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*Editorial*

# Antenna Designs for 5G/IoT and Space Applications, 2nd Edition

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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 restored attention in satellite technologies and applications, such as CubeSats, intersatellite communications, and deep space exploration. All these emerging applications have brought about novel concern 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 intends 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 communication technologies. We invite researchers and practicing engineers to contribute original research articles that discuss issues related but not limited to the following:

- Antenna design for the 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

Arnaoutoglou et al. [1] presented a comprehensive review of tailored Internet of Things (IoT) antenna designs, categorizing them based on their application areas, such as biomedical applications, smart homes, and smart cities. The authors highlight the evolution and specialization of antennas for each sector, noting the specific demands of antennas such as low-profile, efficient antennas for biomedical devices (e.g., implantable antennas) and tunable antennas for smart home connectivity. The review also emphasizes the importance of multifunctional antennas capable of adapting to different IoT environments, with a particular focus on challenges like beam-switching techniques for smart cities. The authors emphasize the need for interdisciplinary collaboration to drive innovation in antenna design, ensuring that both technical performance and practical user needs are met as IoT technology continues to evolve.

Saeidi et al. [2] presented a review that explores the advancements in beam-steering antennas for CubeSats, addressing key challenges such as power efficiency, miniaturization, and integration with CubeSat platforms. Their review provides a detailed analysis of state-of-the-art techniques such as phased arrays, metasurface-based designs, and reconfigurable antennas. The paper highlights the limitations of traditional omnidirectional CubeSat antennas and the need for adaptive communication solutions to improve gain and coverage in Low Earth Orbit (LEO). Moreover, their review paper compares various beam-steering approaches, such as phased arrays (offering fast electronic beam steering, but high complexity and power demands), dielectric lenses (efficient, but reliant on mechanical steering), and leaky-wave antennas (simpler, but constrained by bandwidth limitations). The study suggests hybrid techniques, including passive beamforming networks and metamaterial-based designs, as potential solutions for overcoming current constraints.

Xiao et al. [3] proposed a single-layer, dual-band, shared-aperture phased array that operates at S-/C-band direct-to-cellular satellite communications, using high-dielectric ceramic substrates for miniaturization and optimal element spacing. The $8 \times 8$ Right Hand Circular Polarization (RHCP) S-band receive array and the $16 \times 16$ Right Hand Circular Polarization (LHCP) C-band transmit array achieve $\pm 50°$ beam scanning without grating lobes. To further enhance this performance, the authors used a sequential rotation technique, ensuring improved circular polarization with an axial ratio (AR) of less than 3 dB. Covering 1.93–2.03 GHz (S-band) and 3.32–3.71 GHz (C-band), this design offers a compact, scalable solution for future LEO satellite networks.

Miklavčič et al. [4] designed a novel sum channel radiating element for a patch-monopole monopulse feed for the prime-focus illumination of deep symmetric reflectors in S-band satellite ground stations. The circularly polarized slotted patch enhances monopulse tracking, radiation symmetry, and channel isolation, improving aperture illumination efficiency to 75%. The proposed design demonstrated a LHCP gain of 8 dBi and a 30 MHz narrowband sum channel, making it suitable for LEO-satellite ground stations and small satellite antennas. The design optimizations minimize spillover losses, contributing to efficient and precise satellite tracking systems.

Inclán-Sánchez [5] introduced a low-cost, semitransparent, 3D-printed mesh patch antenna design for urban communication that can be integrated into buildings' windows to enhance 5G/6G connectivity while preserving natural lighting. The proposed substrateless metal mesh structure, fabricated using 3D printing and silver conductive paint, achieves 60% transparency, a 2.7% bandwidth, and a peak gain of 5.4 dBi at 2.6 GHz. By eliminating the substrate, the antenna minimizes losses, cost, and environmental impact, offering a lightweight, scalable solution for smart building applications and urban network infrastructure enhancement.

Kabir et al. [6] proposed a compact, multi-band, circularly polarized, shared-aperture antenna for CubeSat applications at S-band (2013–2043 MHz) and X-band (8320–8530 MHz). The design integrates an S-band slot antenna with an X-band square patch antenna in one signal antenna design to provide uplink/downlink communication links. The antenna has circular polarization and achieves high gains of 7.7 dBic and 12.8 dBic at S-band and X-band, respectively. The use of a partial reflective surface (PRS) dielectric layer enhances the antenna performance. The S-band patch serves as a Telemetry, Tracking, and Command (TT&C) antenna, while the X-band patch supports high-speed data downlink, making it suitable for deep space CubeSat missions. The shared-aperture approach offers an efficient, space-saving solution for future CubeSat communications.

Tran et al. [7] presented a drone-based wireless network system for post-disaster communication, focusing on mitigating cross-link interference in local 5G networks. The numerical analyses presented by the authors show that using circular polarization significantly improves the Signal-to-Interference Ratio (SIR). In a scenario with only access links, circularly polarized antennas improve the SIR from less than 20 dB to over 40 dB. Similarly, in cases involving backhaul links, the proposed antenna system achieves an SIR of 16.8 dB, which was challenging with conventional linear polarization. The proposed system operates at 28 GHz with 100 MHz bandwidth and is suited for rapid deployment in disaster-affected areas.

Yeo et al. [8] proposed a high gain $4 \times 1$ microstrip patch array antenna for 24 GHz radar applications. The main idea is to add two metallic plates along the array axis, resulting in enhanced gain. After appending metallic plates, the gain of the proposed antenna design increased from 9.8 dBi to 16.8 dBi. The gain was maximized with a tilting angle of 70° and a metallic plate length of 50 mm. The method demonstrated significant enhancements in gain, radiation patterns, and input reflection coefficient. This approach can be applied to radar, satellite communications, and future 5G/6G systems.

Abubakar et al. [9] presented an eight-element MIMO antenna system for 5G mobile phones, designed with a modified E-slot on the ground to enhance isolation. The key idea of using the E-slot is to reduce the coupling between antenna elements by suppressing the ground current effects, achieving isolation greater than −21 dB in the 3.5 GHz band. The proposed system operates in the 3.4–3.65 GHz frequency range and achieves a −6 dB impedance bandwidth of 250 MHz. The system exhibits an envelope correlation coefficient (ECC) of <0.01 and an ergodic channel capacity of 43.5 bps/Hz, indicating excellent performance for 5G MIMO applications.

Khaleel et al. [10] introduced a graphene plasmonic MIMO microstrip patch antenna designed for THz wireless communication operating at a 1.9 THz resonance frequency. The authors used E-shaped metamaterial (MTM) unit cells to enhance isolation from −35 dB to −54 dB and employed graphene-based reconfigurable intelligent surfaces (G-RIS) placed above the patches for beam steering in directions of ±60°. Moreover, they placed a graphene artificial magnetic conductor (G-AMC) layer underneath the antenna to further improve the gain from 4.5 dBi to 10 dBi. They claimed that their proposed antenna is suitable for IoT applications, providing high gain, data rates, and beam-steering capabilities for smart homes and radar applications that require wide scanning angles and high-speed communication.

Atta Ullah et al. [11] proposed an eight-element phased array antenna for 5G hand-portable devices, particularly smartphones. The antenna uses air-filled, slot-loop, metal-ring elements arranged in a $1 \times 8$ linear configuration along the edge of the smartphone mainboard, covering the 21–23.5 GHz sub-mm-wave 5G bands. The proposed design is placed on a low-cost FR-4 substrate and provides high performance and low loss due to the air-filled element configuration. It features a broad impedance bandwidth, an end-fire radiation mode, and wide beam steering, making it ideal for 5G applications. The array is insensitive to various substrates and performs well in terms of gain, efficiency, and radiation properties, even in the presence of the user's hand. These characteristics make it a suitable design for modern 5G smartphones, offering high efficiency and stable performance across varying conditions.

Kim et al. [12] designed a flat-panel, metasurface, reflectarray antenna for satellite applications, particularly in the C-band (5.8 GHz). The reflectarray antenna is designed using a dual-ring resonator unit cell, which allows for steering the reflection angle of incident waves without relying on Snell's law. The antenna array consists of a 16 $\times$ 16 unit-cell array, which was validated through measurement. The proposed antenna is fed by a low-cost circular horn antenna, and the design procedure is scalable to any electromagnetic (EM) solvers for analysis. The authors reported a measured gain of 22.4 dBi, with a cross-polarization suppression of 36 dB and a reflection angle of 15° at normal incidence. The design procedure is fully automated and demonstrates good agreement between the simulated and measured results, with a slight error of 1–2° in the beam steering direction.

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## References


1. Arnaoutoglou, D.G.; Empliouk, T.M.; Kaifas, T.N.F.; Chryssomallis, M.T.; Kyriacou, G. A Review of Multifunctional Antenna Designs for Internet of Things. *Electronics* **2024**, *13*, 3200. [CrossRef]
2. Saeidi, T.; Karamzadeh, S. Enhancing CubeSat Communication Through Beam-Steering Antennas: A Review of Technologies and Challenges. *Electronics* **2025**, *14*, 754. [CrossRef]
3. Xiao, Y.; He, L.; Wei, X. Dual-Band Dual-Circularly Polarized Shared-Aperture Phased Array for S-/C-Band Satellite Communications. *Electronics* **2025**, *14*, 387. [CrossRef]
4. Miklavčič, P.; Batagelj, B. A New Sum-Channel Radiating Element for a Patch-Monopole Monopulse Feed. *Electronics* **2024**, *13*, 3187. [CrossRef]
5. Inclán-Sánchez, L. Performance Evaluation of a Low-Cost Semitransparent 3D-Printed Mesh Patch Antenna for Urban Communication Applications. *Electronics* **2024**, *13*, 153. [CrossRef]
6. Kabir, S.S.; Khan, M.H.; Latif, S.I. A Multi-Band Circularly Polarized-Shared Aperture Antenna for Space Applications at S and X Bands. *Electronics* **2023**, *12*, 4439. [CrossRef]
7. Tran, G.K.; Okada, T. Design of Antenna Polarization Plane for Concurrent Uplink/Downlink Drone Networks. *Electronics* **2023**, *12*, 3045. [CrossRef]
8. Yeo, J.; Lee, J.-I. Gain Enhancement of Microstrip Patch Array Antennas Using Two Metallic Plates for 24 GHz Radar Applications. *Electronics* **2023**, *12*, 1512. [CrossRef]
9. Abubakar, H.S.; Zhao, Z.; Wang, B.; Kiani, S.H.; Parchin, N.O.; Hakim, B. Eight-Port Modified E-Slot MIMO Antenna Array with Enhanced Isolation for 5G Mobile Phone. *Electronics* **2023**, *12*, 316. [CrossRef]
10. Khaleel, S.A.; Hamad, E.K.I.; Parchin, N.O.; Saleh, M.B. Programmable Beam-Steering Capabilities Based on Graphene Plasmonic THz MIMO Antenna via Reconfigurable Intelligent Surfaces (RIS) for IoT Applications. *Electronics* **2023**, *12*, 164. [CrossRef]
11. Ullah, A.; Ojaroudi Parchin, N.; Amar, A.S.I.; Abd-Alhameed, R.A. Eight-Element Antenna Array with Improved Radiation Performances for 5G Hand-Portable Devices. *Electronics* **2022**, *11*, 2962. [CrossRef]
12. Kim, G.; Hwang, M.; Jeong, H.; Lim, C.-M.; Park, K.Y.; Kim, S. Design of a Flat-Panel Metasurface Reflectarray C-Band Antenna. *Electronics* **2022**, *11*, 2729. [CrossRef]