

DIGITAL CONVERGENCE IN ENGINEERING SYSTEMS

DIGITAL CONVERGENCE *in* ANTENNA DESIGN *Applications for Real-Time Solutions*

Edited By
**P. Srividya, S. Ramya,
Anitha Peram,
and Ashish Singh**

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Digital Convergence in Engineering Systems

Series Editors

Rathishchandra R Gatti is currently Professor and head, Department of Mechanical and Robotics Engineering at SCEM. Previously, he worked in Curtin University as academic and patent analyst, General Electric as new product development engineer, SVI as manufacturing supervisor, Meritor Automotive as Automotive designer, and Trainee Engineer at Rapsri Engineering. He has PhD in Mechanical Engineering from Curtin University, MBA Operations from IGNOU and BE in mechanical engineering from NITK, Suratkal. He has 18+ patents, 40+ publications and edited/coauthored 8+ SCOPUS Indexed books.

Chandra Singh is an Assistant Professor in the Department of Electronics and Communication Engineering at the Sahyadri College of Engineering & Management. He has Obtained B E and M. Tech from Srinivas School of Engineering, Mukka and NMAM Institute of Technology, Nitte. He is pursuing his PhD from VTU Belagavi, India. He has 10+ patents, 25+ publications. He has also received many awards and accolades during his short carrier He has 8+ books published by Scopus recognised publishers.

Steven Fernandes, currently an Assistant Professor of Computer Science at Creighton University, specializes in extracting patterns from big data using advanced AI techniques. With a postdoctoral background at the University of Alabama at Birmingham and the University of Central Florida—working on projects funded by NIH, DARPA, NSF, and RBC—he has contributed to artificial intelligence research through publications in selective venues and applications in computer vision, natural language processing, and medical image processing.

Srividya P., currently working as Associate Professor in the department of electronics and communication engineering, RVCE, Bangalore, India. Has 20 years of teaching experience. Has 2 patents published and nearly 22 papers in international conferences, 18 papers in International journals and 7 book chapters in different books published by CRC press. Guided around 30 UG projects and 20 PG projects. Is editor for 2 books published by renowned publishers. Areas of interest include Analog VLSI design, Digital VLSI design and embedded systems.

Publishers at Scrivener

Martin Scrivener (martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

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Contents

List of Figures	xi
List of Tables	xvii
Preface	xix
Section 1: 5G and its Applications	1
1 5G and Cognitive Radio	3
<i>Dr. Nagamani K. and Dr. Bhagya R.</i>	
1.1 Introduction	4
1.2 5G System Architecture	5
1.3 An Overview of Network Elements	6
1.4 Design Problems	8
1.5 5G Infrastructure Needs	9
1.6 Features	10
1.7 5G Network Slicing	11
1.8 Pros of 5G	12
1.9 Cons of 5G	13
1.10 5G Applications	14
1.11 Cognitive Radio	15
1.12 Cognitive Radio Network	16
1.13 Spectrum Sensing in CRNs	17
1.14 Classification of CR Spectrum Sensing	17
1.15 Methods of Spectrum Sensing	18
1.16 Routing in Cognitive Radio Network	19
1.17 Terminal Capability of CRN	19
1.18 Reconfigurable Capability	20
1.19 Architecture of CRN	22
1.20 Primary System and CR System	23
1.21 Routing Challenges in CRNs	24
1.22 SDR Architecture	25

1.23	Physical Architecture of CR	28
1.24	Operation of CR	29
1.25	Benefits of CR	30
1.26	Challenges Faced by CR	30
1.27	Techniques of Spectrum Sensing	30
1.28	Cooperative SS Techniques	33
	Conclusions	35
	References	36
2	A Single-Ring SRR Loaded Slot Engraved Rectangular Monopole Antenna for ISM, WLAN, WiMAX, and 5G Application	39
	<i>Prasad Jones Christydass, Asha, Chandra Kumar Dixit, Dhanagopal and Praveen Kitti</i>	
2.1	Introduction	40
2.2	Design of SRR Loaded Slot Engraved Rectangular Monopole	41
2.3	Parametric Analysis	46
2.4	Results and Discussion	50
2.5	Conclusion	53
	References	53
3	Compact Wideband 6-GHz Different Radiating Elements MIMO Antenna with Dual-Band for the 5G/WLAN/C-Band Application	57
	<i>Shrenik Suresh Sarade and Dr. S. D. Ruikar</i>	
3.1	Introduction	58
3.2	Designing of Two-Element and Four-Element MIMO Antenna	62
3.2.1	Two-Element MIMO Antenna with Defected Ground Structure (DGS)	62
3.2.1.1	Optimization of Defected Ground Structure (DGS) in the Ground Plane and Cut Slot in the Radiating Patch	67
3.2.1.2	Result Analysis of Two-Element MIMO Antenna	69
3.2.2	Four-Element MIMO Antenna	74
3.2.2.1	Result Analysis of Four-Element MIMO Antenna	77
3.3	Comparison	81
3.4	Conclusions	82
	References	85

Section 2: Wireless Communication Applications	87
4 Compact Fractal Wearable Antenna with and without Defected Ground Structure for Wireless Body Area Communications	89
<i>S. Ramesh and S. Chitra</i>	
Introduction	90
Design and Methodology of Proposed Antenna	92
Design Process	92
Analysis of Triangular Patch Antenna	93
Defected Ground Structure	94
Proposed Antenna Configuration	94
Results and Discussion	96
S-Parameter	97
Radiation Pattern	97
Specific Absorption Rate (SAR)	98
Prototype Antenna	102
Measured Results	103
Measurement of S_{11}	103
Comparison of Simulated and Measured Results	104
Return Loss	104
Radiation Pattern	104
Conclusion	104
Acknowledgement	110
References	110
5 A Novel Defected Ground Structure Based Analysis of Micro Strip Patch Antenna for Modern Radar Application	113
<i>Amrees Pandey, J. A. Ansari and Iqra Masroor</i>	
5.1 Introduction	114
5.1.1 Antenna Design and Evolution of the Proposed Design Model	116
5.1.2 Results and Discussion	118
5.2 Conclusion	128
References	128
6 A Reconfigurable Antenna for C Band Applications	133
<i>Banuprakash R., Vishakha Yadav, Dwarakanath G. V. and S. A. Hariprasad</i>	
6.1 Introduction	133

6.2	Structure of Antenna	138
6.3	Results and Discussions	139
6.3.1	Intermediate Steps	141
6.3.2	Gain	144
6.3.3	Radiation Pattern	145
6.3.4	Reconfigurable Antenna Prototype	146
6.4	Conclusion	151
	References	151
7	Split-Ring Resonator-Inspired Polygonal-Shaped Printed Antenna for Wireless Application	153
	<i>Prasad Jones Christydass S., Saravanakumar R., Regina S. and Malaisamy K.</i>	
7.1	Introduction	154
7.2	Design of SRR-Inspired Polygonal Antenna	156
7.3	Parametric Analysis	160
7.4	Result and Discussion	162
7.5	Conclusion	167
	References	168
	Section 3: MIMO Techniques	171
8	Dielectric Resonator Antenna for Multiple Input Multiple Output Applications	173
	<i>Mehaboob Mujawar and Subuh Pramono</i>	
8.1	Dielectric Resonator Antennas (DRA)	174
8.2	Multiple Inputs and Multiple Outputs (MIMO)	175
8.3	Comparative Study of Different DRA Antennas for MIMO Applications	176
8.4	H-Shaped DRA MIMO Antenna	183
8.5	Results	184
8.6	Conclusion	187
	References	187
9	A Circular Waveguide Polarizer Based on Periodic Metallic Structure Loading	191
	<i>Swati Varun Yadav and Ashish Chittora</i>	
9.1	Introduction	191
9.2	Design Principle and Structure	195
9.3	Result and Discussion	197
9.4	Conclusions	202
	References	202

10 A Metamaterial-Inspired Monopole Antenna for Multi-Resonance Applications	207
<i>Chetan S. and Chandrappa D. N.</i>	
10.1 Introduction	207
10.2 Reduction of Electrical Size	209
10.3 Reduction of Coupling Effects	209
10.4 Shaping of Aperture Field – Directivity and Gain Enhancement	210
10.5 Scanning of Main Beam Direction	210
10.6 Design of Rectangular Split-Ring Metamaterial Unit Cell	210
10.7 Design of Metamaterial-Loaded Monopole Antenna	213
10.8 Design of Monopole Antenna with Metamaterial	215
10.9 Conclusion	217
References	217
11 Energy-Efficient Technique to Improve the System Using MIMO	223
<i>Manjunath Managuli, Mahantesh K., M. Lakshminarayana and Sangamesh C. Managuli</i>	
Introduction	223
Antenna Node Construction	224
System Specifications	227
Practical Requirements	228
Non-Useful Requirements	228
H/S Requirements	228
Software Environment and Instrument	228
Programming Language	228
C++ Language	229
OTCL Script	229
AWK Characters	229
Prefaces to NST	230
User Vision of System	230
Structure Architecture Design	231
Complete Aim	232
Flow Chart	233
Sequence Diagram	233
Implementation	234
System Component	234
Power Component	235
Node Power Estimate	236
Self-Adaptive Sleep/Awake Module	237

Performance Analysis Module	238
Existing System – Self-Adaptive Sleep/Awake Algorithm Screenshot	238
Proposed System – Energy Efficient Method to Improve Network Lifetime Using MIMO Screenshots	242
Testing	244
Levels of Testing	244
Initialization Testing	245
Functional Testing	245
Results and Analysis	245
Self-Adaptive Sleep/Awake Algorithm Performance Metrics Screenshots	247
Performance Measures – Existing System	248
XGraph – Average Throughput	248
X-Graph – Average End-to-End Delay	249
X-Graph – Overhead	250
X-Graph – Average Energy	251
Conclusions	252
References	253
About the Editors	257
Index	259

List of Figures

- 1.1 5G system architecture.
- 1.2 Architecture of transmitter part of SDR.
- 1.3 Architecture of receiver part of SDR.
- 1.4 Illustration of functions of CR.
- 1.5 Radio frequency front-end of a CR.
- 1.6 Illustration of CR cognitive cycle.
- 1.7 Methods used for SS in CR.
- 1.8 Block diagram of MFD SS method.
- 1.9 Flow diagram illustrating EDSS method.
- 1.10 Block diagram of CFD SS method.
- 2.1 Evolution of proposed design.
- 2.2 Geometry of the proposed design.
- 2.3 s11 comparison graph.
- 2.4 Return loss plot of antenna A vs. antenna E.
- 2.5 Parametric analysis of feed width (wf).
- 2.6 Parametric analysis of strip width (x).
- 2.7 Parametric analysis of slot width (y).
- 2.8 Surface current distribution of the proposed structure.
- 2.9 E-plane and H-Plane pattern at various operating frequency.
- 2.10 Fabricated antenna.
- 2.11 Gain of the proposed structure.
- 2.12 Simulated vs. measured - return loss plot.
- 3.1 Two different-shaped element MIMO antenna.
- 3.2 Geometrical structure of two-different-shaped antenna with cut slot.
- 3.3 Ground plane with DGS.
- 3.4 Ground plane with DGS CS dimensions.
- 3.5 Equivalent circuit model for patch-1 and patch-2.
- 3.6 Equivalent circuit model for ground plane with DGS cut slot.
- 3.7 Graph of return loss (RL) and isolation of patch-1.
- 3.8 Graph of RL and MC of RPE-2.

- 3.9 VSWR of MA (RPE-1 and RPE-2).
- 3.10 Gain of MA.
- 3.11 Directivity of MA.
- 3.12 RP of MA.
- 3.13 4-different-shaped element MA.
- 3.14 Four-different-shaped element antenna with cut slot dimensions.
- 3.15 Ground plane with DGS.
- 3.16 GP with DGS CS dimensions.
- 3.17 RL and isolation of RPE-1.
- 3.18 RL and isolation of patch-2.
- 3.19 VSWR of MA.
- 3.20 Directivity of MA.
- 3.21 Gain of MA.
- 3.22 RP of MA.
- 4.1 Various antenna iterations using a triangular Sierpinski gasket.
- 4.2 Front and back views of a proposed antenna (a) without DGS (b) with DGS.
- 4.3 S_{11} Vs frequency simulation for the antenna (a) with DGS (b) without DGS.
- 4.4 3D view radiation patterns at 3.7 GHz (a) without DGS and (b) with DGS.
- 4.5 Simulation of an antenna radiation pattern without the use of DGS (a) Y-Z plane ($\Phi=90^\circ$), (b) X-Y plane ($\Phi=0^\circ$), (c) X-Z ($\Theta=90^\circ$).
- 4.6 Simulation of an antenna radiation pattern with the use of DGS (a) Y-Z plane ($\Phi=90^\circ$), (b) X-Y plane ($\Phi=0^\circ$), (c) X-Z ($\Theta=90^\circ$).
- 4.7 Gain of the antenna (a) without DGS and (b) with DGS.
- 4.8 The proposed antenna's 3D SAR distribution at 3.7 GHz.
- 4.9 (a) Antenna with VNA, (b) Calibration kit, (c) Antenna front view, (d) Antenna back view.
- 4.10 Measurement of return loss (a) without DGS (b) with DGS.
- 4.11 Return loss vs. Frequency (a) without DGS (b) with DGS.
- 4.12 Far-field measurement setup of the proposed antenna.
- 4.13 A comparison of the radiation patterns observed and those simulated in (a) XY, (b) YZ, and (c) XZ planes without a DGS antenna.
- 4.14 A comparison of the radiation patterns observed and those simulated in (a) XY, (b) YZ, and (c) XZ planes with a DGS antenna.
- 5.1 Top (green color) and bottom (yellow color) view layout of the proposed antenna (Antenna-3).

- 5.2 Simulated return loss versus frequency curve of the Antenna-1, Antenna-2 & Antenna-3.
- 5.3 Simulated gain versus frequency curve of the Antenna-1, Antenna-2 & Antenna-3.
- 5.4 Simulated return loss & gain versus frequency curve of the proposed antenna (Antenna-3).
- 5.5 Simulated VSWR & group delay versus frequency curve of the proposed antenna (Antenna-3).
- 5.6 Simulated three dimensional (3D) gain at 8.80 GHz of the Antenna-3 (proposed).
- 5.7 Simulated three dimensional (3D) gain at 11.53 GHz of the Antenna-3 (proposed).
- 5.8 Simulated surface current distributions at 8.80 GHz of the Antenna-3 (proposed).
- 5.9 Simulated surface current distributions at 11.53 GHz of the Antenna-3 (proposed).
- 5.10 Simulated radiation efficiency of the Antenna-3 (proposed).
- 5.11 Simulated far-field radiation pattern at 8.80 GHz of the Antenna-3 (proposed).
- 5.12 Simulated far-field radiation pattern at 11.53 GHz of the Antenna-3 (proposed).
- 6.1 (a). Forward bias of BAP65-03 (b). Reverse bias of BAP65-03.
- 6.2 Front view.
- 6.3 Back view.
- 6.4 S_{11} in off mode of diode.
- 6.5 S_{11} in on mode of diode.
- 6.6 VSWR during OFF mode of p-i-n diode.
- 6.7 VSWR during ON mode of p-i-n diode.
- 6.8 S_{11} of antenna.
- 6.9 Ground plane current distribution at 5.4GHz.
- 6.10 S_{11} of antenna with rectangular slots.
- 6.11 Return loss for L-shaped slot antenna.
- 6.12 Return loss of antenna with U-shaped slot.
- 6.13 Gain plots in OFF condition.
- 6.14 Gain plots in ON condition.
- 6.15 Pattern at 4.7GHz.
- 6.16 Pattern at 5.6GHz.
- 6.17 Pattern at 7.2GHz.
- 6.18 Fabricated reconfigurable antenna.
- 6.19 Measured return loss of antenna during off condition of diode.

- 6.20 Measured return loss of antenna during on condition of the diode.
- 6.21 Return loss during on and off mode of diode - simulated.
- 6.22 S-parameter comparison (measured and simulated) - off state.
- 6.23 S-parameter comparison (measured and simulated) - on state.
- 6.24 Return loss comparison (measured) - on and off mode of the diode.
- 6.25 Overall result comparison.
- 7.1 SRR-inspired polygonal antenna - design stages.
- 7.2 Front and back view of the proposed antenna with its parameters.
- 7.3 Antenna A, B, C & D – S_{11} comparison.
- 7.4 S_{11} comparison – various feed width (wf).
- 7.5 S_{11} comparison – various ground length (lg).
- 7.6 S_{11} comparison – SRR rings.
- 7.7 Fabricated antenna.
- 7.8 E-plane & H-plane pattern (measured and simulated) at resonating frequencies.
- 7.9 SRR-inspired polygonal antenna - surface current distribution.
- 7.10 Gain of the SRR-inspired polygonal antenna.
- 7.11 Simulated vs. measured s_{11} plot of SRR-inspired polygonal antenna.
- 8.1 H-shaped DRA MIMO antenna.
- 8.2 Complementary meander-line geometry.
- 8.3 Reflection coefficient vs. frequency for MIMO DRA.
- 8.4 Gain and directivity of H-shaped DRA at 3.5 GHz.
- 8.5 Gain and directivity of H-shaped DRA at 5.8 GHz.
- 8.6 Radiation pattern of H-shaped DRA in the H-plane.
- 8.7 Radiation pattern of H-shaped DRA in the E-plane.
- 9.1 Block diagram of high power microwave system.
- 9.2 Linear and circular polarization.
- 9.3 Perspective view and side view of the circular waveguide polarizer.
- 9.4 Conversion of linear to TE_{11} mode circularly polarized output.
- 9.5 Parametric analysis of the polarizer design.
- 9.6 Parametric analysis of metallic strip at different angles.
- 9.7 Simulated axial ratio plot with periodicity of metallic structure.
- 9.8 Simulated S parameter (S_{11}) for proposed waveguide polarizer.
- 9.9 Simulated electric field distribution of the circular waveguide polarizer.
- 9.10 Simulated radiation pattern E plane and H plane.
- 10.1 Geometry of simulated single RSRR.

- 10.2 Equivalent circuit of single RSRR.
- 10.3 S-parameter plot.
- 10.4 Permittivity plot of metamaterial unit cell.
- 10.5 Permeability plot of metamaterial unit cell.
- 10.6 Design process for three stages.
- 10.7 S11 vs. frequency plot for all three stages.
- 10.8 Monopole antenna with MTM.
- 10.9 S11 vs. frequency plot.
- 11.1 Working of wireless sensor networks.
- 11.2 Organization of sensor node.
- 11.3 Flow chart.
- 11.4 Network analysis.
- 11.5 Architecture of adaptive sleep/awake scheduling.
- 11.6 Detail design.
- 11.7 Flow chart.
- 11.8 Sequence diagram.
- 11.9 Random node operation.
- 11.10 Node deployment algorithm for energy calculation.
- 11.11 Self-adaptive sleep/awake approach for energy efficiency.
- 11.12 Flow chart to compute performance metric.
- 11.13 Sleep-awake terminal.
- 11.14 Self-adaptive sleep/awake algorithm at time 0.0 ms.
- 11.15 At time 2.54 ms: source node – 9 and destination node - 23.
- 11.16 At time 3.46 ms, path node between source node 9 and destination node 23.
- 11.17 At time 4.53 ms, source node – 18 and destination node - 12.
- 11.18 At time 4.72 ms, problem node 16.
- 11.19 At time 6.38 ms, new path selected.
- 11.20 At time 2.54 ms: source node – 9 and destination node – 23.
- 11.21 At time 2.56 ms, path node between source node 9 and destination node 23.
- 11.22 At time 4.56 ms, source node – 18 and destination node – 12.
- 11.23 At time 4.88 ms, problem node 16.
- 11.24 At time 6.62 ms, new path selected.
- 11.25 XGraph: average throughput.
- 11.26 X-Graph: average end-to-end delay.
- 11.27 X-Graph: packet delivery ratio/fraction.
- 11.28 X-Graph: overhead.
- 11.29 X-Graph: average energy.

List of Tables

- 1.1 Probable uni-directional connections in CRNs.
- 2.1 Parameters values in mm.
- 2.2 Resonant frequency and bandwidth comparison of evolved antenna.
- 2.3 Comparison of various evolved antenna.
- 2.4 Comparison proposed antenna vs. literature.
- 3.1 The geometrical structure of patches.
- 3.2 Characteristics of substrate.
- 3.3 Characteristics of substrate.
- 3.4 Geometrical structure of DGS in GP.
- 3.5 RL (S_{11}) and isolation (S_{12}).
- 3.6 RL (S_{22}) and isolation (S_{21}).
- 3.7 VSWR of MA (RPE-1 and RPE-2).
- 3.8 CC, ECC and TARC value of MA.
- 3.9 Geometrical structure of cut slot in patch.
- 3.10 GS of GP with DGS CS.
- 3.11 RL (S_{11}) and isolation (S_{12} , S_{13} and S_{14}).
- 3.12 RL (S_{22}) and isolation (S_{21} , S_{23} and S_{24}).
- 3.13 RL (S_{33}) and isolation (S_{31} , S_{32} and S_{34}).
- 3.14 RL (S_{44}) and isolation (S_{41} , S_{42} and S_{43}).
- 3.15 CC, ECC and TARC value of MA.
- 3.16 VSWR of MA.
- 3.17 Comparison of two-element MIMO antenna with other works.
- 3.18 Comparison of four-element MIMO antenna with other works.
- 4.1 The proposed antenna's dimensions.
- 4.2 Results of SAR simulations.
- 4.3 Comparison of results.
- 5.1 Comparative performance of antenna-1, antenna-2 & antenna-3.
- 5.2 A comparative overview of the proposed antenna (antenna-3).
- 6.1 Comparison of PIN diodes with other diodes.

- 6.2 Measurements of the antenna.
- 6.3 Summary of intermediate design steps.
- 6.4 Comparison of simulated and antenna prototype results.
- 7.1 Dimensions of the SRR-inspired polygonal antenna.
- 7.2 Comparison of antenna evolved in the design.
- 7.3 Simulated vs. measured results.
- 7.4 Proposed antenna vs. literature.
- 8.1 Dimensions of the proposed antenna.
- 9.1 Comparison between previously published circular waveguide polarizers.
- 10.1 Comparison between proposed and literature work.
- 11.1 Initialization testing.
- 11.2 Functional testing.
- 11.3 Simulation parameters required for performance evaluation.
- 11.4 Performance table for self-adaptive algorithm.

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 ($32 \times 32 \times 1.6 \text{ mm}^3$), 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 centered 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

5G and Cognitive Radio

Dr. Nagamani K.* and Dr. Bhagya R.†

*Department of Electronics & Telecommunication Engineering,
RV College of Engineering, Bangalore, India*

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.

*Corresponding author: nagamanik@rvce.edu.in

†Corresponding author: bhagyar@rvce.edu.in

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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 UDSE. 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].