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Editorial

Smart Antenna Optimization Techniques for Wireless Applications

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In recent years, antenna design has received a lot of attention. This is due to a surge in interest in a variety of applications, ranging from IoT to low-frequency, long-range applications and to high-frequency mmWave 5G mobile technology. Wearable antennas that build body area networks have also sparked interest. Wearable clothes and materials that adhere directly to the skin, such as e-skin, are examples of this. The supply of even larger data rates to mobile customers, the delivery of zero-latency multimedia content, and the connectivity of diverse services are all intimately linked on the path to designing and implementing next-generation broadband wireless networks. The goal is to create a cellular network environment in which sensors, appliances, automobiles, and drones may interact with one another. The cellular network's capacity must be considerably increased in order to support such interactions. The notion of 5G, a new generation of mobile wireless technology that offers multi-gigabit-per-second data rates with a higher capacity and lower latency than today's wireless systems, was recently announced by the wireless communications industry. Future phones and base stations will need multimode antenna technology that is both energy-efficient and can function in the millimeter wave band in conjunction with legacy 4G and sub-6 GHz 5G.

Antennas should be small in size, but they must meet technical criteria, such as a greater power, wider bandwidth, higher gain, and insensitivity to human users' hand-held influence. The usage of the millimeter wave band, which will provide a network of tiny cells enabling high-capacity and area-efficient hotspot zones, is critical to 5G. The next 5G system will be a true mobile multimedia communication platform, including not just legacy heterogeneous mobile networks but also sophisticated radio interfaces and the ability to operate at millimeter wave frequencies to make use of the vast amount of available capacity. This will impose stringent design standards that go beyond the most recent 5G rollout in the sub-6GHz range.

This Special Issue aims to shed light on recent breakthroughs in antenna design for these new developing applications, as well as highlight more study possibilities in this fascinating field of communications technology. We encourage scholars and practicing engineers to submit original research papers that address:

- Multibeam antenna technologies for 5G wireless communications;
- Millimeter wave (mmWave) and THz antennas for 5G wireless communications;
- Propagation models at mmWave and THz bands;
- Compact antenna arrays for massive MIMO systems;
- mmWave and large-scale MIMO channel models;
- Antennas for implantable systems and IoT applications;
- Advanced antennas and transceivers for full-duplex communication;
- Distributed antenna systems for 5G multiuser networks;
- mmWave and THz cooperative relays for coverage extension;

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- 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;
- mmWave and THz antennas;
- Multiple antennas for advanced 5G transceivers;
- Multiband 5G antenna;
- 5G Dielectric Resonator antennas;
- Antennas on flexible substrates for medical applications;
- Antennas for wireless power transmission and harvesting;
- RFID antennas;
- Reconfigurable antennas and devices;
- Mutual coupling and isolation techniques between antenna elements;
- UWB antennas.

Bluetooth low-energy beacons are active transmitters that send a radio signal at set intervals [1]. Most beacons are powered by small batteries. The problem with systems based on such devices is the need to periodically replace the chemical cells. This is especially tedious when a large number ofthe beacons is used. A solution to these problems is to use beacons with a power supply supported by photovoltaic panels. Their obvious drawback is the need to place them in good lighting conditions. To overcome this disadvantage, the use of a power source that gathers energy due to the Peltier effect is proposed in this paper. Since the temperature difference between two surfaces can be found in almost every environment, the authors analyzed the efficiency of this kind of energy source in the context of powering the beacons. In order to justify the idea, a multitude of measurements and simulations was performed. The power supply demand of the beacon was measured in various modes of operation. Finally, the model of the proposed device was developed. The elaborated solution eliminates the need for batteries and makes the beacon maintenance-free.

A novel compact fractally loaded two- and eight-element multiple-input–multiple-output (MIMO) with strong diversity is designed for 5G Sub 6 GHz and WLAN applications [2]. The proposed layout features a partially grounded, protruding T-shaped stub on the underside of the substrate and a set of fractally loaded circular patch antenna elements on the top. Four triangular slots on the substrate and a T-shaped stub on the ground are employed to produce good isolation over the intended bands. The proposed antenna has a frequency range of (3.3–6.0) GHz, making it compatible with the 5G sub-6 GHz bands and the WLAN band thanks to its high isolation of above 15 dB and good impedance-matching characteristics. Good agreement is observed between the antenna results and the theory of characteristic mode analysis approach.

A frequency reconfigurable multiband multiple-input–multiple-output (MIMO) antenna is developed for 5G communication systems [3]. A split-ring resonator (SRR) is introduced into the upper patch to cover multiple 5G application bands, and an RF PIN diode is embedded between the upper and lower patches to enable the frequency diversity feature. In order to design a MIMO antenna with improved inter-element isolation, four antenna elements are orthogonally located with ground planes connected to each other. The antenna design covers the n41/n46/n48/n79 5G application bands.

Array imperfections may exist in an antenna system subject to non-ideal design and practical limitations. It is difficult to accurately model array imperfections, and thus complicated algorithms are usually inevitable for model-based methods to estimate the direction of arrival (DOA) with imperfect arrays. Deep neural network (DNN)-based methods do not need to rely on pre-modeled antenna array geometries, and have been explored to handle flawed array models because of their better flexibility than model-based methods.In this paper, we study the convolutional AE (CAE) method that substantially focuses on the learning of local features in a different manner from the previous DAE method. The advantage of the convolutional operation using a kernel in CAE is to capture features in a more efficient manner than the DAE, and thus be able to reduce the number of parameters that are required to be trained in the neural networks. From the numerical evaluation of DOA estimation accuracy, the proposed CAE method is also more resistant to the noise effect than the DAE method such that the CAE method has better accuracy at a lower signal-to-noise ratio [4].

Modern navigation requires high accuracy of position coordinate determination, particularly in bathymetric surveys and aerial photogrammetry (Makar, A. et al.). In most cases, the terrain conditions enable positioning with high accuracy and reliability. These particularly involve the terrain conditions, i.e., high harbour infrastructure for bathymetric surveys and trees for railway surveys that hinder the measurement performance with a pre-determined accuracy. This article presents the limitations in unmanned survey vehicle (USV) positioning in an area restricted by a high quay, and difficult observational conditions in the surrounding high harbour infrastructure. The positioning used a four-system receiver that determined position coordinates based on the signals from one, two, three and four satellite navigation systems. The number of available satellites was determined under conditions of the open upper hemisphere and the partially obscured hemisphere based on the surrounding geometry. The determined position coordinates were related to the position determined using robotic total station (RTS). An area was identified in which it becomes difficult or impossible to maintain the required positioning accuracy [5].

The goal of this work was to optimize a wire-bonded patch antenna to minimize losses and maximize the gain in the frequency range from 81 to 83 GHz (Bogdan, G. et al.). Optimization was based on electromagnetic simulations of different variants of the wire bond. Results show that the optimized structure demonstrates two major advantages. Firstly, it does not require any external matching network; hence, it can be directly connected to a contact pad of an MMIC die. Secondly, the wire bond radiation effect is utilized to enhance the patch antenna gain at the broadside direction [6].

A fundamental feature of the functioning of antennas in this area is the possibility of spatial focusing of electromagnetic energy. In this case, it is possible to realize the maximum field strength at a given point in space and reduce the field strength outside this point. The focusing effect itself is provided by the in-phase addition of fields from elementary sources. Additionally, in addition to the formation of the maximum field strength at the focusing point, it is also possible to realize a minimum field strength at the focusing point by implementing antiphase addition of partial fields at the focusing point. The fundamental possibility of forming sum and difference amplitude distributions of electromagnetic fields in the near radiated field zone makes it possible to realize sum–difference signal processing in order to reduce the level of the secondary maximum of the focused field. This article discusses the features of the formation of the sum and difference amplitude distributions and the principles of the sum–difference processing of focused electromagnetic fields, along with the implementation of technical solutions for non-destructive testing and technical diagnostic tasks [7].

The technique relies on the definition of relevant figures of merit (FoM) and the use of a gradient-based minimization algorithm. To this end, the volume where the NF is computed is divided into a number of disjoint regions where the FoM are defined. These FoM define the performance of the antenna and their direct optimization enables improvement compared to previous approaches described in the literature, while reducing the memory footprint of the algorithm and accelerating computation. The optimization procedure is divided into several stages to facilitate convergence towards a successful outcome. First, a phase-only synthesis is carried out at a single frequency. Then, a reflectarray layout is obtained using a method of moments based on local periodicity, accounting for mutual coupling between elements. Finally, an in-band DLO is performed at a number of frequencies directly optimizing the FoM. The results show that the obtained reflectarray layout complies with the requirements in the frequency range 27 GHz–29 GHz within the 5G new radio n257 band [8].

When utilized in wireless communications, high-frequency electromagnetic waves impose several physical restrictions (Hadi, M.U. et al.). To overcome these difficulties and to expand the service coverage, the radio-over-fibre (RoF)-based distributed antenna system (DAS), in particular, can improve the usability of future mobile networks with advantages such as seamless media conversion between wireless and optical signal, flexible multichannel aggregations, and efficiency. RoF technology's inherent advantages are that it improves the DAS network's usability and transmission performance by allowing it to provide both 5G and 6G THz services at the same time over a single optical fibre connection. We experimentally broadcast a single carrier-modulated 6G signal using a 256 quadrature amplitude modulation and a 5G new radio signal across a 10 km single mode fibre optic link. Additionally, the 6G signal is received through a 3 m wireless medium providing, proof of concept for fibre wireless integration. The experimental trials are assessed in terms of error vector magnitude and carrier suppression ratio. The dynamic range of the allowed RF input power for a 6G signal is 10 dB, while the dynamic range for a 5G waveform signal is 18 dB, which meets the 3GPP standardization criteria. Moreover, the bit error rate performance significantly improved as the carrier suppression ratio was increased from 0 to 20 Db [9].

Future wireless systems' adoption of smart antenna techniques is anticipated to have a significant impact on the effective use of the spectrum, the reduction instartup costs for new wireless networks, the enhancement of service quality, and the realisation of transparent operation across multi-technology wireless networks. Its success, however, depends on two factors that are frequently disregarded when researching smart antenna technologies: first, the features of smart antennas must be taken into account early in the design phase of future systems (top-down compatibility); second, a performance evaluation of smart antenna technique must be carried out in accordance with the crucial parameters associated with future systems requirements (bottom-up feasibility). First, a summary of the advantages of and most current developments in smart antenna transceiver architecture are provided in this article. The most significant developments in the use of smart antennas in future systems are then discussed, including reconfigurability to changing channel propagation and network conditions, cross-layer optimisation, and multi-user diversity. Additionally, problems with designing an appropriate simulation methodology and accurately modelling channel characteristics, interference, and implementation losses are discussed. The predicted financial impact of the implementation of smart antenna systems is then explored, along with market trends and future predictions.

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