

# Table of Contents

<b>Introduction</b> . . . . .	xii
<b>Chapter 1. General Information About Printed Antennas</b> . . . . .	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
<b>Chapter 2. Transmission Line Model</b> . . . . .	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
<b>Chapter 3. Cavity Model</b> . . . . .	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

## Compact Antennas for Wireless Communications & Terminals

3.4. Expressions for principal modes . . . . .	31
3.5. Cartography of modal currents and associated radiation patterns . . . . .	33
<b>Chapter 4. Radiation of a Printed Antenna . . . . .</b>	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
<b>Chapter 5. Electrical Equivalent Circuit of a Printed Antenna . . . . .</b>	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
<b>Chapter 6. Feeding Circuits for Microstrip Antennas . . . . .</b>	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

<b>Chapter 7. Circularly Polarized Antennas . . . . .</b>	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
<b>Chapter 8. Wideband Antennas . . . . .</b>	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
<b>Chapter 9. Miniature Antennas . . . . .</b>	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
<b>Chapter 10. Reconfigurable Antennas . . . . .</b>	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
<b>Chapter 11. Introduction to Antenna Diversity . . . . .</b>	205
Lionel RUDANT	
11.1. Benefits of antenna diversity . . . . .	205
11.1.1. Effects of multipath propagation . . . . .	206

## Table of Contents

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
 <b>Bibliography</b> . . . . .	233
 <b>List of Authors</b> . . . . .	241
 <b>Index</b> . . . . .	243