Contents

Preface		xiii
1 Antennas		1
1.1	Introduction	1
1.2	Types of Antennas	4
1.3	Radiation Mechanism	7
1.4	Current Distribution on a Thin Wire Antenna	17
1.5	Historical Advancement	20
1.6	Multimedia	24
	References	24
2 Fundamental Parameters of Antennas		27
2.1	Introduction	27
2.2	Radiation Pattern	27
2.3	Radiation Power Density	38
2.4	Radiation Intensity	40
2.5	Beamwidth	42
2.6	Directivity	44
2.7	Numerical Techniques	58
2.8	Antenna Efficiency	64
2.9	Gain	65
2.10	Beam Efficiency	69
2.11	Bandwidth	70
2.12	Polarization	70
2.13	Input Impedance	80
2.14	Antenna Radiation Efficiency	85
2.15	Antenna Vector Effective Length and Equivalent Areas	87
2.16	Maximum Directivity and Maximum Effective Area	92
2.17	Friis Transmission Equation and Radar Range Equation	94
2.18	Antenna Temperature	104
2.19	Multimedia	108
	References	112
	Problems	114

3 Radiation Integrals and Auxiliary Potential Functions **133**

3.1 Introduction 133
3.2 The Vector Potential A for an Electric Current Source J 135
3.3 The Vector Potential F for a Magnetic Current Source M 137
3.4 Electric and Magnetic Fields for Electric (J) and Magnetic (M) Current Sources 138
3.5 Solution of the Inhomogeneous Vector Potential Wave Equation 139
3.6 Far-Field Radiation 142
3.7 Duality Theorem 144
3.8 Reciprocity and Reaction Theorems 144
References 150
Problems 150

4 Linear Wire Antennas **151**

4.1 Introduction 151
4.2 Infinitesimal Dipole 151
4.3 Small Dipole 162
4.4 Region Separation 165
4.5 Finite Length Dipole 170
4.6 Half-Wavelength Dipole 182
4.7 Linear Elements Near or on Infinite Perfect Conductors 184
4.8 Ground Effects 205
4.9 Computer Codes 214
4.10 Multimedia 217
References 218
Problems 219

5 Loop Antennas **231**

5.1 Introduction 231
5.2 Small Circular Loop 232
5.3 Circular Loop of Constant Current 246
5.4 Circular Loop with Nonuniform Current 255
5.5 Ground and Earth Curvature Effects for Circular Loops 261
5.6 Polygonal Loop Antennas 263
5.7 Ferrite Loop 266
5.8 Mobile Communication Systems Applications 268
5.9 Multimedia 269
References 273
Problems 275

6 Arrays: Linear, Planar, and Circular **283**

6.1 Introduction 283
6.2 Two-Element Array 284
6.3 *N*-Element Linear Array: Uniform Amplitude and Spacing 290
6.4 *N*-Element Linear Array: Directivity 313

6.5 Design Procedure 318
6.6 *N*-Element Linear Array: Three-Dimensional Characteristics 320
6.7 Rectangular-to-Polar Graphical Solution 322
6.8 *N*-Element Linear Array: Uniform Spacing, Nonuniform Amplitude 324
6.9 Superdirectivity 345
6.10 Planar Array 349
6.11 Design Considerations 362
6.12 Circular Array 365
6.13 Multimedia 369
References 370
Problems 371

7 Antenna Synthesis and Continuous Sources **385**

7.1 Introduction 385
7.2 Continuous Sources 386
7.3 Schelkunoff Polynomial Method 388
7.4 Fourier Transform Method 393
7.5 Woodward-Lawson Method 399
7.6 Taylor Line-Source (Tschebyscheff-Error) 406
7.7 Taylor Line-Source (One-Parameter) 410
7.8 Triangular, Cosine, and Cosine-Squared Amplitude Distributions 417
7.9 Line-Source Phase Distributions 418
7.10 Continuous Aperture Sources 419
7.11 Multimedia 423
References 423
Problems 424

8 Integral Equations, Moment Method, and Self and Mutual Impedances **433**

8.1 Introduction 433
8.2 Integral Equation Method 434
8.3 Finite Diameter Wires 442
8.4 Moment Method Solution 450
8.5 Self-Impedance 458
8.6 Mutual Impedance Between Linear Elements 468
8.7 Mutual Coupling in Arrays 478
8.8 Multimedia 491
References 491
Problems 494

9 Broadband Dipoles and Matching Techniques **497**

9.1 Introduction 497
9.2 Biconical Antenna 500
9.3 Triangular Sheet, Bow-Tie, and Wire Simulation 506
9.4 Cylindrical Dipole 508

9.5 Folded Dipole 515
9.6 Discone and Conical Skirt Monopole 521
9.7 Matching Techniques 523
9.8 Multimedia 541
References 542
Problems 543

10 Traveling Wave and Broadband Antennas 549

10.1 Introduction 549
10.2 Traveling Wave Antennas 549
10.3 Broadband Antennas 566
10.4 Multimedia 600
References 600
Problems 602

11 Frequency Independent Antennas, Antenna Miniaturization, and Fractal Antennas 611

11.1 Introduction 611
11.2 Theory 612
11.3 Equiangular Spiral Antennas 614
11.4 Log-Periodic Antennas 619
11.5 Fundamental Limits of Electrically Small Antennas 637
11.6 Fractal Antennas 641
11.7 Multimedia 648
References 648
Problems 650

12 Aperture Antennas 653

12.1 Introduction 653
12.2 Field Equivalence Principle: Huygens' Principle 653
12.3 Radiation Equations 660
12.4 Directivity 662
12.5 Rectangular Apertures 663
12.6 Circular Apertures 683
12.7 Design Considerations 692
12.8 Babinet's Principle 697
12.9 Fourier Transforms in Aperture Antenna Theory 701
12.10 Ground Plane Edge Effects: The Geometrical Theory of Diffraction 721
12.11 Multimedia 726
References 726
Problems 728

13 Horn Antennas 739

13.1 Introduction 739
13.2 *E*-Plane Sectoral Horn 739

13.3 *H*-Plane Sectoral Horn 755
13.4 Pyramidal Horn 769
13.5 Conical Horn 783
13.6 Corrugated Horn 785
13.7 Aperture-Matched Horns 792
13.8 Multimode Horns 794
13.9 Dielectric-Loaded Horns 797
13.10 Phase Center 799
13.11 Multimedia 802
References 802
Problems 805

14 Microstrip Antennas 811

14.1 Introduction 811
14.2 Rectangular Patch 816
14.3 Circular Patch 843
14.4 Quality Factor, Bandwidth, and Efficiency 852
14.5 Input Impedance 855
14.6 Coupling 856
14.7 Circular Polarization 859
14.8 Arrays and Feed Networks 865
14.9 Multimedia 872
References 872
Problems 876

15 Reflector Antennas 883

15.1 Introduction 883
15.2 Plane Reflector 883
15.3 Corner Reflector 884
15.4 Parabolic Reflector 893
15.5 Spherical Reflector 934
15.6 Multimedia 936
References 937
Problems 939

16 Smart Antennas 945

16.1 Introduction 945
16.2 Smart-Antenna Analogy 946
16.3 Cellular Radio Systems Evolution 947
16.4 Signal Propagation 954
16.5 Smart Antennas' Benefits 957
16.6 Smart Antennas' Drawbacks 958
16.7 Antenna 958
16.8 Antenna Beamforming 962
16.9 Mobile Ad hoc Networks (MANETs) 977
16.10 Smart-Antenna System Design, Simulation, and Results 982

16.11	Beamforming, Diversity Combining, Rayleigh-Fading, and Trellis-Coded Modulation	990
16.12	Other Geometries	993
16.13	Multimedia	994
	References	995
	Problems	999
17	**Antenna Measurements**	**1001**
17.1	Introduction	1001
17.2	Antenna Ranges	1003
17.3	Radiation Patterns	1021
17.4	Gain Measurements	1028
17.5	Directivity Measurements	1034
17.6	Radiation Efficiency	1036
17.7	Impedance Measurements	1036
17.8	Current Measurements	1038
17.9	Polarization Measurements	1038
17.10	Scale Model Measurements	1044
	References	1045
Appendix I:	$f(x) = \dfrac{\sin(x)}{x}$	**1049**
Appendix II:	$f_N(x) = \left\lvert \dfrac{\sin(Nx)}{N\sin(x)} \right\rvert N = 1, 3, 5, 10, 20$	**1051**
Appendix III:	**Cosine and Sine Integrals**	**1053**
Appendix IV:	**Fresnel Integrals**	**1057**
Appendix V:	**Bessel Functions**	**1063**
Appendix VI:	**Identities**	**1075**
Appendix VII:	**Vector Analysis**	**1079**
Appendix VIII:	**Method of Stationary Phase**	**1089**
Appendix IX:	**Television, Radio, Telephone, and Radar Frequency Spectrums**	**1095**
Index		**1099**