Table of Contents

Introduction xi

Chapter 1. General Information About Printed Antennas 1
Jean-Marc LAHEURTE

1.1. Physical characteristics 1
1.2. Properties, limitations, and applications 4
1.3. Printed rectangular antenna viewed as a wide microstrip line 7
1.4. Manufacturing processes 8
1.5. Microwave substrates 11

Chapter 2. Transmission Line Model 15
Jean-Marc LAHEURTE

2.1. Introduction 15
2.2. Equivalent circuit 16
2.2.1. Effective permittivity 16
2.2.2. Equivalent line extension 16
2.2.3. End of line equivalent circuit 17
2.2.4. Process for design of a rectangular antenna 19
2.2.5. Example 20
2.3. Input impedance 20

Chapter 3. Cavity Model 25
Jean-Marc LAHEURTE

3.1. Introduction 25
3.2. Formulation of the electromagnetic problem 25
3.3. Calculation of expressions for fields and currents of a rectangular patch 29

3.4. Expressions for principal modes 31
3.5. Cartography of modal currents and associated radiation patterns 33

Chapter 4. Radiation of a Printed Antenna 39
Jean-Marc LAHEURTE

4.1. Introduction 39
4.2. Modelization using two equivalent radiating slots 40
4.3. Calculation of the field radiated by a horizontal radiating slot 43
4.4. Calculation of the field radiated by the rectangular patch 44
4.5. Determination of the radiation pattern in the principal planes 44
4.6. Influence of height 46
4.7. Influence of the ground plane 47
4.8. Polarization 48
4.9. Directivity 49
4.10. Influence of the substrate on resonant frequency: parametric study based on antenna RCS 51

Chapter 5. Electrical Equivalent Circuit of a Printed Antenna 55
Jean-Marc LAHEURTE

5.1. Energy considerations 55
5.2. Equivalent circuit 57
5.3. Determination of W_E, W_M, and B for a rectangular patch 58
5.4. Modeling using a tank circuit 60
5.5. Quality factor of an antenna 62
5.6. Calculation of radiation quality factor 63
5.7. Calculation of efficiency 64
5.7.1. Losses in conductive walls 64
5.7.2. Losses in the dielectric 65
5.7.3. Radiated power 66
5.8. Influence of surface waves on bandwidth and efficiency 67

Chapter 6. Feeding Circuits for Microstrip Antennas 69
Jean-Marc LAHEURTE and Benoît POUSSOT

6.1. Introduction 69
6.2. Direct coupling by coaxial probe 71
6.3. Excitation by proximity coupling 73
6.4. Excitation by slot coupling 74

Chapter 7. Circularly Polarized Antennas 89
Jean-Marc LAHEURTE, Marjorie GRZESKOWIAK and Stéphane PROTAT

7.1. Principles of circular polarization 90
7.1.1. Elliptical and circular linear polarization 90
7.1.2. Right- or left-hand circular polarization 91
7.1.3. Axial and cross-polarization ratios 92
7.1.4. Measurement of circular polarization 93
7.2. Parasitic radiation – degradation of circular polarization 94
7.3. Patch fed by single or dual excitation 96
7.3.1. Single excitation 96
7.3.2. Dual excitation 98
7.4. Sequential array 99
7.4.1. Principle of sequential rotation: initial analysis 99
7.4.2. Sequential rotation applied to a radiating element fed by multiple feeds 106
7.5. Spiral and quadrifilar helix antennas 108
7.5.1. Spiral antennas 108
7.5.2. Quadrifilar helix antennas 113
7.6. Conclusion 119

Chapter 8. Wideband Antennas 121
Xavier BEGAUD

8.1. Multiresonant antennas 122
8.1.1. Principle 122
8.1.2. Widening bandwidth through resonance coupling 122
8.2. Traveling wave antennas 125
8.2.1. Tapered slot antennas 125
8.3. Frequency independent antennas 126
8.3.1. Introduction 126
8.3.2. Equiangular antennas 127
8.3.3. Log-periodic antennas 128
8.3.4. Sinuous antennas 129
8.4. Ultra-wideband antennas 132
8.4.1. Biconical and Bow-Tie antennas 134
8.4.2. Planar monopoles 137
8.5. Conclusion 140

Chapter 9. Miniature Antennas 143
Guillaume VILLEMAUD

9.1. Introduction 143
9.2. Which types of antennas should be used for integration? 144
9.2.1. Non-resonant antennas 144

9.2.2. Resonant antennas 145
9.3. Integration limits in a finite volume 145
9.4. Resonant antennas in fundamental mode 146
9.4.1. General considerations 146
9.4.2. Wire antennas 148
9.4.3. Planar antennas 150
9.4.4. Comparison 152
9.4.5. 3D antennas 152
9.5. Bulk reduction techniques 152
9.5.1. Use of dielectrics with strong permittivity 153
9.5.2. Modification of wave path 153
9.5.3. Utilization of inductive, capacitive, and short-circuit effects 156
9.5.4. Control over radiation 160
9.6. Multiresonant antennas 164
9.7. Synthesis and discussion 166

Chapter 10. Reconfigurable Antennas 169
Jean-Marc LAHEURTE

10.1. Introduction 169
10.2. Basic topologies and constraints 170
10.3. Switched components: available technologies 174
10.4. Frequency reconfigurable antennas (FRAs) 180
10.4.1. Introduction 180
10.4.2. Examples of radiating slot-based FRA 181
10.4.3. Examples of patch- or PIFA-based FRA integrating switchable slots 184
10.4.4. Examples of FRA using switched short circuits 184
10.4.5. FRA utilizing a loaded stub 185
10.5. Introduction to RAs in terms of polarization and radiation pattern 185
10.6. Polarized reconfigurable antennas (PRAs) 187
10.7. Radiation pattern reconfigurable antennas (RPRAs) 190
10.7.1. RPRA with rotational symmetry and switched parasitics 192
10.7.2. RPRA with parasitic elements loaded using switched reactance 193
10.7.3. Unit cell of reflective array based on a patch of slots [CAD 05] 202

Chapter 11. Introduction to Antenna Diversity 205
Lionel RUDANT

11.1. Benefits of antenna diversity 205
11.1.1. Effects of multipath propagation 206

11.1.2. Principles of antenna diversity 207
11.1.3. Non-ideal antenna diversity 211
11.2. Performance of multiantenna systems 214
11.2.1. Antenna balance 214
11.2.2. Antenna independence 216
11.3. Multiantenna systems 222
11.3.1. Space diversity 222
11.3.2. Compact multiantenna system 224
11.4. Conclusion and looking toward MIMO 228

Bibliography 233

List of Authors 241

Index 243