Preface

Microwave and millimeter-wave (mm-wave) circuits and systems have been widely employed in various emerging technologies such as 5G and beyond wireless mobile communication systems, autonomous driving, electronic warfare, and radar systems. To better understand the benefits, challenges, and opportunities of this technology, further study is required.

The *Handbook of Research on Emerging Designs and Applications for Microwave and Millimeter Wave Circuits* describes the latest advances in microwave and mm-wave applications and provides state-of-the-art research in the domain of microwave, mm-wave, and THz devices and systems. Covering key topics such as antennas, circuits, propagation, and energy harvesting, this major reference work is ideal for computer scientists, industry professionals, researchers, academicians, practitioners, scholars, instructors, and students.

A description of the chapters follows.

Chapter 1: MIMO Hybrid Beamforming Performance Assessment in Macrocells and HetNets

This chapter presents solution to the problem of reducing the number of radiofrequency (RF) chains by partitioning beamforming operations between the digital and RF domains, known as hybrid beamforming (HBF), while still achieving the near-optimal performance of the fully-digital beamforming systems with much-reduced hardware complexity. This Chapter reviews different HBF techniques for massive MIMO in 5G and radar systems. The basic HBF structures and their algorithm design is presented in the context of a point-to-point MIMO hybrid beamforming system. Then, some recently proposed HBF techniques for 5G & beyond networks is investigated, followed by a discussion about the benefit of HBF in MIMO radar systems.

Low-complexity hybrid beamforming schemes were investigated for mmWave macrocells and HetNets, where the macro base station, the small base stations, the relay stations, and the mobile stations are all equipped with massive hybrid antenna arrays. For multiuser macrocells, a low-complexity HBF algorithm based on maximizing the ergodic uplink capacity of the effective channel was presented, and its performance was compared to the popular JSDM-based HBF for downlink channels. It was shown that both techniques could achieve near-optimal performance with only 4 RF chains. Relay-assisted multiuser massive MIMO systems were also investigated. Two types of relay systems were considered, namely the classical and RIS-based relays. The classical relay stations were deployed in HetNets to assist the SBSs-MBS backhaul links. The analog beamformers were based on creating the best-fixed multi-beams by eigendecomposition of the uplink channels.

Chapter 2: Metamaterial-Based Electrically Small Antennas (ESAs) – A Review of Antennas and Propagation

Since last decade metamaterial based electrically small antennas (ESAs) are gaining popularity in RF communication devices and systems due to their appealing features. This Chapter attempts to present a compendious and timely review on metamaterial-based ESAs. The metamaterial has been progressively incorporated in different stage-of-art techniques to design more compact antennas to a greater extent keeping their radiation Q-factor, bandwidth, and radiation efficiency in acceptable limits. Planar metamaterial loading has shown simplicity, good performance, and more flexibility in designing ESAs for different RF and mobile communication applications. Different types of planar metamaterial split ring resonators have been used to load the microstrip patch antennas. In this Book Chapter, basics of metamaterial and extensive review of metamaterial based electrically small antennas have been presented.

Metamaterials are artificially realized materials that possesses negative values of magnetic permeability and/or electric permittivity respectively. The negative permeability is achieved through split ring resonators and thin wires reveals negative permittivity. The characteristics of metamaterial is found to be suitable in different applications such as microstrip patch antennas, waveguides, microwave filters etc. By using metamaterials, the performance parameters of microstrip patch antennas such as gain, bandwidth, directivity can be improved. Another important usage of metamaterial is to generate the sub-wavelength resonances by miniaturizing the size of microstrip antennas. In this Chapter, an extensive literature review on metamaterial-based ESA is presented which furnish an insight vision to design planar metamaterial loaded microstrip antennas for various applications. In the ESA configurations presented in this Chapter, the loading distance between antenna and the resonator element varies the magnetic coupling to change the resonant frequency and other parameters.

Chapter 3: Wavelets in Boundary Integral Equation – Applications in Radiation Problems

Wavelet transforms and wavelet bases are widely used for analyzing and solving problems related to science and engineering techniques. This growth is mainly due to speciðc properties that result from decompositions on wavelet bases. In this chapter the electromagnetic modeling of wire antennas by two different methods was presented: the method of moment's procedure matching point and the moments-wavelets method, for solving the integral equation and modeling the characteristics of each structure.

The first part of this work is devoted to the mathematical tools necessary for solving the integral equation by the method of moments and wavelets. A detailed reminder on wavelet theory: definition, multi-resolution analysis, different families, wavelet properties and use of wavelet bases in the method of moments. In the second part, the dipole antenna, loop antenna and helix antenna are examined in order to demonstrate the advantages of MoM-wavelets compared to the method of moments with the traditional bases. Orthogonal wavelets with compact support bases give a sparse matrix and reduce computation time than that obtained by conventional orthogonal bases. To demonstrate the effectiveness and accuracy of the proposed technique, numerical results for error relative for different wavelet families are presented. It is found that wavelets with larger number of vanishing moments and compact support generally give higher accuracy.

The method MoM and wavelet is computationally attractive and applications are demonstrated by three illustrative examples and presented, good accordance with others proposed in the literature.

Chapter 4: Compact Printed Antenna With Loaded and Etched Bandstop Resonators – Applications in UWB Spectrum

This book chapter mainly focuses on band stop embedded structures using half-wavelength circular and quarter wavelength open-ended straight open slots and Split Ring Resonators. Simulation and measured results of some practical applications in the UWB spectrum reported in the literature are discussed proving their radiation characteristics efficiency. This work was started by presenting the research results dealing with a systemic design of embedded slots used to inhibit interferences in the UWB spectrum with narrow band systems. Then, an overview of bandstop/bandpass structures using SRRs coupled to a coplanar waveguide loaded near the feed line and slotted on the patch antenna was presented. Systemic designs reported in the literature followed by the main results proving the efficiency of these structures have been presented and discussed. As results, practical application in UWB spectrum followed by radiation characteristics are presented and show their efficiency. These structures are consisting of half-guided wavelength circular slots, quarter-wavelength straight open-ended slots etched

on the radiating patch or on the ground plane. In addition to that, a UWB antenna with switchable and tunable band notches was presented by using SRR. Indeed, the SRR structures can be loaded near the transmission line or printed on back side of the antenna and coupled to a CPW.

Chapter 5: Phased Millimeter-Wave Antenna Array for 5G Handled Devices

This chapter provides an insight view of fundamental theory behind microstrip antenna array design and beamforming. Thus, design and simulation of low profile microstrip phased arrays for 5G applications will be discussed. It will be organized as follows: firstly, the 5G mobile network frequency spectrums will be discussed, secondly the recent trends and developments on the main used techniques in systemic designs of low-profile antenna arrays was explored. Next, fundamental theory behind phased antenna array, followed by some simulation results, will be presented, and discussed. In this chapter, the fundamental theory of the antenna concept and design was presented followed by some examples of how to design an antenna array and state of art of the theory of design of a beam switching antenna based on Butler matrix.

Chapter 6: Microwave and Millimeter-Wave Pyramidal Horn Arrays Design Using Analytical Techniques

This book chapter describes the design and modeling of horn-based phased-array antennas using analytical approaches. Phased-array antennas are important devices for 5G wireless technologies since their radiation patterns can be reinforced in the desired direction and provided high directivity which can be suppressed in the undesired direction in order to overcome losses during transmission, especially at millimeter-wave frequencies. In this chapter, analytical analysis has been used for single horn element design. Various analytical formulations proposed by previous researchers were comprehensively reviewed.

This chapter presents analytical solutions for the design of microwave and millimeter-wave phased array horn antennas that are a simple, fast, and cost-effective alternative to numerical solutions. Before designing a phased array, a single element of pyramidal horn needs to be properly designed using an analytical solution. After the single horn element is designed, the elements are arranged in the form of an

array so that the direction of the beamforming array can be controlled by adjusting the phase of the feed signal. Furthermore, the directivity and gain of the array are usually higher than its single-element horn.

Chapter 7: Reconfigurable Low-Profile Antenna-Based Metamaterial for On/Off Body Communications

This chapter proposes a novel method to reduce the specific absorption rate (SAR) of a compact CPW antenna. A combination of three efficient techniques is employed to develop a dual-band Bowtie metamaterial antenna with safer SARs. Following this approach, in this chapter we will have the description of an antenna design with a low-profile having a footprint of only 0.074λ02 and low backward radiation. A compact size and dual-band operation were attained by loading the Bowtie-shaped into the CPW antenna.

This book chapter propose a microstrip antenna structure based on metamaterials meeting the requirements of reconfigurability and miniaturization for body area communications. To this end, the chapter is organized into three main topics. The first section defines the reconfigurable antennas and then focuses on the reconfigurable antenna on frequency. Moreover, this study presents the antenna reconfigurability techniques and a comparison table that states of every approach. The second introduced the concept of WBAN antennas with design requirements and critical design issues of BCWC antennas. Next, the phantoms used to mimic the human body tissue and the SAR, which evaluates the human body's antenna safety, are discussed.

The last section proposed the design of a small reconfigurable antenna based on metamaterial for ON and OFF body communication applications. Next, the PIN diode is used as a switch to allow frequency reconfigurability. Finally, the proposed antenna is mounted on a human body phantom to evaluate the antenna's performance in the vicinity of the human body and study the safety of the antenna on the human corp. The proposed antenna exhibits a dual-frequency band coverage with gain values of 2.73 and 4.3 dB. The analyzed SAR values prove that the antenna is safe for use in the vicinity of the human body.

Chapter 8: Antenna Array for Reconfigurations

This chapter deals with a study on Antenna Array for reconfigurations. a reconfigurable antenna is an antenna having a capability to modify its properties dynamically, in a controlled and reversible manner .The need for multi functional, high performance and cost effective devices within a confined volume place a greater burden on today's transmitting and receiving systems. So, a reconfigurable antenna is achieved through deliberately changing its frequency, polarization, or radiation characteristics. Many techniques are to achieve this change by redistributing antenna currents and thus altering the electromagnetic fields of the antenna's effective aperture thereby adapting to changes in system requirements. This concept can significantly reduce the number of components, hardware complexity and cost of the systems. The proposed chapter represents advancement on multipurpose antennas having different applications in communication, broad banding, detection etc.

Reconfigurable antenna is very useful it's applicable in many applications like satellite communication, biomedical applications, radar systems, smart new generation systems like 5G/6G and beyond. Different techniques like electrical, optical, mechanical and physical methods have been widely used but smart material techniques is the most desired techniques now a day in which Graphene comparatively very new material as per design of antenna in terahertz regime is the most required wonder material for reconfigurable array antenna and for GHz frequency liquid crystal, metamaterial/metasurfaces even for

terahertz also are being used. In all the options, the material based reconfigurable antennas are the simplest ones with excellent performance, where liquid crystal is proved to be suitable candidate in microwave frequency range, the 2D material like graphene is proved to be a real gem in THz frequency range.

Chapter 9: Millimeter Wave Microstrip Antennas for Radar Applications in the Ka-Band

The present chapter starts with a general definition of antennas and their necessary parameters, which allow to study all types of antennas. This focuses on the printed antenna which is well-known by its privileges of many applications of RF system. The next part discussion is about the microstrip antenna of the double band in order to get an antenna that can do both reception and emission as well as developing the azimuth and angular resolution. Additionally, the research introduces a radar antenna that effectively divides the feeding part from the radiating part, allowing to enhance the capabilities of the radar antenna, and to avoid spurious signals. Besides, the coverage of the radar system is guaranteed by the mechanical relationship of the antenna. Another work presents the use of electronic scanning in order to benefit from the efficiency and speed of coverage. This leads to use the Butler matrix to eliminate the mechanical rotations. On the other hand, the increase in antenna range is related to the increase of the gain. A microstrip antenna array is developed to improve the angular resolution through widening the bandwidth by DGS (Defected ground structure) technique. Among the biggest problems is the surface waves and mutual coupling that presents significant challenges to the designer because of their graduation of the antenna performance especially in the radar system.

In this chapter, different experiences concerning the design of printed antenna in the millimeter band is presented. The research on multiple beam network antennas feeds gives us a high concentration to use for the radar system and also uses the scanning electronic technique. An important work has been done on inter-element coupling and correlation effects in the millimeter band. That represents a necessary solution for all close antennas in all of their applications.

Chapter 10: MIMO Radar Systems – Deep Learning vs. Traditional Approaches

This Chapter consists of presenting the performance of MIMO radar systems in a cluttered environment using both conventional and DL techniques. Unlike traditional phased-array radars that need successive scans to cover the entire field of view, MIMO radar transmits orthogonal waveforms from each antenna element simultaneously, allowing the illumination of all targets at once. Also, better detection performance and a high spatial resolution can be obtained using all the components extracted by the matched filters. MIMO radar systems can detect the range, angle, and doppler of the targets, using traditional techniques such as the Fast Fourier Transform (FFT), the Multiple Signal Classifier (MUSIC), and the Minimum Variance Distortionless Response (MVDR). On the other hand, deep learning (DL) techniques have been proposed for MIMO radar systems as an alternative to traditional techniques that are computationally expensive and very sensitive to clutters and interferences. MIMO radar high-Resolution algorithms such as MVDR or MUSIC are computationally expensive and very sensitive to array geometry error and clutter/interference. Because of this, alternative techniques, such as DL techniques, were investigated in this Chapter. Two techniques were proposed: the support vector machine (SVM) and the SqueezeNet. The SVM was used to classify the targets, and the SqueezeNet was proposed for range, angle, and speed estimations by treating these parameters as a multilabel classification problem. The training of both

techniques was based on the low-resolution 2D FFT range-angle and range-Doppler plots. It was shown that, unlike the high-Resolution algorithms, both techniques perform well in the presence of clutter and jammers. Acceleration of radar signal processing and incorporation of hybrid beamforming was also discussed as a way to increase the resolution and the refresh rate of the MIMO radar.

Chapter 11: RFID Technology and Challenges in Designing – Miniaturization of Passive TAGs for UHF Applications

This chapter provides a survey on Radio Frequency Identification technology (RFID), especially passive RFID technology which is very recommended and highly used in industrial environment due to its advantages such as lowest cost of manufacturing and high read range. The chapter reviews the historic of RFID technology, including frequency bands allowed, mode of communications and different types of RFID TAGs. Then, description of the methodology of passive RFID TAG design, methods used to match input impedance and miniaturization. Finally, a new contribution in passive RFID TAGs design is presented using miniaturization methods such as integration of split ring resonator theory and meander technique. Relate to technological evolution, the increasing demand for low cost, flexible, reliable, low power consumption, and durable technologies, the RFID technology is one of the compliant technologies for all applications requirements.

This study aims to highlights two issues in this field are matching impedance and miniaturization. A detailed introduction about RFID technology and the theoretical background about matching impedance techniques and miniaturization methods are discussed in this chapter. Those techniques are cited in this work to demonstrate a strong point in reading robustness and miniaturized size.

Three contributions were presented which are conform to Moroccan standard UHF band. The 1st one is based on theory of split ring resonator, it offers small size outer diameter of 32mm which is reduction of 90.7% of the wavelength at 868MHz. The proposed RFID TAG antenna is etched of FR4 substrate and demonstrates a good performance. The 2nd design is expanded from meander technique. The meander RFID TAG antenna is printed on flexible substrate and can be used for applications requiring flexible RFID antennas with shrieked length around 70mm, which is 79.4% reduced from the theorical wavelength and an excellent read range. The last contribution is a proof concept of the combination of the two techniques and their advantages in miniaturized size and high performance of RFID TAG at Moroccan UHF band.

Chapter 12: Design of Compact Planar Filters Miniaturization Challenges

The filters reduction in size becomes a significant difficulty because it frequently has a considerable impact on the wireless system's overall dimensions. This chapter's aim is to introduce new ideas that have been made to miniature filter. Then, a variety of filters which have been created are revealed. Some Microstrip filters are miniaturized using coupled lines, quasilumped elements and stub topology, and other structures are based on resonators. The structures presented are optimized and validated for different frequency bands. Using ADS, HFSS and CST-MWS, a full-wave electromagnetic analysis had been successful in assessing the electrical performances of the suggested structures.

One of the most important and fundamental components of any communication system, including the microwave system, is the filter structures. Any communication system must include filters in its architecture. This research provides an overview of the various structures and technologies used today

for microwave filters, along with their benefits and drawbacks, in this chapter. The selection of a technology is influenced by a number of variables, including the demands for filter response, complexity and cost, size, power supply processing, and insertion loss levels. With regard to planar technologies, the tendency is toward the complexity-driven downsizing of filters. In order to calculate the coupling introduced by the various shapes and placements, electromagnetic simulations have mostly been used in the creation of these planar resonators. The goal is to increase propagation properties while decreasing the overall surface area occupied by the filter. Therefore, this chapter will deal with some contributions concerning the design of compact filters in planar technology and will discuss the different techniques and obtained results.

Chapter 13: Design of a Waveguide Bandpass Filter for Satellite Applications

Filters are known for their possibility of allowing applications to share and make the best issue of spectrum source and limiting the interferences between systems while allowing certain frequencies to pass and rejecting others. As it has known an up growth in the last few decades for its significant addition in many distinct microwave applications, especially in the implementation phase of RF and microwave filters. Despite the fact that this technology is not suitable for operations at low frequencies due to its expanded dimensions, also that it is not fitting by reason of size, cost, and flexibility. In this chapter, a brief state of art about RF and microwave filters is presented, considering the types, the characteristics of these devices, and the presentation of results of two conceptions and simulations results of a bandpass filter dedicated for a satellite application, and a waveguide with resonators and tuning screws for a mobile communication application to show and present the effect of tuning screws on the response of a microwave filter.

In this work, two types of discontinuities added to the waveguide geometry to optimize the frequency response were presented. Since filters are the key issue of all microwave applications it is necessary to improve their principle of working. Yet the tuning task or the regulation process after fabrication may be a little delicate, this is why it is always dedicated to experts in the domain. Especially, since this task is time and effort-consuming, considering microwave filters a none linear complex system. This is why many researchers oriented their work develop intelligent techniques to control the frequency response even after the last step of fabrication. For example, tuning based on fuzzy logic is one of the powerful tools in controlling complex systems, this could be effectuated by only using the expertise of microwave experts as a base of rules, and duplication of human reasoning in terms of these rules if the form of IF-Then rules.

Chapter 14: Survey on RF, Microwave, and Millimeter-Wave Planar Passive Components Design Using Analytical Approach

This chapter come up with a comprehensive review of analytical analysis for microwave planar passive devices, including directional couplers, hybrid branch-line couplers, phase shifters, filters, and power dividers/combiners. The passive devices were fundamental building components for developing 5G wireless and IoT systems. The performance and specifications of the devices were mainly determined by the physical dimension, size, and structure of the microstrip line on the PCB, in this chapter, the analytical analysis for the planar passive devices was mainly focused on which this method provides an explicit solution in the design of the devices. The passive devices can be accurately modeled by the ABCD ma-

trix, transmission line theory, stepped impedance matching, cascaded network approach, and even-odd mode decomposition, which was capable of providing an initial design guide-line for the dimensions of the device. In addition, this chapter attempts to provide a quick guide for the reader to quickly and easily understand the principles of passive components.

In addition, the design steps of RF/microwave circuits are briefly and detailed described. Besides, a lot of design coefficients or factors for those RF/microwave circuits have been extracted from journals and listed to simplify the circuit design process.

The main purpose of this chapter is to provide the reader with a comparison of the similarities and differences of analytical solutions in different passive circuit designs.

Chapter 15: Design of Efficient VLSI Architecture and Implementation of Power Optimized Turbo Decoder for LTE Networks

This chapter is on the design and Application Specific Integrated Circuit (ASIC) implementation to optimize turbo decoder using standard cell library of Complementary Metal Oxide Semiconductor (CMOS). Various constraints like channel noise, number of iteration and frame length performance are analyzed and estimated through reference models. Register Transfer Language (RTL) model for Encoder and Decoder are developed simulated and synthesized by Hardware Description Language (HDL). The ASIC implementation with various performance parameters like power and speed are considered to evaluate the proposed algorithm on decoder blocks. In the proposed low power turbo decoder novel techniques like clock gating and adaptable iteration methods are used. This work proved the energy efficiency through elimination of unwanted iteration and early stopping mechanism. The results of proposed work are compared with other competent research and it evidently shows that power dissipation is reduced by 34% with adaptable data rates for LTE standard wireless applications.

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