

Contents

Preface	xiii
1 A Systematic Survey on Wearable Biomedical Sensors Using Flexible Microwaves Devices	1
<i>Warisha Fatima, Shailendra Kumar, Mohd Javed Khan and Indrasen Singh</i>	
1.1 Introduction	2
1.2 Literature Survey	3
1.2.1 System for Indoor Positioning	4
1.2.2 Fall Detection System	5
1.2.3 Wearable Sensor Device	7
1.2.3.1 UHF RFID: From Identification to Multi-Port Sensing	8
1.2.3.2 Bio-Radar in Microwave Wearable Application	9
1.3 Procedure and Working	11
1.3.1 Sensor Architecture	11
1.3.2 Principle of Measurement	11
1.3.3 Signal Encoding	11
1.3.4 Calibration and Verification	12
1.3.5 Connectivity with Wearable Technology	12
1.3.6 Examining and Implementing	12
1.3.7 Perks of Microwave Wearable Sensors	12
1.3.8 Imperfections in Wearable Sensors	13
1.4 Next-Generation Wearables: A Strategic Plan for the Future	14
1.4.1 Troubleshooting for Microwaves and Extended Inspection	14
1.4.2 Implantable Microwave Technology	15
1.4.3 Medications Using Microwaves	17
1.5 Conclusion	17
References	18

2	Metamaterials in 5G and the Path towards 6G: Enabling Advanced Wireless Communication	25
	<i>Mohd Javed Khan, Saif Ahmad, Indrasen Singh and Zeenat Fatima</i>	
2.1	Introduction	26
2.1.1	Background	26
2.1.2	Role of Metamaterials	26
2.2	Basics of Metamaterials	28
2.2.1	Definition and Characteristics	28
2.2.2	Types of Metamaterials	29
2.2.2.1	Electromagnetic Bandgap (EBG) Structures	30
2.2.2.2	Frequency Selective Surfaces (FSS)	30
2.2.2.3	Reconfigurable Metamaterials	31
2.2.2.4	Plasmonic Metamaterials	32
2.2.2.5	Dielectric Metamaterials	33
2.2.2.6	Nanostructured Metamaterials	34
2.3	Metamaterials in 5G Communication	34
2.3.1	Current Challenges in 5G	35
2.3.1.1	Bandwidth Limitations	35
2.3.1.2	Signal Interference	36
2.3.1.3	Latency Issues in 5G Networks	37
2.3.2	Metamaterials Solutions for 5G	37
2.4	Towards 6G: Future Challenges and Metamaterials Integration	38
2.4.1	Anticipated Challenges in 6G	38
2.4.2	Metamaterials Innovations for 6G	39
2.5	Case Studies and Applications	40
2.5.1	Practical Implementations in 5G Networks	40
2.5.2	Envisioning 6G Applications	41
2.6	Future Directions and Research Challenges	43
2.6.1	Future Directions	43
2.6.2	Research Challenges	44
2.7	Conclusion	44
	References	45
3	Optimization of Time-Modulated Circular Antenna Array for MIMO Systems through Evolutionary Algorithms	49
	<i>Satish Kumar, Gopi Ram, Durbadal Mandal and Rajib Kar</i>	
3.1	Introduction	50
3.2	Design Equations	51
3.3	Evolutionary Optimization Method Used	55
3.4	Cost Function Formulation	55

3.5	Computational Result	56
3.6	The Convergence Curves of DE, PSO, and NPSO	61
3.7	Conclusions	62
	Acknowledgement	62
	References	62
4	Fractal Antenna MIMO Arrays: A Promising Multiband Solution for Modern 5G Wireless Automotive Applications	65
	<i>Gurmeet Singh, Ashish Kumar and Amar Partap Singh Pharwaha</i>	
4.1	Introduction	66
4.2	Various Forms of Antenna Array	69
4.2.1	Array of Two-Point Sources	69
4.2.2	Broadside Array	72
4.2.3	End-Fire Array	73
4.2.4	Parasitic Array	74
4.3	Feed Networks for Antenna Array	75
4.3.1	Corporate Feed Network	75
4.3.2	Series Fed	76
4.4	Fractal Geometries	76
4.5	Fractal Antenna Arrays	82
4.5.1	Deterministic Fractal Arrays	83
4.5.2	Cantor Linear Array	84
4.5.3	Sierpinski Carpet Arrays	87
4.6	Recent Trends in the Fractal Antenna Arrays	89
4.7	Conclusion	93
	References	93
5	Multiband Fractal Antenna: A Novel Miniaturization Technique	97
	<i>Ruchi Kadwane</i>	
5.1	Introduction	98
5.2	Fractal Designs	98
5.2.1	Classes of Fractals	101
5.2.2	Fractal Dimensions	102
5.2.2.1	Similarity Dimension	102
5.3	Iterative Function System	103
5.4	Advantages and Limitations of Fractal Geometry in Antennas	104
5.5	Compact Printed Multiband Fractal Antenna: Novel Design Approach	105

5.5.1	Parametric Analysis	107
5.5.2	Results and Discussion	109
5.6	Conclusion	121
	References	122
6	Applications of Metasurfaces for Modern Planar Antenna Design	125
	<i>V. Bharathi, Parthasarathy Ramanujam and Krishnamurthy Ramanujam</i>	
6.1	Metasurfaces – Introduction and Characteristics Relationship	126
6.1.1	Double Positive Materials (DPS) ($\epsilon > 0$ and $\mu > 0$)	127
6.1.2	Epsilon Negative Materials (ENG) ($\epsilon < 0$ and $\mu > 0$)	128
6.1.3	Mu-Negative Material (MNG) ($\epsilon > 0$ and $\mu < 0$)	128
6.1.4	Double Negative Materials (DNG) ($\epsilon < 0$ and $\mu < 0$)	129
6.1.5	Applications	130
6.2	Characteristics Mode Analysis (CMA)	130
6.2.1	CMA for Impedance Bandwidth Enhancement	132
6.2.2	CM-Based Circular Polarization	133
6.2.3	CM-Based MIMO Systems	134
6.2.4	CM-Based Radiation Pattern Optimization	134
6.2.5	CM-Based Solution to Scattering Problems	135
6.2.6	CM-Based Solution to Electromagnetic Coupling Problems	136
6.3	Realization and Evaluations of MS-Based Antenna Models	137
6.4	Frequency Selective Surfaces and Its Types	139
6.4.1	Operating Principle of FSS	139
6.4.2	Equivalent Circuit of Conventional FSS	140
6.4.3	Types of FSS	141
	6.4.3.1 Basic Shapes	142
	6.4.3.2 Convoluted FSS	142
	6.4.3.3 Fractal Geometry	143
6.5	Relationship Between Mutual Coupling Reduction and FSS Superstrate in CP-MIMO Antennas	144
6.6	Conclusion	146
	References	147
7	A Review on Electromagnetic Metamaterial Absorbers and Its Application	151
	<i>Surender Singh Bisht, Amit Kumar and Dharmendra K. Jhariya</i>	
7.1	Introduction	152

7.1.1	Communication Band	153
7.1.2	Classification of Metamaterial	153
7.2	Types of Electromagnetic Metamaterial Wave Absorbers	156
7.2.1	Resonant Absorbers	156
7.2.2	Broadband Absorbers	157
7.3	Type of Metamaterial	158
7.3.1	Electromagnetic Metamaterial	158
7.3.2	Refractive Index with a Negative Value	158
7.3.3	Various Categories of Electromagnetic Metamaterials	159
7.3.3.1	Metamaterials with a Single Negative Charge	159
7.3.3.2	Metamaterials with Electromagnetic Bandgaps	160
7.3.3.3	Medium with Double Positivity	160
7.3.3.4	Metamaterials with Bi-Isotropic and Bi-Isotropic Properties	160
7.3.3.5	Chiral Metamaterials	160
7.3.4	Split-Ring Resonators	160
7.3.5	Terahertz Metamaterial	161
7.3.6	Photonic Metamaterials	161
7.3.7	Nonlinear Metamaterials	161
7.3.8	Metamaterials Absorber	161
7.3.9	Frequency Selective Surfaces (FSS) Metamaterials	161
7.4	The Metamaterial (MTM) Absorbers Theory	162
7.4.1	Theory of Impedance Matching	162
7.4.2	Electrical and Magnetic Resonance	162
7.4.3	Theory of Interference	163
7.4.4	A Reduction in Plasma Frequency	164
7.4.5	Working of Electromagnetic Absorbers	164
7.5	Different Approaches for Analysis of Microwave Absorption	165
7.5.1	Methodology for Open Circuit	165
7.5.2	Methodology for Short Circuits	166
7.5.3	Impedance Matching	167
7.6	Narrowband Metamaterial Absorbers	167
7.6.1	Broadband Metamaterial Absorbers	168
7.7	Electromagnetic Metamaterial Design Consideration	169
7.7.1	Design Criteria and Their Limitations	169
7.7.2	Dielectric Characteristics of the Substrate	170
7.7.3	Polarization Angle and Oblique Angle	171
7.7.4	Frequency of Resonance	171
7.7.5	Substrate Dimensions	171
7.7.6	Design of Patches	172

7.8	Applications of Electromagnetic Metamaterial Absorbers Are Classified on Frequency Range	172
7.8.1	Microwave Absorber	172
7.8.2	Terahertz Wave Absorber	173
7.8.3	Millimeter Wave Absorber	173
7.9	Applications and Research Area of Electromagnetic Metamaterial Absorber	174
7.9.1	Machine Learning	175
7.9.2	Stealth Technology	175
7.9.3	Solar Absorber	175
7.9.4	Radome	176
7.9.5	Radio Frequency Energy Harvesting	178
7.9.6	Wireless Communications	179
7.9.7	Bolometer Devices	180
7.9.8	EM Compatibility Devices and EMI Shielding	180
7.9.9	Biomedical Sensors	182
7.9.10	Aeronautics and Defense	183
7.9.11	Imaging	184
7.9.12	Microwave Components	186
7.10	Advancements in Metamaterials in Recent Times	186
7.11	Conclusion and Prospects for the Future	187
	References	188
8	RF-Based Wearable PPG Sensor for Real-Time Cardiovascular Health Monitoring	197
	<i>Mohammed Arshad Ali Khan and Geetha Chakaravarthi</i>	
8.1	Introduction	198
8.2	Motivation	199
8.3	The Fundamental of Photoplethysmography	201
8.3.1	PPG Basic Working Principle	202
8.3.2	Relative Positioning of PPG Sensor	203
8.3.3	The Beer-Lambert Law in PPG	203
8.3.4	Application of PPG	204
8.4	RF-Based Wearable Sensors and Applications in Healthcare Monitoring	205
8.4.1	Requirement of Energy Harvesting Module	207
8.4.2	Different Energy Harvesting Sources	208
8.5	Methodology	209
8.5.1	Development of Energy Harvesting Rectification Module	209

8.5.1.1	Design of Antenna	210
8.5.1.2	Comprehensive Analysis of RF Circuit Characteristics Using Keysight ADS	210
8.5.2	Design and Implementation of PPG Sensor	212
8.5.2.1	Signal Processing Circuit	212
8.6	Experimental Setup of EH Module Integrated with PPG Sensor	213
8.7	Data Analysis	214
8.7.1	Calculation of Heart Rate	214
8.7.2	Calculation of SpO_2	214
8.8	Impact of Wearable Sensors in the Market	216
8.9	Conclusion and Future Scope	218
	References	218
Index		223