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Editorial

Antenna Design for Microwave and Millimeter Wave Applications II: Latest Advances and Prospects

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1. Introduction

In recent decades, novel and significant approaches to the design of antennas for various microwave and millimeter-wave applications have been attempted. Although techniques such as antenna miniaturization, array configuration, gain and bandwidth enhancement have been extensively studied, they are still important issues in the practical applications of antennas. With that, in 2020 we prepared and published the Special Issue 'Antenna Design for Microwave and Millimeter Wave Applications: Latest Advances and Prospects' and introduced 14 papers describing the relevant latest issues for advanced antenna designs. However, with the advent of new applications, such as 5G/6G mobile and satellite communications, autonomous driving, and biomedical radars, more advanced techniques are required to develop antennas with compact sizes and better radiation characteristics. Therefore, we are extending the previous Special Issue to Volume 2 to include more recent and important developments. This Special Issue aims to collect relevant papers describing the latest advances and prospects in antenna design for microwave and millimeter-wave applications. The fields of interest for this Special Issue include, but are not limited to, design methods of antennas such as miniaturization, optimization, and array. In total, 24 papers were submitted and 20 of them were published in the Special Issue. The following section provides brief summaries of each published paper.

2. Higher-Order-Mode Triple Band Circularly Polarized Rectangular Dielectric Resonator Antenna

Zambak et al. [1] proposed a triband circular polarized rectangular dielectric resonator antenna. The DRA is fed by a single coaxial cable, and the wide bandwidth of the proposed DRA is achieved by the coupling feed. The antenna can have the higher-order mode with a low-cost simple excitation mechanism. The antenna exhibits a bandwidth of 48% with a gain of ~6–9 dBic with a broad AR bandwidth. A wide beamwidth of 112°, which is good for better signal reception is also obtained. The authors compared the measured results with the simulated results, and two results are in good agreement.

3. Wideband-Narrowband Switchable Tapered Slot Antenna for Breast Cancer Diagnosis and Treatment

Yoon et al. [2] presented a wideband-narrowband switchable tapered slot antenna (TSA) with a compact meander line resonator for an integrated microwave imaging and hyperthermia system. To minimize the degradation of the wideband characteristics, the TSA has a compact meander line resonator using one PIN diode. Moreover, the meander line resonator transfers the electromagnetic energy to ensure effective frequency switching. The authors proved that the proposed antenna is suitable to a treatment system and integrated breast cancer detection.

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4. Statistical Indoor Exclusion Zone Analysis by Investigating Electromagnetic Fields inside a Nuclear Power Plant

Choo et al. [3] investigated a statistical indoor exclusion zone (EZ) that can be efficiently applied to a nuclear power plant (NPP). To obtain the statistical indoor EZ, the received powers inside the Korea Institute of Nuclear Safety (KINS) simulator room are obtained using the Wireless InSite electromagnetic simulation software. Then, a margined regression model is applied to the simulation data, which can determine a reasonable boundary of the statistical indoor EZ. To validate the statistical indoor EZ, the authors compared the measured results with the simulated results, and two results are in good agreement.

5. Phase Compensation Technique for Effective Heat Focusing in Microwave Hyperthermia Systems

In this paper [4], a method of electromagnetic (EM) focusing with a phase compensation technique for microwave hyperthermia systems is proposed. To concentrate on a specific target inside the breast tumor, input phases of each element of a circular antenna array are calculated for single and multiple tumor cell locations. In addition, the input phases of each antenna are calculated for single and multiple tumor cell locations depending on the cancerous cell conditions in the breast. Then, beam focusing technique using sub-array is presented, which can minimize damage to normal cells. The authors verified that the thermal treatment effects on single and multiple tumor locations using both simulated and experimental results.

6. Shape and Weighting Optimization of a Subarray for an mm-Wave Phased Array Antenna

Hwang et al. [5] discussed how to optimize the weighting of individual subarrays to derive the low sidelobe level (SLL). To verify the optimized weighting, the SLLs of a phased array antenna with 576 elements are compared according to presence and absence of the subarray configuration. Then, an array pattern in consideration of the mutual coupling between the radiating elements is calculated. The authors verify that the SLLs of the two antennas are practically identical in a narrow beam-scanning environment.

7. A Compact Sequentially Rotated Circularly Polarized Dielectric Resonator Antenna Array

In this paper [6], the authors propose a compact 2 $\times$ 2 dielectric resonator antenna (DRA) array having sequentially rotated (SR) circularly polarized (CP) characteristics. To obtain the CP radiation, a rectangular dielectric resonator (RDR) is coupled with an elliptical slot (ES). In addition, The SR feeder can maximize the transferred power to each element using four quarter-wavelength microstrip transformers. To validate the proposed antenna, the authors compared the measured results with the simulated results. The results demonstrate that the proposed antenna achieved the axial ratio bandwidth of 0.95 GHz and matching bandwidth of 1 GHz.

8. Polarization and Incidence Angle Independent Low-Profile Wideband Metamaterial Electromagnetic Absorber Using Indium Tin Oxide (ITO) Film

Yoon et al. [7] proposed a metamaterial electromagnetic (EM) absorber with a high absorbance in a wide frequency range using indium tin oxide (ITO) which is one of the representative resistive materials. The proposed absorber has insensitive characteristics for polarization and incidence angles due to symmetrical split ring resonators made of ITO film. The proposed absorber with a size of only 0.171 λ shows a wideband absorbance from 7.2 GHz to 27 GHz, with a 90% absorption criterion.

9. A Cross-Correlation-Based Approach to Pattern Distortion and Mutual Coupling for Shared-Aperture Antennas

In this paper [8], a pattern distortion coefficient is proposed as a new figure of merit to quantitatively estimate both mutual coupling and pattern distortions for multi-antenna

systems. The proposed coefficient is expressed by a cross correlation between unaffected and affected far-field patterns of antennas under test, and the input pattern of a weighted Gaussian function is used to consider the target operation angle. To validate the feasibility of the proposed antenna, a two antennas system which is composed of an inverted-F antenna and a microstrip patch antenna is utilized. Through the results, the authors demonstrate that the proposed figure of merit well describes the amplitude and phase distortions caused by mutual coupling and platform effects.

10. Design of a Printed 5G Monopole Antenna on Vehicle Window Glass Using Parasitic Elements and a Lattice-Structure Reflector for Gain Enhancement

Choo et al. [9] proposed a novel design of a printed 5G monopole antenna on a vehicle window glass. The proposed antenna is composed of a coplanar waveguide (CPW), a monopole radiator, parasitic elements, and a lattice-structure reflector. To improve the bore-sight gain, the parasitic elements are located at either side of the monopole radiator. The lattice-structure reflector can solve the pattern distortion problem caused by the thick vehicle window glass. The authors measured and fabricated the proposed antenna, and the results confirm that the enhancement of the bore-sight gain and the minimization of the pattern distortion.

11. Study of Mesh Pattern for Optically Transparent Flexible Antenna with Feedline

In this paper [10], a systematic parameter study is carried out on mesh pattern for optically transparent flexible antenna. When a transparent flexible antenna is implemented using a metal mesh, the opposite factors are the transparency and performance of antenna. To understand the relation between the mesh design parameters and antenna performance, the authors carried out the parametric study of diamond and square meshes. The authors also provided measured results that demonstrate the feasibility of the proposed antenna.

12. A Dual-Band Dual-Polarized Antenna with Improved Isolation Characteristics for Polarimetric SAR Applications

In this paper [11], a dual-band dual-polarized antenna is proposed with high isolation characteristics for polarimetric synthetic aperture radar (PolSAR) applications. The antenna is composed of 2×2 patch antenna arrays and four dipole antennas. The dipole antennas and the patch antenna arrays require dual-linear polarization characteristics to achieve PolSAR data. Improvements of the isolation characteristics are obtained by inserting a metamaterial absorber with a fractal geometry between the transmitting (Tx) and receiving (Rx) dipole antennas. The isolation characteristics with the absorbers are higher than 23.44 dB over the target operated band. The results demonstrate that the proposed antenna can be a good candidate for PolSAR applications.

13. Near-Field-Based 5G Sub-6 GHz Array Antenna Diagnosis Using Transfer Learning

In this paper [12], the method for near-field-based 5G sub-6 GHz array antenna diagnosis is proposed using transfer learning. The case for normal or abnormal operation of the array system and the failure of a specific port are assorted with a classification network. Moreover, a regression network is employed to predict the amplitude and phase information of the excited signal to the array antenna. Additionally, several near-field samples are applied to the regression network to accelerate the diagnosis. To verify the proposed method, the fabricated 4×4 array antenna is measured, and the results show that the trained network can diagnose 29 of 30 measurement scenarios.

14. Axial-Symmetric Diffraction Radiation Antenna with a Very Narrow Funnel-Shaped Directional Diagram

In this paper [13], the reliable modeling and analysis is introduced for the axially symmetric radiators with a very sharp funnel-shaped radiation pattern. The Smith–Purcell coherent radiation is obtained by such a formed diagram. The surface wave of the dielectric

radiator is swept out by the exponential curve with a concentric periodic grating. The required radiation pattern is generated by the fundamental harmonic which propagates without attenuation in a direction of symmetry axis of the radiator.

15. Machine Learning Technique to Improve an Impedance Matching Characteristic of a Bent Monopole Antenna

In this paper [14], the bent wire monopole antenna designed using a machine learning method, is proposed. They are validated their machine learning model trained with deep neural network (DNN) by calculating the mean squared error and R-squared score. The authors also verify the operating principle of the by analyzing the equivalent circuits corresponding to their structures.

16. Novel Beam Scan Method of Fabry–Perot Cavity (FPC) Antennas

In this paper [15], a Fabry–Perot cavity (FPC) antenna using a new beam scanning method is proposed. The authors design a tapered partially reflective surface (PRS) as a superstrate to obtain high gain characteristics with a reduced sidelobe level (SLL). Moreover, a phase-controllable artificial magnetic conductor (AMC) ground plane with a broad reflection phase and high reflection is proposed to obtain various beam scanning directions. The FPC antenna can accurately scan the main beam in target directions with high gain. The authors also demonstrate the feasibility of electrical beam-scanning antennas by employing active RF systems on the AMC cells.

17. Design of a Polarization-Selective EM Transparent Mesh-Type E-Shaped Antenna for Shared-Aperture Radar Applications

In this paper [16], the authors propose a polarization-selective electromagnetic (EM) transparent E-shaped antenna. The proposed antenna has nine X-band antennas and one S-band antenna, where the simple E-shaped patch is applied for the antenna elements. The mesh structure is applied to reduce performance degradation for S-band antennas and to enhance EM transparency. To verify the performance of the proposed antenna, the antenna unit-cell is fabricated, and the radiation patterns are measured. The results demonstrate that the proposed E-shaped antenna is appropriate for shared-aperture radar applications.

18. Uni-Planar MIMO Antenna for Sub-6 GHz 5G Mobile Phone Applications

Dalarsson et al. [17] proposed the uni-planar MIMO antenna system for sub-6 GHz 5G-enabled mobile phones. The MIMO antenna consists of four loop-shaped radiators placed at each corner of the mobile phone board. Each single antenna resonates at 3.5 GHz, and the matching bandwidth is from 3 GHz to 4.28 GHz, and from 3.18 GHz to 3.9 GHz. A peak gain of the single antenna is 3.64 dBi. It is confirmed that the isolation between each antenna is more than 10 dB. The proposed antenna provides sufficient radiation coverage, which is an important feature for the future 5G application. In addition, the authors investigate the effect of human hands and head on MIMO antenna performances.

19. Quasi-Isotropic Hybrid Dielectric Resonator Antenna—Bow-Tie Patch with Harmonic Suppression

Hwang et al. [18] proposed a quasi-isotropic hybrid dielectric resonator antenna (DRA) and bow-tie patch with harmonics suppression. The proposed antenna consists of a DRA, a bow-tie patch, and a microstrip Chebyshev low-pass filter. A quasi-isotropic pattern is realized by applying a bow tie patch to the designed DRA. The 7th-order Chebyshev low-pass filter is applied to reduce harmonics generated by the proposed antenna. The measured gain isolation between the operating band and the 2nd harmonic is 10.10 dB, and gain isolation between the 3rd harmonic is 18.94 dB. The authors claim that the proposed antenna can be applicable to applications that require omni-directional radio reception, such as wireless access points, Internet of Things, and radio frequency identification.

20. mmWave Four-Element MIMO Antenna for Future 5G Systems

In this paper [19], an S-shape four-port Multiple Input Multiple Output (MIMO) wideband mmWave antenna that operates at 25 GHz to 39 GHz is proposed. The dimensions of single element are 10×12 mm^2, and the proposed S-shape four-port MIMO is 24×24 mm^2. A decoupling network is applied to further compress mutual coupling among elements. The proposed MIMO antenna is fabricated, and measured results agree well with the simulated results. Through the results obtained, the authors claim that the proposed MIMO antenna can be applied for future mmWave devices.

21. A Novel Single-Fed Dual-Band Dual-Circularly Polarized Dielectric Resonator Antenna for 5G Sub-6 GHz Applications

In this paper [20], a single-fed dual-band circular polarized (CP) dielectric resonator antenna (DRA) for dual-function communication is proposed. To obtain CP fields, the cross-shape metal strip is applied to operate in the fundamental and the high-order mode in the two frequency bands. A metal strip is designed on the top of the rectangular DRA to improve the impedance matching and widen the axial ratio (AR) bandwidth. This step led to a 2.73% and 6.5% improvement on the lower band and the upper band, respectively. The AR bandwidth is also significantly improved in both frequency bands. Through these results, the authors claim that the proposed antenna can be applicable to Global Positioning System (GPS) and Wireless Local Area Network (WLAN).

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