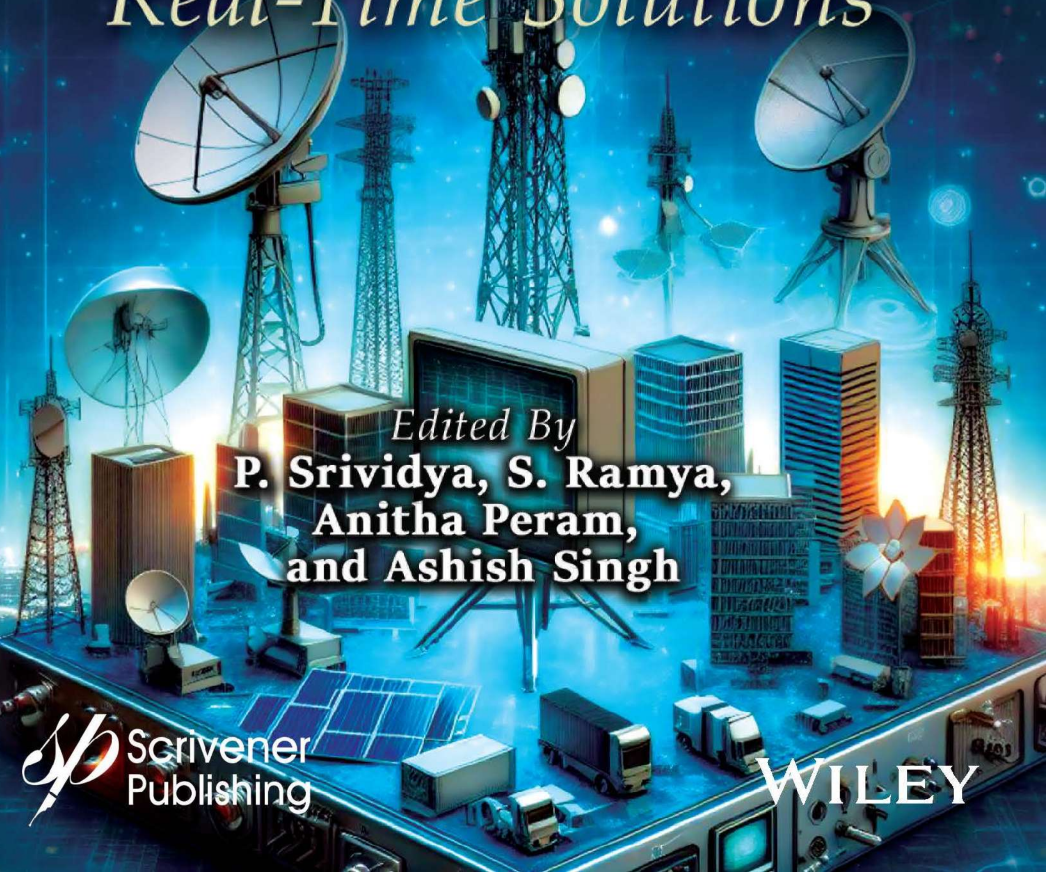
DIGITAL CONVERGENCE IN ENGINEERING SYSTEMS

DIGITAL CONVERGENCE *in* ANTENNA DESIGN

Applications for Real-Time Solutions



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Digital Convergence in Engineering Systems

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Preface

It is indeed a great pleasure for us to present a new book to our esteemed readers, titled on *Digital Convergence in Antenna Designs*. The main objective of the book is to present, in sufficient depth, analytical and practical models and ideas in the field of antennas.

The book is divided into three sections. The first section gives a detailed description of 5G and its applications; the second section deals with wireless communication and its applications, and the third section discusses the various MIMO techniques.

Chapter 1 presents an insight into 5G technology along with cognitive radio that helps in optimum usage of radio resources by providing an efficient way of communication. The technology offers higher speed, lower latency, higher coverage and higher spectral efficiency. 5G provides a great transformation during our lifetime with unlimited possibilities. 5G system architecture, the network elements, design problems, infrastructure needs, features, 5G slicing and pros and cons of 5G are described in detail in this chapter.

A metamaterial-inspired slot antenna with defected ground structure is proposed for the wireless medical device and other wireless applications in Chapter 2. The results are simulated using CST software. The entire structure is characterized with the help of return loss, gain, current distribution, and radiation pattern. The initial design of a rectangular patch antenna has a single-band operation and by introducing slots in the radiating patch and metamaterial at the back of the substrate, the structure is proven suitable for multiband operation.

Chapter 3 suggests an insight on wideband antenna applications. The antenna consists of rectangular radiating components with slots carved out for operation in two or more bands. On an FR4 substrate with a relative permittivity of 4.4 and a height of 1.6mm, both antennas have been built. The radiating patches are excited by the inset feed line. Due to the radiating components' close proximity, high isolation is attained. The simulation results show that the two proposed antennas have a wide bandwidth, better isolation, return loss, correlation coefficients, envelope correlation coefficients, and total active reflection coefficients across the resonating frequency.

Chapter 4 describes the creation of a dumpy-shaped, condensed fractal antenna by conformal characteristics, which is necessary to meet the demands of 5th-generation wireless wearable and flexible device practise. A Computer Simulation Technologies (CST) Microwave Studio (MWS) 3D electromagnetic simulation tool is used to build and analyze the portable antenna. To enable wireless body parts data transmission, the proposed antenna is developed and configured for a wearable wearer.

Chapter 5 presents a compact ($32 \times 32 \times 1.6$ mm^3), microstrip line-fed, dual-frequency X-band (8-12 GHz) application and is largely suitable for modern radar applications. The group delay time of the proposed antenna ranges from -0.90 ns to 0. 0 ns (0.5 ns) and the VSWR of the proposed antenna is close to 1 and obtained below 2. The proposed structure and model of the antenna were analyzed using ANSOFT- HFSS simulation tool version 13.

Chapter 6 focuses on compact reconfigurable antenna for multiband frequencies. The designed patch antenna has been designed on FR 4 glass epoxy substrate. A diode is placed into the U-slot at ground to switch the frequency. The frequency switching from 7.2 to 4.7 GHz is noticed between the pin diode's OFF and ON periods. The antenna resonated at the same frequency during the ON and OFF periods of the diode. The designed antenna has obtained reasonable gain in both the bands.

Chapter 7 focuses on a simple printed antenna with polygonal radiating element feed with a microstrip line feed for the tri-band applications. The polygonal radiating element has five sides, made up of thin copper of thickness 0.0035 mm. The antenna is designed and fabricated on an FR4 substrate. The structure has a pentagonal printed patch as the seed element and is followed by four stages of evolution. The structure with a split-ring resonator can achieve tri-band operation at 3.01 GHz, 3.3 GHz, and 5 GHz. The performance of the antenna, such as return loss, VSWR, surface current density, gain, directivity, 3D radiation pattern, E-plane, and H-plane radiation pattern are presented. Compact size, stable radiation pattern, good gain, tri-band application with good impedance matching makes this antenna more suitable for the WiMAX and WLAN applications.

A dielectric resonator antenna has been proposed in Chapter 8 and is excited with aperture coupled feeding. A slot has been created on the substrate to excite the antenna and a microstrip feed line is connected. The gap between the two elements is 7 mm which is a very minimum. Complementary meander line which is used here works like a stop band filter. The results are satisfying applications of C-band uplink and C-band downlink frequency range and also it satisfies the WiMAX band. After placing the complementary meander-line in high frequency it was found that the electric field distribution is variable.

Chapter 9 presents a circular waveguide polarizer with periodic metallic structure loading. The designed structure consists of a thick metallic structure, periodically placed in a circular waveguide to produce CP TE_{11} mode output. In the proposed design, TE_{11} mode is applied at port-1 of the waveguide, and the circularly polarized output at output port-2 is obtained, due to the periodic structure inside the waveguide. The designed polarizer performs linear to left-hand circular polarization over the bandwidth of 3.42-3.52 GHz, which is very useful for real-time applications. The result cantered at 3.5 GHz indicates that the proposed structure has a high-power handling capability of 464 MW and an axial ratio of 1.5 dB.

A multi-resonant, miniaturized metamaterial-inspired monopole antenna has been designed and discussed in Chapter 10. Left-handed metamaterial is created by combining two rectangular segments with an air gap. Secondary resonances in the WLAN and Wi-MAX bands have been formed by combining the metamaterial structure with a conventional monopole antenna. An FR4 epoxy substrate is used to manufacture a prototype of the antenna. The simulation and measured results are in good agreement, indicating good radiation performance.

Chapter 11 presents energy consumption that causes the nodes to be in sleep or awake states when nodes are transmitting information. Instead, the proposed system achieves energy efficiency using sleep/awake, which ensures a high PDR (packet delivery ratio). This concept does not use the WSN method. This methodology is asynchronous and is self-adaptive to switch between sleep and awake modes and doesn't utilize the duty cycle to assign these methods. In this methodology, the time slots for the nodes are divided and scheduling is done dependent on the self-governing, where the nodes choose to switch their modes.

We would like to acknowledge the authors of the chapters and the useful feedback we received from many distinguished teachers all over India and abroad. We are also thankful to our publishers who were instrumental in bringing out this book in its current form. Suggestions for increasing the usefulness of the book are most welcome.

The Editors

Section 1

5G AND ITS APPLICATIONS

1

5G and Cognitive Radio

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Abstract

In the present scenario, due to the advancement in wireless and mobile technology, there has been a significant increase in the number of wireless devices and also an increase in smart technology. Mobile and wireless communication will increasingly become the primary media for humans and machines to access information to provide services. This will lead to socioeconomic changes including improvements in productivity, sustainability, entertainment and well-being. There is significant growth in the Internet of Things (IoT) due to an enormous increase in the connected devices in every sector. There is huge demand for the spectrum every hour as more and more devices are connected. The spectrum is limited; it has to be used in a smart way as there is no free spectrum available to support the huge demand of the connected wireless devices and to support the data traffic. The spectrum which is allocated to the licensed users is not optimally utilized; sometimes it is overused and sometimes it is underutilized.

Fifth-generation network (5G) supports significantly faster mobile broadband speeds and heavier data usage than previous generations and also enables the full potential of the Internet of Things. Due to an extensive advancement in the 5G technology, one of the important technologies used is the Cognitive radio (CR) system, which is expected to be one of the technical solutions of innovation and development of future wireless systems. The CR system in the 5G network is finding an emerging and potential application by employing CR capabilities used to overcome the shortfall of the spectrum and optimally make use of the available spectrum. The CR dynamically senses the free spectrum available or unutilized and allots to the unlicensed users without affecting the licensed users. This provides a more efficient way of using the limited radio resources.

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1.1 Introduction

The 5th-generation mobile network is termed as 5G. The latest development wireless standard after 1G, 2G, 3G and 4G networks is 5G. A new kind of network is designed in 5G technology to connect everything and everyone virtually together, which includes people, devices, objects and machines.

Mobile operators started operating worldwide in 2019 and are well-known fans of 4G Networks which provide the state of being connected or interconnected to most of the existing phones. By 2026, 5G networks are expected to have more than 2 billion subscribers worldwide. The service area is divided into cells and all 5G wireless devices in the cell are connected to it [1].

In telecommunications, for broadband cellular networks, 5G standards are being used. 5G is the forthcoming revolution of mobile technology. In a 5G system, the network manages various kinds of information like Data files, Policy data, Exposure data, Transient UE context, etc. In earlier generations all the network elements were stateful. In stateful network elements all the data will be stored inside the network element itself. In 5G all Network Functions are stateless. In stateless elements, the data will be hoarded in a separate database called UDSF. The statelessness of 5G network tasks provides better network optimization and improved reliability compared to earlier generations.

A Cognitive Radio (CR) is a wireless communication device which can adjust its transmission depending on information about the use of the local spectrum. A cognitive radio makes a decision on how to use the available radio resources in order to ensure communications with a certain quality of service after getting the information about how the spectrum is being used. It uses this knowledge to adapt itself in order to provide wireless services which are relevant to the user needs and preferences. The radio can learn from its past actions and experience and incorporate this knowledge in future decisions. The CR device would adapt to the new environment to offer personalized services that satisfy the user's needs where the user moves. The key feature of such a cognitive radio is its ability to recognize unused parts of the spectrum assigned to conventional users and adapt its communication strategy to use these parts while minimizing the interference that it generates to the conventional users [2].

The major advancement for getting a higher bandwidth in a cellular communication network is by utilization of cognitive radio (CR) for the next-generation, fifth-generation (5G) communication technology [3]. Both the CR and the 5G of cellular wireless standards are studied to be the future technologies: on the one hand, CR offers the possibility to significantly increase the spectrum efficiency, by smart secondary users (CR users) using the free licensed user's spectrum hole. On the other hand, the 5G implies the whole wireless world interconnection (WISDOM—Wireless Innovative System for Dynamic Operating Mega-communications concept), together with very high data rates Quality of Service (QoS) service applications [4].

1.2 5G System Architecture

The requirements for this architecture are ambitious and can be expressed in three categories of skills:

- To support Great Internet-of-Things, which may include devices with very low power (10+ years of battery life), very low complexity (10 bits per second) and very high density (1 million square nodes kilometers).
- To support Essential Mission Control, which may include high-altitude availability (over 99.999% or "nine-speed"), low-speed delays (as low as 1 ms) and extreme speeds (up to 100 km/h).
- To support Advanced Mobile Broadband and may include higher data rates (maximum Gbps throughput, 100+ Mbps continuous) and overload capacity (10 Tbsp of aggregate throughput per square kilometre) [5].

5G Architecture is highly developed and its network elements and various terminals are technically enhanced which will be able to afford the new state [6]. The 5G architecture has three planes, Data Plane, Control Plane and User Plane. The System Architecture for the 5G System shown in Figure 1.1 contains two planes. The first two lines represent the control plane. All network elements are placed in this control plane. The down line represents the user plane. The data plane will be placed above the control plane where the implemented UDSF will be placed. All network elements present in the system architecture can make use of UDSF for storing and retrieval of corresponding data.

The 5G architecture is defined as service-based and the interaction between network elements is represented in two ways [7].