Antenna Designs for 5G/IoT and Space Applications

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Editorial

Antenna Designs for 5G/IoT and Space Applications

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1. Introduction

Antenna design has received renewed attention in the last few years. This is thanks to an explosion of interest in a range of applications, from the Internet of Things, low frequency long-range applications to high frequency mmWave 5G mobile technologies. There has also been renewed interest in wearable antennas that form body area networks. These include wearable garments, as well as materials that directly attach themselves to skin, such as e-skin. In addition to this, a renewed interest in space and space exploration has renewed interest in satellite technologies and applications, such as CubeSats, intersatellite communications and deep space exploration. All these emerging applications bring a renewed interest in looking at special materials and new designs for antenna systems. This will bring new challenges in designing such antennas.

For this purpose, this Special Issue is intended to shed some light on recent advances in antenna design for these new emerging applications and identify further research areas in this exciting field of communications technologies. We invite researchers and practicing engineers to contribute original research articles that discuss issues related but not limited to:

- Antenna design for Internet of Things;
- Beamforming and smart antennas for 5G;
- Antenna design for wearable applications;
- Antenna design for body area networks;
- Antenna design for chipless RFID;
- Metamaterial-based antennas;
- Smart antennas, beamforming and MIMO;
- Aeronautical and space applications;
- Antenna design for CubeSat;
- Antenna design for deep space communication
- Antenna design for biomedical systems and applications;
- Implanted antennas;
- UWB and multispectral technologies and systems;
- MM-wave and THz antennas.

2. Short Presentation of the Papers

Liu et al. [1] presented a comprehensive survey of antennas used for 120 CubeSat missions from the period from 2003 to 2022, as well as their techniques and approaches. The aim of this paper is to provide an introductory guide on CubeSats antennas for CubeSat enthusiasts and a state of the art for CubeSat designers in this ever-growing field. It

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presents a background on CubeSats and their subsystems to provide newcomers with the fundamental knowledge on CubeSat technologies. In addition, the authors investigated different designs for CubeSats, including single-element antennas and antenna arrays, as well as the aim of capturing the current and future CubeSat trends from an antenna point of view. They also proposed a pictorial representation of how to select an antenna for different types of CubeSat missions.

Farasat et al. [2] surveyed the recent base station antenna (BSA) designs for 5G Sub-6 GHz and their challenges. The authors provided a comprehensive summary of BSAs with particular interest placed on lower microwave bands in sub-6 GHz range. They also provided a brief discussion on the development of the BSA technologies through mobile generations, as well as a detailed discussion on the challenges associated with the BSAs. These challenges include the achieving wide impedance bandwidth while meeting the port-to-port isolation requirements, making the radiating elements of one band transparent to another band and vice versa without causing scattering and undesirable effects on the radiation pattern and meeting the size constrains. The authors have also provided a cohesive list of design techniques adopted to overcome the aforementioned challenges.

Khaleel et al. [3] proposed a graphene plasmonic two port MIMO antenna for 6G/IoT applications. The proposed antenna operates in Terahertz frequency band (e.g., 3.2–3.8 THz) and provides good radiation performance. A technique that the authors used to reduce the mutual coupling between radiating elements is the etching of the dumbbell-structure metamaterial (MTM) unit cell in the ground plane. They reported a high isolation of −55 dB between radiating elements, simulated gain of 7.23 dB and low channel capacity loss of 0.006.

Khan et al. [4] presented an ultra-wideband pentagonal fractal antenna for new-field microwave imaging applications. The proposed compact antenna has a size of 24 mm × 30 mm × 0.787 mm and used the Rogers RT/Duroid 5880 dielectric substrate. The authors used the co-planar waveguide (CPW) feed technique and trapezoidal ground plane to achieve low losses and to enhance the impedance matching, respectively. The proposed antenna provides a fractional bandwidth of 123.56%, and a measured −10 dBi impedance bandwidth of 9.7 GHz (3–12.7 GHz) and a total gain of 3.6 dBi at 8.5 GHz.

Nuñez et al. [5] designed and proposed a compact single-input single-output antenna with a slotted decahedral patch for 5G applications. The main idea is the use of decahedral patch with the eight-pointed star-shaped slot geometry and two rectangular grooves to enhance the antenna's performance and to achieve the stability of the radiation pattern across the wide −10 dB impedance bandwidth (e.g., 23–29.9 GHz). The proposed antenna has a total size of 13 mm × 13 mm × 0.787 mm and achieves a wide −10 dB impedance matching of 6.84 GHz (23.1–29.9 GHz), 89.4% radiation efficiency, a gain of 6.56 dBi and reflection coefficient of −21.5 dB at 29 GHz.

Munir et al. [6] presented a multi-circular loop planar antenna array for next generation mm-wave communication system. The proposed antenna consists of multi circular loop rings, uses Rogers 5880 substrate and has a small size of 18.5 mm × 12.5 mm × 0.254 mm. To enhance the performance (e.g., −10 dB bandwidth, gain and reflection coefficient) of the proposed antenna, the authors used a partial ground plane with a square slot, and four elements. The measure and simulated results are in good agreement and the proposed antenna array provides a dual band with a narrow beamwidth and a small reflection coefficient, wide −10 dB impedance bandwidth (e.g., 26–38.5 GHz) and radiation efficiency of 95%.

Hussain et al. [7] proposed a low-profile meandered loop slot-line antenna for the Internet of Things (IoT) application. The proposed antenna operates in wideband tuning, 0.758–1.034 GHz, has a size 60 mm × 27 mm × 0.76 mm and operates over a wide band of sub-GHz. The miniaturization of the antenna is achieved by using the meandered structured loop slot line loaded on a varactor diode. The varactor diode was used to achieve the wideband frequency reconfigurability. The authors reported an efficiency ranging from 54–67% and total gain ranging from 0.86–1.8 dBi.

Faouri et al. [8] presented a microstrip meandered bowtie antenna with multi-resonant and rejection bands for 5G applications. The antenna has a total size of 30 mm × 30 mm × 1.6 mm and was built on double-sided FR-4 substrate. The shorting via is used to connect one portion of the bowtie to the ground plane, hence enhancing the resonances. Moreover, length, width and spacing of the meander line arms are optimized to produce more resonances with an acceptable bandwidth. The proposed antenna covers S, C and X-bands, has an efficiency of 90.3%, achieved a gain of 4.46 dB and resonates at 2.7, 4.05, 5.05, 6.04, 7.15, 7.9 and 11.55 GHz.

Sadananda et al. [9] presented a compact three-port wide angular coverage patch antenna array for mmWave 5G smartphones. The proposed multi-port electrically connected patch antenna system operates at 28 GHz (Ka-band) and has a size of 24 mm × 6.2 mm. The multiport radiator and ground plane are shared and electrically connected. To achieve the pattern diversity with angular coverage, the authors integrated the stepped impedance transformers with the corner-most elements. Moreover, the feed line is connected to a two-way non-Wilkinson-based power divider. The authors reported a wide angular coverage of 100°, antenna efficiency of 97%, a mutual coupling less than 10 dB and a gain variation of 6 to 11 dBi across the ports.

Alharbi et al. [10] investigated and proposed a compact two antenna MIMO with a dual wideband operation for wireless and satellite applications. The antenna has a total size of 32 mm × 20 mm × 0.8 mm and achieves a dual wideband operation of 3.3–7.8 GHz and 8–12 GHz. The key idea was to load the monopole antenna with number of narrow slots and multiple slotted stubs to achieve multiband characteristics. Furthermore, to achieve an isolation of less than 20 dB, five concentric ring elements were etched between the two adjacent antenna elements. The proposed two antenna MIMO antenna provides a low band operation of 81.08% (3.3–7.8 GHz) and a high band operation of 40% (8–12 GHz), which makes it suitable for the Sub-6 GHz 5G new radio (NR) n77/78/79, IEEE 802.11ac/ax, X-band/C-band wireless and satellite applications. The authors reported a gain of 3–4 dBi and a radiation efficiency of 69–80%.

Khan et al. [11] presented a high efficiency circular-shaped patch antenna array for Sub-6 GHz 5G applications. The proposed antenna operates at 5.57 GHz and has a total size of 160 mm × 70 mm. The main idea was the use of transmission line and quarter wavelength transformation techniques for impedance and phase matching. To achieve the desired operating frequency band of 5.6–5.67 GHz, a circular shape of radiating element with an inner-circular slots and rectangular at its right edge is used. The four-element array configuration of the proposed antenna provides a total gain of 12.4 dB. The authors also reported an isolation between the two used ports of more than −30 dB and a total efficiency of 85.1%.

Kulkarni et al. [12] proposed a planar four-port and four element smartphone flexible antenna for Sub-6 5G and WLAN smart terminals. Its features, including flexibility, bi/omnidirectional radiation pattern, planar structure, wide bandwidth covering Sub6 GHz and WLAN bands, and high inter-elemental isolation make it a good candidate for use on smartphone applications. The proposed antenna consists of one contacting ground at the center placed on the top of a flexible polyamide substrate and four conducting MIMO elements (Radiators) at the four corners on the top of the substrate. The proposed antenna has a total size of 70 mm × 145 mm × 0.2 mm, a wide impedance bandwidth ranging from 2.37 to 5.85 GHz, gain of 4–5.5 dBi, efficiency of 85% and self-isolation of about 17.5 dB.

Azizi et al. [13] presented a wide-band dual concentric phase gradient modulated surface (PGMS) for surface radar cross-section (RCS) reduction at wideband frequency range, 20.9–45.7 GHz (75%). The main idea is using the two single band concentric modulated surfaces, e.g., MS1 and MS2 to reduce the RCS from 20.5–32 GHz (45%) for MS1 and 31.8–46.5 GHz (40%) for MS2, consequently. To enhance the bandwidth, the authors placed MS2 in the central part of MS1 to obtain a concentric configuration and hence achieve a wideband 75% (20.9–45.7 GHz) RCSR performance.

Huang et al. [14] designed a quad-port antenna MIMO antenna array for 5G smartphone applications. The proposed antenna array consists of four elements printed on two side boards, which are positioned vertically to the 150 mm × 75 mm main board. The total size of the main board is 150 mm × 75 mm × 0.8 mm, and the size of the side boards is 150 mm × 6.2 mm × 0.8 mm. Each single element has a size of 14.9 mm × 7 mm × 0.8 mm and includes an L-shaped feed, a strip, a parasitic rectangular strip and a Z-shaped radiation strip that is connected to ground plane. The main idea of printing the quad-port antenna array along two long frames of the smartphones is to reserve space for 2G/3G/4G antennas. Parametric analysis had been completed by the authors to obtain the required results and the optimal dimensions of the proposed antenna array design. The proposed design achieved a dual band operation at 3.5 GHz (3.4–3.6 GHz) and at 5 GHz (4.8–5 GHz). The authors reported a measured efficiency of 82%, isolation of 16.5 dB, and total measured gains of 4.7 and 5 dBi at 3.6 and 5 GHz, respectively.

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