP) linear slotted arrays etched on standard rectangular waveguides.

18:00 ***Penrose Tiling Subarrays Exploiting Mixed Antenna Element Factors for Large-Scanning Phased Arrays***

Francesco Alessio Dicandia (National Research Council (CNR), Italy); Simone Genovesi (University of Pisa, Italy)

A novel strategy for improving the performance of a wide-scan phased array is proposed by resorting to the exploitation of antenna elements with different radiation patterns. Contrarily to works that rely on reconfigurable antenna elements, our approach does not require any switching paradigm or tunable element such as diodes. This allows to prevent the insertion loss typical of these components. The complexity of the array is further decrease by adopting a subarray partitioning scheme based on Penrose tessellation. The pursued goal is to achieve a minimum level of maximum gain within the scan area with the least number of feeding point (i.e., subarrays). The problem is clearly multi-objective and therefore the outcome is represented by a Pareto front.

Tuesday, March 28 16:40 - 18:20

CS5: AMTA session: Satellite Antenna Measurements

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 107

Chairs: Kim Hassett (MVG Orbit/FR, USA), Christian Hunscher (Airbus DS GmbH, Germany)

16:40 ***Uncertainty of a VHF CubeSat Measurement Based on the Synthetic Probe Array Technique***

Francesco Saccardi and Andrea Giacomini (Microwave Vision Italy, Italy); Ruben Tena Sánchez (MVG, Italy); Enrico Tartaglino (Microwave Vision Italy, Italy); Paul Moseley (European Space Agency, Switzerland); Luis Rolo (European Space Agency, The Netherlands); Lars Foged (Microwave Vision Italy, Italy)

In this paper the measurement uncertainty analysis of the radiating tests of the Hera-Juventas CubeSat performed in the indoor HERTZ facility at ESA/ESTEC are presented. The satellite is equipped with a ground penetrating radar mounting two half-wavelength dipoles working in the 50-70MHz band. The nominal lowest frequency of HERTZ is 400MHz hence, to cope with the degraded measurement accuracy at VHF, an ad-hoc measurement solution composed of several "key-components" has been implemented. The synthetic probe array technique, based on the field sampling at different positions generating a virtual array to reduce the illumination of the chamber walls, is the heart of implemented solution. Moreover, the quarter-wavelength averaging technique and the efficiency substitution method, along with RF transparent measurement equipment have also been considered.

17:00 ***Excitation Coefficient Determination for an Antenna Elevation Network Using Installed Performance Radiation Measurements***

Bernd Gabler (German Aerospace Center (DLR), Germany); Alicja Schreiber (German Aerospace Center, Germany)

Phased arrays are typically designed from largely similar radiating elements that are fed by a beam forming network (BFN). The ambient structure thereby impacts the installed performance and needs to be considered in the excitation coefficients determination. However, obtaining reliable results with purely numerical tools for aerospace composite material structures is questionable without electromagnetic parameter investigation. This work describes a method based on individual far-field measurements of sub-arrays in a Compact Antenna Test Range (CATR). The array pattern is synthesized by planar near-field (PNF) techniques. Excitation coefficients are optimized to mitigate structure influence without additional electromagnetic material properties investigation. The procedure is exemplified with a Ka-band phased array for airborne synthetic aperture radar applications. Individual on structure slotted waveguide antenna (SWA) element measurements, excitation coefficients determination and the synthesized radiation pattern are shown. In a proof of concept with structures assuming perfect conductivity, measurement-based processing results are compared with simulations.

17:20 ***2019-2022 ESA-EurAAP Facility Comparison Campaign with the DTU-ESA mm-VAST Antenna - Towards a Reference Pattern***

Javier Fernández Álvarez, Jeppe Nielsen and Michael Mattes (Technical University of Denmark, Denmark); Thomas M. Gemmer (Rohde & Schwarz GmbH & Co. KG, Germany); Anna Granich

(RWTH - Aachen University, Germany); Fernando Las-Heras (University of Oviedo, Spain); Marcos R. Pino (Universidad de Oviedo, Spain); Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain); Xiaoliang Sun (Universidad Politécnica de Madrid, Spain & Universidad Politecnica de Madrid, Spain); Philippe Ratajczak (Orange Innovation, France); Laurent Le Coq (University of Rennes 1 & IETR, France); Roberto Vallauri and Andrea Vicentini (Telecom Italia, Italy); Herald Garcia (THALES ALENIA SPACE, France); Denys Allenic (Thales Alenia Space, France); Luis Rolo (European Space Agency, The Netherlands); Ines Barbary (ESA-ESTEC, The Netherlands); Maria Saporetti (Microwave Vision Group, Italy); Ruben Tena Sanchez (Microwave Vision Group (MVG), Italy); Christian Hunscher (Airbus DS GmbH, Germany); Javier Herreros (EADS-CASA Espacio, Spain)

The ongoing 2019-2022 ESA-EurAAP Facility Comparison Campaign with the DTU-ESA mm-VAST antenna involves 12 European institutions and 13 spherical near-field and compact range measurement facilities. The mm-VAST antenna is employed in three operational configurations at 19.76 GHz, 37.80 GHz, and 48.16 GHz, including both linear and circular polarization. This paper presents results of 10 out of 13 expected measurements from the campaign, from which a set of reference measurements of the mm-VAST will be derived. As a first step towards this task, a comparison of the radiation patterns, and several metrics of difference between these patterns are presented. These comparisons aim to identify those measured patterns most suitable to be incorporated in the future mm-VAST reference pattern, and which should be discarded as outliers.

17:40 ***Introducing HERTZ 2.0 - A New Era in Antenna and Satellite Testing in Europe***

Luis Rolo and Peter de Maagt (European Space Agency, The Netherlands); Damiano Trenta (European Space Agency, ESTEC, Italy); Piero Angeletti (European Space Agency, The Netherlands)

This paper introduces a new antenna, payload and satellite testing facility, called HERTZ 2.0, currently under construction at the European Space Research and Technology Centre (ESTEC) in Noordwijk, The Netherlands. An overview of the building configuration, testing schemes capabilities and applications are provided.

18:00 ***(Sub-)mm-Wave Antenna Measurements Up to 668 GHz on the MetOp-SG Ice Cloud Imager in a Compensated Compact Range***

Philipp Heine and Ulrich Bettin (Airbus Defence and Space, Germany); Marc Bergada and Tamara Coello (Airbus Defence and Space, Spain); Pedro Robustillo (Airbus Defence and Space, Germany); Ulf Klein (European Space Agency, The Netherlands); Luca Salghetti Drioli (European Space Agency-ESTEC, The Netherlands)

The antenna and geometric performance of the Ice Cloud Imager (ICI) radiometer, developed by Airbus Defence and Space Spain for ESA and EUMETSAT's MetOp-SG program, has been verified. The measurements up to 668 GHz were performed in June 2022 in the Compensated Compact Range CCR75/60xi at Airbus Defence and Space in Ottobrunn, Germany. The first-of-its-kind instrument required an innovative antenna test setup. A new mechanical accommodation principle for accurate full-sphere pattern acquisitions was implemented. With help of the newly developed Airbus Search and Tracking System (SAT), frequency instabilities caused by ICI's unlocked local oscillators were removed from the test signal. A measurement dynamic range of 65 dB at 668 GHz up to 87 dB at 176 GHz was achieved. This paper presents the implemented test setup, correlation results between measured and simulated antenna patterns at ICI's 664 GHz channel and a summary of the measured antenna and geometric performance.

Tuesday, March 28 16:40 - 18:20

A10: Innovative Lens Antennas I

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 108

Chairs: Y. Jay Guo (University of Technology Sydney, Australia), Davide Ramaccia (RomaTre University, Italy)

16:40 ***All-Metal Metamaterial Based Luneburg Lens Antenna with Wide Bandwidth and High Efficiency***

Peng Hu and Ji-Wei Lian (Nanjing University of Science and Technology, China); Maral Ansari (CSIRO, Australia); Y. Jay Guo (University of Technology Sydney, Australia); Dazhi Ding (Nanjing University of Science and Technology, China)

A parallel-plate Luneburg lens (LL) based on all-metal metamaterial is presented in this paper. To achieve the required refractive index distribution of the LL, an all-metal unit cell with a separated cuboid is proposed, whose height is related to its refractive index. Based on the designed metamaterial LL, a multibeam antenna is developed by providing seven inputs, which can generate seven predefined beams. Several parts of the prototype are separately fabricated and assembled, and good agreement is observed between simulation and measurement. The designed LL based multibeam antenna has several advantages including flexible structure, wide bandwidth, high aperture efficiency, and high radiation efficiency.

17:00 ***Broadbeam Geodesic H-Plane Horn Antenna***

Mingzheng Chen (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

We propose broadbeam H-plane horn antennas, potentially useful as simple primary feeds for reflectors. Since H-plane horn antennas are implemented in a structure similar to the parallel-plate waveguide, we show that a numerically efficient ray-tracing model can be used to describe wave propagation through them. Using the efficient ray-tracing tool, we optimize three different height profiles to obtain broad beams with different half-power beamwidths at the central operating frequency of 30 GHz. All implemented structures have beamwidths larger than those of a planar reference counterpart.

17:20 ***High Gain W-Band Lens Antenna for Monostatic Radar Applications: A System-Oriented Approach***

Matthias Linder (Ulm University, Germany); Jonas Strauch (Aerospace, Germany); Dominik Schwarz (Ulm University, Germany); Christian Waldschmidt (University of Ulm, Germany)

In order to detect objects with a very small radar-cross section or targets that are positioned at a great distance to the radar sensor, a high signal power is needed. Therefore, the design and evaluation of a large lens antenna for high precision long range radar measurements is presented. To enhance the system's capabilities an advanced design strategy is chosen. The antenna is designed with respect to the interaction within the radar system. As part of the system-centric antenna design, both signal power and noise influence are evaluated. To provide a high range resolution, the frequency band of 76 GHz - 81 GHz is chosen. An efficient matching of the lens antenna is realized by blind holes. The lens antenna has a gain of 35 dBi and beam widths of 1.6 degrees in elevation and 1.75 degrees in azimuth.

17:40 ***Retrodirective Rotman Lens Active Reflector***

Hanieh Kiani Amiri (University of Calgary, Canada); Michal Okoniewski (University of Calgary & Acceleware Ltd, Canada)

This article reports further progress in developing an active-loaded Rotman lens reflector for radar cross section (RCS) enhancement. Although the Rotman lens has been employed in backscattering applications, its passive performance imposes gain constraints when it comes to RCS improvement. In the novel structure we present, the lens is outfitted with custom-designed low-power reflection amplifiers to enable overall system gain amplification and modulation. An array of printed-Yagi antennas has been added to the lens, and the monostatic RCS pattern of the lens antenna has been measured. The lens antenna exhibits a nearly uniform RCS pattern between -35 and 35 degrees at 5.3 GHz in both active and passive modes. The active lens structure demonstrates a 5.5 dB increase in RCS while loaded with 11 amplifiers with a ≈6.5 dB gain. The active reflector consumes only ≈1.2 mw of power. Due to its high gain, wide angular coverage, and low power consumption, this structure is ideally suited for low-power RCS enhancement applications, such as mm-wave automotive radar sensors.

18:00 ***A General Solution for Double-Layer Gradient-Index and Geodesic Lenses with Rotational Symmetry***

Qiao Chen (KTH Royal Institute of Technology, Sweden); Simon Horsley (University of Exeter, United Kingdom (Great Britain)); Nelson Fonseca (European Space Agency, The Netherlands); Tomáš Tyc (Masaryk University, Czech Republic); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

A double-layer lens consists of a pair of rotationally symmetric index profiles or geodesic lens shapes connected by a reflecting mirror partially covering their common periphery. Such a lens can provide a focus in each layer, and a wave travelling between the foci explores both layers. Here, we concentrate on the case with one layer being homogeneous or flat, and derive a general solution for the lens profiles by solving a Luneburg-like inverse problem with pre-specified foci inside or outside the lens, and different background indices in two layers. We demonstrate four examples of interest in ray-tracing plots. These lenses may find application in communications, sensing, and imaging from millimeter waves up to the optical bands.

Tuesday, March 28 16:40 - 18:20

CS13: Characteristic Mode Analysis for Next Generation Systems and Technologies

T09 EM modelling and simulation tools / Convened Session /

Room: Spadolini 109

Chairs: Philipp Gentner (Ericsson Antenna Technology Germany GmbH, Germany), Mahrukh Khan (The College of New Jersey, USA)

16:40 ***Characteristic Modes Theory Exploitation for the Design of Transmission-Type Polarization Converters***

Francesco Alessio Dicandia (National Research Council (CNR), Italy); Simone Genovesi (University of Pisa, Italy)

A novel strategy for the design of a transmission-type polarization converter of linearly polarized (LP) plane waves is proposed. More in detail, a general and straightforward approach based on the exploitation of the characteristic modes analysis (CMA) for identifying the frequency selective surface (FSS) unit cell is described. The excitation of two current modes on the proposed FSS unit cell, both exhibiting a circularly polarized (CP) radiated field, are provided to obtain an efficient polarization rotator. Measurement campaigns confirm the benefits of adopting CMA as well as the remarkable performance.

17:00 ***Fundamental Bound on Maximum Antenna Gain as a Sum of Characteristic Modes***

Miloslav Capek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic)

Characteristic mode theory for lossy obstacles is employed to show that the fundamental bound on maximal antenna gain can be composed of a simple sum of characteristic antenna gains. This connects traditional work on bounds proposed by Harrington and modern current-density-based approaches utilizing convex optimization. The developed theory helps to understand what the true performance bound of a design region is. The paper is accompanied by an example demonstrating the working principles and verifying the developed theory.

17:20 ***Comparison of Floquet Port-Based Unit Cell Design and Characteristic Mode Analysis for Anomalous Reflecting Metasurfaces***

Axel Hoffmann (Leibniz Universität Hannover, Germany); Michael Ponschab (Ericsson Antenna Technology GmbH, Germany); Mathias Pietzka (Ericsson Antenna Technology Germany GmbH,

Germany); Lucas Nogueira Ribeiro (Ericsson Antenna Technology GmbH, Germany); Philipp Gentner (Ericsson Antenna Technology Germany GmbH, Germany); Dirk Manteuffel (University of Hannover, Germany)

A comparison of Floquet port-based design and Characteristic Mode Analysis (CMA) for anomalous reflecting metasurfaces is presented. Floquet port simulations of a unit cell are performed to realize the desired induced phase gradient over the surface. While this method is well established and implemented in commercial software, it offers little insight into the electromagnetics of the structure. Therefore, a CMA utilizing the Floquet theorem is linked to the structure analysis to give further insight into the current distribution of the unit cell. An example setup as well as computational results are provided to compare both methods. It is shown that the CMA method provides advanced analysis of the physical behavior of the reflecting metasurface, which helps to improve the design process.

17:40 *On the Use of Characteristic Mode Analysis for Dual Beam Antenna Array*

Mahrukh Khan and Nicholas Lusdyk (The College of New Jersey, USA)

This paper presents a design of probe fed dual beam 2x2 antenna array at 2.4 GHz. The dual beam of the antenna array was obtained by a simple technique of exciting the neighboring elements with phases of 180o. The characteristic mode analysis (CMA) was performed to get the better understanding of multiport structure. The critical parameters of CMA, such as modal currents, modal radiation patterns, modal significance, and modal weighting coefficient, were used to reveal the physical insight behind the dual beam behavior. It showed how the feed induced phase reversal affects the surface currents to produce a dual beam. The dual beam was produced at the angle of 55o with a beamwidth of 61o and a peak gain of 8 dB. The antenna array showed stable gain with a cross-polarization level as low as -60 dB. The antenna elements were placed at a distance of 0.45λ from each other.

18:00 *Enhancement of Local Field by Using Characteristic Mode Analysis*

Yi Zheng (Shanghaitech University, China); Feng Han Lin (ShanghaiTech University, China)

A method of enhancing local field in the Fresnel region by multimode multi-port antenna element is proposed. Characteristic mode analysis (CMA) is utilized to aid the design of the multimode resonator and guide the multi-mode excitation, with which the peak of the selected polarization component is adjustable over an observation plane at a distance of 1.8λ0 above the antenna, where λ0 is the wavelength in free space at 5.5 GHz. With an overall planar size of 0.62λ0 × 0.62λ0, the proposed antenna is prototyped and measured. At selected positions over the plane, the measured half-receiving-power bandwidth ranges from 9.7% to 15.6%, where the measured AC-to-AC power-transmission efficiencies are from 1.5% to 3.6% accordingly. Compared with conventional methods using antenna arrays and leaky-wave radiation, the proposed method has the advantages of unlimited field region, compact size, large bandwidth, and high efficiency-range ratio for wireless power transfer and harvesting.

Tuesday, March 28 16:40 - 18:20

IW6: On antenna value in the telecommunication industry: Information Theory and EM (Huawei)

Room: Polveriera

Tuesday, March 28 16:40 - 18:20

SW4: Small antennas for societal development goals

Room: Palazzina 7

Wednesday, March 29 9:00 - 10:40

A07: Leaky Wave Antennas I

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 001

Chairs: Darwin Blanco (Ericsson, Sweden), Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain)

9:00 ***Quasi-Optical Excitation of a Modulated Dual-Polarized Leaky-Wave Antenna***

Kamil Yavuz Kapusuz (Ghent University & IMEC, Belgium); Adham Mahmoud (Institut d'Électronique et de Télécommunications de Rennes, France); Sam Lemey (Ghent University-imec, Belgium); Hendrik Rogier (Ghent University, Belgium); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

A multi-beam dual-polarized antenna fed by four quasi-optical beamformers is presented in SIW technology. The beamforming networks are folded in two layers exploiting a pillbox transition based on several coupling slots and a SIW parabolic reflector. Such beamformers allow to transfer efficiently and over a large band the energy coming from feeding sources in the lower substrate to the radiating part located in the uppermost layer. The radiating part consists of a two-dimensional periodic array of cross-slots etched in the upper conducting plane. The slots are tapered to achieve high aperture efficiency and SLL below 25-dB. The proposed antenna system operates in the entire 28-GHz 5G-band. The antenna footprint equals to overall radiating aperture with a size of 11.6x11.6-cm2. The proposed structure features 360° scanning in the azimuth plane by beam switching and more than ±55° in the elevation plane by frequency steering with gain higher than 20 dBi.

9:20 ***Design of Frequency-Beam Scanning Antennas for Ultra Wide Band Impulse RADAR Applications***

Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Miguel Poveda-García and Roberto Romero-Justiniano (Technical University of Cartagena, Spain); Alejandro Gil Martinez (Technical University of Cartagena Cartagena, Spain); David Cañete Rebenaque (Polytechnic University of Cartagena, Spain)

We report the design of microstrip leaky-wave antenna for impulse RADAR applications using Ultra Wide Band (UWB) signals in the 6.5 GHz to 8 GHz band. Thanks to its frequency-beam scanning response, this antenna can be used for low-cost angle-of-arrival and range estimation by simply using three different frequency channels available in the UWB standard. The importance of the selection of the dielectric substrate to optimize the angular scanning range using this 1.5 GHz bandwidth, is studied in detail. Finally, using $\varepsilon_r = 2.2$, it is reported an angular scanning range of 120 degrees, with a simulated peak gain varying from 9.5 dBi at broadside direction to 7.7 dBi when scanning at ±60º. The antenna shows high radiation efficiency above 50%, and good input matching in the whole scanning bandwidth. Also, the unwanted effects of the beam-squinting in the 500 MHz instantaneous bandwidth of an UWB channel, are analyzed.

9:40 ***Directive Leaky-Wave Radiation in Holey Photonic Crystals***

Ludovica Tognolatti, Paolo Baccarelli, Cristina Ponti, Giuseppe Schettini and Silvio Ceccuzzi (Roma Tre University, Italy); Vakhtang Jandieri (General and Theoretical Electrical Engineering (ATE), Faculty of Engineering, Germany)

In this contribution, a study of the directive radiation from 2-D holey photonic crystal structures consisting of air columns in a dielectric medium (HPCs) and excited by an electric line source is presented. Comparisons with the radiation obtained from complementary structures consisting of dielectric cylinders in free space are described, demonstrating how this class of holey lattices can be used to design highly directive leaky-wave antennas, with significant advantages of manufacturing and design simplicity.

10:00 ***Suppressing Open Stopband for Terahertz Periodic Microstrip Leaky-Wave Antennas***

Thomas Haddad (University of Duisburg-Essen, Germany); Carlos Biurrun-Quel (Universidad Publica de Navarra & Institute of Smart Cities, Spain); Peng Lu (University of Duisburg-Essen, Germany); Hacer Kaya (University of Duisburg Essen, Germany); Israa Mohammad (Universität Duisburg-Essen, Germany); Andreas Stöhr (University of Duisburg-Essen, Germany)

This paper reports on a periodic microstrip Leaky-wave antenna (LWA). The open stopband issue is suppressed by altering the unit cell using a matching stub. The developed LWA is based on a grounded InP-substrate of 50 μm and has been fabricated and characterized between 0.23 to 0.33THz. The dispersion diagram of the designed unit cell shows enhancement of the attenuation constant at the broadside frequency of 0.273 THz and about 50% less deflection at the broadside region on the Bloch impedance curves, consequently better impedance matching at the input. The simulated scattering parameters of the proposed LWA show that the return loss S11 is below 17dB except for the broadside, which has a value of 13.8 dB. Furthermore, the beam steering capabilities of the antenna are simulated in the WR3.4 band and confirmed experimentally between 0.26 and 0.33 THz proving the beam direction to steer from −12° to +33°, respectively.

10:20 ***Leaky-Wave Analysis of an Ultrathin Planar High Impedance Surface Antenna***

Ahmad T. Almutawa (PAAET, Kuwait); Filippo Capolino (University of California, Irvine, USA)

High impedance surfaces (HISs) have been used in the past to act like artificial magnetic conductors to improve the efficiency of a dipole parallel to a metallic surface. We demonstrate how such HISs can be directly used as antennas without the need for a dipole on top. The HIS is made of 2D periodic dogbone-shaped patches on top of an extremely thin grounded substrate with a thickness around 1/100 of a wavelength. The analysis of a unit cell of the HIS antenna in terms of its magnetic resonance (zero phase reflection) gives sufficient information on the radiation of the HIS operating as a leaky-wave antenna with large attenuation constant. We implement a fast and simple method based on Floquet-Bloch periodic boundary conditions (PBCs) to design and optimize the radiation properties of such an antenna. Despite being extremely flat, the HIS antenna provides a significantly large relative gain-bandwidth exceeding 15%.

Wednesday, March 29 9:00 - 10:40

CS16: Emerging Antenna Technologies of Beam Manipulation for Beyond 5G and Space Applications

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Peiyuan Qin (University of Technology Sydney, Australia), Hang Wong (City University of Hong Kong, Hong Kong)

9:00 ***Circularly Polarized Shared Aperture K-Band Transmitarray and Beamforming S-Band Patch Antenna Array***

Daniel E. Serup, Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)

This paper presents a circularly polarized shared aperture antenna. The proposed antenna is a combined S-band patch antenna array and a K-band transmitarray antenna. The high-frequency transmitarray feed and the low-frequency patch antenna array share the same aperture area. The high-frequency transmitarray surface only uses a single substrate layer and is electrically transparent to the low-frequency antenna part. With an impressive frequency-ratio of 5.55 and a radiating area of only 10x10 cm the antenna achieves an impedance bandwidth of more than 1 GHz and 5 GHz, and a peak realized gain of 15.35 dBi and 22.85

dBi, in the S- and K-band respectively. Additionally, the low-frequency antenna mode shows a good beamforming performance with a 120-degree steering range with only a 1.25 dB gain variation.

9:20 *Wideband Terahertz Metasurfaces with Beam Manipulations*

Yat Sing To, Quan Wei Lin and Hang Wong (City University of Hong Kong, Hong Kong)

A wideband terahertz (THz) reflective metasurface with reconfigurable beam manipulation operating at 0.1THz is proposed in this paper. A novel 1-bit reconfigurable unit cell is designed and analyzed. Owning to the characteristics of phase change material (PCM), GeTe, the electrical property of the unit cell can be changed to provide 0- and 180-degree phase tuning. To validate the performance of the proposed active element, a coded reflective metasurface is demonstrated by utilizing the geometric phase compensation technique. The proposed metasurface achieves switchable directional beams at 0 and 30 degrees through distinct coded patterns, while maintaining the wide operating bandwidth ranging from 100GHz to 120 GHz with the stable realized gains of 22 dBi. The obtained results indicated the effectiveness of controlling beam angle and directivity and the feasibility of integrating PCM into THz devices. Hence, the proposed THz reflective metasurface shows its potential for future implementation in 6G applications.

9:40 *28 GHz Huygens Antenna Array with Ultrahigh Aperture Efficiency*

Wei Lin (The Hong Kong Polytechnic University, Hong Kong); Richard W Ziolkowski (University of Arizona, USA & University of Technology Sydney, USA)

This paper presents a 28 GHz Huygens antenna array with close to 100% aperture efficiency. The basic radiating element is a 1 × 2 Huygens sub-array that is expanded into a large scale 8 × 16 array that is realized in a full-metal structure. Under uniform excitations, the aperture efficiency of the array reaches 97.5% that is very close to the theoretical maximum 100%. This exceptional performance indicates that almost the entire surface is contributing to the co-polarized radiation with ultrahigh aperture utilization rate due to the Huygens radiation effect. To apply this concept into wireless applications requiring low sidelobe levels, an array with tapered excitations achieving sidelobe levels less than -20 dB was fabricated and tested. The achieved realized aperture efficiency is the highest among all previously reported large scale arrays with low sidelobe levels.

10:00 *Beamforming Metasurface for Antenna Systems in 5G/6G Environments*

Luca Stefanini (Roma Tre University, Italy); Alberto Rech (University of Padova, Italy); Davide Ramaccia (RomaTre University, Italy); Stefano Tomasin and Federico Moretto (University of Padova, Italy); Alessandro Toscano and Filiberto Bilotti (Roma Tre University, Italy)

Fifth-/sixth-generation communication systems are facing several challenges in terms of speed requirements, bandwidth allocation at higher frequencies, and the number of servable users. In this framework, highly directive Phased Array Antennas (PAAs) have been employed with the goal to mitigate the path losses at those frequencies and benefit the narrow beams by reducing interfering signals. However, this shifted the access to the network from omnidirectional search to sequential search, requiring dynamic reconfigurability of PPA on time and thus complex beam-forming networks. In this contribution, we report our results on the design of a beamforming metasurface that behaves as a matrix beamforming network. The proposed system speeds up the IA procedure with respect to traditional systems thanks to its parallel transmission mode: many beams can be fired at the same time drastically reducing the latency. The results demonstrate that a much faster IA with a similar success probability can be reached.

10:20 *Multi-Beam Conformal Transmitarray Synthesis for Advanced Wireless Systems*

Lizhao Song (Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia); Peiyuan Qin (University of Technology Sydney, Australia); Jia Du (CSIRO, Australia); Y. Jay Guo (University of Technology Sydney, Australia)

Multi-beam conformal transmitarrays with a single feed antenna are synthesized using two different methods for the first time. First, a particle swarm optimization (PSO) algorithm is employed for phase-only optimizations on a cylindrical transmitting surface, producing a two-beam radiation pattern at ±30° in the circular cutting plane. Second, a superposition method is investigated to achieve the same objective, showing a higher peak gain and lower sidelobe levels compared to the results from PSO. Third, the superposition method is further analyzed for a single-feed quad-beam conformal transmitarray. As a proof of concept, the prototype designed using the superposition method for two beams is manufactured and tested. Good radiation performance is observed with two beams at +29° and -28°, respectively. The peak measured gain is 18.3 dBi and the gain difference of two beams is only 0.1 dB.

Wednesday, March 29 9:00 - 10:40

CS37: Propagation research at the cross-road of telecommunication, space systems, remote-sensing and meteorology: A tribute to Frank Silvio Marzano

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 101

Chairs: Antonio Martellucci (European Space Agency, The Netherlands), Danielle Vanhoenacker-Janvier (Université catholique de Louvain, Belgium)

9:00 ***Overview on Weather Radar Applications***

Mario Montopoli (National Research Council of Italy, Institute of Atmospheric Sciences and Climate (CNR, ISAC), Italy); Giancarlo Ferrauto (Thales Alenia Space, Italy); Daniele Scaranari (Hisdesat Strategic Services, Spain); Stefano Barbieri and Marianna Biscarini (Sapienza University of Rome, Italy); Vincenzo Capozzi (University of Naples Parthenope, Italy); Luigi Mereu (Istituto Nazionale Geofisica e Vulcanologia, Italy); Marta Tecla Falconi (CETEMPS University of L'Aquila); Rossella Ferretti (CETEMPS University of L Aquila, Italy); Gianfranco Vulpiani (Presidency of the Council of Ministers, Italy)

Several meteorological services across the world are using networks of weather surveillance radars with the aim of advancing timely monitoring and quantification of precipitation as well as increasing the forecast skills through data assimilation into numerical weather prediction (NWP) models. This contribution offers an overview of the most relevant applications of weather radars in the context of operational use of such systems. The applications covered span from algorithms to ensure sufficient radar data quality, to estimate near surface rain, to perform hydrometeor identification and recognize key in-cloud process of volcanic and atmospheric extreme events.

9:20 ***Observations and Retrievals of Volcanic Ash Clouds Using Ground- and Satellite-Based Sensors***

Luigi Mereu (Istituto Nazionale Geofisica e Vulcanologia, Italy); Simona Scollo (Istituto Nazionale di Geofisica e Vulcanologia, Italy); Costanza Bonadonna (University of Geneva, Switzerland); Stefano Corradini (Istituto Nazionale di Geofisica e Vulcanologia, Italy); Franck Donnadieu (Université Clermont Auvergne, France); Mario Montopoli (National Research Council of Italy, Institute of Atmospheric Sciences and Climate (CNR, ISAC), Italy); Gianfranco Vulpiani (Presidency of the Council of Ministers, Italy); Sara Barsotti (Icelandic Meteorological Office, Iceland); Valentin Freret-Lorgeril (Université Clermont-Auvergne, France); Magnús Tumi Guðmundsson (University of Iceland, Iceland); Arve Kylling (Norwegian Institute for Air Research, Norway); Maurizio Ripepe (University of Florence, Italy)

This work was born from a wish of remembering the fundamental contribution of Prof. Frank Silvio Marzano to the field of physical volcanology. In fact, for the last fifteen years and in the context of several European projects, Prof. Marzano collaborated with many volcanologists as well as scientists from different fields and wrote many scientific articles aimed at studying the dynamics of explosive eruptions. He left his imprinting in this research sector laying the foundations of radar volcanology in Italy, and extended his studies to other sensors. His work is relevant for the analysis of the main eruption source parameters needed to

characterize the eruptive events. Here we show how remote sensing instruments applied to analyze explosive activity of different volcanoes worldwide, are going to increase the knowledge in this multidisciplinary research area and the awareness from the scientific community of the potential of these sensors at various wavelengths.

9:40 *Short-Term Forecast of the Signal Propagation Conditions, Based on Numerical Weather Prediction, Radar, and SatCom Ground Terminal Data*

Terje Tjelta (UiO, Norway); Jan Erik Håkegård (SINTEF, Norway); Martin Rytir (Norwegian Defence Research Establishment (FFI), Norway); Knut Grythe (SINTEF, Norway)

Numerical weather prediction products, radar products, and user terminal observations are used to estimate propagation conditions for the nearest hours lead time. Validation results show good correspondence between predictions and observations using beacon data and user terminal data, but with an increasing error with longer lead time forecasts. Initial results include system estimates of an improved SatCom system with smart gateways taking short term propagation condition forecasts into account.

10:00 *Profiling the Atmospheric Boundary Layer: From European Cooperation to Operational Services*

Domenico Cimini (CNR-IMAA & CETEMPS University of L'Aquila, Italy); Martial Haeffelin (IPSL, France); Rolf Ruefenacht (MeteoSwiss, Switzerland); Bernhard Pospichal (University of Cologne, Germany); Alexander Haefele (MeteoSwiss, Switzerland); Antonio Martellucci (European Space Agency, The Netherlands); Jose Villalvilla (ESA, The Netherlands); Saverio Nilo and Sabrina Gentile (Consiglio Nazionale delle Ricerche, Italy); Salvatore Larosa (CNR, Italy); Filomena Romano (IMAA-CNR, Italy)

Despite the importance of the atmospheric boundary layer (ABL) for many aspects of our life, including weather, telecommunication, renewable energy, it currently represents the most under-sampled part of the atmosphere and an observational gap at global level. Cooperation actions at European level are significantly contributing to the development and application of ABL profiling systems within the European observation network. Among these initiatives are the COST action PROBE, the E-PROFILE program, and the ACTRIS research infrastructure. In addition, the European Space Agency (ESA) deployed radiometric thermodynamic profilers at few sites of their satellite tracking station network and is promoting consistent atmospheric retrievals among them. This paper reviews these initiatives focusing on microwave radiometers, presenting preliminary results from an ESA funded project aiming at developing reference and harmonized MWR monitoring and retrievals at several ESA sites.

10:20 *Multiyear Assessment of Ground-Based Sun-Tracking Microwave Radiometric Observations in Rome, NY (USA) at Millimeter and Sub-Millimeter Wavelengths*

Luca Milani (European Space Agency, Germany); Marianna Biscarini (Sapienza University of Rome, Italy); Vinia Mattioli (EUMETSAT, Germany); George Brost (Air Force Research Laboratory, USA); Frank S. Marzano (Sapienza University of Rome, Italy)

Ground-based Sun-tracking microwave radiometric observations allow to exploit the Sun radiation as a signal source, similarly to beacon experiments. Antenna noise temperature measurements are performed by alternately pointing toward-the-Sun and off-the-Sun while tracking the Sun along the diurnal ecliptic. The Sun-Tracking microwave observations are twofold: on one hand, they provide means to estimate the Sun brightness temperature during purely clear-air conditions and, on the other hand, retrieve the atmospheric path attenuation in nearly all-weather conditions, by profiting of the known Sun brightness temperature estimates. In this paper, measurements at K- and Ka-band are analyzed, as well as observations in the marginally explored millimeter-wave frequency region at V- and W-band. A multi-year dataset was assessed, ranging from 2015 until 2018, collected by a Sun-tracking radiometer located in Rome, NY (USA). Expanded considerations on Sun brightness temperature trends are reported, together with long-term estimates of the all-weather atmospheric path attenuation.

Wednesday, March 29 9:00 - 10:40

P01: mmWave and THz propagation measurements

T02 Mm-wave and THz cellular / / Propagation

Room: Spadolini 102

Chairs: Andrés Alayón Glazunov (University of Twente, The Netherlands), Diego Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany)

9:00 ***300 GHz Channel Measurement and Characterization in the Atrium of a Building***

Yuanbo Li and Yiqin Wang (Shanghai Jiao Tong University, China); Yi Chen (Huawei Technologies CO. LTD., China); Ziming Yu (Huawei Technologies CO., LTD, China); Chong Han (Shanghai Jiao Tong University, China)

With abundant bandwidth resource, the Terahertz band (0.1~THz to 10~THz) is envisioned as a key technology to realize ultra-high data rates in the 6G and beyond mobile communication systems. However, moving to the THz band, existing channel models dedicated for microwave or millimeter-wave bands are ineffective. To fill this research gap, extensive channel measurement campaigns and characterizations are necessary. In this paper, using a frequency-domain Vector Network Analyzer (VNA)-based sounder, a measurement campaign is conducted in the outdoor atrium of a building in 306-321~GHz band. The measured data are further processed to obtain the channel transfer functions (CTFs), parameters of multipath components (MPCs), as well as clustering results. Based on the MPC parameters, the channel characteristics, such as path loss, shadow fading, K-factor, etc., are calculated and analyzed. The extracted channel characteristics and numerology are helpful to study channel modeling and guide system design for THz communications.

9:20 ***Attenuation of Building Materials and Structures in 5G Millimeter Wave Band***

Davor Bonefačić and Lara Šarolić (University of Zagreb, Croatia)

Material attenuation in the frequency band from 26 to 40 GHz was measured. Attenuation of building materials as bricks, concrete blocks, and plasterboard, as well as attenuation of glass and artificial materials used for cladding and plating is measured and presented. Furthermore, attenuation of a window with single-chamber insulated glazing unit and aluminum Venetian blinds is given. Finally, attenuation of books and magazines was also investigated. It was found that attenuation introduced by many common materials found in buildings can seriously affect signals in 5G frequency range 2 (FR2).

9:40 ***Outdoor-To-Indoor Loss Measurement for Rural/Suburban Residential Scenario at 6 and 37 GHz***

Ruoyu Sun and Dorin G Viorel (CableLabs, USA); Wilhelm Keusgen (Technische Universität Berlin, Germany)

The 6-GHz unlicensed band (5.925 - 7.125 GHz) and the lower 37 GHz shared band (37 - 37.6 GHz) are low-cost spectra considered by fixed wireless access (FWA) services to provide high throughput for non-mobile users. The propagation channel limits the FWA coverage. In this paper, we report extensive empirical channel measurements on 227 links and statistical models in these 6 and 37 GHz bands in a rural/suburban residential environment. The transmitter is placed outdoors at 5 m above ground, mimicking a strand-mount or pole-mount small-cell base station (BS). The receiver was placed in a single-family house in eighteen indoor positions and one outdoor position (backyard patio). It is observed that the indoor customer premises equipment (CPE) has a larger path loss than the outdoor CPE, being up to 21 dB and on average 12 dB at 6 GHz, and up to 32 dB with an average of 16 dB at 37 GHz. If the homeowner or CPE installer knows the BS location, placing CPE on the side of the house closer to the BS reduces on average 7 dB path loss at 6 GHz and 13 dB at 37 GHz compared to placing it on the opposite indoor side of the house. One aspen tree increases the loss by 8.5 - 10 dB and three bruce/maple trees increase the loss by on average 15 - 16 dB at both frequencies. By comparing 1000 channel impulse responses (CIRs) collected at each receiver position, small-scale fading, delay, and angle of arrival (AoA) of each multipath component (MPC) are extracted. The operator may balance the tradeoffs between different CPE positions and antennas to optimize user throughput.

10:00 ***A Study of FR2 Radio Propagation with Focus on Mobility Management in an Industrial Scenario***

Alejandro Ramírez-Arroyo (University of Granada, Spain); Melisa López (Aalborg University, Denmark); Ignacio Rodriguez (University of Oviedo, Spain); Troels B. Sørensen (Aalborg University, Denmark); Samantha Caporal del Barrio (Nokia, Denmark); Juan Valenzuela-Valdés (Universidad de Granada, Spain); Preben Mogensen (Aalborg University, Denmark)

This work presents the analysis of a measurement campaign performed in a realistic two-hall industrial environment. In order to provide secure, reliable and high available Machine-to-Machine (M2M) communications in the mmWave band for Industrial Internet of Things (IIoT) mobile applications, a study of the physical propagation channel must be carried out. The analysis shows the high variability of the propagation channel depending on the Line-of-Sight (LoS) or Non Line-of-Sight (NLoS) condition, with path loss exponents ranging from 2.10 to 4.56. The mobility analysis demonstrates the high probability of beam switching if a threshold is not defined. By imposing this threshold, there is a decrease in the complexity of mobility management in exchange for a reduction in received power at the end user.

10:20 ***Delay Spread Model for Intra-Device Environments at 285 GHz***

Jong Ho Kim (ETRI, Korea (South)); Youngkeun Yoon (Electronics and Telecommunications Research Institute, Korea (South)); Jang Seok Choi and Jae Ho Seok (National Radio Research Agency, Korea (South))

This document proposes a delay spread model for intra-device wireless communication environments using measurement data with different sizes of two desktop computer enclosures at 285 GHz band. A Vector Network Analyzer(VNA) and frequency extenders to THz band were used for measurement campaign. A delay spread model takes from analysis of measurement data at each enclosure. The proposed model represents as dependence of received power of multipath reflected signals.

Wednesday, March 29 9:00 - 10:40

CS48: Small antenna techniques for large-scale of integration

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 103

Chairs: Adam Narbudowicz (Trinity College Dublin, Ireland & Wroclaw University of Science and Technology, Poland), Divitha Seetharamdoo (IFSTTAR, LEOST & Univ Lille Nord de France, France)

9:00 ***Metamaterial Inspired Electrically Small Antenna: Design Based on Modal Stored Energy Analysis***

Ozuem Chukwuka (University of Lille & IFSTTAR Institute, France); Divitha Seetharamdoo (IFSTTAR, LEOST & Univ Lille Nord de France, France)

We describe here a design approach for a metamaterial-inspired electrically small antenna (ESA). The antenna consists of a ESA printed dipole and a Broadside-Coupled Split-Ring Resonator (BC-SRR) inclusion. The printed dipole of (lambda/14) is used as an exciter and the metamaterial inclusion is chosen to compensate for the stored energy of the dipole. The final antenna design of the exciter and the inclusion resonate at 0.88 GHz with a bandwidth of 14 MHz. The measurement results of the designed prototype are in agreement with the simulation results.

9:20 ***Shared-Aperture Antenna Systems for 5G Applications***

Mohammad S. Sharawi and Reza Shamsaee (Polytechnique Montreal, Canada); Jean-Jacques

Laurin (Ecole Polytechnique de Montrea, Canada)

The need for multi-function, multi-standard antenna systems for modern wireless applications and terminals have been growing with the evolution of wireless communications. Nowadays, there is a need for multi-band, and multi-function antennas to support the various allocated bands and standards all around the world. Various techniques have been adopted for multi-band operation. The concept of shared aperture antenna systems has started to gain more attention due to the stringent space requirements and demand for higher integration. The challenge is in design of widely separated frequency bands (i.e. sub-6 GHz and mm-waves). In this work, we provide an overview of the latest works in shared aperture (SA) antenna systems for mobile terminals, and present two interesting design ideas applied to metallic based and dielectric based antenna systems

9:40 ***Dual-Chip RFID Tag for Enhanced Indoor Localization of IoT Assets***

Jawad Ali (King Mongkut's University of Technology North Bangkok, Thailand); Adam Narbudowicz (Trinity College Dublin, Ireland & Wroclaw University of Science and Technology, Poland); Kamol Kaemarungsi (National Electronics and Computer Technology Center, Thailand); Suramate Chalermwisutkul (King Mongkut's University of Technology North Bangkok & The Sirindhorn International Thai-German Graduate School of Engineering, Thailand)

In this paper, a dual-chip RFID tag antenna with two dipoles of different electrical lengths based on UHF band is proposed. The dipoles are etched on the same substrate to create differential and torus shaped beam radiation patterns. It allows an enhanced power-based orientation sensing of the tagged objects. The antenna is simulated using CST MWS with an input impedance of 23+j224 Ω to match the NXP UCODE G2iL passive RFID chip's impedance. To achieve design compactness, a large dipole with differential beam is miniaturized using a meander line method and a small dipole is also designed on the other side of same substrate. The isolation between the dipoles is 21 dB. The backscattered power from the RFID reader is also analyzed, to demonstrate that the Angle of Arrival data can be extracted based solely on the backscattered power received at a conventional reader.

10:00 ***Digitally Coded Reflector at 140 GHz Targeted for 6G Communications***

Tung Duy Phan, Jiangcheng Chen, Marko E Leinonen and Aarno Pärssinen (University of Oulu, Finland); Ping Jack Soh (University of Oulu & Katholieke Universiteit Leuven, Finland)

The sixth generation (6G) communications is expected to involve the use of the sub-Terahertz. Electromagnetic waves in this band is vulnerable to blockages by physical obstacles, besides the severe limitation of coverage area compared to in conventional microwave communications. Reconfigurable reflectors is one of the promising olutions in mitigating these limitations, as its reflection properties can be designed to redirect incident waves to a desired arbitrary direction, extending range and coverage. This study experimentally demonstrates the design and performance of a set of digitally coded reflectors in improving the wireless link at 140 GHz. These reflectors consists of unit cells which have been designed and optimized on low loss Megtron-7 substrates. Experimental validations of the optimized reflector indicated good agreements with simulations. The use of these reflectors showed 24 dB improvement in signal strength compared to a propagation scenario without such reflectors, demonstrating the significance of this solution.

10:20 ***Printed-Dipole End-Fire Array for mm-Wave Applications***

Neeraj Kumar Maurya and Max James Ammann (Technological University Dublin, Ireland)

A novel curved printed-dipole element in an end-fire array for mm-Wave communication is presented. The curved dipole element is printed on both sides of a RO5880 substrate of 0.5mm thickness. The proposed antenna operates in the frequency bands n257, n258, and n261 (22.79 GHz - 29.7 GHz) and the 4-element array has a peak gain of 8.85 dBi.

Wednesday, March 29 9:00 - 10:40

P03: Imaging, detection and estimation

T04 Biomedical and health / / Propagation

Room: Spadolini 104

Chairs: Julian Bonello (University of Malta, Malta), Daniel Segovia Vargas (Universidad Carlos III de Madrid, Spain)

9:00 ***Dot Product of Confocal Images for Portable Radar-Based Microwave Imaging***

Hang Song (Tokyo Institute of Technology, Japan); Shinsuke Sasada (Hiroshima University, Japan); Morihito Okada and Koji Arihiro (Hiroshima University Hospital, Japan); Xia Xiao (Tianjin University, China); Tomomi Ishikawa and Takamaro Kikkawa (Hiroshima University, Japan)

Objective: The purpose of this study is to develop accurate radar-based microwave imaging. Method: A portable radar-based detector is placed on an excised breast tissue of total mastectomy. Measurements are conducted twice with different orientations for the breast. A two-stage rotational clutter suppression (TSR) algorithm is carried out for the multi-static rotational configuration of the radar-detector. It consists of a signal selection and an adaptive filtering. Dot product is carried out for the two sets of confocal images measured at different orientations to remove clutters. Conclusion: The dot product of two confocal images with different orientations can reconstruct more accurate images than conventional confocal images. It can improve not only image contrast but also the accuracy of tumor location.

9:20 ***Validation of Dielectric Properties Estimation from Magnetic Resonance Images to Accelerate Medical Microwave Applications***

<u>Daniela M. Godinho</u> (Instituto de Biofísica e Engenharia Biomédica - Faculdade de Ciências - Universidade de Lisboa, Portugal); Tiago Castela (Departamento de Radiologia, Hospital da Luz Lisboa, Luz Saúde, Lisbon, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Nuno Silva (Hospital da Luz Learning Health, Luz Saúde, Portugal); M Lurdes Orvalho (Departamento de Radiologia, Hospital da Luz Lisboa, Luz Saúde, Lisbon, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal)

Knowledge about dielectric properties of biological tissues is critical for the development and validation of microwave systems, such as Microwave Imaging (MWI) prototypes. However, measurement of dielectric properties of heterogeneous tissues with conventional techniques present some challenges, as most adopted techniques are designed for homogenous tissues, and limited number of samples may be available. In this study, we validate a methodology to estimate dielectric properties from Magnetic Resonance Imaging (MRI) exams. This is based on the interpolation between voxel intensities in MRI and known dielectric properties of homogeneous surrounding tissues. We test a 3D-printed phantom filled with tissue mimicking liquids in an MRI scanner and further test the proposed methodology. The results suggest estimated properties may present high percentage errors but the contrast between mixtures is underestimated, which is a valid indicator to infer the feasibility of MWI systems.

9:40 ***A Microwave Sensor Based on Double Complementary Split-Ring Resonator Using Hexagonal Configuration for Sensing Diabetics Glucose Levels***

<u>Esraa Elsayed Mansour</u> (Egypt-Japan University of Science and Technology (E-JUST), Egypt); Mohamed Ismail Ahmed (Electronics Research Institute, Egypt & PSATRI, King Saud University, Egypt); Ahmed Sayed Ahmed Abdelhamid Allam (Egypt-Japan University of Science and Technology (E-JUST), Egypt); Ramesh K. Pokharel (Kyushu University, Japan); Adel Bedair (Egypt-Japan University of Science and Technology, Egypt)

In this article, we propose a compact microwave sensor for monitoring the blood glucose level of diabetes patients. The presented sensor utilizes eight cells of hexagonal-shaped complementary split-ring resonators (CSRRS), lined up in honey-cell configuration, fabricated on Rogers RO3210 substrate, and fed by a 50 Ohm microstrip line. The sensor can detect the small changes in the dielectric properties of the blood's glucose across the signal path. This design's main concept is the strong interaction with electromagnetic fields concentrated in the sensing area. Along with theoretical estimations, the sensor is validated experimentally using a convenient setup of a vector network analyzer (VNA) that operated in measuring the transmission coefficient S21 and the phase. The sensor showed a shift in the resonant frequency by around 3 MHz/(mg/dL) of blood glucose concentration, which is significantly better compared to previous studies. This sensor concept is promising for

wearable non-invasive blood glucose monitoring devices.

10:00 ***Repository of Anthropomorphic Models of the Breast Including Normal Tissues, and Benign and Malignant Tumors for Microwave Imaging Research***

Ana Catarina Pelicano (Instituto de Biofísica e Engenharia Biomédica, Fac. Ciências Un. Lisboa & FCiencias ID, Portugal); Maria C. T. Gonçalves (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal); Daniela M. Godinho (Instituto de Biofísica e Engenharia Biomédica - Faculdade de Ciências - Universidade de Lisboa, Portugal); Tiago Castela and M Lurdes Orvalho (Departamento de Radiologia, Hospital da Luz Lisboa, Luz Saúde, Lisbon, Portugal); Nuno Araújo (Centro de Física Teórica e Computacional, Fac. Ciências Un. Lisboa, Portugal); Emily Porter (University of Texas at Austin, USA); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal)

The diagnosis of breast cancer through MicroWave Imaging (MWI) technology has been studied for the past few decades; however, continuous improvements to systems are needed to reach clinical viability. To this end, numerical models used in simulation studies not only need to be diversified and anatomically accurate but also representative of the cases in clinical settings. Hence, we have created the first open-access repository of 3D anthropomorphic models of the breast region, derived from 3.0T Magnetic Resonance Images (MRI) of healthy and cancer patients, which includes normal breast tissues (such as fat, fibroglandular, skin, and muscle tissues), and benign and cancerous breast tumors. Additionally, our repository also contains easily reconfigurable models with single and multiple breast tumors, allowing complex and realistic test scenarios needed for feasibility and performance assessment of MWI devices prior to experimental and clinical testing. This repository includes an executable file which allows researchers to generate models containing breast tissues dielectric properties, for a chosen frequency from 3 to 10 GHz (with a step of 0.01 GHz), which fits their needs and all developmental stages of any MWI prototype system. So far, our dataset comprises MRI scans of 26 patients, but new exams will be continuously added.

10:20 ***Microwave Spectroscopy of Melanoma Progression Model***

Milica Popović, Rachel Tchinov, Oliver Miller, Yanis Jallouli and Jasmine Boparai (McGill University, Canada)

Microwave spectroscopy has shown promise as a novel diagnostic tool for skin anomaly characterization. Due to their increased water content, tumors exhibit dielectric properties that are in contrast to those of the surrounding healthy tissue. In case of melanoma, there is a danger of the cancerous lesion to grow into the deeper skin layers, while still appearing small on the skin surface. We here present a progression model of the melanoma growth, construct tissue-mimicking phantoms of several stages of progressing melanoma and characterize them with the microwave probe in the 0.5 - 26.5 GHz range. Our results indicate that the dielectric measurement on the surface of the skin at the location and in the vicinity of a suspicious lesion may reveal in-depth cancerous tumor progression. Thereby, a microwave-based tool can aid the dermatologist in diagnosing melanoma in time, before its growth reaches layers containing lymph nodes and blood vessels.

Wednesday, March 29 9:00 - 10:40

A22: Antenna Design and Technologies

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 105

Chairs: Erio Gandini (ESA - European Space Agency, The Netherlands), Juan R Mosig (Ecole Polytechnique Federale de Lausanne, Switzerland)

9:00 ***Study on the Generation of Independent Beams from Planar Domains***

Riccardo Ozzola, Roderick Giosevan Tapia Barroso, Daniele Cavallo and Andrea Neto (Delft

University of Technology, The Netherlands)

Maximizing the number of beams for a given antenna size is paramount in massive multiple-input multiple-output (MIMO) communications. This work aims at evaluating the Signal-to-Interference Ratio (SIR), by extending the concept of the observable field to planar domains which have practical relevance. Due to the planarity of the structure, the scan loss affects the overall performance of the architecture. Several practical cases concerning different structures are investigated, and a strategy to reduce interference is discussed.

9:20 ***Synthesis of 3D Antennas with Quasi-Isotropic Radiation Pattern Based on Azimuthal Current Rings***

Ruiqi Wang (King Abdullah University of Science and Technology, Saudi Arabia); Kirill Klionovski (University of Siena, Italy); Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)

Internet of things (IoT) devices require antennas with quasi-isotropic radiation patterns to maintain orientation-insensitive communication. In this work, various combinations of azimuthal electric current rings on a sphere for quasi-isotropic radiation are investigated. A novel theoretical model is proposed to synthesize an antenna with a quasi-isotropic radiation pattern. The synthesis approach demonstrates a gain variation of 2.43 dB on a sphere with a radius of 0.08 λ (ka = 0.5). Inspired by the proposed synthesis model, a practical antenna is designed accordingly with a gain variation of 4.6 dB at 915 MHz, which is suitable for IoT applications.

9:40 ***Synthesis of Circularly Polarized Parasitic Micro-Array Using Spherical Wave Expansion***

Hussein Jaafar and Antonio Clemente (CEA-Leti, France); Christophe Delaveaud (CEA-LETI, France); Thierry Lenadan (Radiall, France)

This paper presents the design of a Right-Hand Circularly Polarized (RHCP) electrically small micro-array. The design principle is composed of a highly coupled three-IFA radiators distributed over a radial configuration. Only one antenna is driven, while optimized parasitic loads are connected on the non-driven elements. The parasitic load values are computed using the Spherical Wave Expansion (SWE) optimization, where an Circularly Polarized (CP) objective radiation is defined. The proposed antenna having an electrical size ka=0.6 exhibits an RHCP radiation in the GPS-L2 band with an 4dBic Gain.

10:00 ***Modeling Active-Integrated Antennas Co-Designed with Power Amplifiers in Scanning Arrays***

Martijn de Kok (Eindhoven University of Technology, The Netherlands); Stefania Monni (TNO Defence Security and Safety, The Netherlands); Marc van Heijningen (TNO Defense Safety and Security, The Netherlands); Alessandro Garufo (TNO, The Netherlands); Peter de Hek (TNO Defense Safety and Security, The Netherlands); A. B. (Bart) Smolders and Ulf Johannsen (Eindhoven University of Technology, The Netherlands)

We present a model of active-integrated power amplifiers (PAs) and antennas in a scanning array environment. The model combines load-pull data with unit-cell antenna simulations and a synthesized power combining network to determine the active load impedance seen by the individual transistors. The resulting output is the overall power-added efficiency, interconnect losses and radiated output power for any scan angle at a given operating frequency. The model is intended to provide a fast, first-order indication of the most suitable technology choice and design strategy for a given operating frequency and transmit power requirement.

10:20 ***Analysis of the 2D Guided Mode Propagation in a 3D Dielectric Rod Antenna***

Seyed Moein Pishnamaz, Andreas Fhager and Mikael Persson (Chalmers University of Technology, Sweden)

This paper presents the analysis of 2-dimensional guided mode propagation in a finite 3-dimensional dielectric rod antenna. An approximated model based on the summation of the guided modes multiplied by the coefficients obtained by projecting the 3D fields on the 2D fields is derived and the accuracy of that is investigated. The factors playing role in the error of the approximation are studied and concluded that the main cause of error in the approximation is the reflection from the truncation at the end of the rod rather than the radiating field along the rod.

Wednesday, March 29 9:00 - 10:40

E05: Optimization and machine learning for EM design

T09 EM modelling and simulation tools / / Electromagnetics

Room: Spadolini 106

Chairs: Miloslav Capek (Czech Technical University in Prague, Czech Republic), Slawomir Koziel (Gdansk University of Technology, Poland)

9:00 ***Fast and Reliable Antenna Optimization by Design Specification Management and Multi-Fidelity Models***

Anna Pietrenko-Dabrowska and Slawomir Koziel (Gdansk University of Technology, Poland)

Rigorous numerical optimization has become vital in ensuring the best possible performance of contemporary antenna structures. Still, computational efficiency and reliability of simulation-driven optimization procedures remain far from satisfactory. The former issue is associated with the computational expenses of repetitive electromagnetic (EM) simulations required by numerical optimization routines, whereas the latter arises partly from the shortage of a sufficient-quality initial designs indispensable for local search procedures. Recently, design specification adjustment procedure has been reported that makes local optimization less vulnerable to inferior-quality starting points. Seeking cost savings, here, we propose an algorithmic framework that introduces multi-fidelity EM models into the design specification adjustment procedure. Throughout the algorithm run, the simulation model resolution is adjusted iteration-wise based on the discrepancy between the assumed and actual operating parameters, and the algorithm convergence status. Verification experiments indicate up to sixty percent savings with respect to a single-fidelity regime, while maintaining comparable reliability.

9:20 ***Efficient Embedded Element Pattern Prediction via Machine Learning: A Case Study with Planar Non-Uniform Sub-Arrays***

Nehir Berk Onat (Delft University of Technology, The Netherlands); Ignacio Roldan (Tu Delft, The Netherlands); Francesco Fioranelli and Alexander Yarovoy (TU Delft, The Netherlands); Yanki Aslan (Delft University of Technology, The Netherlands)

Efficient prediction of embedded element patterns (EEPs) is studied to include the mutual coupling (MC) effects in the optimization of irregular planar arrays. An ANN-based methodology is used to predict the pattern of each element in the whole visible space for a flexible planar array topology in milliseconds for the first time in the literature. As a case study, a 4-element planar non-uniform sub-array structure is chosen to validate the performance of the applied methodology. The implemented network achieves excellent accuracy on the EEP prediction while providing great efficiency in computational time and load in comparison to the full-wave simulations.

9:40 ***Investigating Sparse Reconfigurable Intelligent Surfaces (SRIS) via Maximum Power Transfer Efficiency Method Based on Convex Relaxation***

Hans-Dieter Lang (OST Eastern Switzerland University of Applied Sciences Rapperswil & ICOM Institute for Communication Systems, Switzerland); Michel A Nyffenegger (OST Eastern Switzerland University of Applied Sciences Rapperswil, Switzerland); Heinz Mathis (OST--Eastern Switzerland University of Applied Sciences, Switzerland); Xingqi Zhang (University of Alberta & University College Dublin, Canada)

Reconfigurable intelligent surfaces (RISs) are widely considered to become an integral part of future wireless communication systems. Various methodologies exist to design such surfaces; however, most consider or require a very large number of tunable components. This not only raises system complexity, but also significantly increases power consumption. Sparse RISs (SRISs) consider using a smaller or even minimal number of tunable components to improve overall efficiency while maintaining sufficient RIS capability. The versatile semidefinite relaxation- based optimization method previously applied to transmit array antennas is adapted and applied accordingly, to evaluate the potential of different SRIS configurations. Because the relaxation is tight in all cases, the maximum possible performance is found reliably. Hence, with this approach, the trade-off between performance and sparseness of SRIS can be analyzed. Preliminary results show that even a much smaller number of reconfigurable elements, e.g. only 50%, can still have a significant impact.

10:00 ***Quality Factor Minimization of Electrically Small Antennas by Density Topology Optimization***

Jonas Tucek, Miloslav Capek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Ole Sigmund (Technical University of Denmark, Denmark)

Density-based deterministic topology optimization is formulated for method-of-moments numerical technique, and the corresponding stored energy operator is exploited to evaluate and optimize antenna Q-factor. The settings are briefly discussed, including material interpolation function, density filters, and projection filters. The proposed technique is used to improve fractional bandwidth, i.e., minimize the quality factor of a current density excited on a spherical shell. The results are compared with known fundamental bounds and with realized spherical helices.

10:20 ***Current-Only Metasurface Design with Cell-Level Granularity***

Marcello Zucchi (Politecnico di Torino, Italy); Marco Righero (LINKS Foundation, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

This paper presents the design of metasurface antennas which is based on a current-only optimization. The surface is partitioned into small, electrically isolated cells that effectively model the macroscopic behaviour of constituent unit cells, and the coupling between them. This choice features a regularization effect on the impedance profile and on the obtained current solution. The procedure is applied to the design of circular metasurface antennas. Two types of cells are considered, with square and hexagonal shape. The synthesized impedance profile, the current distribution and the resulting radiation pattern are comparable and in agreement with the corresponding continuous current design.

Wednesday, March 29 9:00 - 10:40

CS3: AMTA session: Advanced Measurement Techniques for 5G and Beyond

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 107

Chairs: Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)), Janet O'Neil (ETS-Lindgren, USA)

9:00 ***Free Space Calibration for 5G Antenna Array***

No-Weon Kang, Dong-Joon Lee and Young-Pyo Hong (Korea Research Institute of Standards and Science, Korea (South)); In-June Hwang (Korea Research Institute of Standards and Science (KRISS), Korea (South))

This paper proposes a photonics-based free-space calibration method for a 5G antenna array. The free-space calibration method uses a highly stabilized planar field imaging system with an electro-optic probe developed by KRISS. This system enables measurements at the reactive near-field region of a 5G antenna array. Then, a complex excitation coefficient of each antenna is determined from the measured magnitude and phase data; based on this, free-space calibration is possible by individually compensating for the magnitude and phase errors of each antenna. The prototype of the 5G antenna array used in the experiment is a 28 GHz 4×1 dual-polarized patch antenna array developed by KRISS. To verify the performance of the proposed free-space calibration method, we present the experimental results demonstrating that the electric field of a dual-polarized antenna array is capable of beam steering at 28 GHz.

9:20 ***PCB-Manufactured Log-Periodic Dipole Array for 0.5-20 GHz***

Mikko K. Leino, Rasmus Luomaniemi, Olli Talvitie and Jari Van Wonterghem (Radientum Oy, Finland)

This paper presents a wideband log-periodic dipole array (LPDA) antenna with operation frequency band from 500 MHz up to 20 GHz. The LPDA has 35 elements with maximum dimension restricted to 300 mm both in length and width of the array. The measured antenna has better than −10 dB reflection coefficient over the whole operation frequency band, and very stable 6.1 dBi realized gain in 4-20 GHz band, as confirmed by measurements. Effects of different surface finishes on manufactured printed circuit board (PCB) antennas have also been studied, but no significant differences have been found whether typical polymer solder mask or electroless nickel immersion gold (ENIG) finish is used to cover the high-frequency elements of the LPDA.

9:40 ***OTA Test Method in Extreme Temperature for 5G Massive MIMO Devices***

Chuanting Liu (Ericsson (China) Communications Co., LTD, China); Jonas Fridén and Bo Xu (Ericsson AB, Sweden); Aurelian Bria (Ericsson, Sweden); Yan Cui (Ericsson, China); Yu Yang, Noor Choudhury, Brett Horrocks and Queenie Zhang (Ericsson AB, Sweden)

Over-the-air testing of 5G Massive MIMO radio base stations was introduced in 3GPP standards and national regulations already a few years ago. One of the most challenging situations is when measurements are performed under extreme temperature conditions. 3GPP radiated conformance testing standards mention two methods: a direct method and a relative method. However, very few details about test method implementation are available in the standard. In this paper we propose a practical implementation of these two methods, and we investigate which aspects are important for achieving consistent results. Through experimental validation we conclude that similar results can be obtained by both methods, and we discuss a number of implementation details that can be included in the standard.

10:00 ***Radio Bursts in Residences During COVID-19: Measured Characteristics for Resiliency Testing***

Daniel Kuester, Xifeng Lu and Dazhen Gu (NIST, USA)

We present an analysis of the time parameters observed in measurements performed at 13 residential sites from June 2020 through September 2021. This discussion is directed toward application to electromagnetic immunity testing for medical devices and household electronics, and in particular the selection of timing parameters for emulating household environments. Summary statistics of the data suggest that different parameter values could make the tests more representative, in order to improve the resilience of household products as the radio spectrum becomes more active. The data further suggest that the radio disturbance excitation in these tests should synthesize a random processes to reproduce realistic spectrum occupancy, instead of simple periodic waveforms that are prescribed today.

10:20 ***A Novel Method for Near-Field Scanning of Phased Arrays at mmWave Frequencies***

Michael D. Foegelle (Keysight Technologies, USA)

Near-field scanning of phased arrays and other antennas traditionally use mechanical scanning techniques that are relatively slow. Switched probe arrays have been used to remove the positioning time for at least one axis of motion, but still suffer from various limitations. Recent advancements in phased array design and calibration methods offer an alternative with potentially near-instantaneous capture of nearfield data using digital coding techniques. This paper will investigate the technique and several variations of possible implementations.

Wednesday, March 29 9:00 - 10:40

CS51: Unconventional electromagnetic phenomena in wave

propagation and beam focusing

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 108

Chairs: Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy), Santi Concetto Pavone (Università degli Studi di Catania, Italy)

9:00 ***The Homogenization and Circuit Representation of All-Metallic Metasurfaces***

Jorge Ruiz-García (University of Michigan, USA); Gurkan Gok (Raytheon Technologies Research Center, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

This paper presents a procedure for extracting the material and circuit parameters of metallic pins within a parallel plate waveguide (PPW). In the approach, the eigenmode fields are averaged over the faces of a sub-wavelength unit cell to calculate the effective permittivity and permeability. In addition, an equivalent circuit model is computed. Two cases representing isotropic (cylindrical pin) and anisotropic (elliptical pin) structures are analyzed and validated. The formulation and the procedure described provide the basis for designing all-metallic metasurface architectures, such as MIMO devices, analog computing metamaterials, and matching networks, through inverse design.

9:20 ***Reconfigurable Metasurfaces and New Imaging Paradigms in Magnetic Resonance Imaging***

Endri Stoja (Fraunhofer FHR, Germany); Dennis Philipp and Simon Konstandin (Fraunhofer MEVIS, Germany); Jürgen W Jenne (Fraunhofer MEVIS & Mediri GmbH, Germany); Thomas Bertuch (Fraunhofer FHR, Germany); Matthias Günther (Fraunhofer Mevis, Bremen, Germany)

In this work, we present novel designs and concepts to enable new imaging paradigms in the field of magnetic resonance imaging (MRI) by means of reconfigurable electromagnetic metasurfaces. Some of the challenges as well as approaches to overcome them are outlined. Our preliminary investigations show that dynamical, electronically-controlled, digital metasurfaces possess a huge potential to allow for manifold applications in MRI. Spatio-temporal recon¬figurability, demonstrated here via the inclusion of low-power BLE microcontrollers and digital capacitors, is the key for all future applications in this field.

9:40 ***Implementation of a Fully Metal PTD-Symmetric Bifilar Edge Waveguide***

Iram Nadeem, Enrica Martini, Alberto Toccafondi and Stefano Maci (University of Siena, Italy); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

This paper demonstrates the practical feasibility of using the bed of nails structure to construct a fully metallic parity (P), time-reversal (T), duality (D) symmetric bifilar edge waveguide. The waveguide design starts by considering first the ideal perfect electric condition (PEC) and perfect magnetic condition (PMC) based parallel plate waveguides (PPW). Then, metallic pillars (Pins) are used to emulate the PMC boundary conditions. Three different kinds of PTD-symmetric unit cells of PEC-pillar PPW are considered initially. The first case has the pillars aligned on top and bottom walls, while in the second case the pillars in the upper wall are shifted in glide manner along the propagation direction with respect to the ones in the lower plate. Numerical results show the backscattering protection and the ability to confine the EM field in the proximity of the edge over a large bandwidth.

10:00 ***Self-Healing Analysis of Distorted Weakly-Diffracting Vector Beams***

Ravel C. M. Pimenta (Aix-Marseille Université, France); Gabriel Soriano (Aix-Marseille University, France); Konstantinos D. Paschaloudis (Université de Rennes, CNRS, IETR, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France); Myriam Zerrad (Aix-Marseille Université, France); Claude Amra (CNRS & Aix Marseille University, France)

A study of the self-healing property of weakly-diffractive vector beams radiated by a finite circular radiating aperture on an infinite ground plane is presented. The obstacle is a circular metallic disk, which is axially aligned and placed at a certain distance over the radiating aperture. Three different field distributions are considered as excitation for the aperture: the non-diffractive Bessel beam (BB), the Bessel-Gauss beam (BG), and the transverse electromagnetic mode (TEM) of a coaxial cable. The analysis is performed resorting to a spectral Green approach and to a Physical Optics (PO) framework. In all cases, a radially polarized

beam is assumed. The results confirm the self-healing property of the non-diffracting beams. They also show the impact on the amplitude of the regenerated field due to the obstacle radius. The chosen approach is validated using a full-wave commercial software.

10:20 ***Localized Waves from Transform and Phase Space Points-Of-View***

Richard W Ziolkowski (University of Arizona, USA & University of Technology Sydney, USA)

The transfer of energy and information is a basic tenet of acoustic, electromagnetic and quantum wave applications. Localized waves are nonseparable space-time solutions of the wave equations associated with these and other physical phenomena. They exhibit unusual propagation characteristics such as nondispersive propagation, i.e., their central region propagates without spreading. While many of these localized waves have been derived directly in space and time coordinates, they have also been represented and studied using transform and phase space techniques. This paper briefly discusses various aspects of these approaches. Both transform and phase space representations of subluminal, luminal and superluminal localized wave solutions of several classes of wave equations will also be discussed in my presentation.

Wednesday, March 29 9:00 - 10:40

A30: Innovative Antenna Designs I

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 109

Chairs: Angelo Freni (Università degli studi Firenze, Italy), Yahya Rahmat-Samii (University of California, Los Angeles (UCLA), USA)

9:00 ***Metal-Only Reflect-Transmit-Array Unit Cell with Polarization-Dependent Performance***

Angel Palomares-Caballero (Universidad de Granada, Spain); Carlos Molero (University of Granada, Spain); Juan Valenzuela-Valdés (Universidad de Granada, Spain); Pablo Padilla (University of Granada, Spain); María García-Vigueras (IETR-INSA Rennes, France); Raphael Gillard (IETR & INSA, France)

A metal-only reflect-transmit-array unit cell whose operation is dependent on the incident polarization is presented. The proposed unit cell is based on 3D geometry which allows a high level of independent phase tuning for orthogonal and linear incident polarizations. In our unit cell, the horizontal polarization is reflected while the vertical polarization is transmitted. The modification of the reflected phase is done by the length of a metal block located at the end of the slits where the horizontal polarization propagates. The modification of the transmitted phase is changed by the depth of the corrugations implemented in the slit that supports the propagation of the vertical polarization. The results obtained in transmission mode show an impedance matching below -15 dB with a linear phase response from 30 GHz to 50 GHz. For the reflected polarization, there is almost total reflection with phase performance that is also linear along the frequency.

9:20 ***Liquid Crystal Meta-Reflectarray for D-Band***

Dayan Pérez (Public University of Navarra (UPNA) & Institute of Smart Cities (ISC), Spain); Erik Aguirre (Universidad Pública de Navarra, Spain); Eduardo Olariaga (TAFCO Metawireless, Spain); Sergei A. Kuznetsov (Rzhanov Institute of Semiconductor Physics SB RAS, Novosibirsk Branch, TDIAM & Analytical and Technological Research Center, Novosibirsk State University, Russia); Antonio Marcotegui (Tafco Metawireless, Spain); Miguel Beruete (Universidad Publica de Navarra, Spain)

A reconfigurable liquid-crystal-based reflectarray (LC-RA) designed for operation in the D-band from 105 to 125 GHz is numerically demonstrated. The device has a configuration of a high-impedance surface with a patch metasurface patterned on

a 2-mm-thick quartz substrate separated from the ground plane through a 40-μm-thick LC layer. The electric biasing of the LC-loaded RA unit cells is introduced by narrow inductive strips connecting neighboring patches in one dimension. The reflection phase tunability for the simulated prototype reaches 266 deg with insertion losses around 2.5 dB. The beam-steering scenario is considered using a single row of the RA with 1 × 33-unit cells, illuminated by a plane wave with horizontal polarization at an incidence angle of θi = 10 deg to obtain a reflected beam at 25 deg. The far-field result validates the good behavior of the system.

9:40 ***Slotted Waveguide Antenna Design at W-Band Using Stacked Glide-Symmetric Metal Sheets***

Sergio García (Universidad Politécnica de Madrid, Spain); Adrián Tamayo-Domínguez and Pablo Sanchez-Olivares (Universidad Politecnica de Madrid, Spain); José Manuel Fernández González (Universidad Politécnica de Madrid, Spain)

This paper presents the design of a slotted waveguide antenna (SWA) in multi-layer waveguide (MLW) technology at 92.5 GHz using a periodic glide-symmetric holey structure with circular holes as electromagnetic band gap (EBG) structure to avoid leaks. The effect of the height of the air gap between the metallic layers on the stopband width produced by the designed unit cell and on the propagation of modes through a guide with WR10 dimensions has been analyzed. The designed antenna composed of stacked glide-symmetric metal sheets presents a high radiation efficiency and is easy to manufacture.

10:00 ***Groove Gap Waveguide H-Plane Horn Antennas with Enhanced Radiation Characteristics***

Ali K. Horestani and Michal Mrozowski (Gdansk University of Technology, Poland)

Considering the wide application of fan-beam antennas, this paper is focused on the improvement of the radiation gain and the operating bandwidth of H-plane sectoral horn antennas in groove gap waveguide technology. It is demonstrated that by modifying the aperture of the horn a very good impedance matching and high gain over a wide frequency band from 13~GHz to 20~GHz can be achieved. The proposed method also improves the front-to-back ratio radiation of the antenna. Moreover, it is shown that the radiation gain of the antenna can be mechanically adjusted by loading the antenna with slabs of dielectric materials.

10:20 ***A PSO-Driven Optimization System for the Unit Cell Design of Reflective Single-Layer Polarizers***

Zhengzheng Wang and Sean V Hum (University of Toronto, Canada)

An optimization system for the design of reflective single-layer polarizers is proposed. Driven by a particle swarm optimization (PSO) algorithm, the optimizer combines a rapid method of moments (MoM) electromagnetic (EM) solver with an edge-based topology model. The optimizer intelligently modifies the MoM impedance matrix in response to geometric changes during the optimization process. Slot features can be generated in the geometry with the edge-based topology model, and a proper estimation algorithm for the slot impedance has been applied to maintain accuracy. A specific topology for the polarizer design is presented, which guides the optimizer to find potential designs and helps achieve fast convergence.

Wednesday, March 29 9:00 - 10:40

SW5: Effectively Addressing the Challenges to Uncertainties Induced by Modern Environment and Positioning Systems in Electromagnetic Compatibility and Antenna Measurements

Organized by: Janet O'Neil (ETS-Lindgren, USA), Carlo Carobbi (University of Florence, Italy)

Room: Sala della Scherma

Any kind of measurement, particularly when carried out for scientific or professional purposes, requires consideration of inherent measurement errors. Evaluation of measurement uncertainty in electromagnetic compatibility and antenna characterization applications is the common thread that connects the presentations in this workshop. Sophisticated data processing techniques and novel measurement methods are presented aiming at enhancing the accuracy of electromagnetic field measurements with specific reference to errors induced by the measuring environment (reverberation chambers and anechoic chambers), robotic positioning systems and phaseless near field detection in the millimetre wavelength frequency range.

9:00 - How Correlation Affects Precision of Reverberation Chamber Measurements (Carlo Carobbi, University of Florence, Italy)

9:30 - Evaluation of Measurement Uncertainties in Multipurpose Robotic Antenna Test System (Dennis Lewis, The Boeing Company)

10:00 - Uncertainty in Use of Time Domain Techniques for VHF/UHF Antenna Calibration (David Knight, NPL)

Wednesday, March 29 9:00 - 10:40

IW4: From Component to mission.... Simulation as Must -Have for Aerospace & Defense Industry (Ansys)

Room: Polveriera

Wednesday, March 29 9:00 - 10:40

Perspectives I: The Evolution of Smart Wireless Environments (I)

Organized by: Filiberto BILOTTI (Università di Roma TRE, Italy); Marco DI RENZO (CNRS & CentraleSupelec - Paris-Saclay University, France); Giacomo OLIVERI, (ELEDIA Research Center, University of Trento, Italy)
This workshop will be aimed at providing a broad and multi-disciplinary view on the current trends, the ongoing initiatives, and the research and industrial perspectives in the field

Workshop Program

• 09:00 - 09:30 "Metasurface driven intelligent antennas for future smart radio environments"
Filiberto BILOTTI, University of Roma TRE, Italy (filiberto.bilotti@uniroma3.it)
• 09:30 - 10:00 "Two-timescale design for reconfigurable intelligent surface-aided massive MIMO systems"
Marco DI RENZO, CentraleSupélec and CNRS, France (marco.direnzo@centralesupelec.fr)
• 10:00 - 10:30 "Static and reconfigurable EM skins: Design approaches, research trends, and open challenges"
Giacomo OLIVERI, University of Trento, Italy (giacomo.oliveri@unitn.it)
Room: Sala Arco

Wednesday, March 29 11:00 - 12:40

A23: Leaky Wave Antennas II

T10 Fundamental research and emerging technologies / / Antennas
Room: Spadolini 001

Chairs: Filippo Capolino (University of California, Irvine, USA), Davide Comite (Sapienza University of Rome, Italy)

11:00 ***Circularly Polarized Annular Leaky-Wave Antenna with Suppressed Open Stop-Band and SIW***

Feeding

Sadia Riaz (The University of Edinburgh, United Kingdom (Great Britain)); Davide Comite (Sapienza University of Rome, Italy); Maksim Kuznetcov (Heriot Watt University, United Kingdom (Great Britain)); Iram Shahzadi (The University of Edinburgh, United Kingdom (Great Britain)); Paolo Baccarelli (Roma Tre University, Italy); Paolo Burghignoli and Alessandro Galli (Sapienza University of Rome, Italy); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

A radially periodic 2-D leaky-wave antenna (LWA) with high gain at broadside and suppressed open stopband (OSB) is presented. It consists of a double strip bull-eye antenna fed with a four-port substrate integrated waveguide (SIW) feeder. The proposed antenna is first excited with a simple and ideal magnetic dipole to show its scanning performance. Then, a four-port SIW configuration is designed with a 90-degree phase difference between adjacent ports, in order to obtain circularly polarized radiation at broadside. Simulated results show a directive gain of 17.9 dBi at broadside, corresponding to a frequency of 18.5 GHz, and, persistent broadside radiation is supported from 18.0 GHz to 19.5 GHz which is in agreement with the numerically determined leaky-wave (LW) phase and attenuation constants. Applications include satellite connectivity, radar systems, and wireless communications, basically, where continuous beam steering through broadside is required, or, broadside radiation over a significant frequency range.

11:20 ***Physical Implementation of Leaky-Wave Antenna with Engineered Aperture Distribution Based on Bianisotropic Huygens Metasurfaces***

Pablo Mateos-Ruiz (University of Malaga, Spain); Vinay Kumar Killamsetty (Technion - Israel Institute of Technology); Ariel Epstein (Technion - Israel Institute of Technology, Israel); Elena Abdo-Sánchez (University of Málaga & E. T. S. I. Telecomunicación, Spain)

A methodology based on omega-type bianisotropic Huygens' metasurfaces is presented to control the aperture field distribution of leaky-wave antennas. The studied structure is a parallel-plate waveguide with the top plate replaced by a metasurface. Previous works achieved independent control of the phase constant and the leakage factor, but they were constrained to be constant. The required theoretical extensions to overcome this limitation are presented in this work, thus enabling the design of arbitrary radiation patterns. A slowly varying amplitude approximation approach is employed to satisfy Maxwell's wave equation and obtain the relation between the horizontal and vertical wavenumbers. In addition, a semianalytical algorithm able to predict near-field coupling effects is applied in the microscopic design of the metasurface unit cells. Two designs are carried out with real unit cells, presenting different aperture configurations. Finally, electromagnetic simulations validate the methodology with an excellent agreement without any further full-wave optimization.

11:40 ***Wide-Angle SSPP-Based Leaky-Wave Antenna with Scanning Improvement in the Forward Quadrant for Millimeter Wave Applications***

Ehsan Farokhipour (University of Duisburg Essen, Germany); Peng-Yuan Wang, Andreas Rennings and Daniel Erni (University of Duisburg-Essen, Germany)

This paper proposes a wide-band wide-angle fre- quency dependent beam scanning antenna (FD-BSA) for applications in mm-wave frequency bands. The proposed leaky-wave antenna (LWA) is composed of three parts: a CPW as the feeding network, a spoof surface plasmon polariton transmission line (SSPP TL) as the waveguide, and circular parasitic patches as periodic modulation parts to change slow wave of SSPP TL to fast-wave radiation. To improve the performance of the LWA at forward directions, slots on circular parasitic patches are introduced. The total beam scanning range of the proposed SSPP- based LWA is from -35° to $+60^{\circ}$ when the operating frequency changes from 55 GHz to 105 GHz (FBW = 62.5%).

12:00 ***Symmetric Tapering of Bi-Directionally Fed Leaky-Wave Antennas for Multi-Beam Synthesis***

Alejandro Gil Martinez (Technical University of Cartagena Cartagena, Spain); Miguel Poveda-García (Technical University of Cartagena, Spain); David Cañete Rebenaque (Polytechnic University of Cartagena, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain)

We report a theoretical investigation on the possibilities and trade-offs when tapering a bi-directional fed leaky-wave antenna

(LWA) to reduce the side lobes level, when operating with the two opposite antenna ports. It is demonstrated that, for high radiation efficiency designs, the directivity can be distorted due to low aperture illumination efficiency if the LWA is not symmetrically tapered with an adequate modulation function. The theory is corroborated with simulations of modulated LWAs in substrate integrated technology.

12:20 ***On the Reduction of the Cross-Polarized Component of the Infinite Leaky Wave Slot***

Dunja Lončarević, Andrea Neto, Sjoerd Bosma and Nuria LLombart (Delft University of Technology, The Netherlands)

Within the framework of this contribution, geometry consisting of multiple radially arranged infinite slots is presented. The main goal of the new geometry is reduction of the cross-polarized component of the original infinite leaky wave slot recognised as its main disadvantage. Firstly, spectral analysis of the infinite leaky wave slot in the near-field is conducted leading to the conclusion that the asymmetry of the dominant leaky wave modes is the main cause of the high cross-pol. Multiple slot geometry attempts to reduce this asymmetry and the results presented show that its cross-pol. levels are significantly lowered as a consequence. Furthermore, comparing the simulated results to the ones of the tapered slot, geometry most often used to reduce the cross-polarization, it is concluded that the geometry with multiple slots outperformes the tapered slot.

Wednesday, March 29 11:00 - 12:40

CS16b: Emerging Antenna Technologies of Beam Manipulation for Beyond 5G and Space Applications (continued)

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Peiyuan Qin (University of Technology Sydney, Australia), Hang Wong (City University of Hong Kong, Hong Kong)

11:00 ***Ku/Ka-Band Wide-Scanning Dual-Polarized Connected Slot Array with Improved Polarization Purity***

Alexander J van Katwijk (Delft University of Technology, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Daniele Cavallo (Delft University of Technology, The Netherlands)

One of the common requirements for wideband wide-scanning arrays in multifunctional platforms is the polarization agility. Cross-polarization levels should be kept low within the entire field of view in dual-polarized arrays. However, polarization purity is hard to achieve especially for arrays that are designed to operate over large bandwidths. Planar connected arrays with artificial dielectric layers have recently emerged as a convenient concept to realize wideband wide-scanning arrays. The artificial dielectrics are used above the antenna aperture to improve the matching while scanning and increase the front-to-back ratio. However, their presence deteriorates the polarization performance on the diagonal planes. The reason for the increase in cross-polarization is investigated and explained. We then propose an approach to reduce the cross-polarization by introducing vertical pins connecting the patches in the artificial dielectric superstrate.

11:20 ***Achieving Full Azimuth Coverage in a Planar Lens Antenna***

Freysteinn Vidar Vidarsson and Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Astrid Algaba-Brazález (Ericsson AB, Sweden); Lars Manholm and Martin Johansson (Ericsson Research, Sweden); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

n this paper we present a lens antenna that can scan in the whole azimuthal plane. This is achieved by using two planar generalized Luneburg lenses that are connected through multiple 3 dB 90 degrees hybrid couplers. The antenna is designed for the 3GPP n260 band operating from 37 to 40 GHz making it suitable for indoor 5G coverage. Simulation results of the antenna are presented to illustrate that it can scan in the full azimuth plane.

11:40 ***A Low Profile Modulated Metasurface Antenna for Multi-Beam Applications***

Wen Yubo (UTS, Australia); Peiyuan Qin and Y. Jay Guo (University of Technology Sydney, Australia)

Modulated metasurface is considered as a good candidate for low-profile multi-beam antennas. Usually, a superposition method of all impedance modulations for different beams is used. However, a limitation of this method is that a very small number of beams can be generated due to the mutual interference of different impedance modulations, which will lead to low gains and high side lobe levels. It is found that the source locations for each beam play a key role in interference suppression. In this paper, instead of using the time consuming full-wave simulation-based optimization, the optimal source locations are obtained by using the aperture fields calculated from the zeroth-order approximation of the currents on the surface. To verify the design concept, a five-beam modulated metasurface antenna has been designed, fabricated and measured, providing an angular coverage up to ±30°. Good agreement between the simulation and measurement has been obtained.

12:00 ***Single-Feed Multi-Beam Beam-Scanning Reflectarray Antennas***

Payam Nayeri (California Polytechnic State University, USA)

The capabilities of reflectarray antennas to generate and scan simultaneous multiple beams with a single feed are studied in this work. The alternating projection approach is used to synthesize the array for multi-beam beam-scanning. A 1600 element reflectarray generating four simultaneous beams with the capability of scanning the beams in elevation is presented. High-gain quad-beam beam-scanning with stable radiation patterns is demonstrated.

12:20 ***Liquid Metal Beam Switching Bull's Eye Antenna Based on 3D Printing***

Yihua Zhou and James Kelly (Queen Mary University of London, United Kingdom (Great Britain))

In this paper, we designed, fabricated and measured a novel liquid metal beam switching Bull's Eye antenna, operating at 10.3 GHz. The antenna was fed by a WR-90 waveguide. We fabricated the antenna based on 3D printing technology. The main beam of the antenna was able to switch ±13.5°, by injecting/removing liquid metal from the designed channels. At 10.3 GHz, the measured realized antenna gain could reach to 11.3 dB with a side lobe level of -9.2 dB. The measured 10-dB return loss bandwidth was 320 MHz. Within this frequency range, the measured realized gain was above 10.3 dB.

Wednesday, March 29 11:00 - 12:40

CS37b: Propagation research at the cross-road of telecommunication, space systems, remote-sensing and meteorology: A tribute to Frank Silvio Marzano (continued)

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 101

Chairs: Antonio Martellucci (European Space Agency, The Netherlands), Danielle Vanhoenacker-Janvier (Université catholique de Louvain, Belgium)

11:00 ***Development and Application of Advanced Experimental Techniques for Ground Microwave Radiometry in All Weather Conditions***

Lorenzo Luini and Carlo Riva (Politecnico di Milano, Italy); Frank S. Marzano and Marianna Biscarini (Sapienza University of Rome, Italy); Luca Milani (European Space Agency, Germany); Domenico Cimini (CNR-IMAA & CETEMPS University of L'Aquila, Italy); Saverio Nilo (Consiglio Nazionale delle

Ricerche, Italy); Antonio Martellucci (European Space Agency, The Netherlands)

Sun-tracking microwave radiometry is an effective technique aimed at estimating the tropospheric attenuation in all-weather conditions by using the Sun emission as an equivalent beacon source. Though such technique definitely represents an interesting alternative to Earth-space electromagnetic propagation experiments, especially in the frequency region beyond 50 GHz for which space-borne beacons are hardly currently available, its application is not trivial, mainly because of the issues arising from the need to precisely pointing at the Sun: catching the Sun peak radiation might not be an easy task, especially if the frequency increases, i.e. the beamwidth gets narrower. This contribution focuses on the advanced experimental techniques developed in the framework of the ESA WRad project (funded by ESA) to maximize the accuracy of the W-band measurements collected by the multi-channel RPG MWR installed at Politecnico di Milano. Issues of the experimental campaign are highlighted and the associated solutions are discussed in detail.

11:20 ***Geolocation Assessment/Validation Methods for EUMETSAT Polar System - Second Generation (EPS-SG) ICI Conical Scanning Radiometer***

Vinia Mattioli (EUMETSAT, Germany); Frank S. Marzano (Sapienza University of Rome, Italy); Christophe Accadia (Eumetsat, Germany); Francesco De Angelis (EUMETSAT, Germany); Mario Papa (Sapienza University of Rome, Germany); Daniele Casella (Italian National Research Council (CNR), Italy); Giulia Panegrossi and Paolo Sanò (National Research Council of Italy Institute of Atmospheric Sciences and Climate, Italy); Mario Montopoli (National Research Council of Italy, Institute of Atmospheric Sciences and Climate (CNR, ISAC), Italy); Bengt Rydberg (Swedish Meteorological and Hydrological Institute, Sweden)

Methodologies have been developed for the validation during the Cal/Val phase of the geolocation error of the ICI radiometer that will be onboard of the Second Generation (SG) of the EUMETSAT Polar System (EPS-SG) satellites. The work investigated how ICI channels can be used to identify optically detectable surface targets, such as landmarks, and atmospheric features, such as water vapour gradients and deep convective clouds. The validation was based on a contour matching technique, using high altitude lakes, ice shelves and mountain chains as landmark targets, and water vapour features and deep convective cloud as atmospheric targets.

11:40 ***Radiometeorological Forecast Model: A New Tool for Deep-Space Link Budget Optimization at Ka-Band***

Marianna Biscarini (Sapienza University of Rome, Italy); Saverio Di Fabio (CETEMPS, Italy); Maria Montagna (SciSys @ ESA, Germany); Klaide De Sanctis (Cetemps, Italy); Mario Montopoli (National Research Council of Italy, Institute of Atmospheric Sciences and Climate (CNR, ISAC), Italy); Luciano Iess (Univerity of Rome La Sapienza, Italy); Livio Bernardini (CETEMPS, Italy); Paolo Antonelli and Paolo Scaccia (AdaptiveMeteo, Italy); Luca Milani (European Space Agency, Germany); Klara Spieker (ESA, Italy); Jose Villalvilla (ESA, The Netherlands); Antonio Martellucci (European Space Agency, The Netherlands); Marco Lanucara (European Space Agency, Germany); Frank S. Marzano (Sapienza University of Rome, Italy)

RadioMetOP (RadioMeteorological Operation Planner) model for the optimization of deep-space satellite links is described. RadioMetOP allows exploiting dynamical statistics (customized on the specific day of the satellite pass) of atmospheric attenuation and brightness temperature derived coupling weather-forecast and radiopropagation models. RadioMetOP has successfully passed the feasibility and validation phases demonstrating a capability of providing extra daily data-volume up to 300% compared to classical link-budget techniques based on static climatological statistics. Validation was possible thanks to the collaboration with both ESA and JAXA that made available Ka-band measurements from Hayabusa2 mission on the asteroid 162173-Ryugu. Since April 2022, RadioMetOP is operative for BepiColombo mission to Mercury at Ka-band. Latest results confirms that the RadioMetOP model is perfectly able to predict measured link performance in all-weather conditions. The future objective is to extend the RadioMetOP scope to make it multi-site, multi-mission and multi-frequency with a focus on its application at optical frequencies.

12:00 ***Synergy Between Radar and Radiometer Observations of Precipitation from Space***

Chandrasekar Radhakrishnan, V. Chandrasekar and Steven C. Reising (Colorado State University, USA)

This paper is a tribute to Prof Frank Marzano's legacy. The objective of this study is to cross-validate the radar (active sensor) and radiometer (passive sensor) observations over tropical cyclones, typhoons and hurricanes. For that, the Global Precipitation Measurement (GPM) dual-frequency precipitation radar (DPR) observations are compared with the GPM Microwave Imager (GMI) and the Temporal Experiment for Storms and Tropical Systems Demonstration (TEMPEST-D) CubeSat observations over precipitating systems. The purpose of this paper is twofold: first, to demonstrate a methodology to show consistency between DPR and GMI, and then use the same, to show the consistency between DPR and TEMPEST-D. This paper also develops a correlation metric, between parameters derived from radar and radiometer observations. The corresponding correlation between DPR and GMI, as well as TEMPEST-D and DPR, are 0.9 and 0.85 respectively.

12:20 ***A Multi-Disciplinary Approach to the Radiowave Propagation Research - A Tribute to Frank Silvio Marzano***

Nazzareno Pierdicca (Uni Roma1, Italy)

The paper gives a review of the scientific, educational and organizational contributions of a brilliant researcher and an extremely nice person whom many regret for his passing. Prof. Marzano was an example of how electromagnetism and radiopropagation can contribute to improve our life through a better monitoring of the environment and an improvement of our communication tools.

Wednesday, March 29 11:00 - 12:40

A20: Mm-wave Phased Arrays

T02 Mm-wave and THz cellular / / Antennas

Room: Spadolini 102

Chairs: Nicola Anselmi (University of Trento, Italy), Goutam Chattopadhyay (NASA-JPL/Caltech, USA)

11:00 ***Fast and Continuously Steerable 1×4 Liquid Crystal Phased Array Antenna with Waveguide Feed Network***

Qipeng Wang (Southeast University, China); Zhiguo Su (JuRong Smartech Display CO LTD, China); Yue Su, Shunli Li and Hongxin Zhao (Southeast University, China); Xiaoxing Yin (State Key Laboratory of Millimeter Waves, China)

This paper presents a fast and continuously steerable 1×4 phased array antenna fed by a low-loss waveguide network. In this phased array antenna, the radiation element is implemented by a patch-excited waveguide, the phase shifter is realized using an LC-based inverted microstrip line with defective ground structures (IMSL-DGSs), and the feed network is achieved based on the air-filled waveguide. A novel conversion structure composed of two symmetric patches is proposed for transition, power division, and DC block from waveguide feed network to IMSL-DGSs phase shifters. The simulation results illustrate that the radiation pattern of the phased-array antenna can be continuously steered from -30° to 30° with the maximum gain decreases from 8.18 dBi to 7.07 dBi. The reflection coefficient is lower than -10 dB from 13.9 GHz to 14.5 GHz.

11:20 ***Phased Array Antenna with Near-Hemisphere Scanning Coverage***

Peng-Fa Li (University of Electronic Science and Technology of China, China); Si-Yi Du (Xi-An Institute of Space Radio Technology, China); Shi-Wei Qu (University of Electronic Science and Technology of China, China)

An X-band planar phased array with near-hemisphere scanning coverage is proposed in this paper, which makes use of three metamaterials as ultra-wide-angle impedance matching (UWAIM) layer. The UWAIM layer is equivalent to a network model to help analyze impedance matching characteristics, in which multiple 1-port and 2-port networks are cascaded together. Eventually, the proposed phased array achieves a near-hemisphere scanning coverage of ±85° in arbitrary planes with voltage standing wave ratio below 3.3 in the operating band of 8 ~ 12 GHz.

11:40 ***On the Design of Next Generation Phased Array Antennas - Methods, Architectures, and Trends***

Nicola Anselmi (University of Trento, Italy); Luca Tosi (ELEDIA Research Center, Italy); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

The study of innovative methods and architectures for the design of next generation phased array antennas is still a research topic of high interest in the antenna academy and industry communities. The design of trade-off solutions balancing between costs/complexity and performance through non-uniformly spaced or clustered arrays is crucial for many forthcoming phased array applications. In this context, a review of the last methodological and architectural advances is reported, focusing on the design of irregular highly modular phased arrays.

12:00 ***Demonstration of the Use of MEMS Phase Shifters for Submm-Wave Phased-Arrays***

Sven L van Berkel (NASA Jet Propulsion Laboratory, Caltech, USA); Subash Khanal and Sofia Rahiminejad (Jet Propulsion Laboratory, NASA, USA); Cecile Jung-Kubiak (NASA-JPL, Caltech, USA); Alejandro Peralta (NASA JPL, USA); Alain Maestrini (Jet Propulsion Laboratory, NASA, USA); Goutam Chattopadhyay (NASA-JPL/Caltech, USA)

The realization of electronic beam-scanning antennas at submillimeter-wave (submm-wave) frequencies has been restrained by the absence of low-loss phase shifters. Recently developed MEMS-based and waveguide-integrated phase shifters are identified as suitable candidates. As a first demonstrator for the efficacy of those phase shifters, we present a linear, 4x1, leaky-wave phased array that operates over a 500 GHz to 600 GHz bandwidth. The MEMS-based phased array is capable of dynamically steering the beam over a ±10˚ field-of-view. The antenna element is a leaky-wave feed consisting of an iris-terminated waveguide in the presence of a silicon micro-machined Fabry-Pérot cavity. The phase shifters are integrated in a corporate feeding network. It is envisioned that those phase shifters are the ideal candidates to realize high-gain and wide-scan lens-scanning phased arrays. The array is fully fabricated and preliminary measurements results are presented.

12:20 ***Beam Scanning by Liquid-Crystal Biasing in a Modified SIW Structure***

Lucia Teodorani (Politecnico di Torino, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

A fixed-frequency beam-scanning 1D antenna based on Liquid Crystals (LCs) is designed for application in 2D scanning with lateral alignment. The 2D array environment imposes full decoupling of adjacent 1D antennas, which often conflicts with the LC requirement of DC biasing: the proposed design accommodates both. The LC medium is placed inside a Substrate Integrated Waveguide (SIW) modified to work as a Groove Gap Waveguide, with radiating slots etched on the upper broad wall, that radiates as a Leaky-Wave Antenna (LWA). This allows effective application of the DC bias voltage needed for tuning the LCs. At the same time, the RF field remains laterally confined, enabling the possibility to lay several antennas in parallel and achieve 2D beam scanning. The design is validated by simulation employing the actual properties of a commercial LC medium.

Wednesday, March 29 11:00 - 12:40

CS48b: Small antenna techniques for large-scale of integration (continued)

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 103

Chairs: Adam Narbudowicz (Trinity College Dublin, Ireland & Wroclaw University of Science and

Technology, Poland), Divitha Seetharamdoo (IFSTTAR, LEOST & Univ Lille Nord de France, France)

11:00 ***SAR Measurements for Back Cover Mobile Antennas***

Harri Varheenmaa and Anu Lehtovuori (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

We compare different low-profile antenna prototypes designed on the back cover of mobile devices around 2 GHz. Especially, we focus on controlling the specific absorption rate (SAR) without sacrificing the antenna efficiency. In addition, we study techniques to reduce the size of the antenna. We compare a traditional patch antenna, a sophisticated SAR-optimized design, and a patch minimized with a matching circuit. All these three options are manufactured. The measurement results show that SAR values can be decreased remarkably without compromising the antenna performance if exposure effects are taken into account in the design.

11:20 ***A 72GHz 64-Elements Antenna-In-Package Phased Array Module***

Wenyao Zhai (Huawei Technologies Canada Research Center, Canada); Ahmed Shehata Abdellatif, Sam Tiller and Hari Krishna Pothula (Huawei Technologies Canada, Canada); David Wessel (Huawei, Canada); Guangjian Wang (Huawei Technologies Co., Ltd., China); Guolong Huang and Songlin Shuai (Huawei Technologies, China)

This paper presents the LTCC package design details for a 72GHz phased array transceiver. The design is based on 8X8 patch antenna array with additional two rings of padding. The measured EIRP of the module is 39dBm. The radiation patterns show an azimuth steering of ±60 o and an elevation steering of ±15 o .

11:40 ***Small Antennas with Broad Beamwidth Integrated on a Drone Enclosed in a Protective Structure***

Ismael Vico Triviño and Anja K. Skrivervik (EPFL, Switzerland)

In this paper, we analyze the integration of small antennas in a drone protected by a conductive structure. They must be light and resistant to provide high collision resilience, which critical for drones flown indoors and in complex environments. To achieve these mechanical advantages, the material of the cage is carbon fiber, which is electrically conductive and degrades the performance and reliability of the radio link. We compare performance of a CP small, lightweight antenna with broad beamwidth with an omnidirectional dipole. We validate the performance of the antennas with the cage through system measurements using the SNR of the transmission system to quantify and assess the reliability of the link. The CP broadbeam patch antenna show an improved performance and reliability compared to dipoles in NLOS scenarios with strong multipath effect.

12:00 ***Small On-Ground LTCC Chip Antenna for 2.4 GHz IoT Aplications***

Jaime Molins-Benlliure (Universitat Politècnica de València & ITEAM, Spain); Eva Antonino-Daviu (Universitat Politècnica de València, Spain); Marta Cabedo-Fabrés (Universidad Politécnica de Valencia, Spain); Miguel Ferrando-Bataller (Universitat Politècnica de València, Spain)

This paper presents a very low-profile on-ground chip antenna. The antenna is designed using LTCC technology. The total volume of the antenna is 0.067λ × 0.048λ × 0.019λ, and the antenna does not require a clearance area on the ground plane. The antenna is proposed for 2.4 GHz IoT applications for extreme size-limited devices. A study in terms of matching and total efficiency is performance in two different size ground planes with the antenna installed in different positions. Results show a total efficiency difference up to 4 dB and a high frequency stability.

12:20 ***Tunable UHF Antenna for CubeSat***

Robert Borowiec (Wroclaw University of Technology, Poland)

This article is a continuation of the miniaturized UHF antenna concept for Cubesat satellites [1] for tracking, telemetry, and command systems, which does not require deploying for proper operation after reaching the desired orbit by satellite. The actual work concerns the extension of the supported frequency range by the antenna.

Wednesday, March 29 11:00 - 12:40

CS29: Inversion in Antennas and Scattering and Applications

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 104

Chairs: Giovanni Leone (Università di Reggio Calabria, Italy), Rocco Pierri (Università della Campania Luigi Vanvitelli, Italy)

11:00 ***On the Generation of Distributed Spherical Harmonics Expansions for Inverse Source Solutions***

Thomas F. Eibert, Daniel Ostrzyharczik, Jonas Kornprobst and Josef Knapp (Technical University of Munich, Germany)

Distributed spherical harmonics expansions are a powerful approach for the efficient solution of inverse source problems. They allow for a relatively accurate representation of the geometric support of the source distribution without the overhead of handling a mesh and mesh-specific basis functions representing the commonly utilized surface current densities. Standard spherical harmonics expansions distributed over a Huygens surface around the source domain are, however, redundant. Therefore, we discuss ways towards the reduction of this redundancy, where we are in particular interested in the construction of spherical harmonics with predominant radiation into the actual solution domain. Several sets of such spherical harmonics are presented and their utilization with measured and synthetic near-field data is demonstrated.

11:20 ***Deep Variational Inverse Scattering***

AmirEhsan Khorashadizadeh (University of Basel, Switzerland); Ali Aghababaei (Sharif University of Technology, Switzerland); Tin Vlašić (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia); Hieu Nguyen (University of Basel, Switzerland); Ivan Dokmanic (University of Basel and University of Illinois, Switzerland)

Inverse medium scattering solvers generally reconstruct a single solution without an associated measure of uncertainty. This is true both for the classical iterative solvers and for the emerging deep learning methods. But ill-posedness and noise can make this single estimate inaccurate or misleading. While deep networks such as conditional normalizing flows can be used to sample posteriors in inverse problems, they often yield low-quality samples and uncertainty estimates. In this paper, we propose U-Flow, a Bayesian U-Net based on conditional normalizing flows, which generates high-quality posterior samples and estimates physically-meaningful uncertainty. We show that the proposed model significantly outperforms the recent normalizing flows in terms of posterior sample quality while having comparable performance with the U-Net in point estimation.

11:40 ***Identification of Defective Elements in Antenna Arrays Through an Inverse Approach***

Valentina Schenone, Alessandro Fedeli, Claudio Estatico, Matteo Pastorino and Andrea Randazzo (University of Genoa, Italy)

An approach for the identification of defective elements in antenna arrays is presented in this paper. Specifically, the diagnostic problem is recast as the solution of an inverse problem, in which information about the excitation coefficients of the array are retrieved starting from measurements of the radiated field. Such an inverse problem is solved, in a regularized sense, using an inversion procedure developed in the framework of Lebesgue spaces. The effectiveness of the method has been numerically evaluated using realistic planar microstrip patch arrays, showing very good detection capabilities.

12:00 ***Regularization and Optimization Techniques for Inverse Source Problems***

Mats Gustafsson and Johan Lundgren (Lund University, Sweden)

Inverse source problems in electromagnetism are linear and, in principle, trivial to solve. At the same time, they are virtually impossible to solve due to the ill-posedness implying that there typically are infinitely many sources that approximately solve a problem. Here, we discuss how prior information can be incorporated into formulations of source reconstruction problems. Moreover, a connection between source reconstruction and physical bounds is presented.

12:20 ***Microwave Holography Techniques for Radiotelescopes Surface Errors Diagnosis and Adaptation to Conformal Reflectors***

Celia Fontá Romero (Universidad Politécnica de Madrid, Spain); Fernando Rodríguez Varela (Universidad Rey Juan Carlos de Madrid, Spain); Belen Galocha (Universidad Politecnica de Madrid, Spain); Jose-Antonio López-Pérez (IGN Spain & Yebes Observatory, Spain)

Radiotelescopes need a high level of gain. After designing an installation, the efficiency of the antenna suffers degradation over time due to gravity and thermal load that affects the surface of the reflector. Periodical measurements are crucial in order to identify the surface perturbations and correct them. The optimal method to identify these errors is microwave holography. This technique permits a recreation of the surface of the reflector by measuring the complex radiation pattern and computing the aperture field. In this paper the holography process is discussed, as well as different sources of error that must be identified and substracted during holography process to guarantee the correct recreation of the surface. Morever, the adaptation of this techniques to conformal reflectors is also described.

Wednesday, March 29 11:00 - 12:40

P05: Localization and imaging

T07 Positioning, localization & tracking / / Propagation

Room: Spadolini 105

Chairs: María García Fernández (Queen's University Belfast & University of Oviedo, United Kingdom (Great Britain)), Andrea Motroni (University of Pisa, Italy)

11:00 ***Accurate Three-Dimensional Point Cloud Radar Imaging by k- and Doppler Decomposition for Millimeter Wave Radar***

Takeru Ando and Shouhei Kidera (University of Electro-Communications, Japan)

Multi-functional three-dimensional imaging for millimeter wave (mmW) radar is presented, where the range points migration (RPM) point cloud is solely associated with the weighted kernel density (WKD) based Doppler analysis. Furthermore, considering a narrow aperture array of mmW module, k-space and Doppler velocity decomposition scheme is implemented to maintain accuracy for 3-D imaging and Doppler velocity analysis. The experimental validation, assuming a real human walking target, with the 79 GHz band mmW radar, demonstrates that it achieves a multi-information associated 3-D point cloud imaging with high temporal resolution, aiding in the recognition of the human gait level.

11:20 ***Measurement Testbed for Radar and Emitter Localization of UAV at 3.75 GHz***

Julia Beuster (Technische Universität Ilmenau & Fraunhofer Institute for Integrated Circuits IIS, Germany); Carsten Andrich (Technische Universität Ilmenau, Germany); Michael Döbereiner (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany); Steffen Schieler (Technische Universität Ilmenau, Germany); Maximilian Engelhardt (Fraunhofer Institute for Integrated Circuits IIS, Germany); Christian Schneider (Technische Universität Ilmenau, Germany);

Reiner S. Thomä (Ilmenau University of Technology, Germany)

This paper presents an experimental measurement platform for the research and development of unmanned aerial vehicles (UAVs) localization algorithms using radio emission and reflectivity. We propose a cost-effective, flexible testbed made from commercial off-the-shelf (COTS) devices to allow academic research regarding the upcoming integration of UAV surveillance in existing mobile radio networks in terms of integrated sensing and communication (ISAC). The system enables nanosecond-level synchronization accuracy and centimeter-level positioning accuracy for multiple distributed sensor nodes and a mobile UAV-mounted node. Results from a real-world measurement in a 16 km2 urban area demonstrate the system's performance with both emitter localization as well as with the radar setup.

11:40 ***Fast Calibration-Free Single-Anchor Indoor Localization Based on Limited Number of ESPAR Antenna Radiation Patterns***

Mateusz Groth, Krzysztof Nyka and Lukasz Kulas (Gdansk University of Technology, Poland)

In this article, we investigate how the calibration-free single-anchor indoor localization algorithm developed for base stations equipped with electronically steerable parasitic array radiator (ESPAR) antennas can further be improved. By reducing the total number of ESPAR antenna radiation patterns used in localization process, one can significantly reduce the time needed for an object localization. Performed localization measurements involved different placement and number of reference nodes used by the calibration-free single-anchor indoor localization algorithm, as well as different possible radiation patterns sets involving 6, 4 or 3 radiation patterns. Test results show that without significant deterioration of the overall accuracy one can easily speed up the algorithm execution time.

12:00 ***Ultra-Wideband D-Band MIMO-Radar System for 2D Inline Imaging***

Christian Krebs (Fraunhofer FHR, Germany); Marta Arias Campo (IMST GmbH, Germany); Sabine Guetgemann (Fraunhofer FHR, Germany); Simona Bruni (IMST GmbH, Germany); Enrico Tolin (IMST GmbH, Germany & Politecnico di Torino, Italy); Sven Leuchs (Fraunhofer FHR, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany); Hakan Papurcu and Justin Romstadt (Ruhr-University Bochum, Germany); Bettina Fischer (IMS Messsysteme GmbH, Germany)

A highly integrated ultra-wideband 1-D MIMO ARRAY with multiple sensor nodes in D-band (110-160GHz) was developed for 2D real time imaging of hot steel slabs during the hot rolling process. In this paper, the radar hardware design based on a SiGe MMIC (D-band) and in particular the optimized lens antenna will be presented.

12:20 ***Rotational Micro-Doppler for Rotor CW Localization and Target Classification***

Dmytro Vovchuk, Vitali Kozlov, Ofek Primor and Daniel Gudinetsky (Tel Aviv University, Israel); Serhii Haliuk (Yuriy Fedkovych Chernivtsi National University, Israel); Pavel Ginzburg (Tel Aviv University, Israel)

Objects in motion generate Doppler frequency shifts, upon which their velocities can be detected remotely. While Doppler frequency shift is associated with a center of mass motion, complex targets have other mechanically moving degrees of freedom. Each oscillating component interacts with incident radiation, imprinting spectral features on returns. Those micro-Doppler signatures provide extra possibilities to detect and even classify targets. To mimic complex scenarios with easy-to-handle models, we investigate interactions with two closely rotated dipoles. This system has a rather big number of degrees of freedom, including different rotation frequencies, the direction of rotation, and the distance between the scatterers. Owing to mutual interactions within this nonrigid system, mixed micro-Doppler harmonics were found and analyzed. Information on rotors' orientation and distance between them can be found by analyzing the micro-Doppler frequency combs that allow performing an accurate triangulation of a target, using CW signals and without relying on bandwidth limitations.

Wednesday, March 29 11:00 - 12:40

E02: Computational Electromagnetics 1

T09 EM modelling and simulation tools / / Electromagnetics

Room: Spadolini 106

Chairs: Francesco P. Andriulli (Politecnico di Torino, Italy), Michalis Nitas (Aristotle University of Thessaloniki, Greece)

11:00 ***Multi-Probe Array Design for Partially-Coherent Phase Retrieval in Near-Field Measurements***

Jonas Kornprobst, Alexander Paulus, Josef Knapp and Thomas F. Eibert (Technical University of Munich, Germany)

Phase retrieval, in particular for the operators arising from near-field measurements, is a non-convex task suffering from a severe lack of reliability due to local minima and false solutions. Approaches to tackle this issue, in turn, suffer from strict and often unrealistic oversampling requirements and possibly unfeasible computational complexities-in particular when larger scenarios are considered. In this paper, we analyze the sampling requirements for convex phase retrieval based on partially coherent observations which are captured with multi-probe arrays. We discuss requirements for the orientation and positioning of the probe antennas in the probe arrays. Following these conditions, a recently introduced linearized method is able to reconstruct a unique global solution reliably. The theoretical deliberations are corroborated with simulated near-field data.

11:20 ***Time Domain Analysis of PEEC Models Through the FFT Acceleration Technique***

Giuseppe Pettanice, Fabrizio Loreto, Roberto Valentini and Piergiuseppe Di Marco (University of L'Aquila, Italy); Giulio Antonini (Università degli Studi dell'Aquila, Italy)

This paper presents a novel approach to solve time domain Maxwell's equation through the partial element equivalent circuit (PEEC) method. To achieve this, the matrix-vector products involving the full matrices describing magnetic and electric field couplings, namely partial inductances and coefficients of potential matrices, are performed exploiting the translational invariance of the physical interactions by resorting to the fast Fourier transform. The proposed approach is applied to time-stepping methods and to the methods based on the numerical inversion of the Laplace transform, requiring matrix-vector products in the complex plane when iterative solvers are adopted to handle a large number of unknowns. Then, the quality of this approach is validated by comparing the results with those obtained with a commercial solver based on the finite integration technique.

11:40 ***Non-Dense Thin Sheets Analysis Through Method of Moment Based on a Second-Order Transition Condition***

Agnese Mazzinghi (University of Florence, Italy); Alessandro Mori, Mirko Bercigli and Mauro Bandinelli (IDS Ingegneria Dei Sistemi S. p. A, Italy); Angelo Freni (Università degli studi Firenze, Italy)

A second-order approximation of the transition boundary condition is used for the analysis of not-very thin permeable layers of non-dense materials. The independence of the formulation from the incidence angle of the impinging wave allows its implementation in a numerical method as the method of moments. The formulation allows reconstructing with an error of less than 1% the scattering from a dielectric slab characterized by a thickness of the order of a tenth of wavelength, even when the relative dielectric constant is two.

12:00 ***Fast Direct Solvers for Integral Equations at Low-Frequency Based on Operator Filtering***

Clément Henry (IMT Atlantique, France); Davide Consoli, Alexandre Dély and Lyes Rahmouni (Politecnico di Torino, Italy); Adrien Merlini (IMT Atlantique, France); Francesco P. Andriulli (Politecnico di Torino, Italy)

This paper focuses on fast direct solvers for integral equations in the low-to-moderate-frequency regime obtained by leveraging preconditioned first kind or second kind operators regularized with Laplacian filters. The spectral errors arising from boundary element discretizations are properly handled by filtering that, in addition, allows for the use of low-rank representations for the compact perturbations of all operators involved. Numerical results show the effectiveness of the approaches and their effectiveness in the direct solution of integral equations.

12:20 ***Wave-Front Behaviour of the Pulsed EM Field - Complexity and Implications***

Junhong Gu, Andrea Neto and Ioan E. Lager (Delft University of Technology, The Netherlands); Martin Štumpf (Brno University of Technology, Czech Republic)

The pulsed electromagnetic (EM) field radiated by a gap-fed, long slot in a perfectly conducting thin sheet located in between dielectric and free-space subdomains is examined. A phenomenological interpretation of the so-called head wave (HW) constituent is proposed, this fostering the understanding of the complex EM behaviour at, and immediately behind, the HW wave-front. The EM field is also examined numerically for identifying features that may lead the way towards inferring a causal counterpart of the leaky-wave propagation.

Wednesday, March 29 11:00 - 12:40

CS3b: AMTA session: Advanced Measurement Techniques for 5G and Beyond (continued)

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 107

Chairs: Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)), Janet O'Neil (ETS-Lindgren, USA)

11:00 ***An Investigation into the Spatial Heterogeneity of MIMO Device with 3D Deterministic Channel Modelling Using Single-Probe Anechoic Chamber Method***

Qiwei Zhang (University of Chinese Academy of Sciences, China); Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)); Zhipei Huang (University of Chinese Academy of Sciences, China); Fei Qin (Chinese Academy of Sciences, China)

The multiple-input-multiple-output (MIMO) over-the-air (OTA) testing technique is envisaged capable of effectively emulating the channel environment. While characterizing classical cellular channels, spatial correlation can be used to evaluate the differences correlation between each pair of transmit and receive antennas. In the next-generation wireless systems, the presence of reflectors close to the wireless device in a complex electromagnetic environment as well as toward higher carrier frequency will cause heterogeneous channel characteristics. Consequently, the current MIMO OTA emulation techniques represented by multi-probe anechoic chamber (MPAC) method will hardly emulated the heterogeneity channels by planewave-based architecture. We propose a single-probe anechoic chamber (SPAC) based MIMO OTA solution to emulate the heterogeneous deterministic channel, which has been decomposed and synthesized for each array element in a temporally sequential manner. Both the theoretical analysis and simulation results demonstrate the proposed method can effectively extend the application scenarios for SPAC based MIMO OTA emulation.

11:20 ***Multi-Feed Antennas for Wireless Communications***

Walid El Hajj and Tsitoha Andriamiharivolamena (Intel Corporation, France); Juan Antonio Del Real (Intel Corporation SAS & Wireless Telecom Group Inc., France); Serge Dao, Alexandre Lacoste Novailles and Nawfal Asrih (Intel Corporation, France)

In this paper, two designs of multi-feed antennas are presented. These designs have each two ports, one port covering two bands, and the second port covers a third band with a good isolation above 15 dB over the bands and compact dimensions taking into account the integration constraints within the wireless devices. The three respective bands are those of Wi-Fi 6E technology i.e. (2.412-2.483 GHz), (5.15 -5.85 GHz), (5.925-7.125 GHz) respectively. However, the same concept can be applied and extended to any wireless technology including LTE, 5G, etc. with possibility to share and split bands between technologies. The design concept and ports isolation performances are validated by experimental measurement outside and inside final host. The measurement challenges of this kind of multi-feed antennas are presented and illustrated.

11:40 ***Towards Complex Over-The-Air Calibration of a MIMO mmWave Testbed***

Koen Buisman (University of Surrey, United Kingdom (Great Britain) & Chalmers University of Technology, Sweden); Thomas Eriksson (Chalmers University of Technology, Sweden)

Calibration of mm-wave transceiver arrays with respect to phase and amplitude of signals on all its elements is essential for proper operation. Moreover, during operation it may be necessary to update such calibration coefficients. Here we present an algorithm based on channel symmetries to calibrate amplitude and phase in a mm-wave testbed using Over-The-Air measurements only.

12:00 ***Antenna Measurement System Using an Optical Fiber Link Millimeter Wave Generator and a Receiving System***

Satoru Kurokawa (National Institute of Advanced Industrial Science and Technology, Japan); Michitaka Ameya (NMIJ/AIST, Japan); Masanobu Hirose (7G aa Co., Ltd., Japan)

In this paper, we newly developed a millimeter wave receiving system using our developed optical fiber link millimeter wave generator. Our millimeter wave receiving system consists of a subharmonic mixer and our developed millimeter wave generator as a local signal input for the mixer. For measuring the millimeter wave from 75 GHz to 110 GHz, our developed signal generation technique uses for the local signal for the subharmonic mixer from 18.75 GHz to 27.5 GHz. Finally, we show a measurement result for an FMCW radar using our developed millimeter wave receiving system.

12:20 ***Research on the Performance of Automotive Antenna on Intelligent Connected Vehicle***

Zhanyuan Gao (China Academy of Information and Communications Technology, China)

The Intelligent Connected Vehicle (ICV) is an important part of Internet of Vehicle. Therefore, accurate evaluation of the wireless communication performance is critical for vehicle manufactures. Automotive antenna, which plays the key role in ICV, can't be neglected. In this paper, the performance of automotive antenna will be studied by comparing the character of a communication antenna before and after installed on a simulated vehicle. In addition, the effect of different antenna installation positions on the over the air (OTA) performance should also be investigated, which could also make effect on the overall wireless performance of the Internet of Vehicle.

Wednesday, March 29 11:00 - 12:40

CS51b: Unconventional electromagnetic phenomena in wave propagation and beam focusing (continued)

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 108

Chairs: Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy), Santi Concetto Pavone (Università degli Studi di Catania, Italy)

11:00 ***Dispersion Diagram Analysis of a Two-Dimensional Hexagonal Periodic Structure***

Shiyi Yang (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Oskar Zetterstrom, Sarah E Clendinning and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

This paper focuses on the analysis of the dispersion diagram of a two-dimensional hexagonal periodic structure. The periodic inclusions are placed in a parallel plate waveguide environment and are circular holes located at the vertices of the hexagonal unit cells. The connection between the geometry of the periodic structure and the dispersion diagram is discussed. The wavevector information in the Brillouin zone is illustrated using the reciprocal lattice, from which the shape of the irreducible zone can be derived. The results give insight into the characteristics of the wave propagation characteristic of hexagonal units.

11:20 ***Toroidal Dipole Dielectric Metasurfaces for Mechanically Tunable Polarization Beam Splitting***

Dimitrios Zografopoulos (CNR-IMM, Italy); José Francisco Algorri (Universidad de Cantabria, Spain); Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy); Jose Miguel Lopez Higuera (Universidad de Cantabria, Spain); Ricardo Vergaz and Jose M. Sánchez-Pena (Carlos III University of Madrid, Spain); Ion-Anastasios Karolos (Aristotle University of Thessaloniki, Greece); Romeo Beccherelli (Consiglio Nazionale delle Ricerche, Italy); Vassilios Tsioukas, Traianos Yioultsis and Emmanouil E. Kriezis (Aristotle University of Thessaloniki, Greece)

An all-dielectric metasurface composed of high- permittivity ceramic cuboid resonators embedded in polylactic acid is investigated as an angular-dependent polarization beam splitter in the K-band. The operation is based on a strong toroidal resonance with a highly asymmetric Fano profile and the very low (high) dispersion of the associated p-(s-) polarized mode stemming from the particular field profile of the toroidal mode. Large extinction ratios, low insertion losses, and mechanically tunable polarization beam splitting ratio are experimentally demonstrated.

11:40 ***Recent Advances in Beam Focusing Through Resonant Bessel-Beam Launchers for Millimeter-Wave WPT Applications***

Edoardo Negri (Sapienza - Università di Roma, Italy); Francesca Benassi (University of Bologna, Italy); Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy); Diego Masotti (University of Bologna, Italy); Paolo Burghignoli (Sapienza University of Rome, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy); Alessandro Galli (Sapienza University of Rome, Italy)

Resonant Bessel-beam launchers have recently gained much attention due to their capability to radiate focused beams by means of a compact and low-cost devices at microwave and/or millimeter waves. Most realizations consider only the use of TM-polarized beams, whereas only few works deal with the TE case. Here, we present an original workflow based on leaky-wave theory for the design and performance analysis of both kinds of launchers in wireless power transfer (WPT) scenarios. Simple analytical formulas are provided and validated with both numerical and full-wave methods for different case studies. The results obtained here offer considerable insight into the WPT performance of such devices.

12:00 ***On Local Pulsed Beam Solutions of the Time-Dependent Wave Equation***

Ehud Heyman (Tel Aviv University, Israel)

Iso-diffracting pulsed beams (ID-PB) are space-time wavepacket solutions of the time-dependent wave equation that propagate along ray trajectories even in non-uniform medium, while maintaining their wavepacket structure and satisfying a local adiabatic wave-dynamics. In that sense, the ID-PB can be regarded as ``beam-waves.'' The "local adiabatic wave-dynamics" criterion is then applied to clarify the properties of other classes of focused wave fields that have been introduced in the past.

12:20 ***A Novel Approach to the Design of Inhomogeneous Dielectric Lens Antennas Based on Geometrical Optics***

Ilir Gashi, Anastasios Paraskevopoulos, Stefano Maci and Matteo Albani (University of Siena, Italy)

In this paper we present a novel approach to the design of inhomogeneous lenses which is obtained by inverting the standard method of Geometrical Optics for inhomogeneous media. As a result of this method, we obtain the refractive index spatial distribution that is capable to drive the rays along prescribed ray paths which are defined to transform the impinging field on the input surface into the target aperture distribution on the output surface of the lens. After the first part where the method is presented, two examples of a telescopic lens (a lens that magnifies an impinging planar wavefront) will be shown.

Wednesday, March 29 11:00 - 12:40

E13: EM computing and optimization

T09 EM modelling and simulation tools / / Electromagnetics

Room: Spadolini 109

Chairs: Oscar Borries (TICRA, Denmark), Johan Lundgren (Lund University, Sweden)

11:00 ***Heterogeneous Computing and Visibility Preprocessor Accelerated Full-3D Ray Tracing for Large Scale Outdoor Propagation Modeling***

Yongwan Kim (Seoul National University, Korea (South)); Hyunjun Yang (SeoulNationalUniversity, Korea (South)); Jungsuek Oh (Seoul National University, Korea (South))

This study presents a novel full-3D heterogeneous computing and visibility preprocessor accelerated image method ray tracing framework for large scale outdoor propagation modeling It is demonstrated that the proposed simulator is faster than the prior image method ray tracing solver of WinProp by 1,039 times for tetrahedron scenario allowing maximum ray bouncing number of 6 within the root mean squared percentage error having lower than 1%. The proposed framework is divided into three parts: 1. GPU-based visibility preprocessing part. 2. CPU parallel computing-based visibility tree generation part. 3. Backward shadowing test and field calculation part. Finally, for tetrahedron and urban scenarios our simulator and the commercial ray tracing program, WinProp, are compared, validating the effectiveness of the proposed methodologies. For the urban scenario, our simulator takes 6 h, 33 min, and 43 s for simulation, while computation time of WinProp diverges.

11:20 ***Matrix Completion Methods for Fast Computation of Characteristic Modes on General Scatterers***

Johan Lundgren (Lund University, Sweden); Kurt Schab (Santa Clara University, USA); Miloslav Capek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Mats Gustafsson (Lund University, Sweden)

An iterative, scattering-based formulation of characteristic modes is applied to generate modal data for structures consisting of arbitrary materials. The core of the method is the iterative approximation of the dominant eigenvalues of an object's scattering dyadic, rather than the complete scattering dyadic itself. The method relies on general-purpose full-wave electromagnetic solvers and does not require the use of the method of moments. Numerical examples demonstrate that the method affords significant speed-up over the explicit calculation of the scattering dyadic, particularly in electrically small objects.

11:40 ***Design of Dielectric Structures with Nonuniform Holes Optimized for Backscattering Reduction***

Şirin Yazar (Middle East Technical University & ASELSAN Research Center, Turkey); Ozgur Ergul (Middle East Technical University, Turkey)

We present design and optimization of three-dimensional dielectric structures that provide efficient backscattering reduction (BSR). Although BSR is a subject involved in a plethora of applications and is studied intensively in the literature, the complexity of the designed structures often leads to challenges in fabrication and production phases. In this study, very effective BSR is achieved with relatively simple dielectric geometries using only a single material and air-filled holes. Moreover, with the designed structures, BSR can be achieved not only in a single frequency range but also in two frequency bands. All structures are solved and analyzed by the multilevel fast multipole algorithm (MLFMA) and optimizations are successfully performed by combining this method with genetic algorithms (GAs). By optimizing the size, arrangement, and depth of holes on dielectric structures, backscattering from a metal plate can be reduced by as much as 37 dB.

12:00 ***Full-Wave Monostatic Radar Cross Section Using the Multilevel Fast Multipole Method***

Asger Limkilde, Oscar Borries, Peter Meincke and Erik Jørgensen (TICRA, Denmark)

An efficient full-wave solver for the computation of monostatic Radar Cross Section (RCS) for electrically large structures using the method of moments is developed. This is accomplished by utilizing higher-order basis functions, to reduce the number of

unknowns, and the multilevel fast multipole method, to reduce the computational effort and memory footprint. These techniques are combined with a compression of the right hand sides arising from the different incident angles. We demonstrate that this solver allows for efficient full wave RCS computations of electrically large structures on a laptop.

12:20 ***Using a Non-Physical Absorber Termination for the Analysis of RCS Pylons Using a Higher Order Basis Function Method of Moments***

Vince Rodriguez (NSI-MI Technologies & University of Mississippi, USA)

Low back-scattering pylons are a typical feature of RCS measurement ranges [1], these can achieve levels between -25 and -45 dBsm [2]. The measurement of the RCS level from a pylon is a difficult task. The Measurement requires adding a low RCS target to hide the top edge of the pylon. In this paper a numerical technique is explored to estimate the RCS of a pylon using a high order basis function method of moments technique (HOBF-MoM). The paper explores a technique to hide the top and bottom features of the pylon using a non-physical lossy material to get the RCS from the main pylon structure. The effects of the structure on the RCS of standardized targets like spheres is also explored.

Wednesday, March 29 11:00 - 12:40

SW5b: Effectively Addressing the Challenges to Uncertainties Induced by Modern Environment and Positioning Systems in Electromagnetic Compatibility and Antenna Measurements (continued)

Organized by: Janet O'Neil (ETS-Lindgren, USA), Carlo Carobbi (University of Florence, Italy)

Room: Sala della Scherma

Any kind of measurement, particularly when carried out for scientific or professional purposes, requires consideration of inherent measurement errors. Evaluation of measurement uncertainty in electromagnetic compatibility and antenna characterization applications is the common thread that connects the presentations in this workshop. Sophisticated data processing techniques and novel measurement methods are presented aiming at enhancing the accuracy of electromagnetic field measurements with specific reference to errors induced by the measuring environment (reverberation chambers and anechoic chambers), robotic positioning systems and phaseless near field detection in the millimetre wavelength frequency range.

11:00 - Uncertainty Contributions from EMC Test Site Imperfections for mmWave Measurements (Zhong Chen, ETS-Lindgren, USA)

11:30 - Overcoming Probe Positioning Errors: To Phase or Not to Phase in Planar Near Field Measurements (Yahya Rahmat-Samii, UCLA, USA)

12:00 - Panel Session

Wednesday, March 29 11:00 - 12:40

IW5: Uncertainty Quantification with TICRA Tools (Ticra)

Room: Polveriera

Wednesday, March 29 11:00 - 12:40

Perspectives II: The Evolution of Smart Wireless Environments (II)

Organized by: Filiberto BILOTTI (Università di Roma TRE, Italy); Marco DI RENZO (CNRS & CentraleSupelec - Paris-Saclay University, France); Giacomo OLIVERI, (ELEDIA Research Center, University of Trento, Italy)

11:00-11:30 "RIS-N: a characterization of metasurfaces for smart environments"

Stefano MACI, University of Siena, Italy (macis@dii.unisi.it)

Giuseppe VECCHI, Politecnico di Torino, Italy (giuseppe.vecchi@polito.it)

• 11:30-12:00 "Optimizations of millimeter-wave propagation environments using anomalous reflectors and splitters"

Sergei TRETYAKOV, Aalto University, Finland (sergei.tretyakov@aalto.fi)

• 12:00-12:30 "Towards Inclusive, Immersive, and Intelligent Connectivity in 6G - The role of THz Communications and RIS"

Angeliki ALEXIOU, University of Piraeus, Greece (alexiou@unipi.gr)

Room: Sala Arco

Wednesday, March 29 13:30 - 15:00

PA4: Poster Session on Antennas for Health Applications

/ / Antennas

Rooms: Spadolini 001, Spadolini 002

Chairs: Ali Khaleghi (NTNU, Norway & OUS, Norway), Anja K. Skrivervik (EPFL, Switzerland)

Body Posture Measurement Based on Textile UHF-RFID Technology

Chengyang Luo and Ignacio Gil (Universitat Politècnica de Catalunya, Spain); Raul Fernandez-Garcia (Universitat Politecnica de Catalunya, Spain)

With the development of the healthcare field, multi-application textile tags are worth exploring. In this paper, three types of body postures are tested by a proposed textile UHF-RFID tag, including monitoring a bent knee, a bent elbow and bent back. The RSSI-angle fitting curves on the bent knee and elbow conform to quadratic function models whereas the fitting curve on the back conforms to an exponential function. Through the experimental measurements, the proposed textile UHF-RFID tag is proved to have the feasibility of monitoring the bending level of the three types of body postures by the correspondence between the RSSI and bending angles.

Wireless Dual-Loaded Loop ELF Antenna

Christopher G Hynes and Rodney Vaughan (Simon Fraser University, Canada)

This work presents a novel wireless dual-loaded loop antenna system for extremely low frequencies. The antenna port signals are digitized and transmitted to a receiver using 802.15.4. The port sensor passband is designed for up to 108 Hz with a sampling rate of 256 samples per second. The receiver gain of 32 dB and noise figure near 1 dB makes this sensor suitable for low signal detection. Three dual-loaded loop antennas, with six sensors, can be configured orthogonally to create a three-loop antenna system suitable for extremely low frequencies, with each loop port signals transmitted across a 802.15.4 wireless channel and processed in parallel. The motivation is for detecting biological signals in terms of the six field components.

Breathing Pattern Characterization Based on Wireless e-Textile Antenna-Sensor for Respiratory Disease Surveillance

Mariam El gharbi (Universitat Politècnica de Catalunya, Spain); Raul Fernandez-Garcia (Universitat

Politecnica de Catalunya, Spain); Ignacio Gil (Universitat Politècnica de Catalunya, Spain)

The paper presents a system for monitoring breathing patterns based on an antenna-sensor integrated into an e-textile T-shirt with a Bluetooth transmitter. The main aim of the system is to detect and monitor respiratory diseases. The sensor consists of a meander dipole antenna made of a silver-coated nylon thread attached to a compact transmitter. The respiratory signal is extracted from the received signal strength indicator (RSSI) emitted from the antenna-based sensor and detected wirelessly by a base station, which contains a computer with a receiver Bluetooth module. We analyzed the feasibility assessment of using a textile antenna-based sensor for respiratory monitoring of a female volunteer in sitting position with different breathing patterns. The experimental results showed that respiratory signals can be acquired wirelessly by the RSSI via Bluetooth for Eupnea, Biot and Cheyne-stokes, respectively.

A Low-Profile Wide Bandwidth Circularly Polarized Dielectric Resonator Antenna for mm-Wave for Off-Body Applications

Tarek Saleh Abdou (The University of Sheffield, United Kingdom (Great Britain)); Salam Khamas (University of Sheffield, United Kingdom (Great Britain))

A low profile wideband circularly polarized, CP, layered dielectric resonator antenna, DRA, is proposed for off-body applications. The rectangular DRA consists of two dielectric layers, and as result, the robustness and the radiation characteristics have been enhanced. Moreover, the antenna has been simulated using various distances from the equivalent human body tissue. In addition, the DRA alignment has been achieved using a removable customized holder that has been designed particularly for this purpose. The antenna offers a measured impedance bandwidth of ~75% that extends from 14 GHz to 30.9 GHz in conjunction with an axial ratio, AR, bandwidth of ~ 26.9% as well as a maximum gain of ~ 8.9 dBic at 24 GHz. Close agreement has been achieved between simulations and measurements.

Circularly Polarized Wearable Antenna with Miniature Feeding

Zhensheng Chen (KU Leuven, Belgium); Jiahao Zhang (Naval University of Engineering, China); Xuezhi Zheng and Guy Vandenbosch (KU LEUVEN, BELGIUM)

An aperture-fed textile-based antenna is designed for wearable applications. This is done by using a miniature feeding on a rigid substrate, which is sewn onto the textile ground. A capacitive and inductive loading technique is exploited to miniaturize the antenna feed. This is done by taking advantage of the flexibility of textiles, simultaneously mitigating the risk of cracking on textile-to-rigid (feeding) interfaces and chip components in traditional flexible designs due to flexing stresses. The full size of the antenna is 0.667 λ^2 (10 cm x 10 cm) while the rigid substrate area for the feeding is only 0.015 λ^2 (1.5 cm x 1.5 cm) at 2.45 GHz. Simulations and measurements were carried out to validate the functioning of the antenna.

Investigation of Capsule Localization Using 3-D Printed Spiral WPT Coil

<u>Sadeque Reza Khan</u> (Heriot-Watt University, United Kingdom (Great Britain)); Marc Desmulliez (Heriot Watt University, United Kingdom (Great Britain))

Wireless capsule endoscopy (WCE) is an effective tool for the diagnosis of pathologies of the gastrointestinal (GI) tract. In its most common version, WCE provides the wireless transmission of optical images and videos of the GI tract helping diagnosis of luminal disorders. However, one of the most challenging aspects of WCE is the identification of the exact location of the capsule within the GI tract. Such information is important for the subsequent treatment of detected pathologies either through surgery or by local drug delivery. This paper assesses the potential of using wireless power transfer for the accurate localization of the capsule using 3-D printed spiral receiver coil. The results presented here demonstrate that the magnetic field variations and mutual coupling between transmitters and receiver coils can be utilized for localization, enabling thereby the dual role of WPT as a means to transfer electrical power and determining location of a capsule.

Performance Evaluation of Fractal-Inspired Miniaturized Planar Inverted-F Antennas

Sandra Costanzo and Adil Masoud Qureshi (University of Calabria, Italy)

The performance of miniaturized Planar Inverted-F Antenna (PIFA) configurations are presented in this work. The first design is based on a pre-fractal geometry aiming to reduce the resonant frequency by increasing the perimeter of the radiating element. An evolution of the first design, based on the analysis of the miniaturization mechanism, is then considered, and a final variant,

optimized for the wearable use-case, is presented. All PIFA configurations been realized and tested to validate the simulations. Measured characteristics including reflection coefficient, boresight gain, as well as efficiency are presented.

An RFID Sensor with Microfluidic for Monitoring the pH of Sweat During Sport Activity

Alessia Riente (University of Rome Tor Vergata, Italy); Giulio M. Bianco (University of Roma Tor Vergata, Italy); Luca Fiore (Tor Vergata, Italy); Fabiana Arduini and Gaetano Marrocco (University of Rome Tor Vergata, Italy); Cecilia Occhiuzzi (University of Roma Tor Vergata, Italy)

Among the multiple healthcare applications and systems exploiting sensing RFID boards, monitoring sweat's pH can be extremely useful for sportsmen and sportswomen. Furthermore, given the multiple known benefits that sports yield, measuring pH during physical activity can be integrated with points-of-care (PoCs) for patients who need working out. This contribution details the experimental testing of an RFID sensor for measuring sweat's pH during sporting activity. The electromagnetic (EM) performances are quantified over multiple wearers, and new, low-cost microfluidics made of absorbent paper is manufactured, characterized, and tested so that the use of the tag during exercise is proven feasible.

Design and Characterization of Modified Comb Patch Antennas

Elena Marongiu and Alessandro Fanti (University of Cagliari, Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy); Matteo Bruno Lodi and Andrea Melis (University of Cagliari, Italy); Nicola Curreli (Italian Institute of Technology, Italy); Gino Sorbello (University of Catania, Italy); Giuseppe Mazzarella (University of Cagliari, Italy)

In this paper, a new microstrip antenna design is proposed, formed by n parallel conductors, fed by a common strip. The proposed antenna is called MCPA, which is a modified comb antenna. In addition, a dedicated mathematical framework for antenna analysis and design is proposed. The analytical model is numerically validated with full wave simulations, resulting in a 4.4% error in the expected resonant patch length. Subsequently, eighty conductors were made and measured to evaluate the frequency response of the antenna, as well as its radiation performance. An error of 1% was observed between the resonant frequency of the predicted and the measured value. There was a difference of approximately 0.67 dB for the maximum measured antenna gain compared to the simulated one. The proposed antenna design is interesting for printed electronics and wearable applications on fabric. The proposed antenna design is appealing for printed electronics and wearable, on-textile applications.

Wearable Radiofrequency Metasurface for Inflammatory Process Monitoring

Angelica Masi (University of Pisa, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy); Danilo Brizi (University of Pisa, Italy)

This work reports the development of a low-cost, high-sensitive, and reusable sensor that can be integrated into dressing bandages to monitor pathological processes. The proposed radiating system consists of an actively fed RF probe loop and a planar 2×2 metasurface made of passive spiral resonator unit cells. The Q-factor maximization approach was used to achieve an effective unit-cells design. The inflammatory state identification is carried out by analyzing the amplitude and frequency shift variation of the external planar probe input impedance, caused by the self-resonant unit-cells sensing activity. We performed full-wave simulations to evaluate the radiating system performance in presence of healthy and inflamed tissue. Numerical results validated the introduced theoretical approach, confirming both the ability to identify the presence of the inflammatory state and also the spatial position of the disorder. Therefore, the proposed sensor is a promising alternative to help to allow better treatment decisions in wound healing.

Design Limitations of Using Magnetic Inductive Coupling to Verify Nasogastric Tube Placement

Nuno P. Silva (University of Galway, Ireland); Martin O'Halloran and Muhammad Adnan Elahi (National University of Ireland, Galway, Ireland); Derek OKeeffe (University of Galway, Ireland); Declan O'Loughlin (Trinity College Dublin, Ireland)

Nasogastric tube insertion is a standard procedure but potentially fatal consequences if misplaced. Many bedside methods have been proposed for identifying misplacement including magnetic inductive coupling. This study aims to identify the coil design limitations for nasogastric tube placement confirmation using magnetic inductive coupling. The fundamental limits on the

coil sizes and detection distances are identified based on the anatomical understanding. Candidate designs are simulated and fabricated, and key parameters (coil radius and penetration depth) are examined. The mutual inductance and coupling factor between the coils in the designs are both calculated and measured with respected to distance. This work highlights that a small coil of up to 3 mm in radius could be integrated into a nasogastric tube without impairing clinical function. These preliminary results suggest that magnetic inductive coupling is a promising approach for nasogastric tube localisation, however, optimisation of the detector coil size could improve localisation performance.

Hip Implant Micromotion Monitoring Using Microwave-Photonic Hybrid Device

Shamba Mitra (IIEST, SHIBPUR, India); Debasis Mitra (Indian Institute of Engineering Science & Technology, Shibpur, India); Souptcik Chanda (IIT Guwahati, India); Rik Chattopadhyay (CSIR-Central Glass & Ceramic Research Institute, India); Bappaditya Mandal (Uppsala University, Uppsala, Sweden); Robin Augustine (Uppsala University, Sweden)

In this work, our objective is to develop a noninvasive, portable, user-friendly, non-ionizing, cost-effective system that will be used for post-surgical continuous monitoring of hip implant micromotion. The system we have tried to construct here has been built by integrating microwave sensors and optical interferometric systems. A simple antenna and optoelectrical modulator have been used to devise this hybrid system. Proof of the concept of this novel idea has also been established.

Design of a Cardiopulmonary Antenna for Vital Signs Monitoring Robust to Different Subjects

João Cardoso (Instituto Superior de Engenharia de Lisboa, Portugal); Pedro Pinho (UA - Universidade de Aveiro & IT - Instituto de Telecomunicações, Portugal); Carolina T. S. Gouveia (Instituto de Telecomunicações, Aveiro & University of Aveiro, Portugal); Daniel Albuquerque (CISED - Polytechnic of Viseu, Portugal)

With the advancement of wireless diagnosis and treatment technologies, antennas deployed close to the human body are now widely used. The use of on-body antennas, along with other technologies, presents itself as an innovative method for detecting and monitoring vital signs. These antennas can be attached directly on the body or on clothes, making it comfortable to use and less invasive when compared to conventional methods, allowing at-home monitoring of elderly patients or high risk workers with a single antenna. In this paper, a robust high bandwidth patch antenna was developed to operate in the dedicated Industrial, Scientific and Medical frequency band, namely at 2.45 GHz, capable of monitoring vital signs in any subject. This work presents the design and results of a robust cardiopulmonary antenna, to be further used to monitor the respiratory rate of five different subjects, each one with different physiognomy.

Asymmetric Use of 8-Legged Conventional Birdcage

Thomas Clerbois and Antoine Rampelbergh (Universite Catholique de Louvain, Belgium); Farzad Jabbari gargari (Université Catholique de Louvain, Belgium); Chan-Sun Park (Universite Catholique de Louvain, Belgium); Redha Abdeddaim (Aix Marseille University, France); Christophe Craeye (Université Catholique de Louvain, Belgium)

In high-frequency magnetic resonance imaging (MRI) system, shaping of the magnetic field inside the body becomes an important challenge. The choice of the Radio-frequency (RF) coils and their design is essential if a quality image is expected. This paper presents the asymmetric use of a conventional Birdcage RF coil and answers the problem of homogeneity as well as localizing an off-centered region of interest (ROI).

Simulations Predict Increased Brain Antenna Performance Robustness by Adding Biocompatiblility Layer

Leroy H.P. Driessen, L. A. (Sander) Bronckers and Margarethus M. Paulides (Eindhoven University of Technology, The Netherlands)

The goal of this paper is to study the effects of the simulated reflection coefficient of a cortical UWB antenna in a planar multilayered head model. This study shows that the reflection in these deeply implanted antennas can be heavily influenced by the presence of cerebrospinal fluid. However, when including a thin biocompatible layer of alumina with a thickness of 0.1mm, the reflection coefficient shows much more robustness to interpersonal differences in head geometry and to small variations in antenna placement. This stable behavior to these uncontrollable parameters suggest that direct, untethered, high- speed brain communication could be feasible. This topology would more elegant than the conventional tethered, subcutaneous approach, as this wire-free option eases surgical implantation and can prevent tissue damage due to the mechanical interaction between the tissues and the tether cables.

Experimental Characterization of a Passive Wearable Tag for Respiration Rate Monitoring

Mahmoud Elgeziry, Filippo Costa, Alessandro Tognetti and Simone Genovesi (University of Pisa, Italy)

The rise of interest in the Internet of Things (IoT) and the demand for the devices to keep up with the requirements of this new paradigm is driving the research community to develop innovative solutions and products for this purpose. In particular, for the monitoring of vital signs, including the respiration rate, the sensing devices used must measure and store measured data regarding the vital signs, generate reports, and alert healthcare professionals in dangerous or critical situations. In this paper, a passive wearable sensor tag for the monitoring of the respiration rate is presented. The proposed tag is suitable for real-time continuous monitoring and for integration and conformity with IoT requirements. The proposed sensor was experimentally verified on a human test subject and the respi- ration frequency at different breathing patterns was accurately retrieved.

Flexible RF-Power Harvesting System for Smart Bandages Using a Textile Dipole Antenna Array

Irfan Ullah and Abiodun Komolafe (University of Southampton, United Kingdom (Great Britain)); Mahmoud Wagih (University of Glasgow, United Kingdom (Great Britain)); Stephen Beeby (University of Southampton, United Kingdom (Great Britain))

We present a fabric bandage integrated rectenna array for wireless and battery-free smart bandages in healthcare applications. The integrated array consists of 3 rectenna elements and each element comprises an embroidered dipole antenna and a rectifier. The antennas resonate in the UHF band 915 MHz in the presence of the human tissue, with the inter-element mutual coupling under −10 dB. The rectifier design is based on voltage doubler topology with an RF-to-dc conversion efficiency of 48% for an RF input power of 0 dBm.

Compact Optimized Antenna Solution for Radiation Coupling Improvement in the Subcutaneous Fat Layer

Rossella Gaffoglio (Fondazione LINKS, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Lucia Teodorani (Politecnico di Torino, Italy); Marco Righero (LINKS Foundation, Italy); Giuseppe Musacchio Adorisio (Fondazione LINKS, Italy); Bappaditya Mandal (Uppsala University, Sweden); Mauricio D Perez (Uppsala University, Sweden & National Technological University, Argentina); Robin Augustine (Uppsala University, Sweden); Giuseppe Vecchi (Politecnico di Torino, Italy)

Fat intra-body communication (Fat-IBC) aims at confining microwave propagation to the subcutaneous adipose tissue layer for the creation of a safe high-speed, high-bandwidth data transmission link through the body. This technique can be exploited to connect implantable medical devices and to implement a two-way transmission of recorded neural data and sensory stimulation signals between brain and robotic limbs. In this paper, a compact printed antenna solution for non-invasive tests of the Fat-IBC on non-human primates (NHPs) is proposed. This antenna is a printed monopole with a triangular radiating element embedded into a rigid brick, properly optimized to favor the radiation coupling in a 5mm-thick fat layer and minimize the signal propagation through the air. A promising wave coupling in the adipose tissue is achieved and a compact realizable layout is finalized for future prototyping and testing.

Liquid Based Phantom Preparation and Dielectric Characterization for Breast Cancer Imaging

Rakesh Singh (IIT Roorkee, India); Dharmendra Singh (Indian Institute of Technology Roorkee, India); Manoj Gupta (Aiims Rishikesh, India)

Developing of the phantom for specific reason like skin, fat, glandular and tumor for breast tissue is very important part of the actual measurement of the Devices or antenna which is useful for the breast cancer imaging system. Till now such phantom is not reported very clearly therefore in this paper we have attempted to develop the phantom material for different dielectric properties similar to breast phantom. In this proposed work Polyethylene Glycol (PEG) and NaCl and water based liquid phantom has been prepared for breast cancer imaging. Various range of the Dielectric properties of the mixture has been achieved with the variation of PEG, Water and NaCl. This liquid based phantom deals with the development of realistic breast phantom dedicated to microwave imaging for breast cancer detection. Liquid based phantom have been prepared with PEG, water and NaCl.

Wideband Substrate Integrated Waveguide Antenna for Electromagnetic Torso Imaging System

Seyed Mohammad Hadi Mousavi (The University of Queensland, Australia); Amin Darvazehban (University of Queensland, Australia); Sasan Ahdi Rezaeieh (The University of Queensland, Australia)

A body-matched wideband directional Substrate Integrated Waveguide (SIW) antenna is presented for torso imaging systems. The proposed antenna comprises a rhombus-shaped patch on the top layer fed by a coaxial cable from the bottom layer. This patch is then surrounded by vias to achieve wideband impedance matching. Then, a quarter-wavelength rectangular-shaped slot is etched on top of the patch to enhance the impedance matching. The structure is printed on Rogers TMM 13i substrate. The results indicate that the designed antenna has three resonance frequencies at 0.65, 0.87, and 1.10 GHz. The antenna covers a wide frequency band from 0.58 to 1.17 GHz (67.4 % fractional bandwidth). Moreover, the antenna occupies 112×112×12.7mm3, equaling 0.21×0.21×0.02 λ_0^3, where λ_0^ is the wavelength at the lowest working frequency. The study of wave penetration inside the torso indicates that the power flow intensity in the middle of the torso is -20.10dB.

A Low-Profile Textile MIMO Antenna Using Felt Substrate for Industrial, Scientific and Medical Band

Sana Ullah (Universitat Politècnica de Catalunya, Spain); Raul Fernandez-Garcia (Universitat Politecnica de Catalunya, Spain); Ignacio Gil (Universitat Politècnica de Catalunya, Spain)

A low profile textile MIMO antenna design for Industrial scientific and medical bands at 5.8 GHz is presented. The design consists of 2 embroidered antennas based on vertical and horizontal strips with a shared partial ground structure on Felt substrate. The dimensions of the designed MIMO are 50×50×1 mm3 with a permittivity of 1.2 and 0.02 loss tangent. An isolation of 18 dB between the two ports is achieved. The gain and the efficiency of the flat textile MIMO antenna are 3.64 dBi and 98%, respectively. Bending impact with different radius has been considered with a slight shift in the resonance frequency and a small reduction of gain, efficiency and isolation in the ISM band. The Envelope Correlation Coefficient (ECC) between the antennas is less than 0.01 at the operation frequency band.

Wednesday, March 29 13:30 - 15:00

PA5: Poster Session on Antennas for Space Applications

/ / Antennas

Rooms: Spadolini 101, Spadolini 102

Chairs: Eduardo Carrasco (Universidad Politécnica de Madrid, Spain), Petrie Meyer (Stellenbosch University, South Africa)

Analytical Solution of an Aplanatic Afocal Dual Reflector/Refractor System

Giuseppe Orlando (ThalesAleniaSpace Italia, Italy)

An analytical solution for an aplanatic afocal dual reflector/refractor system is proposed. Numerical verifications carried out through ray tracing and electromagnetic simulations on specific optics geometries confirm the validity of the solution.

Design and Testing of the Quasi-Optical Network for the MetOp-SG Microwave Sounder

Adam L Woodcraft and Stuart Froud (Thomas Keating Ltd., United Kingdom (Great Britain)); Richard

Wylde (Thomas Keating Ltd., United Kingdom); Peter Ade, Rashmi Sudiwala and Carole Tucker (Cardiff University, United Kingdom (Great Britain)); Soe Tun (SMT Consultancies Ltd, United Kingdom (Great Britain)); Michael Bray (Atkins, United Kingdom (Great Britain)); Peter Campbell, Paul Crampton and Graham Maxwell-Cox (Airbus Defence and Space, United Kingdom (Great Britain)); Ville Kangas (European Space Agency, The Netherlands)

We describe the design and performance of the quasi-optical network (QON) that has been manufactured for the Microwave Sounder (MWS) instrument on the MetOp Second Generation weather satellite programme. The QON is a key part of the instrument, which will provide a considerable improvement in spatial resolution and sensitivity compared to instruments currently in operation.

Preliminary Design Study of a Simultaneous S/Ka Monopulse Tracking Antenna

Christophe Granet (Lyrebird Antenna Research Pty Ltd, Australia); Robert Hoferer (Spacetime Machine Co, unknown); John Kot (Young & Kot Engineering Research, Australia)

The preliminary theoretical design study of a simultaneous S/Ka 7.3m-diameter monopulse tracking antenna is presented. Predicted results will be presented at EuCAP'2023.

A New Simultaneous S/X 3.7m Antenna Designed and Manufactured down Under

Christophe Granet (Lyrebird Antenna Research Pty Ltd, Australia); Kerry Clapham and Robin McNeill (Space Operations New Zealand Ltd, New Zealand); Christopher Hann (University of Canterbury, New Zealand)

This paper recounts the refinement in design of two brand new simultaneous S/X 3.7m earth stations by an Australian and New Zealand team at the height of the COVID Pandemic, which have subsequently been fully manufactured and tested in New Zealand.

Effect of Mechanical Tolerances in Deployable Multi-Faceted Reflectarrays

Borja Imaz-Lueje, Marcos R. Pino and Manuel Arrebola (Universidad de Oviedo, Spain)

In this paper, an analysis of the performance degradation in a multi-faceted reflectarray antenna because of the assembling tolerances is presented. In different scenarios of misalignment between panels, two multi-faceted reflectarrays which work in linear polarization at Ka-band are evaluated. They are designed to generate a pencil beam pattern in a certain direction of space. The results of this study show that the errors in the relative placement and tilting between panels in the sectored cut cause an increase in the side lobe levels. When these errors are significant, this means a degradation of the main beam, leading to an increase in the beamwidth and a significant loss of gain.

Broadband Reflectarray Antenna by Controlling Phase Center of Primary Radiator

Masayoshi Takao, Ryusei Yamada, Yusuke Kaimori and Shigeru Makino (Kanazawa Institute of Technology, Japan); Shin-ichi Yamamoto and Yasuhiro Nishioka (Mitsubishi Electric Corporation, Japan)

A reflectarray antenna controls the reflection phase by the size and shape of the metal elements placed on the mirror surface, thereby correcting the optical path length. Therefore, phase errors on the aperture plane occur at frequencies other than the design frequency, and the narrow bandwidth is a disadvantage. Although various studys have been made to improve the narrow bandwidth characteristics, gain reduction due to phase error is still a major bottleneck in reflectarray design. In this study, regarding residual aberration, which has been considered unavoidable due to the nature of reflectarray antennas, we focused on the primary radiator, which is a parameter that constitutes the reflectarray, and investigated broadband reflectarray. A method to correct the residual aberration by controlling the phase center position of the primary radiator is proposed. The broadband reflectarray antennas using the method is also described, and its validity is verified by measurement results.

A Compact Multi-Faceted Reflectarray Based-On Cassegrain Optics

Borja Imaz-Lueje (Universidad de Oviedo, Spain); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Marcos R. Pino and Manuel Arrebola (Universidad de Oviedo, Spain); Ronan Sauleau (University of Rennes 1, France)

This paper presents a compact Cassegrain reflector antenna in which a multi-faceted reflectarray plays the role of main reflector. The reflectarray surface is composed by three identical panels, arranged following a cylindricalparabolic structure. The designed antenna provides a dual linear polarization (LP) and radiates a pencil around a center frequency of 31 GHz. The performance of this antenna is evaluated and compared with an equivalent single-facet Cassegrain reflectarray. The sectorization in the multi-faceted structure relaxes the phase requirements to be provided by the unit-cell, which reduces the phase errors in simple cell topologies. The multi-faceted structure achieves a better performance in terms of gain bandwidth, showing an improvement of at least 30% in the relative bandwidth and 50% in the gain-bandwidth product regarding a conventional singlefacet reflectarray.

RF Self-Interference Cancellation for Wideband Tightly Coupled Antenna Arrays

Zhenyu Li and Chao Sun (University of Electronic Science and Technology of China, China); Feng Yang (University of Electronic Science and Technology of China & University of Electronic Science and Technology of China (UESTC), China); Shiwen Yang (University of Electronic Science and Technology of China (UESTC), China)

This paper proposes a radio frequency (RF) self-interference cancellation (SIC) approach for wideband tightly coupled antenna arrays (TCAAs) for in-band full duplex. Two 64-element TCAAs operating at 8GHz~12GHz are used as the transmitting and receiving subarrays, respectively. Miniaturized divider network constructed by chips converges multiple ports of the array into a single port, so that RF cancellation can implement at sub-array level. We construct a cancellation channel by a four-taps analog circuit with time delay lines, attenuators and phase shifters. The parameters of the cancellation circuit are optimized by the joint of differential evolution (DE) algorithm and convex optimization algorithm. Simulation results show that the method can provide 26.6dB cancellation cross a 100MHz bandwidth at the center frequency of 9.6GHz.

Comparison of Effective Permittivity Retrieval Methods of 3D-Printed Unit Cells for Dielectric Resonator Antenna Applications

Gaëtan Antoine (ISAE-SUPAERO, France); Bruno De Araujo (ENAC, France); Romain Pascaud (ISAE-SUPAERO, Université de Toulouse, France); Christophe Morlaas and Alexandre Chabory (ENAC, France); Vincent Laquerbe (CNES, France); Gautier Mazingue (Anywaves, France)

In this paper, three methods to retrieve the effective permittivity of 3D-printed unit cells for dielectric resonator antenna (DRA) applications are compared: Maxwell Garnett approximation (MGA), S-parameters method, and plane wave expansion method (PWEM). More specifically, three common topologies are studied: simple cubic (SC), body-centered cubic (BCC) and face-centered cubic (FCC). From numerical analyses, we explain which method is the most appropriate for designing a DRA using 3D-printed periodic unit cells.

3D Printed Graded Index Lenses Using High Relative Permittivity Filaments for Directive Antennas

Thomas Whittaker, Aakash Bansal and William Whittow (Loughborough University, United Kingdom (Great Britain))

The paper presents results of 3D printed graded index (GRIN) lenses used to enhance the gain of antennas. Three different filaments were used with relative permittivity values of 4.5, 10 and 15. The design process is discussed, and simulations are compared to measurements. The higher relative permittivity decreased the thickness, however, the total weight remained relatively constant, due to higher ceramic content for the higher permittivity filaments. The lenses increased the gain by up to 10.04 dB over the frequency range 25 to 40 GHz.

A Dual-Wideband Power Distribution Circuit in the Ka-Band for a New Steerable Multi-Beam Satellite Antenna Array

Andreas Krause (Werner-Heisenberg-Weg 39 & University of Bundeswehr, Germany); Engelbert

Tyroller (Werner-Heisenberg-Weg 39, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany)

A power distribution circuit is investigated for beam steering of a new satellite antenna array in the Ka-band. Together with stacked metal layers with integrated Rotman lenses, the power distribution circuit enables the simultaneous steering of several beams in the forward and backward direction of two 16x15 antenna arrays on a satellite. Based on a matrix of PIN diode switches on a printed microwave circuit low insertion losses and high isolations are obtained. The power distribution circuit is investigated by way of simulation and measurements of test circuits showing good agreement.

A Novel Ku-Band Circularly-Polarized Horn Antenna Based on a Ridged Wall

Andoni Marzo (Anteral S. L., Spain); Fernando Teberio (Anteral, Spain); Jorge Teniente-Vallinas (Public University of Navarra & Institute of Smart Cities, Spain)

In this paper, a novel wideband (31.5 % bandwidth) circularly-polarized antenna based on a ridged wall is presented. A pair of ridges on the inner wall of the horn serves as an inbuilt polarizer, which can generate left-hand or right-hand circular polarization without any additional polarizer. The ridged wall is placed at 45º with respect to the input port linearly polarized wave to generate a 90º phase delay and obtain the desired circular polarization at the aperture. The simulated results show that the antenna works great in the whole Ku satellite band (from 10.7 to 14.7 GHz) with more than 20 dB return loss and below 1 dB axial ratio. The antenna can be fabricated using traditional computer numerical control machining techniques or the new 3D metal additive manufacturing processes.

Folded Parallel Plate Waveguide Launcher for Surface Wave Antennas at Ku-Band

Aqeela Saghir (LINKS Foundation & Frederick University, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Nicola Bartolomei and Cristian Della Giovampaola (Wave Up srl, Italy); Francesco Caminita (Wave-Up SRL, Italy); Luca Marcaccioli (RF Microtech srl & University of Perugia, Italy); Marco Bernabei and Paola Farinelli (RF Microtech, Italy)

This paper presents a novel design of a folded parallel plate waveguide launcher. A low height overmoded waveguide is adopted making the structure low loss and compact. The waveguide generates a quasi-TEM wavefront to feed radiating structures based on surface waves, such as leaky wave or metasurface antennas. The height of the fold can be adjusted accordingly. As a design example, results of two folded structures having heights 10mm and 17mm is shown here. Also, to show the functionality of the structure, the launcher is integrated with a n-furcated divider and a taper to connect to a standard waveguide flange. The designed feeding part works well in the Ku band with a return loss below -18dB from 11.7 to 13.1 GHz and a suppression of higher modes is achieved below -15dB for most of the band resulting in a quasi-TEM mode.

Wednesday, March 29 13:30 - 15:00

PA6: Poster Session on Antenna Design I

/ / Antennas

Rooms: Spadolini 103, Spadolini 104

Chairs: Max James Ammann (Technological University Dublin, Ireland), Annalisa Iacono (Inmarsat, United Kingdom (Great Britain))

Reactance Dependence of Radiation Efficiency and Impedance Matching of A Wrapped Loop Antenna

Kyoichi Iigusa, Hirokazu Sawada, Amane Miura and Hiroyuki Tsuji (National Institute of Information and Communications Technology, Japan); Hiroshi Harada (National Institute of Information & Communications Technology (NICT), Japan)

Instead of optimizing dimensions of an antenna, variable reactors are loaded on the antenna and the reactance values are optimized to achieve desired characteristics. The possibility of achieving both high radiation efficiency and good impedance matching is examined by visualizing the reactance regions where the characteristics are satisfied. Examination for a triple wrapped loop antenna shows that the reactance regions where impedance matching is good overlap the reactance regions where radiation efficiency is low when the antenna is electrically small. The influence of conductivity to the reactance regions is investigated with comparing the reactance regions with respect to input power and total radiated power.

Planar Phased Array Based on Stripline-Fed Antenna with a Parallel Feeding Network

Quoc Duy Nguyen (Viettel High Technology Industries Corporation & Viettel Group, Vietnam); Thi Huong Ngo and Dinh Toai Pham (Viettel High Technology Industries Corporation, Vietnam); Hoang Ha Bui (Hanoi University of Science and Technology, Vietnam); Hoang Viet Tran (Can Tho University, Vietnam)

The design of planar phased array composing of 12 linear subarrays in the vertical plane has been investigated in this paper. Each linear in-phase subarray consists of 24 compact stripline-fed antennas in the horizontal plane. The proposed linear subarray is fed by 24-port parallel feeding network where amplitudes at the output ports are controlled by a Taylor distribution with side lobe level of -36 dB. The planar array has been fabricated and measured in the frequency band from 3.2 - 3.6 GHz. The simulation and measurement results show a good agreement and the planar phased array is adapted to the requirements for 3D radar application.

Design of a Circularly Polarized Underwater Antenna and Its Experimental Verification Using a Water Tank

Takashi Kawamura, Takuma Matsushita, Toshiori Kondo, Futoshi Takeuchi, Kazuhiro Hongo, Yasuhiro Matsui, Takashi Takinami, Akihiro Horii and Kazunobu Ohkuri (Sony Group Corporation, Japan)

Sea waves or a tidal current can cause unstable connectivity attitude between antennas in underwater radio frequency communication systems such as underwater wireless sensor networks. To compensate such instability and maximize the coverage area of communication systems, we propose a circularly polarized underwater antenna with wideband characteristics. This is realized through two vertically crossed half-sheath dipole antennas (HSDAs) and a phase shifter consisting of two inductors and two capacitors. They achieve wideband of over 50 % in the fractional bandwidth despite their inductors and capacitors. Down-scaled experiments using a water tank at 400 MHz verify that the proposed antenna performs as a circularly polarized omni-directional antenna with an axial ratio of less than 0.5 dB and can maximize the coverage area of underwater wireless sensor networks.

A Dual Polarized All Metal Ultra-Wideband Vivaldi Antenna Array with 70° Scan Ability

Burak Alptug Yilmaz (Aselsan & XX, Turkey)

This paper presents dual polarized all metal ultra-wideband Vivaldi antenna arrays with 70° scan ability. The antennas are fabricated from a monoblock metal structure. Accordingly, the arrays do not require any soldering or screwing process for the electrical connection of their main body to a ground plane. Thanks to this manufacturing process advantage, the antenna is robust to harsh environmental conditions, and features high polarization purity, low reflection and wide scan characteristics in the principal planes (E, H, and D). Sample tapered and stepped antenna array designs are optimized with respect to improved mechanical tolerances, and their simulation results are provided. According to full wave simulation results, the antennas operate from 1.42 to 20.68 GHz (1:14 frequency ratio) at broadside for a voltage standing wave ratio (VSWR) specification of 2:1.

Single-Element Patch Antenna with Multi-Port Feeding for Dual-Circularly Polarized Radiation

Mazen Almalki (University of Edinburgh & King Abdulaziz City for Science and Technology, United Kingdom (Great Britain)); Maksim Kuznetcov and Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

A dual-circularly polarized (CP) S-band antenna is proposed based on a sequential rotation technique whilst exploiting only a

single patch element. The antenna offers left-handed circular polarization (LHCP) or right-handed circular polarization (RHCP) by proper sequential phase rotation of its eight ports. Impedance matching bandwidths (BWs) of about 20\% are observed and realized gain values approach 9.5 dBic. Also, low axial ratio values are achieved (0.5 dB or below) over this same operating BW. These CP performances metrics and the noted polarization agility can be useful for satellite connectivity, for example, and other RF challenged environments where the dominant polarization is not known a priori. Other applications include signal transmission and reception duplex communications as well as other wireless communication systems where antenna diversity and general structure compactness is required.

Folded Waveguide Antenna for Handset Devices

Yunfeng Dong (vivo Mobile Communication Co., Ltd, China); Shen Wang (vivo Mobile Communication co., Ltd, China)

This paper presents a dual-band folded waveguide antenna for mobile handset devices. The proposed antenna performs a three dimensional miniaturized design. In comparison with the conventional waveguide antenna, it merely occupies 25% of the area while the radiation efficiency of the antenna is kept at the same level. Besides, the proposed antenna can be implemented into the devices having a metallic cavity and radiates through a narrow slot realized on the corner of the structure. The antenna can be placed under the display module neither requiring cuttings on the main frame nor rearranging the existing components. For proving the concept, a folded waveguide antenna operating at both 2.40-2.50 GHz and 5.15-5.85 GHz for WiFi applications is designed. When taking into account the major components of the handset device, the proposed antenna achieves radiation efficiencies of -2.20 dB and -1.84 dB at 2.45 GHz and 5.50 GHz, respectively.

A Reconfigurable Dual Sharp Notch-Band UWB Antenna

Anees Abbas, Md. Abu Sufian and Wahaj Abbas Awan (Chungbuk National University, Korea (South)); Niamat Hussain (Sejong University, Korea (South)); Jaemin Lee and Nam Kim (Chungbuk National University, Korea (South))

This article presents a dual-notch band Ultra-wideband (UWB) reconfigurable antenna. The antenna consists of a radiation patch, coplanar ground, electromagnetic bandgap (EBG) structures, and switches. The lower edges of the radiating patch are truncated to enhance the antenna's UWB spectral bandwidth, and pairs of EBG structures are utilized to form sharp-notch characteristics. The antenna is made reconfigurable by using RF switches (diodes) and has four modes of operation. Based on the simulation results, the presented antenna operates at a 3.1-11.8 GHz bandwidth for |S11|<-10. The antenna is small in size, has dimensions of 20 × 27 × 1.52 mm3, and offers a good radiation pattern and stable gain.

Design and Improvement of a Wideband Angled Dipole Array Antenna for S-Band Applications

Qasid Hussain (Chungbuk National University, South Korea, Korea (South)); Domin Choi (Chungbuk National University, Korea (South)); Niamat Hussain (Sejong University, Korea (South)); Anees Abbas, Md. Abu Sufian and Nam Kim (Chungbuk National University, Korea (South))

This paper investigates the design and optimization of the dipole array antenna. Unlike conventional dipoles, the presented work contains eight dipole antennas connected to a feedline having an angle of 250. Moreover, the non-uniform distance between consecutive elements as well as different dipole lengths helps in achieving a wideband antenna having a compact size. The antenna is designed using a 3.175 mm thick ROGERS 5880 substrate and the optimized antenna offers |S11| < -10 dB wide impedance bandwidth ranges from 1.86 - 4.12 GHz along with a peak gain of more than 6.8 dB in the operational region.

Improving the Radiation Characteristics of Shorted Annular Ring Antennas Through Symmetric Aperture-Coupled Feeding

Hannes Bartle (Ecole Polytechnique Federale de Lausanne & ClearSpace SA, Switzerland); German Augusto Ramirez Arroyave (EPFL - École Polytechnique Fédérale de Lausanne & Universidad Nacional de Colombia, Switzerland); Anja K. Skrivervik (EPFL, Switzerland)

In this paper, a novel feeding method for shorted annular ring (SAR) antennas is presented. SAR antennas can be designed to not excite surface waves and hence have desirable properties for many applications. The traditional method of feeding a SAR is

through a single probe. Using two probes i.e. a differential feeding method, the current distribution and hence the pattern become more symmetric. However, steep current gradients on the patch make it difficult to obtain a robust design against manufacturing tolerances. A novel feeding method based on a dual aperture coupling approach is proposed to overcome the limitations of a dual-probe feeding approach while still maintaining the reduced surface wave characteristics. Additionally, this feeding method is shown to provide an increase in broadside gain of almost 3dB through eliminating disturbances in the current density on the SAR.

Non-Volatile Pattern Reconfigurable Antenna Based on Even- and Odd-Mode Spoof Surface Plasmon Polaritons

Yibo Ning, Xiaoyu Xiao, Zirui Zhang and Zhirun Hu (University of Manchester, United Kingdom (Great Britain))

In this paper, a novel non-volatile radiation pattern reconfigurable spoof surface plasmon polaritons (SSPPs) antenna is proposed. The antenna can radiate between even- and odd-mode to radiate broadside and endfire beams respectively. Due to the feature of non-volatile switches, no static power is needed to maintain the antenna operation states, significantly reducing the DC power consumption. Such non-volatile reconfigurable antennas will be highly desirable, especially for low power sensing systems and large antenna arrays where hundreds even thousands switches.

Omnidirectional Circularly Polarized Reconfigurable Antenna Using Endfire Elements Based on SIW

Peng Liu (AVIC Research Institute for Special Structures of Aeronautical Composites, Tsinan, Shandong, China); Qing Zhang, Wenwu Zhang, Di Gao and Qian Wang (AVIC Research Institute for Special Structures of Aeronautical Composites, China)

In this paper, an omnidirectional circularly polarized reconfigurable antenna has been designed. The antenna consists of five H-plane horn structures and five parallel strips. There are phase shift lines between the horn structures and parallel strips to achieve the circular polarization radiation. Several slots are etched on the parallel strips to solder the PIN diodes. Through controlling the on/off state of the diodes, the left-hand circular polarization and right-hand circular polarization antenna can be reconfigured. Finally, the both 3-dB VSWR bandwidths and 3-dB axial ratio bandwidths of the proposed antenna are about 2.9 % (2.42 ~ 2.49 GHz) for LHCP mode and RHCP mode. And the antenna has an omnidirectional pattern with the non-roundness of 1.12 dB in the horizontal plane at 2.45 GHz. With the omnidirectional and circularly polarized reconfigurable characteristics, the proposed antenna is a good candidate for the polarization diversity and wireless communication of unmanned aerial vehicles.

Development of a Miniaturized Blade Antenna for Aeronautical Applications

Zahir Hamouda (High School of Aeronautical Techniques, Algeria); Tuami Lasri (IEMN - University of Lille, France)

Antennas installed on aircraft are used for communications as well as for various radio navigation systems such as direction finders, distance measuring systems, global positioning systems, microwave landing systems and altimeters. These systems use antennas that operate in the L frequency band and have an omnidirectional radiation pattern in the H plane and a vertical polarization. In this study, we propose a new low-profile broadband blade antenna entirely made of aluminum, enclosed in a radome, that meets in particular the radio navigation requirements. It demonstrates an omnidirectional radiation pattern in the H plane, a vertical polarization, a frequency band spanning from 800MHz to 1.22 GHz and a gain of 2.2dBi at 1 GHz. This antenna performance, analyzed on the basis of simulation and measurement results, validates its possible use for Radio Navigation and Aeronautical Communication Systems.

A Monoblock Dielectric Resonator Filtering Patch Antenna

Xiao Tan, Yuliang Chen and Ke-Li Wu (The Chinese University of Hong Kong, Hong Kong)

A monoblock dielectric resonator (MDR) filtering patch antenna is proposed for the first time. The dielectric patch antenna is designed at 3.61 GHz and the 6-pole filtering function is specified with 230 MHz bandwidth and two designated transmission zeros (TZs). The antenna and the coupled resonator filter are consolidated into one single ceramic monoblock, leading to good frequency selectivity, low insertion loss, and a compact functional module. To accommodate the required filtering bandwidth, the high-Q patch antenna is modified, and a buffer resonator is introduced adjacent to the antenna. The experimental results of the

prototyped monoblock dielectric resonator filtering patch antenna have shown a good impedance matching bandwidth and high frequency selectivity in total antenna gain.

Compact Quarter-Mode SIW Self-Triplexing Antenna for C-Band and X-Band Applications

Noureddine Melouki (University of Quebec INRS, Canada); Hassan Naseri Gheisanab (University of Quebec, INRS, Canada); Amjad Iqbal (University of Quebec INRS, Canada); Tayeb Denidni (INRS, Canada)

An ultracompact substrate integrated waveguide (SIW)-based triplexing antenna operating at three independent frequencies of 4, 7.8, and 10.68 GHz is proposed in this study. It is consisting of two miniaturized Square-shaped quarter-mode SIW (SQMSIW) resonators and one triangular one (TQMSIW). Their miniaturization was accomplished by inserting rectangular slots at the closed ends of each resonator, resulting in an increased shunt capacitance. As a result, the resonance frequencies were shifted to the lower end of their fundamental frequencies. The proposed design has a dimension of just 0.08 λg2. Furthermore, the lowest attainable isolation level was as low as 27.5 dB. At the design frequencies, the highest realized peak gains were 4.9, 5.43, and 5.3 dBi at 4, 7.8, and 10.68 GHz, respectively. The final design has been fabricated, and the simulation findings agree well with the measured ones. In terms of independent frequency tuning functions, the proposed design demonstrated its versatility.

Four-Arm Log-Periodic Toothed Antenna Backed by a Hybrid Meta-Material Reflector

Donghyun Kim (Yonsei University, Korea (South)); Chan Yeong Park (Yonsei Universitiy, Korea (South)); Young Joong Yoon (Yonsei University, Korea (South))

A novel method to improve the radiation efficiency is demonstrated by applying it to a four-arm log-periodic toothed antenna with a meta-material reflector. Various meta-cells are placed under the antenna to observe the operation and radiation performance for a wide bandwidth. Through analysis of changes in electric field distribution, the cause of antenna performance degradation is identified and resolved. The newly proposed antenna with hybrid meta-reflector is suitable for electronic support measures systems can implement unidirectional pattern with high radiation efficiency.

A Wideband Dipole Antenna Design for Thought-The-Wall Imaging on Security Applications

Sulayman Joof and Semih Dogu (Istanbul Technical University, Turkey); Feza Turgay Çelik (Delft University of Technology, The Netherlands); Kamil Karacuha (Istanbul Technical University, Turkey)

This study proposes a dipole antenna with wide-band characteristics for microwave imaging (MWI) applications. The wide-band characteristic of the antenna is achieved by reshaping the geometry of the conventional dipole. The dipole is fed by a specially designed balun, together with a ground reflector in order to obtain a high gain unidirectional pattern. The antenna is operating from 2.7 to 5 GHz with a maximum realized gain of 8.39 dBi and |S11| less than -10 dB within this frequency band. The simulation results and evolution of the design procedures are presented. Furthermore, a through-the-wall MWI scenario consisting of thirteen antenna elements, a concrete wall, and two hidden objects behind the wall is implemented to evaluate the performance of the antenna. The 2-D reconstruction results obtained from inversion methods indicate that the proposed antenna is a potential candidate for through-the-wall MWI applications.

Compact Non-Reflecting Tapered Slot Antenna with Effective Short-Pulse Transmission Capability

Yue Su, Hongtai Chen, Shunli Li and Hongxin Zhao (Southeast University, China); Xiaoxing Yin (State Key Laboratory of Millimeter Waves, China)

A compact non-reflecting tapered slot antenna (NRTSA) with effective short-pulse transmission capability is proposed. The NRTSA integrates a loading network composed of a resistor, an inductor, and two lumped resistively loaded loops. The loading network can effectively absorb the non-radiated reflection signal, and maintain the radiation efficiency and realized gain of the NRTSA. The NRTSA is fabricated to demonstrate its performance. The measured results show that the NRTSA features a -10-dB impedance bandwidth from DC to 20.24 GHz, a peak realized gain of 8.24 dBi at 13.5 GHz, and a 3-dB realized gain bandwidth from 9.5 GHz to 20.5 GHz (73.33%). Meanwhile, a waveform fidelity of 0.939 and a ringing level of -24.14 dB when transmitting a Gaussian pulse with a spectrum from 9 GHz to 20 GHz is achieved. Thus, the compact NRTSA with effective short-pulse transmission capability is promising in ultra-wideband short-pulse scenarios.

A Novel Substrate Integrated Gap Waveguide Ultra Wide-Band Circular Directional Coupler for Ku Band Applications

Mehmet Faruk Cengiz (Izmir University of Economics, Turkey); Abdelmegid Allam (German University in Cairo, Egypt); Diaa Fawzy (Izmir University of Economics, Turkey)

This study presents a new circular compact Ultra Wide-Band (UWB) substrate integrated gap waveguide (SIGW) based 3 dB hybrid coupler for Ku band applications. The coupling section is a circular structure with an elliptic slot and additional via to achieve equal-power division in two ports and isolation in the 4th port. To optimize the design parameters of the hybrid coupler, the Finite Integration Time-Domain (FITD) approach is employed. The operating frequency of the coupler is between 12.14 to 15.4 GHz with a central frequency of 13.5 GHz, a bandwidth of 3.26 GHz, and a Fractional Band Width (FBW) being 23.67%. A phase difference throughout the operational spectrum around 90° has been attained. The coupler is fabricated with an overall dimension of 33.8 x 33.8 mm2. The measured and simulated scattering parameters demonstrate satisfactory agreement.

Triple-Band Modified Printed Inverted-F Antenna Design for WI-FI-7 Applications

Lazaros Alexios Iliadis, Vasileios P. Rekkas and Achilles D. Boursianis (Aristotle University of Thessaloniki, Greece); Panagiotis Sarigiannidis (University of Western Macedonia, Greece); George K. Karagiannidis (Aristotle University of Thessaloniki, Greece); Christos Christodoulou (The University of New Mexico, USA); Sotirios Goudos (Aristotle University of Thessaloniki, Greece)

WI-FI-6/6E is now commercialized and the WI-FI community is currently developing the IEEE 802.11be standard, namely WI-FI-7, which will offer enhanced throughput and higher data rate than its predecessors. In this article, a compact triple-band printed inverted-F (IF) antenna operating at 2.4 GHz, 5 GHz, and 6 GHz frequency bands is designed for WI-FI-7 applications. We design a novel antenna structure that is well- suited for triple-band operation. The core idea is to use a stripline as a feeder that also couples two modified IF designs. A nature- inspired optimization method, namely artificial hummingbird algorithm (AHA), is used to achieve optimal design solution for the triple-band IF antenna. Simulation results demonstrate that the proposed antenna achieves really satisfactory results regarding the S11 value and the gain in all the operating frequencies.

Metamaterial-Based Planar GRIN Lens Antenna for D-Band Wireless Communications

Gian Marco Zampa (UNIVPM, Italy); Davide Mencarelli (Università Politecnica dell Marche, Italy); Matteo Stocchi (Università Politecnica delle Marche, Italy); Luca Pierantoni (Università Politecnica delle Marche, Ancona & Istituto Nazionale Fisica Nucleare (INFN), Italy)

This paper presents a metamaterial-based planar GRIN lens antenna for wireless communications, modeled and designed using COMSOL Multiphysics. The antenna is designed to work at 140 GHz in the D-band, proposed for the next mobile generation (6G). Such devices could be produced by using the SiGe technology, that allows large scale production. The proposed device shows a 11 dB gain in the center band. This value is about five times higher than the same antenna without the lens.

A Bulb Shaped ACS Fed Triband MIMO Antenna for ISM/LTE/WLAN/Wi-Fi Applications

Praveen Naidu Vummadisetty (JNTUK, India)

In this article bulb shaped antenna is designed with ACS feeding technic. The single element with the dimensions of 23 × 11 × 1.6 mm3 on FR4. The antenna elements are organized orthogonally with 48 × 48 × 1.6 mm3 dimensions for further examination. This MIMO design achieved an operating triband operating frequency of 2.22GHz-2.41GHz,3.48GHz-3.80GHz and 4.96GHz-6.24GHz along with a peak gain of 4.5dB and efficiency of 98%. This design strategy resolved coherence within signals with isolation of less than -20dB. ISM/LTE/WLAN/Wi-Fi are the applications for the proposed bulb shaped design with acceptable diversity parameters like ECC, DG, MEG, TARC and CCL. The acceptable ranges of diversity parameters decreased fading of signals, improved impedance matching and multipath mitigation. By using 3D EM tool antenna design and analysis are carried.

Wednesday, March 29 13:30 - 15:00

PE2: Poster Session on Electromagnetics II

/ / Electromagnetics

Rooms: Spadolini 105, Spadolini 106

Chair: Nikolaos L. Tsitsas (Aristotle University of Thessaloniki, Greece)

Beam Frame Representations: New Alternatives to the Plane Wave and Green Function Representations in the Frequency and Time Domains

Ehud Heyman (Tel Aviv University, Israel)

Beam summation methods have long been utilized for modeling wave propagation in complex environments due to their unique properties, combining (i) local resolution of the (real or induced) source distributions; (ii) asymptotically uniform spectral representation; and (iii) algorithmic ray-based structure. We use the generic term "beam waves" for both the frequency-domain and the time-domain formulations, where the propagators are iso-diffracting Gaussian beams or iso-diffracting pulsed beams, respectively.

So far, the beams were used for local spectrum expansion of the source, and thereafter as propagators. The beam frame is a new concept where a properly constructed phase-space set of beams is shown to constitute a frame everywhere in the propagation domain, and thus can be used for local expansion not only of the source field but also of the medium and the local interaction of the field with the medium.

Proposal of an EM Energy Harvesting Solution from Ambient Railway Communication Systems Based on Focusing Metasurfaces

Mohammed Kalaagi III (20 Élisée Reclus, Villeneuve-d'Ascq, France & Railenium, France); Divitha Seetharamdoo (IFSTTAR, LEOST & Univ Lille Nord de France, France); Matthieu Appenzeller (Paris, France); Christophe Rosinski (Villeneuve dAscq, France)

In this paper, we investigate the potential of an EM energy harvesting system based on focusing metasurfaces to enhance the performance of off the shelf rectenna systems, and overcome the challenges of low efficient ambient EM energy harvesting from railway communication systems. The metasurface is designed based on the hyperboloidal profile of the generalized phase law. Our energy harvesting system is deployed in the railway environment in three configurations: The receiving antenna of the rectenna along side the focusing metasurface, the antenna along side a metallic plate and the antenna alone. The focusing concept shows remarkable results compared to the other configurations with a receiving power up to 10 μW compared to that of the antenna with a metal plate and alone of 1 μW and 0.1μW respectively, which can be an interesting result to supply low input WSNs where such power in needed to wake up the device.

A Roadmap for the Generation of Bessel Beams: Challenges and Opportunities from Microwave to Terahertz Frequencies

Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy)

The focused character and the limited-diffraction properties of Bessel beams make them attractive in various modern applications, such as wireless power transfer, medical imaging, chip-to-chip communications, and so on. While devices capable of generating Bessel beams at optical frequencies are now widespread, the microwave and terahertz (THz) wave generation of Bessel beams is more recent. In this contribution, we aim at giving the reader a clear perspective on the potentialities offered by Bessel beams as well as on the difficulties that still hinder their full development in certain frequency ranges. Starting from well-consolidated techniques, we discuss the recent advances in their efficient generation from the microwave to the THz domain. An outlook on possible future theoretical and practical developments in this field is finally provided.

Development of TETRA Radio Backhaul Network Redundancy Plan for Disaster Recovery in Mission

Critical Communications

Samuel Mendes Heleno (Polytechinc of Leiria (IPL) & Instituto de Telecomunicações (IT-Leiria), Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Carlos Salema (I.S.T. - Technical U. Lisbon / IT Lisbon, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal); Nuno R. Leonor (Polytechnic Institute of Leiria (IPL) & Instituto de Telecomunicações (IT), Leiria, Portugal)

This paper presents a redundancy plan (1+1) based on millimetre wave (mmWave) backhaul links applied to a realistic network mimicking the Portuguese emergency communication system, in which the base stations (BSs) were selected according to favourable high ground elevation points with clear LOS between different BSs. The feasibility of establishing radio links between different BSs was analysed, not only in term of maximum range limited by the signal attenuation and system sensitivity, but also in terms of Fresnel Zones clearance. A shortest-path algorithm was then used to process all valid radio link and generate a redundancy plan in a tree topology. Finally, the shortest-path algorithm was used with specific constraints, to generate a redundancy plan (1+1).

Equidistant Sub-Nyquist 3-D Microwave Imaging Using Rational Thin-Plate Spline Interpolation

Ting-Yang Lin, Hsin-Jung Yang and Shih-Yuan Chen (National Taiwan University, Taiwan)

High sampling rates required by the Nyquist sampling theorem impose limitations on both rapid data acquisition and measurement system design in planar microwave holographic imaging, rendering sub-Nyquist sampling a desirable feature. Compared to the incoherence requirement in compressed-sensing-based methods, equidistant sampling schemes are favorable for a more general and intuitive system design. In this paper, a 3D microwave imaging scheme using equidistant sub-Nyquist samples is proposed. The method is based on the open-circuit voltage formulation in [1], but the reconstruction with sub-Nyquist data is done using the rational thin-plate spline (RTPS) interpolation. Determination of the interpolation function involves finding an eigenvector with the smallest eigenvalue to a generalized eigenproblem. A remedy procedure is also developed to address the singularities or outliers produced by the ill-conditioning in such a problem. The effectiveness and robustness of the developed method are verified with numerical experiments in X-band, showing significant improvements in image quality.

Dynamic Tuning of Superoscillatory Lensing Based on Reconfigurable Metasurface

Menglan Lin (Key Laboratory of Integrated Services Networks, Xidian University, China); Badreddine Ratni (Univ Paris Nanterre, France); Peihan Qi (Xidian University, China); Jianjia Yi (Xi'an Jiaotong University, China); Gérard-Pascal Piau (Airbus, France); André de Lustrac (C2N, Université Paris-Saclay, France); Shah Nawaz Burokur (LEME, France)

Metasurface-based devices have drawn considerable attention in recent years. However, conventional passive metasurfaces can only achieve fixed functionalities once designed. In this paper, we propose a two-dimensional reconfigurable reflective metasurface to realize individual phase modulation of each unit cell. The proposed reflective metasurface is exploited to implement a dynamic superoscillatory lens in the microwave regime that can form sub-diffraction focusing spots at different focusing distances and operating frequencies.

Optimization-Assisted Design of Wide-Band Structured Microwave Absorbers

Erika Vandelle (Thales Research & Technology, France); Sebastien Heron (Thales Research and Technology, France); Thi Quynh Van Hoang and Brigitte Loiseaux (Thales Research & Technology, France)

The obtention of highly absorptive surfaces over a wide frequency band and a wide angular range requires the complex manipulation of both electromagnetic properties and geometrical structure of materials. As a matter of fact, a periodic arrangement of sub-wavelength patterns can greatly improve the performance of an absorber with minimum thickness over a large set of conditions. Yet, this inevitably leads to a significant number of geometrical parameters making the design of absorbers fastidious and time-consuming. This paper presents a fast design methodology for microwave absorbers. An optimizer based on the algorithm Covariance Matrix Adaptation Evolution Strategy (CMA-ES) iterates over the results provided by a

simulation code based on the Fourier Modal Method (FMM), in order to reach a targeted absorptivity of 1. To illustrate this fast design methodology, we present the optimization of a 10mm-thick structured microwave absorber made of a magneto-dielectric material.

Analysis of Moving Bodies with the FDTD Method

Mohammad Marvasti (Université du Québec en Outaouais, Canada); Halim Boutayeb (University of Quebec in Outaouais, Canada)

A thorough analysis of the behavior of electromagnetic waves in the presence of moving bodies is proposed using the numerical Finite Difference Time Domain (FDTD) method. In this work, the effect of movement of the observation point, plan wave source, and scatterer bodies on the frequency and amplitude of the reflected waves are studied for the case of normal- and oblique-direction of wave incidence. Moreover, an analysis of the Michelson-Morley experiment and time delay versus the velocity of motion is reported for co-moving observer, source, and scatterer in longitudinal and transversal cases.

Design of an Ultra-Wideband Microwave Metamaterial Absorber Using VO2 Material

Thi Quynh Hoa Nguyen (Jeonbuk National University, Korea (South) & Vinh University, Vietnam); Dac Tuyen Le (Hanoi University of Mining and Geology, Vietnam); Dinh Lam Vu (Graduate University of Science and Technology, Vietnam); Jung-Mu Kim (Jeonbuk National University, Korea (South))

We propose a design of an ultra-wideband microwave metamaterial absorber using Vanadium dioxide (VO2) based on dual-layer structure. The ultra-wideband absorption performance of proposed structure can switch by using the phase transition of VO2. When the VO2 is in the insulator state, the proposed absorber achieves an ultra-wideband absorption response in the frequency range of 3.7-22.5 GHz with an absorptivity above 90% and a relative bandwidth of 143.5% at normal incidence, which covers the entire bands from the C to Ku. The designed absorber is polarization insensitive and wide incident angle stable for both transverse electric (TE) and transverse magnetic (TM) modes. Owing to outstanding merits of high absorption performance and frequency-tunable capability, our design structure can be suitable for many promising applications in the microwave range such as smart radar, camouflage and stealth radome technology.

Multi-Objective Optimisation of Metamaterial Antenna

James Capers (University of Exeter, United Kingdom (Great Britain)); Stephen Boyes (DSTL, United Kingdom (Great Britain)); Alastair Hibbins and Simon Horsley (University of Exeter, United Kingdom (Great Britain))

Passive manipulation of radiation is key to many modern technologies for sensing and communication. While many techniques exist to design electromagnetic systems that perform a single desired function, the design of systems which are multi-functional remains challenging. We have developed a versatile semi-analytic framework for designing multi-functional metamaterials to shape antenna radiation. To demonstrate the versatility of this method we design two devices: one which re- shapes the radiation pattern of an emitter while also enhancing the efficiency, and one which beams radiation into different directions depending upon the polarisation of a driven element.

Fixed-Length Arbitrary-Phase Tunable NRI-TL Metamaterial Phase Shifter for Antenna Beam-Steering Applications

Asif Bilal (EMPHASIS Research Center, University of Cyprus, Cyprus); Abdul Quddious (KIOS Research and Innovation Center of Excellence, University of Cyprus, Cyprus); Atsushi Kanno (Japan Graduate School of Engineering, Nagoya Institute of Technology, Japan); Tetsuya Kawanishi (Waseda University & National Institute of Information and Communications Technology, Japan); Marco A. Antoniades and Stavros Iezekiel (University of Cyprus, Cyprus)

A fixed-length arbitrary-phase tunable phase shifter, based on the concept of negative-refractive-index transmission-line (NRI-TL) metamaterials for sub-6 GHz antenna beam steering applications is proposed. The design consists of a fixed microstrip transmission line which is reconfigured by loading varactor diodes in both the series and shunt branches. A continuously tunable phase of 210° at 3.2 GHz for the transmitted signal is achieved at the output by varying the biasing voltage from 0 - 7 V for the

varactor diodes. The insertion loss varies from 0.9 - 2.5 dB for the design in the frequency range of 3.2 - 3.6 GHz. The total length of the tunable NRI-TL metamaterial phase shifter is λg/4.

Experimental Demonstration of Directive Scattering from Reconfigurable Dielectric Resonators with Impedance Surfaces

Rasmus E. Jacobsen, Andrei Lavrinenko and Samel Arslanagić (Technical University of Denmark, Denmark)

Metallic and dielectric resonators are one of the main components in many electromagnetic structures as they enable efficient tailoring of the underlying fields. In this work, a dielectric resonator with reconfigurable scattering properties is examined analytically, numerically and experimentally. The resonator consists of an impedance surface integrated in a dielectric resonator. We utilize the hybrid configuration to enable simultaneous excitation of different modes to effectively shape the scattered fields. In particular, we demonstrate a reconfigurable resonator, which scatters mainly in the forward direction. A simple prototype, consisting of metal and water, is fabricated and characterized experimentally demonstrating the forward scattering properties. The resonator design holds a strong potential within the area of functional material structures, antennas and sensing for operation from microwave to optical frequencies.

Development of Optimization Algorithms for Electromagnetic Characterization in Free Space

Jose Cidrás Estévez, David Ramos Somolinos, Borja Plaza Gallardo and David Poyatos Martínez (INTA, Spain)

In recent years, in the aerospace industry, there has been a trend based on replacing the classic metallic materials with new advanced materials such as carbon fiber composites (CFC), fiberglass, etc. Due to this, the electromagnetic (EM) characterization of these new materials is essential to maintain safety and EM compatibility. This article will focus on the free space measurement technique, from which a series of optimization algorithms have been developed, allowing the extraction of permittivity and permeability of materials in a frequency range up to 40 GHz using the Time-Domain Gating from a Vector Network Analyzer (VNA).

Dual-Band Single-Layer Frequency Selective Surface for Millimeter-Wave 5G Applications

Mousa Abdollahvand (University of Mohaghegh Ardabili, Iran); Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain); Kanishka Katoch (Jaypee University of Information Technology, India)

This contribution presents the design of a dual-band frequency selective surface (FSS) for millimeter-wave 5G applications in the 28 and 39 GHz bands. The FSS consists of a single dielectric layer with printed elements on its bottom face. The spectral response of the FSS is characterized by two reflection bands at 28 and 39 GHz, and it presents a stable performance under oblique incidence angles of up to 45º. The FSS also supports operation in dual-linear polarization, due to the twofold-symmetric pattern of the printed elements. The proposed FSS has a great potential to be used in millimeter-wave 5G networks as part of dual-band Intelligent Reflecting Surfaces (IRS), which can be formed by combining in the same panel the proposed FSS and a dual-band printed reflectarray.

Towards Real-Time Three-Dimensional (3D) Imaging Using Dynamic Metasurface Antennas

Vasiliki Skouroliakou, Amir Masoud Molaei and Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

Dynamic Metasurface Antennas (DMAs) have been recently proposed as a computational imaging platform that relaxes the hardware constraints. These antennas produce tailored radiation patterns to multiplex the spatial information from the scene compressing the measurements into a single channel. Despite simplifying the hardware layer, the compression of the signal sets challenges in image reconstruction. The indirect sampling of the imaged scene makes it necessary to use computationally intense sensing-matrix based solutions since Fourier-based image reconstruction techniques are not directly applicable. In this paper, a bistatic case using DMAs as transmit and receive apertures is discussed and a pre-processing step is proposed to render the measurement set compatible with conventional Fourier-based imaging algorithms. The performance of the reconstruction algorithm including the pre-processing step is demonstrated when the algorithm is parallelized using a single

Graphical Processing Unit (GPU) card arguing that real-time image reconstruction is possible when imaging with DMAs.

Low-Profile UWB Probe for Precise Time-Domain Functional Imaging

Youness Akazzim (Universitat Politècnica de Catalunya, Spain & System of Information and Telecommunications Laboratory, Morocco); Otman EL Mrabet (System of Information and Telecommunications Laboratory, Morocco); Luis Jofre (Universitat Politecnica de Catalunya, Spain)

In this paper a Double Ridge Waveguide (DRW) antenna fed by a microstrip line covering a frequency band from 0.5GHz to 2.5GHz is designed, fabricated, and measured, for functional microwave imaging. The proposed DRW antenna is used as the probe element in a collateral multi-static system to detect a cylindrical target located inside a human brain liquid medium. Also an approach for the spatial reconstruction accuracy based on maximum time resolution is presented. Measured and simulated results are conducted and discussed.

Dual Polarized High Gain Resonant Cavity Antenna (RCA) with a Single Layer Metasurface for 6G Applications

Mehrab Ramzan (Barkhausen Institut, Germany); Padmanava Sen (Research Group Leader, Barkhausen Institut gGmbH, Germany)

This paper presents a dual-polarized single layer metasurface in order to increase the gain of a single microstrip patch antenna in the X-band. The metasurface is comprised of circular unit cells with cross slots, exhibiting the same magnitude (S11 and S21) and phase responses when subjected to TE and TM polarized waves. This single layer planar metasurface can boost the gain of a probe feed single microstrip patch antenna from 7.2 dBi to 16.2 dBi at 10 GHz. The antenna's gain and reflection coefficient with reference to the polarization of the antenna are made stable by employing cross slots, making it a more improved and robust design compared to the metasurface with rectangular slots. Moreover, a strong coupling is observed on the metasurface with cross slots considering both polarized waves.

Semitransparent Planar Corrugated Surface for Antenna Applications

Luis Inclan-Sanchez (University Carlos III of Madrid, Spain)

In this work, a novel version of partially transparent filtering soft surface is proposed. The surface is implemented by semitransparent planar corrugations that prevent the propagation of surface waves in the soft direction. The corrugations are formed by metallic grids that reproduces the behavior of the strip type planar corrugations but allows the passage of most of the visible light. In the case studied, it is proposed to use a transparent dielectric as a substrate. The behavior of the surface is analyzed using its dispersion diagrams and shows similar behavior than the non-transparent version of the surface. The semitransparent surface presented can allow controlling the mutual coupling between radiating elements in applications that require the use of natural lighting or low visual impact.

Energy Transfer Process of the Electromagnetic Fields Radiated by the Interaction Between a Set of Line Sources and a Layered Cylinder

Andreas Kalogeropoulos and Nikolaos L. Tsitsas (Aristotle University of Thessaloniki, Greece)

A set of line sources stimulates an infinite, multilayered, arbitrarily-shaped cylinder. An energy conservation law and related optical theorems concerning the overall scattering cross section and the interaction scattering cross sections are derived. Numerical results demonstrating the behaviour of the overall differential cross section and the total interaction differential cross section are presented.

Analysis of Plane Wave Propagation in Biaxial Media for Arbitrary Incidence Angles

Jeffrey Massman (United States Air Force Insititute of Technology & United States Air Force Research Laboratory Sensors Directorate, USA); Michael J Havrilla (Air Force Institute of Technology, USA)

An analysis to determine the explicit eigenwave so- lutions for electric and magnetic field components of anisotropic permittivity and permeability biaxial media for any plane wave angle of incidence is introduced. Forward and reverse propa- gating

eigenvalues are identified. Then, the eigenvector is solved to define the electric field polarization before determining the electric and magnetic field eigenwave solutions. Finally, a special case condition is applied where it is shown that the expressions introduced in this work converge to prior known results. The generalized biaxial media eigenwave solutions in this paper can be used to address scattering problems as well as boundary interfaces for material measurement techniques.

X-Band Bandpass Frequency Selective Surface Based on a New Biosourced Substrate of Natural Flax Fiber for Radome Application

Adel Sennouni and Adnane Labdouni (IETR Rennes 1 University, France); Jean-Marie Floc'h (INSA of Rennes, France); Sébastien Guéret (GDS Composites, France); Franck Callebert (RID Depestele Groupe, France); Anne-Claude Tarot (University of Rennes, IETR, France)

This article presents a biosourced band-pass Frequency Selective Surface (FSS) with wideband frequency response. The single-layer designed FSS is made of a simple miniaturized elements unit cell and a new biocomposite substrate. The bio-based substrate of the natural flax fibers and compatible resin is developed using the vacuum infusion manufacturing process, and its dielectric properties were obtained by microwave characterization using the free-space measurement method over a wide frequency range. The FSS exhibit a stable frequency response to different angles of incidence and polarizations. Simulation and measurement results are in good agreement and show that the structure occurs a bandwidth of 1.95 GHz ranging between 9.3 GHz and 11.25 GHz with a fractional bandwidth of 19%.

Measurement of the Vacuum Electromagnetic Energy from a Quantum Perspective

Luis-Enrique Garcia-Muñoz (University Carlos III of Madrid, Spain)

It is well known from quantum electrodynamics that the vacuum state possesses infinite electromagnetic energy. This fact may seem a priori to be a mathematical artefact of the quantum theory itself, or even lead to the conclusion that we are missing some unknown aspects of the nature of light in the theory. At the same time, however, this infinite value leads to a simple explanation of the Casimir force or effect by which two perfect, unloaded, conducting metal plates attract each other when placed in a vacuum. This manuscript answers the question why we are then not able to measure the infinite value of this electromagnetic energy of the vacuum. This situation is analogous to measuring the amount of energy radiated by an antenna in a radiation null omitting thermal noise. We offer an explanation of what happens using precisely the theory of quantum electrodynamics itself.

Analysis of Arbitrarily Conformal Low-Frequency Magnetic Metasurfaces

Martina Falchi, Alessandro Luigi Dellabate and Danilo Brizi (University of Pisa, Italy); Pierpaolo Usai (University of Pisa & Microwave and radiation laboratory, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)

In this paper, the design and response control over an arbitrarily conformal low-frequency magnetic metasurface are presented. Typically, low-frequency magnetic metasurfaces are designed for infinite, planar array configurations in which the same subwavelength pattern is repeated infinitely. The proposed procedure shows that it is possible to control the behavior of a finite conformal magnetic metasurface composed by an array of spirals arbitrarily located in the 3D space. In particular, we performed accurate full-wave simulations showing different current distributions. By loading the metasurface unit-cells with the same capacitor, as in the classical approach, no control over the current distribution can be obtained. Instead, by loading the unit-cells with an appropriate set of capacitors, a control over the amplitude and phase of the unit-cells can be obtained. These preliminary results can be important towards novel implementation of magnetic metasurfaces, especially for Wireless Power Transfer and Magnetic Resonance Imaging applications.

A Compact Antipodal Vivaldi Antenna for Food Investigation

Noemi Zeni (Federico II University of Naples, Italy); Gennaro Bellizzi (University of Naples Federico II, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Marta Cavagnaro (Sapienza University of Rome, Italy)

In food industry, the analysis of packaging and the quality of the food inside it is becoming important. Thus, the food industry is looking for a low-cost solution for the inspection of food during the production and packaging process, in order to detect any small

foreign body. The aim of this work is developing a microwave device capable of inspecting foodstuffs, directly on the production line. The solution proposed is a microwave imaging system that detects fragments in homogenous food packaged in circular plastic/glass jars. The system relies on a particular Antipodal Vivaldi antenna which, due to its ultra-wideband characteristics, can carry out the detection of various types of food, thus avoiding the need to use multiple antennas working at different frequencies to inspect foods with different characteristics. Numerical analysis shows Ultrawideband behavior (1-15GHz), suitable for applications in food quality control. Additionally, its detection capabilities are numerically proved.

Inverse Source and Scattering Solution with Phaseless Data: Near Field In-Silico Validation

Sandra Costanzo and Giuseppe Lopez (University of Calabria, Italy); Natalia Nikolova (McMaster University, Canada); Giuseppe Di Massa (University of Calabria, Italy)

The solution of an inverse source problem usually embraces the microwave imaging context. Indeed, microwave imaging solutions require the incident field distribution within the imaging domain. In the field of microwave imaging with amplitude only data, a phaseless inverse source problem has been addressed, by combining a holography-based method, directly operating into the spatial domain, with a source reconstruction method. The combined method is tested for the field characterization of a series of source with different directivity levels. Then the field modeling strategy has been included within a phaseless inverse scattering solution and applied to a 3D in-silico test case.

Wednesday, March 29 13:30 - 15:00

PM2: Poster Session on Measurements II

/ / Measurements

Rooms: Spadolini 107, Spadolini 108

Chairs: Francesco D'Agostino (University of Salerno, Italy), Francesco Saccardi (Microwave Vision Italy, Italy)

MIMO OTA Testing for 5G User Equipment: Standardization Progress and Challenges

Xuan Yi, Shuai Zhang, Beiqi Zhou, Ying Deng and Siting Zhu (China Academy of Information and Communications Technology, China)

Standardized over-the-air (OTA) test methodologies have been developed to evaluate and verify the performance of multiple-input multiple-output (MIMO) receivers of LTE and NR user equipment. In this paper, the MIMO OTA test methodologies and recent standardization progress in 3GPP are reviewed. The work plan in 3GPP and the potential challenges of 5G MIMO OTA testing are discussed. We also demonstrate the channel model validation measurement results in our multi-probe anechoic chamber (MPAC), which validated the good channel model implementation in the test zone.

A Radio-Frequency High-Q System for Biomedical Sensing Applications

Sabrina Rotundo (University of Pisa, Italy); Valeria Lazzoni (University of Pisa & Consorzio Nazionale Interuniversitario per Le Telecomunicazioni, Italy); Danilo Brizi (University of Pisa, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)

In this paper, a preliminary analysis of a near-field radiating system for biomedical sensing applications by using a radio-frequency magnetic field is presented. The proposed system, operating at 50 MHz, consists in a resonant helical coil wrapped around on a ferromagnetic core and inductively coupled with an unloaded probe loop. The system design has the main purpose to produce a focused magnetic field distribution, and to guarantee a good spatial resolution of the sensing device. In addition, the introduction of the ferromagnetic material allows to improve the device detection sensibility at the operating frequency.The main advantages of the proposed non-invasive system include the possibility to reduce the health risks associated with the actual diagnostic techniques, as the X-rays. The preliminary numerical results suggest the feasibility for an innovative near-field clinical device, to be employed in future for non-invasive sensing applications, as malignant inclusions detection; thus, further analysis is

encouraged.

Heterogeneous Breast Phantoms Based on Real in -Vivo and Ex-Vivo Measurements

Miñano Ivana (Universidad Católica San Pablo, Peru); E Fernandez-Aranzamendi (Universidad Carlos III de Madrid, Peru & Universidad Católica San Pablo, Peru); Manuel Alejandro Condori Huayna and Patricia Castillo (Universidad Católica San Pablo, Peru); Vicente González Posadas (Polytechnic University of Madrid, Spain); Daniel Segovia Vargas (Universidad Carlos III de Madrid, Spain)

This work focuses on the development of homogeneous and heterogeneous phantoms that mimic the dielectric behavior of biological breast tissues. In order not to depend on patients and simulations, and thus to perfect device models in a timely and cost-effective manner. The results were analyzed in contrast to in vivo and ex vivo measurements performed on biological breast tissues of real patients with the help of an open-circuit coaxial probe, in a frequency range from 500 MHz to 7 GHz, the controlled environment ensured that criteria and protocols were followed for an accurate and efficient recording of the measurements. The dielectric behavior of real fabrics with high stability was achieved.

Non-Destructive Inspection of Chocolate Cream with THz Imaging

Sonia Zappia (CNR- National Research Council of Italy, Italy); Rosa Scapaticci (CNR-National Research Council of Italy, Italy); Giuseppe Ruello (University of Naples, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Ilaria Catapano (IREA-CNR, Italy)

Terahertz imaging is the newest among non-invasive sensing technologies, and its use is currently considered in various applications. Among the potential applications, food inspection is one of the most important cases due to the possible dangerous impact on human safety. Terahertz (THz) systems are, indeed, attracting increasing attention in food inspection due to their ability to detect surface defects and foreign body contamination in a non-invasive way. In order to evaluate the capabilities of THz technology, laboratory experiments were carried out by using a fibre-coupled THz time-domain system. The surveys were performed by preparing ad-hoc samples realized by filling a plastic support with a commercial chocolate cream covered by a cap mimicking a commercial packaging. The presented results provide further evidence of the THz waves ability to detect foreign body in food.

Utilizing Spherical Resonances for Microwave Breast Cancer Detection

Christoph Jannick Salomon, Nikola Petrovic and Per Olov Risman (Mälardalen University, Sweden)

In this paper, we investigate if the normal electric field component measured at the surface of a hemispherical breast phantom is better suited to detect a tumor than the surface-parallel component. Numerical simulations are being performed for two cases, low-adipose and high-adipose average breast tissue. The electric field is probed along the breast surface with and without a spherical tumor model being present. It is shown that in the high-adipose case, an external spherical resonance created at the tumor introduces unique electric field components normal to the breast surface that do not occur in the absence of a tumor. These field components almost exclusively provide a higher contrast between tumor and background signal. Even in the low-adipose case where no such external tumor resonance could be identified, measuring the normal electric field component at the breast surface provided higher contrast at almost all measurement positions along the breast surface.

Spatial Statistics of Received UHF RFID Phase in Indoor Environment Using Distributed Reader Antenna System

Thomas M. Pohl (TU Wien, Austria); Holger Arthaber (Vienna University of Technology, Austria); Christoph F Mecklenbräuker (TU Wien, Austria)

We report on Ultra High Frequency (UHF) Radio Frequency Identification (RFID) received phase and signal strength measurements in an experimental lab. The lab consists of a UHF RFID reader connected to a distributed antenna system installed in a lab room at TU Wien. The antennas are multiplexed in time by phase-stable coaxial switches. Precise tag positioning is realized by motorized linear axes. The lab provides detailed maps of received phase and signal strength for all tag positions in a rectangular area in the lab. Key measurement statistics are reported forming the basis for tag localization: maps of signal strength and phase, their mean and standard deviation for individual antennas, and numbers of antennas providing coverage

for each position. For 11 installed reader antennas, 99.96 percent of tag positions are covered by at least four reader antennas indicating the feasibility of high precision localization at 0.04 percent outage.

Equivalent Sources Formulation for Phase Recovery with a Reference Antenna

Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Giuseppe Musacchio Adorisio (Fondazione LINKS, Italy); Marco Righero (LINKS Foundation, Italy); Gianluca Dassano, Riccardo Maggiora and Giuseppe Vecchi (Politecnico di Torino, Italy); Frederick Mayer, Michael Maurer and Georg Peters (Spidercam GmbH, Austria); Luis Rolo (European Space Agency, The Netherlands)

A procedure to recover the phase difference between the signal sent from a probe antenna and the signal received at an antennas under test when the two antennas are not phase-locked is presented. The procedure uses the signal received at a reference antenna whose position, orientation and radiation pattern are known and is based on the use of equivalent sources.

Validation of Blended Rolled Edge Reflector Characteristics for Compact Test Ranges

Rostyslav Dubrovka (Queen Mary, University of London, United Kingdom (Great Britain)); Clive Parini (Queen Mary University of London, United Kingdom (Great Britain)); Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain))

This paper presents a recent advance in designing and validating blended rolled edge (BRE) reflectors for compact antenna test range (CATR) applications. BRE reflectors offer the potential of very smooth near-field patterns in the quiet zone (QZ) due to their improved diffraction characteristics. In house equivalent currents based physical optics (PO) simulation code results were compared and validated against Altair Feko Method of Moment (MoM) simulations for various BRE reflectors. Reflector comparisons have been shown for different modelling scenarios, e.g. imported CAD files versus surface created using Lua macros coding, which is a built-in macros language in Altair Feko. All results are in a very good agreement, including cross polar magnitude and phase.

Impact of Introducing A Spacer Between Microwave Absorbers and the Shielding Layer in Anechoic Chambers

Amin Enayati (Emersun and Cumming Anechoic Chambers, Belgium); Arya Fallahi (IT'IS Foundation, Switzerland)

The problem of introducing a spacer between Microwave absorbers and the shielding layer in an anechoic chamber is addressed. To investigate the problem for different absorber profiles, various simulation and measurement techniques were used and impact of the spacer was quantified

Quantitative Characterisation of Heterogeneous Additive Manufactured Materials

Chloé Scotti (Aix-Marseille University & CEA DAM - LE RIPAULT, France); Xavier Faget (Aix Marseille Universite, France); Nicolas Mallejac (CEA, France); Stefan Enoch (CNRS & Institut Fresnel, France); Amélie Litman (Aix-Marseille Univ, CNRS, Centrale Marseille, Institut Fresnel, France)

A free-space set-up and a Born method have been used in previous works to perform non destructive quantitative imaging of heterogeneous permeability. This work present an application of this technique to retrieve permittivities of non magnetic non homogeneous materials. The additive manufacturing facilities has been used to design heterogeneous controlled dielectric materials.

A Realisation of Channel Emulation in a Reverberation Chamber Method for Over-The-Air Compliance Testing in Support of 3GPP Standardisation

Yunsong Gui (National Physical Laboratory (UK), United Kingdom (Great Britain)); Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain))

The inherent long decay power delay profile (PDP) in the reverberation chamber (RC) is a major challenge for accurate channel

emulation of 3GPP channel model, which is widely used in performance test of the physical layer. To tackle this challenge, we propose in this paper a novel two-step "closed-loop" approach consisting of (i) a channel measuring step and (ii) a channel model synthesis step. The channel measurement step is used to capture the wireless channel of the RC. In the channel model synthesis step, an additional IQ signal convolution process is introduced prior the IQ signal passes through the channel emulator (CE). This process filters the IQ signal by an equalizer filter derived from the measured channel impulse response (CIR) of the RC obtained in channel measurement step. From the measurement results, the proposed approach is proven that able to effectively emulate typical 3GPP 5G channel model.

Flexible and Deployable Antenna Measurement System

Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Marco Righero (LINKS Foundation, Italy); Giuseppe Musacchio Adorisio (Fondazione LINKS, Italy); Frederick Mayer, Michael Maurer and Georg Peters (Spidercam GmbH, Austria); Gianluca Dassano, Riccardo Maggiora and Giuseppe Vecchi (Politecnico di Torino, Italy); Luis Rolo (European Space Agency, The Netherlands)

The paper proposes an innovative deployable measurement system for large antennas. By taking advantage of new approaches and technologies to move the probe within a large volume space, the presented system will be really flexible and able to perform conventional Near Field (NF) measurements (i.e., spherical, planar, cylindrical) and non standard scanning surfaces.

The proposed approach will exploit a free moving probe system coupled to a laser-tracker and a software solution able to perform Near Field to Far Field transformation that includes also the probe-compensation and phase recovery in a direct way.

Preliminary results are provided to show the potentials of the system, through a Near Field data set acquisition, which is then transformed to the Far Field to compare the final antenna performance.

A Chipless Piezoresistive Strain Sensor

Sandra Rodini, Simone Genovesi and Filippo Costa (University of Pisa, Italy)

Strain sensors are widely used in various applications and, depending on the specific application, it is necessary they operate completely wireless. The first step for the realization of a wireless strain sensor is the choice of the transducing material. Piezoresistive materials, whose surface impedance varies when a mechanical stimulus is applied, are suitable candidates for fabricating a strain sensor. Here an innovative and simple wireless strain sensor is proposed which exploits the intrinsic properties of piezoresistive materials combining with a suitably designed frequency selective surface.

Investigation on the Feasibility of Blood Pressure Estimation Through Millimeter-Wave FMCW Radar

Yunsoo Kim and Jinwoo Kim (Sogang University, Korea (South)); Sungjin You and Byung Jang Jeong (Electronics and Telecommunications Research Institute, Korea (South)); Youngwook Kim (Sogang University, Korea (South))

In this paper, we investigate the feasibility of estimating blood pressure through millimeter-wave FMCW radar. As high blood pressure can cause many diseases including stroke, heart attack, kidney disease, and vision loss, it is important to measure blood pressure regularly. Even though the cuff-based device has been commonly used owing to its accuracy, it is cumbersome to wear and provide only a one-time reading. Remote and continuous monitoring of blood pressure can offer a chance for convenient early detection and diagnosis of heart disease. We study the correlation between blood pressure and FMCW radar returns. The pulse wave velocity is known to be highly correlated with blood pressure. We use radar to measure the pulse wave velocity through features obtained from skin displacement. We measured the chest of a human and the measured data verifies that the sharpness of the graph has a strong correlation with blood pressure.

Using a Reverberation Chamber to Estimate the Noise Figure of Integrated Low Noise Amplifiers

Sean Manas and Jacki Gilmore (Stellenbosch University, South Africa)

A measurement technique is formulated to determine the noise figure of a low-noise amplifier in an integrated active antenna. By placing the integrated active antenna in a reverberation chamber with another antenna, s-parameter measurements can be used to estimate the low-noise amplifier noise figure. The method proved to deliver measured results within 0.42 dB of the expected

mean.

Coplanar Electrode Near-Field Radiation Optimization for Single-Cell Detection

César A Palacios, Marc Jofre and Lluís Jofre (Technical University of Catalonia, Spain); Jordi Romeu (Universitat Politècnica de Catalunya, Spain); Luis Jofre (Universitat Politecnica de Catalunya, Spain)

Microwave and microfluidic techniques may enable wireless monitoring and interaction with bio-particles, yet still is a largely uncharted territory. Fortunately, the requirements and capabilities of microfluidics and microwave techniques converge to the system miniaturization for reaching the sensitivity levels required. Accordingly, in this work, it is presented the design of a coplanar electrode geometry to optimize the near-field reactive radiated field intensity into the position of the bioparticle. A measurement setup for the system-level characterization of different designs of bio-particle-sensing coplanar-electrodes on a microfluidic-platform will be also described. The design of the signal chain of the measurement setup is optimized for a RF superheterodyne receiver. The signal-integrity is achieved with a compact microwave-shielded-chamber, protecting from electromagnetic interference the coplanar electrodes on a microfluidic platform. Finally, experimental validation of the system-level performance of the measurement setup are provided, for different coplanar-electrodes designs.

Wednesday, March 29 13:30 - 15:00

PP2: Poster Session on Propagation II

/ / Propagation

Rooms: Spadolini 109, Spadolini Ground Floor

Chairs: Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France), Roberto Nebuloni (Ieiit - Cnr, Italy)

Structural Health Monitoring of Metallic Tubes Inducing Guided Electromagnetic Waves

Vittorio Memmolo (Goethe University Frankfurt, Germany & University of Naples Federico II, Italy); Lennart Fox (Goethe University Frankfurt Am Main, Italy); Jochen Moll (Goethe University Frankfurt am Main, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany)

Guided electromagnetic wave (GEMW) propagation using ultra-wideband signals is a novel approach for damage detection. Wave transmission and reflection can be used to warn the presence of such a defect within the waveguides. The present work proposes a feasibility analysis for a structural health monitoring system employing permanently integrated GEMW sensors. This concept allows to interrogate the structure continuously using transmitters and receivers when the electromagnetic waveguide is established. To this end, a metallic tube is equipped with a microwave broadband attached to the structures' surface. To validate the detectability of damage, a reversible defect is modeled through removable bolts accessible from one side of the surface of the cylinder. The experiments are carried out considering different damage severity and keeping constant the environmental scenario. The characteristic changes of GEMW signals are adopted in a damage index approach employed to show that defect can be detected sensitively.

Propagation of Radiation in Random Media: Channels and Modes

Valentin Freilikher (Bar-Ilan University, Israel)

Channeling of radiation trough transmission eigenchannels and resonant quasi-normal modes are the dominant mechanisms of wave propagation in scattering random media. In this presentation, the physical properties of these channels and modes are studied numerically and analytically, and possibilities of applications are discussed.

Human Activity Recognition Based on On-Body Antennas and Semi-Supervised Learning

Yanyang Zhang, Yu Shao and Lian Xiong (Chongqing University of Posts and Telecommunications, China); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

Human activity recognition is of great importance in the field of health rehabilitation, man-machine interaction, physical training and so on. On-body propagation in wireless body area network provides a low-cost and power-efficient method to detect and recognize human activity. In this paper, radio propagation data related to human activities are collected by on-body antennas, and a semi-supervised learning method is proposed to recognize human activity. Specifically, transmission coefficient data of four activities are recorded. Short-time Fourier transform is carried out on the original measurement signal to get the time-frequency spectrograms. An autoencoder is employed to extract low-dimensional feature of the data and K-Means algorithm is used for clustering. The autoencoder and clustering are trained by a small number of labeled data to improve the clustering accuracy. After the semi-supervised learning model is optimized, the remaining large number of unlabeled data are clustered and different human activities are recognized.

Neural Network Modeling of Antennas on Package for 5G Applications

Ekin Su Saçın and Ahmet C. Durgun (Middle East Technical University, Turkey)

The design and optimization of microwave devices require rigorous electromagnetic (EM) analysis requiring excessive computational resources. To mitigate this, neural network based machine learning methods can be used to generate surrogate models for EM performance analysis. In this study, we constructed a spectral transposed convolutional neural network model for a microstrip patch antenna printed on a package. The model takes geometrical parameters and material properties of the antenna as inputs and generates S11 parameter within the band of 23-33 GHz as output. The results showed a very good correlation between simulations and predictions. This verifies that NN based models can be used for EM analysis of antennas, particularly at the earlier stages of a design process.

Ka-Band 180-Degree Phase Shifter with Stub Loading

Zhiyong Dong (Concordia University, Canada); John Zhang (Concordia, Canada); Ahmed A Kishk (Concordia University, Canada)

A pair of broadband 180-degree phase shift lines are realized in printed circuit technology. Almost constant phase shift over 40.5 % bandwidth without reference lines in the Ka-band is achieved.

Advantages and Limitations of Quantum Radar

Isabel Carnoto Amat (University Carlos III Madrid, Spain); Alfonso Gonzalez Jimenez (Universidad Carlos III Madrid, Spain); Enderson Falcón-Gómez (University Carlos III of Madrid, Spain); Kerlos Atia Abdalmalak and Pablo Fajardo (Universidad Carlos III de Madrid, Spain); Juan Francisco Cabrero (Ingeniería de Sistemas para la Defensa de España Isdefe, Spain); Luis Enrique García Muñoz (Universidad Carlos III de Madrid, Spain)

This paper presents the advantages and limitations of a quantum radar system. The use of entangled photons to interrogate a region of space where a target is supposed to be, gives a lower probability of error than using a classical signal. This is possible because of the extra information that the quantum entanglement property can give us. This information helps us to distinguish between the signal reflected from the target and the background noise. Finally, through simulations, it is shown that the actual advantage of the quantum radar is the ability to detect a target in a high-losses and high-noise environment using a weak signal.

Electromagnetic and Thermal Analysis of Coaxial Cable Connection Embedded in an Intelligent Wall

Lorenzo Veggi (University of Bologna, Italy); Lauri Vähä-Savo (Aalto-University, Finland); Katsuyuki Haneda (Aalto University, Finland); Enrico M. Vitucci and Vittorio Degli-Esposti (University of Bologna, Italy)

A joint thermal and electromagnetic analysis of a wall with a regular distribution of embedded coaxial cables is presented in the paper. The cables are aimed, for instance, at connecting regularly spaced antennas on both wall sides with the scope of reducing wall-penetration loss in mm-wave and sub-THz wireless systems, as proposed in a previous study. The present study reveals the trade-off between good electromagnetic transmission, that is proportional to cable density, and modern building's requirements

for high thermal insulation, that degrades with it. The study eventually suggests the optimum cable density and materials' choice to satisfy both requirements in future low-energy buildings with intelligent, signal-transmissive walls.

Monitoring Wet Snow with a Dual-Receiver Radar Architecture: Preliminary Experimental Results

Martina Lodigiani and Lorenzo Silvestri (University of Pavia, Italy); Riccardo Barella and Carlo Marin (Eurac Research, Italy); Marco Pasian (University of Pavia, Italy)

In the latest years the role of the cryosphere in our daily life has been constantly growing. The climate change rules the process of melting and the snow has become a crucial medium to observe. In particular, the monitoring of slightly or moderately wet snow is nowadays a significant challenge under different perspectives. In this paper, a preliminary experimental test, carried during spring 2022 using a portable microwave radar architecture, normally used for dry snow monitoring, shows the capability of working also for in wet snow condition. Here, a comparison between radar and manual data is reported. Even if more analysis has to be carried out in the future, the preliminary results show a general agreement.

Air-To-Indoor Propagation Measurements with a Focus on Low RF-Based Navigation

Ignacio Rodriguez (University of Oviedo, Spain); Melisa López (Aalborg University, Denmark); Wahyudin Syam, David Scott and Alejandro Perez-Conesa (GMV NSL, United Kingdom (Great Britain)); Rigas Themistoklis Ioannidis (European Space Agency, The Netherlands)

Providing global communication, navigation and positioning with outdoor systems might be challenging in indoor and deep indoor situations, due to the limited penetration capabilities of the radio signals into buildings. The use of drones as radio source platforms and low radio frequencies might help alleviate the problem due to improved propagation characteristics in terms of elevation angle and coupling into construction materials. This paper explores air-to-indoor propagation based on an operational proof-of-concept navigation system working at 133, 401.5 and 500 MHz in two different building scenarios. The results demonstrate the favorable radio propagation conditions experienced by the setup, which resulted in viable outdoor transmission of navigation signals into indoor and deep indoor locations.

Numerical Investigation of the Interaction of Wireless EM Fields with Implantable Medical Devices

Jose Duque (Universidad Nacional de Colombia, Colombia); Robert A. Urbina and Manuel Pérez (Pontificia Universidad Javeriana, Colombia); Javier Leonardo Araque Quijano (Universidad Nacional de Colombia, Colombia)

This work presents an analysis of the interaction of the electromagnetic field generated by wireless communication systems on Implantable Medical Devices (IMDs) via a simplified model that provides a first-order approximation and via high accuracy full-wave simulation that takes into account the details of the human body holding the implant, the source of electromagnetic field, and the Implantable Medical Devices (IMDs) geometry and materials. Our results indicate that cellular communication devices, both Base Transceiver Station (BTS) and User Equipment (UE) do not exceed the susceptibility requirement specified for Implantable Medical Devices (IMDs), while walkie-talkie, even when used according to common manufacturer recommendations, generate a field significantly above this limit.

Broadband Isotropic Magnetic Field Probe to Assess Human Exposure in the 5G FR1 Band in Colombia

Javier Leonardo Araque Quijano (Universidad Nacional de Colombia, Colombia); Julian Osvaldo Garnica (National University of Colombia, Colombia)

In this paper we present the design and evaluation of an isotropic magnetic field probe to assess the broadband contribution of the magnetic field to human exposition within the FR1 band foreseen for the deployment of the 5G technology in Colombia. This device complements the current practice in this band, based on the measurement of electric field only, which may underestimate the overall exposition in the near field of particular sources or scatterers. The frequency response of the magnetic probe is designed to correctly weight the various frequency components according to the ICNIRP 2020 guidelines, and takes into account the detailed frequency response of all the system components including the elementary sensor and the power detector. The performance of the resulting design in isotropic configuration is validated.

Design and Manufacture Procedures of Phantoms for Hyperthermia QA Guidelines

Mattia De Lazzari, Wojtek Napieralski, Thien Nguyen, Anna Ström and Hana Dobšíček Trefná (Chalmers University of Technology, Sweden)

Clinical evidences highlight how hyperthermia acts as an efficient enhancer of current available cancer treatments. The achievement of a proper temperature distribution within the target is essential to guarantee an adequate tumor control. The ESHO-TC has been working towards the development of Quality Assurance (QA) guidelines for different hyperthermia techniques which aim to obtain an accurate physical characterization of HT systems, but the lack of proper phantom materials represents a limitation for the guidelines implementation. We propose the design of two different phantoms. The need of a proper fat-tissue phantom for superficial HT QA procedures led efforts to focus on the development of such a material, resulting in an oleogel based on ethylcellulose with good dielectric properties and mechanical stability. This contribution also proposes a standardized phantom for QA procedures specifically tailored for Head and Neck and extremities applicators aiming to provide a proper temperature monitoring within the target area.

Power Angular Spectrum Versus Doppler Spectrum - Measurements and Analysis

Jan M. Kelner, Cezary Ziółkowski, Michał Kryk, Jarosław Wojtuń, Leszek Nowosielski, Rafal Przesmycki and Marek Bugaj (Military University of Technology, Poland); Aniruddha Chandra (National Institute of Technology Durgapur, India); Rajeev Shukla (National Institute of Technology, India); Anirban Ghosh (SRM University Amaravati, India); Ales Prokes (Brno University of Technology & Sensor, Information and Communication Systems Research Centre, Czech Republic); Tomas Mikulasek (Brno University of Technology, Czech Republic)

In this paper, we present an empirical verification of the method of determining the Doppler spectrum (DS) from the power angular spectrum (PAS). Measurements were made for the frequency of 3.5 GHz, under non-line-of-sight conditions in suburban areas characteristic of a university campus. In the static scenario, the measured PAS was the basis for the determination of DSs, which were compared with the DSs measured in the mobile scenario. The obtained results show that the proposed method gives some approximation to DS determined with the classic methods used so far.

Challenges and Achievements Setting Up a Propagation Campaign with MEO Satellites

Susana Mota (University of Aveiro & Institute of Telecommunications, Portugal); Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal); Luis Cupido, Mariana Oliveira and Jorge Costa (LC Technologies, Portugal)

This paper addresses briefly the challenges and solutions of setting up a receiver for a MEO satellite constellation. The challenge is clearly higher to the same task for a geostationary satellite or a satellite with a small inclination as in the case of Alphasat. The wide variation in satellite coordinates; the satellite handover; having different beacon frequencies; and, the beacon modulation; add complexity to the entire system. The developed low cost two channels beacon receiver is described: the pointing system, the RF hardware, the software detection and the data handling. Some collected time series data are presented and described.

Wednesday, March 29 13:30 - 15:00

Perspectives III: The Evolution of Smart Wireless Environments (III)

Organized by: Filiberto BILOTTI (Università di Roma TRE, Italy); Marco DI RENZO (CNRS & CentraleSupelec - Paris-Saclay University, France); Giacomo OLIVERI, (ELEDIA Research Center, University of Trento, Italy)

• 13:30-14:00 "Smart Electromagnetic Environment as enabler for 5G mmw: Research and industry trends"
Renato LOMBARDI, HUAWEI Technologies, Italy (renato.lombardi@huawei.com)

• 14:00-14:30 "Internet of Surfaces: Self-configuring or externally-controlled RIS?"
Vincenzo SCIANCALEPORE, NEC, Germany (vincenzo.sciancalepore@neclab.eu)

• 14:30-15:00 "Recent advances in space-time coding metasurfaces"

Tie Jun CUI, Southeast University, China (tjcui@seu.edu.cn)
Vincenzo GALDI, University of Sannio, Italy (vgaldi@unisannio.it)
• 15:00-15:30 "Orange's Experiments on Reconfigurable Intelligent Surfaces"
RATAJCZAK Philippe, Orange, France (philippe.ratajczak@orange.com)
Room: Sala Arco

Wednesday, March 29 13:30 - 15:00

CM-SIG: Characteristic Modes Special Interest Group

Room: Palazzina 7

Wednesday, March 29 15:00 - 16:20

Invited Speakers: Cathryn Mitchell and Piero Angeletti

Room: Spadolini 001

Chairs: Paolo Focardi (Jet Propulsion Laboratory & California Institute of Technology, USA), Sana Salous (Durham University, United Kingdom (Great Britain))

15:00-15:40 Invited Speaker: **Cathryn Mitchell**

Title: **"The Future Challenges of Ionospheric Tomography and Data Assimilation with Applications for Communication and Navigation Systems"**

Abstract: The ionosphere has been studied extensively; notably in the early days by Appleton who coined the term ‘space weather'. This term denotes the variability in the ionospheric propagation environment because the medium is driven, both electromagnetically and mechanically, by constantly changing solar and terrestrial activity. There are many electromagnetic sensing instruments that can measure the ionosphere and help to characterise it in an instant, however they are not sufficiently accurate, numerous or widely distributed to provide observations that can be interpolated into a highly accurate 3D specification.

There is no single instrument to provide a 3D specification of the Earth's ionosphere at spatial scales of metres and temporal scales of seconds across a large region of continental/global scale. However, there are techniques to obtain electron density maps out of line-integral observations (tomography) or to merge models and observations together (data assimilation). The talk will describe the current state of the art and the upcoming requirements based upon the likely needs of future communication and navigation systems.

15:40-16:20 Invited Speaker: **Piero Angeletti**

Title: **"European Developments on Antenna and RF Technologies for Space Application"**

Abstract: This presentation provides an overview of some of the recent antenna and RF technology developments and R&D activities supported by the European Space Agency in the areas of Earth Observation, Satellite Communications and Navigation. In particular, recent technology developments on active antennas, MMICs, on-board array processing, deployable reflectors, and end-to-end payload/antenna testing will be reported.

Wednesday, March 29 15:00 - 16:20

Invited Speakers: John L. Volakis and Thomas Kürner

Room: Spadolini 002

Chairs: Matteo Albani (University of Siena, Italy), Anja K. Skrivervik (EPFL, Switzerland)

15:00-15:40 Invited Speaker: **John L. Volakis**

Title: **"UWB Future 5G Transceivers & Wearable Electronics"**

Abstract: Future communication links (future 5G) will require higher data rates, multiple beams, and higher transmit/receive gains, in addition to smaller weight, cost, and power. With the growing interest for reduced size platforms and the requirement for ultra-wideband (UWB) performance to address multi-functionality, there is a strong need for UWB RF front-ends with ultra flexible interfaces. The latter will include millimeter wave and THz capabilities to enable increased spectral efficiency, multi-functionality and security. Simultaneous transmit and receive (STAR) transceivers are also becoming a focus for the coming decade.

Further, in recent years, a variety of flexible fabric-based electronics have been proposed. To this end, our team proposed a new class of conductive textiles that have demonstrated unique capabilities in terms of flexibility, durability and manufacturing-ease using standard automated embroidery machinery. These electronic threads (E-threads) have the capability to generate fully embroidered microwave circuitry that has the same electrical properties as traditional microwave circuits printed on PCBs. As such, a new class of wearable devices that are fully integrated and inconspicuously placed within clothing is possible.

This presentation will focus on innovative methods for handling UWB communications with RF front end and back-end capabilities having historically low power and game-changing frequency-independent operation. They will include low power MIMO and beamforming across large bandwidths, from MHz to millimeter wave bands. Challenges in realizing future textile-based electronic devices, including wearable wideband transceivers will be presented. Among them, reliable wearable interconnects, chipsets that are less bulky and integrated with the textile circuitry, and manufacturing challenges will be discussed.

15:40-16:20 Invited Speaker: **Thomas Kürner**

Title: **"Channel Modelling for THz Communications"**

Abstract: THz communications is one of the physical layer candidates for the upcoming 6th generation of wireless systems. Although the propagation channel at sub-THz frequencies has similarities to those at Millimeter waves, the higher path loss, the required higher antenna gains and the smaller wave lengths and the operational environments coming along with new applications are calling for specific channel models. For the standardisation process appropriate channel models for the various applications are required. Corresponding channel modelling activities are ongoing at ITU-R, IEEE 802 and in the recently established ETSI ISG THz. In this talk a brief overview on the status of channel models for THz communications focussing on the needs for standardisation bodies will be provided. This includes a review on relevant propagation phenomena, results from measurement campaigns, already existing channel models and a summary of requirements on channel models for future applications.

Wednesday, March 29 16:20 - 16:40

Wednesday, March 29 16:40 - 18:20

A04: Reflectarrays

T02 Mm-wave and THz cellular / / Antennas

Room: Spadolini 001

Chairs: Antonio Clemente (CEA-Leti, France), Jose Antonio Encinar (Technical University Madrid, Spain)

16:40 ***Tuneable Polarisation Agnostic Reflectarray Element at mmWave Using Polymer Dispersed Liquid Crystal***

Stephen Henthorn and Kenneth Lee Ford (University of Sheffield, United Kingdom (Great Britain))

A reflectarray element operating at 73 GHz is designed using polymer dispersed liquid crystal (PDLC) to allow tuning of the reflected phase. Liquid crystals allow low-loss tuning at mmWave frequencies, but add complexity to the fabrication process. PDLCs trap pockets of liquid crystal in polymer, simplifying fabrication at the cost of reduced birefringence in permittivity. This paper proposes and simulates a polarisation agnostic element design achieving 200 degrees phase change with only 2.1 dB magnitude variation using PDLCs by using a slotted, rotationally symmetrical unit cell with two closely spaced resonances.

17:00 ***Smart EM Environments Planning - Concepts, Advances, and Trends***

Arianna Benoni, Federico Capra, Pietro Da Rù and Marco Salucci (ELEDIA Research Center, Italy); Giacomo Oliveri and Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

Within the Smart Electromagnetic Environment (SEME) framework, the planning of electromagnetic skins (EMSs) in both outdoor and indoor wireless scenarios is addressed to restore/enhance the received power in a given region-of-interest (RoI). Towards this end, a customization of the System-by-Design (SbD) is developed in order to solve the arising SEME optimal planning problem exploiting either single-hop (SH) or multi-hop (MH) links between the base-station (BTS) or router/access point (AP) and the RoI. Two illustrative numerical examples are reported to demonstrate the effectiveness and potentialities of the proposed planning strategies in real-world scenarios.

17:20 ***Evaluation of Low-Cost Compact Multi-Beam Reflectarray Antenna***

Andrés Gómez-Álvarez, Manuel Arrebola and Marcos R. Pino (Universidad de Oviedo, Spain)

A technique for the design of passive multi-beam reflectarray antennas based on a one-feed-per-beam configuration is presented. The reflection coefficients modeling the behavior of the reflectarray cells are selected to equalize the performance of all feeds in the system. An optimization process is proposed, which is based on the compensation of the phase errors in the reflected fields tangential fields associated to each feed position. Using this technique, a compact multi-beam antenna is designed. An offset focal arc geometry is introduced, which prevents feed blockage while providing wide-angle scanning ranges in a compact configuration (F/D below 0.7).Highly directive beams are simultaneously achieved for a 50-degree range while showing a scan loss of 0.4 dB, side-lobe levels (SLL) below -15 dB and minimal overall distortion in the beam shapes.

17:40 ***Wirelessly Controllable Reflectarray Antenna***

Bruno Correia (University of Porto, Portugal); Sérgio Cunha (FEUP-DEEC, Portugal); Min Zhou (TICRA, Denmark); Vítor Cristina (TEKEVER Asds, Portugal); Benedikt Byrne and Petronilo Martin-Iglesias (European Space Agency, The Netherlands)

The demand for high gain and high aperture satellite antennas has been evolving tremendously recently and will carry on. They may be required to provide a good RF performance yet versatile operation and an easy integration mechanism with the platform for applications requiring beam steering. One such application for large aperture antennas is Synthetic Aperture Radar (SAR). This paper presents a novel concept of a wirelessly controllable electronic modular beam steerable and beam shaping X-Band reflectarray concept. The reflectarray is composed of a two-dimensional array of identical tiles, where each one is composed of several similar unit cells. Each one has an active low-power device to control its reflection phase, allowing beam manipulation. Simple radio control signals provide the command for specific antenna pattern configurations. This command is interpreted and decoded by a low-footprint circuit that actuates on the phase control elements of each unit phase cell.

18:00 ***A Dual-Polarized Reconfigurable Reflectarray Antenna Based on Alternated Single-Polarized Unit Cells***

Sun-Gyu Lee and Jeong-Hae Lee (Hongik University, Korea (South))

A dual-polarized reconfigurable reflectarray antenna (RRA) with a low cross-polarization level (CPL) is presented. The realization of a dual-polarization is achieved by alternately arranging single polarized unit cells. The RRA of a symmetrically rotated sub-array are compared with that of a conventional monotonic array. The symmetrically rotated sub-array significantly reduces the CPL and slightly enhances the gain. The characteristics of the fabricated dual-polarized RRA at 10.1 GHz were measured and confirmed to be beam-steered with relatively high aperture efficiency. The measured results indicate that the proposed dual-polarized RRA operates with aperture efficiencies of 25.5% and 21.4% and CPLs of -20.7 dB and -21.3 dB for x- and y-polarization, respectively.

Wednesday, March 29 16:40 - 18:20

CS9: Antenna solutions for broadband satellites and constellations

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Jean-Philippe Fraysse (Thales Alenia Space, France), George Goussetis (Heriot-Watt University, United Kingdom (Great Britain))

16:40 ***Wideband Deployable VHF Crossed-Dipole Antenna Development for DEBRIS Mission***

Gaurangi Gupta (NASA Jet Propulsion Laboratory, Caltech, USA); Robert Beauchamp (Jet Propulsion Laboratory, California Institute of Technology, USA); Paolo Focardi (Jet Propulsion Laboratory & California Institute of Technology, USA)

This paper discusses the development of a wideband deployable VHF Crossed Dipole antenna for a research and development project called Distributed Element Beamformer Radar for Ice and Subsurface Sounding (DEBRIS) at NASA Jet Propulsion Laboratory (JPL). The antenna consists of wide-surface petals made out of gold-plated Kapton sheets held together using a stainless-steel ring forming the periphery of the dipole arms. This structure has the potential to be folded and restored easily, thus resulting in a wideband deployable dipole. The antenna has been designed, fabricated and measured along with the balanced to unbalanced (balun) feeding network. The VHF band presents unique challenges in the fabrication and the measurements, owing to the large antenna size and long wavelengths which are discussed in the paper.

17:00 ***Low-Profile Steerable Antennas for User Terminals***

Francesco Caminita (Wave-Up SRL, Italy); Massimo Nannetti (Wave Up Srl, Italy); Giuseppe Labate (Wave Up S. R. L., Italy); Nicola Bartolomei and Cristian Della Giovampaola (Wave Up srl, Italy); Gabriele Minatti (Wave Up S. r. l., Italy); Enrica Martini (University of Siena, Italy); Benedikt Byrne (European Space Agency, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Stefano Maci (University of Siena, Italy)

We present an innovative solution for a low-profile antenna with mechanical beam steering capability in a wide angular range, within a large bandwidth. The device has been conceived for next generation SATCOM communication in the Ka-band from user terminals on board moving platforms. It consists of a fixed primary feed and two rotatable metalens deflectors, which exploit the Pancharatnam-Berry phase effect to steer the beam. Experimental results performed on a fabricated prototype showed how the proposed design is able to effectively scan the beam with low grating lobes across the full field of view, with a scan loss in line with other flat solutions.

17:20 ***Flat Panel Mobility User Terminals for Ka-Band GEO/NGSO Broad Band Satellite Access***

Frank Klefenz (ViaSat Antenna Systems SA, Switzerland); Frédéric Bongard and Maria Carolina Vigano (Viasat Antenna Systems SA, Switzerland)

Viasat invested in the past years essential effort to develop airborne and land-mobile user terminals, suitable for future GSO (Geostationary) and new upcoming NGSO (Non-Geostationary Satellite Orbit) connectivity demands. The electronical steerable antenna approach is based on a phased array technology, composed of a custom printed circuit board equipped with a proprietary RFIC. The same building blocks of this array have been successfully used across the different markets. We intent, with this paper, to gives a summary of the main design features and an overview of the antenna performance and results achieved on first flight tests.

17:40 ***A New Antenna Array Architecture with Hybrid Beamforming for Broadband Satellite Communications***

Margaux Pellet (Heriot-Watt University & Thales Alenia Space, France); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Hervé Legay (Thalès Alenia Space, France); Joao Mota (Heriot-Watt University, United Kingdom (Great Britain)); Bingen Cortazar (European Space Agency, The Netherlands & European Space Agency (ESA), The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

In this paper, an antenna array architecture for broadband space communications with overlapped square subarrays is proposed. Analog and digital beamforming are performed consecutively at subarray level and across all subarrays. Subarrays are considered at digital beamforming level as large radiating elements, and thus the spacing between adjacent subarrays is not sufficient to prevent from interference. This leads to the creation of grating lobes. Overlapping methodologies have been studied in the literature and is an effective solution to mitigate this non-desired grating lobes. An overlapping strategy is proposed in this paper and can be seen as a shift by half the size of a subarray along 2-D. This enables a total mitigation of odd grating lobes. A comparison is made to benchmark this architecture performance compared to other existing strategies.

18:00 ***A Wideband X/Ku/Ka-Band SATCOM 8-Channel SiGe Transmit Beamformer Chip in a 16-Element Phased-Array***

Gabriel Rebeiz (UCSD, USA)

This paper presents a 5-33 GHz 8-channel transmit beamformer implemented in 90nm SiGe BiCMOS HBT technology. Each channel is composed of a wideband two-stage power-amplifier (PA), a phase-shifter (PS), a variable gain amplifier (VGA) and single-ended to differential converter (S2D). The input RF power is distributed to the 8-channels using a two-stage Wilkinson network and active dividers. The measured small-signal gain is 24-27 dB at 5-33 GHz with 5-bit phase-shifter operation and > 20 dB gain control. A peak OP1dB and OPsat of 13-14 dBm is achieved at Ku-band. The beamformer is attached to a 16-element wideband antenna array and shows scanning performance at 8-30 GHz. To author's knowledge, this work achieves the widest bandwidth Tx beamforming chip. Application areas are ground terminals capable of communications with X, Ku and Ka-band satellite constellations.

Wednesday, March 29 16:40 - 18:20

E04: Frequency-selective surfaces

T10 Fundamental research and emerging technologies / / Electromagnetics

Room: Spadolini 101

Chairs: Valentin de la Rubia (Universidad Politecnica de Madrid, Spain), Paola Pirinoli (Politecnico di Torino, Italy)

16:40 ***A Novel Frequency Selective Rasorber Based on Receiving and Transmission Antenna Pairs***

Hao Jiang (South China University of Technology & School of Electronic and Information Engineering, China); Shaowei Liao and Quan Xue (South China University of Technology, China)

Frequency selective rasorbers with out-of-band absorption and in-band transmission capabilities have been widely studied for stealth radome applications, but designing an FSR with excellent angular stability in the transmission band is still difficult. Therefore, in this work, a new architecture for developing a 3D FSR with absorption and transmission paths has been proposed. First, a planar band-stop frequency selective surface (FSS) and the absorbing materials are used in the absorption path to achieve out-of-band absorption. Second, the receiving (RX) and transmission (TX) antenna pairs attached by the enclosed transmission lines make up the transmission path. In particular, the wide-beam RX antenna can capture the incident electromagnetic wave at a large angle and is used to obtain in-band transmission with high angular stability. Finally, simulation results confirm that the reported FSR exhibits 8.41% 3-dB transmission bandwidth with good angular stability of 60, and the -10-dB low-reflection band within 4-10 GHz.

17:00 ***Frequency Selective Surfaces for Reduced Specular Reflection Under Oblique Incidence at 240 GHz***

Susanne Brandl, Adrian Diepolder, Mario Mueh, Christian Damm and Christian Waldschmidt (Ulm University, Germany)

As the alignment of a feed antenna to a steerable reflectarray becomes increasingly complicated at upper mm-wave frequencies, illuminating the structure from the far field is desirable. Simultaneously, the required fabrication precision makes large arrays expensive, effectively limiting the size. Consequently, spill-over feed radiation results in specular reflections, degrading the array's far-field pattern. To mitigate these undesired reflections, planar periodic structures can be employed to implement spatial filtering. Three designs that reduce specular reflections of a planar surface, caused by an obliquely-incident wave at 240 GHz, are proposed. Additional to standard evaluation of the absorptivity per unit cell, this paper examines the suppression mechanism by studying the scattered far field of size-limited structures. To verify each design, the frequency dependency of the specular reflection and the far-field pattern of a small array are measured. In accordance with simulations, two polarization-maintaining variants feature 10dB attenuation, whereas a mode-converting design achieves 23dB.

17:20 ***Application of FSS-Cells Stacking to the Conception of Compact Inline Waveguide Polarizers***

Lucas Polo-López and Lisa Berretti (IETR-INSA Rennes, France); Carlos Molero (University of Granada, Spain); Esteban Menargues (SWISSto12, Switzerland); Romain Contreres (CNES, France); Juan Córcoles (Universidad Autónoma de Madrid, Spain); Jorge A Ruiz-Cruz (Universidad Autonoma de Madrid & Escuela Politecnica Superior, Spain); María García-Vigueras (IETR-INSA Rennes, France)

This work presents the design of a compact inline waveguide polarizer. The device is inspired by a polarizing frequency selective surface, which allows to significantly reduce the length of the designed waveguide polarizer. A circuit model of the frequency selective surface unit cell is established and used both to better explain the operating principle of the device and also to speed up the optimization process. A numerical example at C-band is presented, and the device performance is compared with other state of the art devices.

17:40 ***Fully Metallic Frequency Selective Surface Design via Electromagnetics Coupling Matrix***

Ignacio Parellada, Carlos Molero and Pablo Padilla (University of Granada, Spain); Valentin de la Rubia (Universidad Politecnica de Madrid, Spain)

This work presents the design of fully metallic frequency selective surface (FSS) cascade filters through the use of a recently proposed electromagnetics coupling matrix approach. The filtering structure is composed of a cascade of unit cells with resonators in z direction, and a periodic repetition of the structure in the x-y direction. The fully metallic cascade unit cell can be analyzed as a coupled resonator electromagnetic (EM) circuit, where evanescent fields are pushed forward by properly designed EM resonators. This coupled resonator FSS structure is especially suitable for an EM coupling matrix characterization, where all the EM couplings among resonators can be easily identified, providing valuable design information in the different parameters for the final performance of the FSS.

18:00 ***EM-Based Design of All Metal Frequency Selective Surfaces with Finite Transmission Zeros***

Valentin de la Rubia (Universidad Politecnica de Madrid, Spain); Ignacio Parellada, Carlos Molero and Pablo Padilla (University of Granada, Spain)

An electromagnetic design methodology for all metal frequency selective surfaces with finite transmission zeros is proposed in this work. Single polarization is considered in the design, which is based on an evanescent field mechanism. An infinite 2D-periodic square-shaped metallic lattice performs the stopband behavior of the FSS, whereas H-shaped slot resonators on the sidewalls of the metallic lattice allow for the evanescent field in the desired polarization to be pushed forward in the FSS at some target passband. Finite transmission zeros next to the passband are introduced to increase the FSS selectivity using concepts from filter theory.

The EM design is carried out by means of a recently proposed approach based on the electromagnetics coupling matrix. In this new methodology, not only the S parameter response is obtained out of one single full-wave simulation with the finite element method, but also the EM couplings among the EM circuit resonators.

Wednesday, March 29 16:40 - 18:20

P02: Evaluation of mmWave and THz channels

T02 Mm-wave and THz cellular / / Propagation

Room: Spadolini 102

Chairs: Ke Guan (Beijing Jiaotong University, China), Ruoyu Sun (CableLabs, USA)

16:40 ***Comparison of Measured and Simulated Radiation from 5G Cellphone Antennas with Hand Phantoms***

Bing Xue and Katsuyuki Haneda (Aalto University, Finland); Clemens Icheln (Aalto University & School of Electrical Engineering, Finland); Lauri Vähä-Savo (Aalto-University, Finland)

In this manuscript, hand effects on cellphone antennas at 5G millimeter-wave frequencies are evaluated through measurements using hand phantoms and are compared with results from electromagnetic simulations. First, two configurations of a dual-polarized 4-element linear antenna array operating at 28 GHz are introduced. One-hand and two-hand physical phantoms and their numerical models for electromagnetic simulations are illustrated. Then, the array evaluation metric, i.e., spherical coverage, is introduced to assess statistics of realized gain across the solid angle. Next, antenna measurement setups are implemented for the two antenna arrays combined with the two physical hand phantoms. Finally, the spherical coverage and the corresponding cumulative distribution function are calculated. Differences in the realized gains derived from simulated and measured antenna arrays are about 1 dB at the median levels of the cumulative distribution. The differences are comparable to those observed when real hands are used in measurements instead of phantom hands [1].

17:00 ***Simulation and Automatic Planning of NLoS Backhaul Links at 300 GHz Using Ring Topology***

Bo Kum Jung and Thomas Kürner (Technische Universität Braunschweig, Germany)

In 5G and beyond cell deployment is expected to be ultra-dense to provide the possibility of high data rate transmission to the users. Providing fibre backhaul links to all new cell sites is costly, time-consuming, and not available everywhere. THz links operating at 300 GHz can be a fair compromise to replace fibre backhaul links enabling more than 100 Gbps data rate based on IEEE Std 802.15.3d. In a recent hardware demonstration within the Horizon 2020 EU-Japan project ThoR, the potential of high data transmission via a wireless link has been verified. In the same project, several algorithms for the automatic planning of 300 GHz backhaul links have been developed taking into account various network topologies. In this paper, a novel algorithm taking into account NLoS links in a ring topology will be presented. The performance of this algorithm has been analyzed and compared with the previously introduced algorithm.

17:20 ***Correlation and Non-Orthogonality Figures of Merit of Beamforming Fields***

Reza Gheybi Zarnagh and Andrés Alayón Glazunov (University of Twente, The Netherlands)

New figures of merit are introduced to characterize the correlation and the non-orthogonality of multiple beams produced by an array antenna or two different array antennas. The figures of merit take into account the polarization correlation or non-orthogonality between beamforming fields of two separate array and the beams produced by each at once. As an example, two adjacent modified microstrip Franklin array antennas. The non-orthogonality and isolation between steered radiation patterns have been studied for arrays operating at the same center frequencies 77 GHz. Array antenna consists of 5 linear sub-arrays with 10 rectangular microstrip patch elements. Chebyshev tapering and open circuit stubs have been applied to the microstrip patches to obtain a low side lobe level and better impedance matching, respectively. The achieved peak gain, minimum side lobe level (SLL) and impedance bandwidth are 14.1 dBi, −13.6 dB and 581 MHz for a single sub-array at 77 GHz, respectively.

17:40 ***Statistical Effects of Propagation Environment and Transmit Array Topology on Cell-Edge User Service Quality at mm-Waves***

Nicolas Van de Kreeke, Yanki Aslan and Nehir Berk Onat (Delft University of Technology, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands)

The effects of multipath on the statistical cell-edge user service quality is investigated for mm-wave multi-user communication systems. The focus is given on setting the user spacing constraints and the transmit array topology via thinning, which can be used to enhance wireless security or decrease analog/digital complexity. A hybrid line-of-sight/non-line-of-sight channel is created by using a statistical model following the communication standards. The multipath signal components are included in the model by using non-coherent or coherent modes of operation. The simulation results motivate the use of large angular spacings between the simultaneously served users in the medium access control layer and apply antenna element thinning from the array edges when required.

18:00 ***Propagation Study in a Dense Urban Environment at the Sub-THz Band for Future Wireless Communications***

Nektarios Moraitis (National Technical University of Athens & Institute of Communications and Computers Systems, Greece); Konstantina Nikita (National Technical University of Athens, Greece)

This paper presents the preliminary results of a propagation study at sub-THz frequencies considering line-ofsight (LOS) links in a dense urban environment. Path loss and wideband parameters are estimated and assessed through a deterministic simulation, using a software tool and a high-resolution digital map of the area. The study reveals that in street canyons reliable coverage can be provided up to 237 m at 140 GHz, provided that directional antennas are exploited in both terminals. In open spaces using omnidirectional and directional antennas at the terminals, wireless links can be established up to 140 m. The path loss can be predicted accurately by the close-in (CI) model, yielding path loss exponents 2.2 and 1.7, and standard deviations 2.2 and 1.8 dB, for open space and street canyons, respectively. Finally, the delay spread of the channel is found in the range of 7.0-21.0 ns.

Wednesday, March 29 16:40 - 18:20

CS23: Human RF Exposure to Present and Future Wireless Communication Systems

T04 Biomedical and health / Convened Session /

Room: Spadolini 103

Chairs: Wout Joseph (Ghent University/IMEC, Belgium), Lisa-Marie Schilling (Technische Universität Ilmenau, Germany)

16:40 ***Radio Frequency EMF Measurements and Exposure Assessment from 5G Outdoor Base Stations***

Nektarios Moraitis (National Technical University of Athens & Institute of Communications and Computers Systems, Greece); Ileana Popescu, Alexandros Rogaris and Konstantina Nikita (National Technical University of Athens, Greece)

This paper presents preliminary results of radiofrequency electromagnetic field (RF-EMF) measurements in outdoor environments. The purpose is to measure and evaluate the exposure levels of general public from fifth generation (5G) base stations, and compare them with the enforced national and international guidelines. Frequency selective measurements have

been performed in diverse urban and rural locations between 27 MHz and 6 GHz, comparing the 5G emissions with other cellular or broadcast exposure levels. The electric field, explicitly from 5G emissions, varies in the range of 0.14-0.57 V/m, and 0.19-4.10 V/m, in urban and rural locations, respectively. The maximum 5G emission, in terms of power density (44.6 mW/m2), is measured in rural areas and corresponds to about 0.4% of the legislated limits in the European Union. The inherent structure of the 5G networks corroborate the observed difference in exposure levels between urban and rural areas.

17:00 *Optimized Assessment Procedure for Maximal RF Exposure to 5G Massive MIMO Base Stations in Non-Line-Of-Sight Scenarios - Part 1: Theoretical and Numerical Investigations*

Lisa-Marie Schilling and Christian Bornkessel (Technische Universität Ilmenau, Germany); Anna-Malin Schiffarth and Dirk Heberling (RWTH Aachen University, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

The evaluation of the maximal RF exposure to 5G base stations acquires a specific extrapolation procedure due to the massive MIMO antennas. Up to now, large misestimations of the extrapolated exposure compared to the reference value were found at measurement points under non-line-of-sight conditions. One possible cause is the incorrectly determined gain correction factor based on free space assumptions which is used for extrapolation. This gain correction factor may differ greatly between line-of-sight and non-line-of-sight scenarios. In this paper, considerations based on geometrical optics are used to identify such scenarios. Here, the measurement points are in multipath environments, where the resulting field distributions and the corresponding gain correction factors are not identical compared to the free space. Numerical simulations with ray tracing confirm this assumption as the determined gain correction factor in the multipath scenario is significantly lower compared to the free space case.

17:20 *Optimized Assessment Procedure for Maximal RF Exposure to 5G Massive MIMO Base Stations in Non-Line-Of-Sight Scenarios - Part 2: Verification by Field Measurements*

Anna-Malin Schiffarth (RWTH Aachen University, Germany); Lisa-Marie Schilling and Christian Bornkessel (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany); Dirk Heberling (RWTH Aachen University, Germany)

At measurement points (MP) with line of sight (LOS) to the base station, measurement and extrapolation procedures already exist to determine the maximal exposure to 5G massive MIMO base stations. However, for MPs with non-LOS (NLOS) to the base station, incorrect estimations of the maximal exposure have been found. Based on the theoretical considerations in part 1 of this paper, the exposure at NLOS MPs has been determined at 63 MPs in the vicinity of seven Huawei base stations. The gain correction factors used by assuming LOS have been compared with the actual gain correction factors derived from the measurements. It is shown that the resulting misestimation and the actual gain correction factors depend on the distance between the MP and the base station. From this, generalised extrapolation factors are derived for NLOS MPs. Theoretical and numerical investigations are explained in detail in the accompanying paper "part 1".

17:40 *A Preliminary Investigation of EMF Exposure from Access Points in a Distributed MIMO System*

Bo Xu and Carla Di Paola (Ericsson AB, Sweden)

Distributed multi-input multi-output (D-MIMO) is one of the most promising technology candidates for 6G infrastructure. When the access points (APs) of the D-MIMO network are placed sufficiently close, the cumulative electromagnetic field (EMF) exposure might differ significantly from the EMF exposure of a single AP. In this paper, a simple approach is proposed to assess EMF exposure using the standalone AP and a correction factor. Good agreement is obtained using simulation results. It is expected that for large AP separation distances, e.g., a few meters and above, the EMF contribution from adjacent APs might be considered negligible (less than 1 dB and even lower).

18:00 *Non-Invasive SAR Using OTA Measurements and Numerical Post Processing*

Lucia Scialacqua (Microwave Vision Italy, Italy); Shoaib Anwar (Microwave Vision Group, Satimo Industries, France); Francesca Mioc (Consultant, Switzerland); Aurelien Lelievre (MVG Industries Technopole Best Iroise - Plouzane, France); Mohamad Mantash (INRS-EMT, Canada); Jerome Luc (MVG Industries Technopole Best Iroise - Plouzane, France); Nicolas Gross (MVG Industries,

France); Lars Foged (Microwave Vision Italy, Italy)

In the last few years, the use of wireless devices has increased significantly, the evaluation of the Specific Absorption Rate (SAR) is fundamental to comply with human safety regulations. Different methodologies can be used for SAR assessment, crucial parameters are the reduction of testing time and the achievable accuracy. Recently a Non-Invasive SAR evaluation technique based on passive Near-field measurements and numerical assisted post-processing has been studied and validated for a connectorized radiating element [1]. In this paper this technique is applied to an Over The Air (OTA) measurements combined with post processing and numerical simulations of a Golden Wireless Device (GWD). Reference measurements using a standard legacy SAR measurement system have been performed and compared with the proposed technique showing a good agreement. These results validate the approach and confirm the applicability of Non-Invasive SAR as a faster alternative for pre-compliance SAR measurements for modern day communication devices.

Wednesday, March 29 16:40 - 18:20

CS11: Biomedical Microwave Techniques and Devices: from Diagnosis to Treatment

T04 Biomedical and health / Convened Session /

Room: Spadolini 104

Chairs: Daniela M. Godinho (Instituto de Biofísica e Engenharia Biomédica - Faculdade de Ciências - Universidade de Lisboa, Portugal), Jorge A. Tobon Vasquez (Politecnico di Torino, Italy)

16:40 ***SbD-Driven Microwave Imaging for Biomedical Diagnosis***

Francesco Zardi and Marco Salucci (ELEDIA Research Center, Italy); Lorenzo Poli (ELEDIA Research Center, University of Trento, Italy); Andrea Massa (University of Trento, Italy)

Microwave Imaging (MI) provides a low-cost and safe approach to the non-invasive diagnosis of biological structures. However, solving the associated Inverse Scattering Problem (ISP) in a timely manner poses several challenges. To jointly achieve high reconstruction accuracy and low computation time, an imaging strategy based on the System-by-Design (SbD) paradigm is presented. The proposed SbD approach can deal with ISPs with an inhomogeneous background and is capable of exploiting a-priori information on the electromagnetic (EM) characteristics of the biological structure under investigation. Preliminary results based on a realistic brain phantom show that a remarkable reconstruction accuracy is achieved together with a significant reduction in terms of computation times as compared to competitive state-of-the-art approaches.

17:00 ***Using Impedance-Matching Metasurfaces to Enhance the Signal Penetration Through Water Solutions and Biological Tissues***

Eleonora Razzicchia, Helena Cano-Garcia, Fergus O Brien, Efthymios Kallos and Panagiotis Kosmas (Medical Wireless Sensing Ltd. - Meta Materials Inc., United Kingdom (Great Britain))

In this paper, we present experimental results of a thin impedance-matching metasurface (MTS) designed to operate in contact with the skin. This MTS was tested in the Ka-band using two different types of antennas and transmission was measured through several tissue-mimicking samples. The measurements show that the MTS enhances the signal penetration and minimizes reflection from the samples. Thus, the proposed MTS can be a powerful hardware advance for non-invasive biomedical applications, such as glucose sensing, while maintaining a subwavelength thickness.

17:20 ***Machine Learning Based Reconstruction of Point-Like Scatterers in a Portable Microwave Detection Device***

Gabrielle Fontaine and Stephen Pistorius (University of Manitoba, Canada)

Access to breast cancer screening is limited in low-income and remote areas, resulting in late-stage diagnosis and increased mortality rates. A portable microwave system was created by minimizing the device cost, size, and complexity. The small, cylindrical device features twenty-six patch antennas and inexpensive vector network analyzers operating from 0.7 - 3 GHz. A microwave radar model was modified to simulate S11 measurements of the physical device. Radar simulations were performed on numerical phantoms consisting of two rod-like point scatterers with varying reflectivities of 10%, 30%, 50%, 70%, 90%, or 100%. A convolutional neural network (CNN) was trained to directly reconstruct the rod phantoms from their simulated S11 sinograms. Despite the narrow bandwidth, the CNN could detect point scatterers with an accuracy up to 85%, improving on conventional resolving capabilities. Artificial intelligence microwave sensing methods offer promising possibilities for automated, low-cost breast cancer screening.

17:40 ***Microwave Medical Imaging of the Human Neck Using a Neural-Networks-Based Inversion Procedure: A Phantom Study***

Chiara Dachena and Alessandro Fedeli (University of Genoa, Italy); Alessandro Fanti, Matteo Bruno Lodi and Giorgio Fumera (University of Cagliari, Italy); Matteo Pastorino and Andrea Randazzo (University of Genoa, Italy)

A preliminary experimental validation of a machine-learning technique for microwave imaging of the neck is reported in this paper. Specifically, a fully-connected neural network is used to retrieve the dielectric properties of a simplified neck phantom. The architecture of the network, e.g., number of layers and neurons in each layer, is optimized through a numerical analysis on simulated data. The initial results confirm that it is possible to train the network with simulated data only and to test it with real data, obtaining good reconstruction results.

18:00 ***Towards a Low-Complexity Microwave Imaging Strategy for Liver Ablation Monitoring***

Rosa Scapaticci (CNR-National Research Council of Italy, Italy); Roberta Palmeri (IREA-CNR, Napoli, Italy); Sandra Costanzo (University of Calabria, Italy); Marta Cavagnaro (Sapienza University of Rome, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy)

Thermal ablation represents an innovative treatment strategy for liver cancer therapy, having tangible advantages with respect to surgery. However, the main shortcoming, particularly crucial for microwave thermal ablation, is the necessity of monitoring in real time the treated region, so to provide information on the effectiveness of the treatment. Microwave imaging has been recently proposed as an effective tool for this goal, as it is capable of imaging the dielectric properties variations of liver tissues undergoing the ablation therapy. First investigations on simulated and experimental data corroborated the expected potentials. In this communication, a novel imaging approach able to work with a simplified measurement set-up is presented. The system simplification consists in a reduction of the number of antennas and in a measurement protocol which does not require any movement of the antenna array nor of the target under test. Preliminary results on experimental data are reported.

Wednesday, March 29 16:40 - 18:20

A12: RFID Antennas

T07 Positioning, localization & tracking / / Antennas

Room: Spadolini 105

Chairs: Filippo Costa (University of Pisa, Italy), Daniel Valderas (University of Navarra, Spain)

16:40 ***Wireless Sensing with Enhanced Interrogation Range by Passive Ultrasensitive NSRR Sensors***

Burak Ozbey (Ankara University, Turkey)

Wireless sensing with an extended interrogation range is demonstrated using coupling-based passive sensors designed in nested split-ring resonator (NSRR) geometry. Contrary to previous utilization of the NSRR as a sensor placed within the near-field region of the transceiver antenna, the proposed sensing system uses separate antennas for TX and RX so that the signal reflected from the NSRR sensor is not affected by the dominating effect of the clutter, which limits the interrogation distance dramatically. The separation of the communication channels into TX and RX enables the extension of the interrogation distance to far field, which is critical for applications such as Structural Health Monitoring. The proposed sensing method is validated by experiments where NSRR sensor is used to detect displacement. However, the system can be exploited for measurement of different quantities such as strain and moisture content, as well.

17:00 ***Characterizing Harmonic Transponder Performance Jointly over Frequency and Power***

Milan Polivka (Czech Technical University in Prague, Czech Republic); Jeff Frolik (University of Vermont, USA)

Harmonic transponders are passive wireless devices that hold great promise for a variety of long-term tracking and sensing applications. These nonlinear devices receive an interrogation signal at one frequency (f_0) and return its harmonics. Due to these separate bands, over-the-air laboratory characterization of these devices typically leverages a signal generator on the transmit side and a spectrum analyzer on the receive side. Herein, we present an approach that instead uses a standard two-port vector network analyzer (VNA), along with a frequency divider, for both functions and demonstrate its use. The advantage of this approach is that high resolution measurements can be quickly made jointly over frequency and over power. This approach can thus characterize devices whose resonant frequency may change with a locally sensed phenomena or by the environment in which the device is deployed. Our measurements are within 0.5 dB of those using a high-end VNA having advanced capabilities.

17:20 ***Analysis of Machine Learning Algorithms for USRP-Based Smart Chipless RFID Readers***

Fatima Villa-Gonzalez (Massachusetts Institute of Technology, Spain & Tecnun - University of Navarra, Spain); Jafait Junior Fodop Sokoudjou, Odon Pedrosa, Daniel Valderas and Idoia Ochoa (University of Navarra, Spain)

The classification performance of machine learning (ML) on measurements from a low-cost chipless RFID reader is examined. We first justify the need of replacing the laboratory equipment used for chipless measurements with cheaper and less bulky devices such as software defined radios (SDRs). We take reflection measurements of four circular ring resonator (CRR) tags with different IDs employing a custom programmed USRP N210 SDR. We describe the step by step workflow followed to train five different ML models and correctly identify the tag IDs with over 93.3% accuracy. Future directions of research are also discussed.

17:40 ***Hybrid Time/Frequency Domain Electromagnetic Encoders Dispenser-Printed on PET Substrate***

Amirhossein Karami-Horestani (CIMITEC, Departament d'Enginyeria Electrònica & Universitat Autònoma de Barcelona, Spain); Ferran Paredes (Universitat Autonoma de Barcelona, Spain); Ferran Martín (Universidad autónoma de Barcelona, Spain)

In this paper, hybrid time/frequency domain electromagnetic encoders implemented on polyethylene terephthalate (PET) substrate by means of direct-write dispenser-printing, using conductive inks, are presented for the first time. The encoders are based on chains of linear strips (inclusions) transversally oriented with regard to the chain axis, and frequency encoding is achieved through the size of the inclusions. Specifically, four different sizes are considered, corresponding to two bits of information per chain period. The determination of the specific 2-bit ID code for each chain period is carried out sequentially, in a time-division multiplexing scheme, by means of a dedicated reader, able to detect the size of the inclusions. The main relevant contribution of this paper concerns the fact that it is demonstrated that enhancing the bit density in electromagnetic encoders is compatible with encoder implementation on PET substrate through dispenser-printing process.

18:00 ***Isotropic Magnetic Field Probe with ICNIRP 2020 Frequency Shaping in the Band Up to 400 MHz***

Juan Felipe González Pardo (Universidad Nacional de Colombia, Colombia); German Augusto Ramirez Arroyave (EPFL - École Polytechnique Fédérale de Lausanne & Universidad Nacional de Colombia, Switzerland); Javier Leonardo Araque Quijano (Universidad Nacional de Colombia, Colombia)

We present the design and validation of an isotropic field probe with geometry and frequency response shaped to correctly weight the aggregate contribution of the various frequency components of a broadband magnetic field in the band 100 kHz - 400 MHz

according to the ICNIRP 2020 guidelines. The elementary sensor is a small strip loop printed on a thin dielectric substrate. The elementary sensor is initially analyzed via full-wave simulation from which a Th´evenin equivalent model is extracted. Careful consideration of the frequency response of the loop and the power detector enabled the optimization of a canonical filtering topology to obtain the desired frequency response. Finally, the isotropic probe assembly consisting of a cubic arrangement of three elementary sensors is validated with respect to isotropy and isolation.

Wednesday, March 29 16:40 - 18:20

E03: Computational Electromagnetics 2

T09 EM modelling and simulation tools / / Electromagnetics

Room: Spadolini 106

Chairs: Matthys M. Botha (Stellenbosch University, South Africa), Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy)

16:40 ***A Discontinuous Galerkin Time-Domain Scheme to Simulate Semiconductor Lasers***

Ming Dong (King Abudullah University of Science and Technology (KAUST), Saudi Arabia); Liang Chen and Ran Zhao (King Abdullah University of Science and Technology, Saudi Arabia); Hakan Bagci (King Abdullah University of Science and Technology (KAUST), Saudi Arabia)

A computational framework, which relies on the discontinuous Galerkin time-domain scheme, is proposed to simulate transient lasing generated by interactions of light with an active medium. The proposed scheme solves a coupled system of the Maxwell and the rate equations. The active medium inside the laser region is described quantum-mechanically by the rate equations to account for the atomic transitions of a multi-level system, while electromagnetic field interactions are described classically by the Maxwell equations. Numerical examples are provided to demonstrate the accuracy and the applicability of the proposed framework.

17:00 ***Iterative Physical Optics Method for Electromagnetic Analysis of Radomes Based on the Well-Conditioned N-Cross Muller Formulation***

Michael Katsav (Tel Aviv University, Israel)

An improved iterative physical optics (IPO) scheme based on the well-conditioned N-Müllerr formulation is proposed to analyze the RF performance of a dielectric radomes. It is shown that the use of the N-Muller formulation in combination with the Rao-Wilton-Glisson basic functions leads to a well-conditioned matrix equation and rapidly converging iterative solutions. The main advantage of the proposed IPO method is that it excludes hypersingular and strongly singular terms from the integral equations of the electric and magnetic fields, leaving only weakly singular terms that can be easily treated by the singularity extraction method. The proposed IPO scheme was used to analyze the antenna pattern in the presence of an arbitrary dielectric radome. The results obtained were compared with the results obtained from the CST Integral Equation Solver software and good agreement is observed.

17:20 ***Calculation of Characteristic Modes of Antenna Arrays Using Spherical Wave Functions and Transition Matrices***

Leonardo Mörlein and Adrian Mrochen (Leibniz Universität Hannover, Germany); Dirk Manteuffel (University of Hannover, Germany)

A method to calculate the characteristic modes of antenna arrays is proposed. In this method, the transition matrix of an antenna array is derived from the transition matrices of the individual array elements. Based on this transition matrix, the characteristic modes of the array are calculated. An exemplary problem is solved and compared with a reference simulation to demonstrate the validity of the proposed method.

17:40 ***Field-Flux Finite Element Formulation for Wave Propagation in Bianisotropic Media***

Michalis Nitas and Vasileios N. Salonikios (Aristotle University of Thessaloniki, Greece); Stamatis A. Amanatiadis (Aristotle University of Thessaloniki & Ormylia Foundation, Greece); Samel Arslanagić (Technical University of Denmark, Denmark)

We derive a field-flux Finite Element formulation for the inclusion of bianisotropic materials in wave propagation electromagnetic problems. A boundary condition is proposed for the efficient excitation and absorption of the supported modes. Computational results are compared with analytical solutions from the literature for a homogeneous omega bianisotropic medium. Perfect agreement is exhibited, proving the efficiency and robustness of the proposed formulation.

18:00 ***Results in Adaptive MoM Analysis with Goal-Oriented Error Estimation***

Ralph J. McDougall, Pierre I. Cilliers and Matthys M. Botha (Stellenbosch University, South Africa)

Adaptive analysis consists of refining meshes selectively, based on a posteriori error estimation information, such that degrees of freedom are optimally applied. In the method of moments (MoM) context, comparatively little work has been done on a posteriori error estimation and on putting forth adaptive analysis schemes. This paper presents adaptive analysis results for the electric field integral equation (EFIE) MoM with Rao-Wilton-Glisson (RWG) basis functions, with particular focus on showing new comparative results for conventional error estimators and for a goal-oriented error estimator, with the adaptive MoM setting. The conventional estimators are two smoothing type estimators based on identifying solution discontinuities and an explicit residual-based estimator. The goal-oriented estimator incorporates knowledge of the postprocessing observable of interest. Results show that goal-oriented a posteriori error estimation is a generally superior approach to driving adaptive mesh refinement for the MoM.

Wednesday, March 29 16:40 - 18:20

CS6: AMTA Session: UAV-based Antenna and Field Measurements

T05 Aircraft (incl. UAV, UAS, RPAS) and automotive / Convened Session /

Room: Spadolini 107

Chairs: Torsten Fritzel (Aeroxess UG, Germany), Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy)

16:40 ***Indoor Antenna Calibration with UAVs - on Time Domain Gating and the Influence of Motion***

Robert Geise (HTWK University of Applied Science Leipzig & Technische Universität Braunschweig, Germany); Anne Vaske (TU Braunschweig, Germany); Torsten Fritzel and Rüdiger Strauß (Aeroxess UG, Germany)

This contribution discusses the applicability of a UAV as positioning and measurement system for antenna calibration in an arbitrary indoor environment. Since such an environment - unlike an anechoic chamber bears the possibility of multiple reflections the feasibility of time domain gating network analyzer measurements is investigated for the time-variant propagation channels due to the motion of the UAV. Based on a simple simulation time domain gating model taking into account the motion of a UAV and its influence on measurement parameters in the frequency domain it is shown that the motion of the UAV can be neglected. The propagation channel can be considered basically static provided a usual hovering flight with a typical motion uncertainty, the data of which is obtained from an exemplarily flight trajectory.

17:00 ***UAV-Based Near-Field Measurements at a Doppler Very High Frequency Omnidirectional Radio Range***

Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany); Stefan Punzet (Technical University of Munich & Chair of High-Frequency Engineering (HFT), Germany); Thomas Mittereder, Fabian T. Faul and Alexander Paulus (Technical

University of Munich, Germany)
Unmanned aerial vehicle (UAV)-based near-field (NF) measurements of installed radio devices provide comprehensive information on the operational status of such instruments with full consideration of the local environment. In order to establish NF measurements for Doppler very high frequency omnidirectional radio ranges (DVORs) and other navigational aids such as instrument landing systems, electromagnetic simulations of the NF and far-field (FF) behavior of a DVOR are performed and analyzed. NFFF transformations are carried out with an inverse source solver and the diagnostic information of the equivalent sources is illustrated. Exemplary UAV-based measurements are performed with a dedicated measurement setup and the measurement results are evaluated in comparison to the simulation results.

17:20 ***Verification of a Multi-Beam HF Radar-Embedded Communication System Using a Drone***

Simon Henault (Defence Research and Development Canada, Canada)
The performance of the hybrid far-field radiated emission design phase-attached radar/communication (FFRED/PARC) approach for simultaneous transmission of radar and communication signals in multiple beams is verified experimentally using a drone and an experimental 64-monopole over-the-horizon radar (OTHR) transmitter. It is demonstrated that very closely separated beams are possible if the transmitter is calibrated correctly in particular for demodulation of secondary beam signals. Excellent power and spectral efficiencies are demonstrated while also verifying the impact on the radar ambiguity function. The approach inherently adds a physical-layer level of communication security and is an attractive option for leveraging costly OTHR installations.

17:40 ***Radiation Physics Allows Ten-Fold Optimization of UAV Near-Field Scanning***

Lorenzo Ciorba (Institute of Electronics, Computer and Telecommunication Engineering (IEIIT-CNR), Torino & Politecnico di Torino, Torino, Italy); Fabio Paonessa (National Research Council of Italy (CNR - IEIIT), Italy); Marco Righero (LINKS Foundation, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)
This paper presents the first implementation of an optimum flying path for UAV-based Near-Field Antenna Measurements. The path is obtained solving the Travelling Salesperson Problem on a set of waypoints determined with a truncated Column Pivoting QR factorization of the matrix given by the discretization of the radiation operator. The optimum flight has been implemented on a non-tethered small octocopter showing approximately a 10-times reduction of the path length (and duration) with respect to a regular raster with half-wavelength spacing. The phase information has been retrieved using a dual-polarized reference antenna and a multi-channel acquisition system. The measured results are in agreement with simulated data.

18:00 ***Improving the Accuracy of a Model-Based Approach for the Near-Field Measurement of Antenna Arrays with UAVs***

Quentin Gueuning (University of Cambridge, United Kingdom (Great Britain)); Christophe Craeye (Université Catholique de Louvain, Belgium); Eloy de Lera Acedo (University of Cambridge, United Kingdom (Great Britain)); Anthony Keith Brown (University of Manchester, United Kingdom (Great Britain))
We improve the accuracy of a technique developed in [Hoorebeeck] for the evaluation of the embedded element patterns from near-field measurements taken with a source mounted on an unmanned areal vehicle. The method relies on a reduced model of the current distributions induced on the array using a collection of current modes. This model-based approach possibly allows for a smaller number of measurement samples than classical transformation techniques. However, the numerical accuracy of the near-field link between the drone and these modal currents is currently limiting the reconstruction errors. Hence, we derive a new set of measurement equations by substituting a multipole decomposition into the Lorentz reciprocity theorem. A numerical experiment including an array of 16 log-periodic antennas and a quadcopter shows that, with this new formulation, an element pattern can be reproduced to 2 digits at small intermediate-field distances.

Wednesday, March 29 16:40 - 18:20

A11: Innovative Lens Antennas II

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 108

Chairs: Nelson Fonseca (European Space Agency, The Netherlands), Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

16:40 ***Experimental Validation of a 3D-Printed Telescopic GRIN Lens for Antenna Aperture Magnification***

Anastasios Paraskevopoulos, Ilir Gashi, Matteo Albani and Stefano Maci (University of Siena, Italy)

In this paper, we verify experimentally the performance of a 3D-printed lens antenna system based on graded index (GRIN) material. The GRIN lens system is composed of two cylindrical confocal lenses: one divergent and one convergent GRIN lens and the feed is positioned on the interface of the first lens. The telescopic GRIN lens is useful for aperture magnification of antenna arrays or for reusing already available medium-gain arrays and bring them to a high-gain, occupying a reduced volume as compared to traditional lenses or multi-reflector systems. To validate the telescopic GRIN lens design based on a GO-derived formula of the refractive index, 3D far-field radiation pattern measurements are performed at the Ku band between 12 to 18 GHz. Two lens feeds are tested: a rectangular and a conical horn antenna. The resulting maximum gain magnification for a lens diameter of 3.5 wavelength is 4.1 and 6.1 dB respectively.

17:00 ***Radiation Pattern Synthesis of Folded Geodesic Lens Antennas***

Germán León (Universidad de Oviedo, Spain); Susana Loredo (University of Oviedo, Spain); Enrique G. Plaza and Set Pérez-González (Universidad de Oviedo, Spain)

The fifth and sixth generation of mobile communication systems will allow the development of several new services. New millimetre-wave multibeam antennas are needed to provide wide and stable beams. Rotationally symmetric geodesic lens antennas (GLA) can fulfil these requirements. In this work, a two-step method to design folded GLAs is presented. In the first step, a folded focusing lens is searched such that its radiation pattern minimizes a cost function. In the second step, a genetic algorithm is run to diminish the value of the cost function. As an example, this method has been used to design a GLA with 24º of beamwidth and side lobe level below -15 dB. A multibeam antenna has been simulated based on this lens. The antenna is fed by nine ports, which ensures high overlapping between independent beams. This antenna can provide a coverage of 110º.

17:20 ***Ka-Band Planar Dielectric GRIN Lens Antenna with Circular Polarization***

Jose-Manuel Poyanco (University Carlos III of Madrid, Spain); Francisco Pizarro (Pontificia Universidad Catolica de Valparaiso, Chile); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

This article presents the design of a planar circularly polarized graded index lens. Each section of the lens is implemented with an anisotropic material made by a dielectric periodic structure, which changes the polarization from linear to circular, and simultaneously, it has an effective refractive index that allows the focusing of the impinging wave as a lens. The design is made for Ka band and it considers realistic filaments and the previous experience of the authors to guarantee the viability of manufacturing via conventional 3D printing.

17:40 ***Glide-Symmetric Holey Metasurface with Enhanced Isotropic Properties Implemented in Mikaelian Lens Design***

Dubravko Tomić (University of Zagreb, Croatia); Jose-Manuel Poyanco (University Carlos III of Madrid, Spain); Marko Bosiljevac (University of Zagreb, Croatia); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain); Zvonimir Sipus (University of Zagreb, Croatia)

Design of a fully metallic metasurface based implementation of planar Mikaelian lens is presented in this paper. The proposed lens has excellent potential in beam scanning applications and can be used as an alternative to exhaustively investigated

Luneburg lens. In order to produce the necessary spatial variation of refractive index the lens is realized as a parallel plate waveguide loaded with quasi-periodic glide-symmetric holey metasurface. It is demonstrated that inserting coaxial pins into the cylindrical holes increases index of refraction, but also enhances isotropic properties, which is exploited in the design of the Mikaelian lens based multibeam antenna. The constructed lens antenna works in X-band, has 60◦ angular beam coverage and over the scanning range has side lobe levels below -10 dB and scan loss below 1.5 dB.

18:00 ***A Lightweight Metalized-Insert Luneburg Lens***

Maral Ansari (CSIRO, Australia); Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Nelson Fonseca (European Space Agency, The Netherlands); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Y. Jay Guo (University of Technology Sydney, Australia)

In this paper, a lightweight spherical Luneburg lens with high performance is introduced for use in the frequency range 1 (FR1). The continuously varying refractive index profile of the lens is implemented using a quasi-isotropic partially metalized periodic structure. Much of the lens volume is made of foam, so the design is lightweight, making it applicable for low-band microwave frequency communication systems and, more specifically, 5G communications in FR1. The periodic structure allows a simple and low-cost layered construction with a quasi-isotropic response. This approach improves the scanning performance of the lens in all angular directions when compared to equivalent lens designs previously reported. Such a structure is an ideal candidate for high-gain multi-beam communication systems.

Wednesday, March 29 16:40 - 18:20

A32: Technologies for Antenna Systems I

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 109

Chairs: Yang Hao (Queen Mary University, United Kingdom (Great Britain)), Jiro Hirokawa (Tokyo Institute of Technology, Japan)

16:40 ***Design and Testing Radome for D-Band Applications***

Vladimir Ermolov and Arto Hujanen (VTT Technical Research Centre of Finland, Finland); Alexandros I. Dimitriadis (SWISSto12 SA, Switzerland); Jussi Säily (VTT Technical Research Centre of Finland, Finland)

The paper presents results of characterization of dielectric properties of several commercial radome materials in D-band. It is demonstrated that there are commercial radome materials on the market already today which can be used for D-band radome. A multilayer radome based on selected materials Preperm RS260 and Rohacell HF is designed and tested. The radome demonstrates transmission losses not higher than 0.75 dB in the frequency band of 130 - 165 GHz. Usage of the radome in a combination with a D-band antenna array is studied.

17:00 ***Multi-Mirror Quasi-Optical Beamformer for Wide Scanning Linear Apertures***

Léonin Lassauce (Université de Rennes 1 & IETR, France); Jean-Philippe Fraysse and Ségolène Tubau (Thales Alenia Space, France); Hervé Legay (Thalès Alenia Space, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

In this article, the design of a low profile multi-mirror quasi-optical beamformer is presented. The beamformer consists of stacked parallel plate waveguides operating with the principal transverse electromagnetic mode. Vertical mirrors and slot-based transitions are used to shape in amplitude and phase the guided mode for feeding a linear aperture located at one edge of the beamformer. A physical optics tool is used to optimize the shape and location of the mirrors for wide scanning. The proposed concept is validated by full-wave simulations by considering the example of a two-mirror design operating in the Ka-band (17.3

GHz - 20.2 GHz) generating nine beams over ± 57° field of view in azimuth with reduced scan losses in the order of 2.5 dB.

17:20 ***Compact Liquid Crystal-Based Defective Ground Structure Phase Shifter for Reconfigurable Intelligent Surfaces***

Robin Neuder (Technical University Darmstadt, Germany); Dongwei Wang (Technical University of Darmstadt, Germany); Martin Schüßler (TU Darmstadt, Germany); Rolf Jakoby (Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany); Alejandro Jiménez-Sáez (Technische Universität Darmstadt, Germany)

This paper investigates the applicability of defective ground structure inverted microstrip lines (DGS-IMSL) for liquid crystal (LC)-based phase shifters that can be integrated in a Reconfigurable Intelligent Surface (RIS). The DGS features a slow-wave effect as well as low insertion losses even for thin LC-layer thicknesses, making it a promising candidate for compact phase shifting elements with low insertion loss and response times below 100 ms . Using Merck's commercially available GT7-29001 LC, simulations and measurements are presented from 25 to 30 GHz. The compact, wideband phase shifters cover the entire band with a FoM > 74 ◦/dB reaching up to 79 ◦/dB. The 4.6 μm thick LC layer permits full 360◦phase shift with a bias voltage of only 10 V. The phase shifter's physical lengths could be miniaturized down to 0.35 to 0.45 λ0 due to the slow-wave effect of the DGS.

17:40 ***Substrate-Less Vertical Chip-To-Waveguide Transition for W-Band Array Antenna Integration***

Juan Luis Albadalejo Lijarcio (Chalmers University of Technology & Gapwaves AB, Sweden); Abbas Vosoogh (Gapwaves AB, Sweden); Vessen Vassilev and Jian Yang (Chalmers University of Technology, Sweden); Thomas Emanuelsson and Ingmar Andersson (Ericsson AB, Sweden); Ashraf Uz Zaman (Chalmers University of Technology, Sweden)

This paper presents a vertical transition from a high permittivity GaAs MMIC to rectangular waveguide using bondwires as a coupling structure. The transition is advantageous for the direct integration of any off-the-shelf chip into a waveguide antenna since no modification of the GSG-pad or additional substrate is needed. An EBG structure consisting of pins is used for the packaging of the chip in order to avoid field propagation in undesired directions. The simulations results show that the reflection coefficient is lower than -10 dB and the average insertion loss is better than 0.5 dB from around 87 to 101 GHz (14% relative bandwidth).

18:00 ***Impact of Strut Diameter on the European Space Agency Deep Space Antennas Efficiency and Sidelobes***

Davide Arenare (University of Pavia, Italy); Fabio Pelorossi (ESOC, ESA, Germany); Filippo Concaro (European Space Agency, Germany); Marco Pasian (University of Pavia, Italy)

Large reflector antennas require the presence of struts to support both feeds or sub-reflectors. These additional structures affect the antenna behavior. This paper proposes an investigation between struts of different radius, considering the structure of the European Space Agency Deep Space Antenna 3 (DSA3), in terms of sidelobes and efficiency.

Wednesday, March 29 16:40 - 18:20

ESR: Exhibitors and Sponsors Reception

Room: Sala della Scherma

Wednesday, March 29 16:40 - 18:20

WG PROP: EurAAP Propagation WG meeting

Room: Polveriera

Wednesday, March 29 16:40 - 18:20

IW7: Novel Antenna and Architecture for Future 6G Wireless Communication and Sensing (Huawei)

Room: Sala Arco

Wednesday, March 29 16:40 - 18:20

SW8: Women in Antennas and Propagation (WiAP) workshop

Organized by: Francesca Vipiana (Politecnico di Torino, Italy); María García Vigueras (Institut National des Sciences Appliqees - INSA, France)

Room: Palazzina 7

16:40 - Building a career and a personal brand as a woman in engineering (Katerina Galitskaya, Radientum, Finland)

17:10 - Challenges in building a career in propagation (Sana Salous, Durham University, UK)

Thursday, March 30

Thursday, March 30 9:00 - 10:40

CS18: Emerging Technologies for Reflectarrays and Transmitarrays

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: Nader Behdad (University of Wisconsin, USA), Nima Ghalichechian (Georgia Institute of Technology, USA)

9:00 ***Millimeter-Wave Scattering Mitigation Transmitarray for Unidirectional Cloaking of Obstacles***

Youngno Youn, Daehyeon Kim, Suho Chang and Jaehyun Choi (Pohang University of Science and Technology, Korea (South)); Wonbin Hong (Pohang University of Science and Technology (POSTECH), Korea (South))

This paper presents a new concept of unidirectional scattering mitigation transmitarray (TA) using a single substrate frequency selective surface (FSS). This engineered electromagnetic surface formulates complementary fields for rendering obstacles to become electromagnetically-transparent without blockage modification. Spatial impedance distribution of the proposed TA is calculated by superposition and linearity. A double-layer FSS, which features wide tunable transmission phase shift range within 1-dB transmission loss, is implemented for proof-of-concept demonstration. The proposed cloaking technique is confirmed by full-wave simulations and measurements at 30.0 GHz.

9:20 ***K/Ka-Band Full-Duplex Satcom ESA Using a Varactor-Based Metasurface Aperture***

Amin Momeni, Mohsen Sazegar and Ryan Stevenson (Kymeta Corporation, USA)

We present a shared aperture electronically scanned array (ESA) with full duplex capability. The antenna covers the full K/Ka commercial and military receive (17.7-21.2 GHz) and transmit (27.5-31 GHz) bands for satellite communications (Satcom). The antenna is based on the concept of holographic beam forming and is implemented using diffractive metasurfaces and varactor diode tuning. The metasurface was manufactured using processes commercialized for mini-LED displays and was experimentally characterized. With an 82cm radial radiative aperture, the antenna achieves a maximum gain of 40.4 dBi at receive and 40.7 dBi at transmit bands in full duplex mode. Electronic control over polarization and a wide beam scanning from 15 degrees to 90 degrees in elevation and 360 degrees in azimuth were also experimentally demonstrated, with a scan loss near to theoretical limits at the receive band.

9:40 ***Electronically Reconfigurable Reflectarray Antennas for Mobile Troposcatter Communications***

Jiahao Zhao, Mohammad Mahdi Honari, John Booske and Nader Behdad (University of Wisconsin-Madison, USA)

Conventional tropospheric scattering (troposcatter) communications primarily use electrically large reflector antennas for point-to-point communications, which suffer from bulky volumes and difficulties in maintaining beam-pointing accuracy. Beam pointing and tracking problems in troposcatter communications applications may be alleviated by the aid of phased-array antennas at the transmit and receive locations. In this paper, we present an electronically reconfigurable reflectarray designed to perform accurate beam steering and tracking in trposcatter communications systems. This reflectarraty uses an electronically reconfigurable unit cell providing 2-bit reflection phase shift quantization. The unit cell consists of an E-shaped patch placed above a ground plane. The patch is connected to a reflecting circuit electronically controlled by three PIN diodes below the ground plane to provide 2-bit phase shift. Full-wave simulations of a 208-element reflectarray incorporating the proposed unit cell have demonstrated the performance feasibility of the design concept.

10:00 ***Dual-Band Metal-Only Antenna Combining Reflectarray and Reflector Functionalities***

Zhihang AN (INSA Rennes, France); Tony Makdissy (FRECNSYS, France); María García-Vigueras (IETR-INSA Rennes, France); Raphael Gillard (IETR & INSA, France)

This paper presents a dual band metal-only antenna that operates at 20/40GHz. The proposed metal-only antenna combines the functionalities of reflectarray and parabolic reflector antennas. The unit cell consists of a square waveguide with short circuit termination and a square metallic block in the center. At 20GHz, the reflected beam is determined by a parabolic surface. At 40GHz, the reflected beam is controlled by the phase distribution of cells in the antenna. The gain increases with frequency in the lower frequency band, which is similar to what happens in a parabolic reflector antenna. The aperture efficiency at 40GHz is about 43.79%.

10:20 ***Wideband Transmitarrays Based on Anisotropic Unit-Cells for Next Generation Sub-THz Applications***

Orestis Koutsos (IETR & CEA Leti, France); Francesco Foglia Manzillo (CEA-LETI, France); Antonio Clemente (CEA-Leti, France); Ronan Sauleau (University of Rennes 1, France)

This paper presents an anisotropic transmitarray for next-generation applications in the 300-GHz band. First, the proposed three-layer unit-cell is analyzed theoretically to demonstrate its effectiveness in transmission and bandwidth operation. Then, two designs using different manufacturing technologies are synthesized. The first one is based on a standard printed circuit board process to represent a low-cost solution. The second one uses lithography in fused quartz, leveraging a higher fabrication and transmission phase resolutions for more efficient transmitarray design. Based on the two structures, two 40×40-element prototypes are realized considering these two fabrication streams. The low-cost prototype is measured, achieving a peak gain of 32.2 dBi with 31.8% aperture efficiency and a 3-dB gain bandwidth of 55 GHz (19%).

Thursday, March 30 9:00 - 10:40

CS42: Recent advances in sub-millimeter wave antenna systems for radio-astronomy and space exploration

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Luis Enrique García Muñoz (Universidad Carlos III de Madrid, Spain), David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

9:00 ***QUBIC - the Q & U Bolometric Interferometer for Cosmology***

Creidhe O'Sullivan (National University of Ireland Maynooth, Ireland)

In this paper we briefly describe QUBIC, the Q & U Bolometric Interferometer for Cosmology, a novel ground-based instrument designed to measure the extremely faint polarization anisotropy of the cosmic microwave background at intermediate angular scales. In particular we will describe simulations of the optical combiner and feedhorn array used to generate synthesized beam patterns for each detector on our focal plane. A QUBIC technical demonstrator has been built and is being installed in the observing site at Alto Chorrillos, Argentina with first light expected in 2022.

9:20 ***Submillimeter Wavelength Radiometry Dedicated to Spectral Analysis of Planetary Atmospheres: Low Noise System Development at Paris Observatory***

Gregory Gay (Observatoire de Paris - LERMA, France); Jeanne Treuttel (Observatoire de Paris, France); Lina Gatilova (Centre de Nanosciences et de Nanotechnologies (C2N), CNRS, France); Alexandre Feret and Thibaut Vacelet (Observatoire de Paris, France); Jérôme Valentin (Observatoire de Paris PSL, France); Antonella Cavanna and Yong Jin (Centre de Nanosciences Et de Nanostructures, France); Jean-Michel Krieg (Observatoire de Paris PSL, France); Jean-Luc Roux, Valerio Cipolla and Jérome Puech (CNES, France)

We address the development of low noise system radiometer for heterodyne detection at Terahertz frequencies for high spectral resolution instruments at Observatoire de Paris PSL. This work highlights constant effort to aim at keeping state-of-the-art receiver noise performances from 300 GHz to 1200 GHz and above for molecular line and continuum detection. In this work we concentrate on the mixer element as the first active element of the radiometric chain. We present the current ongoing work for the demonstration of a low-noise 325 GHz radiometer for atmospheric sounding applications. Three types of mixer configurations have been optimized and some of them fabricated and measured. We discuss some, but not all, of the system related aspect and the choice of mixer parameters for best performance that will provide stability for the long-term operation.

9:40 ***New Antenna Challenges of Microwave Instruments for Meteorology Space Missions in Airbus DS***

Laurent Costes, Benjamin Carayon, Jean-Claude Orlhac, Samuel Mellé, Asma Kallel and Christophe Malassingne (Airbus Defence and Space, France); Jérome Puech and Aurélie Bornot (CNES, France); Michel Tossaint (European Space Agency, The Netherlands); Carole Tucker and Peter Ade (Cardiff University, United Kingdom (Great Britain))

This document gives an overview of the antennas involved in the recent developments and studies in the Microwave Instruments department of Airbus Defence and Space (Airbus DS) in Toulouse (France) and the related challenges.

10:00 ***Photonic Source-Based THz Phase-Shifting Interferometry for Characterization of Widefield Submm Optics***

Ivan Cámara Mayorga (Max Planck Institute for Radioastronomy, Germany); Nicolas Reyes (Max Planck Institut for Radio Astronomy, Germany)

The characterization of wide-field optics operating in the terahertz regime is a major challenge as it involves very demanding requirements many of which are hardy to meet with the available testing systems technology. Whilst scalar or thermal sources placed in the focal plane allow basic characterization, important features such as coupling efficiency or the effect of curved focal planes cannot be assessed by such approaches. Ideally, in order to gather complete information of the optical system, an amplitude and phase measurement is required. The present paper reports on our work to implement a testing system capable of performing amplitude and phase measurements based on two interfering photonic sources of coherent terahertz radiation at 850 GHz. The described testing system allowed to characterize the optics of our wide-field kinetic inductance detector instrument (A-MKID), which will be shortly installed in the Atacama Pathfinder Experiment telescope (APEX) in Chile.

10:20 ***Q-Band Front-End Radiating Module for Next Generation Active Antennas at Thales Alenia Space***

Benoit Lejay, David Serres, Nicolas Ferrando and Olivier Vendier (Thales Alenia Space, France); Václav Valenta (European Space Agency, The Netherlands)

This paper presents a status of development of a Q-band front-end radiating module (FERM) for next generation active antennas dedicated to Geostationary Earth Orbit (GEO) missions at Thales Alenia Space France.

Thursday, March 30 9:00 - 10:40

CS20: Frontiers in Propagation and Wireless Channel Modeling — Assembly 2

T01 Sub-6GHz cellular / Convened Session /

Room: Spadolini 101

Chairs: Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany), David W Matolak (University of South Carolina, USA)

9:00 ***Future of Terahertz Channel Measurements and Modeling in Computer Systems***

Alenka Zajic (Georgia Institute of Technology, USA)

To enable future THz wireless communication in computer systems, it is imperative to understand the application needs, propagation mechanisms, and to develop good channel models to enable communication in these new challenging environments. Note that these propagation environments significantly differ from typical wireless channels because there might be significant propagation losses due to signal interaction with metal and plastic parts of the packaging as well as from air circulation inside the packaging/data center. This paper summarizes the latest results on THz channel modeling and measurements in computer systems and proposes new applications for computer systems where THz wireless signals may play significant role and require detailed THz channel measurements and modeling.

9:20 ***Tropospheric Attenuation: A Challenge for Future Earth-Space Communications Systems***

Lorenzo Luini (Politecnico di Milano, Italy)

In approximately 60 years, Earth-space communications have evolved from early broadcasting systems to the modern complex interactive ones able to deliver worldwide broadband coverage. This was made possible by the gradual transition of carrier frequencies from the S band (2-4 GHz) to the Ka band (26.5-40 GHz), which is still partially taking place. Unfortunately, the increase in the carrier frequency is also accompanied by the growing impact of the troposphere, which induces several negative effects, attenuation being the most detrimental one. If the troposphere already poses clear limitation to modern Earth-space communications, even more it will to future systems, which are foreseen to operate at even higher carrier frequencies. This contribution discusses such challenges, specifically targeting next generation Earth-space communication systems operating at V band (40-75 GHz), W band (75-110 GHz) and, possibly, even up to the sub-THz band.

9:40 ***Future Channel Modelling Needs in ITU Recommendations***

Sana Salous (Durham University, United Kingdom (Great Britain))

Fifth Generation fixed, and mobile radio networks targeted a wide range of frequencies from 24 GHz to 86 GHz to enable high data rates over different types of links which included indoor, outdoor, outdoor to indoor and in cluttered environments. Some of the new models to cover these frequency bands were incorporated in existing ITU Recommendations such as the indoor and outdoor models whereas new recommendations were introduced for the outdoor to indoor and the clutter loss models. Future generation radio networks are expected to operate at frequencies above 100 GHz in different scenarios. This paper presents an overview of the channel models that have recently been adopted in the ITU recommendations and the need for updates.

10:00 ***Wireless Channel Modeling: Challenges Across the Field and Significance of Modeling Inaccuracies***

David W Matolak (University of South Carolina, USA); Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany)

The modeling of wireless channels has been ongoing for over a century. Recent expansion of wireless applications in an expanding variety of environments along with the use of higher frequency bands has brought the need for new types of channel models, new modeling techniques, and greater modeling accuracy. In this paper we review these topics as an introduction to our special session Frontiers in Propagation and Wireless Channel Modeling. We describe the session contents, current active channel modeling areas and techniques, and how new applications bring new and more stringent requirements for accurate channel modeling. We also briefly describe the importance of accurate channel modeling to new and future applications.

10:20 ***A Statistical Sensing Channel Modeling Framework***

Pengqi Zhu, Xuefeng Yin, José Rodríguez-Piñeiro and Ping Wang (Tongji University, China)

Integrated communication and sensing (ICAS) is considered as an essential step in the Sixth Generation (6G) communication systems development. However, there are hardly available complete channel modeling frameworks for sensing. Conventional channel models for communication are often difficult to apply to perceptual matters. In this paper, a complete statistical modeling framework for sensing channels is proposed. The steps, methodologies and data flows contained therein are discussed to lay the foundation for further enrichment and expansion.

Thursday, March 30 9:00 - 10:40

A02: Antennas for mm-Wave Applications

T02 Mm-wave and THz cellular / / Antennas

Room: Spadolini 102

Chairs: Maria Alonso-delPino (Delft University of Technology, The Netherlands), Jian Yang (Chalmers University of Technology, Sweden)

9:00 ***Pattern Distributed Pins in Half-Mode Groove Gap Waveguide for Stable Performance and Low Cost***

Enlin Wang and Ashraf Uz Zaman (Chalmers University of Technology, Sweden); Zehong Yan (Xidian University, China); Jian Yang (Chalmers University of Technology, Sweden)

In this paper, a new concept of pattern distributed pin structure is proposed to improve the stability of the phase performance when there is a misalignment in a half-mode groove gap waveguide (HM-GGW) and therefore reduce the manufacture cost. To demonstrate the advantages of the pattern distributed pin structure, a non-collinear pin pattern and a rotated pin pattern are proposed and applied to a straight HM-GGW and a 90-deg bend HM-GGW. The dispersion diagram and simulation results show that the pattern distributed pin structure has a similar stop-band characteristics as the standard pin structure with much less sensitivity to misalignments between the upper pins and the lower wave-guiding structure. By applying a proper pattern distributed pin structure, a larger flexibility is obtained in design of GW devices and the manufacture cost can be reduced significantly.

9:20 *Single Layer Sequential-Phased Slot Antenna Array Based on Ridge and Groove Gap Waveguide*

Rahman Askarzadeh (Shahid Bahonar University of Kerman, Iran); Ali Farahbakhsh (Graduate University of Advanced Technology, Iran)

In this paper, a planar single layer circular polarized array antenna is proposed using sequential-phased feeding network in V-band frequency range based on gap waveguide technology. The antenna used a 2×2 elements with 45-degree tilted slots to provide proper electrical field distribution in the slots to produce circular polarization. To excite slots, a feeding network based on combination of E-plane groove and ridge gap waveguide is utilized. To realize 90- degree phase rotation between slots, ridge waveguides are inversely shifted. The proposed antenna presents 14% impedance bandwidth below -10 dB and 8% axial ratio bandwidth under 3 dB.

9:40 *A High Gain Metalens Antenna Based on Huygens' Metasurface for Millimeter-Wave Applications*

AmirMasood Bagheri and Shadi Danesh (5GIC & 6GIC, Institute for Communication Systems (ICS), University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Seyed Ehsan Hosseininejad (University of Surrey, United Kingdom (Great Britain)); Irshaad Fatadin (National Physical Laboratory, United Kingdom (Great Britain))

A metasurface-based thin flat lens operating at millimeter wave frequencies is presented. The three-layered Huygen Metalens indicates collimating/focusing of broadband frequencies from 60 to 74 GHz, with a gain enhancement of 22.5 dBi at a central frequency of 69 GHz while fed by a dipole antenna. The metasurface transmission performance is designed and simulated by numerical and analytical approaches. By integrating multilayered 1-bit Huygens unit cells, the metasurface produced 1800 phase coverage with constant high amplitude. The proposed design comprised of 50×50 unilcells, creating an area of 75 × 75mm2. The dipole antenna is applied to illuminate the proposed metasurface where the distance between the feeder and metalens is 27 mm. The result shows that the proposed metalens antenna achieves a maximum gain of 25 dBi at 69GHz GHz. The unique features of the proposed light-weight metalens will be widely used in wireless communication system for mmW wave frequencies.

10:00 *Millimeter-Wave Array Antenna Architectures Employing Joint Power Combining and Beam Steering for Next-Generation Backhaul Applications*

Artem Vilenskiy and Sohaib Yaqoob Chaudhry (Chalmers University of Technology, Sweden); Hsi-Tseng Chou (National Taiwan University, Taiwan); Marianna Ivashina (Chalmers University of Technology, Sweden)

We investigate the capabilities and limitations of joint power combining and beam steering techniques for millimeter-wave antenna applications. In this analysis, both functionalities are realized simultaneously through a power-combining and beamforming (PC-BF) network interconnecting an input array of active channels with an array of antenna elements. The first part of the paper provides a review of state-of-the-art hardware architectures of such PC-BF networks and examines their suitability for the millimeter-wave applications. The architectures are grouped into two classes depending on the array embedded element patterns properties. Next, a unified PC-BF network is proposed where both functionalities are implemented in a single millimeter-wave waveguiding block. A full-wave model of such a network with 6 inputs and 7 outputs is investigated, with its application demonstrated for a W-band focal-plane array feeding a backhaul reflector antenna.

10:20 *Quasi-Omnidirectional Millimetre Wave 5G Handset Antenna*

Christopher P Larmour (Queen's University Belfast, United Kingdom (Great Britain)); Mark Megarry and Neil Buchanan (Queens University Belfast, United Kingdom (Great Britain)); Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain)); Muhammad Ali Babar Abbasi (Queen's University Belfast & The Institute of Electronics, Communications and Information Technology (ECIT), United Kingdom (Great Britain))

This paper presents a handset antenna array operating within approved millimetre-wave 5G (mmWave) 3GPP n257 band 26.5-29.5 GHz and providing quasi-omnidirectional radiation characteristics. A 4 x 1 linear antenna array is placed into 3 distinct locations within a handset for testing against a numerical hand model which allows simulation of the effects of a user in a specific handset holding scenario. Blockages can cause significant degradation of the performance of the antenna, however, the optimized antenna locations presented achieved 52% coverage for gain values greater than 0 dBi, achieved using a 3-bit phase shifter. Single 4x1 array characteristics were confirmed by far-field measurements. Beam steering characteristics are thoroughly investigated, showcasing how signal coverage can be improved in the event of a blockage. Study was also carried out into the effectiveness of increasing the size of multi-bit phase shifters and it is shown how improvement is negligible beyond a certain point.

Thursday, March 30 9:00 - 10:40

CS22: Future trends of RFID systems and applications

T07 Positioning, localization & tracking / Convened Session /

Room: Spadolini 103

Chairs: Alice Buffi (University of Pisa, Italy), Diego Masotti (University of Bologna, Italy)

9:00 *Comparison Between Bluetooth Indoor Location Techniques Based on RSSI and AoA*

Marc Casanova-Murillo and Miguel Ferrando-Bataller (Universitat Politècnica de València, Spain); Marta Cabedo-Fabrés (Universidad Politécnica de Valencia, Spain); José Fco. Hernández-Cuartero (MYSPHERA, Spain)

In this paper, a comparison between two location techniques based on the Bluetooth Low Energy communication protocol is presented: RSSI (Received Signal Strength Indicator) and AoA (Angle of Arrival). RSSI indicator has been used in indoor location environment (using another technique called trilateration) to provide an estimated position of the item to be located. AoA technique has been previously applied in other technologies, and recently, it has been incorporated into Bluetooth under Direction Finding profile for the same purpose: location or positioning of nearby devices. The comparison is based on a set of movements/paths and fixed positions in an indoor environment with defined areas where it is measured: latency and reliability. For any indoor positioning system, it is important to offer optimal precision, and therefore, having limitations in the signal reception stage conditions its processing and therefore increases the error in the final position result.

9:20 *Enhancing the Bit Density in Linear Electromagnetic Encoders for Chipless-RFID and Motion Sensing Applications*

Ferran Paredes (Universitat Autonoma de Barcelona, Spain); Amirhossein Karami-Horestani (CIMITEC, Departament d'Enginyeria Electrònica & Universitat Autònoma de Barcelona, Spain); Ferran Martín (Universidad autónoma de Barcelona, Spain)

This paper presents a technique to increase the density of bits per unit length (DPL) in linear electromagnetic encoders, which are useful for near-field chipless-RFID applications. The proposed encoders are made of two chains of resonators, transversally oriented with regard to the chains' axis. Encoding is achieved by the size of the resonators, which determines their frequencies. The reader is made of two transmission lines loaded with series gaps, axially aligned in the gap region. By encoder motion over the reader, when a resonator lies on top of the line gap, it modifies the transmission coefficient of the corresponding line. Consequently, such resonator can be detected by the variation of the amplitude of a harmonic signal injected to the corresponding line, which should be tuned to the resonance frequency of the inclusion. The proposed system provides 5.58 bits per chain position, and a density of DPL = 11.16 bit/cm.

9:40 *RFID Robots and Vehicles for Item Inventory and Localization*

Andrea Motroni and Alice Buffi (University of Pisa, Italy)

Radio Frequency Identification (RFID) vehicles are intensely becoming more and more pervasive in many fields concerning daily-life and work environments. This paper presents a state-of-the-art analysis of vehicles and robots adopting Ultra-High-Frequency (UHF) RFID technology. First, tagged vehicles are analysed to assess the main features and possible application scenarios. Then, vehicles equipped with UHF-RFID readers are presented with special focus on UHF-RFID robots which represent the prevailing category. Besides classical inventory operations, localization solutions are described together with novel applications in both social and industrial contexts.

10:00 ***An ISM-Band RFID Module for Simultaneous Wireless Information and Power Transfer with High Gain Antenna in Multi-Layer Configuration***

David Chatzichristodoulou (RF AND MICROWAVE SOLUTIONS LTD & Frederick Research Center, Nicosia, Cyprus); Giacomo Paolini (University of Bologna, Italy); Photos Vryonides (Frederick Research Center and Frederick University, Cyprus); Dimitra Psychogiou (University College Cork and Tyndall National Institute, Ireland); Diego Masotti (University of Bologna, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy); Symeon Nikolaou (Frederick Research Center & Frederick University, Cyprus)

This paper presents an implementation of an ISM RFID module capable of simultaneous wireless information and power transfer, that is implemented in a three-layer configuration. The top two layers of the RFID module are used for the low profile, high gain (8 dBi), circular polarization antenna implementation. The proposed antenna consists of four radiating L-shaped patches on the top layer, which are fed from a circular power divider. The energy harvesting (EH) system and the communication module are implemented on the bottom third layer. A four-port coupler is used to direct 85-90% of the received power from the antenna to the EH system and the remaining to the communication module. TI CC2530 IC is used, and it is powered from the PMU of the EH system. With -13 dBm input power, at the coupler's port 3, the communication module can support TX/RX communication cycle lasting up to 3.5 ms.

10:20 ***A mm-Wave Depolarizing Chipless Pressure Sensor***

Sandra Rodini (University of Pisa, Italy); Yuting Zhao (Harbin Engineering University, USA); Simone Genovesi, Giuliano Manara and Filippo Costa (University of Pisa, Italy)

A novel mm-wave chipless pressure sensors configuration is designed and tested. The sensor relies on a mm-wave chipless RFID tag designed within 30 GHz frequency band. The designed tag consists of a periodic surface, including three dipole resonators, printed on a thin grounded dielectric substrate. The structure provides multiple resonant peaks in the cross polar response. The resonator is then loaded with a superstate which determines a frequency shift of the resonant peaks proportional to the applied pressure. The Radar Cross Section (RCS) cross section of the tag can be adjusted by selecting a proper number of unit cell thus guaranteeing a reading range from 30 cm to 1 m.

Thursday, March 30 9:00 - 10:40

CS52: Use of base materials not intended for RF applications and eco-friendly materials

T01 Sub-6GHz cellular / Convened Session /

Room: Spadolini 104

Chairs: Loic Bernard (ISL & IETR, France), María Elena de Cos Gómez (Universidad de Oviedo, Spain)

9:00 ***A Smart Suitcase with Overmolded Inkprinted Dual-Band Antennas***

Patrick Van Torre, Igor Lima de Paula and Hendrik Rogier (Ghent University, Belgium)

Nowadays, the Internet of Things is continuously expanding, with more and more objects connected. The seamless integration of wireless communication systems into smart objects is possible thanks to ink-printed antennas. A smart suitcase is manufactured, where ink-printed antennas are overmolded into the plastic shell of the suitcase, during its production process. The result is a smart object where the antennas are fully integrated inside the material, including printed transmission lines, which interface to a small printed circuit board by means of a dedicated interposer board. The radiation patterns of the suitcase are measured into the anechoic chamber and its performance is analyzed.

9:20 ***Eco-Friendly Based Substrates for Telemetry Antennas in UHF- and S-Bands***

Loic Bernard (ISL & IETR, France); Clément Campo (French-German Research Institute of Saint-Louis, France); Emmanuel Roussel (ISL, France)

circularly polarized (CP) patch antenna and a CP 2×2 antenna array on thick (0.075 λ450MHz and 0.11 λ2300MHz respectively) polypropylene substrates are introduced; the numerical design and the manufacturing concept are presented. Two prototypes are characterized and validated for different applications. The first prototype is used for communication and telemetry around 450 MHz between the autopilot of a UAV and the ground station. The second antenna is used both for flight tracking and telemetry at around 2300 MHz.

9:40 ***24GHz Radar Antenna on Eco-Friendly Substrate***

María Elena de Cos Gómez (Universidad de Oviedo, Spain); Alicia Flórez Berdasco (University of Oviedo, Spain); Humberto Fernandez Alvarez (EME, Antenna Systems and Signatures Engineering SP, Airbus Defense and Space, Getafe, Spain); Fernando Las-Heras (University of Oviedo, Spain)

A compact and low-cost wearable grid array antenna (GAA) for 24GHz radar applications is proposed. It is designed on eco-friendly Polypropylene (PP) substrate with aluminum claddings. The overall size of the antenna is 60 x 60 x 0.52 mm3. Prototypes of the antenna are fabricated and tested, achieving results that meet typical requirements for collision avoidance applications, as the envisioned one in aid of visually impaired people. The presented antenna overcomes the state of the art on 24GHz wearable radar antennas according to a comparison based on a literature survey

10:00 ***High Temperature Permittivity Measurement in Microwave Domain***

Pierre Sabouroux Pierre Sabouroux (Institut Fresnel, France)

This paper deals with a method for measuring the electromagnetic parameters of solid materials over a large frequency band and at very high temperatures (up to 400°C). The particularity of this new prototype is a system of connection and disconnection between the temperature controlling structure and the Radiofrequency (RF) measurement system, to overcome the constraints of standard connectors, only allowing measurements from ambient temperature to 85°C.

10:20 ***Optimized Printed Antennas Based on Paper Substrate for Wifi Applications***

Georges Zakka El Nashef (& CISTEME, France); Ahmad Sabra (University of Limoges, France); Pascal Xavier (IMEP-LaHC, France); Eric Arnaud (XLIM, France); Nicolas Chevalier (CISTEME, France)

Environmental concerns occupy an increasingly prominent place in society. We have therefore decided to develop RF products which are environment friendly. This paper shows two antennas on paper substrate, offering the same electromagnetic (EM) behavior as on conventional ones, e.g., FR4 but with much lower environmental impact. Both antennas have been validated theoretically and experimentally. The manufactured antennas operate at the WIFI 5 Band [5.15 GHz - 5.35 GHz].

Thursday, March 30 9:00 - 10:40

E09: Theory and Design of Metasurfaces

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / / Electromagnetics

Room: Spadolini 105

Chairs: Vincenzo Galdi (University of Sannio, Italy), Francesco Vernì (Huawei Technologies, Italy)

9:00 *Leaky Waves in Flatland*

Massimo Moccia and Giuseppe Castaldi (University of Sannio, Italy); Andrea Alù (CUNY Advanced Science Research Center, USA); Vincenzo Galdi (University of Sannio, Italy)

We introduce a new in-plane radiation mechanism that can occur in artificial or natural low-dimensional materials, which can be viewed as the "flatland" analog of conventional leaky-wave radiation. We show that this concept can be physically realized in suitably designed planar junctions of purely reactive, isotropic metasurfaces supporting line waves. Our results provide a new tool for manipulating surface waves, which can find interesting applications in the emerging field of van der Waals polaritonics.

9:20 *Line-Wave Waveguides: Design Procedure and Performance Comparison*

Alessio Monti (Roma Tre University, Italy); Stefano Vellucci and Mirko Barbuto (Niccolò Cusano University, Italy); Davide Ramaccia (RomaTre University, Italy); Valentina Verri (Huawei Technologies Italia S. R. L., Italy); Francesco Vernì (Huawei Technologies, Italy); Claudio Massagrande (HUAWEI Technologies, Italy); Alessandro Toscano and Filiberto Bilotti (Roma Tre University, Italy)

Line waves are one-dimensional (1D) interface modes excited at the discontinuity between two reactive sheets of opposite sign, i.e., inductive and capacitive. Their inherent propagation confinement, low-losses and robustness towards imperfections are attractive characteristics that have recently pushed the efforts of the community in the field. Still, a straightforward procedure for designing guiding structures supporting this edge mode is not available. In this contribution, we describe a simple workflow for designing waveguides supporting 1D modes propagation. The workflow involves a proper combination of analytical tools and full-wave numerical simulations and allows quickly retrieving the final geometries of the complementary metasurfaces composing the waveguides. In addition, we discuss several layouts supporting line-wave propagation and compare their transmission performance. The results of the experimental measurements carried out on some manufactured prototypes are also reported to assess the effectiveness of the design approach and the suitability of line-wave waveguides for low-loss wave propagation.

9:40 *Analysis of Time-Periodic Metallic Metamaterials*

Salvador Moreno-Rodríguez (University of Granada, Spain); Antonio Alex-Amor (Universidad San Pablo-CEU, Spain); Pablo Padilla (University of Granada, Spain); Juan Valenzuela-Valdés (Universidad de Granada, Spain); Carlos Molero (University of Granada, Spain)

This paper presents an analytical framework based on circuit models to describe periodically time-varying metallic metamaterials. The structure is illuminated by a plane wave with arbitrary frequency. The interaction between the incident electromagnetic wave and the time-varying metamaterial, both vibrating differently, results in rich an exotic phenomenology. The derivation of the circuit model, based on integral-equation techniques and Floquet-Bloch expansions, is quite useful to reproduce the system behavior as well as to predict the dynamic response by means of temporal harmonics. Anomalous diffraction or pulsed beams are two of the possible physical manifestations that are well represented by the proposed approach.

10:00 *Morphogenetic Design for Band Gap Engineering*

Fadhila Chehami (University of Limoges, XLIM, France); Cyril Decroze (XLIM, France); Thomas Fromenteze (University of Limoges & Xlim Research Institute CNRS, France)

Recently, a new way of forming electromagnetic band gaps with correlated disordered media has attracted a great attention to replace the ones based on photonic crystals. Indeed, due to the cristallinity, applications based on periodic structures have suffered from many fabrication issues. So far, the different protocols proposed to design disordered crystals consist on constrained optimization methods complex to scale to large systems. In this paper, we propose a new method inspired by the morphogenesis for designing correlated disordered materials displaying large electromagnetic band gaps, in the desired frequency range, using a technique that is simple to implement, easily adaptable to large-scale problems and requiring no gradient descent, unlike the optimization techniques usually used in inverse design. This exploratory work may find applications in the synthesis of electromagnetic waveguides and components from the microwave to photonic bands. As an illustration, a freeform waveguide synthesis is presented in this work.

10:20 ***A Physically Realizable Metasurface Incorporating Auxiliary Surface Waves for Power Redistribution***

Max Kelly, Mario Phaneuf and Puyan Mojabi (University of Manitoba, Canada)

The allowable electromagnetic wave transformations supported by lossless and passive metasurfaces are typically constrained by the enforcement of local power conservation (LPC) at each of the metasurface unit-cells. Incorporating auxiliary surface waves tangential to the metasurface in the design procedure provides a means for power redistribution along the metasurface, thus permitting a wider variety of possible field transformations. This paper utilizes a previously developed integral-equation-based solver to incorporate such auxiliary surface waves into the design of omega-bianisotropic Huygens' metasurfaces. Subsequently, a physically realizable metasurface that utilizes such auxiliary surfaces waves is designed and simulated to verify the performance of this solver. The proposed design includes a three-layer copper trace design supported by practical dielectric substrates and bondply.

Thursday, March 30 9:00 - 10:40

P07: Simulations and modeling of long range links

T09 EM modelling and simulation tools / / Propagation

Room: Spadolini 106

Chairs: Marianna Biscarini (Sapienza University of Rome, Italy), Conor Brennan (Dublin City University, Ireland)

9:00 ***An ANN Approach to Determine the Radar Cross Section of Non-Rotationally Symmetric Rain Drops***

Franz Teschl (Graz University of Technology, Austria); Merhala Thurai (Colorado State University, USA); Sophie Steger (Graz University of Technology, Austria); Michael Schönhuber (Joanneum Research, Austria); Reinhard Teschl (Graz University of Technology, Austria)

Non-rotationally symmetric rain drops can often be observed in turbulent weather situations. The main reason is the occurrence of asymmetric drop oscillation modes that are induced due to winds and collisions of drops. In recent studies, scattering parameters of thousands of individual drops were determined for C- and S-Band weather radar frequencies, by fully reconstructing the drops that were observed during turbulent weather situations with two-dimensional video disdrometers (2DVD). The computational effort, however, was considerable. In this study, therefore, a feed forward neural network was trained to predict the radar cross section of rain drops only by using a few selected characteristic parameters of the drops as input, all of which can be extracted from 2DVD data. Based on the comprehensive dataset for test, training, and validation, it could be shown that the reported radar cross sections are in general accurate by a fraction of a dB.

9:20 ***Estimation of Rain Attenuation in FSO Links Based on Visibility Measurements***

Elizabeth Verdugo (PUC RIO, Brazil & Politecnico di Milano, Italy); Luiz da Silva Mello (CETUC-PUC-Rio & Inmetro, Brazil); Claiton Pereira Colvero (Universidade Federal de Santa Maria - UFSM, Brazil); Roberto Nebuloni (Ieiit - Cnr, Italy)

Rain affects FSO links even where fog occurrence is not low. However, rain has a major impact on FSO performance in locations where fog occurrence is statistically not relevant. The classical modeling of specific attenuation due to rain relies on the knowledge of rain statistics or measurements of raindrop size distribution. This contribution proposes a new wavelength-independent method to estimate rain attenuation based on visibility measurements under rainy conditions for FSO links. As input, a long-term database of surface records is considered, and four locations with different climate conditions are studied: Taipei, Taiwan, with a subtropical climate; Kuala Lumpur, Malaysia, with equatorial climate and characterized by tropical rain-forests; Rio de Janeiro, Brazil, with a tropical climate; and Milan, Italy, with a mid-latitude climate. The results obtained by the V-based model agree with the bounds retrieved from micro-physical models.

9:40 ***Discrete Turbulent Spectrum Modelling for 2D Split-Step Electromagnetic Propagation Schemes***

Victor Darchy and Rémi Douvenot (ENAC, France); Helene Galiègue (ENAC, Université de Toulouse, France); Stéphane Jamme (ISAE-SUPAERO, France)

The multiple phase screen method is widely used for modelling the electromagnetic propagation in a turbulent medium. In this technique, the turbulent phase screens are classically generated from a continuous Von-Karman Kolmogorov scintillation spectrum. Recent works led to the development of an auto-coherent split-step wavelet propagation method based on a discrete formulation of the parabolic wave equation. In this configuration, the use of continuous spectra is no more suitable. In this paper, we propose an auto-coherent generation method of the turbulent phase screens. To do so, a discrete formulation of the classical Von-Karman Kolmogorov spectrum is introduced. The impact of the modelled turbulence is finally discussed through the computation of the log-amplitude variance to validate this approach.

10:00 ***Evaluation of the Norton Surface Wave Radiated by a VED in Presence of an Electromagnetic Interface***

Hocine Anis Belaid (Univ Gustave Eiffel, CNRS, ESYCOM, France); Shermila Mostarshedi and Benoit Poussot (University Gustave Eiffel, France); Laheurte Jean Marc (ESYCOM, France)

We present a unified approach detailing the computation of electric field components radiated by a Vertical Electric Dipole (VED) near an electromagnetic interface. The dipole position and the nature of both media are arbitrary as far as the observation point is in dipole's region. A quantitative study dealing with the appearance of the Norton Surface Wave (NSW) is also presented.

10:20 ***Modelling of Scintillation at Radio and Optical Frequencies from Radiosonde Observations***

Florian Quatresooz (UCLouvain, Belgium); Danielle Vanhoenacker-Janvier (Université catholique de Louvain, Belgium); Claude Oestges (Université Catholique de Louvain, Belgium)

The future of Earth-to-space communications relies on the use of higher radio-frequencies and optical frequencies. For such frequencies, tropospheric turbulence starts to have deleterious effects, leading to important phase variations and amplitude scintillation. Those effects can be described thanks to the knowledge of vertical profiles of the refractive index structure parameter (C_n^2). In this work, two approaches relying on radiosonde measurements are presented to obtain radio-frequency and optical (C_n^2). Theoretical developments highlighting the contribution of humidity to radio-frequency scintillation are presented. This contribution is also illustrated with high resolution radiosonde data at Trappes (France) and Hilo (HI, USA). Obtained (C_n^2) profiles are in agreement with the literature and will be validated with measurements at millimeter waves in the future.

Thursday, March 30 9:00 - 10:40

CS4: AMTA session: Post Processing Techniques in Antenna Measurements and Recent advances in Robotic Antenna Measurements

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 107

Chairs: Dennis Lewis (Boeing, USA), Francesco Saccardi (Microwave Vision Italy, Italy)

9:00 ***Reduction of Sampling Sizes in Spherical Phaseless Antenna Measurements Using Filters***

Nicolas Mezieres (University of Rennes 1, France); Laurent Le Coq (University of Rennes 1 & IETR, France)

The 3D radiation pattern of antennas is often required for characterization but is a complex task. Magnitude-only measurements have been proposed to mitigate the sensitive phase acquisition but bring theirs new set of challenges. In particular, current procedures in phaseless antenna testing require many field samples. To enable a reliable reduction of the sampling sizes, a filtering approach for the two scan technique is reviewed and proposed. The validity and stability of the approach is evaluated using both simulation and experimental dataset.

9:20 ***A near to Far-Field Transformation from Plane-Polar Near-Field Measurements Affected by 3-D Probe Positioning Errors***

Florindo Bevilacqua (Università di Salerno, Italy); Francesco D'Agostino, Flaminio Ferrara, Claudio Gennarelli, Rocco Guerriero and Massimo Migliozzi (University of Salerno, Italy)

In this work, an effective algorithm aimed to compensate known 3-D probe positioning errors corrupting the near- field (NF) data in the near-to-far-field transformation (NTFFT) with plane-polar (PP) scanning is developed and numerically assessed. Initially, the so named k-correction is adopted to compensate the positioning errors associated with the deviation from the scanning plane. Next, an iterative approach is properly exploited to retrieve the NF data at the points specified by the nonredundant sampling representation from those computed at the previous step and now affected by 2-D positioning errors. At last, once the correctly distributed PP data have been accurately recovered, those necessary to execute the classical plane-rectangular NTFFT are efficiently obtained by exploiting a 2-D optimal sampling interpolation algorithm. This latter has been developed by exploiting the nonredundant sampling representations and choosing an oblate spheroid to model the antenna. A wide range of numerical results are provided.

9:40 ***Spherical near Field Measurements of Electrically Large Offset Antennas with Minimum Sampling***

Francesco Saccardi (Microwave Vision Italy, Italy); Nicolas Gross (MVG Industries, France); Giancarlo Vincenzi (Amazon, USA); Lars Foged (Microwave Vision Italy, Italy)

The translated spherical wave expansion is an advanced near field to far field transformation technique which allows to efficiently deal with spherical near field measurement of offset mounted antennas. While in the past this technique has been extensively validated considering low/medium directive antennas mounted on complex structures like vehicles, it hasn't yet been applied to electrically large antennas. In this paper, spherical near field measurements of a 30dBi reflector antenna measured in different offset configurations will be presented. The effectiveness of the translated wave expansion will be validated considering up to more than 4-time down-sampling with respect to the conventional requirements.

10:00 ***Separating Field Contributions by Their Source Volumes: Uniqueness and Limitations***

Josef Knapp (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

Reconstructing the sources of a radiated electromagnetic field is important for echo suppression as well as source diagnostics. If two source domains are too close, the sources cannot be assigned uniquely to either of the source domains due to the finite measurement accuracy. This work investigates how the ability of source separation depends on the distance between the source domains. By studying the singular values of the system matrices an estimate for the critical distance is developed after which no source ambiguities appear. If only one source domain is considered in the reconstruction, source contributions from the other source domain distort the reconstruction. An estimate for the magnitude of the distortion is also reported. Modified formulations avoid explicit singular value decompositions and allow to apply the estimates also to electrically large source domains. A numerical example shows that the predictions accurately match the observed error behavior in the reconstructed sources.

10:20 ***Fast Radome Antenna Testing Using Single-Cut and Slide Measurements***

Fernando Rodríguez Varela (Universidad Rey Juan Carlos de Madrid, Spain); Jorge Calatayud Maeso (Universidad Politécnica de Madrid, Spain); Xiaoliang Sun (Universidad Politécnica de Madrid, Spain & Universidad Politecnica de Madrid, Spain); Belen Galocha (Universidad Politecnica de Madrid, Spain); Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain); Jose Iglesias-Gonzalo (Sistemas Radiantes F. Moyano S.A., Spain)

Cylindrical near-field measurements are suitable for Base Station (BTS) antennas testing due to their fanned-beam radiation patterns. BTS often incorporate large radomes that need to be tested as well to ensure they don't distort the antenna pattern or the reflection coefficient. This increases measurement time because the complete antenna becomes electrically larger. This paper presents a technique to minimize BTS radome testing. The technique is based on measuring the antenna near-field over a ring and a vertical slide to compute the one dimensional versions of the cylindrical and plane wave expansions, for the horizontal and vertical planes, respectively. We show how such reduced expansions can be used to retrieve the far-field pattern on the main planes E and H, as well as its gain. We report measurements with real BTS and radomes reducing the testing times from several hours to minutes.

Thursday, March 30 9:00 - 10:40

A17: Reconfigurable Antennas

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 108

Chairs: Christos Christodoulou (The University of New Mexico, USA), Joseph Costantine (American University of Beirut, Lebanon)

9:00 ***Ultra-Wideband Air-Filled SIW Cavity-Backed Slot Antenna with Multipolarization Reconfiguration***

Kamil Yavuz Kapusuz (Ghent University & IMEC, Belgium); Sam Lemey (Ghent University-imec, Belgium); Hendrik Rogier (Ghent University, Belgium)

Air-filled substrate integrated waveguide (AFSIW) cavity-backed slot antenna topologies are promising candidates to address the specific design challenges posed by the Internet of Things (IoT). We demonstrate a new single-feed ultrawideband cavity-backed slot antenna with multipolarization reconfiguration by leveraging four quartets of PIN diodes in substrate-independent AFSIW technology for operation in the [5.15-5.85] GHz frequency band. To achieve ultra-wideband performance, two concentric annular slots are created on the top of the circular cavity. By electrically shorting these annular slots at well-defined positions by the aforementioned PIN diodes, dynamic polarization reconfiguration is achieved by switching their DC bias current. Moreover, systematic investigation of the loss contributions and power consumption is performed. A physical explanation of the different effects is also provided. Finally, a fabricated prototype exhibits a measured impedance bandwidth of 1.6GHz, a total efficiency higher than 74%, and a gain higher than 5.2dBi for all four states in free-space conditions.

9:20 ***Active Non-Foster-Based Magneto-Electric Antenna***

Darin Nozina, Juraj Bartolić and Silvio Hrabar (University of Zagreb, Croatia)

The basic magneto-electric antenna is modified by the inclusion of a non-Foster negative inductor. Full-wave simulations showed that this modification allows a reduction in both antenna thickness and antenna footprint by a factor of 1/25 and 1/4, respectively. Additional circuit-theory simulations using a simple single-pole negative inductance model showed that the proposed antenna can operate in both stable mode (RX/TX) and self-oscillating mode with a frequency tuning range of 1:1.3.

9:40 ***A Pattern Reconfigurable Microstrip Patch ESPAR Designed for a Hybrid Beam-Forming Testbed***

Leonidas Marantis, Apostolos Spanakis-Misirlis and Dimitrios K. Rongas (University of Piraeus, Greece); Konstantinos Maliatsos (University of Aegean & University of Piraeus, Greece); Charalampos Armeniakos and Athanasios G. Kanatas (University of Piraeus, Greece)

This paper focuses on the design of a hybrid beamforming transceiver, serving as a BS testbed of a 6G indoor network. A specific transceiver configuration is proposed, mainly composed by SDR resources, circulators, amplifiers and phase shifters. Moreover, a novel microstrip ESPAR antenna, operating at 3.5 GHz, is suggested for the system. The antenna exhibits pattern reconfigurability (beam-switching with 9 directive beams), low cost, reduced complexity and small dimensions, and it demonstrates satisfactory impedance matching for all antenna states. A four element ESPAR antenna array (MuPAR) is proposed in order to combine the conventional beam-steering technique (through phase shifting) and the beam-switching operation of the ESPARs. Consequently, a hybrid beamforming array system is presented, offering a multiple scanning capability.

10:00 ***Extending the Scan Range of Phased Arrays Using Reconfigurable Antenna Elements***

Gabriele Federico and Guilherme Theis (Eindhoven University of Technology, The Netherlands); Diego Caratelli (The Antenna Company, The Netherlands); A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

In this paper, a novel multi-mode antenna element for mm-wave communications is introduced. The antenna element can be integrated in array configurations so to achieve broad scan capability. While scanning, the gain degradation of ideal arrays follows a cos(θ_0) behaviour due to the element pattern. By using an antenna element with a reconfigurable pattern, it is possible to extend the scan range and increase the realized gain by using the radiating mode which covers the subspace of scanning. With the three-port antenna element proposed in this paper, this is possible by modifying the phase offset between the three ports. The antenna consists of a capacitively fed triangular patch loaded with a cross-shaped dielectric resonator. Three radiating modes can be generated introducing a 180◦ phase offset across the input ports according to a specific configuration. In this way, the antenna beamwidth can be increased up to 135◦.

10:20 ***Circularly Polarized Planar Antenna with Axially Symmetric Beamwidth Reconfigurability***

German Augusto Ramirez Arroyave (SCI-STI-AS Microwaves and Antennas Group (MAG), EPFL, Station 11, CH-1015 Lausanne, Switzerland); Hannes Bartle (Ecole Polytechnique Federale de Lausanne & ClearSpace SA, Switzerland); Ismael Vico Triviño and Anja K. Skrivervik (EPFL, Switzerland)

This contribution presents the design of a compact circularly polarized antenna featuring beamwidth reconfiguration in both the horizontal and vertical planes. The observed radiation patterns in each of the reconfigurable states presents axial symmetry and circular polarization. The antenna is based on an arrangement of microstrip patches that can serve a dual purpose as a conventional array and as a fed central element with 4 parasitic elements. The reconfiguration is attained by switching the input signal towards either the parasitic or the conventional array. A particular design demonstrating a beamwidth reconfiguration in (math) \Delta\theta_{3dB}={38^\circ,105^\circ} (math), with circular polarization and axial symmetry is presented.

Thursday, March 30 9:00 - 10:40

E14: Imaging, Inverse Design and Optimization

T10 Fundamental research and emerging technologies / / Electromagnetics

Room: Spadolini 109

Chairs: Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy), Mats Gustafsson (Lund University, Sweden)

9:00 ***MIMO-SAR Imaging System on Board a UAV***

María García Fernández and Guillermo Alvarez Narciandi (Queen's University Belfast & University of Oviedo, United Kingdom (Great Britain)); Fernando Las-Heras and Yuri Alvarez-Lopez (University of Oviedo, Spain)

In the last few years, radar systems on board Unmanned Aerial Vehicles (UAVs) have experienced a significant development. This research effort, driven by the multiple applications of these systems, has mainly focused on improving their detection capabilities. However, there are several other aspects of these systems that remain a challenge. This contribution presents a Multiple-Input-Multiple-Output Synthetic Aperture Radar (MIMO-SAR) imaging system on board a UAV, which allows to significantly increase the information gathered per unit of time. In particular, an array of 3 transmitters and 4 receivers was integrated into a UAV platform, and several test measurements were performed. Results show that this configuration enables to retrieve high quality radar images, while reducing the required flight time to scan a given area.

9:20 ***Preliminary Investigation on the Use of Focused Bessel-Shaped Beams for Imaging of PEC Objects***

Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy); Tommaso Isernia (University of Reggio Calabria, Italy); Loreto Di Donato and Gino Sorbello (University of Catania, Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy)

In this contribution, preliminary analyses are performed on the use of focused beams for imaging of PEC targets. In particular, the data collected in case of Bessel-shaped beam as incident field are processed by means of the well-known physical optics approximation and also by a recently introduced qualitative method, which exploits sparsity regularization and solves the related inverse source problem. A preliminary example against 2D scalar geometry and a C-shaped PEC cylinder is reported and discussed.

9:40 ***Inverse Scattering Using a Kohn-Vogelius Formulation and Shape Optimization Method***

Thomas Bonnafont (ENSTA Bretagne, France); Fabien Caubet (UPPA, France)

This paper presents a method to retrieve the form of a metallic object given partial electromagnetic measurements. We propose a numerical resolution of this inverse problem based on a shape optimization method. More precisely, we aim to minimize the so-called Kohn-Vogelius functional, which is numerically more stable than the least-squares functional, by computing its shape gradient. The optimization problem is then solved using a Nesterov inertial scheme to accelerate the descent algorithm. Numerical simulations in 2D are provided to highlight the efficiency of the proposed method.

10:00 ***Method for Robust Estimation of the Resonance Frequency of Microwave Biosensors***

Giovanni Buonanno and Sandra Costanzo (University of Calabria, Italy); Antonio Cuccaro (University of Campania, Italy); Raffaele Solimene (Università degli studi della Campania Luigi Vanvitelli, Italy)

In this work, a procedure for robust estimation of the resonance frequency of microwave biosensors is presented. Usually, the sensor response is captured at a finite number of frequencies. Hence, inadequately fine frequency sampling step and the presence of noise negatively affect the estimation quality. The possibility to robustly evaluate the resonance frequency by exploiting efficient spectral estimation algorithms is demonstrated in the present contribution. This allows the use of inexpensive and lightweight devices suitable for self-monitoring. The method is validated against numerical and experimental data, the latter referring return loss measurements of a microwave patch antenna used for blood glucose monitoring.

10:20 ***Simultaneous Optimization of a Right-Handed and Left-Handed Circular Polarizations of Antenna Arrays Using Genetic Algorithms***

Ricardo Carrizales-Juarez (University of Limoges & CNES, France); Priscillia Daquin (CNES, France); Aurelian Crunteanu (XLIM, CNRS/ University of Limoges, France); Laure Huitema (University of Limoges, France)

In this paper, the results on the simultaneous optimization of two arrays of antennas with complementary circular polarizations (right-handed and left-handed) are introduced, using a numerical model based on a genetic algorithm approach. Both antennas were designed such that their axial ratios are as low and symmetrical as possible while having the same fundamental geometry. Current results show that both antennas have symmetrical axial ratios smaller than 3 dB for all theta angles from -35° to 35° and for all phi planes while having the same core geometry.

Thursday, March 30 9:00 - 10:40

SW11: Quantum Electromagnetics for Antennas and Propagation

Organized by: Paolo ROCCA (ELEDIA@UniTN, University of Trento); Luis Enrique GARCIA MUÑOZ (University Carlos III of Madrid)

Room: Sala della Scherma

9:00 - Quantum Electromagnetics Theory (Weng C. CHEW, Thomas ROTH, Purdue University)

9:40 - Atomistic Scale Simulation of Nano-antennas (Amir BOAG, Tel Aviv University)

10:10 - Quantum Radar (Luis Enrique GARCIA MUÑOZ, Carlos III University of Madrid)

Thursday, March 30 9:00 - 10:40

SW10: Stand on the IEEE Antennas & Propagation Standards

Organized by: Vikass Monebhurrun (CentraleSupélec); Lars Foged (MVG-World); Jeff Fordham (AMETEK); Vince Rodriguez (AMETEK)

Room: Polveriera

9:00 - Overview of IEEE AP-S Standards (Vikass Monebhurrun, CentraleSupélec)

9:50 - Terminology Standards (IEEE Std 211-2018, IEEE Std 145-2013) (Vikass Monebhurrun, CentraleSupélec)

10:15 - Antenna Measurement Standard (IEEE Std 149-2021) (Jeff Fordham/Vince Rodriguez, AMETEK)

Thursday, March 30 9:00 - 10:40

IW8: Radio channel modelling and emulation for NTNs and for terrestrial sub-THz links (Keysight)

Room: Sala Arco

Thursday, March 30 11:00 - 12:40

CS18b: Emerging Technologies for Reflectarrays and Transmitarrays (continued)

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: Nader Behdad (University of Wisconsin, USA), Nima Ghalichechian (Georgia Institute of Technology, USA)

11:00 ***Overview of Reconfiguration Technologies for Reflectarrays and Trasmitarrays***

Walter Royal Disharoon and Seung Yoon Lee (Georgia Institute of Technology, USA); Jordan A Ramsey (The Ohio State University, USA); Nima Ghalichechian (Georgia Institute of Technology, USA)

Recent advances in reconfigurable reflectarrays and transmitarrays continue to provide an excellent option for expansion to mmWave bands. The high-gain, low-cost, low-profile, and tunability make for a desirable antenna array. This paper reviews modern approaches employed to enable reconfiguration with a focus on material and mechanical reconfiguration. Finally, future applications and challenges such as wideband, multi-bit, high-power, and reconfigurable intelligent surfaces are discussed.

11:20 ***Reducing the Refractive Index Range of GRIN Lenses Through the Integration of a Reflectarray***

Sarah E Clendinning and Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

This paper presents a half-lens antenna integrated with a reflectarray. The combination of the half-lens and the reflectarray provides additional design freedom. In this work, this design freedom is used to reduce the refractive index range required to produce a planar wavefront using a half-lens, as compared to the half-Luneburg lens. Specifically, we demonstrate that the properties of a half-Luneburg lens can be mimicked with a lens that has reduced the maximum refractive index by 30\% by integrating the reflectarray with the lens.

11:40 ***Dynamic Effects of Scaling and Biasing on Liquid Crystal-Based Reflectarray Antennas***

Robert Guirado, Gerardo Perez-Palomino and Eduardo Carrasco (Universidad Politécnica de Madrid, Spain)

The effect of different biasing techniques on the electromagnetic response of reflecting metasurfaces based on Liquid Crystals is analyzed is this paper. Even though the design of such arrays is typically focused only on the unit cell, their biasing must be considered as it can completely modify the performance of such devices, and understanding their implications is important to prevent unwanted effects. For the first time, a tool capable of predicting the dynamic response of the LC resonant metasurfaces, considering both the electromagnetic effects of the cell and the array biasing technique at the same time, is introduced.

12:00 ***Transmissive and Leaky-Wave Beamforming Metasurfaces***

Malik Almunif (University of Michigan, USA); Jordan Budhu (Virginia Tech, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

This paper describes our efforts to develop transmissive and leaky-wave metasurfaces for the control of electromagnetic wavefronts. The transmissive metasurfaces consist of three spatially-varying capacitive sheets separated by two dielectric spacers. They are designed using an integral equation formulation and optimization that accounts for the inhomogeneity of the impedance sheets. The transmissive metasurface beamshapes and collimates the field radiated by an electric line source. Furthermore, directly-fed leaky-wave metasurfaces consisting of a spatially-varying capacitive sheet on top of a ground plane of varying height are also reported. A leaky-wave metasurface design that produces a uniform aperture pointed at 45 degrees is reported.

12:20 ***Reflectarrays and Metasurface Antennas at Millimeter and Terahertz Waves***

Goutam Chattopadhyay (NASA-JPL/Caltech, USA); Nacer Chahat and Adrian Tang (NASA-JPL, Caltech, USA); Choonsup Lee (JPL, USA); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

In this paper we present an overview of different metasurface antenna technologies at millimeter and terahertz waves for space applications. We will show that even though transmit- and reflect-arrays have made tremendous progress at millimeter-wave frequencies in recent years, it is challenging to use them at terahertz frequencies. Moreover, for space applications, metasurface antennas at these frequencies are sometimes preferable as they require less volume. We provide detailed scientific motivations

for some of the metasurface antennas working in the Ku-band to W-band and beyond. We report all-metal metasurface antennas with high efficiency working in the Ka-band and beam-steering metasurface antennas working in W-band for radar and spectrometer applications.

Thursday, March 30 11:00 - 12:40

CS42b: Recent advances in sub-millimeter wave antenna systems for radio-astronomy and space exploration (continued)

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Luis Enrique García Muñoz (Universidad Carlos III de Madrid, Spain), David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

11:00 ***Indirect Detection of Gravitational Waves Method Validation Using an Analogue Electromagnetic Spacetime Modulated Medium***

Enderson Falcón-Gómez (University Carlos III of Madrid, Spain); Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain); Adrian Amor-Martin (Universität des Saarlandes, Germany); Alfonso Gonzalez Jimenez (Universidad Carlos III Madrid, Spain); Valentin de la Rubia (Universidad Politecnica de Madrid, Spain); Gabriel Santamaria Botello (Universidad Carlos III de Madrid, Spain); Vittorio De Falco (Scuola Superiore Meridionale, Italy); Luis Enrique García Muñoz (Universidad Carlos III de Madrid, Spain)

This manuscript studies the interaction between Gravitational Plane Waves and Electromagnetic Plane Waves by means of an analogous electromagnetic model of gravity, where the electromagnetic properties codify the variations in the metric tensor produced by the Gravitational Plane Wave. A space-time modulation of the electromagnetic properties of the medium is generated and analyzed via the Finite-Difference Time-Domain method. We find that, when a Gravitational Plane Wave interacts with a monochromatic Electromagnetic Plane Wave, it is triggered a multiple scattering of photons by gravitons resulting in the apparition of an infinite number of electromagnetic sidebands, equally separated between themselves by the Gravitational Plane Wave frequency. We numerically prove in this paper a totally novel effect that might be used in the detection of gravitational waves.

11:20 ***Optical Design of Arctic Weather Satellite Microwave Sounder***

Roland Albers and Mikko Kotiranta (University of Bern, Switzerland); Anders Emrich (Omnisys Instruments, Sweden); Axel Murk (IAP, Switzerland)

The Arctic Weather Satellite (AWS) mission by the European Space Agency is a prototype mission for a constellation of small meteorological satellites. The AWS mission is intended to be a lower cost mission at a faster development rate than previous meteorological missions. The payload is a cross-track scanning radiometer which operates in the 50-57, 89, 165-183 and 325 GHz frequency bands. This paper presents the optics of the AWS radiometer. The calibration concepts for in flight and onground are also discussed.

11:40 ***An Overview of Recent Research on Antennas and Feeds for mm-Wave Radio Astronomy at NAOJ***

Hiroaki Imada, Keiko Kaneko and Ryo Sakai (National Astronomical Observatory of Japan, Japan); Haoran Kang (The University of Tokyo, Japan); Takaho Masai (The Graduate University for Advanced Studies, Japan); Makoto Nagai and Wenlei Shan (National Astronomical Observatory of Japan, Japan); Shohei Ezaki (NAOJ, Japan); Yoshinori Uzawa and Takafumi Kojima (Advanced Technology

Center, National Astronomical Laboratory of Japan, Japan); Alvaro Gonzalez (National Astronomical Observatory of Japan, Japan)

National Astronomical Observatory of Japan is involved in the development of millimeter and sub-millimeter instrument. We are contributing various project through designing components, prototyping, measurement, and production. We will briefly introduce the developement related to the Atacama Large Millimeter/submillimeter Array telescope in this presentation.

12:00 ***Development of Radiometers for Space-Based Applications: Examples from 114 GHz to 2.5 THz***

Jeffrey Hesler (Virginia Diodes, Inc., USA)

In this article the development of compact radiometers for space-based applications will be reported. Examples will include the TROPICS and SSOLVE instruments, focusing on antenna design and testing and radiometric performance.

Thursday, March 30 11:00 - 12:40

CS20b: Frontiers in Propagation and Wireless Channel Modeling — Assembly 2 (continued)

T01 Sub-6GHz cellular / Convened Session /

Room: Spadolini 101

Chairs: Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany), David W Matolak (University of South Carolina, USA)

11:00 ***On Evaluating V2X Channel Models with COTS 802.11p Devices in Urban Field-Trials***

Lennart Thielecke (Technische Universität Braunschweig, Germany); Mahboubeh Ansari (Technical University of Braunschweig, Germany); Thomas Kürner (Technische Universität Braunschweig, Germany)

In this paper, we compare a simulated 802.11p V2X packet error rate with a measurement campaign in an urban field-trial scenario to estimate the validity of the utilized channel model. A tapped delay line channel model is selected and evaluated in comparison to the real-world performance of a commercial of-the-shelf unit. Finally, potentially problematic pitfalls of the utilized V2X devices in future field-trials and performance evaluations in lab environments are identified.

11:20 ***Measurement Validation of Ray-Tracing Propagation Modeling for mm-Wave Networking Studies: How Detailed is Detailed Enough?***

Aron Schott and Aleksandar Ichkov (RWTH Aachen University, Germany); Petri Mähönen (RWTH Aachen University, Germany & Aalto University, Finland); Ljiljana Simić (RWTH Aachen University, Germany)

The spectrum-rich millimeter-wave (mm-wave) bands are envisioned as a key enabler for future high speed communication networks. Given the high path and penetration loss and the spatially sparse nature of the mm-wave channel, connectivity at mm-wave is dependent on line-of-sight (LOS) or strong non-LOS directional links. This makes deterministic propagation modeling via ray-tracing an important tool for environment-specific mm-wave networking studies. In this paper we validate the accuracy of ray-tracing against large-scale mm-wave outdoor measurements using commercially-viable phased antenna arrays. Towards making practical modeling recommendations, we investigate how detailed the models of the urban environment and the directional antennas need to be for ray-tracing to accurately predict the measured channel. Our results indicate that even simple 3D environment models are sufficient for reasonably accurate ray-tracing results but that realistic measured antenna models are essential for reducing the typical prediction error to within 4 dB.

11:40 ***Differential Geometric Description of Future Mobile-To-Mobile Channels***

Michael Walter and Miguel Angel Bellido-Manganell (German Aerospace Center (DLR), Germany)

In this paper we present differential geometric concepts for future mobile-to-mobile channel models. Those concepts enable the reader to generalize the channel description and apply it to different mobile-to-mobile scenarios. The geometric description allows for a non-stationary model, which thus incorporates high mobility scenarios, which are very important in future systems. Hereby, the mathematical concepts are similar to the theory of general relativity. Differential forms and coordinate system transforms are part of a tensor description of the channel. Our channel model for mobile-to-mobile channels is based on two important mathematical concepts: prolate spheroidal coordinates and differential forms. Furthermore, both the coordinate transform and the differential forms can be uniformly described by the tensor theory. Thus, we use co- and contravariant tensors to express both the gradient of the Doppler frequency in prolate spheroidal coordinates and differential forms, which are used to calculate the scattering area, in a uniform way.

12:00 ***Accurate Urban Path Loss Models Including Diffuse Scatter***

Dmitry Chizhik and Jinfeng Du (Nokia Bell Labs, USA); Manav Kohli and Abhishek Adhikari (Columbia University, USA); Rodolfo Feick (Universidad Técnica Federico Santa María, Chile); Reinaldo Valenzuela (Nokia Bell Labs, USA); Gil Zussman (Columbia University, USA)

Standard ray tracing predictions are found to overpredict signal strength in "down the street" scenarios when compared against over 800 urban street measurements on 12 Manhattan streets, nominally Line of Sight (LOS) scenarios, by over 20 dB at 300 m. Use of Uniform Theory of Diffraction (UTD) formulas for around corner cases is found to underpredict signal strength in comparison to observations, with 7.8 dB RMS error. It is found that including effects of scatter from street clutter, such as vegetation and street poles results in simple path loss expressions with RMSE of 7.8 dB for down-street cases and 2.3 dB for around corner.

12:20 ***To Know Channels Better: Challenges and Opportunities of Ray Tracing***

Ke Guan and Danping He (Beijing Jiaotong University, China); Thomas Kürner (Technische Universität Braunschweig, Germany); Zhangdui Zhong (Beijing Jiaotong University, China)

How to know wireless channels better in a more accurate and efficient way is the motivation and goal of wireless propagation and channel modeling, including but not limited to ray tracing (RT) and stochastic channel models (CMs). Although being called "deterministic channel modeling", the essence of RT is still electromagnetic (EM) calculation. This is dramatically different from the mainstream CMs (short for stochastic CMs in the following text). In order to understand the prospects of these two approaches, we provide insight into the comparison of RT and CMs in terms of essence, usage, and cost (of complexity). In order to enhance the potential of RT, we identify the challenges and contemplate the future research outlook toward breaking through these bottlenecks from the perspectives of the input data, algorithms, and computing power.

Thursday, March 30 11:00 - 12:40

A09: Sub-mm wave and Terahertz Antennas

T02 Mm-wave and THz cellular / / Antennas

Room: Spadolini 102

Chairs: Nuria LLombart (Delft University of Technology, The Netherlands), Miguel Navarro-Cía (University of Birmingham, United Kingdom (Great Britain))

11:00 ***Dual-Polarized Geodesic Lens Antenna at Sub-THz***

Qiao Chen and Wenfu Fu (KTH Royal Institute of Technology, Sweden); Kun Zhao (Aalborg University, Denmark & Sony, Sweden); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

We present a dual-polarized lens antenna for point-to-multipoint communications at sub-THz. The lens is constructed by a doubly-curved parallel plate following a geodesic lens shape equivalent to the Luneburg index profile. The polarization is changed by metallic screens patterned with complementary split resonant rings (CSRRs). These screens are integrated in the radiation aperture of the lens. Two lenses are stacked up, one for each polarization. Each lens is fed by 11 waveguide ports, providing beam steering or multiple beams. The antenna is fully metallic and hence, highly efficient. In the operating band from 115 GHz to 125 GHz, the simulation shows a realized gain of 20 dBi with a maximum scan loss of 0.6 dB up to 60 degrees, a cross-polarization discrimination around 20 dB, and an insertion loss smaller than 1.5 dB.

11:20 ***Modulated Metasurface Array for Photonic Beam Steering at W Band***

Jérôme Taillieu (Université de Rennes 1, France); Ronan Sauleau (University of Rennes 1, France); Mehdi Alouini (Institut de Physique de Rennes - Université Rennes 1 - CNRS, France); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

This contribution presents a photonically excited modulated metasurface array, which enables one dimensional beam steering with a medium-to-high gain in the sub-THz range. The designed array consists of four rectangular subarrays separated 1.16×λ0, with λ0 being the free-space wavelength at 100 GHz. This spacing permits a scanning range of +/-5° to avoid appearance to grating lobes. The sub-arrays are excited at their center by a simple substrate integrated waveguide (SIW) circuit and radiate at broadside. They are fed photonically by Uni-Traveling-Carrier photodiodes (UTC-PD) connected to a wideband DC biasing network. The structure at hand exhibits 26 dB of gain with a 3% relative gain bandwidth, enables power-combining and it is easily scalable for higher gains.

11:40 ***Gap Waveguide Hyperbolic Metalens at 300 GHz***

Dayan Pérez (Public University of Navarra (UPNA) & Institute of Smart Cities (ISC), Spain); Carlos Biurrun-Quel (Universidad Publica de Navarra & Institute of Smart Cities, Spain); Iñigo Ederra (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Miguel Beruete (Universidad Publica de Navarra, Spain)

In this paper, a flat hyperbolic lens-corrected H-plane horn antenna is designed at 300 GHz using Groove Gap Waveguide (GGW) technology. A GGW horn antenna is employed to feed the metamaterial lens, in order to increase the directivity in the direction of propagation. Both devices, the metalens and the GGW antenna, achieve excellent radiation results when combined together.

12:00 ***Lens-Antenna-Coupled MKIDs for Ultra-Sensitive Terahertz Spectral Imagers***

Alejandro Pascual Laguna (SRON & Delft University of Technology, The Netherlands); Juan Bueno (Delft University of Technology, The Netherlands); Stephen J.C. Yates and Lorenza Ferrari (SRON, The Netherlands); David Thoen (Kavli Institute of NanoScience, Delft University of Technology, The Netherlands); Dimitry Lamers, Vignesh Murugesan and Jochem Baselmans (SRON, The Netherlands)

Lens-antenna-coupled MKIDs give great promise for the realization of ultra-sensitive pixels for future terahertz imaging spectrometers. In this paper we provide guidelines to design efficient pixels in an imaging scenario at terahertz frequencies; emphasizing in particular on the quasi-optical coupling of the lens-antenna and the sensing of the captured power. The pixel consists of a hybrid CPW MKID coupled to a synthesized silicon-lens with a leaky-wave antenna on a dielectric membrane. We investigate the possibility of using such pixels up to 12 THz, where the dielectric losses and the microfabrication tolerances become critical. A 7.8 THz prototype chip is fabricated and preliminary measurements indicate a detector sensitivity of 5e-20 W*Hz^-0.5 and an optical efficiency of 20%.

12:20 ***3D-Printed D-Band Lens Antenna with Gratings Matching Layer for Sensing Applications***

Marta Arias Campo, Wolfgang Wischmann, Peter Uhlig, Oliver Litschke and Simona Bruni (IMST GmbH, Germany)

Dielectric lens antennas represent a high-performance, cost-effective solution to provide wideband high gain at sub-THz frequencies. However, in particular in sensing applications, multiple reflections in the interface between the lens and air cause false echoes which may lower the dynamic range and accuracy of the system. In this paper, we present a low-cost polypropylene FFF (Fused Filament Fabrication) 3D printed matching layer solution working at 110-170 GHz, implemented on the surface of an elliptical lens. The false echo power level is reduced in more than 20 dB, keeping the wideband gain (>30 dB) over the whole frequency band.

Thursday, March 30 11:00 - 12:40

A13: Wireless Power Transfer Antennas

T03 Wireless LANs, IoT and M2M / / Antennas

Room: Spadolini 103

Chairs: Mahmoud Wagih (University of Glasgow, United Kingdom (Great Britain)), Lei Wang (Heriot-Watt University, United Kingdom (Great Britain))

11:00 ***RFID-Enabled Energy Harvesting Using Unidirectional Electrically-Small Rectenna Arrays***

Mahmoud Wagih, Rory Nesbitt, Shuja Ansari, Qammer H Abbasi and Muhammad Ali Imran (University of Glasgow, United Kingdom (Great Britain))

RFID has been widely adopted in sensing applications based on passive tags. We present, for the first time, a practical room-scale demonstration of a wireless power grid based on 868 MHz UHF RFID, with 27 dBm radiated power. The proposed harvester is a state-of-the-art flexible rectenna surface based on serially-connected tightly-coupled electrically-small rectenna elements. Reflector-backing is proposed increasing the harvester's effective area by 3 dB with over two-fold increase in the harvested energy. The DC power harvesting pattern of the array are experimentally characterized showing an 18 dB front-to-back ratio. In a 40 m2 room with a single reader and 3 antennas, a maximum energy of 5.3 mJ was harvested using the unidirectional array in a capacitor over a 1-minute charging period. The minimum energy yield of 0.5 mJ, sufficient for powering a Bluetooth beacon, evidences that, despite its intermittency, RFID packets can create an indoor RF grid.

11:20 ***Design Methodology of Near-Field Transmitter Coil Antenna for Maximizing Efficiency of the WPT System***

Ananth Bharadwaj Madduluri and Vivek Kumar Srivastava (Indian Institute of Technology Ropar, India); Chakradhar Reddy Chandupatla (IIT Ropar, India); Ashwani Sharma (Indian Institute of Technology Ropar, India)

This article provides a comprehensive stepwise procedure to develop a transmitter (Tx) coil antenna for a near-field WPT system. The design procedure enables to determine the parameters such as distance between Tx and Receiver (Rx) coils (h), side-length (2a), the number of turns (Nt), and resonant frequency (fc) of Tx coil. These parameters are optimized based on the application scenario, maximum magnetic field strength (H), safety guidelines, and quality factor (Q). Further, the analytical H-field results are verified by the EM simulator. Moreover, by choosing an appropriate load resistance (RL) and optimal circuit parameters, the link efficiency (η) between Tx- Rx coils and system efficiency (ηdc−dc) are maximized using the LT-Spice circuit simulator.

11:40 ***Distance and Efficiency Improvement in Wireless Power Transfer Systems Through Steering Magnetic Field Using Metasurface with Negative Permeability***

Said Choukri (Université Gustave Eiffel, France); Hakim Takhedmit (Université Gustave Eiffel & ESYCOM Lab, France); Otman EL Mrabet (System of Information and Telecommunications Laboratory, Morocco); Amine-Mahdi Hamidouche (Universite Gustave EIffel & ESYCOM Lab, France); Laurent Cirio (Université Gustave Eiffel & ESYCOM Lab, France)

This work presents a new Wireless Power Transfer (WPT) system with improved transfer distance and power efficiency. The enhancement of power transmission is provided by integrating a metasurface with negative permeability in the middle of the transfer distance between the Tx and Rx antennas. A new design of magnetic dipole antenna is done, and used for both Tx and Rx sides. Simulation results show that the Power Transfer Efficiency (PTE) of the Tx/Rx elements achieves 33.74 %, while when integrating the metasurface the PTE is about 75 %, hence 41.26 % of PTE improvement is achieved at the transfer distance of 60 mm.

12:00 ***Comparison of Different Solar Cell-Antenna Integration Designs on a Thin Film Space-Based Solar Power Station***

Charleston Dale M. Ambatali and Shinichi Nakasuka (The University of Tokyo, Japan); Yasuyuki Miyazaki (Japan Aerospace Exploration Agency, Japan)

Practical space-based energy harvesting requires a large structure to make the microwave power transferring beam localized to a small area on Earth. A thin foldable membrane satellite is proposed to reduce the cost of building this structure. The membrane is formed by the solar cell and antenna array, but since they exist on the same plane, the solar cell area is reduced to accommodate antennas. Power lost due to pointing is also expected once the membrane is misaligned with the sunlight or with the beaming direction towards the Earth. Antenna designs incorporating optically invisible conductors, or the use of slot antennas were proposed to integrate with solar cells when area is limited. We examined their performance in terms of wireless power transfer efficiency in the context of a thin membrane and compared their mass per area to get an idea of the relative cost of launching the designs.

12:20 ***A Polarization Insensitive Circular Rectenna Array System for Microwave Power Transfer and Energy Harvesting Applications***

Sundeep Kumar and Ashwani Sharma (Indian Institute of Technology Ropar, India)

The power harvested by a rectenna (Rx) module is highly dependent on its relative orientation with respect to the dedicated RF transmitter (Tx) which can cause polarization mismatch. Therefore, a polarization insensitive rectenna system is proposed here to address the mentioned problem. A multipolarized circular rectenna array is designed using the conjugate impedance matching technique and a shunt dc combining topology for realizing a completely integrated design. This resulted in a low-cost, miniaturized rectenna array system making is suitable for space constraint sensor nodes utilized in IoT applications.

Thursday, March 30 11:00 - 12:40

CS52b: Use of base materials not intended for RF applications and eco-friendly materials (continued)

T01 Sub-6GHz cellular / Convened Session /

Room: Spadolini 104

Chairs: Loic Bernard (ISL & IETR, France), María Elena de Cos Gómez (Universidad de Oviedo, Spain)

11:00 ***Optically Transparent and Reconfigurable Printed Vivaldi Antenna***

Cherif Amani (Universite de Rennes 1, France); Mohamed Himdi (Université de Rennes 1, France); Xavier Castel (IETR-Université de Rennes 1, France); Quentin Simon Simon and Edgar Chaslin (Universite de Rennes 1, France); Saber Dakhli (IETR Laboratory, INSA Rennes & Innov'Com Laboratory, SUPCOM, University of Carthage Tunis, France); Fethi Choubani (Innov'Com Laboratory, SUPCOM, University of Carthage, Tunisia)

The work concerns the combination of transparent ultra-wideband and reconfigurable radiation patterns in one antenna. The proposed antenna can cover the entire 20-30 GHz band of interest by incorporating only three PIN diodes. The beam orientation

is reconfigured by using an RF switch to redirect the electric current flow so that the signal can be radiated in the intended direction. This concept helps reduce size and gives wireless terminals the flexibility to operate in several different direction with one antenna. A reconfigurable transparent Vivaldi antenna is presented in various forms of reconfiguration on a quartz substrate for 5G green communications with very low visual pollution. Very well-matched measurement and simulation results are presented to validate the proposed concept. The proposed antenna offers radiation pattern agility that can cover 330° with the choice of controlling the beam direction. Antennas may be suitable for dynamic switching of radiation patterns and cognitive radio.

11:20 ***A Planar Pattern Reconfigurable Yagi-Uda Antenna Using Electrically Biased Vanadium Dioxide (VO2)***

Grant Jack Gourley (Heriot-Watt University, United Kingdom (Great Britain)); Eric Kumi-Barimah (The University of Leeds, United Kingdom (Great Britain)); Gin Jose (University of Leeds, United Kingdom (Great Britain)); Dimitris E. Anagnostou (Heriot Watt University, United Kingdom (Great Britain))

A proof-of-concept vanadium dioxide (VO2) enabled planar pattern reconfigurable Yagi-Uda antenna operating at 5.8 GHz has been designed based on measured VO2 conductivity values of a 750 nm thick film.

11:40 ***Liquid Metal mm-Wave Phased Array Antenna for 5G Wireless Communication***

Shaker Alkaraki (Queen Mary University Of London, United Kingdom (Great Britain)); Chen Wang and James Kelly (Queen Mary University of London, United Kingdom (Great Britain)); Syeda Fizzah Jilani (Aberystwyth University & Queen Mary University of London, United Kingdom (Great Britain))

This paper presents a mm-wave phased array antenna enabled by Liquid Metal technology. The proposed mm-wave phased array antenna operate on 26 GHz band and it is intended for 5G wireless applications. The proposed array consists of 1×4 array of printed dipole antennas with reconfigurable directors consisting of Liquid metal. The proposed array combines two different beam steering concepts to maximize the beam steering angle and the gain of the array with minimum number of elements; while keeping the side lobe level (SLL) performance low. These two concepts are reconfigurable one through using liquid metal directors rotation and electronic one through using phased shifters. The proposed array resonates at 26 GHz with a wide bandwidth performance and beam steering angle up ±40° in the end fire direction with gain performance exceeds 12.6 dBi.

12:00 ***The Characteristics of Liquid Metals and Possible Uses as RF Antennas***

David M. Hensley (United States Air Force Academy, USA); Christos Christodoulou (The University of New Mexico, USA); Nathan Jackson (University of New Mexico, USA)

This work provides general characteristics or properties of several liquid metals and introduces their potential use as RF antennas by presenting an example of how liquid metals could be used in the design of a reconfigurable, stretchable liquid metal monopole antenna.

12:20 ***A Rubber-Based Dual-Mode Button Antenna***

Xiaoyang Yin (The University of Adelaide, Australia); Christophe Fumeaux (The University of Adelaide & School of Electrical and Electronic Engineering, Australia); Shengjian Jammy Chen (Flinders University, Australia & The University of Adelaide, Australia)

Natural rubber is a material of interest in the scope of antenna design because of its multiple qualities in mechanical properties, electromagnetic characteristics and economic values. To demonstrate these advantages, here we prepose a wearable button antenna based on rubber for Wireless Body Area Networks (WBAN) applications. Given the distinct demands of directional properties for on-body and off-body channels, the proposed button antenna is equipped with two operation modes at two neighbouring frequencies in the 5 GHz Wireless Local Area Network (WLAN) band. Specifically, through radiation superposition of magnetic currents, the proposed antenna is capable of simultaneously providing an end-fire pattern at 5.2 GHz and a broadside pattern at 5.6 GHz. A rubber-based prototype is fabricated and experimentally validated on a phantom, demonstrating the expected operation modes in the corresponding bandwidths for relevant body-centric communications.

Thursday, March 30 11:00 - 12:40

A01: Fundamental Research on Antennas I

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 105

Chairs: George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)), Agnese Mazzinghi (University of Florence, Italy)

11:00 ***Frequency-Domain Norton Resistance for Pulsed Photoconductive Antennas***

Huasheng Zhang and Nuria LLombart (Delft University of Technology, The Netherlands); Angelo Freni (Università degli studi Firenze, Italy); Andrea Neto (Delft University of Technology, The Netherlands)

Photoconductive antennas can be used to generate short pulses of electromagnetic energy with wide spectra in the THz domain. Their characterization with a Norton circuit has been recently provided via rigorous marching-on-time analysis. Although this analysis is accurate, it does not lead to immediate design equations for the optimal load, i.e., the antenna. Here we propose a frequency-domain Norton circuit where an approximate resistive component represents the active material. This component can be evaluated analytically and provides insight useful for the design of broadband antennas. Moreover, it can be used to accurately estimate the total power radiated by a PCA. The simulated power is validated by the measurement with excellent agreement.

11:20 ***On the Exploitation of Non-Radiating Currents for the Design of EM Skins***

Francesco Zardi (ELEDIA Research Center, Italy); Giacomo Oliveri (University of Trento & ELEDIA Research Center, Italy); Marco Salucci (ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

The constrained design of static passive Electromagnetic Skins (EMS) is addressed within the Smart Electromagnetic Environment (SEME) framework. A synthesis approach employing non-radiating (NR) currents is illustrated to enable the decoupling of (i) the wireless coverage requirements and (ii) the manufacturing and installation constraints. Subsequently, the two objectives can be attained separately in a fast and effective way. In order to validate the proposed NR synthesis method, the constrained design of a multi-beam EMS is presented.

11:40 ***Continuous Rectangular Phoenix Cells Mapping for Direct Copolar and Crosspolar Optimization of Quasi-Periodic Reflective Surfaces***

Andrea Guarriello (IETR & INSA Rennes, France); Renaud Loison (IETR & INSA, France); Daniele Bresciani (Thales Alenia Space, France); Hervé Legay (Thalès Alenia Space, France); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain))

This paper proposes a general methodology to enhance the efficiency of the direct optimization of the copolar and crosspolar radiation of large aperture quasi-periodic reflective surfaces (QPRS) antennas by ensuring the layout continuity without abrupt geometrical variation. This is done through the exploitation of the Phoenix cells (PC) properties, by efficiently parametrizing and interpolating PC lookup tables. In particular, the proposed parametrization allows the description of the QPRS layout through continuous functions without losing precision. Indeed, the description of the QPRS through continuous functions, namely B-spline functions, allows for to reduction of the large-scale optimization problem dimensions and naturally ensures the layout smoothness. A use case of a large faceted contour beam reflectarray (RA) is presented, showing a remarkable improvement in both the copolar and the crosspolar discrimination levels compared to classical synthesis techniques and the RA layout smoothness is practically demonstrated.

12:00 ***A Study on Phase Center Locations in Dense Arrays***

Alejandro Murillo Barrera, Grzegorz Wolosinski and Bruno Biscontini (Huawei Technologies, Germany); Federico Puggelli (Huawei Technologies); Matteo Albani (University of Siena, Italy)

This paper applies a novel phase center calculation procedure to the study of dense arrays, showing that very tightly packed arrangements of parallel dipoles experience a spread of the spatial distribution of their phase centers. Such effect implies an increase of the effective aperture of the array, which is linked to the increase of the array directivity; eventually to the attainment of superdirectivity. The phenomenon is analyzed by means of spherical wave expansion of the electric fields, with the purpose of exploring its nature. Considerations on the radiation efficiency are also included, as a primary aspect of the practical suitability of such arrays

12:20 ***A Possible Solution for Bumper Effect Mitigation***

Agnese Mazzinghi (University of Florence, Italy); Alejandro Garcia-Tejero (Universidad Politecnica de Madrid, Spain & HUBER SUHNER, Switzerland); Francesco Merli (HUBER SUHNER, Switzerland); Angelo Freni (Università degli studi Firenze, Italy)

The paper concerns a possible solution for the mitigation of the pattern distortion caused by the presence of the bumper fascia in front of a MIMO radar antenna. In particular, it demonstrates how the introduction on the antenna surface of elements that ensure an alternating phase variation of the reflected wave can effectively reduce the oscillations introduced in the radiation diagram by the multiple reflections between the bumper fascia and the antenna surface.

Thursday, March 30 11:00 - 12:40

CS25: Innovative Metasurface Applications for Next-Generation Antenna Systems

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 106

Chairs: Alessio Monti (Roma Tre University, Italy), Stefano Vellucci (Niccolò Cusano University, Italy)

11:00 ***Wave-Manipulating Skins for Wide Angle Scanning Arrays - Recent Advances and Future Trends***

Giacomo Oliveri and Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Marco Salucci (ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

The availability of inexpensive phased array technologies capable of supporting wide scanning angles with stable performance is of increasing interest for both communications and radar applications. Unfortunately, popular planar phased arrays usually suffer from scan blindness and limitations to the field-of-view (FoV) caused by the inter-element mutual coupling. In this framework, the possibility offered by passive static electromagnetic skins employed as "artificial proximity objects" (APOs) to stabilize the active element impedance has recently gathered a considerable attention with several different customization already demonstrated. The objective of this work is to review the most recent advances and current research trends in the design and implementation of APOs for wide-angle scanning arrays.

11:20 ***Low Complexity Design Methods of the Space-Time Modulated Metasurface: Theory and Experiments***

Mengmeng Li (Nanjing University of Science and Technology & Communication Engineering, China); Dazhi Ding, Ziyang Lai, Xinyu Fang and Yonggeng Zhu (Nanjing University of Science and Technology, China)

In order to manipulate electromagnetic wave in both space and frequency domain with metasurface, low complexity methods of space-time modulated metasurface design is proposed in this paper. Firstly, ideal time-varying scattering coefficient is introduced and discretized. Then, Fourier Series is applied to analyze time series so as to realize manipulation in both space and frequency domain analytically with low complexity. In the end, the proposed method is applied to achieve I/Q two paths modulation and

DoA estimation, which paves a new way for the applications in radar, communication and other fields.

11:40 ***Cavity-Excited Switched-Beam Metagrating Antennas***

Fengming Hu and Ariel Epstein (Technion - Israel Institute of Technology, Israel)

We present a semianalytical scheme to design cavity-excited switched-beam antennas based on printed-circuit-board (PCB) metagratings (MGs), sparse arrays of subwavelength scatterers (meta-atoms) synthesized via accurate tailoring of mutual coupling. Multiple simple sources embedded in the cavity serve as excitations for a passive multilayered multielement MG superstrate, designed to generate different radiation patterns in response to each of the source ports. The developed synthesis approach utilizes the cavity eigenmode expansion of the source and radiation fields to realize the desired aperture field distribution (and consequently the target radiation patterns). To validate our model and methodology, a switched-beam antenna with three sources is designed and verified in full-wave simulations, exhibiting aperture illumination efficiencies superseding 90% for all three radiation states. This work offers effective and versatile means to implement high-directivity steerable antennas without nonlinear components, especially useful for high-frequency regimes expected in future communication systems.

12:00 ***Beam-Shaping of Wired Antennas Through Huygens' Metasurface Coatings***

Stefano Vellucci and Michela Longhi (Niccolò Cusano University); Alessio Monti (Roma Tre University, Italy); Mirko Barbuto (Niccolò Cusano University, Italy); Alessandro Toscano and Filiberto Bilotti (Roma Tre University, Italy)

In this contribution, we discuss the possibility to exploit functionalized metasurface coatings wrapping wired antennas for manipulating their radiation pattern. Through a proper design of a cylindrical Huygens metasurface coat, the quasi-cylindrical wavefront of the field radiated by the antenna is locally transformed into a plane wave, leading to the generation of either multiple or single radiating beams from the original omnidirectional pattern. The semi-analytical model of the device is presented, and some relevant examples are provided. Finally, a realistic configuration of the device enabling reconfigurability of the antenna's radiation pattern is discussed.

12:20 ***Metasurface-Enabled Bound States in the Continuum for Wireless Power Transfer***

Rasmus E. Jacobsen and Samel Arslanagić (Technical University of Denmark, Denmark)

Recently, several new principles for wireless power transfer have been demonstrated overcoming the limitations of the conventional wireless power transfer systems. In this work, we investigate a metasurface-enabled bound states in the continuum for near-field wireless power transfer. The metasurface is made of complimentary split-ring resonators in which a symmetry-protected bound state in the continuum is formed. We show that a wireless power transfer channel emerges between the metasurface and a single complimentary split-ring resonator element effectively increasing the transferred power by 15 dB compared to the case without the single element.

Thursday, March 30 11:00 - 12:40

CS4b: AMTA session: Post Processing Techniques in Antenna Measurements and Recent advances in Robotic Antenna Measurements (continued)

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 107

Chairs: Dennis Lewis (Boeing, USA), Francesco Saccardi (Microwave Vision Italy, Italy)

11:00 ***Reflectivity Reconstruction with Planar Wide-Mesh Scanning Adopting Phaseless Near-Field Data: Numerical Validation***

Florindo Bevilacqua (Università di Salerno, Italy); Amedeo Capozzoli and Claudio Curcio (Università di Napoli Federico II, Italy); Francesco D'Agostino, Flaminio Ferrara and Rocco Guerriero (University of Salerno, Italy); Angelo Liseno (Università di Napoli Federico II, Italy); Massimo Migliozzi (University of Salerno, Italy); J (Yiannis) Vardaxoglou (Loughborough University, United Kingdom (Great Britain))

This work provides an approach to reconstruct the reflectivity distribution of targets exploiting a reduced set of only amplitude Near-Field (NF) data. A monostatic measurement setup is here considered. The problem of restoring the missing phase information is tackled as a quadratic inverse one. Accordingly, a priori information on the target is taken into account by adopting an effective representation of the unknown reflectivity distribution, thus improving the accuracy and reliability of the phaseless procedure. The non-redundant sampling technique has been applied to the squared amplitude of the NF scattered data to derive a non-conventional plane-rectangular scan. Such a scanning strategy, derived on considering the target as enclosed in a double bowl, results in a reduction of about 93% of the needed NF samples as compared to the standard sampling strategy. The technique is numerically validated.

11:20 ***Array Faulty Element Diagnostics by Few Phaseless Data and Convex Optimization***

Raffaele Moretta and Giovanni Leone (University of Campania, Italy); Maria Antonia Maisto (Università degli studi della Campania Luigi Vanvitelli, Italy); Rocco Pierri (Università della Campania Luigi Vanvitelli, Italy); Raffaele Solimene (Università degli studi della Campania Luigi Vanvitelli, Italy)

The problem of detecting defective turned-off elements in antenna arrays from amplitude-only data is addressed. Commonly used antenna diagnostics methods exploit amplitude and phase field data. Here, instead, the diagnostics is cast as the recovery of a binary signal from few amplitude measurements of the near-field. Therefore, it is basically a phase retrieval problem. Taking inspiration from the PhaseMax algorithm, the phase retrieval is formulated as a convex optimization. In particular, PhaseMax is adapted to the faults detection problem by removing the need to estimate a reference solution. Moreover, it is shown that the convex optimization is equivalent to a sparse minimization problem which allows to employ all the powerful tools of compressive sensing realm. Preliminary numerical results are presented to assess the achievable performance as the number of faulty elements increase. Finally, a strategy that reduces the number of measurement points by employing steering diversities is presented and checked.

11:40 ***Near Field Evaluation by Back Propagation of the Measured or Simulated Far Field***

Federico Puggelli (Huawei Technologies Italia); Alejandro Murillo Barrera and Bruno Biscontini (Huawei Technologies, Germany); Enrica Martini, Alberto Toccafondi and Stefano Maci (University of Siena, Italy)

In this work the authors present and discuss a technique to evaluate the near field radiated by an antenna when the far field is known, either from simulations or as a result of a measurement campaign, so as to determine and assess the possible hazards that an operator is exposed to when inspecting, maintaining or repairing equipment installed on cell phone towers.

12:00 ***Hybrid Measurement and Post-Processing Method for Human RF Exposure Assessment of Mobile Radio Small-Cells***

Tobias Struck, Lisa-Marie Schilling and Christian Bornkessel (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

Established methods for determining electromagnetic field exposure of mobile radio small-cell base stations to the general public are currently based either on numerical far-field computation or field strength measurement at selected evaluation points. It means that they are not capable of providing a realistic 3-dimensional near- and far-field evaluation of mobile radio small-cell base stations. For this reason, an innovative hybrid exposure assessment approach - which combines antenna nearfield pattern measurements and numerical computations under varying environmental conditions - was specially adapted to small cells. While the conservatively determined measurement uncertainty of ± 3 dB is comparable to already established methods such as electric field probe measurement, the hybrid assessment offers novel possibilities in terms of flexibility. By moving exposure assessment

into virtual domain, complex installation scenarios or varying antenna operation parameters can typically be investigated within simulation environment, so that complex measurement campaigns may be substituted by hybrid assessment.

12:20 ***A Closed-Form Solution for the Synthesis of the Excitations of a Plane Wave Generator***

Francesco Lisi and Paolo Nepa (University of Pisa, Italy)

Plane Wave Generators (PWG) represent an attractive technology for the measurement of 5G New Radio base station antennas since they significantly reduce the dimensions of the required anechoic chamber. By properly selecting the complex weights of the array, a PWG allows to generate a planar wavefront in a confined volume within the array near-field region, known as Quiet Zone (QZ). In this paper, the "minimum error field norm" method is exploited to synthesize the PWG excitations. In addition to having a closed-form solution, this technique allows to control the tradeoff between the PWG performance and the amount of power that flows through the QZ. The method is applied to an octagonal-shaped planar array with 156 elements to create a spherical QZ, and its performance is evaluated for various values of the QZ radius. Finally, the method is compared with the simpler Conjugate Phase method with Dolph-Chebyshev amplitude tapering.

Thursday, March 30 11:00 - 12:40

E07: Inverse problems and radar imaging

T10 Fundamental research and emerging technologies / / Electromagnetics

Room: Spadolini 108

Chairs: Giovanni Leone (University of Campania, Italy), Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

11:00 ***Machine Learning Approach to Microwave Imaging for Cancer Detection***

Alexandra Flores, Giovanni Buonanno and Sandra Costanzo (University of Calabria, Italy)

Conventional methods to solve inverse problems face with some difficulties, including ill-posedness, nonlinearity, and high computational cost. To overcome the above drawbacks, a new approach is proposed which unifies the Iterative Born Method (BIM) with a quadratic programming procedure based on the adoption of Convolutional Neural Networks. BIM is used to obtain an initial estimate of the dielectric profile, which is processed by the convolutional neural network to improve the reconstruction. The dielectric profiles obtained with the proposed scheme show that the network is able to provide images with greater precision as compared to the case of single BIM technique, thus opening new interesting scenarios for quantitative microwave imaging in real time and with low computational cost.

11:20 ***A Microwave Imaging Sensor Composed of a Dielectric-Loaded Double-Polarized Horn Antenna***

Yoshihiko Kuwahara (Shizuoka University, Japan); Kimihito Fujii (Aichi Medical University, Japan)

The inverse scattering problem is a technique for finding the complex permittivity of an imaged object so that the experimental scattering fields results match the analysis results of an imaging system including the imaged object. There is a little change in the scattered field caused by perturbation of the voxels filling the imaging region. On the other hand, the current technology cannot perfectly model the imaging model, and non-negligible analysis errors occur. For the inverse scattering problem, a highly sensitive antenna that the variation of the scattered field caused by the perturbation of the voxel group greatly exceeds the analysis error is required. In this paper, a highly sensitive antenna for early breast cancer detection is proposed, then a new imaging sensor using this antenna and an image reconstruction algorithm are introduced.

11:40 ***Frequency-Diverse Metasurface Antenna for Computational Through-Wall Imaging***

María García Fernández and Guillermo Alvarez Narciandi (Queen's University Belfast & University of Oviedo, United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

Computational imaging has emerged as a promising paradigm to overcome some drawbacks of conventional radar systems based on raster scanning. This approach relies on using compressive antennas that radiate quasi-random spatially-incoherent patterns, which in turn enables to compress the information from the imaged scene into a single channel (or a reduced number of channels). Despite the success of computational imaging for multiple free-space applications (such as personnel screening), its extension to deal with through-wall imaging scenarios has been hardly explored. This contribution presents a frequency-diverse antenna working at X-band to perform through-wall computational imaging. First, we show that the designed antenna radiates distinct patterns as a function of frequency, which is essential to achieve physical layer compression. Then, we demonstrate the capability of this antenna to detect targets hidden behind a wall, provided that a clutter removal technique is applied to mitigate the wall reflection.

12:00 ***Breast Cancer Detection Using Machine Learning Approaches on Microwave-Based Data***

Lorenzo Papini (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Mario Badia (UBT - Umbria Bioengineering Technologies, Italy); Lorenzo Sani (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Soumya Prakash Rana (School of Engineering London South Bank, Italy); Daniel Álvarez Sánchez-Bayuela (University of Castilla - La Mancha & University Hospital of Toledo, Spain); Alessandro Vispa and Alessandra Bigotti (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Giovanni Raspa (UBT - Umbria Bioengineering Technologies, Italy); Navid Ghavami (Umbria Bioengineering Technology (UBT), United Kingdom (Great Britain)); Cristina Romero Castellano (Hospital Virgen de la Salud, Toledo, Spain); Daniela Bernardi (Humanitas Research Hospital, Milan, United Kingdom (Great Britain)); Alberto Tagliafico (University of Genoa, Italy); Massimo Calabrese (IRCCS Ospedale Policlinico San Martino, Genoa, Italy); Mohammad Ghavami (London South Bank University, United Kingdom (Great Britain)); Gianluigi Tiberi (London South Bank University, United Kingdom (Great Britain) & UBT - Umbria Bioengineering Technologies, Italy)

Microwave breast imaging is being investigated by research groups worldwide for its promising applications in early cancer detection, overcoming key limitations of conventional imaging systems. In this framework, artificial intelligence may play an important role to enhance the performances of new systems, based on this novel technology, for breast cancer detection. Research is being carried out to demonstrate the potential of implementing machine learning tools that have already been investigated for conventional mammography and MRI. This work presents the retrospective implementation of several supervised machine learning approaches on the microwave data obtained by MammoWave device in the framework of a clinical trial. Two different approaches are explored and explained in detail: the application of artificial intelligence directly on the MammoWave raw data and on dedicated features extracted from microwave images. Both approaches lead to promising results with high (>80%) and quite balanced specificity and sensitivity.

12:20 ***Muscle Rupture Microwave Imaging with a Lossy Gel to Reduce Multipath Interference***

Laura Guerrero Orozco (Chalmers University of Technology, Sweden); Lars Peterson (Sahlgrenska Academy, Sweden); Andreas Fhager (Chalmers University of Technology, Sweden)

Imaging can make a difference in the diagnosis and management of athletes with muscle injuries, especially those in the hamstring muscles where they commonly happen. Unfortunately, muscle injuries are often not diagnosed due to the cost and availability problems encountered when using conventional imaging methods. Microwave imaging could bring a solution to this problem and improve availability at lower costs. We have earlier presented a semicircular microwave imaging system made of monopole antennas embedded in lossy gel. The purpose of the lossy gel was to reduce direct coupling between antennas and thereby improve image reconstruction accuracy. In this work, we expanded the previous work by exploring different positions and object sizes of blood phantom targets immersed in a muscle phantom. The results showed that the reconstruction results were significantly more repeatable and accurate regardless of object size and position when a lossy gel was used instead of a non-lossy gel.

Thursday, March 30 11:00 - 12:40

A34: Technologies for Antenna Systems II

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 109

Chairs: Marco Antoniades (Ryerson University, Canada), Guido Valerio (Sorbonne Université, France)

11:00 ***Orthomode Transducers in Additive Manufacturing for Broadband and High-Power Applications***

Charalampos Stoumpos (IETR-INSA Rennes, France); Juan-Antonio Duran-Venegas and Thierry Pierré (Thales Alenia Space, France); María García-Vigueras (IETR-INSA Rennes, France)

This paper presents two designs of Orthomode Transducers (OMTs) tailored to the disruptive additive manufacturing (AM) technology. In particular, in this work we propose guidelines and rules which can be adopted for the efficient design and development of such broadband OMT components in vertical 3D-printing. The final objective relates to the creation of a generic framework which should enable any designer to realize OMT topologies following specific criteria dictated by both the limitations and flexibilities of the AM technology. The numerical models of a turnstile and Boifot OMT achieve a 35% frequency bandwidth with a return loss better than 25 dB. The experimental characterization of a Ku-band Boifot OMT verifies the high RF performance of the component as well as its efficient manufacturing. The designed and optimized OMTs are targeted for high-power applications and, therefore, we further provide the multipactor analysis performed to characterize their power handling capabilities.

11:20 ***Plasma-Based Intelligent Reflective Surfaces for Beam Steering Operations***

Mirko Magarotto (University of Padova, Italy); Luca Schenato (National Research Council, Italy); Paola De Carlo and Antonio-D. Capobianco (University of Padova, Italy)

Plasma-based Intelligent Reflective Surfaces (IRSs) have been recently proposed to control the environment between transmitting and receiving antennas. This work demonstrates the feasibility of a plasma-based IRS that enables beam-steering operations. First, a theoretical model has been developed to assess the use of plasma as a reflector for a generic angle between the incident wave and the broadside direction. Subsequently, a numerical design is proposed to align the main radiation lobe with the broadside direction, provided that the incidence angle is 20 deg. To this end, continuous control of the plasma density, and in turn of the reflection coefficient, is implemented.

11:40 ***Time-Modulated Antenna Array for Shaped Beam Patterns in Wideband 5G Applications***

Alberto Reyna (Autonomous University of Tamaulipas, Mexico); Gonzalo Maldonado and Luz Idalia Balderas (Universidad Autonoma de Tamaulipas, Mexico); Marco Panduro (Mexico)

This paper describes the design of a time-modulated antenna array for shaped-beam patterns in wideband 5G applications. The array is formed by eight disk-notch patch antennas in a linear topology. The antennas are fed with random distributions of switching time sequences and phases. The design process is carried out by the bacterial foraging optimization. The simulation results show the good performance of the array for providing shaped beam patterns from 3.4 GHz to 4.2 GHz. The shaped beam patterns generate side lobe level and side band level reductions within the wideband frequency range.

12:00 ***Coupled Resonator Configuration for Enhanced Reflectarray Magnitude and Phase Control***

Mohamed K. Emara (Carleton University, Canada); Debidas Kundu (IIT Roorkee, India); Leandro Rufail and Shulabh Gupta (Carleton University, Canada)

A reflectarray metasurface unit cell consisting of two coupled resonators and three variable controls is proposed. The configuration consists of an outer split-ring resonator (SRR) responsible for resonance at the desired frequency and includes two variable elements; one capacitive and one resistive. A dipole-ring resonator (DRR) is inserted inside the SRR with a capacitive element, creating a resonance at a higher frequency than the SRR. Variation of the DRR resonance affects both the magnitude

and the phase of the lower resonance of the SRR. For any given constraint on the available capacitive or resistive values, the coupled resonator configuration provides a significantly enhanced reflection magnitude and phase variations compared to a single isolated resonator. Control over magnitude and phase is used to demonstrate four cases of beamforming in the X-band at 9 GHz: side-lobe level (SLL) reduction, beam-steering, beam-steering with SLL reduction, and dual-beam generation.

12:20 *Optically Transparent Microstrip Patch-Based Antenna with 3D Pattern Diversity*

Maria M Bermudez Arboleda (King Abdullah University of Science and Technology, Saudi Arabia); Mohammad Vaseem (King Abdullah University of Science and Technology (KAUST), Saudi Arabia); Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)

A known method to achieve high transparency and efficiency for vertically integrated microstrip patch antennas, is the meshed conductor approach. Nevertheless, the impedance bandwidth of regular meshed antennas does not cover the whole 2.4 GHz band used by typical protocols like BLE. On the other hand, optimization of how the collected energy is spent becomes extremely relevant. Antenna designs with spatial pattern diversity can be implemented to automatically adapt and focus the radiation only in the direction of communication towards the base station avoiding power wastage. In this paper, a dodecahedron hollow acrylic structure is used as antenna substrate for twelve microstrip patch antennas that can be activated independently by using radiofrequency switches. Moreover, the bandwidth of the radiators is enhanced by implementing E-shape microstrip patches. The design has 96% transparency, impedance bandwidth of 6.98 %, and a gain of 6.1 dBi at 2.45 GHz.

Thursday, March 30 11:00 - 12:40

SW11b: Quantum Electromagnetics for Antennas and Propagation (continued)

Organized by: Paolo ROCCA (ELEDIA@UniTN, University of Trento); Luis Enrique GARCIA MUÑOZ (University Carlos III of Madrid)

Room: Sala della Scherma

11:00 - From Qubits to Quantum Algorithms for Antennas and Propagation (Paolo ROCCA, University of Trento)

11:30 - Quantum Annealing for Reconfigurable Intelligent Surfaces (Gabriele GRADONI, University of Nottingham)

12:00 - Electromagnetic Fields for Superconducting Qubits Control (Thomas ROTH, Purdue University)

Thursday, March 30 11:00 - 12:40

IW2: Antenna Design and Test Considerations for Future 5G/6G Wireless Communication (ETS Lindgren)

Room: Polveriera

Thursday, March 30 11:00 - 12:40

IW9: Antenna Array Design & Coverage Analysis of Private Wireless Networks (Dassault)

Room: Sala Arco

11:00- Workshop 1 : Antenna Array Design using Frequency Domain Decomposition & Time Domain Numerical Methods

Abstract: As our world becomes more connected, higher data rates will be required to support the transmitted data volume.. Data links at millimeter-wave frequencies as part of the upcoming 5G standards will make this possible. The smaller physical size of antennas and arrays at higher frequencies means they will be seen in many new application areas as agile, responsive beamforming becomes feasible for base stations and user terminals. This will be a critical enabling technology for future wireless applications. The array design capabilities of SIMULIA CST Studio Suite have grown dramatically over the last years and are relied on by many companies around the world.

Speaker: Davide Tallini

11:55 Workshop 2: Coverage Analysis of Private Wireless Networks in Industrial Environments

Abstract: Digitalization and wireless connectivity are key enablers of the Industrial Internet of Things (IIoT), also referred to as the "Industry 4.0". Private wireless networks and new standards like 5G enable strategies for more agile and efficient production lines, facilities and plants. The benefits go beyond the connectivity, which is why private networks is a topical subject for the communication industry. In this presentation, we explore how simulation can be used to perform coverage analysis and extract channel information for the proper design of devices and the network for complex industrial environments.

Speaker: Rodrigo K. Enjiu

Thursday, March 30 11:00 - 12:40

WG SA: EurAAP Small Antenna WG meeting

Room: Palazzina 7

Thursday, March 30 13:30 - 15:00

PA7: Poster Session on Antenna Design II

/ / Antennas

Rooms: Spadolini 001, Spadolini 002

Chairs: Eva Antonino-Daviu (Universitat Politècnica de València, Spain), Daniel Sjöberg (Lund University, Sweden)

Mutual Coupling Reductions of Dielectric Resonator Antennas Without Extra Circuits

Peng Mei, Gert Pedersen and Shuai Zhang (Aalborg University, Denmark)

This paper describes a strategy to reduce the mutual couplings of dielectric resonator antennas without extra circuits. The strategy is enabled by etching an elliptical cylinder in a dielectric resonator along its diagonal direction. By optimizing the dimension and location of the elliptical cylinder, the mutual coupling of the orthogonal polarizations of the dielectric resonator antenna can be effectively reduced. For demonstration, a cube-shaped dielectric resonator antenna operating at 5.8 GHz is configured with a proper elliptical cylinder drilled properly. The simulated results demonstrate the mutual couplings of the orthogonal polarizations can be reduced to -25 dB from 5.6 to 5.95 GHz, where an average of 8 dB mutual coupling reduction is obtained compared to the one without the ellipse cylinder. The radiation patterns and total efficiencies of the dielectric resonator antenna with the elliptical cylinder drilled are maintained, verifying the effectiveness of the strategy to reduce the mutual coupling.

Comparison Between Wideband Array Antennas for Ground Penetrating Radar Applications

Kenan Çapraz (ASELSAN INC., Turkey)

Wideband antenna arrays are considered for use in ground penetrating radars (GPR) to detect buried objects, such as cables, pipes and mines. There is a variety of elements for antenna arrays for GPR applications. Vivaldi arrays can be a candidate for GPR due to their good wideband performance with high efficiency. Resistively loaded antennas such as resistively loaded vee dipoles (RVD) can be also utilized due to their wideband performance despite of their inefficiency due to resistive loading. In this paper, Vivaldi and RVD arrays are designed in 0.5-3GHz band for an air-coupled GPR. Performances of those arrays are compared in terms of antenna ringing and target imaging.

A New ABS Conductive Material to Develop Fully 3D-Printed Patch Antennas

Javier Jiménez (Naitec - Technological Center of Automotive and Mechatronics & University of Navarre, Spain); Joseba Irigoyen and Maite Aresti (NAITEC - Technological Center of Automotive and Mechatronics, Spain); Iñigo Ederra (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain); Javier Bravo (NAITEC - Technological Center of Automotive and Mechatronics, Spain); JuanCarlos Iriarte (Public University of Navarra & Antenna Group, Spain)

Additive manufacturing technology is rapidly overcoming some of its initial limitations and, thus, creating a very useful engineering option for prototyping complex geometries for a wide range of electronic devices. Based on important advantages such as turn-around, reliability, material waste reduction, and low implementation costs, the technology is being continuously developed and improved. This paper presents a completely 3D-printed microstrip patch antenna to demonstrate the feasibility of a new conductive Acrylonitrile Butadiene Styrene (ABS) material in the fabrication of three-dimensional (3D) antennas using additive manufacturing method. The prototype of the antenna has been fabricated using Raise3D E2 printer, commercial ABS and a new ABS filament developed by Naitec for dielectric and conductive parts of the antenna, respectively. The fabricated antenna is compact and light. Preliminary prototypes and fabrication techniques are presented.

Technique to Tackle Resonant Frequency Variations for 3D-Printed Microstrip Patch Antennas

Zere Iman (King Abdullah University of Science and Technology, Saudi Arabia); Zubair Akhter (Technical Fellow, Saudi Arabia & Kaust, Saudi Arabia); Yiyang Yu and Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)

Due to waste minimization, and capability to construct complex geometries, additive manufacturing is a promising candidate for large-scale manufacturing of radiofrequency components. However, 3D-printed microwave substrates suffer from a relative permittivity variation of 4-9%. Thus, the antennas realized on these substrates can have variations in their intended resonant frequencies. This issue is critical for narrow-band microstrip patch antennas (MPA). In this work, we propose an easy-to-implement post fabrication technique to compensate for the permittivity variations of the 3D-printed substrates (particularly for MPA). The proposed technique corrects the resonant frequency by introducing blind vias at specific locations. We show, by experimentally applying this technique, that resonant frequencies can be shifted to lower or higher values as desired. The maximum shift in the resonant frequency, without significantly affecting the MPA performance, can be up to 13%, which is sufficient to cater for typical variations of material properties in 3D printed substrates.

Wideband Patch Antenna Array with Capacitive Proximity Sensor for Hand Grip Detection of 5G Millimeter Wave Terminals

Jeong-Ung Yoo and Hae-Won Son (Jeonbuk National University, Korea (South))

This paper presents a patch antenna array with a capacitive proximity sensor function that detects the user's hand grip on the 5G terminal in the millimeter wave band.

Improved Isolation Between Ports of MultiMode Antenna with a Reconfigurable Pattern by Decoupling Network

Muhammed Tonga (Middle East Technical University, Turkey); Lale Alatan (METU, Turkey); Ozlem Aydin Civi (Middle East Technical University, Turkey)

In this study, a decoupling network is designed and implemented to a concentric circular patch with a ring antenna whose two ports are strongly coupled. The ports of the antenna are excited with phase differences to have different radiation modes at the

same frequency for pattern diversity. Strong coupling between the ports is inevitable and a decoupling network consisting of a lumped element is inserted between the ports to improve the isolation. With inductive and capacitive decoupling network designs, the ports of the antenna are decoupled. Lower than -20 dB isolation (|S21|) is achieved which improves active |S11| substantially. As a result, realized gain values of the antenna are increased by 2-3 dB.

Including Spillover in the Synthesis of Transmitarrays: A Convex Optimization Approach

Marie Defives (CEA-Leti University Grenoble-Alpes Grenoble, France); Francesco Foglia Manzillo (CEA-LETI, France)

We present a new synthesis approach for transmitarray antennas, based on convex optimization techniques, which takes into account the spillover radiation. We first show that the power of the radiated far-field co-polar component, including spillover from the feed, can be expressed as a convex function. Then, we propose an iterative procedure to solve the phase-only synthesis problem. Thanks to a semidefinite relaxation, the phase profile is eventually derived by finding, at each iteration, the optimal solution of a convex sub-problem. The analysis model is validated by comparison with full-wave simulations. The proposed optimization approach is numerically demonstrated with the synthesis of a broadside pencil beam with reduced sidelobe levels.

Combinatorial Feeding to Controlling and Combining Power on a Coupled Antenna Array

Jaanus Kalde (University of Tartu & University of Aalto, Estonia); Veli-Pekka Kutinlahti (Aalto University, Finland); Alvo Aabloo (IMS Lab, Institute of Technology, University of Tartu, Estonia); Anu Lehtovuori (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

The paper proposes a combinatorial feeding scheme for coupled arrays making it possible to combine and control the output power in air. In this scheme, amplifiers feeding the array elements can be switched on and off and the excitation phase of each element can be selected according to the intended beam direction and output power level. We derive a model for the combined system of amplifiers and coupled antenna elements and verify the model by simulations. For reference purposes, we design an uncoupled array and show that the proposed concept enables more efficient power combining and control than the reference array.

Reduction of Mutual Coupling Between Dual-Polarized Antenna Elements Using Defected Ground Structures

Ali Rashidifar and Kevin Etienne Drenkhahn (Technische Universität Ilmenau, Germany)

To accurately model a communication channel using channel sounding technique, having dual-polarized antenna elements and low mutual coupling between them is required. In this work a Defected Ground Structure (DGS) is proposed to reduce the mutual coupling between two dual polarized mmWave antenna elements in an array structure. The defected ground is made of etched C-shape slots. The presence of the DGS has a strong impact on H-plane coupling where a suppression of 35 dB is achieved, while the reduction of E-plane coupling is about 4 dB. The unwanted effect on the radiation patterns is negligible and the back radiation is not increased.

A Planar Metasurface Cloaked Dipole Antenna Designed for Multifunction Apertures

Alexandros Pallaris and Daniel Sjöberg (Lund University, Sweden)

We designed and simulated a 1 GHz planar dipole antenna that is cloaked in a band around 10 GHz. Relative to an uncloaked antenna it has a reduced extinction cross-section for the co-antenna polarization, at the cost of an increased cross-polarization. This reduced extinction cross-section characterizes a reduction in scattering and absorption, and so reduced interference to electromagnetic waves in the frequency of cloaking. The dipole antenna element is cloaked by the introduction of sub-wavelength capacitive strips surrounding its length. The cloaking results were obtained using full wave simulations, showing for the realistic, lossy design a reduction of at least 5 dB in the extinction cross-section over a bandwidth of more than 1.5 GHz in comparison with the uncloaked antenna.

A Rectenna Design with Harmonic Suppression for RF Energy Harvesting Applications

Gholamhosein Moloudian (Tyndall National Institute, Ireland); Brendan O'Flynn (Tyndall National

Institude, Ireland); John Laurence Buckley (Tyndall National Institute & University College Cork, Ireland)

A compact rectenna for radio frequency (RF) energy harvesting applications is presented. The antenna also features a lowpass (LPF) structure to suppress unwanted harmonics. A zero bias and low-power Schottky diode SMS7630 is utilized as the rectifying element. A circular patch antenna is designed and optimized to resonate at 2.44 GHz. A microstrip matching network is placed between the proposed antenna and rectifier to maximize power conversion efficiency. According to the results, by using the proposed LPF structure, first and second harmonics have been suppressed with a large rejection level of 10 dB. The proposed rectenna shows a maximum power conversion efficiency (PCE) and output voltage approximately 40.2% and 2.19 V at 2.44 GHz for an optimum load resistance RL = 1.2 kΩ and an input RF power of 10 dBm.

A Dual-Band and Flexible CPW-Fed Antenna for RF Energy Harvesting Applications

Alassane Sidibe (LAAS-CNRS, France); Alexandru Takacs (LAAS-CNRS Université de Toulouse, France); Daniela Dragomirescu (LAAS-CNRS, France); Samuel Charlot (LAAS, France)

It is proposed in this paper a new design of a dual-band and flexible monopole antenna fed by coplanar waveguide. The final purpose of the antenna will aim to be used with a rectifier circuit as a rectenna for RF energy harvesting. In order to optimize the whole design, the layout of the rectifier was considered on simulation step because of it coplanar waveguide configuration. cerns the design, printing process, and performance of a novel antenna on a polyimide flexible substrate. It is based on a loop antenna and has dimensions of 40 mm × 35 mm × 0.127 mm. Its very wideband behavior from 2.4 GHz to 4 GHz allows targeting S-Band applications such as LTE and Wi-Fi. Interesting performances are also achieved in terms of radiation patterns.

Miniaturized Broadband Dual-Polarized Dielectric Resonator Antenna Using Characteristic Modes

Ahmed El Yousfi (Universidad Carlos III De Madrid, Spain); Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain); Abdenasser Lamkaddem (Carlos III University of Madrid, Madrid, Spain); Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)

This paper presents a compact and broadband dielectric resonator antenna (DRA) with dual polarization radiation. To achieve a compact size the high permittivity technique is used which results in a narrow bandwidth. In an effort to improve the resultant bandwidth of the DRA, the characteristic mode analysis (CMA) is used. First, a conventional rectangular DRA is analyzed by CMA, as a result, two pairs of degenerate modes resonating at two different frequencies (0.41GHz and 0.61 GHz) are selected for having dual polarization performances. Based on that and to adjust the selected modes so that to merge them for broadband radiation, the DRA's shape has been changed to a cross-notch shape with a size of 0.2λ × 0.2λ. The simulation results show a bandwidth of 20.6%, a gain of 5dBi, and high isolation of more than 50 dB. The proposed antenna can be used in MIMO antenna applications in the low-band.

Tunable Circularly Polarized Ferrite-Based Antennas for Passive Direction Finding

AmirMasood Bagheri (5GIC & 6GIC, Institute for Communication Systems (ICS), University of Surrey, United Kingdom (Great Britain)); Behzad Rejaei (Sharif University of Technology, Iran); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Irshaad Fatadin (National Physical Laboratory, United Kingdom (Great Britain)); Seyed Ehsan Hosseininejad (University of Surrey, United Kingdom (Great Britain))

A tunable circularly polarized ferrite-based antenna array is proposed to estimate the direction of received signals without ambiguity using the applied magnetic bias to rotate the far-field phase pattern around the antenna boresight. The proposed structure can be implemented in a small area because of low coupling between antenna elements and it is capable of estimating the direction of arrival for signals coming from ±40◦ respect to the body coordinate of structure. This simple and compact direction finder structure is easy to fabricate and the proposed algorithm is frequency independent.

A Novel Dual-Band Electrically Small Quasi-Isotropic Antenna

Hanguang Liao and Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)

Quasi-isotropic antennas have gained attention due to the emergence of the Internet of Things (IoT) and Wireless Sensing

Networks (WSNs), for their orientation-insensitive communication ability. For those applications, electrically small (ES) antennas are usually preferred, which can save space for the IoT or sensing nodes, while reducing the material cost. Several compact isotropic antennas have been reported recently. However, only very few of them have shown dual-band operation ability. A novel design method to design a dual-band quasi-isotropic ES antenna is presented in this conference proceeding. The utilization of a band stop filter (BSF) enables the conventional single-band quasi-isotropic split ring resonator (SRR) antenna to behave in a dual-band operation, while maintaining the quasi-isotropic radiation for both bands. The proposed antenna is designed, fabricated, and measured, which shows a dual-band operation (both bands in ka<1 region) while maintaining decent performance.

Ultra-Wideband Modified Bow-Tie Antenna for FMCW GPR Applications

Werner Steyn (Stellenbosch University, South Africa)

This paper describes the design and performance of an ultra-wideband (UWB) modified bow-tie antenna for Frequency Modulated Continuous Wave (FMCW) Ground Penetrating Radar (GPR) applications. The antenna consists of a printed triangular bow-tie antenna PCB that is placed in a shielding channel that contains layers of absorbing material. The antenna reflection bandwidth is from 700 MHz to 4 GHz, the isolation performance is very good, and the radiation patterns remain stable over the full frequency range.

RHCP/LHCP Reconfigurable Patch Antenna for Telemetry Applications with UAV

Hernán V. Barba Molina (Escuela Politécnica Nacional & IEEE, Ecuador); Diana Navarro-Méndez and Fernando Carrera-Suárez (Universidad Politécnica de Valencia & Escuela Politécnica Nacional, Spain); Eva Antonino-Daviu (Universitat Politècnica de València, Spain); Mariano Baquero-Escudero (Universidad Politécnica de Valencia, Spain)

This manuscript presents a novel patch antenna that shows LHCP/RHCP reconfiguration by selecting a feeding port. Whit this characteristic, the antenna exhibits a good performance for telemetry application when mounted on a UAV. Simulated and measured results of the reflection coefficient magnitude show a good agreement. Furthermore, simulated radiation diagram verifies, for both cases, an axial ratio below 3 dB. Likewise, the antenna shows a simulated directivity of about 4 dBi and a simulated efficiency of 75%.

Ink-Jet Implementation of Stacked Planar and Conformal Array Antennas for Wireless Applications

Mohamad Hosein Rasekhmanesh and Asrin Piroutiniya (Universidad Autónoma de Madrid, Spain); Jose Luis Masa-Campos (Universidad Autonoma de Madrid, Spain); Enrique Márquez-Segura (Universidad de Malaga, Spain); Eduardo Garcia-Marin (Universidad Autonoma de Madrid, Spain); Juan Córcoles (Universidad Autónoma de Madrid, Spain); Jorge A Ruiz-Cruz (Universidad Autonoma de Madrid & Escuela Politecnica Superior, Spain)

This work addresses a double stacked array antenna with linear and circularly conformal disposition of patch elements. The single patch element is designed in the 5 GHz band based on the inkjet-printing technique. The idea is to generate a microstrip lines using conductive silver ink which is applied on a thin Kapton film. To improve the mechanical stability, a high impact polyester (HIPS) is used as a substrate to fix the Kapton layers which also improves the impedance matching bandwidth. After designing the single patch element with 7.2% impedance bandwidth under -20 dB and 7.7 dBi directivity, the linear array antenna is designed to improve impedance bandwidth to 11.6% and directivity to 11.2 dBi. 3D printed cylindrical structure is created to achieve the omnidirectional pattern for many applications such as wireless local area network or unmanned aerial vehicles

Optimized Dual Frequency, Wideband Millimeter-Wave Antenna Array for Next Generation Advanced Imaging Technology

Guanying Sun and Carey Rappaport (Northeastern University, USA)

In this paper, a dual frequency, wideband antenna array is designed by combining a high frequency subarray with a low frequency subarray. The image of the dual frequency array is obtained by multiplying the images of the two subarrays. The PSF analysis and the system imaging simulation show that the grating lobes are significantly reduced for the dual frequency array with

fewer radar modules/elements than the conventional array. This design will make the new generation system superior to the conventional scanning system.

Analysis and Design of a Substrate Integrated Waveguide (SIW) Cavity Slot Antenna for DSRC-Band Applications

Anil Nayak, Mr and Devraj Gangwar (IIT Roorkee, India); Igor Filanovsky (University of Alberta, Edmonton, Canada); Kambiz Moez (University of Alberta, Canada); Amalendu Patnaik (IIT Roorkee, India)

This paper presents a substrate integrated waveguide (SIW) cavity slot antenna for a dedicated short-range communication service (DSRCS)-band. The DSRCS-band (5.9 GHz) covers the vehicle-to-vehicle communication frequency range. Conductor-backed coplanar waveguide is used to feed the antenna. To ensure the improvement in the bandwidth, the out-of-band harmonics are suppressed by employing two-quarter wave resonators and a shorting pin in the feed of the antenna. The antenna radiation characteristics are also improved by good impedance matching that is achieved by placing two L-shape stubs between patches. Moreover, a SIW concept is implemented in the antenna to reduce the cross-polarization level and lateral leakage. An antenna is designed, fabricated, and measured to validate the design approach. The antenna achieves fractional bandwidth of 8.81%, with a gain of 7.45 dBi. Furthermore, the measurement also achieved the radiation efficiency of 88.68% and cross-polarization level of below 33 dB.

A Compact Pattern Reconfigurable Antenna with 4 Different Radiation Modes

Çağlar Gök (Middle East Technical University, Turkey); Lale Alatan (METU, Turkey)

This letter presents the design, fabrication, and measurements of a pattern reconfigurable antenna operating at 3.3 GHz. A circular patch in the center and a ring around it are excited by two feeds to obtain broadside and conical radiation patterns through out of phase and in phase excitations, respectively. In order to improve the pattern diversity ability of the antenna by introducing asymmetry to the radiation patterns, two slots are opened in the ground plane of the microstrip antenna. Short circuiting one of these slots results in an asymmetric pattern in conical beam mode and steers the main radiation direction in broadside radiation mode.

A Low-Profile Cellular Antenna Module for Vehicular Applications

Andrea Michel (University of Pisa, Italy); Rajesh K Singh (Defence Institute of Advanced Technology Pune, India & DIAT Pune, India); Paolo Nepa (University of Pisa, Italy)

Since the number of wireless systems integrated into vehicles is increasing, the design of radiating elements and their positioning on the vehicle has become challenging. For this reason, there is a need to find new positions on a vehicle for the antenna elements, different from the typical location on the car roof (e.g. under the plastic shark-fin cover). In this paper, a novel system of 4 low-profile radiating elements for 4x4 MIMO LTE/5G cellular applications is presented to be integrated into a vehicle, for example inside the rear spoiler or under the dashboard.

Lateral and Rotational Misalignment Tolerance in Separated Gap Waveguides Made of Periodic Bed-Of-Nails

Mourad Ibrahim (Prince Sultan University & Modern Science and Arts University, Saudi Arabia); Walid Dyab (Prince Sultan University, Saudi Arabia); Ahmed Sakr (Polytechnique Montreal, Canada); Ke Wu (Polytechnique Montréal, Canada)

Various forms of misalignment in separated gap waveguides made of periodic bed-of-nails are investigated numerically. Separated gap waveguides which are suitable for wireless power transfer applications are considered in this analysis. Two equivalent problems using perfect magnetic conductor boundaries are derived from the original problem with the periodic structure. The two equivalent problems are validated using simulation and prototype measurements. The equivalent problems are then solved with a parametric sweep to investigate the effect of lateral and rotational misalignment on this type of waveguides. The numerical results are plotted and compared to investigate the tolerance of gap waveguides in terms of power transfer efficiency.

Thursday, March 30 13:30 - 15:00

PA8: Poster Session on Antenna Systems

/ / Antennas

Rooms: Spadolini 101, Spadolini 102

Chairs: Dayan Pérez (Public University of Navarra (UPNA) & Institute of Smart Cities (ISC), Spain), Philippe Ratajczak (Orange Innovation, France)

Energy-Efficient Physical Layer Security for Wearable IoT Devices

Abel Abdul Zandamela and Nicola Marchetti (Trinity College Dublin, Ireland); Adam Narbudowicz (Trinity College Dublin, Ireland & Wroclaw University of Science and Technology, Poland)

This work proposes an energy-efficient Directional Modulation (DM) scheme for on-body Internet of Things (IoT) devices. DM performance is tested using a 5-port stacked-patch MIMO antenna under two scenarios: free space case and using a four-layer human forearm phantom to simulate the user's wrist. It is demonstrated that the scheme achieves steerable secure transmissions across the entire horizontal plane. With low Bit Error Rate (BER) of 1.5x10^(−5) at the desired directions, eavesdroppers experience a high error rate of up to 0.498. Furthermore, this work investigates the DM performance using a subset of the stacked patches in the MIMO antenna, revealing that some combinations achieve low BER performance using a lower antenna profile, albeit high sidelobes of BER< 10^(−2) seen outside the desired region. Overall, the solution is proposed as a good candidate to enable secure wireless communications in emerging wearable IoT devices that are subject to size and energy-constraints.

Quadrature Hybrid Coupler Implemented in Half-Mode Groove Gap Waveguide

Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain); Jose I Herranz-Herruzo (Universitat Politècnica de València & APL - iTEAM, Spain); Alejandro Pérez-Guimerá (Universitat Politècnica de València, Spain); Alejandro Valero-Nogueira (Universidad Politécnica de Valencia, Spain)

This communication presents a low-loss single-layer half-mode gap waveguide-hybrid branch-line coupler. The working band of the quadrature hybrid coupler ranges from 29 GHz to 31 GHz. Simulated output power of -3 dB is achieved for both the direct port and the coupled port. A level of -20 dB is obtained for the decoupled port. The total dimensions of the device are 10mm x 10 mm x 14 mm. This design, while simple, is a helpful block that can later be integrated into more complex structures, such as beam-forming networks for mm-wave antenna arrays.

Electrically Small Multimodal 3D Beamforming MIMO Antenna for PHY-Layer Security

Abel Abdul Zandamela and Nicola Marchetti (Trinity College Dublin, Ireland); Adam Narbudowicz (Trinity College Dublin, Ireland & Wroclaw University of Science and Technology, Poland)

This work proposes an electrically small 3D beamforming antenna for PHYsical Layer (PHY-layer) security. The antenna comprises two layers of stacked patch structures, and is a five-mode five-port MIMO system operating around 1.85 GHz with electrical size ka = 0.98 and radiation efficiency of up to 55%. By studying the properties of the excited modes, phase and amplitude control allow for unidirectional beam scanning towards any direction around the elevation and azimuth planes. PHY-layer security is investigated using the directional modulation (DM) technique, which transmits unscrambled baseband constellation symbols to a pre-specified secure direction, while simultaneously spatially distorting the same constellations in all other directions. Bit Error Rate (BER) calculations reveal very low values of 2 × 10^(−5) for the desired direction of the legitimate receiver, with BER< 10^(−2) beamwidths of 55° and 58° for the azimuth and elevation planes, respectively.

Synthesis of Maximum Beam Efficiency Irregular Antenna Arrays for Wireless Power Transmission

Feng Yang (University of Electronic Science and Technology of China & University of Electronic Science and Technology of China (UESTC), China); Shi Wen Yang (University of Electronic Science and Technology of china, China)

The synthesis of maximum beam collection efficiency (BCE) irregular transmitting antenna arrays for microwave wireless power transmission (MWPT) is fulfilled by using iterative convex approximation in this paper. By adopting irregular subarray technique, the number of radio frequency (RF) chain can be greatly reduced while suppressing high sidelobes level. For a fixed subarray tiling configuration, the problem of maximum BCE satisfying peak SLL constraint is actually a non-convex constrained Rayleigh entropy maximization problem with respect to subarray complex excitations, which can be efficiently solved by iterative convex approximation algorithm. The numerical results are provided to verify the effectiveness of the proposed method

Flexible Multimode-Based Beamforming MIMO Antenna

Abel Abdul Zandamela and Nicola Marchetti (Trinity College Dublin, Ireland); Adam Narbudowicz (Trinity College Dublin, Ireland & Wroclaw University of Science and Technology, Poland)

This work proposes compact, flexible Multiple Input Multiple Output (MIMO) antennas. The design principle is based on the excitation of different orthogonal radiating modes within the same antenna volume. Via phase control of the excited modes, beamforming is demonstrated in azimuth and elevation planes using single-layered structures. For flexibility, the antennas are designed using Polydimethylsiloxane (PDMS) as the substrate. Numerical results demonstrate that isolation better than 23 dB is realized in all investigated antennas under different bend configurations. Moreover, the proposed technique demonstrates an antenna with unidirectional beamsteering across the entire elevation plane, and a second design realizes a bi-directional beamsteering in the horizontal plane. Overall, the results highlight the potential of multimode-based beamforming for flexible MIMO antennas in Internet of Things (IoT) systems.

Transmitter and Receiver Design in Compressive Sensing Based Direction of Arrival Estimation

Muhammet Umut Bahceci and Berkan Kilic (Aselsan Inc., Turkey)

Compressive sensing (CS) has led to significant performance improvements in many research areas including medical imaging, image processing, and direction of arrival (DOA) estimation. Most CS-based DOA estimation studies solely address passive sensor arrays, yet detection of non-broadcasting targets is often desired. In these cases, the DOA estimation system needs a transmit mode or an external electronic support system. In this study, we design a CS-based DOA estimation system which operates both in receive and transmit modes. Our design transmits a pulse, then receives a return signal where the receiver samples the signal using a few channels. In transmit mode, we investigate alternative transmit beam patterns; in receive mode, we leverage prior target scene information to construct an adaptive measurement matrix. Our design reduces the number of transmit beams and receive channels while maintaining accurate estimation. Our design can be used for bistatic radar despite our monostatic demonstration.

A Novel Blind Adaptive Beamformer with Robustness Against Mutual Coupling and Miscalibration Effects

M. Yaser Yağan (Bogazici University & HISAR Lab., Turkey); Ahmet F Coskun (The Scientific and Technological Research Council of Turkey, Turkey); Ali E. Pusane (Bogazici University, Turkey)

Beamforming techniques utilized either at the transmitter or the receiver terminals have achieved superior quality-of-service performances from both the multi-antenna wireless communications systems, communications intelligence and radar target detection perspectives. Despite the overwhelming advantages in ideal operating conditions, beamforming approaches have been shown to face substantial performance degradations due to unknown mutual coupling effects and miscalibrated array elements. As a promising solution, blind beamformers have been proposed as a class of receiver beamformers that do not require a reference signal to operate. In this paper, a novel gradient-based blind beamformer is introduced with the aim of mitigating the deteriorating effects of unknown mutual coupling or miscalibration effects. The proposed approach is shown to find the optimal weights in different antenna array configurations in the presence of several unknown imperfections (e.g., mutual coupling effects, miscalibration effects due to gain and phase variations, inaccurate antenna positions). By providing numerical results related to the proposed algorithm for different array configurations, and bench-marking with the other existing approaches, the proposed scheme has been shown to achieve superior performance in many aspects. Additionally, a measurement-based analysis has been included with validation purposes.

8-Port Quad-Band MIMO Antenna with an Isolation Enhancement Technique for Sub-6 GHz 5G Applications

Tanjir Alam and Michael Cheffena (Norwegian University of Science and Technology, Norway); Eva

Rajo-Iglesias (University Carlos III of Madrid, Spain)

In this paper, an eight-port quad-band multiple-input-multiple-output (MIMO) antenna system with an isolation enhancement technique is presented. The proposed isolation technique is used to improve the isolation between the ports with higher mutual coupling. This technique can also be repeatedly applied between other ports to improve the isolation without affecting the impedance bandwidth and other transmission coefficients. Each radiating element of the proposed system is excited using an offset-fed coaxial port. The multiple radiating elements are placed in a double-folded symmetry fashion to reduce the number of different parameters in the global S-parameter matrix. The designed quad-band 8-port MIMO antenna system is printed on Rogers RO4350B (εr=3.55, tanδ=0.004) substrate with dimensions of 120x70x1.52 mm^3. The proposed MIMO antenna system's frequency bands lie in 5G n77, n78, n79, and n46 sub-6 GHz bands. The simulated and measured parameters are in good agreement.

GPS-Aided Electronically Controlled 360o Beam-Switching Antenna System

Charles Ng, Yiqi An, Lap On Wong and Chi-Yuk Chiu (Hong Kong University of Science and Technology, Hong Kong); Ross Murch (Hong Kong University of Science and Technology, China)

In this paper, a pattern reconfigurable antenna system is proposed for enhancing the connectivity of unmanned surface vessels (USVs). The proposed system is assumed to be located on a USV which is able to determine the relative position of the base station (BS) antenna and to select one out of four directional antenna arrays electronically. The appropriate array can then be directed to the BS antenna according to the associated Global Positioning System (GPS) information. The performance of individual components, including the proposed antenna array and switching circuit are first presented. Then, a comparison of the proposed entire GPS-aided electronically controlled beam-switching antenna system and a conventional dipole is carried out. The experimental result shows that the proposed system can potentially provide more than double communication distance with respect to the same received signal strength indicator (RSSI).

Half-Mode Groove Gap Waveguide to Coaxial In-Line Transition for mm-Wave Applications

Alejandro Pérez-Guimerá (Universitat Politècnica de València, Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain); Jose I Herranz-Herruzo (Universitat Politècnica de València & APL - iTEAM, Spain); Alejandro Valero-Nogueira (Universidad Politécnica de Valencia, Spain)

In this communication, an in-line transition between the novel half-mode groove gap waveguide (HM-GGW) technology and a coaxial probe in the Ka-band is presented. The high impedance surface (HIS) is realized with mushroom-type electromagnetic band gap (EBG) for its simple manufacturing on a printed circuit board (PCB). A microstrip-ridge gap waveguide (MRGW) intermediate stage is used to connect both structures due to its easy integration with the mushroom-type EBG on the same PCB. The simulated results of the back-to-back transition show a return loss of 20 dB and an insertion loss of 0.03 dB over the 29-31 GHz frequency band.

Biomaterial Devices on Arecanut Palm Leaf for Microwave Applications

Sujith Raman (EPFL Lausanne, Switzerland); Anja K. Skrivervik (EPFL, Switzerland)

This paper presents an investigation on the possibility of arecanut palm leaf as a biomaterial substrate for various microwave devices such as transmission lines, antenna, filter and a radio frequency identification device (RFID). The dielectric properties of naturally available arecanut palm leaf is characterized at microwave frequency region. A Microstrip patch antenna is designed and fabricated on this material using parasitic coupling and its characteristics are analyzed and presented. The antenna is operating at wide frequency band with considerably high gain throughout the bands. A basic band pass filter is also designed using microstrip transmission line topology. A four-bit RFID is presented as a proof of concept with different types of resonators. Four bits are chosen in this work but can be extended to n-bits by inserting n-resonators in the tapered transmission line depending on the space availability and by extending the transmission line to form an n-bit RFID.

A Novel Antenna System for Direction Finding Applications Using BLE 5.1 Technology

Ioannis Gouzouasis, Stylianos Papaharalabos, Mohamad Abou Nasa and Peter Karlsson (U-BLOX, Greece)

In this paper, a novel antenna system is presented for direction finding applications. The system can estimate the angle of arrival (AoA) of a Bluetooth low energy tag by an appropriately designed anchor point. Both the anchor point and the tag are described in detail from the hardware perspective, the direction finding algorithm is briefly explained, the novelties of the system are identified and the measurement results validate the proof of concept for the AoA application targeted with the proposed system.

Radiofrequency System for Localizing a Robotic Hand on a Surface Tagged with Passive Resonators

Armin Gharibi (University of Pisa & CROSSLAB, Italy); Mahmoud Tavakoli, Filippo Costa and André Silva (Institute of Systems and Robotics University of Coimbra, Portugal); Simone Genovesi (University of Pisa, Italy)

This study aimed at detecting the placement of a robotic hand working on a surface for layout and assembly purposes is presented. The goal is pursued by using a radiofrequency probe on the robotic hand and printed resonators on the surface. To detect the location of the hand orientation on the surface, the real part of the probe input impedance examined for different orientations for each resonator placed on the surface. A design of a coplanar dipole antenna with ground plane as a probe on the hand and a bended metal strip (bended dipole resonator) with different sizes placed on the sheet is employed. IT performed within a near-range distance from the surface in one direction. The proposed probe-resonator configuration allows the identification of the relative location of the hand with respect to the one of the resonators on the work surface with an encouraging level of accuracy.

Experimental Study of Wavelet-OFDM Radio Communication System for AUVs Under Seawater

Ryosuke Hasaba (Tokyo Institute of Technology, Japan); Kazuhiro Eguchi (Panasonic Connect Co., Ltd, Japan); Toshiyuki Wakisaka (Panasonic, Japan); Hiroshi Sato (Panasonic Corporation, Japan); Jiro Hirokawa (Tokyo Institute of Technology, Japan); Miyuki Hirose, Tohlu Matsushima, Yuki Fukumoto, Yuya Nishida and Kazuo Ishii (Kyushu Institute of Technology, Japan)

AUVs are used for marine resource exploration, and although acoustic, laser, etc. are often used for wireless communication for AUVs, wireless communication using RF signals will be investigated. By placing the VNA in a pressure-resistant container, we have measured the pass characteristics between antennas in seawater, and obtained good results with simulation results. Using a Wavelet-OFDM module as the communication method, a maximum communication speed of 6.8 Mbps was achieved with the antennas embedded in the AUV.

Preliminary Study on Novel 3D Printed Radio-Frequency Pressure Sensor

Daniela Gasperini, Filippo Costa, Giuliano Manara and Simone Genovesi (University of Pisa, Italy)

Pressure sensors are exploited in a wide range of applications, from industry to healthcare. In the state of the art, pressure sensors convert mechanical energy into electric energy and often they may result difficult to realize. However, recent advances in Additive Manufacturing (AM) allows to create customized low-cost devices in short time. Here we present an initial study for the realization of a pressure sensor based on radio-frequency, consisting of a flexible substrate and a single antenna. Different loads are placed upon the proposed system, in order to measure the correspondent changes in the reflection coefficient of the antenna. Two different substrates are realized with different printing settings. Preliminary measurements show that when the load is increased, the resonant frequency of the antenna is shifted to lower values. Some considerations about the relation between printing parameters (infill density and infill pattern) and substrate deformation are also given.

Compact Superdirective Electric Dipole Array for Far-Field Measurement in a Semi-Anechoic Environment

Frederic Munoz (CEA LETI & University of Grenoble-Alpes, France); Serge Bories (CEA, France); Mathieu Caillet, Laurent Lombard and Jean-François Pintos (CEA-LETI, France)

This paper investigates the theory of superdirective arrays with electric dipoles as elements placed over a metallic reflector. A practical design of such antenna array is designed with a primary concern on the antenna compactness while keeping a relatively wide adaptation bandwidth. This antenna array, contained in a ka = 1.8 Chu sphere, shows a maximum directivity of 11.8 dBi at 80 MHz while being adapted over a 15.6 % fractional bandwidth. The proposed antenna is a good candidate for far-field

measurements in presence of specular reflection inside an anechoic chamber below its minimal working frequency.

Improved Hybrid Beamforming Algorithm for Fast Target Tracking in NTN-LEO and V2X Scenarios

Aral E. Zorkun, Miguel Salas-Natera and Ramón Martínez (Universidad Politécnica de Madrid, Spain)

Adaptive and smart antenna systems consist of adaptive processing algorithms and are used for noise mitigation and interference suppression, as well as, directing multiple beams simultaneously to distinct users. Such systems enable the implementation of Non-Terrestrial-Networks in future B5G/6G connecting a ground station of Low-Orbit-Satellite and Vehicular-to-Thing communications. In the presence of fast target tracking, improving the capabilities of adaptive processing algorithms in smart antenna systems is essential. Hybrid beamforming algorithm is a concept of blending two and/or more different beamforming algorithms to be used in this sense. This paper proposes an improved hybrid beamforming algorithm based on sliding window constant modulus and recursive least squares algorithm (CMARLS) with adaptive forgetting factor and variable regularization factor. It is observed that, the proposed algorithm outperforms conventional sliding window RLS and CMARLS algorithms in terms of convergence rate, interference, and target tracking.

A Compact Stand-Alone Circuit for GNSS-Antenna-Diversity

Emanuel Panholzer (University of the Federal Armed Forces Munich & Mercedes-Benz AG, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany); Wolfgang Schmidt (Universität der Bundeswehr München, Germany)

As a compact solution for GNSS antenna diversity in cars a compact diversity circuit is presented with integrated logics which is able to act independent from the receiver. The circuit enables a low-loss signal combination and phase alignment for two independent antenna paths. The function of the circuit is shown by way of simulations and laboratory measurements of a fabricated compact functional demonstrator. In real field measurements it is further shown that a significant increase in GNSS performance and especially in position accuracy is achieved.

Effective Use of Metamaterial Slabs in Enhancing the DGS-Based WPT System Performance

Zhanel Kudaibergenova, Kassen Dautov, Galymzhan Nauryzbayev and Mohammad Hashmi (Nazarbayev University, Kazakhstan)

The effective utilization of metamaterial slabs in the defected ground structure-based wireless power transfer (WPT) system performance improvement is reported in this work. WPT is designed to operate at practical 900 MHz and has transmitting and receiving resonators with a 20-by-20 sq. mm area. Furthermore, developed WPT demonstrated the power transfer efficiency of 57% when two resonators were separated by 19 mm. The MTM slabs, with the negative permeability property, were positioned in the middle between two resonators. In this context, it is imperative to note that MTMs were constructed using two different array configurations. As a consequence, the 2 × 2 and 3 × 3 arrays resulted in the efficiency enhancement of 64% and 68%, respectively.

Ku-Band Twisted Slotted Waveguide Antenna for Innovative "Plasma-Shaped" Cavity of Ion Sources

Giuseppe Torrisi, Giorgio Sebastiano Mauro and Angelo Pidatella (INFN-LNS, Italy); Gino Sorbello (University of Catania, Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy); David Mascali (INFN-LNS, Italy)

This paper reports about the measurements of a twisted slotted waveguide which will be used as microwave launching system for plasma heating in an innovative resonant cavity (plasma chamber) of ion sources. The proposed slotted waveguide antenna geometry smoothly matches the walls plasma chamber which has a peculiar shape based on the 3D structure of the plasma itself and in turn of the confinement magneto-static field. The complicated resulting structure has been 3D printed using the selective laser melting (SLM) technique which enables the possibility to fabricate complex shapes. The measured S11 parameter and radiation patterns confirm the goodness of the achieved manufacturing tolerances and precision, validating the numerical design.

Reconfigurable Half Mode Substrate Integrated Waveguide Phase Shifter

Franky Dakam Wappi, Bilel Mnasri and Halim Boutayeb (University of Quebec in Outaouais, Canada);

Larbi Talbi (University of Quebec - Outaouais, Canada)

In this work, we propose a novel phase shifter based on an eclectically reconfigurable half mode substrate integrated waveguide (HMSIW). The proposed structure uses a single PCB layer and does not require wire bounding for the bias circuit. Its principle consists in the integration, in the HMSIW, of several parallel lines, each of which is connecting the open edge of the HMSIW to a PIN diode and a radial stub. Simulation results are presented to validate the proposed concept. With the proposed design, for the two states of the PIN diodes (ON and OFF), broadband matching is obtained and a relatively constant phase difference is achieved in a broad frequency range.

Lateral Misalignment Sensor for Autonomously Guided Vehicles

Mahmoud Elgeziry, Filippo Costa and Simone Genovesi (University of Pisa, Italy)

In this paper, a lateral displacement sensor is pre- sented. The proposed sensor is based on a resonating tag in the shape of a Triangular Spiral Resonator (TSR) that is coupled with a rectangular probe that is the antenna of the reader. The sensing modality is based on the variation of the variation of the coupling strength due to a change in the displacement. The sensor has the advantage of single frequency operation as well as capability to detect the direction of displacement due to the asymmetric design of the tag. An envisioned application for the proposed is as a guidance sensor on-board Autonomously Guided Vehicles (AGVs). The design of the sensor is optimized using parametric design techniques, and the numerical results shows the potential of this sensing technique in guidance applications.

Co-Design Strategies for AFSIW-Based Remote Antenna Units for RFoF

Olivier Caytan, Igor Lima de Paula, Laurens Bogaert, Joris Van Kerrebrouck, Arno Moerman and Muhammad Muneeb (Ghent University, Belgium); Guy Torfs (Ghent University & Imec, Belgium); Johan Bauwelinck (Ghent University - imec, Belgium); Piet Demeester (Ghent University - iMinds, Belgium); Gunther Roelkens (Ghent University - imec, Belgium); Sam Lemey (Ghent University-imec, Belgium); Hendrik Rogier (Ghent University, Belgium)

This contribution discusses several recently proposed remote antenna units (RAUs) based on air-filled substrate-integrated-waveguide technology, specifically focusing on the co-design between antenna elements and optoelectronic transducers. These include two passive sub-6 GHz transmit RAUs and one active mmWave transmit RAU. It is concluded that the RAU's performance benefits from a thorough co-design, aiming for a conjugate-match between both components, when compared to a diakoptic design procedure, optimizing both components separately. Specifically, this approach resulted in a significant miniaturization of the sub-6 GHz RAU, while in case of the mmWave RAU, the efficiency was improved.

Autonomous Reconfigurable Intelligent Surface Based on Highly-Efficient Solar Cells

Anton Tishchenko (University of Surrey, United Kingdom (Great Britain)); Ali Ali (Institute for Communication Systems, United Kingdom (Great Britain) & University of Surrey, United Kingdom (Great Britain)); Ali Araghi (University of Surrey, United Kingdom (Great Britain)); Christopher P. Botham (BTexact, United Kingdom (Great Britain)); Fraser Burton (BT, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain))

The power consumption of reconfigurable intelligent surfaces (RIS) has not been addressed enough in the state-of-the-art. This paper proposes a paradigm for converting RISs into eco-friendly structures that generate their needed power by the high-efficiency multiple junctions (MJ) solar cells. This work considers the impact of adding solar cells to the RIS and investigates the amount of generated power. Moreover, the inclination angle of the solar irradiance is considered as well as the needed batteries and converters. Since the introduced RIS can be a potential candidate for the 5G-and-beyond-communications, two ranges of frequencies will be discussed in this work: sub-6GHz and 5G Millimeter wave (mmWave).

A Multi-Band Antenna with an Aesthetic Design for Ambient RF Energy Harvesting

Blagovest N Atanasov (Technical University of Munich, Germany); Nikolay T Atanasov and Gabriela Atanasova (South-West University Neofit Rilski, Bulgaria)

This paper presents a novel multi-band patch antenna with an aesthetic design for ambient RF energy harvesting applications. A new approach is applied to create antenna elements with unique shapes on a 3D-printed substrate for easy antenna integration into different objects. The measured results show that the proposed antenna provides three frequency ranges over which the reflection coefficient magnitude is below -10 dB of 1.71-1.80 GHz, 2.33-2.60 GHz, and 3.3-3.6 GHz. The antenna radiation patterns show that the antenna enables multi-direction harvesting from unknown RF sources. Moreover, the proposed antenna has been embedded in a 3D-printed flower pot. The results show that the embedded antenna has a robust input impedance when a flower is placed in the flower pot close to the antenna ground plane. These demonstrated properties of the proposed novel antenna with an aesthetic design make it an appropriate candidate for incorporation into next-generation IoT self-powered devices.

Bistatic Configuration Reading for Sub-Millimeter Displacement Chipless Tag Sensor

Raymundo Amorim (University Grenoble Alpes, Grenoble INP, LCIS, France); Romain Siragusa (Grenoble INP, France); Nicolas Barbot (University Grenoble Alpes, Grenoble INP, LCIS, France); Etienne Perret (Grenoble INP - LCIS, France)

A phase measurement technique for millimeter wave chipless tag μ-displacement sensor considering bistatic configuration is presented. For this purpose, a bi-static antenna configuration is employed, where the angle between the incident wave and the backscattered signal is chosen to increase the useful part of the tag signal. The displacements are analyzed along the 1D axis parallel to the alignment of the antennas. The validity and accuracy of the displacement method have been verified by moving the tag to different positions considering static antennas. The measured displacement deviations achieved based on the proposed approach are around 5 μm for a 30 μm step. It indicates precise and low-cost displacement chipless tag sensors for millimeter-wave applications.

Thursday, March 30 13:30 - 15:00

PE3: Poster Session on Electromagnetics III

/ / Electromagnetics

Rooms: Spadolini 103, Spadolini 104

Chairs: Vince Rodriguez (NSI-MI Technologies & University of Mississippi, USA), Felipe Vico (Universitat Politècnica de València, Spain)

Assessment of a Non-Hilbertian Inverse Scattering Approach for Electromagnetic Tomography in Subsurface Environments

Valentina Schenone, Alessandro Fedeli, Claudio Estatico, Matteo Pastorino and Andrea Randazzo (University of Genoa, Italy)

In this paper, a technique for the electromagnetic tomography of buried objects is proposed. More precisely, in the present approach a finite-element (FE) formulation of the electromagnetic problem is coupled with an inversion procedure performed in non-Hilbertian variable-exponent Lebesgue spaces to provide an image of the distribution of complex dielectric permittivity in the inspected subsurface environment. A test concerning a void-filled cylindrical target imaged by a set of waveguide antennas in a two-layer configuration has been performed to validate the method.

Microstrip Coupled Line Directional Coupler Design via Block-Based Microwave Training Kit

Umut Bulus (Antenom Antenna Technologies, Turkey)

This paper presents the design of a single section and multi-section microstrip coupled line directional couplers with the brick-based microwave component design methodology. The brick shaped metal and dielectric cells enable the design of microwave components directly in front of a network analyser. Students can calculate, design, build, measure and iterate their design easily in time-limited microwave laboratory classes. The measurement and simulation results with the free circuit simulator software

Qucs are compared throughout the paper. The design of brick-based microwave components in microwave laboratory lectures increases the microwave education quality.

Minimization of Channel Correlation Between Antenna Clusters

Vojtech Neuman, Miloslav Capek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Anu Lehtovuori (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

An existing method for maximization of the total efficiency of antenna clusters is modified so that the correlation between the channels can be suppressed while maintaining good balance of powers in different channels. This is achieved by setting additional constraints based on matrix description which control the system radiated power by means of weighted feeding coefficients. The developed theory is demonstrated on the example of four parallel dipoles forming two antenna clusters.

Millimetre-Wave Phase Shifting Metasurface Element Enabled by Air-Bridged Schottky Diodes with Enhanced Performance

Savvas Chalkidis, Evangelos Vassos and Alexandros Feresidis (University of Birmingham, United Kingdom (Great Britain))

A parasitic element coupling technique is applied within the framework of this paper in order to improve the response of a tunable split patch unit cell. The initial design comprises a split patch with a Schottky diode in contact with both patches, modifying the total impedance under various bias voltages. The paramount goal of the study presented in this paper is the mitigation of losses of the resonances and increase of tuning range by exploiting the presence in the unit cell of an additional parasitic non-resonant element. As a result, the unit cell exhibits double the tuning range of the initial design with lower losses. CST Microwave Studio was used to evaluate the proposed design's tuning range and reflection characteristics.

Microwave Imaging of Perfectly Conducting Objects

Gregory Samelsohn (Shamoon College of Engineering, Israel)

In this paper, a new algorithm for tomographic imaging of perfectly conducting scatterers, with boundary conditions of the Dirichlet or Neumann type, is proposed. The boundary value problem is converted into a volume integral equation with a singular double-layer potential. No approximations are made in the construction of the forward model and derivation of the inversion algorithm. Instead, some elementary facts of the microlocal analysis are used to recover the support of the scattering potential, and therefore, the shape of the obstacle. Mathematically, the problem is reduced to the Radon inversion of a classical computed tomography. It is shown that the algorithm is also capable of classifying the type (Dirichlet or Neumann) of the boundary condition imposed.

Accuracy Improvement of the Huygens' Principle-Based Method for UWB Microwave Imaging

Eliana Canicattì (University of Pisa, Italy & RaSS, CNIT, Italy); Navid Ghavami (Umbria Bioengineering Technology (UBT), United Kingdom (Great Britain)); Gianluigi Tiberi (London South Bank University, United Kingdom (Great Britain) & UBT - Umbria Bioengineering Technologies, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)

In recent years, microwave imaging has been recognized as a promising non-ionizing and non-invasive alternative for several medical applications, including breast cancer screening. To broaden the limits of microwave imaging, new research and novel techniques are necessary. In this paper, a new fitting approach for an efficient evaluation of Green's function in a specific medium and its application to a Huygens' Principle (HP)-based method for microwave imaging are discussed. We have demonstrated that a sum of sine fitting function allows us to accurately reconstruct a dielectrics homogeneity map of a cylinder containing an inclusion, achieving detection, localization and characterization of the inclusion size. Moreover, it significantly reduces image noise and artifacts. Validation of the novel methodology through analytical simulations has been performed and presented, illustrating the effectiveness of the methods.

Reconfigurable FSS Based on Movable 3D-Printed Metal-Dielectric Grids

Siyu Li, Peter M. Njogu, Benito Sanz-Izquierdo and Steven Gao (University of Kent, United Kingdom (Great Britain)); Zhijiao Chen (Beijing University of Posts and Telecommunications, China)

A reconfigurable frequency selective surface (FSS) based on movable 3D-printed grids is present in this paper. By moving the 3D-printed grid up and down in purposely made channels between two adjacent unit cells, a reconfigurable FSS with different frequency responses could be achieved. The FSS unit with channels and the insertable grids are first simulated and studied using Ansys HFSS. Then a 9 × 9 FSS array with channels is fabricated using standard etching techniques and milling. Finally, the FSS structure and the insertable grids are tested under various conditions. This work aims to demonstrate a new concept for the reconfigurable FSS based on movable metallic and dielectric grids. These are based on low-cost, high-flexibility, and ease-of-fabrication 3D printing technique, and provide a new path for designing reconfigurable FSSs by inserting and removing materials with different electrical properties to achieve different frequency responses.

Evaluation of Machine Learning Models for a Chipless RFID Sensor Tag

Nadeem Rather and Roy B. V. B. Simorangkir (Tyndall National Institute, Ireland); John Laurence Buckley (Tyndall National Institute & University College Cork, Ireland); Brendan O'Flynn (Tyndall National Institude, Ireland); Salvatore Tedesco (Tyndall National Institute, Ireland)

In this paper, for the first time, several regression-based machine learning (ML) models are evaluated to detect identification and sensing information for an RCS-based chipless RFID tag. The simulated EM RCS signatures containing an 8-bit identification code and six capacitive sensing values are evaluated. The EM RCS signatures are evaluated within the UWB frequency band from 3.1 to 10.6 GHz. A dataset of 1,530 simulated signatures with relevant features are utilised for model training, validation, and testing. Root mean square error (RMSE) is used as the quantitative metric to evaluate their performance. It is found that Support Vector Regression (SVR) models provide the minimum RMSE for the identification code. At the same time, Gradient Boosted Trees (GBT) regression model performed better in detecting the sensing information.

Investigating Low-Rank Approximations for the Finite Element-Boundary Integral Method

Niklas Wingren and Daniel Sjöberg (Lund University, Sweden)

This paper explores acceleration of the finite element-boundary integral hybrid method using the adaptive cross approximation. Our code implementing the hybrid method in Python based on open source packages is briefly presented. A simple one-level version of the adaptive cross approximation is described and it is used to accelerate the boundary integral matrices. We present results for scattering against a dielectric sphere with a comparison to analytical results for verification. We also present results for scattering against cylinders with varying length, where cylinders were selected as a simplification of wind turbine blades. Comparisons between a full matrix assembly and the acceleration method show that significant compression can be achieved, even with a simple acceleration scheme. We also present the monostatic radar cross-section for the largest cylinder computed for multiple angles of incidence.

Graphene-Based Radiofrequency Resonator for Non-Invasive Glucose Detection

Patrizia Savi (Politecnico di Torino, Italy)

This paper presents a radio-frequency (RF) sensor to detect glucose oxidase. At the core of the proposed approach is a graphene film deposited on a gap connected to a microstrip loop. The graphene film is doctor bladed on the gap. The film is then properly chemical functionalized in order to detect the presence of glucose. In this paper, we validate the proof-of-concept operation of glucose concentration detection by measuring the frequency shift of the reflection coefficient of the sensor.

Investigating the Use of Supervised Descent Method for Electromagnetic Imaging in PEC Enclosed Chambers

Seth J Cathers and Ian Jeffrey (University of Manitoba, Canada); Colin Gilmore (University of Manitoba & 151 Research Inc, Canada)

We consider the use of the Supervised Descent Method (SDM) for 2D transverse magnetic imaging inside perfect electric conductor (PEC) enclosed electromagnetic imaging problems. When the electromagnetic imaging region is surrounded by PEC,

and the background permittivity is lossless, classic optimization-based inversion algorithms such as Contrast Source Inversion sometimes provide degraded results compared to those obtained from unbounded domains. The SDM, by learning average search directions based on a large synthetic data set, may be able to avoid certain local minima that normally trap other optimization methods. Through the use of synthetic examples, we show that SDM can provide improved performance within an enclosed chamber.

Cycle-GAN-Based Calibration of Microwave Imaging Systems

Ben J Martin, Keeley Edwards and Ian Jeffrey (University of Manitoba, Canada); Colin Gilmore (University of Manitoba & 151 Research Inc, Canada)

An electromagnetic imaging system calibration method that uses a Cycle-GAN to convert (synthetically generated) uncalibrated microwave imaging system measurements to calibrated scattered field data is developed and applied to 2-D imaging data. The calibrated data are then successfully inverted using a U-net machine learning architecture trained with EMNIST targets, demonstrating that the Cycle-GAN successfully learns a transformation between simulated experimental field quantities and their true model counterparts. The performance of the presented method justifies further research on experimentally collected data.

Benchmarking Conformal BoR FDTD Algorithm for Efficient mm-Wave Design of Multiflare Antennas

Lukasz Nowicki (QWED Sp. z o. o., Poland); Lucas Polo-López (IETR-INSA Rennes, France); Juan Córcoles (Universidad Autónoma de Madrid, Spain); Jorge A Ruiz-Cruz (Universidad Autonoma de Madrid & Escuela Politecnica Superior, Spain); Malgorzata Celuch (QWED, Poland)

This work is concerned with the assessment of accuracy and efficiency of FDTD algorithms for the design of millimetre-wave horn antennas. Specific interest is in smooth-walled multiflare horns, which at such frequencies appear as promissing alternatives to corrugated horns, due to lower sensitivity to manufacturing tolerances and lower costs. Yet their modelling poses new challenges due to inclined or curved walls. We demonstrated that a conformal FDTD method in the Bodies-of-Revolution 2D formulation in cylindrical coordinates is specifically suitable for the task, retaining the geometrical flexibility of FDTD with the computational efficiency dedicated Method-of-Moment solvers.

An Accelerated PMCHWT-CBFM with Multipole Method for Dielectric Scattering Problem

Hyeong-Rae Im (Yonsei University, Korea (South))

In this paper, an acceleration method for electromagnetic scattering analysis of a dielectric object with numerical method when using characteristic basis. Multipole method is used to reduced matrix generation when PMCHWT and CBFM are combined. PMCHWT-CBFM with multipole method is developed theoretically. In case of a canonical model, time consumption is reduced when relatively small number of unknowns.

Scattering Analysis of Thin, Single-Layer Radiator with Parity, Time-Reversal, Duality Symmetry

Jan Kracek (Czech Technical University in Prague, Czech Republic); Enrica Martini and Stefano Maci (University of Siena, Italy)

Scattering analysis of a thin, single-layer radiator with parity, time-reversal, duality symmetry is discussed. The analysis is based on the network description of the radiator by a scattering matrix in conjunction with the transformation of its electromagnetic field by parity, time-reversal, and duality operators. The full-wave simulation of the radiator is also presented.

Thursday, March 30 13:30 - 15:00

Poster Session: Best Paper Awards

Rooms: Spadolini 105, Spadolini 106

Best Electromagnetics Award

"Analogous Electromagnetic Wave Propagation in a Schwarzschild Black Hole Space-time Using a Parallel Pair of Curved Conducting Surfaces", Enderson Falcón-Gómez (University Carlos III of Madrid, Spain); Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain); Adrian Amor-Martin (Universität des Saarlandes, Germany); Alfonso Gonzalez Jimenez (Universidad Carlos III Madrid, Spain); Valentin de la Rubia (Universidad Politecnica de Madrid, Spain); Gabriel Santamaria Botello (Universidad Carlos III de Madrid, Spain); Vittorio De Falco (Scuola Superiore Meridionale, Italy); Luis Enrique García Muñoz (Universidad Carlos III de Madrid, Spain).

"Investigations on the Low-Frequency Stability of Inverse Surface Source Field Transformations Based on the Electric Field Integral Operator", Bernd Hofmann (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany); Francesco P. Andriulli (Politecnico di Torino, Italy); Simon B Adrian (Universität Rostock, Germany).

"A Classical Electromagnetic Model for Thermal Emission from Ohmic Materials", Andrea Neto (Delft University of Technology, The Netherlands).

"Frequency-Domain Norton Resistance for Pulsed Photoconductive Antennas", Huasheng Zhang and Nuria LLombart (Delft University of Technology, The Netherlands); Angelo Freni (Università degli studi Firenze, Italy); Andrea Neto (Delft University of Technology, The Netherlands).

"On the Comparison between Local and Optimized Approach for the Design of a Beam-Tilting Metasurface", Federico Giusti, Enrica Martini, Stefano Maci and Matteo Albani (University of Siena, Italy).

Best Theory and Design Antenna Paper Award

"Metal-Only Reflect-Transmit-Array Unit Cell with Polarization-Dependent Performance", Angel Palomares-Caballero (Universidad de Granada, Spain); Carlos Molero (University of Granada, Spain); Juan Valenzuela-Valdés (Universidad de Granada, Spain); Pablo Padilla (University of Granada, Spain); María García-Vigueras (IETR-INSA Rennes, France); Raphael Gillard (IETR & INSA, France).

"Wideband mmWave Wireless Power Transfer: Theory, Design and Experiments", Chaoyun Song and Lei Wang (Heriot-Watt University, United Kingdom (Great Britain)); Zhensheng Chen (KU Leuven, Belgium); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium); Yi Huang (University of Liverpool, United Kingdom (Great Britain).

"Metasurface Antenna Enabling Dual Polarization Operation in Ka-Band", Ravikanth Thanikonda, Marco Faenzi, Alberto Toccafondi, Enrica Martini and Stefano Maci (University of Siena, Italy).

"Evaluation of a Dual-Circularly-Polarized Reflective Metasurface as a Plane Wave Generator in Ka-Band", Álvaro F. Vaquero (Universidad de Oviedo, Spain); Daniel Martinez-de-Rioja (Universidad Politécnica de Madrid, Spain); Manuel Arrebola (Universidad de Oviedo, Spain).

"Achieving wide-angle mechanical beam steering in Ka-band with low-profile Transmit-array antennas", Sergio Matos (ISCTE-IUL / Instituto de Telecommunicações, Portugal); Álvaro F. Vaquero and Manuel Arrebola (Universidad de Oviedo, Spain); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Nelson Fonseca (European Space Agency, The Netherlands).

Best Applied Technology Antenna Paper Award

"3D-Printed D-Band Lens Antenna with Gratings Matching Layer for Sensing Applications", Marta Arias Campo, Wolfgang Wischmann, Peter Uhlig, Oliver Litschke and Simona Bruni (IMST GmbH, Germany).

"Reconfigurable Transmitarrays at Ka-Band with Beam-Forming and Polarization Agility", Antonio Clemente and Reda Madi (CEA-Leti, France); Francesco Foglia Manzillo (CEA-LETI, France); Maciej Smierzchalski and Jacques Reverdy (CEA, France); Ronan Sauleau (University of Rennes 1, France).

"Lens-Antenna-Coupled MKIDs for Ultra-Sensitive Terahertz Spectral Imagers", Alejandro Pascual Laguna (SRON & Delft University of

Technology, The Netherlands); Juan Bueno (Delft University of Technology, The Netherlands); Stephen J.C. Yates and Lorenza Ferrari (SRON, The Netherlands); David Thoen (Kavli Institute of NanoScience, Delft University of Technology, The Netherlands); Dimitry Lamers, Vignesh Murugesan and Jochem Baselmans (SRON, The Netherlands).

"Novel Low-loss Coaxial Slot Array Based on Gap Waveguide Technology for E-band Automotive Radar Applications", Abbas Vosoogh (Gapwaves AB, Sweden); Abolfazl Haddadi (Gapwaves AB, Gothenburg, Sweden); Carlo Bencivenni (Gapwaves AB, Sweden).

"A 450-GHz Wideband On-Chip Antenna with an Extremely Low Profile", Shangcheng Kong, Kam-Man Shum and Chi Hou Chan (City University of Hong Kong, Hong Kong).

Best Measurement Paper Award

"Excitation Coefficient Determination for an Antenna Elevation Network Using Installed Performance Radiation Measurements", Bernd Gabler (German Aerospace Center (DLR), Germany); Alicja Schreiber (German Aerospace Center, Germany).

"MammoWave Breast Imaging Device: An International and Multicentric Clinical Investigation", Navid Ghavami (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Daniel Álvarez Sánchez-Bayuela (University Hospital of Toledo, Servicio de Salud de Castilla - La Mancha, Toledo, Spain); Lorenzo Sani, Alessandro Vispa and Alessandra Bigotti (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Mario Badia (UBT - Umbria Bioengineering Technologies, Italy); Lorenzo Papini (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Giovanni Raspa (UBT - Umbria Bioengineering Technologies, Italy); Soumya Prakash Rana (London South Bank University, United Kingdom (Great Britain)); Cristina Romero Castellano (Hospital Virgen de la Salud, Toledo, Spain); Daniela Bernardi (Humanitas Research Hospital, Milan, Italy); Alberto Tagliafico (University of Genoa, Italy); Massimo Calabrese (IRCCS Ospedale Policlinico San Martino, Genoa, Italy); Mohammad Ghavami (London South Bank University, United Kingdom (Great Britain)); Gianluigi Tiberi (London South Bank University, United Kingdom (Great Britain) & UBT - Umbria Bioengineering Technologies, Italy).

"Multi-Probe Array Design for Partially-Coherent Phase Retrieval in Near-Field Measurements", Jonas Kornprobst, Alexander Paulus, Josef Knapp and Thomas F. Eibert (Technical University of Munich, Germany).

"Measurement of the V2I Channel in Cell-free Vehicular Networks with the Distributed MaMIMOSA Channel Sounder", Eric P. Simon (IEMN CNRS UMR8520, France); Pierre Laly (University of Lille, France); Joumana Farah (Lebanese University, Faculty of Engineering, Lebanon); Emmeric Tanghe (Ghent University, Belgium); Wout Joseph (Ghent University/IMEC, Belgium); Davy P Gaillot (University of Lille, France).

"Analysis of Machine Learning Algorithms for USRP-based Smart Chipless RFID Readers", Fatima Villa-Gonzalez (Massachusetts Institute of Technology, Spain & Tecnun - University of Navarra, Spain); Jafait Junior Fodop Sokoudjou, Odon Pedrosa, Daniel Valderas and Idoia Ochoa (University of Navarra, Spain).

Best Propagation Paper Award

"Capacity Analysis for Time-Variant MIMO Channel Measurements at Low THz Frequencies", Johannes M. Eckhardt, Carla E. Reinhardt, Tobias Doeker, Eduard A Jorswieck and Thomas Kürner (Technische Universität Braunschweig, Germany).

"Development and Application of Advanced Experimental Techniques for Ground Microwave Radiometry in All Weather Conditions", Lorenzo Luini and Carlo Riva (Politecnico di Milano, Italy); Frank S. Marzano and Marianna Biscarini (Sapienza University of Rome, Italy); Luca Milani (European Space Agency, Germany); Domenico Cimini (CNR-IMAA & CETEMPS University of L'Aquila, Italy); Saverio Nilo (Consiglio Nazionale delle Ricerche, Italy); Antonio Martellucci (European Space Agency, The Netherlands).

"Measurement Validation of Ray-Tracing Propagation Modeling for mm-Wave Networking Studies: How Detailed is Detailed Enough?", Aron Schott and Aleksandar Ichkov (RWTH Aachen University, Germany); Petri Mähönen (RWTH Aachen University, Germany & Aalto University, Finland); Ljiljana Simić (RWTH Aachen University, Germany).

"Modeling the Drone-to-Drone Communications Channel for Urban Environments", Dennis Becker, Uwe-Carsten G. Fiebig and Lukas Marcel Schalk (German Aerospace Center (DLR), Germany).

"Channel Correlation and Stationarity in mm-wave V2V Channels", Joseph Hoellinger (CEA-LETI, Université Grenoble Alpes, France);

Gloria Makhoul (CEA-LETI & Université Grenoble Alpes, France); Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France); Thierry Marsault (DGA-MI, France).

Thursday, March 30 15:00 - 16:20

Invited Speakers: Jeff Guerrieri and Jun-Ichi Takada

Room: Spadolini 001

Chairs: Vittorio Degli-Esposti (University of Bologna, Italy), Katsuyuki Haneda (Aalto University, Finland)

15:00-15:40 Invited Speaker: **Jeff Guerrieri**

Title: **"Metrological Traceability"**

Abstract: Metrological traceability requires a documented, unbroken chain of calibrations to specified reference standards, including the stated measurement uncertainties. Ideally the references are national or international standards that are realizations of the measurement units of the International System of Units (SI). This makes the calibration traceable to the SI through an organization or laboratory, and not traceable to the organization or laboratory. Requirements and methods for establishing metrological traceability are defined in international: standards, laboratory accreditation cooperatives, and metrology organizations. With the intent to provide confidence in consistency and comparability of global measurements. The methods used for establishing traceability will be presented.

15:40-16:20 Invited Speaker: **Jun-Ichi Takada**

Title: **"Site-Specific Radio Channel Modeling in Cyber-Physical Wireless Emulator"**

Abstract: Design, evaluation, and verification of a large-scale wireless system with high accuracy is essential prior to the implementation. Stochastic channel models are utilized for the link level and system level simulations for the performance evaluation, and the exhaustive drive-testing method is deployed for the validation. The former technique can be applicable for intra-system evaluation, but not suitable for inter-system coexistence in the realistic scenarios. The latter technique is time and cost inefficient. A cyber physical wireless emulator is developed to overcome drawbacks of both of these approaches. It emulates the real-world wireless network scenarios in real-time, not only within cyber space but also with real or prototype radios via physical interface. Hence, scenario-based radio channel modeling framework is necessary for the implementation of the cyber-physical wireless emulator, which should have site-specific and system-independent features in either local/wide and stationary/dynamic scenarios, and which generates continuous and spatially-consistent channel responses.

This invited talk presents the concept of cyber-physical wireless emulator in brief, and explains how the dynamic channels are modelled within the real-time emulator in site- and scenario-specific manner, considering antenna directivity, multipath fading, shadowing by moving objects, death and birth of clusters, and large scale path loss. The work has been conducted under the contract JPJ000254 with the Ministry of Internal Affairs and Communications of Japan.

Thursday, March 30 15:00 - 16:20

Invited Speakers: George V. Eleftheriades and Yang Hao

Room: Spadolini 002

Chairs: Anthony Grbic (University of Michigan, Ann Arbor, USA), Richard W Ziolkowski (University of Arizona, USA & University of Technology Sydney, USA)

15:00-15:40 Invited Speaker: **George V. Eleftheriades**

Title: **"Huygens' Metasurfaces for Precise Antenna Beamforming and Beamsteering"**

Abstract: We will describe the concept of the Huygens' metasurface which comprise co-located electric and magnetic dipoles forming an electrically dense array of Huygens' sources or scatterers. These engineered surfaces can be designed to control electromagnetic waves at will. Unlike traditional antenna transmitarrays, Huygens' metasurfaces can be made sub-wavelength thin and deprived of spurious Floquet modes, while preserving excellent matching characteristics. Huygens' metasurfaces can be used to manipulate the phase, magnitude and polarization of incident electromagnetic waves, including those from nearby elementary antennas, for a variety of applications. For example, Huygens' omega bi-anisotropic metasurfaces enable wave refraction at extreme angles without any reflections. We will review progress of such Huygens' Metasurfaces for antenna beamforming and beamsteering. Examples to be discussed include high aperture efficiency/low-profile antennas, antenna aperture beamforming with simultaneous magnitude and phase control, and electronic beam steering.

15:40-16:20 Invited Speaker: **Yang Hao**

Title: **"Unlocking Potentials of LIS via New Material and Antenna Technologies"**

Abstract: A key technical challenge arising from industry is to develop autonomous and reconfigurable systems which integrate communication, sensing and computing functionalities, operating and delivering effects in contested domains. The talk will provide a summary of scientific research related to above objectives. I will describe our research in three themes, namely, material discovery and machine learning; smart materials fabrication and characterisation; large intelligent surface (LIS) and new antenna theories. Especially one of limiting factors in the design of LIS is the use of tunable materials. Currently, almost all LISs are designed based on conventional PIN diodes/varactors, a technology developed in 1970s, which cannot be readily scaled up for 6G. We have proposed a new concept of formula graph that unifies structure-based and structure-agnostic materials descriptors enabling us to design a general GNN architecture for materials property prediction.

Finally, the current design strategy of LIS and large antenna arrays was restricted to the topology with periodic, aperiodic, and random distributions. We have theoretically and experimentally reported that the array with hyperuniform disorder exhibits extraordinary directive emission and scanning features, while being scalable for extra-large arrays without any additional computational effort.

Thursday, March 30 16:20 - 16:40

Thursday, March 30 16:40 - 18:20

E11: Applications of Metasurfaces

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / / Electromagnetics

Room: Spadolini 001

Chairs: Enrica Martini (University of Siena, Italy), Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

16:40 ***Effects of Mismatch on IC-Equipped Programmable Metasurfaces***

Kypros Kossifos and Julius Georgiou (University of Cyprus, Cyprus); Marco Antoniades (Ryerson University, Canada)

Existing programmable metasurfaces (PMSFs) need significant steps for their commercialization. Integrated circuits (ICs) offer the potential to increase the functionality of PMSFs while reducing their cost and energy consumption. This approach requires a large number of ICs and entails significant challenges for the PMSF development. Statistical models of radio frequency (RF) and microwave (MW) components are not provided by the majority of commercially available semiconductor technologies, so their effects are usually tackled in an empirical manner. These RF and MW components are used for the loading of each unit cell within the PMSF, and the effects of component's mismatch cascades to the scattered far field of the PMSF. A study of the effects of mismatch on the scattered far field of an IC-equipped PMSF is presented. A correlation between the degradation of the

scattered far field and the components' standard deviation is shown.

17:00 ***An Upconverting Superheterodyne Metamaterial***

Douglas A Bowe (The University of Sheffield, United Kingdom (Great Britain)); Kenneth Lee Ford and Alan Tennant (University of Sheffield, United Kingdom (Great Britain))

A metamaterial capable of providing frequency conversion, through the use of a mixing effect, is presented. The metamaterial comprises of a square loop frequency selective surface (FSS) with embedded Schottky diodes, and a second layer which acts as a local oscillator for mixing purposes. An illuminating, plane wave, signal is converted to a number of high frequency harmonics providing an overall reduction, of the illuminating signal, of approximately 3dB. Numerical simulations are presented, along with prototype measurements which also demonstrate how the scattering pattern of the metamaterial can be modified due to the non-linear mixing effects.

17:20 ***Circularly Polarized Metasurface Lens Antenna for Millimeter Waves***

Cristina Yepes (Public University of Navarra (UPNA)); Fernando Teberio (Anteral, Spain); Andoni Marzo (Anteral S. L., Spain); Jorge Teniente-Vallinas (Public University of Navarra & Institute of Smart Cities, Spain); Miguel Beruete (Universidad Publica de Navarra, Spain)

This paper presents the design of a metalens based on the Pancharatnam-Berry (PB) principle applied to half-wave plate (HWP) metasurface allowing the manipulation of wavefronts with circular polarization conversion by rotating the elements that composed the metasurface. The metalens unit cell is designed at 132 GHz and is composed of two H-shaped aluminum elements printed on both faces of a thin polytetrafluoroethylene slab. The metalens is then combined with a wide-bandwidth circularly polarized horn antenna. The combined structure presents a gain 25.7 dB with an axial ratio below 1.5 dB over a bandwidth from 130.9 to 132.8 GHz.

17:40 ***Wideband Radar Cross Section Reduction Using Cubic Phased Metasurfaces in the Microwave Regime***

Mustafa Khalid Taher Al-Nuaimi (Loughborough University); William Whittow (Loughborough University, United Kingdom (Great Britain))

This paper presents the design of single layer metasurface for wideband radar cross section (RCS) reduction. The phase distribution across the proposed metasurface aperture is implemented using a cubic phase profile. The proposed cubic phased metasurface has a sub-wavelength periodicity. In addition, the unit cell was designed according to the Pancharatnam-Berry (PB) phase theory to make the proposed metasurface insensitive to the polarization of the incoming EM-wave which is very important for radar stealth application. When illuminated by far-field EM-plane waves, the proposed metasurface can significantly reduce the RCS by more than 10-dB from 10 GHz to 26 GHz. The proposed cubic phased metasurface severely diffused the backscattered energy in numerous angles in front of the metasurface. The fractional RCS reduction bandwidth (FBW) of the cubic metasurface is 88.8%, which is much wider than the FBW of metasurfaces in the literature.

18:00 ***Mechanically Tunable Capacitive Wire Media Sensor***

Dmytro Vovchuk (Tel Aviv University, Israel); Mykola Khobzei, Vladyslav Tkach and Mykhailo Apostolyuk (Yuriy Fedkovych Chernivtsi National University, Ukraine)

The paper is dedicated to the development of metamaterial sensing based on wire media (WM). While the WM is conventionally used for different devices taking into account its resonance properties, so-called Fabry-Perot, that are depended only on the length of wires, at the same time the Fabry-Perot resonances are quite sensitive to changing of wire radius and lattice period. Therefore, we suggest 4-by-4 WM-based capacitive sensing with first initiated time-variant WM detector. The capacitance tuning is caused by changing the physical sizes of WM, namely the lattice period. The suggested device supports detection of small displacements of large parallel dielectric bricks around WM from 10 to 50 mm with accuracy ~0.5 mm and is quite reliable that is proven by standard deviation value less than 1% from a set of repeated measurements. The suggested device is totally low-cost because the detector consists of widely accessible usual copper wires.

Thursday, March 30 16:40 - 18:20

A18: Antenna for Satellite Systems

T08 Space technologies, e.g. cubesats, satellite networks / / Antennas

Room: Spadolini 002

Chairs: Yann Cailloce (Thales Alenia Space, France), Ronan Sauleau (University of Rennes 1, France)

16:40 ***High-Gain Wideband Circularly Polarized Metasurface Antenna Array for C-Band Satellite***

Tuan-Anh Le Trong (Chungnam National University, Korea (South)); Quyet Nguyen Manh (Viettel Group, Vietnam); Tung Duong Thanh (Hanoi, Vietnam); Linh Le Kha (Viettel Company, Vietnam)

In this paper, a circularly polarized (CP) metasurface (MS) antenna array with high-gain and wideband for C-band Satellite is proposed. The array consists of 2×2 CP MS-based antennas fed with a sequential phase rotation feeding network. The proposed MS-based antenna array with an air gap exhibits compact size of 1.58λ0 × 1.58λ0 × 0.077λ0. Simulated and measured results show that the antenna array offers a wide impedance bandwidth (45.34%) for |S11|<-10 dB with a peak gain of 14.1 dBic, and a 3-dB axial ratio (AR) bandwidth of 34.34%. Moreover, the proposed array yields smooth gain response with a 3-dB realized gain bandwidth of 38.62%. The experimental results indicate good agreement with the simulation results.

17:00 ***Wideband Wide Scan Unit-Cell of a Connected Slot Array for SatCom Applications***

Mattia Maggi (Université de Rennes 1 & Centre National Etudes Spatiales, France); Rémi Fragnier and Romain Contreres (CNES, France); Ronan Sauleau (University of Rennes 1, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

This work introduces an improved wideband unit-cell for a connected slot array backed by a ground plane and loaded with artificial dielectric layers (ADLs). The unit-cell design includes a detailed feeding system for a single linear polarization with an integrated coaxial transition. Three capacitive elements are introduced in the design to reach a flat frequency response of the active impedance for a wideband behavior. The entire unit-cell design achieves an active voltage standing wave ratio (VSWR) below 3 over a 7.3:1 bandwidth, within a large field of view of 60° in elevation along the E- and D-planes.

17:20 ***A Reflectarray for CubeSat Applications***

Tonny Rubæk, Min Zhou, Andreas Ericsson, Mustafa Murat Bilgic and Erik Jørgensen (TICRA, Denmark)

A reflectarray has been designed and measured. The reflectarray is intended for use as downlink antenna on the 2-by-3 unit surface of 6U and 12U CubeSats in the X band from 8.025 GHz to 8.4 GHz. A main design requirement has been to minimize the internal volume in the CubeSat required to stove the antenna. The antenna design is based on a polarising reflectarray surface and is designed to work in the frequency band from 8.025 GHz to 8.4 GHz. The antenna has been manufactured and measured.

17:40 ***Novel Phased Array Terminal Antenna for M2M Satellite Networks***

Christian Steinmetz (Fraunhofer Institute for Integrated Circuits (IIS), Germany); Frank Mayer (Fraunhofer Institute for Integrated Circuits IIS, Germany); Mengistu Tessema (Fraunhofer Institute for Integrated Circuits, Germany); Hans Adel (Fraunhofer Institute for Integrated Circuits IIS, Germany)

This paper presents a novel phased array terminal antenna for machine to machine or internet of things type satellite networks in C-band. The proposed planar array consists of 25 circular polarized elements that are arranged in two concentric rings. Hemispherical beam scanning coverage with a high directive pencil beam is achieved with only a very limited set of phase shifts per antenna element. The phase shifts can be realized as switchable delay lines, instead of using expensive off-the-shelf phase shifter ICs. A fully functional array prototype consisting of a spacer PTFE plate, a top antenna circuit board and a bottom multi-layer feeding network circuit board was designed and manufactured. Measurements confirm the hemispherical beam forming capability.

18:00 ***A Compact RHCP and LHCP Antenna Array for L1 and L5 Band on a Satellite***

Azat Meredov (Universität der Bundeswehr München, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany)

A new, circularly polarized, and compact antenna array is presented for application on a satellite at L1 and L5 bands. The designed array antennas can be easily realized and they are mechanically stable to withstand harsh environmental conditions. The presented antennas have good dual-band matching, selectable RH and LH circular polarization, and decent gain at L1 and L5 bands. The measurement results of a fabricated antenna sample show its function and align well with the simulation results.

Thursday, March 30 16:40 - 18:20

CS26: Innovative Research on Millimeter-Wave and THz Radio Propagation Towards Beyond 5G and 6G

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 101

Chairs: Minseok Kim (Niigata University, Japan), Jun-ichi Takada (Tokyo Institute of Technology, Japan)

16:40 ***Measurement and Analysis of Radio Signal Propagation in and from Corridor at 300 GHz***

Anirban Ghosh (SRM University Amaravati, India); Riku Takahashi, Kosuke Shibata and Minseok Kim (Niigata University, Japan)

To realize the potential of the Terahertz band (0.1-10 THz) in providing high data rate, low latency, and improved reliability extensive measurement campaigns are the need of the hour. In this context, the current study presents the results from a first-of-its-kind measurement campaign conducted in corridor and from corridor to room at 300 GHz. The investigated positions consist of both line-of-sight and non-line-of-sight cases. The measurement data is processed to generate the power delay profile and environment-embedded azimuth delay power spectra for the positions under study. A careful analysis of the generated results helps in identifying the dominant specular components for each position using ray tracing. We further confirm the poor penetration property of signals at 300 GHz through regular building materials like concrete and plasterboard. The current results lay the foundation for more extensive analysis to develop a channel model for one of the common yet unexplored indoor scenarios.

17:00 ***Cluster Association for 3D Environment Based on 60 GHz Indoor Channel Measurements***

Hang Mi, Bo Ai and Ruisi He (Beijing Jiaotong University, China); Raied Caromi (National Institute of Standard and Technology, USA); Jian Wang (NIST, USA); Anuraag Bodi (National Institute of Standards and Technology, USA); Camillo Gentile (NIST, USA); Yang Miao (University of Twente, The Netherlands)

In this paper, we present a ray tracing (RT) assisted multipath cluster association method. This work is based on an indoor channel measurement at 60 GHz, where a LiDAR sensor was co-located with channel sounder and time-synchronized point cloud was captured to describe environmental information. Based on the point cloud, a 3D environment is reconstructed and fed into RT simulation. Then multipath components (MPCs) estimated from the measured channel and that from the RT are clustered, respectively. A novel cluster association algorithm is then proposed to associate the clusters between the measurements and RT. The interaction objects in the 3D environment can be found through this association. From cluster association results, we can better understand the relationship between measured radio channel, environment and channel characteristics in an automatic manner. As an example, the indoor multi-bounce scattering and composite channel parameters are investigated.

17:20 ***High-Accuracy and High-Speed Beam Tracking Algorithm for THz Short-Range Mobile Communication***

Hiromi Matsuno, Tatsuya Nagao and Takahiro Hayashi (KDDI Research, Inc., Japan)

This paper proposes each direction estimation and direction prediction algorithm. The direction estimation error of the proposed algorithm is reduced to 50% of the conventional algorithm. By utilizing the estimation results to the prediction, the prediction error is also reduced. Sweeping the predicted direction range, the proposed algorithm reduces the number of sweeps to 3.3% of the conventional algorithm

17:40 ***Synchronized Dynamic Channel Sounder and Posture Capture for Millimeter Wave Radio Channel Suffered from Human Body Shadowing***

CheChia Kang, Xin Du and Jun-ichi Takada (Tokyo Institute of Technology, Japan)

Millimeter wave (mmW) band has been deployed in the fifth generation (5G) mobile communication system to realize the enhanced mobile broadband (eMBB) service. Systems at mmW points the main beam of the base station to the line-of-sight (LoS) toward the mobile stations but suffer from a deep fading due to human blockage. To predict the impact due to human blockage, a synchronized measurement system including dynamic channel sounding and motion capture is needed. This paper proposes the synchronization method between 2 different types of instruments by using a bottom trigger as the reference of time. For validation, the measurement of dynamic channel and motion capture, and the prediction of the channel gain based on uniform theory of diffraction (UTD) were done. The results show that the proposal matching the time stamps well. The proposal provides a reliable synchronization of channel sounder and motion capture for developing dynamic channel model.

18:00 ***Terahertz Propagation Modeling for Office and Corridor Environments***

Hirokazu Sawada (National Institute of Information and Communications Technology, Japan); Takeshi Matsumura (National Institute of Information and Communications Technology (NICT) & Kyoto University, Japan); Keizo Inagaki and Atsushi Kanno (National Institute of Information and Communications Technology, Japan); Katsumi Fujii (NICT, Japan); Jerdvisanop Chakarothai (National Institute of Information and Communications Technology, Japan); Norihiko Sekine (National Institute for Information and Communications Technology, Japan); Akifumi Kasamatsu (National Institute of Information and Communications Technology, Japan); Hiroyo Ogawa (National Institute of Information and Communications Technolgy, Japan)

For the wireless communication systems in Beyond 5G era, utilization of the frequency range above 100 GHz is considered for high-speed transmission. Therefore, transmission loss models above 100 GHz will be required to design such sub-terahertz and terahertz wireless communication systems. In this paper, transmission loss coefficients in office and corridor environments are studied based on indoor propagation measurements at multiple frequencies from 232 to 330 GHz. Also, the parameters of the transmission loss model for office and corridor environments are extracted with reference to the site general model of ITU-R Recommendation P.1238-11.

Thursday, March 30 16:40 - 18:20

A05: Reflectarrays and Transmittarrays

T02 Mm-wave and THz cellular / / Antennas

Room: Spadolini 102

Chairs: Francesco Foglia Manzillo (CEA-LETI, France), Renaud Loison (IETR & INSA, France)

16:40 ***A Wideband Reconfigurable Reflectarray Based on Aperture Coupled Delay Line***

Peyman Aghabeyki, Zheng-Hua Tan and Shuai Zhang (Aalborg University, Denmark)

This paper presents a unitcell configuration for a wideband beam-steering reflectarray (RA). A rectangular patch is designed that is coupled through an H-shape slot to a spiral delay line. The substrate of the delay line is designed with Liquid Crystal (LC) layer. By applying a bias voltage between the delay line and slot-loaded ground plane, the permittivity of LC can be changed, and the concomitant change of electrical length can provide over 300º phase shift in a wide frequency range. The LC layer thickness is also reduced to 0.0042λ to improve the beam-steering speed. To overcome the issue of complex basing voltage implementation and still achieve a focused beam, a hybrid phase compensation for 1D beam-steering is proposed. The simulated results show that the main beam of the RA can be steered to ±60º and the maximum boresight gain reaches 19.5 dBi with 32% 3-dB gain bandwidth.

17:00 ***Low Profile Dual-Band Dual-Polarized Transmitarray Antenna for Satellite Communications***

Raffaele De Marco and Luigi Boccia (University of Calabria, Italy); Giandomenico Amendola (Università della Calabria, Italy); Emilio Arnieri (University of Calabria, Italy); Francesco Greco (Universita' delle Calabria, Italy); Arman Bordbar (University of Calabria, Italy)

A novel dual-band dual-polarized transmitarray antenna is presented. The antenna consists of 5 layers printed circuit board. At variance of previous designs, the proposed configuration is conceived without using air gaps; this leads to a low-profile structure. The designed unit-cell is dual polarized, and it works at 20 and 30 GHz exploiting an interleaved lattice configuration. At both bands, the phase of the transmitted field can be controlled in a range of 310 degrees, within a transmission loss above 3.5 dB. In order to validate the design, an 87×87mm2 transmitarray has been analysed with a maximum gain of 21.3 and 23 dB, respectively, at 20 and 30 GHz corresponding to an aperture efficiency of 33 and 25%. The -1dB gain bandwidth is 4.2 % for both bands.

17:20 ***Dual Circularly Polarized Reflectarray Antenna for High Throughput Links from Small Satellites***

Daniel Martinez-de-Rioja (Universidad Politécnica de Madrid, Spain); Borja Imaz-Lueje (Universidad de Oviedo, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain); Manuel Arrebola and Marcos R. Pino (Universidad de Oviedo, Spain)

A high-gain reflectarray antenna is proposed with dual-linear to dual-circular polarization conversion for small satellite missions in Ka-band. The reflectarray antenna consists of 42 × 42 reflectarray cells based on two orthogonal and stacked sets of three parallel dipoles. The unit-cell has been characterized to provide a suitable in-band performance. The polarizer reflectarray antenna has been designed cell by cell considering the real angles of incidence on each cell. The simulated radiation patterns show a remarkable operation, with less than 0.2 dB of losses due to the phase errors occurred during the design process and the dielectric losses at 28 GHz. The simulations show a highly satisfactory in-band operation, with at least a 2 GHz bandwidth with an axial ratio lower than 1.5 dB

17:40 ***Near-Field Shaped Transmitarray Antennas: Synthesis and Impact of Phase Quantization***

Sergio Menéndez Feito (University of Oviedo, Spain); Francesco Foglia Manzillo (CEA-LETI, France); Antonio Clemente (CEA-Leti, France); Manuel Arrebola (Universidad de Oviedo, Spain)

In this work, a procedure based on the Intersection Approach, is proposed to synthesize the near-field pattern of transmitarray antennas. First, the model for the computation of the amplitude and phase of the electric field in the near-field region is described and validated by comparison with full-wave simulations. Next, the proposed phase-only synthesis algorithm is detailed. Using fast Fourier transforms, it iteratively seeks for a feasible aperture phase profile that can fit near-field pattern constraints. The procedure is applied to synthesize a transmitarray generating a near-field shaped pattern on a plane parallel to the aperture. The impact of a uniform phase quantization on the near-field pattern and amplitude is analysed to provide design guidelines.

18:00 ***Design and Optimization of a Double Circular Polarization Large Deployable Reflectarray for Direct Broadcast Satellite in S-Band***

Andrea Guarriello (IETR & INSA Rennes, France); Daniele Bresciani (Thales Alenia Space, France); Renaud Loison (IETR & INSA, France); Juan-Antonio Duran-Venegas, Eric Labiole, Céline Leclerc, Renaud Chiniard and Olivier Bardel (Thales Alenia Space, France)

The design and the optimization of a large deployable reflectarray (RA) in S-band working in double circular polarization is presented. The optimization consists in directly adjusting the rectangular Phoenix cells distribution on the RA layout in order to minimize the residuals on the realized Gain and the cross-polar discrimination (XPD) on a large set of ground stations distributed on three geographic coverage regions. The optimized nine-panels RA shows a continuous and smooth layout. The RA performances on a narrow bandwidth are verified against strict requirements on the coverage areas and on a set of cities. Moreover, a comparison of the optimized RA with respect to a RA obtained through phase only synthesis and a theoretical shaped reflector is presented, showing enhanced performances of the optimized RA.

Thursday, March 30 16:40 - 18:20

E06: EM theory 1

T10 Fundamental research and emerging technologies / / Electromagnetics

Room: Spadolini 103

Chairs: Andrea Neto (Delft University of Technology, The Netherlands), Martijn van Beurden (Eindhoven University of Technology, The Netherlands)

16:40 ***A Classical Electromagnetic Model for Thermal Emission from Ohmic Materials***

Andrea Neto (Delft University of Technology, The Netherlands)

Rytov's impressed currents have been for 70 years the basis of modern radiometry. This paper clarifies that they are affected by an important unjustified assumption: they are characterized by zero cross correlation. However, at a close look, the demonstrations provided by Rytov, or by Landau around the same times, are less than water proof. Here, resorting to a rigorous Electromagnetic analysis we propose an expansion for the electromagnetic fields in lossy media in terms of quasi-orthonormal functions that verify Maxwell's equations. These functions naturally define the independent currents that can co-exist in a lossy medium: the degrees of freedom of the medium. An entirely classic model, with Johnson like thermal sources, emerges to estimate the radiated power from samples of ohmic materials. A high frequency cut off in thermal radiation is found to be dependent from the conductivity and the related scattering time.

17:00 ***Jordan Block Eigenvalue Shift in the Marching-On-In-Time Electric Field Integral Equation***

Petrus W. N. van Diepen, Martijn van Beurden and Roeland J. Dilz (Eindhoven University of Technology, The Netherlands)

The Marching-on-in-Time Electric Field Integral Equation (MOT-EFIE) and its time differentiated variant (MOT-TDEFIE) both suffer from the linear-in-time instability caused by dimension-two Jordan blocks in the companion-matrix representation. We prove that these Jordan blocks are centered around a specific eigenvalue that depends on the recurrence relation between the interaction matrices. By adapting the recurrence relation, we can move the pertaining eigenvalues of the Jordan blocks to the interior of the unit circle and therefore remove the linear-in-time instability from the scheme. We provide numerical evidence to further illustrate these findings.

17:20 ***Analogous Electromagnetic Wave Propagation in a Schwarzschild Black Hole Space-Time Using a Parallel Pair of Curved Conducting Surfaces***

Enderson Falcón-Gómez (University Carlos III of Madrid, Spain); Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain); Adrian Amor-Martin (Universität des Saarlandes, Germany); Alfonso Gonzalez Jimenez (Universidad Carlos III Madrid, Spain); Valentin de la Rubia (Universidad Politecnica de Madrid, Spain); Gabriel Santamaria Botello (Universidad Carlos III de Madrid, Spain); Vittorio De Falco (Scuola Superiore Meridionale, Italy); Luis Enrique García Muñoz (Universidad Carlos III de Madrid, Spain)

We demonstrate that a waveguide consisting in a Pair of Parallel Curved Conducting Surfaces can be used as an analogous electromagnetic model of the gravitational field generated by a Schwarzschild black hole. The influence of gravity on the propagation of electromagnetic waves is encoded in the curvature of the surfaces of the waveguide. The results obtained for the propagation of a one-dimensional Gaussian Beam by full-wave simulations show excellent agreement with the Schwarzschild geodesic structure. To the best of our knowledge, we highlight that this is the first time that an analogous electromagnetic model, based on this type of waveguide, has been proposed to reproduce the electromagnetic wave propagation within the gravitational field of a Schwarzschild black hole. This approach can be advantageously employed by the whole astrophysical community as a means to better inquire the propagation of electromagnetic waves inside the Schwarzschild gravitational field, as well as their interactions.

17:40 ***Bound on Q-Limited Super-Gain***

Laura Passalacqua, Enrica Martini and Stefano Maci (University of Siena, Italy)

The authors have recently derived a maximum bound of antenna super-directivity for a given frequency bandwidth linking the number of Degrees of Freedom (DoF) of the field to the corresponding number of spherical wave harmonics excited over the minimum sphere satisfying a bound on the quality factor Q. It is well known that a super-directivity does not always correspond to a super-gain, especially for high Q, due to the presence of losses. Studying the unconstrained super-gain for a spherical source system, it is seen that the amplitude spectrum of spherical harmonics needed to reach the super-gain limit has a gaussian-type shape concentrated around the harmonic whose radiation resistance equates the ohmic resistance, with non negligible excitation of higher order harmonics. Therefore, reaching the super-gain limit is very difficult in practice since it requires a strong excitation on the minimum sphere of reactive harmonics.

18:00 ***On the Use of the Volumetric Method of Moments for THz Applications***

Riccardo Ozzola, Jinglin Geng, Daniele Cavallo and Nuria LLombart (Delft University of Technology, The Netherlands); Angelo Freni (Università degli studi Firenze, Italy); Andrea Neto (Delft University of Technology, The Netherlands)

The analysis of dielectric lens antennas and the accurate estimate of the power emitted by warm bodies are important aspects for THz applications. To this purpose, a Volumetric Method of Moments (V-MoM) has been developed, allowing the simulation of non-homogeneous and dispersive materials and the characterization of multiple types of excitations, i.e., plane waves, discrete ports, and electric sources embedded inside the body, representing thermal sources. Moreover, the volumetric formulation allows filling the system matrix only once for a given mesh, allowing the method to be used efficiently in optimization loops. Thanks to the Conjugate Gradient-Fast Fourier Transform (CG-FFT), the memory requirements and the computational complexity are significantly reduced.

Thursday, March 30 16:40 - 18:20

A21: Antennas for Health Applications

T04 Biomedical and health / / Antennas

Room: Spadolini 104

Chairs: Marko Bosiljevac (University of Zagreb, Croatia), Milica Popović (McGill University, Canada)

16:40 ***An Optimization of a Circular Antenna Array for On-Body Communication***

Hanne Herssens and Arno Thielens (Ghent University, Belgium)

A non-uniform circular array wrapped around the waist is proposed for on-body communication with uniform on-body coverage at 5 GHz. To investigate the feasibility of such an array, we determined the path loss between such an array and on-body nodes using simulations and measurements on a cylindrical phantom and a real person. The number of array elements is varied to establish that uniform on-body coverage can be achieved. The best combination of array elements on a real person in terms of uniform on-body coverage is found with 4 elements distributed along the array, i.e., they were not found on one side of the body. A higher number of elements leads to a higher potential on-body gain, but also to a decrease in uniformity of the on-body coverage. These results are important for emerging WBAN applications that require uniform coverage of a large number of nodes spread over the human body.

17:00 *Textile Cardiopulmonary Antenna Design*

Tiago Cunha (Instituto Superior de Engenharia de Lisboa, Portugal); Pedro Pinho (UA - Universidade de Aveiro & IT - Instituto de Telecomunicações, Portugal); Caroline Loss (Universidade da Beira Interior, Portugal); Carolina T. S. Gouveia (Instituto de Telecomunicações, Aveiro & University of Aveiro, Portugal); Daniel Albuquerque (CISED - Polytechnic of Viseu, Portugal)

Vital signs monitoring is a crucial medical application to monitor the health status of a subject. The existing methods used so far are based on the usage of intrusive and rigid devices, such as the Holter monitors, which are uncomfortable for the subject. Textile antennas can be a solution since they are more comfortable and less intrusive for the user. This paper presents a textile antenna with slots designed to detect vital signs. The textile antenna was designed to operate at 433.92 MHz and close to a human body, being able to detect vital signs through the variation in the reflection coefficient phase of the antenna. The results obtained proved that the antenna is capable of detecting respiratory signs.

17:20 *Performance Degradation of an Uncooled Coaxial Monopole Antenna: A Preliminary Investigation of PTFE Expansion at Ablative Temperatures*

Federico Cilia, Lourdes Farrugia, Julian Bonello, Charles Sammut and Iman Farhat (University of Malta, Malta); Evan Dimech (University of Malta & University of York, Malta)

During microwave tumour ablation, the antenna's performance primarily depends on the material properties of the surrounding tissues. This is mainly due to the temperature-dependent dielectric permittivity and effective conductivity. Active cooling is commonly employed within microwave ablation applicators. However, there is emerging interest in uncooled applicators. This study shows how the elevated ablation temperatures will adversely impact the structure and, consequently, the performance of the coaxial-based uncooled antenna. It was determined that this is primarily catalysed by the thermal expansion of the Polytetrafluoroethylene (PTFE) dielectric, which decreased the antenna's return loss. Moreover, this investigation proposed an adequate ablation temperature operating region where the uncooled antenna structural changes will marginally affect its performance

17:40 *MIMO Radar Antenna with Sectorial Human Torso Illumination for an In-Cabin Breathing Detection System*

María-José López and César A Palacios (Technical University of Catalonia, Spain); Jordi Romeu (Universitat Politècnica de Catalunya, Spain); Luis Jofre (Universitat Politecnica de Catalunya, Spain)

The vital sign measurement systems inside vehicles have taken great or impulse in recent years, and the technologies that have been most welcomed are based on wireless measurements that do not interrupt driving and are imperceptible to the driver. There are disorders in breathing patterns, which include the movement of different regions of the human thorax mainly. In this sense, the objective of this paper is to determine the dimensions of a lens-based antenna system and the pointing angles of the radiation main lobe of the six antenna-elements to measure the elongation of six regions of the human torso and determine breathing patterns. The pointing angle is controlled by the position of the antenna behind the lens, and the beamwidth of the lobe depends on the directivity achieved by the antenna. An electronic system to simulate torso elongation is also presented to calibrate and test the sensitivity of the system.

18:00 *Design Strategy of Microwave Resonant Sensors with Stable Response for Blood Glucose Monitoring*

Antonio Cuccaro (Università degli Studi della Campania, Italy); Raffaele Solimene (Università degli studi della Campania Luigi Vanvitelli, Italy); Angela Dell'Aversano (Seconda Università degli Studi di Napoli, Italy); Giovanni Buonanno and Sandra Costanzo (University of Calabria, Italy)

Microwave signals have gained significant interest for emerging medical applications. An example includes blood glucose monitoring where the complex scenario can compromise an accurate sensing, due to a number of factors, such as system noise, environmental temperature, and all those factors affecting the dielectric properties of tissues (e.g., variation across people). In order to mitigate such a drawback, a modified patch resonator (2.3 GHz) with a solid "matching layer" interposed between a traditional microstrip antenna and the phantom under test, is presented. Numerical results confirm this solution allows to achieve a good trade-off between measurement stability and sensitivity, allowing to discriminate glucose concentrations in a broad range from 100 up to 350 mg/dL.

Thursday, March 30 16:40 - 18:20

P04: Channel simulations, measurements and emulation

T05 Aircraft (incl. UAV, UAS, RPAS) and automotive / / Propagation

Room: Spadolini 105

Chairs: Wout Joseph (Ghent University/IMEC, Belgium), Michael Walter (German Aerospace Center (DLR), Germany)

16:40 ***Validation of a Reproducible Semi-Virtual Driving Test Platform for C2X in Comparison with Real Driving Tests***

Anton Dobler (Universität der Bundeswehr, Germany); Emanuel Panholzer (University of the Federal Armed Forces Munich & Mercedes-Benz AG, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany)

For the investigation of Car to X (C2X) transmission systems a semi-virtual driving test platform is used which allows the comparison of alternative components in a fully reproducible virtual driving scenario. While the driving scenarios are performed via ray tracing in a virtual city model the transmitter and receiver are real hardware devices, leading to real measurement data for driving scenarios with different antenna mounting positions. In order to investigate the quality of such semi-virtual driving tests a measurement campaign has been performed where real test drives are compared with semi-virtual test drives for the same driving scenarios. It can be shown in comparison with the real driving tests, the recorded time history of received signal strength and error vector magnitude are in good agreement.

17:00 ***Low-Altitude Ground-UAV LoRa Path Loss over Mountainous Hills with and Without Snow***

Giulio M. Bianco (University of Roma Tor Vergata, Italy); Abraham Mejia-Aguilar (EURAC Research, Italy); Gaetano Marrocco (University of Rome Tor Vergata, Italy)

The low-power wide-area network (LPWAN) LoRa protocol has been recently proposed for enabling a new generation of search-and-rescue (SaR) systems. The use of unmanned aerial vehicles (UAVs) and systems (UASs) can further improve the effectiveness of such SaR devices. However, the path loss (PL) of ground-air (GA) LoRa links is still underexplored, even in the simplest case of LoS (line-of-sight) links. In this work, the LoRa GA PL, when the receiver is mounted on a UAV in the presence and absence of snow, is characterized in the particular case of mountainous hills. In both cases, the PL is higher than predicted by the free space (FS) single-ray model, and the snowy environment did not show a higher PL than the dry one. The new PL fits can be used to extend existing GA frameworks to describe the mountainous hills scenario.

17:20 ***Path Loss Modeling for Flying Ad-Hoc Networks: An Ensemble Learning Approach***

Vasileios P. Rekkas, Sotirios Sotiroudis and Achilles D. Boursianis (Aristotle University of Thessaloniki, Greece); Georgia E. Athanasiadou and George Tsoulos (University of Peloponnese, Greece); Christos Christodoulou (The University of New Mexico, USA); Sotirios Goudos (Aristotle University of Thessaloniki, Greece)

Several Machine Learning (ML) approaches have been proposed for path loss (PL) prediction in emerging fifth generation and beyond (5G/B5G) cellular communication networks. In the domain of next-generation high-availability communications, flying ad hoc networks (FANETs), which function as clusters of deployable relays or base stations for the on-demand extension of cellular coverage, represent a promising alternative. Thus, the highly accurate path prediction is crucial for the FANETs deployment and for emerging B5G wireless networks design, planning, and optimization. In this paper, we model the path loss in an urban environment for different heights using different ensemble learning approaches. More specifically, we apply five different boosting approaches are, as well a new ensemble model based on a stacked generalization technique for more robust and accurate predictions. The proposed ensemble approaches exhibit great accuracy and efficiency in predicting the path loss for FANETs deployment in cellular networks.

17:40 ***Channel Correlation and Stationarity in mm-Wave V2V Channels***

Joseph Hoellinger (CEA-LETI, Université Grenoble Alpes, France); Gloria Makhoul (CEA-LETI & Université Grenoble Alpes, France); Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France); Thierry Marsault (DGA-MI, France)

This paper investigates different methods to estimate the channel correlation properties over time for millimeter wave vehicle-to-vehicle channels. The proposed metrics are applied on three V2V scenarios measured at 26GHz. The correlation properties are derived from the Power Delay Profile and the Local Scattering Function. The results are then analyzed in terms of quasi-stationary time intervals obtained from each approach.

18:00 ***Impacts of Mutual Interference Analysis in FMCW Automotive Radar***

Utku Kumbul, Yue Chen and Nikita Petrov (Delft University of Technology, The Netherlands); Cicero S Vaucher (NXP Semiconductors, Eindhoven & Delft University of Technology, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands)

Mutual interference in the frequency modulated continuous wave (FMCW) radar is studied, and the influence of the FMCW interference on the beat frequency is analyzed. An analytical expression for the victim radar received signal spectrum is derived. Different interference scenarios are investigated by means of interference impact on the range-Doppler profile. It is shown that coherent interference concentrates within multiple range cells while non-coherent interference spreads the interference power over the whole range-Doppler plane.

Thursday, March 30 16:40 - 18:20

E10: Modelling and simulation of metasurfaces

T09 EM modelling and simulation tools / / Electromagnetics

Room: Spadolini 106

Chairs: Davide Ramaccia (RomaTre University, Italy), Marcello Zucchi (Politecnico di Torino, Italy)

16:40 ***Non-Uniform Spatially Dispersive Metasurfaces as Locally Linear Space Invariant (LSI) Systems***

Jordan R. Dugan, Joao Guilherme Nizer Rahmeier, Tom Smy and Shulabh Gupta (Carleton University, Canada)

A zero thickness model of uniform spatially dispersive metasurfaces was proposed and demonstrated in [1] and [2]. That method works due to the ability to treat uniform metasurfaces as linear space-invariant structures (LSI). Recently, in [3], this method was extended to non-uniform metasurfaces, with great success, by assuming the non-uniform surfaces can be treated as a locally LSI system. This paper provides a theoretical explanation with illustrative examples to support the validity of the local LSI assumption for an arbitrary average field around the surface

17:00 ***Characterization and Compensation of RIS Scattering Gain Loss Due to Electromagnetic Phase Roughness***

Luca Stefanini (Roma Tre University, Italy); Davide Ramaccia (RomaTre University, Italy); Alessandro Toscano and Filiberto Bilotti (Roma Tre University, Italy)

Fabrication process tolerances, mechanical deformation, temperature variation, dust accumulation are the main causes of alteration of the surface scattering response of a Reconfigurable Intelligent Surfaces (RIS). In this contribution, we study and fully characterize the reduction of the scattering gain when the electromagnetic reflection response of an RIS is not perfect as designed but affected by a random variation of its surface properties. Here, we assume unitary reflection and a random variation applied to only the phase profile. The proposed characterization, together with the wireless propagation models, allows estimating the worst achievable performances in terms of channel capacity and coverage area when a generic realistic RIS is assumed to be present in the smart electromagnetic environment. A compensative design strategy is here discussed and provided to mitigate the observed scattering gain loss.

17:20 ***Analytic Modelling 3D Fully-Dielectric Metamaterials***

Miguel Angel Balmaseda-Marquez (University of Granada, Spain); Guido Valerio (Sorbonne Université, France); Carlos Molero (University of Granada, Spain); Angel Palomares-Caballero (Universidad de Granada, Spain); Pablo Padilla (University of Granada, Spain)

This paper presents a novel type of characterization for 3D fully-dielectric unit cell. The unit cell structure is formed by a block of dielectric with different insets of air on it. The performed characterization is carried out up to the frequency where the electric-size of the unit cell is lambda/2. Based on the results obtained in simulation, design equations for the effective permittivity can be extracted for the two different dielectric unit cell designs. Using equivalent circuit, several arrangements of dielectric unit cells have been modelled. The results obtained with the circuit models are in good agreement with the simulated S parameters in a wide frequency range.

17:40 ***Broadband Waveguide Characterization of 3D-Printed Anisotropic Dielectric Crystals***

Simon P Hehenberger (DLR- German Aerospace Center & TU Delft, Germany); Stefano Caizzone and Stefan Thurner (German Aerospace Center (DLR), Germany); Alexander Yarovoy (TU Delft, The Netherlands)

Additive manufactured structured dielectrics with engineered permittivity tensors are promising tools for novel microwave components and are drawing increasing attention from researchers. However, design modeling and experimental verification of anisotropic materials are challenging and have not yet been thoroughly explored in the literature. In this work, a design approach based on superimposed spatial harmonics for the design of anisotropic lattices called dielectric crystals is used. Furthermore, the plane wave expansion method (PWEM) is identified as a powerful tool for modeling the effective permittivity tensor. A wideband material characterization measurement setup based on rectangular waveguides is utilized for experimental verification. Experiments with uniaxial anisotropic dielectric crystals are carried out and are shown to be in satisfying agreement with our theoretical modeling.

18:00 ***1-D Broadside-Radiating Leaky-Wave Antenna Based on a Numerically Synthesized Impedance Surface***

Lucia Teodorani and Marcello Zucchi (Politecnico di Torino, Italy); Rossella Gaffoglio (Fondazione LINKS, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

A newly-developed deterministic numerical technique for the automated design of metasurface antennas is applied here for the first time to the design of a 1-D printed Leaky-Wave Antenna (LWA) for broadside radiation. The surface impedance synthesis process does not require any a priori knowledge on the impedance pattern, and starts from a mask constraint on the desired far-field and practical bounds on the unit cell impedance values. The designed reactance surface for broadside radiation exhibits a non conventional patterning; this highlights the merit of using an automated design process for a design well known to be challenging for analytical methods. The antenna is physically implemented with an array of metal strips with varying gap widths and simulation results show very good agreement with the predicted performance.

Thursday, March 30 16:40 - 18:20

CS34: Novel Antenna Measurement Techniques and Data Analysis

T10 Fundamental research and emerging technologies / Convened Session /

Room: Spadolini 107

Chairs: Dennis Lewis (Boeing, USA), Janet O'Neil (ETS-Lindgren, USA)

16:40 ***Near-Field Far-Field Transformations with Unknown Probe Antennas***

Alexander Paulus (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

The characterization of unknown antennas under test (AUTs) from measurements of the radiated near field (NF) is commonly performed with known probe antennas. By accounting for the behavior of a given probe in the processing of the NF data, the obtained quantities of interest, e.g., the far-field (FF) behavior of the radiator, are free of biases and distortions caused by the probe sensor. We discuss an NF FF transformation (NFFFT) which can fully compensate the effect of the probe, while only requiring knowledge about its electrical size, position, and orientation. An iterative nonconvex technique based on alternating projections is discussed, as well as a convex approach utilizing bilinear forms is provided. Connections to the related problem of phase retrieval are highlighted. Simulation results showcase the validity of NFFFTs with full probe correction of unknown probes and shed some light on potential limitations.

17:00 ***Determination of Antenna Displacement from a Single Cut Quasi-Farfield Pattern for Cylindrical Mode Filtering Applications***

Zhong Chen and Yibo Wang (ETS-Lindgren, USA); Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain))

In the quasi-far-field, the tangential orthogonal electric field components are decoupled, which means that only the co-polarized field component is sufficient to transform antenna patterns to the cylindrical mode domain. When the antenna pattern is measured with a displacement from the center of rotation, a mathematical translation to the center of rotation promotes mode separation between the modes of the antenna and those of the chamber reflections. A mode filter can then be applied to remove effects due to chamber multipath reflections. In this scheme, an accurate measurement of the displacement distance from the rotation center is essential. We investigate several techniques to automatically retrieve the requisite offset distance using the vector pattern data, including using: the unwrapped phase response, through time domain transformation, and by examining mode concentration within the spectrum domain. Each method is studied for its robustness, limitations and efficiency in accurately determining the displacement distance.

17:20 ***An Experimental System for the Measurement of Electromagnetic Propagation on Curved Surfaces***

Michal Cerveny, Alan Tennant and Kenneth Lee Ford (University of Sheffield, United Kingdom (Great Britain))

Practical measurements of electromagnetic propagation around the circumference of large cylinders is difficult due to the dimensions of such a setup. This paper presents a new measurement approach where a large cylinder was replaced with a small section of a curved surface, yet maintained the large radius. To mitigate the unwanted edge effects, a time-gating technique was used. Two specially designed wideband horn antennas were designed and manufactured. The presented setup allows the measurement of different types of materials, such as metamaterials, that can either support or reduce propagation along the curved surface. The entire setup was modelled using a full-wave electromagnetic simulator and experimentally verified.

17:40 ***Comparison of Spherical Wave Expansion and Source Reconstruction Method for Near-Field to Far-Field Transformation***

Narjes Jalali (Helmut Schmidt Universität / Hamburg, Germany); David Ulm (Physikalisch-Technische Bundesanstalt, Germany); Marcus Stiemer (Helmut-Schmidt-Universität, Germany); Thomas Kleine-

Ostmann (Physikalisch-Technische Bundesanstalt (PTB), Germany)

There are two widely used classes of algorithms to determine the far-field properties of antennas from near-field measurements: modal expansion, e.g., spherical wave expansion and source reconstruction. In this paper, the robustness of both approaches with respect to typical uncertainty contributions to the near-field data is assessed based on real measurements. Particularly the influence of incomplete probe correction and multipath propagation are considered exemplarily.

18:00 ***Revisiting the Location of Phase Center of Reflector Antennas***

Yahya Rahmat-Samii (University of California Los Angeles (UCLA) & UCLA, USA)

The aim of this paper is to provide insights into the location of phase center of reflector antennas. Analytical equations that can provide an initial estimate of the phase center are revisited and the dependency of the phase center on the reflector geometry (aperture diameter, focal length and offset height) are highlighted. These formulations, however, do not account for several factors such as the illumination characteristics, wavelength of operation, feed position, etc. In this work, the analytical equations are improved to incorporate the effect of feed illumination taper. The effectiveness of these equations are then assessed by employing Particle Swarm Optimization (PSO) to optimize the phase center based on the far-field data generated via full-wave simulations.

Thursday, March 30 16:40 - 18:20

A25: Fundamental research on Antennas II

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 108

Chairs: Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium), John L. Volakis (Florida International University, USA)

16:40 ***On the Radiation of a Longitudinally-Polarized Bessel Beam in a PEC Cylindrical Cavity***

Santi Concetto Pavone (Università degli Studi di Catania, Italy); Loreto Di Donato and Gino Sorbello (University of Catania, Italy)

This contribution deals with the evaluation of effects of a cylindrical metallic cavity on the radiation of a planar longitudinally-polarized Bessel beam launcher, and it is related to applications of nondiffractive waves to microwave heating or plasma excitation. A full analytical model is developed to extract fundamental physics insight of the problem at hand. Full-wave numerical simulations by COMSOL Multiphysics have been adopted to validate the proposed model, showing fair agreement between simulations and theoretical predictions.

17:00 ***Characteristic Mode Analysis of a 3U CubeSat for VHF Communications***

Thao Manh Nguyen (Université Côte d'Azur & LEAT, France); Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France); Vincent Laquerbe (CNES, France)

This paper presents the Characteristic Mode Analysis (CMA) of a 3-unit CubeSat structure with deployable solar panels. The satellite structure is analyzed to find the dominant as well as higher-order modes in the VHF band (150MHz). The far fields of the significant radiating modes are simulated and analyzed for potential use in future CubeSat missions. The combination of two dominant modes can be used to provide a wide beam width circularly polarized radiation pattern at 150MHz.

17:20 ***An Antenna with a Modulated Self-Complementary Metasurface Ground Plane for GPS Application***

Kirill Klionovski, Enrica Martini and Stefano Maci (University of Siena, Italy)

Global Positioning System (GPS) base station antennas should have a quasi-isotropic radiation pattern in the upper hemisphere and provide almost zero radiation in the bottom hemisphere for positioning error reduction. Usually, a base station GPS antenna consists of an omnidirectional antenna element and a ground plane, which suppresses the back radiation. However, along with the back radiation suppression, a ground plane makes the radiation pattern in the upper hemisphere narrower. To avoid this negative effect of a ground plane, we propose the use of a modulated self-complementary metasurface ground plane. As an antenna element, we use a three-dipole antenna with quasi-isotropic radiation and circular polarization patterns. We demonstrate that the antenna with a modulated self-complementary metasurface ground plane provides quasi-isotropic radiation and polarization patterns in a required angular sector. For the purpose of back radiation suppression, we use a semitransparent cylindrical surface located near the ground plane's edge.

17:40 ***Analysis of GRIN Lenses with PEC Elements Using a 2D Cylindrical Electromagnetic Solver***

Vincent Kaschten, Dimitri Lederer and Christophe Craeye (Université Catholique de Louvain, Belgium)

We propose a mathematical formulation for studying the 2D propagation of electromagnetic waves throughout a cylindrical GRIN lens, when the source is located inside the lens. The lens can contain electrically small cylindrical PEC elements, whose effect on the propagation can be analyzed.

18:00 ***Utilizing the Effects of Interactions Between Multiple Time-Varying Elements on Antennas***

Stephen F Bass (University of Illinois at Urbana-Champaign, USA)

Recently, time-varying (TV) antennas have become a common path of research in an attempt to improve antenna performance beyond the linear, time-invariant (LTI) limits, but generally only implemented a single TV load in their design. Utilizing multiple TV loads could allow for more control over generated frequencies and their impact on antenna performance. The conversion matrix method combined with the method of moments (CMMoM) has previously been shown to accurately model TV components on electromagnetic structures by allowing for a network representation of the TV system. This method has been implemented in several aspects of antenna design, such as radiated power, fundamental bounds, and the effect of a single TV load, but the interactions between multiple TV structures have not been fully explored. This work seeks to provide a better understanding of how TV loads interact with each other and how the interactions can be leveraged to improve antenna performance.

Thursday, March 30 16:40 - 18:20

E15: Analysis, desing and application of metasurfaces

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / / Electromagnetics

Room: Spadolini 109

Chairs: Francesco Foglia Manzillo (CEA-LETI, France), Sergei Tretyakov (Helsinki University of Technology, Finland)

16:40 ***Analysis of Huygens' Metasurfaces for the Design of Transmit-Reflect Arrays***

Alessio Berto (CEA & Sorbonne Université, France); Francesco Foglia Manzillo (CEA-LETI, France); Guido Valerio (Sorbonne Université, France)

In this article, we propose a rigorous approach to determine the surface parameters of Huygens' metasurface cells for the design of high-efficiency transmit-reflect arrays. We demonstrate that the power of a normally incident plane wave can be evenly split into the transmitted and reflected ones, and that, at the same time, arbitrary phase shifts can be introduced on the scattered waves. As a proof of concept, four cells realizing a uniform 2-bit quantization of the phase range, in transmission and reflection, are designed. Each cell comprises two dielectric slabs and three impedance sheets which are derived from the optimal surface parameters. Moreover, the bandwidth performance are preliminarily assessed.

17:00 ***A 3D-Printed Holographic Impedance Surface for Sub-THz Enabled by Transmission Line***

Method

Ming Yao, Peng Mei, Gert Pedersen and Shuai Zhang (Aalborg University, Denmark)

The eigenmode method is typically leveraged to determine the dispersion characteristics of the element for holographic impedance surface (HIS), i.e., the relation between surface impedance and the element geometry of a HIS. This relation is based on curve fitting according to the extensive simulation samples, which is time-consuming due to the great number of simulations needed to ensure accuracy, especially for high-frequency bands (e.g., sub-THz or THz). As the sub-THz and THz frequency spectra are promising for 6G wireless communications, an effective method is highly demanded to significantly reduce the holistic design period. To this end, the transmission line method is proposed to directly formulate the relation between the surface impedance and the element geometry, which highly reduces the design complexity and time. To proof the concept, a 3D-printed HIS enabled by the proposed TL method is demonstrated. The performance of the proposed HIS has been verified with full-wave simulations.

17:20 ***Metamaterial Absorber for Multipath Reduction in Navigation Applications***

Ramy A. Gerguis (German Aerospace Center DLR, Germany); Stefano Caizzone (German Aerospace Center (DLR), Germany)

Reference stations for (satellite or terrestrial) navigation are often showing performance reduction due to multipath effects, provoked by reflecting objects in their vicinity (buildings, vegetation, big telemetry antennas at spaceports, ...). Solutions capable to selectively minimizing these reflections without needing a system redesign nor implying substantial loss in coverage for not-affected directions are therefore strongly needed. This paper describes the design, measurement and test of a metamaterial-based absorber to be used to selectively reduce the antenna pattern in specific directions and hence minimize multipath errors in navigation applications.

17:40 ***Full-Space Metasurface at Millimeter-Wave Frequencies***

María Ruiz (Public University of Navarra, Spain); Miguel Beruete (Universidad Publica de Navarra, Spain); Asier Marzo (Public University of Navarra, Spain)

Conventional metasurfaces provide control over the electromagnetic waves in a single working frequency operating either in transmission or reflection. Full-Space Metasurfaces (FSM) are an extension that allows operation at two erent frequencies with independent functionalities in transmission and reflection. This paper presents a gradient index FSM device based on a 3-layered unit cell where the phase modulation is implemented following the Pancharatman-Berry (PB) principle. The device is designed to operate at millimeter waves, with the lowest frequency operating in reflection and the highest one in transmission. To check the structure performance, a metasurface was designed to provide beam steering in reflection at 49.4 GHz and an amplitude image hologram in transmission at 104 GHz.

18:00 ***A Preliminary Study of a Conformal Electromagnetic Metasurface for Brain Tumor Detection***

Martina Falchi and Danilo Brizi (University of Pisa, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)

We introduce a radiofrequency system for brain tumor detection, where a conformal metasurface is employed, by opportunely modifying the classical planar structure. The proposed system, working at 3 MHz, consists in a 5×5 matrix whose unit-cells are made of 8-turn spirals, excited by an active RF coil placed in its near-field region. The detection of the tumors is carried out by observing the amplitude variation and the frequency shift of the driving coil input impedance. By performing accurate full-wave simulations, we demonstrated that, by designing the metasurface in order to produce a 5-spot magnetic field distribution, it is possible to detect and spatially identify brain tumor malignancies, despite the extremely low frequency herein adopted. The findings suggest that the conformal near-field focused metasurface is able to detect inclusions as small as 1 mm, demonstrating excellent sensitivity and spatial resolution.

Thursday, March 30 16:40 - 18:20

SW10b: Stand on the IEEE Antennas & Propagation Standards

(continued)

Organized by: Vikass Monebhurrun (CentraleSupélec); Lars Foged (MVG-World); Jeff Fordham (AMETEK); Vince Rodriguez (AMETEK)

Room: Sala della Scherma

16:40 - Near-Field Antenna Measurement Standard (IEEE Std 1720-2012) (Lars Foged, MVG-World)

17:25 - Computational Electromagnetics Standard Development (IEEE P2816) (Vikass Monebhurrun, CentraleSupélec)

Thursday, March 30 16:40 - 18:20

Student Paper Award

Room: Polveriera

- "Anisotropic Metagratings for Simultaneous Polarization Conversion and Anomalous Reflection", Sharon Elad and Ariel Epstein (Technion - Israel Institute of Technology, Israel).
- "A Cylindrical, Metasurface-Based, Azimuthally-Symmetric Beam-Shaping Shell", Chun-Wen Lin (University of Michigan - Ann Arbor, USA); Richard W Ziolkowski (University of Arizona, USA & University of Technology Sydney, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA).
- "A Closed-Form Solution for the Synthesis of the Excitations of a Plane Wave Generator", Francesco Lisi and Paolo Nepa (University of Pisa, Italy).
- "Nonlinear FDTD Simulation of Optical Thin Films with Intensity-Dependent Drude-Lorentz Parameters", Joao Guilherme Nizer Rahmeier, Tom Smy and Shulabh Gupta (Carleton University, Canada).
- "A Novel High-Order Spectral Element Method for the Analysis of Cylindrical Waveguides Filled with Complex Anisotropic Media", Raul Oliveira Ribeiro (Pontifical Catholic University of Rio de Janeiro, Brazil); Jose R Bergmann (PUC-Rio, Brazil); Fernando Teixeira (The Ohio State University, USA); Guilherme Simon Rosa (Pontifical Catholic University of Rio de Janeiro, Brazil).

Thursday, March 30 16:40 - 18:20

ESoA: ESoA WG Meeting

Room: Sala Arco

Friday, March 31 9:00 - 10:40

CS31: Metagratings, Sparse metasurfaces, and beyond-homogenization design schemes

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: George V. Eleftheriades (University of Toronto, Canada), Ariel Epstein (Technion - Israel Institute of Technology, Israel)

9:00 ***Anisotropic Metagratings for Simultaneous Polarization Conversion and Anomalous Reflection***

Sharon Elad and Ariel Epstein (Technion - Israel Institute of Technology, Israel)

We present a semi-analytical framework for designing highly efficient polarization and wavefront manipulating metagratings (MGs). The required anisotropy is achieved by introducing rotated dipole scatterer lines as meta-atoms in these sparse periodic composites, using an extended analytical model to capture the polarized near- and far-field interactions between the elements. By tying the MG degrees of freedom, namely, the meta-atom rotation angle, position, and induced current, to the scattered fields, this model enables resolution of the MG configuration that would realize a given (desirable) combined polarization conversion and anomalous reflection. This approach, verified in commercial solvers, presents an appealing alternative for tensor metasurfaces typically utilized to realize such functionalities, featuring simpler meta-atoms, sparser designs, and minimal reliance on full-wave optimizations. These results further augment the range of MG-based solutions, marking an important milestone towards achieving a complete control of scattered fields via this platform.

9:20 ***Multi-Input Multi-Output Beamforming with Single Layer Impedance Metasurfaces***

Vasileios G. Ataloglou, Jean Louis Keyrouz and George V. Eleftheriades (University of Toronto, Canada)

Metasurfaces can shape electromagnetic wavefronts at will with electromagnetically thin structures. In this paper, we discuss metasurfaces, consisting of an impedance layer above a grounded substrate, that handle multiple inputs simultaneously. When combined with embedded sources, such surfaces can radiate highly-directive beams at prescribed directions. On the other hand, when illuminated by incident plane waves, they can manipulate the direction and far-field pattern of the reflected radiation. Both scenarios are examined for a dual-input operation with the aim of producing highly-directive beams for both inputs. Full-wave simulations, where the metasurface is implemented with realistic copper traces, are performed to verify the desired dual-input operation.

9:40 ***Perfect Control of Reflection Using Aperiodic Arrays***

Yongming Li and Xikui Ma (Xi'an Jiaotong University, China); Grigorii Ptitcyn and Sergei Tretyakov (Aalto University, Finland)

In this study, we present a novel method to design anomalous reflectors using arrays of loaded strips. To cancel specular reflection and create the reflected wave propagating toward the desired direction, we assume two different sets of induced polarization currents flowing on the surface. Directly calculated loads in this case have real and imaginary parts. To obtain purely reactive loads we tune surface waves by optimizing the current distribution. Inserting additional loaded strips within a ~ $\lambda/2$ cell of the structure, we obtain the necessary freedom for optimization. The results show that perfect anomalous reflections have been realized. We compare of the obtained results with the conventional reflectarray based method and demonstrate a clear improvement.

10:00 ***Passive and Lossless, Closed Metasurfaces for Illusion Electromagnetics***

Jordan Budhu (Virginia Tech, USA); Luke J Szymanski (University of Michigan, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

A two stage algorithm for the design and optimization of three-dimensionally contoured metasurfaces is presented. The first stage involves integral equation modeling and a moment method solution resulting in a local active/lossy design. The second stage involves optimization. It uses the gradient descent method and a semi-analytic gradient calculation using the adjoint variable method to obtain a non-local passive/lossless metasurface design with identical far field performance to the local active/lossy design. An example of an electromagnetic illusion is presented for a cubical metasurface which scatters the fields of a PEC sphere.

10:20 ***Conformal Sparse Metasurfaces for Controlling Scattering Cross Section***

François Villamizar, Cedric Martel, Sylvain Bolioli and Fabrice Boust (ONERA, France); Shah Nawaz Burokur (LEME, France)

In this work, sparse metasurfaces are proposed to reduce the scattering cross section (SCS) of metallic cylinders illuminated by a plane wave. The design methodology of the sparse metasurfaces is based on the numerical calculation of Green's functions. The diameter of the metallic cylinders is of the order of the wavelength at the operating frequency of 5 GHz. In a first step, we design fully passive metasurfaces capable of reducing scattering in desired directions. Then, we investigate the concept of cloaking by reducing not only the back- and sidescattering, but also the forward-scattering of the metallic cylinder through the incorporation of active components in the metasurface.

Friday, March 31 9:00 - 10:40

A06: Reflector systems

T08 Space technologies, e.g. cubesats, satellite networks / / Antennas

Room: Spadolini 002

Chairs: Olav Breinbjerg (ElMaReCo, Denmark), Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

9:00 ***Design of a 150GHz Band Omnidirectional Reflector Antenna Using a Circular TE11-TM01 Mode Converter***

Jiro Hirokawa, Riki Yanagisawa and Takashi Tomura (Tokyo Institute of Technology, Japan)

We propose a 150GHz omnidirectional reflector antenna using a TE11-TM01 mode converter and a radiator. The TE11-TM01 mode converter takes into account two aspects: the reciprocity relating to the input-output port exchange and that relating to the mode conversion coefficient between the two propagating modes. Good conversion efficiency is obtained from the TE11 mode to the TM01 mode. The radiator has a simple structure, and the reflector is designed by ray tracing. As a result, an omnidirectional pattern with a 3 dB beamwidth of 18 deg is obtained on the horizontal plane at the design frequency of 158 GHz.

9:20 ***A Multi-Beam Ka-Band Deployable Mesh Reflector Antenna for the INCUS Mission***

Alessio Mancini (NASA Jet Propulsion Laboratory, USA); Nacer Chahat (NASA-JPL, Caltech, USA); Simone Tanelli (Jet Propulsion Laboratory, California Institute of Technology, USA); Paolo Focardi (Jet Propulsion Laboratory & California Institute of Technology, USA)

This paper presents the design of a multi-beam Ka-band deployable mesh reflector antenna and the corresponding feed assembly currently considered for a new NASA Earth science mission. The mission objective is to better observe the behavior of tropical convective storms and thunderstorms. This paper focuses on the design of the antenna system operating at Ka-band

and on the general system architecture. The antenna system is comprised of a deployable mesh reflector illuminated by seven offset feed horns to achieve seven independent and partially superimposed ground tracks.

9:40 ***3BRAD POLAR: Development of a New Generation of Tri-Band (S/X/K) Radomes for Ground Stations at Polar Regions Environments***

Nicola Cigolotti and Celeste Messina (Vega Composites, Italy); Andreina Armogida (RTW Ride The Wave, Italy); Giovanni Matticari (Pasquali Microwave Systems, Italy); Marco Sabatini (Pasquali Microwave Systems & Hitec LU, Italy); Yves Leiner and Jérémy Laumesfelt (Hitech Luxembourg, Italy); Filippo Concaro (European Space Agency, Germany)

This document describes the activities carried out by VEGA COMPOSITES and HITEC LUXEMBOURG within the framework of an ESA contract aiming at the design, prototyping and manufacturing of demonstrative frames and components of large radomes for the coverage of polar ground stations of next-generation weather and satellite space missions (S/X/K bands) with applications in remote sensing and TLC communications. The paper addresses in particular the approach at industrial research and engineering level followed by the team in design and development of the project, specifically for: identification of materials for radome sandwich-panel structures, RF characterization of materials and stratifications, definition of the whole radome geometry/ configuration, characterization of the panel-to-panel joints, identification and preliminary design of automatic de-icing system, FEA for validation of mechanical performances vs harsh environmental conditions, EM modelization for validation the RF performances, manufacturing technologies assessment for Large Domes supplying, criteria and trade-off for final configurations definition

10:00 ***Novel Single-Reflector Multiple-Feed-Per-Beam Feed System for Enhanced Spectral Density***

Nelson Fonseca (European Space Agency, The Netherlands)

Modern day communication satellites require antennas with more and more beams to increase the total system capacity. There is also an interest in developing antenna geometries that reduce the spacing between beams to enhance the spectral density over the service area, typically a continental or sub-continental coverage. On smaller platforms, or as a secondary payload on larger satellites, there is also a need to produce multiple beam antenna solutions using only one reflector. In this context, a patent pending multiple-feed-per-beam feed system implementation technique has been developed. Compared to state-of-the-art solutions, the proposed technique is found to increase significantly the spectral density over the service area while maintaining the key performance indicators at antenna level (i.e. aggregate gain and C/I). A design is presented for a geostationary broadband mission, which displays an increase of about 50% in the number of beams, assuming same reflector geometry and feed array size.

10:20 ***Strut Analysis and Effect on Performance of Cassegrain Reflector Antennas at mm-Wave D-Band***

Aris Tsolis, Stefanos Lampiris and Vasileios Vlachodimitropoulos (NCSR Demokritos, Greece); Fotis Lazarakis (NCSR Demokritos, Institute of Informatics & Telecommunications, Greece); Antonis A Alexandridis (NCSR Demokritos, Greece)

This paper presents the effect of circular cross-section struts used on two 30cm diameter Cassegrain reflector antennas appropriate for the 5G mm-Wave D-band. The Cassegrain antennas and their feed horns geometry, simulation models and performance are presented. Struts' analysis main aim is to study the effect of strut diameter using parametric analysis. Maximum degradation on gain, compared with the no-struts reference case, is found to be 1.4dB. Also, Perfect Electric Conductor (PEC) and Polyamide (PA) dielectric struts' materials are examined, where different performance was noticed. Finally, a real and feasibly solution using struts of diameter equal to 10mm (≈5λ in D-band) has been proposed for various realistic strut materials.

Friday, March 31 9:00 - 10:40

CS35: Plastic Based Antennas: a Real Alternative

T01 Sub-6GHz cellular / Convened Session /

Room: Spadolini 101

Chairs: Angelo Freni (University of Florence, Italy), Paola Pirinoli (Politecnico di Torino, Italy)

9:00 *Dielectric Versus Patch-Based Implementations of Risley Prism Transmit-Arrays in Ka-Band*

Sergio Matos (ISCTE-IUL / Instituto de Telecommunicações, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Nelson Fonseca (European Space Agency, The Netherlands)

Many millimeter wave applications related with 5G and Satellite on the move (SoTM) communications rely on cost-effective high-gain antennas with wide beam scanning. Mechanical steering solutions can reduce the complexity and cost of the fully-electronic beam steering counterpart (e.g. phased arrays). Mechanical scanning with Transmit-array (TA) antennas can provide a balanced compromise between cost, size, and efficiency. TAs are usually associated with a thin metasurface composed by a tailored distribution of patch-based unit cells. However, fully-dielectric unit cells can also be used for the design of the aperture, which can be viewed as gradient index (GRIN) lenses. In this work we compare fully-dielectric and stacked patch-based implementations of the Risley Prism scanning concept. This configuration consists of two independent axially rotating TA that can provide elevation and azimuth mechanical scanning. The dielectric version can further reduce the cost of these antennas trading-off with some antenna efficiency degradation caused by material losses, free-space mismatch, and higher lens thicknesses. This work also includes the experimental validation of the dielectric Risley prism implementation, less explored in the state of-the-art.

9:20 *Millimeter Wave User Equipment Beamforming Concept Compliant with 3GPP Specifications*

Tim Hahn (Leibniz University Hannover, Germany); Dirk Manteuffel (University of Hannover, Germany)

A beamforming concept for mobile handsets operating in the millimeter wave frequency range is proposed to comply with specifications defined by the 3rd Generation Partnership Project (3GPP). By integrating antenna elements directly into the smartphone corner, realized on a metallized injection molded plastic carrier, a large spherical coverage is achieved. To maximize antenna gains, calculation methods for chassis conformal arrays are derived and applied. Simultaneous excitation of two elements is suggested for operation to maximize the cumulative distribution function (CDF) of the equivalent isotropic radiated power (EIRP). Compliance of the proposed chassis conformal array concept with 3GPP specifications is shown by evaluation of the spherical coverage.

9:40 *Metal-Coated 3D-Printed Waveguide Antenna for 77 GHz Automotive Radar Applications*

Carlos Salzburg (Fraunhofer, Germany); Thomas Bertuch (Fraunhofer FHR, Germany); Jürgen Hofinger (Biconex GmbH, Germany); Steve Lee, Frank Schüssler and Andrew Kwon (LG Chem Europe GmbH, Germany)

This work presents the design, fabrication, and characterization of a metal-coated MIMO antenna for 77 GHz automotive applications. The MIMO antenna consists of 4 RX and 2 TX H-plane sectoral horn antennas. The antennas are fed by a hollow rectangular waveguide feeding network implemented by stacking two metal-coated plates with optimized transitions between layers.

The current antenna configuration exhibits large matching bandwidth, and the radiation patterns satisfy typical requirements in the elevation and azimuthal planes. In addition, antenna gain is not affected due to the metal coating, and the antennas exhibit similar properties as the antennas of a full-metal reference array.

10:00 ***Single-Prism Risley Scanner at Ka-Band***

Matthieu Bertrand (Thales Research and Technology, France); Jorge Ruiz-García (University of Michigan, USA); Thomas Potelon (DGA, France); Jean-Francois Allaeys (Thales Research and Technology, France); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Thi Quynh Van Hoang and Brigitte Loiseaux (Thales Research & Technology, France); Ronan Sauleau (University of Rennes 1, France); Romain Czarny (Thales Research & Technology France, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

This contribution presents a new Risley scanner architecture for beam-steering antennas based on leaky-wave feed and a single prism. The leaky-wave feed radiates its main beam at about 30° in elevation and is based on a modulated metasurface fed by a pillbox beamformer. The prism consists of dielectric loaded metallic waveguides, realized through the combination of two additively manufactured parts. The proposed structure is validated by full-wave simulations and a prototype. The antenna operates in the 19.2-21.2 GHz band for a field of view of 360° in azimuth and 60° in elevation.

10:20 ***Integrated Carbon Fiber Microwave Circuits for Lightweight Antenna Applications***

Christopher M Preddy (QinetiQ & University of Surrey, United Kingdom (Great Britain)); Rajinder Singh (QinetiQ Ltd., United Kingdom (Great Britain)); S. Ravi P Silva and Peter Aaen (University of Surrey, United Kingdom (Great Britain))

The implementation of a slotted substrate integrated waveguide (SIW) antenna within a fiber reinforced composite is presented as a lightweight method of integrating microwave functionality into composite components. The SIW circuit is fabricated within a foam core composite using copper-coated carbon veils. The use of a coated veil as the conductor reduces the attenuation effects normally experienced with carbon-based microwave circuits, while minimizing the introduction of additional materials that could mechanically weaken the composite. The application of an integrated composite SIW as an antenna is demonstrated through the design, fabrication and gain characterization of two slotted waveguide antennas, with measured gains of -3 dBi at 3.66 GHz and 0.2 dBi at 6.75 GHz respectively.

Friday, March 31 9:00 - 10:40

M03: MM-Wave, THz and Quasi-Optical antenna measurement

T02 Mm-wave and THz cellular / / Measurements

Room: Spadolini 102

Chairs: Zhong Chen (ETS-Lindgren, USA), Lars Foged (Microwave Vision Italy, Italy)

9:00 ***Integrated Photonic-Based Low Noise Radiometer for Millimeter and Sub-Millimeter Applications***

Jessica Cesar Cuello and Enderson Falcón-Gómez (University Carlos III of Madrid, Spain); Alberto Zarzuelo (University Carlos III of Madrid); Robinson Guzmán and Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain); Gabriel Santamaria (University of Colorado, Spain); Luis Enrique García Muñoz (Universidad Carlos III de Madrid, Spain); Luis Gonzalez-Guerrero (University Carlos III of Madrid); Guillermo Carpintero (Universidad Carlos III de Madrid, Spain)

Millimeter-wave and THz photonic radiometers based on electro-optic upconversion represent a novel detection approach to overcome the limitations in terms of volume, size and complexity of state-of-the-art detectors based on low noise amplifiers (LNAs) and mixers. Theoretical studies have shown that room-temperature radiometers based on an efficient upconverter followed by a direct detection stage could be competitive with conventional, and even cryogenic, mixers and LNAs in the THz range. In this work we present the development of a Lithium Niobate (LN) Photonic Integrated Circuit (PIC) as part of an integrated upconversion radiometer. Two optical components: an asymmetric Mach-Zehnder interferometer (AMZI) and a Whispering Gallery Mode Resonator (WGMR) were designed, fabricated and characterized. Based on the characterization

results of the first PIC, a second one was designed and fabricated, where the antenna for RF signal detection has been included. Details of the antenna design are also presented here.

9:20 ***TX Beamforming EVM Performance of a 65 dBm-EIRP Slant-Polarized Gapwaveguide Phased Array at 28 GHz***

Alireza Bagheri (Gapwaves AB, Sweden & University of Twente, The Netherlands); Hanna Karlsson and Carlo Bencivenni (Gapwaves AB, Sweden); Jose-Ramon Perez-Cisneros (Chalmers University of Technology, Sweden); Parastoo Taghikhani (Ericsson AB, Sweden); Christian Fager (Chalmers University of Technology, Sweden); Andrés Alayón Glazunov (University of Twente, The Netherlands)

The transmit error vector magnitude (EVM) performance measurements of a slant-polarized 28 GHz gapwaveguide based phased array is analyzed in this paper. The performance is studied by using a large range of signals, with varied powers, symbol rates, and quadrature amplitude modulation (QAM) orders. The measurements have been conducted for four different scanning angles. A non-standardized over-the-air (OTA) link between the phased array and the receiver in a laboratory environment is used. The results show that the phased array antenna supports a 31 dB effective isotropic radiated power (EIRP) dynamic range at a maximum 2% EVM when transmitting a 64-QAM modulated signal with 250 MS/s symbol rate at all scanning directions.

9:40 ***Design and Manufacture of a Broadband CATR Reflector System for MM-Wave Bands***

Jorge Calatayud Maeso (Universidad Politecnica de Madrid, Spain); Fernando Rodríguez Varela (Universidad Rey Juan Carlos de Madrid, Spain); Belén Galocha Iragüen (Universidad Politécnica de Madrid, Spain); Jose Luis Besada (Universidad Politécnica de Madrid (Technical University of Madrid), Spain); Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain)

Serrated reflector systems are widely used in compact range antenna measurement (CATR) setups. Besides maximizing the size of the reflector, serrations offer a solution for improving the size and quality of quiet zones. In contrast to rolled edge reflector, serrations offer a low radiation percentage redirected to the walls which can be critical for small size chambers with suboptimal size absorbent material. Simulation of the quiet zone's behaviour has been done with PO and PTD. An iterative manufacturing procedure for reducing surface errors on the reflector is shown. Measured fabrication imperfections and constrains have been introduced into the simulation model to illustrate their effect and ensure the correct behaviour of the system.

10:00 ***Total Radiated Power Measurement at 100 GHz in a Reverberation Chamber***

Anouk Hubrechsen (Eindhoven University of Technology & AntenneX B. V., The Netherlands); Tim Stek, Roel X.F. Budé, Rainier Van Dommele, L. A. (Sander) Bronckers, Ad Reniers and A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

In this work, a proof-of-concept of a total-radiated-power (TRP) measurement in a mm-wave reverberation chamber at 100~GHz is shown for the first time. A signal generator connected to a horn antenna was used as a device under test, to be able to have a reference value. The over-the-air measured TRP is within 0.45~dB of the reference value, where the expanded uncertainty is 0.53~dB. This shows a proof-of-concept of the suitability of this chamber for TRP measurements of 6G integrated devices, paving the way for measurements of antenna-in-package or antenna-on-chip applications.

10:20 ***An Efficient Multi-Beam Pattern Measurement Campaign for Millimeter-Wave Phased Arrays***

Huaqiang Gao, Fengchun Zhang, Gert Pedersen and Wei Fan (Aalborg University, Denmark)

The performance of millimeter-wave (mmWave) radio systems depends on accurate knowledge of mmWave phased array multi-beam patterns. However, the conventional antenna pattern measurement methods are inefficient for mmWave multibeam measurements. To solve the problem, a fast multi-beam reconstruction method has been proposed in the literature. Based on that, this paper conducts an efficient multi-beam pattern measurement campaign for a practical 4 × 4 mmWave phased array antenna-in-package (AiP). The measurement results show that the element patterns of an active phased array AiP measured in the on-off and all-on modes might differ, especially for large-scale arrays. Furthermore, the reconstructed array multi-beam patterns by the proposed method are compared with the conventional compact antenna testing range (CATR) measurement data. The all-on reconstructed array multi-beam patterns matches better with the target array patterns than the

on-off reconstructed array patterns.

Friday, March 31 9:00 - 10:40

A14: Wearable Antennas

T03 Wireless LANs, IoT and M2M / / Antennas

Room: Spadolini 103

Chairs: Sema Dumanli (Bogazici University, Turkey), Christophe Fumeaux (The University of Adelaide & School of Electrical and Electronic Engineering, Australia)

9:00 ***Dual-Band Dual-Mode Center-Shorted Wearable Textile Antennas for Body-Centric Communications***

Quoc Hung Dang (The University of Adelaide & Australia, Australia); Nghia Nguyen-Trong (University of Adelaide, Australia); Shengjian Jammy Chen (Flinders University, Australia & The University of Adelaide, Australia); Christophe Fumeaux (The University of Adelaide & School of Electrical and Electronic Engineering, Australia)

A dual-band dual-mode center-shorted wearable textile antenna for on-body and off-body communications is proposed. The antenna radiates simultaneously in the 5G standards band centered at 3.5 GHz and the 5.8 GHz Industrial, Scientific and Medical (ISM) band. An omnidirectional pattern is achieved in the lower band, while at the higher band, the antenna exhibits a broadside radiation pattern. Based on the antenna concept, two wearable textile prototypes are optimized and fabricated using eyelets and embroidered vias to implement the center shorting. These textile antennas are then measured in various wearable scenarios to validate the concept.

9:20 ***A Pattern and Polarization -Reconfigurable Fully-Textile Wearable Antenna***

Sofia Bakogianni (National Centre for Scientific Research Demokritos, Greece); Aris Tsolis and Antonis A Alexandridis (NCSR Demokritos, Greece)

A single-layer textile pattern and polarization reconfigurable patch antenna that operates within the 2.4 GHz industrial, scientific, and medical (ISM) band is numerically investigated for wearable applications. Four pairs of metallic snap-on buttons are integrated into the main corner-truncated and stub-loaded radiated patch to serve as detachable shorting pins. By engaging/ disengaging the buttons, the textile antenna can achieve a monopole-like radiation pattern with linear polarization or a patch-like radiation pattern with circular polarization enabling on- and off-body wireless communication, respectively. Simulations indicate that by applying two parasitic elements gap-coupled into the non-radiating edges of the main patch, both the impedance bandwidth and axial ratio bandwidth are enhanced in the off-body communication mode. A multi-layer tissue phantom is used to emulate realistic wearing conditions. Resonance and radiation performance characteristics of the proposed antenna are examined in both radiation modes. The specific absorption rate (SAR) is, also, evaluated in terms of safety.

9:40 ***Textile Slotted Waveguide Antenna: Feeding Considerations***

Davorin Mikulic, Evita Sopp, Davor Bonefačić and Zvonimir Sipus (University of Zagreb, Croatia)

One of the major challenges in the development of wearable antennas is to design an antenna that can at the same time satisfy technical requirements and be aesthetically acceptable and suitable for clothing applications. Slotted waveguide antennas made of conductive textiles meet all the demands for integration into clothing. However, the transition from a classic coaxial line into a waveguide remains an open problem and the aim of this paper is to consider and experimentally characterize different possibilities for making this transition.

10:00 ***A Low Profile Dual-Band Dual-Polarized Wearable Antenna for 2.4/5.8 GHz ISM Band***

Biomedical Applications

Rania Rabhi (University of Tunis El Manar, Tunisia); Hamid Akbari-Chelaresi (University of Waterloo, Canada); Ali Gharsallah (University of Tunis El Manar, Tunisia); Omar Ramahi (University of Waterloo, Canada)

A Compact CPW fed wearable dual-band dual-polarized antenna is proposed in this paper. The antenna is linearly polarized (LP) at 2.45 GHz and circularly polarized (CP) at 5.8 GHz. The presented antenna with the dimensions of 15 mm × 36 mm × 0.80 mm ($0.12\lambda_0 \times 0.29\lambda_0 \times 0.006\lambda_0$ at lower frequency) was tested both in free space and on-body environment, showing a high performance. The on-body antenna was able to attain a maximum peak gain of 5.72 dBi, a wide impedance bandwidth of 21%, and an ultra wide axial ratio bandwidth. The antenna was fabricated and characterized, and the simulated as well as measured results are found to be in good agreement. Moreover, for wearable safety validation, the Specific Absorption Rate (SAR) was also investigated. These merit features make the proposed antenna suitable to wearable medical applications.

10:20 *Wide-Band Dual Port Cross Slot Wearable Antenna for In-Body Communications*

Ahmet Bilir and Sema Dumanli (Bogazici University, Turkey)

Wearable antennas are commonly required for devices that operate within the BAN. Depending on the application, the wearable antenna might be forming an off-body, on-body or an in-body link. Forming an in-body link is often more challenging due to reflection at the air-human body boundary and the path loss within the body. The performance of the antenna is going to be dependent on where it is located on the human body as the effective permittivity changes according to the dominant tissue. To improve the reliability or the data rate of the in-body link, multiple polarization and wide-band operation can be utilized. Here, a wide-band dual port wearable antenna is presented. The input bandwidth of the antenna is 1.52 GHz operating from 0.91 GHz to 2.43 GHz, a fractional bandwidth of 91%, on human muscle. The isolation between its ports is shown to be greater than 40 dB throughout the bandwidth.

Friday, March 31 9:00 - 10:40

A24: Antennas for Imaging Systems

T06 Defence and security / / Antennas

Room: Spadolini 104

Chairs: Daniele Cavallo (Delft University of Technology, The Netherlands), Francesca Vipiana (Politecnico di Torino, Italy)

9:00 *Multi-Layered Proximity Probe-Fed E-Shaped Patch Antenna Array for Terahertz Imaging System*

Ian Huang, Ling-Yun Kung and Shih-Yuan Chen (National Taiwan University, Taiwan)

This work presents a multi-layered proximity coupled meandering-probe-fed E-shaped patch antenna array for terahertz imaging system with a center frequency at 150 GHz. The E-shaped patch antenna is proximity coupled using a meandering-probe feed. A test kit was designed, fabricated, and measured to verify the design and resonance of the E-shape patch antenna. An antenna feeding structure was also designed, with a 2.52 dBi total broadside realized gain of the antenna and feeding structure combined. A 4x4 subarray provided a 30% impedance bandwidth and an 80% radiation efficiency. A decoupling design for the antenna array was also proposed.

9:20 *C-Band Two-Dimensional Dynamic Metasurface Antenna for Through-The-Wall Computational Imaging*

Guillermo Alvarez Narciandi and María García Fernández (Queen's University Belfast & University of Oviedo, United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

This contribution presents the design of a two-dimensional (2D) dynamic metasurface antenna (DMA) for a through-the-wall computational imaging system. The use of C-band is intended to achieve enough penetration capabilities to image different types of wall. The 2D DMA comprises a set of randomly distributed dynamically tunable unit cells which can be activated and deactivated by switching off and on PIN diodes. This reconfigurability enables to generate quasi-orthogonal radiation patterns, or measurement modes, to encode the information of the area under inspection and compress it into a reduced number of channels. The imaging performance of the proposed imaging system was validated through electromagnetic simulations considering two metallic patches placed in front of the DMA panels as test targets and a scenario with and without a wall. Results show that, even when a significantly reduced number of radiation patterns is considered, targets concealed behind a simple wall can be accurately imaged.

9:40 ***Optimal Linear Sparse Array Design for On-The-Move mm-Wave Imaging Systems***

Lorena María Pérez Eijo (Universidade de Vigo, Spain); Marcos Arias, Borja Gonzalez-Valdes, Antonio Pino and Oscar Rubiños-López (University of Vigo, Spain); Jesús Grajal (Universidad Politécnica de Madrid, Spain)

A linear sparse matrix configuration capable of multistatic imaging is presented. In order to achieve a wide field of view, a configuration based on a large array of which only a few elements are used for each observation zone is proposed. This upgraded version involves the design of a new imaging strategy, as the image plane is scanned in sections, rather than as in the initial design, where it is fully scanned. With this renewed approach, imaging performance is significantly improved and, since only the elements closest to the scanned area are used (the same number as in the base configuration), data acquisition time is not affected. This array thus designed would move vertically as a synthetic aperture in the vertical plane. Simulation results validating the proposed architectures are shown. This contribution is intended to help the development of better imaging systems for security applications in the near future.

10:00 ***Characterization of Tightly Sampled, Direct-Detection THz Imager Integrated in 22 nm CMOS***

Martijn Hoogelander (Delft University of Technology, The Netherlands); Sven L van Berkel (NASA Jet Propulsion Laboratory, Caltech, USA); Satoshi Malotaux (Tusk-IC, The Netherlands); Maria Alonso-delPino, Marco Spirito, Andrea Neto, Daniele Cavallo and Nuria LLombart (Delft University of Technology, The Netherlands)

The design procedure of a focal plane array (FPA) for THz imaging generally presents a trade-off between resolution and sensitivity. Ideally, a tight sampling of the focal plane is desired to realize the high angular resolution offered by the THz regime. The small feed elements required to achieve this, however, leads to a sharp increase in spillover losses in turn deteriorating the sensitivity of the imaging system. This work presents the characterization of an ultra-wideband (200 GHz - 600 GHz) FPA with integrated direct-detectors that achieves a tight sampling of the focal plane by implementing overlapping of the feed elements, hence alleviating the penalty in efficiency. The measured radiation patterns and efficiency show a good agreement with simulations. Moreover, a beam spacing corresponding to a near diffraction-limited resolution achieved combined with a minimum cross-over level below 1 dB, making this design a promising candidate for high-resolution THz imaging systems.

10:20 ***Sparse 2D Array Design Optimization for Imaging Systems Using Genetic Algorithm***

Lorena María Pérez Eijo (Universidade de Vigo, Spain); Marcos Arias, Borja Gonzalez-Valdes, Antonio Pino and Oscar Rubiños-López (University of Vigo, Spain); Jesús Grajal (Universidad Politécnica de Madrid, Spain)

This work shows a method to find the optimal configuration of a sparse symmetric 2D array for multi-static imaging in security systems once a set of configuration parameters (such as number of radiating elements, operating frequency range, standoff distance to the imaging target, etc...) have been selected. Advanced electromagnetic simulation algorithms based on Physical Optics and Genetic Algorithm as an optimization tool are used. The simulation results to validate the performance of the proposed methodology and architecture are provided.

Friday, March 31 9:00 - 10:40

P06: Detection and estimation

T07 Positioning, localization & tracking / / Propagation

Room: Spadolini 105

Chairs: Ignacio Rodriguez (University of Oviedo, Spain), Markus Ulmschneider (German Aerospace Center (DLR), Germany)

9:00 ***Correlation-Based Motion Estimation for the Compensation of Horizontal Movements of a Hovering UAV***

Philipp Stockel (Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany); Patrick Wallrath and Reinhold Herschel (Fraunhofer FHR, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany)

This paper deals with the horizontal motions of a UAV equipped with a MIMO radar pointing to the ground. For the estimation of the horizontal motions a correlation-based method is used to calculate the current velocities from the radar data. Afterwards, the velocities are fused with data from an IMU and the resulting position is used to compensate the horizontal motions of the system. The effectiveness of the proposed method is proven by compensating the motions of a radar on a moving platform to make the breathing motion of a person in the measured scene visible.

9:20 ***Direction of Arrival Estimation on Sparse Arrays Using Compressive Sensing and MUSIC***

Ram Kishore Arumugam (Fraunhofer Institute for High Frequency Physics and Radar Technology & Ruhr University of Bochum, Germany); André Froehly, Reinhold Herschel and Patrick Wallrath (Fraunhofer FHR, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany)

Target detection in automotive applications is a safety feature and trustworthiness of such systems is critical. A sparse interleaved array for improving security and an angle estimation algorithm for this sparse array are presented in this paper. We introduce an improved compressed sensing approach which estimates the azimuth angle and recovers the signal using Orthogonal Matching Pursuit (OMP) and root-MUSIC. This recovered signal is then used for estimating elevation angle. This approach compensates the major drawbacks of compressed sensing which consists in the choice of an underlying grid of azimuth angles, which is used for the signal approximation. The method is evaluated using simulated signal of the proposed 4x4 MIMO array and measurements using commercially available 4x3 MIMO radar. An increased dynamic range of 3dB is achieved and both target's DoA are estimated, which was not possible with conventional methods.

9:40 ***Modelling of the Floor Effects in Device-Free Radio Localization Applications***

Federica Fieramosca (Politecnico di Milano, Italy); Vittorio Rampa (Consiglio Nazionale delle Ricerche (CNR), Italy); Stefano Savazzi (Consiglio Nazionale delle Ricerche CNR, Italy); Michele D'Amico (Politecnico di Milano, Italy)

Device-Free Localization (DFL) systems exploit the human-induced perturbations of the electromagnetic (EM) fields as a sensing tool for passive recognition and vision. Since the targets modify the EM field in a way that depends on their location relative to the wireless devices, DFL systems use specific radio maps to enable motion tracking. These maps can be learned from training data or obtained from a physical/EM model. Typical EM models are based on the scalar diffraction theory, that are efficient from a computational point of view but often limited by free space propagation assumptions. The paper discusses an extended diffraction-based model that accounts for the effect of the floor and tailored for indoor radio localization applications. The model is validated by EM simulations and indoor experiments. The impact of the proposed model on the statistical characterization of the RSS is also analyzed for selected body locations.

10:00 ***Wi-Fi Direction and Range Estimation with a Single Frequency-Scanned Antenna Using RSSI and RTT***

Miguel Poveda-García, Jose A López Pastor, Alejandro Gil Martinez, David Cañete Rebenaque and

Jose-Luis Gómez-Tornero (Technical University of Cartagena)

In this paper, we present a 2D localization system (range and direction) for WLANs, using a single Wi-Fi access point connected to a frequency-scanned antenna. The received signal strength indicator and the round-trip time metrics must be acquired for different frequency channels. To validate the technique, a real prototype based on a Wi-Fi card has been developed and tested in a controlled scenario. The challenges when combining both metrics in the processing, due to the performance of the Wi-Fi card, are exposed along with an algorithm to reduce the overall estimation error. This technique might find interest in smart areas to locale IoT devices.

10:20 ***Deep Learning Approach Based on GBSAR Data for Detection of Defects in Packed Objects***

Filip Turčinović, Marin Kacan, Dario Bojanjac and Marko Bosiljevac (University of Zagreb, Croatia)

Expansion of monitoring and control requirements in industry is a constant drive for development of new technologies and principles. To inspect the integrity of packed objects we utilize Ground Based Synthetic Aperture Radar system (GBSAR) for scanning and deep learning model for data processing to detect and localize defects. The GBSAR system is based on a 24 GHz FMCW module which is controlled by embedded computer with precise motion control. Radar raw data received from the scanning is directly processed using developed deep learning approach based on ResNet18 neural network architecture. This avoids the need for SAR image reconstruction and reduces the time needed for inspection. Following several test runs in laboratory environment where we emulated the industrial process and potential defect, we have obtained promising results although the test scenario was very challenging and demonstrated the potential of this principle in this and similar applications.

Friday, March 31 9:00 - 10:40

M04: Data Acquisition, Imaging Algorithms and Measurement Post-Processing

T09 EM modelling and simulation tools / / Measurements

Room: Spadolini 106

Chairs: Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)), Lucia Scialacqua (Microwave Vision Italy, Italy)

9:00 ***Application of Accelerated Polar Near-Field to Far-Field Transform to Plane-Bi-Polar Measurements***

Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)); Clive Parini (Queen Mary University of London, United Kingdom (Great Britain))

The plane-bi-polar near-field measurement technique is a well-known and long-established method for determining far-field antenna patterns of medium to high gain antennas that is predicated on the use of a simple positioning system that comprises two rotation stages. This technique has been comparatively sparsely deployed however the recent heightened interest in articulated multi-axis industrial robots for the positioning systems of modern antenna test systems has increased the amount of interest that this technique has received. This paper is an extension of the authors' prior work where here, the recently developed efficient polar near-field to far-field transform is adapted to accommodate the plane-bi-polar case. The plane-bi-polar non-interpolatory transform is developed with preliminary simulation results presented that verify the success of the efficient, data processing technique.

9:20 ***Simulation of a Novel Phase Retrieval Technique for Multi-Axis Robotic Arm Based Near-Field Antenna Measurements***

Clive Parini (Queen Mary University of London, United Kingdom (Great Britain)); Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain))

The simulation of a novel robot-arm based near-field/far-field (NF/FF) antenna measurement system enabling the reconstruction of measured AUT phase without the need for a phase reference cable is described. The mathematical approach follows the principle used within GPS position. This work addresses the need for industrial robot arm-based NF/FF antenna measurements at both microwave and millimetrewave frequencies where the transmitting probe RF phase reference cannot be guaranteed to be provided with the necessary stability by cable management or rotary joints. A computer simulation of the measurement system is constructed, and its performance analysed in terms of the accuracy of reconstruction of the AUT phase and true NF probe location, as well as the NF/FF radiation pattern accuracy in terms of Equivalent Multipath Level (EMPL). We demonstrate that a microwave system can offer EMPL > -60dB and that a millimetrewave system operating from 40GHz to 100GHz can offer EMPL > -50dB

9:40 ***Super-Resolution Reconstruction and Denoising of 3D Millimetre-Wave Images Using a Complex-Valued Convolutional Neural Network***

Rahul Sharma (Queen's University Belfast, United Kingdom (Great Britain)); Jiaming Zhang (Institute of Electronics Communication and Information Technology, United Kingdom (Great Britain)); Rupesh Kumar (Queen's University Belfast, United Kingdom (Great Britain)); Bhabesh Deka (Tezpur University, India); Vincent Fusco and Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

Imaging systems leveraging millimetre-wave (mmW) frequencies suffer from poor resolution images as compared to higher frequency reconstructions. Also, practical radar systems are susceptible to noise. To recover the original mmW image from these poorly resolved noisy images, two individual image processing steps are required, that is, super-resolution and denoising. This paper focuses on using a complex-valued convolutional neural network (CV-CNN) to combine the two individual processing steps into one single algorithm. By designing the CV-CNN to accommodate complex-valued reconstruction data, the phase information content of the input images, along with the magnitude information, is considered in the process. A computational imaging (CI) numerical model is used to train and test the neural network. By comparing the performance metrics of the final reconstruction images, it is observed that the developed CV-CNN can resolve and de-noise the poorly resolved noisy input mmW images to a high degree of fidelity.

10:00 ***Numerical Simulation of Probe Transverse Errors in Spherical Near-Field Antenna Measurements***

Kyriakos Kaslis and Samel Arslanagić (Technical University of Denmark, Denmark); Olav Breinbjerg (ElMaReCo, Denmark)

Every antenna measurement has an associated uncertainty, and the estimation of this uncertainty, when performed experimentally, may be more time-consuming than the nominal measurement. In this work, we investigate and test a new method for the numerical estimation of the uncertainty originating from a probe transverse error in spherical near-field antenna measurements, i.e. an improper positioning of the probe with respect to the measurement coordinate system. The method we propose exploits the spatial positioning of the probe when an error of this type is present in order to acquire the error signals numerically through the signals acquired in the nominal measurement. As a result, our method is considerably faster, since it does not require additional full-sphere measurements and, moreover, it does not occupy the antenna under test for any additional time than that required for its nominal measurement.

10:20 ***Reconstruction of Sparse Array Pattern from a Limited Number of Samples with a Compressive Sensing Inspired Approach***

Daniele Pinchera and Marco Donald Migliore (University of Cassino, Italy)

n this paper, we discuss an approach for the reconstruction of the far-field pattern of unknown sparse sources. Starting from the measurement of a small number of near-field samples, we employ a compressive-sensing inspired elaboration that performs a smooth-weighted constrained minimization. This technique allows better performance with respect to similar concurrent techniques that employ the same computational effort for elaboration.

Friday, March 31 9:00 - 10:40

CS32: mmWave and THz channel sounding for Beyond 5G communications

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 107

Chairs: Diego Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany), Wei Fan (Aalborg University, Denmark)

9:00 ***Spatial/Temporal Characterization of Propagation and Blockage from Measurements at Sub-THz in Industrial Machines***

Diego Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany); Alexander Ebert, Yanneck Völker-Schöneberg and Leon Loeser (Technische Universität Ilmenau, Germany); Mate Boban (Huawei Technologies Duesseldorf GmbH, Germany); Reiner S. Thomä (Ilmenau University of Technology, Germany)

In the present paper we introduce novel ultra-wideband dual-polarized double-directional measurements at sub-THz (300 GHz) in an access point to inside of machine application in an industrial scenario. The results show a sparse spatial/temporal channel with multiple paths from the different metallic objects and their influence on polarization. In addition, different LOS blockage situations were investigated, showing the presence of alternative paths for communications.

9:20 ***Path-Loss Characteristics and Modeling for 2-300-GHz Bands in Urban Microcell Environment***

Minoru Inomata, Wataru Yamada, Nobuaki Kuno and Motoharu Sasaki (NTT, Japan); Mitsuki Nakamura, Koshiro Kitao, Takahiro Tomie and Satoshi Suyama (NTT DOCOMO, INC., Japan)

Sixth generation (6G) mobile communication networks will require extremely high-speed and high-capacity communications data rates exceeding 100 Gbps using sub-terahertz bands. However, path-loss characteristics above 100 GHz have not been sufficiently studied in terms of distance attenuation and frequency dependency. Therefore, to clarify the system performances of 6G in new frequency bands and determine the service frequency bands, it is needed to clarify the basic path-loss characteristics above 100 GHz. We investigated the path-loss characteristics and propagation mechanism from 2 to 300 GHz in an urban microcell environment. We also clarified the dominant paths that affect the distance attenuation and frequency dependency of path loss.

9:40 ***Ambiguity in RMS Delay Spread of Millimeter-Wave Channel Measurements***

Robbert Schulpen, Ulf Johannsen, A. B. (Bart) Smolders and L. A. (Sander) Bronckers (Eindhoven University of Technology, The Netherlands)

The root mean square (RMS) delay spread is an important statistical parameter in channel modeling. This paper addresses the ambiguity in the estimation of the RMS delay spread from millimeter-wave (mm-wave) channel measurements, which is caused by the need for a threshold to exclude noise and spurious peaks. An overview of various thresholds used in literature is provided. The suitability of these threshold implementations and methods is investigated by applying them to mm-wave channel measurements. Based on the corresponding results, recommendations are proposed to ease the threshold selection and to enable more consistency in RMS delay spread estimates between different authors. These recommendations include the definition of a noise threshold, a 30 dB multipath threshold and the use of a sample method. The recommendations are derived from mm-wave data, but can also be applied to RMS delay spread measurements at other radio-frequencies.

10:00 ***On Predistortion Filtering for Switched Beamforming with Phased-Array Antennas***

Derek Caudill, Jack Chuang and Camillo Gentile (NIST, USA); Sung Yun Jun (National Institute of Standards and Technology, USA)

In recent work on channel sounding, we proposed scanning the antennas of phased arrays and beamforming in postprocessing - what we coined switched beamforming - instead of scanning beams through analog beamforming - what the arrays are designed for. Not only is switched beamforming orders of magnitude quicker to scan than analog beamforming, it synthesizes beam patterns that are quasi-ideal. In the same work, we proposed predistortion filtering to calibrate the channel sounder by designing a separate filter for each of the scanned antennas. It was later found that the design neglects the residual leakage between the antennas on the printed circuit board. In this paper, we propose an improved design that considers all antennas collectively, to account for the leakage. Not only does it increase the peak-to-sidelobe ratio of the channel impulse response by up to 21 dB, the response is also stable across the range of beamformed angles.

10:20 ***Capacity Analysis for Time-Variant MIMO Channel Measurements at Low THz Frequencies***

Johannes M. Eckhardt, Carla E. Reinhardt, Tobias Doeker, Eduard A Jorswieck and Thomas Kürner (Technische Universität Braunschweig, Germany)

THz communication is widely discussed as prospective technology for the next generation of mobile systems. This paper presents time-variant multiple-input multiple-output (MIMO) channel measurements at 300 GHz for two representative scenarios. The averaged signal-to-noise ratio shows the impact of blockage and interference whereas the eigenvalues of the MIMO channel matrix reveal a periodic oscillation that is due to the change of the relative path lengths of the direct paths in the order of wavelengths for moving users at THz frequencies. The measurement results serve as foundation for realistic assumptions for future theoretical works and simulation activities.

Friday, March 31 9:00 - 10:40

A16: Aditive Manufacturing Antennas

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 108

Chairs: Pablo Padilla (University of Granada, Spain), Francisco Pizarro (Pontificia Universidad Catolica de Valparaiso, Chile)

9:00 ***Design of Additive Manufacturing Oriented Top-/Narrow-Wall Couplers and 4×4 Butler Matrices***

Charalampos Stoumpos (IETR-INSA Rennes, France)

This paper presents the design of two hybrid couplers tailored to be 3D-printed. The topologies refer to the well-established narrow- and top-wall coupler architectures. These topologies were selected because of their structural and mechanical simplicity as well as their relatively compact footprint and broad bandwidth. The design techniques followed and presented in this paper enable the rigorous conception of such components with self-supporting structure aimed to be printed vertically (i.e., without inclining the model during the printing process). This later fact leads to high-quality manufacturing mainly because of symmetrical printing, which in turn minimizes the fabrication uncertainties and leads to microwave components with excellent RF performance. The combination of hybrid couplers allows also the conception of Butler matrices. A design example and the perspective of 3D-printed Butler matrices is also presented and discussed here. The proposed structures can be efficiently realized by fully-metallic additive manufacturing.

9:20 ***Additive Manufacturing of a 460mm-Diameter Flat Off-Axis Lens for Ka-Band Communications***

Thi Quynh Van Hoang (Thales Research & Technology, France); Julien Sourice (Nanoe, France); Erika Vandelle (Thales Research & Technology, France); Romain Faye (Nanoe, France); Matthieu Bertrand (Thales Research and Technology, France); Brigitte Loiseaux (Thales Research & Technology, France)

This article presents a large-aperture flat off-axis lens operating in the Ka-band around 30 GHz and fully 3D-printed by FDM (Fused Deposition Modelling) technique with a high-permittivity dielectric material. The refractive index profile, which is required to transform a spherical wave into a tilted plane wave, is implemented by structuring the material at a sub-wavelength scale. The fabricated 460mm-diameter off-axis lens is composed of around 20 000 circular pillars whose diameter varies from 0.8 mm to 2.6 mm. To the best of our knowledge, this is the first RF component made by additive manufacturing with such a large dimension associated to such a high precision and resolution. Simulation and preliminary measurement results show a good agreement, that confirms the possibility to exploit 3D-printing for large-aperture planar lenses operating in millimeter wave bands.

9:40 ***Disruptive C-Band Corrugated Horn Antenna in Additive Manufacturing***

Laura Foucaud and Erwan Cartaillac (Thales Alenia Space, France); Florent Lebrun (Thalès Alenia Space, France); Thierry Pierré, Yann Cailloce and Juan-Antonio Duran-Venegas (Thales Alenia Space, France); Loren Vancleef (3DSystems, Belgium); Antoine De Crombrugghe (3DSystems, France); Koen Huybrechts (3DSystems, Belgium)

This paper summarises the work undertook in order to design, manufacture and test a compact and lightweight corrugated horn compatible with additive manufacturing processes. Our study is driven by the trade-off between reducing the size of the horn and keeping the main performances of the conventional corrugated horns, especially for their low cross polarization requirements. A design that combines axial and radial corrugations was chosen as the best solution. Firstly, a C-band corrugated horn with this new profile has been designed, Secondly a method has been put in place in order to adapt the profile of the corrugated horn to additive manufacturing. The horn has been optimized with the new profile and was 3D printed in aluminum in one single piece . The horn's length was reduced by 35 per cent and RF measurements shown the compliance with the requirements. This new product is very attractive for space applications.

10:00 ***Dispersion Characteristics of Additive-Manufactured Metasurfaces***

Kristy Hecht (University of North Carolina at Charlotte, USA); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Mario Junior Mencagli (University of North Carolina at Charlotte, USA)

This paper presents an efficient and accurate approach for the analysis of additive-manufactured metasurfaces (MTSs) consisting of dielectric posts grown on a grounded slab. The formulation is based conventional effective medium theory that allows modeling such MTSs as uniaxially anisotropic grounded slabs. This procedure can be used to effectively characterize the surface waves supported by additive-manufactured MTSs, as needed in the design of planar lenses and leaky-wave antennas.

10:20 ***The Role of Additive Manufacturing in Space-Borne Active Antenna***

Lisa Berretti and Lucas Polo-López (IETR-INSA Rennes, France); Esteban Menargues (SWISSto12, Switzerland); Renaud Loison (IETR & INSA, France); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); María García-Vigueras (IETR-INSA Rennes, France)

This article aims at illustrating the role that Additive Manufacturing can play in the development of active antennas for space applications. Three relevant examples are considered: a new radiating element for low power consumption in LEO satellites, an iso-phase waveguide cluster to simplify the accommodation of active arrays in GEO payloads; and antenna clusters to reduce the mass and cost of GEO DRAs.

Friday, March 31 9:00 - 10:40

A35: Innovative Antenna Designs II

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 109

Chairs: Stefania Monni (TNO Defence Security and Safety, The Netherlands), Elena Saenz (European Space Agency, The Netherlands)

9:00 ***High Isolation Novel Interleaved TRX Antenna Array with Defected Ground Structure for In-Band Full-Duplex Applications***

Merve Tascioglu Yalcinkaya (Barkhausen-Institut gGmbH, Germany); Padmanava Sen (Research Group Leader, Barkhausen Institut gGmbH, Germany); Gerhard Fettweis (Barkhausen Institut, Germany)

A compact symmetrical simultaneous transmit and receive antenna with high isolation is one of the main barriers that restrict the in-band full-duplex (IBFD) communication system architecture. To overcome this barrier, a novel interleaved transmit and receive antenna array with plus shaped defected ground structure (DGS) has been developed and presented in this paper. It is designed at 10 GHz, fabricated and validated with the measurements. The proposed interleaved array consists of symmetric 2x1 transmitter (TX) antenna elements and symmetric 2x1 receiver (RX) antenna elements with spacing of 1λ while the spacing between TX and RX (TRX) antenna elements is 0.5λ similar to a checkerboard pattern. The plus-shaped DGS is applied to reduce self interference (SI) by suppressing the existing surface wave between the TRX antenna elements. The measurement results confirm that this technique increased the isolation from 16.5 dB to 56.5 dB between TRX antenna arrays.

9:20 ***A 450-GHz Wideband On-Chip Antenna with an Extremely Low Profile***

Shangcheng Kong, Kam-Man Shum and Chi Hou Chan (City University of Hong Kong, Hong Kong)

This paper presents a 450-GHz on-chip antenna with wide bandwidth under an extremely low profile. Adopting the dual-patch structure, the antenna achieves an impedance bandwidth of wider than 15 % under an extremely low profile of 0.013 λ0. A peak gain of 2.7 dBi and radiation efficiency of 31.7 % are achieved according to the simulation. For validation, the presented antennas are fabricated using 65-nm CMOS technology and tested by a dedicated terahertz probe station. The preliminary result from the measurement agrees with the simulation, showing an impressive impedance bandwidth of 15.9 %. The proposed antenna is suitable for future wireless systems such as 6G, short-range communication, and terahertz detection.

9:40 ***Frequency Reconfigurable Millimeter Wave Antenna Integrating Ferroelectric Interdigitated Capacitors***

Vincent Muzzupapa (University of Limoges & XLIM, France); Aurelian Crunteanu (XLIM, CNRS/ University of Limoges, France); Damien Passerieux (University of Limoges, France); Caroline Borderon and Hartmut Gundel (IETR/University of Nantes, France); Laure Huitema (University of Limoges, France); Raphael Renoud (IETR/University of Nantes, France)

We present the design and the simulation of a frequency reconfigurable millimeter waves patch antenna integrating ferroelectric interdigitated capacitors (FIDCs) based on BST (Barium Strontium Titanate) thin films. The capacitors are designed to operate up to 65 GHz, offering tunabilities of the order of 40% for a 100 V bias voltage and with relatively low losses. To ensure maximum frequency agility, FIDC devices are specifically designed and integrated into the excitation circuit of a patch antenna. The DC voltage bias applied on the FIDCs modifies their capacitance values and thus shifts continuously the operating frequency of the antenna, from 26.7 GHz to 31.2 GHz (16.85% frequency agility).

10:00 ***Development of a 96-Element mm-Waves Antenna Array for mMIMO Applications***

Tiago Brandão (Inatel, Brazil); Hugo R. D. Filgueiras (Instituto Nacional de Telecomunicações - Inatel, Brazil); Arismar Cerqueira S. Jr. (INATEL, Brazil)

We report the development of a dual-polarized and dipole-based 96-element antenna array for massive multiple-input multiple-output (mMIMO) communication systems operating in millimeter waves (mm-waves). The proposed array is composed of +-45° polarized elements based on half-wavelength printed dipoles, which are properly connected to a waveguide for enabling boresight radiation. Moreover, such array elements are directly fed by a K-connector and shielded by metallic vias, aiming at low mutual coupling levels. Experimental results, in accordance to the ANSYS HFSS numerical simulations, demonstrate bandwidth from 24.9 to 27.8 GHz, gain of 9.7 dBi gain and 60° beamwidth in both planes at 26 GHz. Regarding the MIMO figures of merit, the envelope correlation coefficient (ECC) and mutual coupling among the array adjacent elements are kept lower than 0.002 and -20 dB, respectively.

10:20 ***Compact Circularly Polarized Array for Direction Finding: Use of Conventional Steering Vector Versus Embedded Radiation Patterns***

Ottavio Crisafulli (Università Mediterranea of Reggio Calabria, Italy); Andrea Francesco Morabito (University Mediterranea of Reggio Calabria, Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy); Nicolo' Ivan Piazzese (STMicroelectronics, Italy); Loreto Di Donato (University of Catania, Italy); Tommaso Isernia (University of Reggio Calabria, Italy); Gino Sorbello (University of Catania, Italy)

In this contribution, we explore a novel approach in the framework of direction finding for Bluetooth Low Energy application. Embedded Radiation Patterns are used to compute the required pseudo-spectrum, by experiencing an improvement with respect to Conventional Steering Vector approach. Specific tests on direction of arrival computation have been performed on a novel monolithic circularly polarized 3 × 3 microstrip antenna-array locator, fed by a grounded coplanar waveguide (GCPW). The array single element exhibits a 3.1% 6-dB axial ratio bandwidth, larger than other monolithic antennas proposed in the literature. The GCPW configuration ensures low crosstalk in the feeding network of a 3×3 array, with inter-element distance d = 0.4λ. We show that, thanks to the use of Embedded Radiation Patterns, that compensate mutual coupling and non-idealities, the inter-element distance can be reduced without affecting overall antenna performances in direction finding application.

Friday, March 31 9:00 - 10:40

SW2: Material and RCS Measurements

Organized by: Michael Havrilla (Air Force Institute of Technology, AFIT); Stephen Blalock (NSI-MI Technologies, NSI-MI)

Room: Sala della Scherma

9:00 - Material Measurements and Demonstrations (Michael, Havrilla, AFIT)

Friday, March 31 9:00 - 10:40

SW6: Antenna-Enabled Systems: An Inter-Society Perspective

Organized by: Mahmoud Wagih (University of Glasgow)

Room: Polveriera

9:00 - CYBER-PROSTHESIS: From silent implantable devices to wireless data generators for Personal and Predictive Medicine (Gaetano, Marrocco, University of Rome Tor Vergata)

9:25 - Materials Interaction with Resonant-based Microwave Devices for Sensing Applications (Mohammad, Zarifi, University of British Columbia)

9:50 - Antenna-Based Sensor Tags: Sensing Using Signal Patterns (Jasmin Grosinger)

10:15 - A next wave of Wireless Communication is Here: How 6G will Evolve? (Qammer Abbasi, University of Glasgow)

Friday, March 31 11:00 - 12:40

CS39: Radio propagation characterizations and channel modelling

for RIS and sub-THz channels

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / Convened Session /

Room: Spadolini 001

Chairs: Joonas Kokkoniemi (University of Oulu, Finland), Pekka Kyösti (Keysight Technologies & University of Oulu, Finland)

11:00 ***Proposal on RIS Scattering Model Based on Physical- Optics Approximation***

Tetsuro Imai (Tokyo Denki University, Japan); Akira Kumagai, Kouichirou Takahashi and Osamu Kagaya (AGC Inc., Japan)

Nowadays, in next generation mobile communication systems (6G), the use of RIS (Reconfigurable Intelligent Surface), which enable active control of reflection direction of radio waves, has been investigated in order to eliminate coverage hole and improve communication quality in high frequency bands. Here, conventionally, the propagation characteristics of the reflected waves by RIS have been evaluated by the bistatic RCS pattern of RIS and the radar equation. However, this method deteriorates accuracy and efficiency in the evaluation of the vicinity of RIS and the multipath environment. To solve these problems, this paper proposes RIS scattering model based on physical-optics approximation. In addition, the results of evaluating the effect of installing RIS in an indoor L-shaped corridor using this model are shown.

11:20 ***A Deterministic Channel Modeling Method for RIS-Assisted Communication in Sub-THz Frequencies***

Jianhua Zhang and Zhengfu Zhou (Beijing University of Posts and Telecommunications, China); Yuxiang Zhang (Beijing University of Posts & Telecommunications, China); Lei Tian (Beijing University of Posts and Telecommunications & Wireless Technology Innovation Institute, China); Zhiqiang Yuan (Beijing University of Posts and Telecommunications, Denmark & Aalborg University, Denmark); Tao Jiang (China Mobile Research Institution Future Research Lab, China)

Sub-Terahertz (THz) communications and reconfigurable intelligent surface (RIS) are envisioned as key technologies for 6G. The development and evaluation of sub-THz and RIS are highly dependent on their channel models. Therefore, it is critical to model the channel characteristics accurately. In this paper, a surface electromagnetics based physical model is proposed firstly, which can explain the angle-dependent electromagnetic response characteristics of RIS elements. Then, the physical optics method is used to characterize the anisotropic scattering characteristics of RIS elements. On this basis, a channel modeling method for RIS-assisted communication systems is further proposed. After that, the proposed method is verified by comparing the measurement and simulation results. Finally, the channel characteristics of RIS-assisted communication systems in sub-THz and millimeter wave bands are analyzed based on the proposed method. These results provide some basic channel characterizations for the future research of sub-THz and RIS technologies.

11:40 ***Ultra-Wideband Metasurface at SubTHz: Hardware Design and Reflection Optimization***

Qi Luo (University of Herfordshire, United Kingdom (Great Britain)); George C. Alexandropoulos (University of Athens, Greece); Yonggang Zhou and Xianjun Ma (Nanjing University of Aeronautics and Astronautics, China)

In this paper, a novel ultra-wideband Reconfigurable Intelligent Surface (RIS) operating at the sub-THz frequency band is presented. The proposed design is based on the concept of the tightly coupled dipole for implementing each of the metasurface's unit cells. A radio-frequency (RF) switch is integrated into each of the RIS meta-elements, and by changing between its ON and OFF states, the polarization of each dipole is rotated by 180-degree, resulting in a 180-degree phase shift within a wide bandwidth. We present full-wave electromagnetic simulation and array synthesis results for the proposed RIS design, which showcase its efficient performance in terms of the operation bandwidth and beam steering capability. We also apply a reflection optimization approach to the designed 1-bit phase states for arbitrary beam pattern realization.

12:00 ***Measurement-Based Characterization of D-Band Human Body Shadowing***

Peize Zhang (University of Oulu, Finland); Pekka Kyösti (Keysight Technologies & University of Oulu, Finland); Mikkel Bengtson (Keysight Technologies Finland Oy, Finland); Veikko Hovinen, Klaus Nevala, Joonas Kokkoniemi and Aarno Pärssinen (University of Oulu, Finland)

The D-band among all sub-THz and THz radio frequencies is foreseen as the first one to be utilized for communications. Such high frequency communication links are particularly susceptible to shadowing events, e.g., caused by human body. In this paper we present results of a D-band channel measurement campaign, which was conducted to characterize the impact of human blockage on the excess attenuation and temporal evolution of human body shadowing. The attenuation caused by single-person blockers with different physical characteristics was measured with human frontal and lateral crossing the line-of-sight link. Predicting results of two KED models are compared with the measurement curves, which both underestimate the attenuation levels especially for the volunteer with larger size. Meanwhile, we quantify the deep fading duration varying with the fading depth, which helps to optimize the beam alignment strategy in order to maintain the sufficient signal-to-noise ratio when the dominant path is heavily obstructed.

12:20 ***Rain Attenuation of Millimeter Waves Investigated from Drop Size Distributions***

Ignacio Mata-Alonso (Universidad Politecnica de Madrid, Spain); Jose M Riera, Domingo Pimienta-del-Valle and Ana Benarroch (Universidad Politécnica de Madrid, Spain)

Rain attenuation is one of the most relevant propagation effects in mmW bands, compromising the maximum distance and/ or availability achievable at these frequencies. Research based on detailed long-term meteorological data can be used to predict rain attenuation. An investigation of this kind is presented in this paper, using a 14-year database of rain DSD gathered in Madrid, Spain with a laser disdrometer and values of extinction cross-sections of drops with the normalized diameters of the disdrometer obtained with electromagnetic simulations for H and V polarization and a model for non-spherical raindrops. The results of the research are used to assess the predictions of the ITU-R model, to analyze the impact of using this approach instead of the conventional use of that ITU-R model in the design of millimeter-wave links, and to validate, as far as possible, the procedures by the comparison with some available measurements from the same site.

Friday, March 31 11:00 - 12:40

CS10: Antennas for Radio Astronomy

T08 Space technologies, e.g. cubesats, satellite networks / Convened Session /

Room: Spadolini 002

Chairs: Quentin Gueuning (University of Cambridge, United Kingdom (Great Britain)), David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands)

11:00 ***A Method to Design Trapped-Mode Free Quadruple-Ridged Flared Horn Antennas***

Robert Lehmensiek (National Radio Astronomy Observatory, USA & Stellenbosch University, South Africa); Dirk de Villiers (Stellenbosch University, South Africa)

A quadruple-ridged flared horn antenna is typically fed asymmetrically by the centre conductor of a coaxial transmission line. Both the odd and even modes are excited at the feeding junction. If the undesired even mode is trapped along the length of the horn, resonances may be observed. Determining them with an electromagnetic solver requires a fine frequency sweep. Computationally this requires an enormous effort and thus cannot be done during optimization. Trapped modes are, however, easily predictable given the cut-off frequencies of the horn's waveguide structure. With a little initial effort, a surrogate model can be constructed of the cut-off frequencies for all possible waveguide geometries. A geometric feasibility parameter is then included in the optimization, indicating the possibility of trapped modes before any electromagnetic solver is invoked. The infeasible geometries are removed from the computation domain. The technique is illustrated by an all-metal QRFH design for the ngVLA optics.

11:20 ***Dual Band Feeds for Earth Observation***

Jesús M. García, Alberto Bravo and Carlos A. Leal-Sevillano (SENER Aeroespacial, Spain)

Earth observation is a key activity to mitigate and monitor the impact of the human civilization. Satellites in charge of these missions are equipped with reflectors and feeds onboard as part of the imaging devices, which gather information about the planet in many ways (land, sea, air, climate change…). This paper presents Sener Aeroespacial solution for satellites devoted to Earth Observation in the bands C, X, K and Ka.

11:40 ***The UK 64-Element SKA1-LOW Development Array***

Nima Razavi-Ghods (University of Cambridge, United Kingdom (Great Britain)); Alessio Magro (University of Malta, Malta); Riccardo Chiello (University of Oxford, United Kingdom (Great Britain)); John Ely, Steve Carey, Quentin Gueuning, Clive Shaw, Paul Scott and Andrew Faulkner (University of Cambridge, United Kingdom (Great Britain)); Kristian Zarb Adami (University of Oxford, United Kingdom (Great Britain)); Eloy de Lera Acedo (University of Cambridge, United Kingdom (Great Britain))

The Square Kilometre Array (SKA) telescope is designed to operate concurrently over multiple frequency bands across two continents. The low frequency instrument which will be deployed in Western Australia will operate in the 50MHz to 350MHz band using thousands of broadband log-period antennas (SKALA type). In this paper, we present a verification array consisting of 64 SKALA4 antennas operating at Lord's Bridge, Cambridge. The array utilises much of the technology proposed for SKA1-LOW, including RF-over-Fibre WDM optical transmitters. Some changes to the system architecture have been made, including switchable filters to allow operation in a higher RFI environment, especially from FM and digital radio. In this paper, we present an overview of the system which will be used for validation of EM models proposed for SKA1-LOW.

12:00 ***The Current Status and Upgrading Plan for the FAST Telescope***

Chengjin Jin (National Astronomical Observatories, Chinese Academy of Sciences, China); Bo Peng (National Astronomical Observatories Chinese Academy of Sciences, China)

This paper gives a brief description of the structural aspects of the Five hundred Aperture Spherical radio Telescope (FAST). Including the active main reflector and the focus suspension system. The special structure of FAST brings in engineering challenges in construction and operation of the telescope. The scientific outputs of FAST will be mentioned. And plans to improve the capability of FAST will also be presented.

12:20 ***Design of the CUBIQU Cubesat High-Polarization- Purity Antenna for Calibration of Ka-Band Astronomical Instrumentation***

Miguel Salas-Natera, Daniel Kohler García, Marta Donate Fuente, Alfonso-Tomás Muriel-Barrado, Roberto Garrote and Ramón Martínez (Universidad Politécnica de Madrid, Spain); Julio Gallegos (Serco for the European Space Agency (ESA), Spain); Fernando Martín Porqueras (Telespazio for the European Space Agency (ESA), Spain); Xavier Dupac (European Space Agency (ESA), Spain)

This work gives an overview the main aspects concerning the design of ultra-low-profile CubeSat antennas for the scientific mission with high-polarization-purity calibration payload within CUBIQU (CUBesat for I.Q.U) program from ESA. However, this paper is focused on the proposed ultra-low profile and high-polarization purity antenna based on microstrip patch antenna array technology. This antenna is an on-board Cubesat polarization source for astronomical instrumentation operating at 30 GHz. In this sense, the cross- polar discrimination required is 42.9 dB and 55.2 dB for 0.2° and 0.1° of precision, respectively.

Friday, March 31 11:00 - 12:40

CS35b: Plastic Based Antennas: a Real Alternative (continued)

T01 Sub-6GHz cellular / Convened Session /

Room: Spadolini 101

Chairs: Angelo Freni (University of Florence, Italy), Paola Pirinoli (Politecnico di Torino, Italy)

11:00 ***Antenna Array Based on 3D-Printed Plastic BoR Elements Coated with Conductive Paint***

Matti Kuosmanen (Aalto University & Saab Finland Oy, Finland); Juha Ala-Laurinaho and Jari Holopainen (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

The body-of-revolution (BoR) Vivaldi arrays are usually all-metal, including both antenna elements and the antenna base. However, despite the robustness and low losses of the all-metal designs, they are often heavy and expensive. In this paper, we investigate 3D-printed, dual-polarized BoR antenna elements operating at 2-6 GHz. By 3D printing the antenna elements from plastic, we can make them less expensive, hollow, and thus lightweight. The elements are made conductive by painting them with silver paint. The performance of the antenna array is evaluated with simulations and measurements. Due to the relatively low conductivity of the paint, resistive losses of the array are higher than those of the all-metal counterparts. Nevertheless, the measured total efficiency of the array is still high, 95% at the highest, which confirms the applicability of the proposed manufacturing technique. Furthermore, we compare the proposed design to a previously published inverted BoR antenna array.

11:20 ***Integrated Waveguide-In-Radome Antenna for V-Band In-Cabin Automotive Radar Applications***

Alejandro Garcia-Tejero (Universidad Politecnica de Madrid, Spain & HUBER SUHNER, Switzerland); Fernando Rodríguez Varela (Universidad Rey Juan Carlos de Madrid, Spain); Mateo Burgos-García (Universidad Politécnica de Madrid, Spain); Francesco Merli (HUBER SUHNER, Switzerland)

The concept of an integrated waveguide-in-radome antenna is introduced. Even though this concept could be helpful for 76 GHz automotive radar or industrial applications at 120 or 140 GHz, an exemplary design for automotive in-cabin MIMO radar application is presented. The radiator consists of a slotted waveguide antenna manufactured and metalized over the inner surface of the radome. By placing the radome over the metallic ground plane of the printed circuit board, a waveguide is obtained, which routes the signal from the MMIC output to the different radiators of the MIMO antenna. Furthermore, an AMC surface is included to cancel parasitic waves propagating through the radome and improve the radiation characteristics. Excellent free space performance is achieved in the 59-64 GHz band, with impedance bandwidth up to 15%, a FOV of 120◦ in all planes, and a radiation efficiency of 83%.

11:40 ***High-Volume Manufacturing of Metallized Plastic Gapwaves Antennas for mmWave Applications***

Carlo Bencivenni (Gapwaves AB, Sweden); Abolfazl Haddadi (Gapwaves AB, Gothenburg, Sweden); Abbas Vosoogh (Gapwaves AB, Sweden); Stefan Carlsson (Gapwaves AB, Gothenburg, Sweden)

In this paper we review the state of the art of high-volume production and give an overview of the main manufacturing aspects that are making plastic antennas a real alternative. Waveguide-based antennas are competing to become the technology of choice for a range of high-frequency high-volume products, such as modern telecommunication and radar systems. To reach widespread adoption however, the performance benefits must be supported by low-cost production. Coupled with the relaxed manufacturing and assembly allowed by gapwaveguide technology, metallized plastic injection molded antennas stand as a compelling solution to bring this vision to reality.

12:00 ***A Study on Shaped Lens Antennas for Wide Scanning Applications in Low Permittivity Dielectrics***

Shahab Oddin Dabironezare, Leila Gottmer and Nuria LLombart (Delft University of Technology, The Netherlands)

In this work an efficient optimization method is described for synthesizing lens antennas fabricated in low permittivity plastic materials to achieve wide scanning performances. The method is based on an antenna in reception representation. The optimized parameters are the location and orientation of the antenna feeder, lens angular region and its shape by adding Zernike polynomials to standard ellipsoidal shape. The synthesized lens antennas achieve scan losses lower than 3dB while scanning up to 60°. The presented theoretical results are validated using full wave simulations.

12:20 *In-House Copper Plated and 3D-Printed Antennas. A Low Cost and Rapid Iteration Process*

Adrián Tamayo-Domínguez, Pablo Sanchez-Olivares and Jorge Calatayud Maeso (Universidad Politecnica de Madrid, Spain); Fernando Rodríguez Varela (Universidad Rey Juan Carlos de Madrid, Spain); Juan A. Vásquez Peralvo (University of Luxembourg, Luxembourg)

This article presents the capabilities and results obtained from an in-house 3D-printing and metallization process. This process allows a drastic reduction in the manufacturing cost of prototypes as well as in the lead times for various iterations. The process is applied to horn antennas, lenses, metasurfaces, etc., with results very similar to those obtained in simulation. This process has been validated on prototypes up to 110 GHz with very low losses, equivalent to a metallic surface roughness of less than 0.5 μm.

Friday, March 31 11:00 - 12:40

A31: Antennas for Emerging applications

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 102

Chairs: Zvonimir Sipus (University of Zagreb, Croatia), Alberto Toccafondi (University of Siena, Italy)

11:00 *IoT-Based Transceiver Antenna System for 5G Future High-Speed Train Communications*

Farzad Karami and Halim Boutayeb (University of Quebec in Outaouais, Canada); Larbi Talbi (University of Quebec - Outaouais, Canada)

The serious problems with rail radio systems across the world mainly originated from poor train antenna design and deployment. Hence designing antennas for reliable radio access is so essential in public advanced railway systems. On the other hand, the mm-wave frequency spectrums are recognized sources of valuable frequencies to supply the high-rate 5G and beyond 5G Internet services with a speed of over than 10 GB per second. In this article, an mm-wave 5G transceiver antenna which includes a tapered-slot antenna and an EM signal distribution network has been introduced to overcome the challenges of harmful interaction between the transmitting and receiving high-speed train antennas and reduce their technical conflicts in the installation.

11:20 *Compact Wideband Circularly-Polarised Slot Antenna for Ambient RF Energy Harvesting*

Khatereh Nadali (Technological University Dublin, Ireland); Jakub Przepiorowski (Technological University Dublin & Antenna and High Frequency Research Centre, Ireland); Neeraj Kumar Maurya, Patrick McEvoy and Max James Ammann (Technological University Dublin, Ireland)

A dual-port dual-sense wideband circularly-polarised (CP) printed slot antenna is proposed. The compact coplanar waveguide (CPW)-fed antenna is proposed for ambient energy harvesting applications. Two identical CPW feeds excite ±45° fan-shaped stubs in the elliptical slot, providing a wide bandwidth. By separating the ground plane and slot by two narrow strips, an isolation better than 19.4 dB between the ports is achieved. The measured impedance bandwidth is 850 MHz (2.08 GHz to 2.93 GHz) and the 3dB axial-ratio bandwidth is 870 MHz (2.04 GHz to 2.91 GHz).

11:40 *Implementation of a Microwave Sensor for the Non-Destructive Detection of Plant Water Stress*

Valeria Lazzoni (University of Pisa & CNIT Italy); Riccardo Rossi (University of Florence, Italy); Danilo Brizi (University of Pisa, Italy); Francesca Ugolini (Istituto di Bioeconomia CNR); Silvia Baronti and Marco Moriondo (Istituto di Bioeconomia CNR, Italy); Marco Bindi (University of Florence, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)

In this paper, the preliminary results from a measurement campaign of a novel sensor for plants water stress monitoring are presented. The proposed microwave radiating system, consists of a microstrip self-resonant spiral coil inductively coupled to an external concentric planar probe loop. The microwave sensing configuration is the result of an optimization process aimed at maximizing the spiral coil Q-factor, required to obtain high sensitivity. The experiments have been conducted on 22 maize plants randomly divided into two water treatments: T25 (applying 25% of the irrigation requirements) and T100 (full watering). In particular, plant responses to soil water depletion were detected by monitoring the amplitude and frequency shift variation of the external planar probe input impedance acquired by the sensor. We detected an upshift in the inner spiral resonant frequency and a rise in the probe loop input impedance amplitude as irrigation water decreased.

12:00 ***Dual-Band Beamsteering Microstrip Antenna Array for Joint Communication and Sensing***

Martijn de Kok, Gina S.C. Sprenger, A. B. (Bart) Smolders and Ulf Johannsen (Eindhoven University of Technology, The Netherlands)

This article introduces a simple, but novel, concept of a single-layer dual-frequency microstrip patch antenna array for joint communication and sensing operating at 24 and 28 GHz. The frequencies are separated by polarization: the radar sensing function at the 24-24.25 GHz ISM band is vertically polarized, whilst communication at the n261 (27.5-28.35 GHz) band for 5G NR uses horizontal polarization. Based on simulation results, the antenna array is expected to achieve an azimuthal scan range of ±45◦ at the radar band with frequency scanning in elevation limited to only ±1◦. The scan ranges for communication are ±45◦ and ±40◦ in azimuth and elevation, respectively.

12:20 ***New mmWave Bowtie-Slot Antenna for Photonic Integrated Base-Station Applications***

Saeed Haydhah, Zhangbin Wu and Ahmed A Kishk (Concordia University, Canada); John Zhang (Concordia, Canada)

A compact filtering Bowtie-slot antenna of 20*18*2.21 mm^3 at 38 GHz is proposed for 5G base-stations. Quarter-wavelength serrated slots extend the sides of the Bowtie to provide a uniform field distribution across the Bowtie-slot. Thus, broadside radiation is achieved with a minimum peak gain of 8.5 dBi, minimum radiation efficiency of -0.55 dB, and matching bandwidth from 31.3 to 39.4 GHz. The filtering is achieved using the F-shaped strips within the Bowtie slot in addition to the feeding matching stubs. The lower-band null occurs at 27.1 GHz with a roll-off of 15.57 dB, and the higher-band null occurs at 40.75 GHz with a roll-off of 5.25 dB.

Friday, March 31 11:00 - 12:40

M05: General antenna measurements and other topics

T10 Fundamental research and emerging technologies / / Measurements

Room: Spadolini 103

Chairs: Vince Rodriguez (NSI-MI Technologies & University of Mississippi, USA), Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain)

11:00 ***Receiver Bandwidth Extension Beyond Nyquist Using Channel Bonding***

Sebastian Giehl and Carsten Andrich (Technische Universität Ilmenau, Germany); Michael Schubert and Maximilian Engelhardt (Fraunhofer Institute for Integrated Circuits IIS, Germany); Alexander Ihlow (Ilmenau University of Technology, Germany)

Current and upcoming communication and sensing technologies require ever larger bandwidths. Channel bonding can be utilized to extend a receiver's instantaneous bandwidth beyond a single converter's Nyquist limit. Two potential joint front-end and converter design approaches are theoretically introduced, realized and evaluated in this paper. The Xilinx RFSoC platform with its 5 GSa/s analog to digital converters (ADCs) is used to implement both a hybrid coupler based in-phase/quadrature (I/Q) sampling and a time-interleaved sampling approach along with channel bonding. Both realizations are demonstrated to be able to reconstruct instantaneous bandwidths of 5 GHz with up to 49 dB image rejection ratio (IRR) typically within 4 to 8 dB the front-ends' theoretical limits.

11:20 ***Reconfiguration Capabilities of the Anechoic-Reverberation Hybrid Chamber for TRP Measurements of Active Antenna Systems***

Pavlo Krasov and Oleg Iupikov (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden); Andrés Alayón Glazunov (University of Twente, The Netherlands); Jonas Fridén (Ericsson AB, Sweden)

A hybrid, reconfigurable anechoic-reverberation antenna measurement chamber was recently introduced with the vision to enable fast characterization of the active antenna radiated power and directive characteristics in a single measurement environment. The initial studies included its design and analysis in the plane wave spectrum generator scenario. In the present work, we investigate chamber reconfiguration capabilities for performing total radiated power (TRP) measurements. We show how different types of interchangeable hybrid chamber modules allow realizing several possible ways of measuring TRP. Trade-offs in terms of measurement time and implementation complexity are discussed. Finally, one of the methods, using a chamber array antenna module, is selected and demonstrated in simulations. Our initial results indicate TRP measurement error within ±0.5 dB.

11:40 ***Daily Thermo-Elastic Distortion Characterisation During Antenna In-Orbit Test for Geostationary Satellites***

Annalisa Iacono (Inmarsat, United Kingdom (Great Britain)); Bertrand Pinsard (Airbus DS, France)

Before bringing a new satellite into service after launch, in-orbit testing (IOT) is essential to compare in-flight performance with on-ground references. Antenna IOT is essential to remove any mechanical depoint in order to optimize the alignment of the antenna and therefore RF performance. Depending on the frequency band of operation, thermo-elastic distortion (TED) evaluations could play an important role into the determination of the correct amount of mechanical correction to apply to the antenna. It is in fact essential to discriminate between a fixed contribution derived from an authentic geometry misalignment and an expected TED behavior. The aim of this paper is to describe the methodology to show the correlation between the antenna thermal behaviour, as-measured in-orbit, and its predictions over a period of 24 hours for the Inmarsat-6 F1 Ka-band commercial payload.

12:00 ***Detailed Electrical Design of a Novel High Performance Compensated Compact Antenna Test Range***

Cecilia Cappellin, Pasquale Giuseppe Nicolaci, Stig Sørensen, William Hamilton Yatman and Mustafa Murat Bilgic (TICRA, Denmark); Damiano Trenta (European Space Agency, ESTEC, Italy); Luis Rolo (European Space Agency, The Netherlands)

The detailed electrical design of a new compensated compact antenna test range (CATR) to be installed in the HERTZ 2.0 measurement facility at the European Space Agency (ESA) is described. The CATR meets the stringent requirement of a peak-to-peak amplitude ripple of 0.5 dB and phase ripple of 4 deg, from 1 GHz to 400 GHz. To design the system, a novel approach making use of an initial trade-off with ray tracing and a subsequent detailed full wave analysis and optimization of the serrations profile, length and orientation was used. In this paper we describe the choices taken during the design and show the detailed performances at L band

12:20 ***Impact of Excitation and Weighting Errors on Performance of Compact OTA Testing Systems***

Alejandro Antón Ruiz and Andrés Alayón Glazunov (University of Twente, The Netherlands)

This paper investigates the impact of excitation errors of the chamber array on the accuracy of the test zone of a random line-of-sight over-the-air testing setup. First, various combinations of lengths L of 100 elements, linearly tapered chamber arrays and distances D between test zone and chamber array, emulating a plane wave impinging at the test zone are obtained. A subset of compact L and D was chosen, investigating the tolerance to excitation errors of the chamber array, concluding that they must be considered when defining appropriate L and D combinations. Moreover, the performance of matched filter and zero-forcing algorithms is evaluated for errors of the device-under-test array weighting coefficients. A random line-of-sight over-the-air testing setup with two arrays was simulated, emulating each one the desired and interfering signals, respectively. Results show more impact of weighting errors for higher signal-to-noise ratios, as well as for zero-forcing compared to matched filter.

Friday, March 31 11:00 - 12:40

E08: EM theory 2

T10 Fundamental research and emerging technologies / / Electromagnetics

Room: Spadolini 104

Chairs: Xenofon Mitsalas (University of Brescia, Italy), Alex Schuchinsky (University of Liverpool, United Kingdom (Great Britain))

11:00 ***Contact Nonlinearities of Rough Conductors in Antennas and Connectors***

Amir Dayan, Yi Huang and Alex Schuchinsky (University of Liverpool, United Kingdom (Great Britain))

Contacts of conductors with rough surfaces cause losses and nonlinear distortion of the high-power signals at high frequencies. The contact nonlinearities are analysed in a pair and array of the contact asperities in metal-insulator-metal (MIM) junctions. An improved model of the tunnelling resistivity is proposed and its accuracy is demonstrated for the harmonic signals. The model is also applied to the analysis of the thermal effect on the contact resistivity of rough conductors.

11:20 ***Parity-Time Symmetry for Electromagnetic Transparency of Lossy Media***

Thi Hai-Yen Nguyen (Ulsan National Institute of Science and Technology, Korea (South)); Dimitrios Sounas (Wayne State University, USA); Gangil Byun (Ulsan National Institute of Science and Technology (UNIST), Korea (South))

This paper presents the exact conditions of the parity-time symmetry for electromagnetic transparency through lossy media. The material loss is modeled in a one-dimensional non-Hermitian multilayer system and is balanced with gain media. The gain layer is realized by four equivalent models, and their exceptional points are analyzed by varying dielectric loss. The tunability of the exceptional point is further explored to make the parity-time symmetric non-Hermitian system more robust to the uncertainty of material properties and incident angles perturbing the impedance and propagation constant inside the system. We believe the proposed approach will bring potential advances in future wireless communications for better emission of electromagnetic fields through lossy materials, such as glass.

11:40 ***Design and Applications of Spatially-Dispersive Phase-Gradient Metasurfaces***

Alessio Monti (Roma Tre University, Italy); Andrea Alù (CUNY Advanced Science Research Center, USA); Alessandro Toscano and Filiberto Bilotti (Roma Tre University, Italy)

In this work, we explore the design of spatially-dispersive gradient metasurfaces able exhibiting different phase profiles as the angle of incidence changes. Differently from earlier designs, characterized by an intrinsically-weak spatial-dispersion, here the angular selectivity of the individual Huygens cells composing the metasurface is intentionally enhanced and optimized. With a combination of analytical and numerical results, it is shown that such optimized devices exhibit different macroscopic behaviors vs. the incidence angle and offer additional possibilities compared to conventional gradient metasurfaces in many relevant applicative scenarios.

12:00 ***Scattering of a TM Wave on a Dielectric Dimer: Radiated Field and Strong Coupling Effects***

Xenofon Mitsalas (University of Brescia, Italy); Davide Rocco and Andrea Locatelli (Università degli Studi di Brescia, Italy); Fabio Mangini (University of Brescia, Italy); Fabrizio Frezza (Sapienza University of Rome, Italy); Costantino De Angelis (Università degli Studi di Brescia, Italy)

This paper aims at analyzing the electromagnetic scattering of transverse magnetic (TM) waves impinging on a dimer of dielectric subwavelength scatterers. Our work provides a novel analytical method, based on amplitude weighted coefficients to describe the role of strong coupling in the molding of the total scattered field. The obtained results reveal to be an optimum tool to engineer electromagnetic and geometric features in order to get the desired radiated field, without resorting to full wave simulations. Analytical results exhibit excellent agreement with exact numerical results obtained with COMSOL Multiphysics.

12:20 ***Stored Energies Derived from Material Perturbation***

Ben A. P. Nel (Lund University, Sweden); Anja K. Skrivervik (EPFL, Switzerland); Mats Gustafsson (Lund University, Sweden)

Interpreting stored energies of radiating structures has been a topic of interest for several decades. While there is still lack of consensus on a method to compute these quantities, the approach of taking angular frequency derivatives of the method of moments impedance matrix is widely used. In this paper it is shown that these same expressions can also be derived by taking permittivity and permeability derivatives that lead to expressions for stored electric and stored magnetic energies, respectively. This alternative interpretation leads to additional physical insight on stored energies.

Friday, March 31 11:00 - 12:40

E12: Reconfigurable metasurfaces for 5G and beyond

T11 Smart surfaces (RIS, LIS) for 5G and B5G systems / / Electromagnetics

Room: Spadolini 105

Chairs: Mirko Barbuto (Niccolò Cusano University, Italy), Carey Rappaport (Northeastern University, USA)

11:00 ***Design of a Reconfigurable Phase Gradient Metasurface for Beam Steering Applications***

Callum J Hodgkinson (University of Edinburgh & Heriot Watt University, United Kingdom (Great Britain)); Dimitris E. Anagnostou (Heriot Watt University, United Kingdom (Great Britain)); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

This paper presents a novel, reconfigurable phase gradient metasurface (PGMS) for beam steering applications. By embedding varactors into the unit cells of a three-layered metasurface (MS) and adjusting the biasing in each column, a completely reconfigurable and tuneable PGMS has been achieved. The structure is capable of steering a main beam from broadside to 48 degrees in either direction and can tune to intermediate angles by adjusting the phase gradient at the aperture interface. Furthermore, the surface can operate at broadside as a tuneable frequency selective surface (FSS). This highly reconfigurable design overcomes limitations in previous static, fixed-beam PGMS implementations, and thus offers a new radome structure capable of operational versatility and selective beam steering. Applications include radar antennas as well as other directive beam steering scenarios and this allows for enhancement of conventional phased array systems.

11:20 ***A New Design Strategy for Reconfigurability of Smart Electromagnetic Devices***

Mirko Barbuto (Niccolò Cusano University, Italy); Andrea Alù (CUNY Advanced Science Research Center, USA); Filiberto Bilotti and Alessandro Toscano (Roma Tre University, Italy)

The aim of this contribution is to discuss the possible application of composite vortex theory to introduce a new design strategy for adding reconfigurability to different electromagnetic devices. In particular, the concept of composite vortices will be exploited to control the radiating and reflecting properties of patch antennas and reflective metasurfaces, respectively. Compared to other approaches, this design strategy allows for reducing the number of elements to be controlled and, thus, simplify the practical implementation of reconfigurable antennas and reflective intelligent surfaces, which are fundamental elements of next-generation wireless systems.

11:40 ***Scattering Gain Loss Bounds for Discretized Reconfigurable Intelligent Surfaces***

Luca Stefanini (Roma Tre University, Italy); Davide Ramaccia (RomaTre University, Italy); Alessandro Toscano and Filiberto Bilotti (Roma Tre University, Italy)

In this contribution, we study how the unavoidable discretization process affects the scattering gain of a Reconfigurable Intelligent Surface (RIS). We characterize the discretization as an equivalent random variable with a proper expected value and variance depending on the unit cell (UC) dimensions and the phase profile exhibited by the RIS. This consideration allows us to model the response of a discrete RIS as a continuous RIS perturbed by that random variable. From there, we evaluate the expected value on the radiation patterns and define the discrete RIS scattering gain loss. We numerically verify our model by comparing a discrete RIS with a continuous RIS whose phase is perturbed by a random variable with adequate statistical characteristics. The proposed model gives an interesting tool to evaluate the communication channel of a realistic RIS.

12:00 ***Study on the Effect of the Wall in the Performance of an Intelligent Reflective Surface for Providing Coverage in mm-Wave Frequencies***

Álvaro F. Vaquero (Universidad de Oviedo, Spain); Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain); Manuel Arrebola (Universidad de Oviedo, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain)

This work presents the design of a passive reflectarray-based Intelligent Reflective Surface (IRS) to improve the coverage in a 5G scenario at 28 GHz. The IRS generates a wide beam in azimuth with a narrow beam in elevation, using a Phase-Only Synthesis with the Intersection Approach to design it. The resulting phase-shift distribution radiates a field pattern that covers an angular range of 12.75° and 2° in azimuth and elevation. Due to the IRS is placed on a building face, the surrender wall effect is analyzed. Different building materials are electromagnetically characterized in the Ka-band. Then, the effect of the wall is included in the radiated field. The results clearly demonstrate that the wall produces a strong reflection on the specular direction, deeply affecting the coverage. These preliminary results show the importance of including the wall in the design process.

12:20 ***Electromechanically Reconfigurable Intelligent Reflection Surface for Millimeter-Wave Indoor Application***

Park Eiyong (University of Chung-Ang, Korea (South)); Heijun Jeong, Ratanak Phon and Sungjoon Lim (Chung-Ang University, Korea (South))

Electromechanically reconfigurable intelligent reflection surface (RIS) has been proposed to overcome the current technical issues in millimeter-wave wireless communication systems. Although reconfigurable intelligent surfaces are considered a promising solution for fifth-generation wireless communication, their practical implementation has challenges because RIS require a large number of active devices, leading to parasitic effects, high costs, modulated signal distortion, and increased design complexity. Herein, we report electromechanically RIS for millimeter-wave indoor application. We use rotatable unit structures and rack gear systems for implementing the innovative beam control function. To demonstrate the proposed method feasibility, the novel RIS was measured using modulation signal which required for future 5G wireless communication based on 5G New Radio Frequency Range 2 standards for indoor environments.

Friday, March 31 11:00 - 12:40

CS28: Inverse Problems for Electromagnetics

T10 Fundamental research and emerging technologies / Convened Session /
Room: Spadolini 106
Chair: Roberta Palmeri (IREA-CNR, Napoli, Italy)

11:00 ***Recent Advances in IMSA for Electromagnetic Inverse Problems***

Marco Salucci (ELEDIA Research Center, Italy); Zhichao Lin (Tsinghua University, Italy); Maokun Li (Tsinghua University, China); Andrea Massa (University of Trento, Italy)

The Iterative Multi-Scaling Approach (IMSA) is a powerful and flexible framework for the accurate, reliable, and robust solution of electromagnetic (EM) inverse problems (IPs) arising in several applicative scenarios. It relies on the adaptive refinement of the resolution within the so-called regions-of-interest (RoIs), where a discontinuity with respect to the surrounding medium has

been detected. This work presents some recent advances in this field, proposing a first attempt to integrate the IMSA with a data-fusion imaging strategy. More precisely, a novel IP solution scheme is described, which combines the capabilities of the IMSA with those of a multi-physics (MP) technique jointly processing EM and acoustic (AC) data. An illustrative example is shown to preliminarily assess the effectiveness of the proposed IMSA-MP methodology in retrieving accurate guesses of multiple (i.e., EM and AC) constitutive parameters with high fidelity.

11:20 ***Ground and Aerial Subsurface Radar Imaging via Microwave Tomography***

Ilaria Catapano, Gianluca Gennarelli, Giovanni Ludeno and Giuseppe Esposito (IREA-CNR, Italy); Francesco Soldovieri (CNR, Italy)

The interest in non-destructive surveys of natural and anthropic environments makes subsurface radar imaging an ever-green research topic and the current trend concerns the design of technological solutions conjugating the potentialities of Ground Penetrating Radar (GPR) systems with those of Unmanned Aerial Vehicles (UAV). In this frame, Microwave Tomography (MWT) deserves attention because it allows facing the imaging by using the same mathematical tools regardless of the observation platform mounting the radar. This paper reviews the formulation of GPR imaging as a linear inverse scattering problem and discusses how the same formal equation can be specified to process data collected by ground or UAV-based systems. Specifically, the paper shows that subsurface imaging from UAV GPR data is faced with the same computational complexity encountered when standard on ground measurements are processed. Results referred to an experiment carried out in controlled conditions are provided as a proof of concept.

11:40 ***Flexible Set-Up of Measurement Configurations in Inverse Scattering by SVO***

Amedeo Capozzoli, Claudio Curcio and Angelo Liseno (Università di Napoli Federico II, Italy)

We show that the SVO approach can also be used in linear inverse scattering under the Born approximation in a very flexible, efficient and effective way. In particular, we numerically highlight that Singular Value Optimization (SVO) is able to manage different measurement configurations, in particular multimonostatic, multistatic/single-view and multistatic/multi-view configurations, while properly taking into account the shape and size of both the investigation and measurement domains as well as partial acquisitions due to aspect limitations of the data. We also show numerically how SVO is able to determine the frequency sampling, however in the simplified hypothesis of uniform frequency step to keep the computational burden of the optimization low.

12:00 ***Data Reduction in Linear Phased Array Diagnostic by a TR-MUSIC Based Approach***

Mario Del Prete (University of Campania Luigi Vanvitelli, Italy); Maria Antonia Maisto (Università degli studi della Campania Luigi Vanvitelli, Italy); Giovanni Leone (University of Campania, Italy)

In this paper, the problem of linear phased array antenna diagnostics from a small number of near-field measurements is addressed. Thanks to a new method to collect measurements suitable for phased array, a TR-MUSIC based algorithm is explored. Finally, numerical examples show the effectiveness of the proposed method.

12:20 ***Preliminary In-Line Microwave Imaging Experimental Assessment for Food Contamination Monitoring***

Marco Ricci and Jorge A. Tobon Vasquez (Politecnico di Torino, Italy); Rosa Scapaticci (CNR-National Research Council of Italy, Italy); Giovanna Turvani and Mario Roberto Casu (Politecnico di Torino, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Francesca Vipiana (Politecnico di Torino, Italy)

Food producers must deal with contaminants (as e.g. fragments of wood, plastic and glass) inside packaged products that could lead to customer dissatisfaction. The assessed technologies can fail to detect some of these contaminants, leading to the need for new technologies with different signal qualities, such as microwave sensing and imaging. This paper presents a preliminary experimental assessment of a microwave imaging system designed for industrial applications. The measurement system is designed for and works on an industrial conveyor belt where packaged products are scanned. The scanned signals are processed to obtain an accurate 3D image of the size and position of the contaminant inside the food package.

Friday, March 31 11:00 - 12:40

CS32b: mmWave and THz channel sounding for Beyond 5G communications

T02 Mm-wave and THz cellular / Convened Session /

Room: Spadolini 107

Chairs: Diego Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany), Wei Fan (Aalborg University, Denmark)

11:00 ***Frequency Dependence of Millimeter-Wave Urban Macrocell Multipath Cluster Channels***

Minseok Kim, Naoya Suzuki, Hibiki Tsukada and Riku Takahashi (Niigata University, Japan)

It is essential to understand the site-specific propagation channel characteristics, which are highly environment- and frequency-dependent, for the operation of the millimeter-wave radio systems. This study conducted double-directional (D-D) channel measurements in an urban macrocell (UMa) environment using 24/60-GHz dual-band channel sounder. In the post-processing, multipath components (MPCs) were extracted from the measured data, and then grouped into several clusters. Here, the clustering was conducted with the composite datasets of 24~GHz and power-compensated 60~GHz MPCs to obtain the common clusters at both frequencies. From the results, this study compared the scattering processes in the two frequency bands. The statistical characteristics obtained at two frequencies such as the power difference and relative delay of common clusters at two frequencies were compared and discussed.

11:20 ***Measurement-Based Multi-Link Massive MIMO Channel Characterization at Millimeter-Wave Bands***

Yejian Lyu (Aalborg University, Denmark); Allan Mbugua (Huawei Technologies Duesseldorf GmbH, Munich Research Center, Germany); Zhiqiang Yuan (Beijing University of Posts and Telecommunications, Denmark & Aalborg University, Denmark); Wei Fan (Aalborg University, Denmark)

This paper presents a multi-user channel measurement campaign using a recently developed VNA-based multi-link channel sounder in an indoor hall scenario. The channel sounder architecture and comparison with the conventional multi-link channel sounder are firstly demonstrated, with a focus on the cost-effectiveness of the developed channel sounder. The two multi-user location combinations are considered in these channel measurements. The empirical channel data for the multi-user is then processed using the calibration procedure. By using the classical beamforming algorithm, the power-angle-delay-profiles (PADPs) are obtained from the calibrated channel response. The channel characteristics of the two links, i.e., PADP, delay, and angular spread, are analyzed and compared.

11:40 ***Experimental mmW Channel Sounding in the 60 GHz Band in Railway Environments***

Nicholas Attwood, Francois Gallée and Patrice Pajusco (IMT Atlantique, France); Marion Berbineau (COSYS, Université Gustave Eiffel, IFSTTAR, Univ Lille & Railenium, France)

Railways are facing an ever increasing needs for safe and secure wireless communications with the generalisation of automatic and driverless trains. In this context, frequency scarcity is a real bottleneck. To overcome this blockage, opportunities offered by mmW frequency bands are explored. Due to the specificity of environments, researches conducted for general 5G and beyond deployments can not be transposed easily. Channel sounding in the mmW bands in real railways environments should be conducted. In this context, this paper presents preliminary experimental results in a railway environment with a relative low cost and reconfigurable channel sounder operating at 60 GHz.

12:00 ***H-Plane-Scanning Multibeam Leaky-Wave Antenna for Wide-Angular-Range AoA Estimation at mm-Wave***

Julien Sarrazin and Guido Valerio (Sorbonne Université, France)

A fully-metallic periodic leaky-wave antenna well suited for angles-of-arrival estimation with a reduced frequency bandwidth is presented. The design is based on a leaky rectangular waveguide loaded with corrugations and periodically modulated by longitudinal slots, which produces a frequency beam scanning in the H-plane. By exploiting multiple visible spatial harmonics, multiple beams are radiated for each frequency. This enables the antenna main beam to scan the 180°-angular range with a bandwidth of only 3.7% at 27 GHz. Simulations show that using a frequency-domain MUSIC approach, it is possible to estimate angles of arrival of several incoming sources without ambiguity.

12:20 *EM-Based Building Material Parameter Estimation with Wideband Free Space Measurement Method*

Kentaro Saito (Tokyo Denki University, Japan); CheChia Kang and Jun-ichi Takada (Tokyo Institute of Technology, Japan)

Recently, the cyber-physical system (CPS) has attracted the great interest of society for speedup and cost reduction of the development of wireless communication systems. In CPS, since the communication characteristics are reproduced based on radio propagation simulations, obtaining the correct communication environment model is important. In this paper, we propose the estimation method of material parameters of building structures. In our proposal, the complex permittivities and the thicknesses of the building materials are obtained by the wideband measurement based on the free space method and the maximum likelihood based estimation algorithm. The experiment was conducted in the 33 GHz band, and the material parameters of a door glass were estimated. The estimation result entirely matched the measurement, and it showed that our proposal is effective in obtaining equivalent material parameters for radio propagation simulation. Further experiments with various building materials and their utilization in the CPS are future works.

Friday, March 31 11:00 - 12:40

A26: Innovative Array Designs

T10 Fundamental research and emerging technologies / / Antennas

Room: Spadolini 108

Chairs: Matteo Albani (University of Siena, Italy), A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

11:00 *Cost-Effective Ultra-Wideband Tightly Coupled Dipole Array (TCDA) with Low Profile*

Wen Dang, Wai Yan Yong and Andrés Alayón Glazunov (University of Twente, The Netherlands)

In this paper, a low-profile tightly coupled dipole array (TCDA) with ultra-wideband (UWB) and wide scanning capability has been proposed for Ku-band communication. The proposed dipole is excited by a simplified Γ-shaped probe. A wide impedance bandwidth matching is achieved by three shorting posts connected to each dipole arm. The unwanted common mode is suppressed by means of an E-wall constructed from a pair of shorted strips beneath the dipole. Also, a metasurface (MS) is used as a wide-angle impedance matching (WAIM) layer realized with H-shaped elements to increase the impedance matching performance of the proposed TCDA in both E- and H-planes. Numerical simulations show that the TCDA antenna has a relative bandwidth of 3.17:1 (10.3−32.7 GHz) at a VSWR ≤ 2.3 for broadside. The good performance is maintained for a 60◦ scanning angle from 10.5−22.5 GHz at a VSWR ≤ 2.6 in both the E- and H-planes.

11:20 *Multi-Layer Sub-Array Overlapping*

Shahin Sheikh (LATYS Intelligence, Canada); Ahmed A Kishk (Concordia University, Canada)

Contiguous sub-array overlapping is investigated for multilayer sub-arrays. The structures are implemented in multiple layers to realize complex sub-array overlapping with a smaller number of crossovers. It is shown that complex sub-array schemes, which might be impossible to realize in one layer, can be implemented in several layers with less complication. The computed results of array factors and Full-wave simulation results are presented. The Full-wave results are acceptably compatible with design computations.

11:40 ***Performance Enhancement of a mmWave Antenna Using Modified Series-Fed Array Structure***

Md. Abu Sufian (Chungbuk National University, Korea (South)); Niamat Hussain (Sejong University, Korea (South)); Anees Abbas and Domin Choi (Chungbuk National University, Korea (South)); Qasid Hussain (Chungbuk National University, South Korea, Korea (South)); Nam Kim (Chungbuk National University, Korea (South))

In this paper, a modified series-fed array antenna with wideband characteristics is presented for the 5G mmWave applications. Additional loaded patches in both the E-plane and H-plane of the proposed antenna offer wider bandwidth and high gain with side lobe suppression of the conventional rectangular series-fed antenna. The proposed antenna is simulated and fabricated on a 0.787 mm thick Rogers RT5880 substrate with an overall size of 16 mm × 16 mm. According to the results of both simulations and measurements, the suggested antenna has a broad operational bandwidth that ranges from 24.62 - 30.64 GHz, which corresponds to 21.78% of the central frequency. The antenna also offers unidirectional radiation patterns with a peak gain of 12.4 dBi. The proposed antenna is a viable option for 5G mmWave communications due to its complete set of performance features.

12:00 ***Linear Rampart Array with Two-Dimensional Scanning for FMCW Radar***

Tudor Ioan Popa (The Antenna Company & Eindhoven University of Technology, The Netherlands); Gabriele Federico and A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands); Diego Caratelli (The Antenna Company, The Netherlands)

A novel rampart array with eight active and two parasitic elements that is able to steer in the azimuth plane through frequency sweeping and in the elevation plane through phase shifts, has been developed. The presented system has an impedance matching bandwidth of 15% centered around 8.625 GHz and has a field of view of 140 degrees in both scanning planes. A prototype has been manufactured and characterized. The measured radiation characteristics show a good agreement with the simulation model.

12:20 ***Multipurpose Antenna Array for Backscattering, Reconfigurable Intelligent Surfaces and MIMO Communications***

Abdelwaheb Ourir (Institut Langevin ESPCI Paris CNRS, France); Dinh-Thuy Phan-Huy (Orange, France); Philippe Ratajczak (Orange Innovation, France); Julien de Rosny (CNRS, ESPCI Paris, PSL Research University, France)

Energy consumption of mobile network is a major issue. One solution is to use antenna arrays to focus RF field on the receiver. But recently two other techniques have been also proposed. First the RIS are programmable mirrors which can be used to redirect a RF wavefront emitted by a source toward one or several receivers. Second the ultra-low power backscattering devices recycle the ambient RF field to transmit information. Actually, the best energy aving approach depends on many different parameters. So here we propose a multipurpose antenna array (MAA) able to manage these three operating modes simultaneously. The MAA switches between the different modes thanks to an electronic circuit made of PIN diodes. We propose a simple model of MAA based on impedance analysis. Finally, we evaluate experimentally the performances of the three operating modes of a MMA made of 4 patch antennas working at 3.7 GHz.

Friday, March 31 11:00 - 12:40

P09: Medium- and Long-Range Propagation Measurements and Analyses

T09 EM modelling and simulation tools / / Electromagnetics

Room: Spadolini 109

Chairs: Marianna Biscarini (Sapienza University of Rome, Italy), Franz Teschl (Graz University of

Technology, Austria)

11:00 *Cross-Polarization Discrimination Interference Analysis of Alphasat Satellite Measurements in Ka and Q Bands*

Arsim Kelmendi (Jozef Stefan Institute, Slovenia); Mihael Mohorcic (Jozef Stefan Institute & Jozef Stefan International Postgraduate School, Slovenia); Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal)

The implementation of satellite communication systems with a throughput of terabits per second requires the use of the Ka and Q bands and above, which can accommodate radio channel bandwidths in the gigahertz range. In addition, the spectral efficiency of these systems can be increased by using the dual orthogonal polarization mode. At these high frequencies, among other tropospheric phenomena affecting electromagnetic wave propagation, rain attenuation represents the major obstacle in the design of high-frequency satellite communication systems. Furthermore, the depolarization interference caused by raindrops and ice particles degrades the performance of dual-polarized systems. In this paper, the cross-polarization discrimination (XPD) from the beacon measurements of the Alphasat satellite at 19.7 GHz and 39.4 GHz in Ljubljana, Slovenia, are investigated. The complementary cumulative distribution (CCDF) of the one-year XPD measurements is also presented.

11:20 *Site-Specific Deep Learning Path Loss Models Based on the Method of Moments*

Conor Brennan and Kevin McGuinness (Dublin City University, Ireland)

This paper describes deep learning models based on convolutional neural networks applied to the problem of predicting EM wave propagation over rural terrain. A surface integral equation formulation, solved with the method of moments and accelerated using the Fast Far Field approximation, is used to generate synthetic training data which comprises path loss computed over randomly generated 1D terrain profiles. These are used to train two networks, one based on fractal profiles and one based on profiles generated using a Gaussian process. The models show excellent agreement when applied to test profiles generated using the same statistical process used to create the training data and very good accuracy when applied to real life problems.

11:40 *Relationship Between Cloud Cover and Rainfall Rate in Madrid: First Results*

Ana Benarroch (Universidad Politécnica de Madrid, Spain); Gustavo Siles (Universidad Privada Boliviana, Bolivia); Jose M Riera (Universidad Politécnica de Madrid, Spain)

A first analysis of the relationship between cloud cover and rainfall rate has been performed using two years of total cloud cover data provided by ERA5 and experimental rainfall rate measurements collected with a disdrometer at UPM. The results obtained include cumulative distributions and histograms of both parameters, and the scatter plots of total cloud cover against the hourly average of rainfall rate and hourly maximum rainfall rate. The duration of events has also been investigated for both parameters.

12:00 *A Proposed Mid-Band Statistical Clutter Propagation Model Utilizing Lidar Data*

William Kozma, Jr. (Institute for Telecommunication Sciences, USA); Michael Cotton (NTIA, USA)

This paper proposes a mid-band statistical propagation model where objective clutter metrics derived from LiDAR data provide the means to predict the distribution of clutter loss. Model performance is compared with 3.5 GHz propagation measurements performed in Boulder, Colorado at two different antennas heights. Results demonstrate that this approach provides improved accuracy when compared to traditional modeling approaches that use subjective clutter categories such as urban, suburban, and rural.

12:20 *Tropospheric Scintillation and Simultaneous Rain Attenuation at 19.7 GHz and 39.4 GHz for Tito Scalo and Spino D'Adda*

Alef Comisso, Lorenzo Luini and Carlo Riva (Politecnico di Milano, Italy); Giuseppe Codispoti (Italian Space Agency, Italy); Giorgia Parca (Agenzia Spaziale Italiana, Italy)

Beacon power levels measured in 2015 in the framework of the Alphasat Aldo Paraboni propagation experiment at the two receiving station in Tito Scalo and Spino D'Adda, for beacon frequencies of 19.7 GHz and 39.4 GHz, are calibrated to extract total attenuation timeseries. These timeseries are then used to perform an analysis on scintillations during rain events. The analysis

shows that there is some deviation (23% and 38% at Ka band and Q band, respectively) in the slope of the power law fitted to the data, with respect to the slope of the power law provided in the thin layer model. Furthermore, it was found that the scintillation intensity ratio at Spino D'Adda and Tito Scalo are 22.2% and 21.1% smaller, respectively, than the theoretical one.

Friday, March 31 11:00 - 12:40

SW2b: Material and RCS Measurements (continued)

Organized by: Michael Havrilla (Air Force Institute of Technology, AFIT); Stephen Blalock (NSI-MI Technologies, NSI-MI)

Room: Sala della Scherma

11:00 - Radar Cross Section (RCS) Measurements and Demonstrations

Friday, March 31 11:00 - 12:40

SW6b: Antenna-Enabled Systems: An Inter-Society Perspective (continued)

Room: Polveriera

11:00 - Emerging antenna-enabled wireless power and connectivity for human, machine and robotics (Chaoyun Song, King's College London)

11:25 - Antennas Co-Designed with Circuits: System Integration outside Antenna Engineering (Mahmoud Wagih, University of Glasgow)

11:50 - Interactive panel discussion

Friday, March 31 12:40 - 13:50

Closing Ceremony

Room: Spadolini 001

Friday, March 31 14:00 - 17:00

Short Courses