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Editorial

Reconfigurable Antennas

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Antennas that can operate in different complex environments will be part of every modern wireless communication network, such as 5G, Internet-of-Things (IoT), and radar sensing. These new networks require antennas with a high degree of reconfigurability. In order to meet the performance requirements for each application scenario, reconfigurable antennas and advanced phased arrays with adaptive nulling, multiple beams, low side-lobes, as well as different signal processing techniques provide effective solutions. Such kinds of antennas are commonly used in several fields of applications, such as surveillance, tracking, and search and rescue. Of particular interest for this Special Issue are novelties in the element design and materials, novel switching and performance boosting technologies, system architecture, and array radiation and scattering properties. As these research areas have different developmental statuses and trends, in this Special Issue we examine, through articles, the current state of the art and project future research directions of reconfigurable antennas for solving different design problems. Despite substantial progress over the last twenty years, all these antenna devices are still the subject of intense research aiming to reach their full potential.

In this Special Issue, 10 papers are published, covering various aspects of antenna technology, from antenna boosters to radio-frequency switching using novel materials.

J. Anguera et al. [1] introduce antenna boosters. Antenna boosters are non-resonant small antenna elements that excite currents on the ground plane of the wireless device and do not rely on shaping complex geometric shapes to obtain multiband behavior, but rather the design of a multiband matching network. Their design approach results in a simpler, easier, and faster method for creating multiband and efficient antennas. Since multiband operation is achieved through a matching network, frequency bands can be configured and optimized with a reconfigurable matching network. The authors present two kinds of reconfigurable multiband architectures with antenna boosters. The first one includes a digitally tunable capacitor, and the second one includes radiofrequency switches. The results show that antenna boosters with reconfigurable architectures feature multiband behavior with very small sizes, compared with other prior art techniques.

Mohamadzade et al. [2] present recent developments and state-of-the-art flexible and conformal reconfigurable antennas. Flexible and conformal antennas rely on non-conventional materials and realization approaches, and thus, despite the mature knowledge available for rigid reconfigurable antennas, conventional reconfigurable techniques are not translated to a flexible domain in a straightforward manner. There are notable challenges associated with the integration of reconfiguration elements such as switches, the mechanical stability of the overall reconfigurable antenna, and the electronic robustness of the resulting devices when exposed to folding of sustained bending operations. This review paper discusses various approaches to realize flexible reconfigurable antennas, categorizing them on the basis of reconfiguration attributes, i.e., frequency, pattern, polarization, or a combination of these characteristics. The challenges associated with the development and characterization of flexible and conformal reconfigurable antennas and the strengths and limitations of available methods are reviewed considering the progress in recent years, and open challenges for future research that are identified.

Alharbi et al. [3] discuss the application of metasurfaces for three different classes of antennas: reconfiguration of surface-wave antenna arrays, realization of high-gain polarization-reconfigurable leaky-wave antennas (LWAs), and performance enhancement of van Atta retrodirective reflectors. The proposed surface-wave antenna is designed by embedding four square ring elements within a metasurface, which improves matching and enhances the gain when compared to conventional square-ring arrays. The design for linear polarization is comprised of a 1×4 arrangement of ring elements, with a 0.56 λ spacing, placed amidst periodic patches. A 2×2 arrangement of ring elements is utilized for reconfiguration from linear to circular polarization, where a similar peak gain with better port isolation is realized. A prototype of the 2×2 array is fabricated and measured; a good agreement is observed between the simulations and the measurements. In addition, the concepts of the design of polarization-diverse holographic metasurface LWAs that form a pencil beam in the desired direction with a reconfigurable polarization are discussed. Recent developments incorporating polarization-reconfigurability in metasurface LWAs are briefly reviewed. In the end, the theory of Van Atta arrays is outlined and their monostatic radar cross-section (RCS) is reviewed. A conventional retrodirective array is designed using aperture-coupled patch antennas with a microstrip-line feeding network, where the scattering from the structure itself degrades the performance of the reflector. This is followed by the integration of judiciously synthesized metasurfaces to reconfigure and improve the performance of retrodirective reflectarrays by removing the abovementioned undesired scattering from the structure.

Iftikhar et al. [4] present a new model for radio-frequency switching technology called magnetostatic responsive structure (MRS) that enables reconfigurable operation in 4G/5G antenna frequency bands. Specific frequencies of interest include but are not limited to advanced wireless services (AWS) from 2.18 GHz–2.2 GHz, mid-bands of sub-6 GHz 5G (2.5 GHz and 3.5 GHz), and 4G bands around 600 MHz/700 MHz, 1.7 GHz/2.1 GHz/2.3 GHz/2.5 GHz. The ABCD matrices of the MRS switch are derived from the S-parameter values and are shown to be a good model from 100 kHz to 3.5 GHz. Agreement between simulations, analytical results, and circuit model values is shown.

Koutinos et al. [5] present a robust pin-diode based reconfigurable antenna for WLAN/WiMAX applications. A super-shape elliptical radiator is used to achieve wider intrinsic bandwidth compared to the classical rectangular patch antenna, while the dimensions remain comparable. The proposed antenna is fed at two points, exciting both horizontal and vertical polarization but in different operating frequencies. To achieve wider bandwidth, as a whole but also for each polarization, the symmetrical feeding points for each excitation are also employed with a proper feeding network. PIN diodes are also used in the feeding network to provide the option of narrower bandwidth.

A compact reconfigurable UWB MIMO antenna with four radiators that accomplish on-demand band rejection from 4.9 to 6.3 GHz is presented by Khan et al. in [6]. Two radiators are then placed perpendicular to each other to exploit the polarization diversity, leading to high miniaturization. Two additional radiators are then fixed obliquely on the same laminate (without increasing its total size) in an angular configuration at a $\pm 45^{\circ}$ angle to the first two planar radiators to further exploit polarization diversity. The design is validated by measurements of a fabricated prototype. On demand band rejection through the use of PIN diodes, wide impedance matching (2–12 GHz), high isolation amongst the radiators, compactness achieved by angular placement of the radiators, low gain variation over the entire bandwidth, band rejection control achieved by adjusting the gap between stub and ground plane, and low total active reflection coefficient (TARC) values make the proposed design very suitable for commercial handheld devices.

Yang [7] presents a reconfigurable 3D slot antenna for 4G and sub-6G smartphones with a metallic casing. The antenna is located at the bottom of a smartphone and is integrated with the metallic casing. PIN diodes are loaded at the dual-open slot and the folded U-shaped slot, respectively, which realize four working states. The antenna has a compact volume and covers the long-term evolution (LTE) bands of 698–960 MHz and 1710–2690 MHz, and the sub-6G bands of 3300–3600 MHz & 4800–5000 MHz. The design is fabricated together with the measured performance and a comparison to other state-of-the-art antennas that shows the proposed design has multiband characteristics with small size.

Shereen et al. [8] presents a novel combo-reconfigurable antenna architecture for the frequency and pattern reconfiguration of a novel antenna system for 5G millimeter-wave mobile communications. The tuning system independently controls the frequency and radiation pattern shifts, without letting them affect each other. The proposed antenna consists of two patches, radiating at 28 GHz and 38 GHz. A negative-channel metal–oxide semiconductor (NMOS) transistor is used as an ON/OFF switch. Frequency reconfiguration is controlled by two switches that vary the patch dimensions. Pattern reconfiguration is achieved by the remaining 16 that connect and disconnect parasitic stubs to the ground to control the surface currents. Results are shown for 18 different combinations of the switches' states.

The optimal design of an aperiodic reconfigurable microstrip antenna array for broadcasting applications is introduced by Gravas et al. in [9]. The array is designed to serve as a DVB-T base station antenna operating in a single broadcasting channel (optimized at 698 MHz, center frequency of DVB-T channel 49). This allows the array to concurrently achieve a particular radiation pattern shaping with high forward gain, main lobe tilting, and null filling inside the service area, as well as low sidelobe level outside the service area. To concurrently satisfy all the above requirements, the geometry dimensions and the array feeding weights (amplitudes and phases) are optimized, thus leading to a complex multi-variable and multi-objective problem. The problem is solved by applying a recently developed particle swarm optimization (PSO) improved variant, called PSO with velocity mutation (vm), in conjunction with the CST electromagnetic simulation software, which is employed by the PSOvm every time a full-wave analysis is required. Furthermore, all the optimization methods found in the CST environment are compared with the PSOvm. The results show that the PSOvm is capable of producing an antenna array geometry that is closer to the predefined requirements than the geometries derived by the rest of the optimizers in the least amount of computational time.

Last but not least, Farooq et al. [10] present a highly compact frequency-selective surface (FSS) that has the potential to switch between the X-band (8 GHz–12 GHz) and C-band (4 GHz–8 GHz) for RF shielding applications. The proposed FSS is composed of a square conducting loop with inward-extended arms loaded with curved extensions. The symmetric geometry allows the RF shield to perform equally for transverse electric (TE), transverse magnetic (TM), and 45° polarizations. The unit cell has excellent angular stability up to 60°. The resonance mechanism is investigated using equivalent circuit models of the shield. The design of the unit element allows for the incorporation of PIN diodes between adjacent elements for switching to a lower C-band spectrum at 6.6 GHz. The biasing network is on the bottom layer of the substrate to avoid effects on the shielding performance. A PIN diode configuration for the switching operation is also proposed. In simulations, the PIN diode model is incorporated to observe the switchable operation. Two prototypes are fabricated, and the switchable operation is demonstrated by etching copper strips on one fabricated prototype between adjacent unit cells (in lieu of PIN diodes) as a proof of the design prototypes. Comparisons among the results confirm that the design offers high angular stability and excellent performance in both bands.

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