
Contents

Preface to the First Edition	xv
Preface to the Second Edition	xvii
1 Introduction	1
1.1 Array Background	1
1.2 Systems Factors	2
1.3 Annotated Reference Sources	3
1.3.1 Adaptive Antenna Reference Books	5
References	5
2 Basic Array Characteristics	7
2.1 Uniformly Excited Linear Arrays	7
2.1.1 Patterns	7
2.1.2 Beamwidth	9
2.1.3 Sidelobes	11
2.1.4 Grating Lobes	11
2.1.5 Bandwidth	15
2.2 Planar Arrays	17
2.2.1 Array Coordinates	17
2.2.2 Beamwidth	18
2.2.3 Grating Lobes: Rectangular Lattice	21
2.2.4 Grating Lobes: Hexagonal Lattice	23
2.3 Beam Steering and Quantization Lobes	25
2.3.1 Steering Increment	25
2.3.2 Steering Bandwidth	26
2.3.3 Time Delay Deployment	27

2.3.4 Phaser Quantization Lobes	28	4 Planar and Circular Array Pattern Synthesis	109
2.3.5 Sub-array Quantization Lobes	32	4.1 Circular Planar Arrays	109
2.3.6 QL Decollimation: Overlapped Sub-arrays	35	4.1.1 Flat Plane Slot Arrays	109
2.4 Directivity	36	4.1.2 Hansen One-Parameter Pattern	110
2.4.1 Linear Array Directivity	36	4.1.3 Taylor Circular \tilde{n} Pattern	114
2.4.2 Directivity of Arrays of Short Dipoles	39	4.1.4 Circular Bayliss Difference Pattern	118
2.4.3 Directivity of Arrays of Resonant Elements	40	4.1.5 Difference Pattern Optimization	123
2.4.4 Planar Array Directivity	42	4.2 Noncircular Apertures	125
References	46	4.2.1 Two-Dimensional Optimization	125
3 Linear Array Pattern Synthesis	49	4.2.2 Ring Sidelobe Synthesis	126
3.1 Introduction	49	Acknowledgment	127
3.1.1 Pattern Formulations	49	References	127
3.1.2 Physics versus Mathematics	51	5 Array Elements	129
3.1.3 Taylor Narrow-Beam Design Principles	52	5.1 Dipoles	129
3.2 Dolph–Chebyshev Arrays	53	5.1.1 Thin Dipoles	129
3.2.1 Half-Wave Spacing	53	5.1.2 Bow-Tie and Open-Sleeve Dipoles	136
3.2.2 Spacing Less Than Half-Wave	59	5.2 Waveguide Slots	139
3.3 Taylor One-Parameter Distribution	60	5.2.1 Broad Wall Longitudinal Slots	140
3.3.1 One-Parameter Design	60	5.2.2 Edge Slots	145
3.3.2 Bickmore–Spellmire	65	5.2.3 stripline Slots	147
Two-Parameter Distribution	65	5.2.4 Open-End Waveguides	147
3.4 Taylor N -Bar Aperture Distribution	66	5.2.5 Substrate Integrated Waveguide	148
3.5 Low-Sidelobe Distributions	72	5.3 TEM Horns	149
3.5.1 Comparison of Distributions	72	5.3.1 Development of TEM Horns	149
3.5.2 Average Sidelobe Level	75	5.3.2 Analysis and Design of Horns	151
3.6 Villeneuve N -Bar Array Distribution	76	5.3.3 TEM Horn Arrays	152
3.7 Difference Patterns	79	5.3.4 Millimeter Wave Antennas	153
3.7.1 Canonical Patterns	79	5.4 Microstrip Patches and Dipoles	154
3.7.2 Bayliss Patterns	81	5.4.1 Transmission Line Model	157
3.7.3 Sum and Difference Optimization	85	5.4.2 Cavity and Other Models	159
3.7.4 Discrete Zolotarev Distributions	87	5.4.3 Parasitic Patch Antennas	159
3.8 Sidelobe Envelope Shaping	89	5.4.4 Balanced-Fed Patches	163
3.9 Shaped Beam Synthesis	92	Acknowledgments	163
3.9.1 Woodward–Lawson Synthesis	92	References	163
3.9.2 Elliott Synthesis	94	6 Array Feeds	171
3.10 Thinned Arrays	98	6.1 Series Feeds	171
3.10.1 Probabilistic Design	98	6.1.1 Resonant Arrays	171
3.10.2 Space Tapering	102	6.1.1.1 Impedance and Bandwidth	171
3.10.3 Minimum Redundancy Arrays	103	6.1.1.2 Resonant Slot Array Design	176
Acknowledgment	104		
References	104		

6.1.2 Traveling Wave Arrays	178	7.3 Spatial Domain Approaches to Mutual Coupling	235
6.1.2.1 <i>Frequency Squint and Single-Beam Condition</i>	178	7.3.1 Canonical Couplings	235
6.1.2.2 <i>Calculation of Element Conductance</i>	181	7.3.1.1 <i>Dipole and Slot Mutual Impedance</i>	235
6.1.2.3 <i>TW Slot Array Design</i>	185	7.3.1.2 <i>Microstrip Patch Mutual Impedance</i>	239
6.1.3 Frequency Scanning	188	7.3.1.3 <i>Horn Mutual Impedance</i>	241
6.1.4 Phaser Scanning	193	7.3.2 Impedance Matrix Solution	242
6.2 Shunt (Parallel) Feeds	194	7.3.3 The Grating Lobe Series	244
6.2.1 Corporate Feeds	194	7.4 Spectral Domain Approaches	246
6.2.2 Distributed Arrays	196	7.4.1 Dipoles and Slots	246
6.3 Two-Dimensional Feeds	197	7.4.2 Microstrip Patches	258
6.3.1 Fixed-Beam Arrays	197	7.4.3 Printed Dipoles	261
6.3.2 Sequential Excitation Arrays	199	7.4.4 Printed TEM Horns	262
6.3.3 Electronic Scan in One Plane	199	7.4.5 Unit Cell Simulators	266
6.3.4 Electronic Scan in Two Planes	201	7.5 Scan Compensation and Blind Angles	266
6.4 Photonic Feed Systems	207	7.5.1 Blind Angles	266
6.4.1 Fiber Optic Delay Feeds	207	7.5.2 Scan Compensation	269
6.4.1.1 <i>Binary Delay Lines</i>	207	7.5.2.1 <i>Coupling Reduction</i>	269
6.4.1.2 <i>Acousto-Optical Switched Delay</i>	209	7.5.2.2 <i>Compensating Feed Networks</i>	269
6.4.1.3 <i>Modulators and Photodetectors</i>	210	7.5.2.3 <i>Multimode Elements</i>	272
6.4.2 Wavelength Division Fiber Delay	211	7.5.2.4 <i>External Wave Filter</i>	276
6.4.2.1 <i>Dispersive Fiber Delay</i>	211	Acknowledgment	276
6.4.2.2 <i>Bragg Fiber Grating Delay</i>	212	References	277
6.4.2.3 <i>Traveling Wave Fiber Delay</i>	212	8 Finite Arrays	285
6.4.3 Optical Delay	213	8.1 Methods of Analysis	285
6.4.4 Optical Fourier Transform	213	8.1.1 Overview	285
6.5 Systematic Errors	214	8.1.2 Finite-by-Infinite Arrays	289
6.5.1 Parallel Phasers	214	8.2 Scan Performance of Small Arrays	293
6.5.2 Series Phasers	215	8.3 Finite-by-Infinite Array Gibbsian Model	300
6.5.3 Systematic Error Compensation	216	8.3.1 Salient Scan Impedance Characteristics	300
Acknowledgments	216	8.3.2 A Gibbsian Model for Finite Arrays	310
References	216	References	313
7 Mutual Coupling	221	9 Superdirective Arrays	317
7.1 Introduction	221	9.1 Historical Notes	317
7.2 Fundamentals of Scanning Arrays	221	9.2 Maximum Array Directivity	318
7.2.1 Current Sheet Model	221	9.2.1 Broadside Directivity for Fixed Spacing	318
7.2.2 Free and Forced Excitations	223	9.2.2 Directivity as Spacing Approaches Zero	320
7.2.3 Scan Impedance and Scan Element Pattern	225	9.2.3 Endfire Directivity	321
7.2.3.1 <i>Transmit versus Receive SEP</i>	228	9.2.4 Bandwidth, Efficiency,	
7.2.3.2 <i>Measurement of Scan Impedance</i>	233	and Tolerances	322
7.2.4 Minimum Scattering Antennas	233		

9.3	Constrained Optimization	330	11	Conformal Arrays	399
9.3.1	Dolph–Chebyshev Superdirective	330	11.1	Scope	399
9.3.2	Constraint on Q or Tolerances	336	11.2	Ring Arrays	400
9.4	Matching of Superdirective Arrays	338	11.2.1	Continuous Ring Antenna	400
9.4.1	Network Loss Magnification	338	11.2.2	Discrete Ring Array	403
9.4.2	HTS Arrays	340	11.2.3	Beam Cophasal Excitation	407
	References	340	11.3	Arrays on Cylinders	411
10	Multiple-Beam Antennas	343	11.3.1	Slot Patterns	411
10.1	Introduction	343	11.3.2	Array Pattern	412
10.2	Beamformers	343	11.3.2.1	<i>Grating Lobes</i>	416
10.2.1	Networks	344	11.3.2.2	<i>Principal Sidelobes</i>	419
10.2.1.1	<i>Power Divider BFN</i>	344	11.3.2.3	<i>Cylindrical Depolarization</i>	421
10.2.1.2	<i>Butler Matrix</i>	344	11.3.3	Slot Mutual Admittance	422
10.2.1.3	<i>Blass and Nolen Matrices</i>	348	11.3.3.1	<i>Modal Series</i>	426
10.2.1.4	<i>The 2D BFN</i>	350	11.3.3.2	<i>Admittance Data</i>	430
10.2.1.5	<i>McFarland 2D Matrix</i>	350	11.3.4	Scan Element Pattern	430
10.2.2	Lenses	351	11.4	Sector Arrays on Cylinders	434
10.2.2.1	<i>Rotman Lens BFN</i>	351	11.4.1	Patterns and Directivity	434
10.2.2.2	<i>Bootlace Lenses</i>	368	11.4.2	Comparison of Planar and Sector Arrays	437
10.2.2.3	<i>Dome Lenses</i>	372	11.4.3	Ring and Cylindrical Array Hardware	441
10.2.2.4	<i>Other Lenses</i>	374	11.5	Arrays on Cones and Spheres	442
10.2.3	Digital Beamforming	377	11.5.1	Conical Arrays	443
10.3	Low Sidelobes and Beam Interpolation	378	11.5.1.1	<i>Lattices on a Cone</i>	444
10.3.1	Low-Sidelobe Techniques	378	11.5.1.2	<i>Conical Depolarization and Coordinate Systems</i>	447
10.3.1.1	<i>Interlaced Beams</i>	378	11.5.1.3	<i>Projective Synthesis</i>	455
10.3.1.2	<i>Resistive Tapering</i>	379	11.5.1.4	<i>Patterns and Mutual Coupling</i>	455
10.3.1.3	<i>Lower Sidelobes via Lossy Networks</i>	379	11.5.1.5	<i>Conical Array Experiments</i>	456
10.3.1.4	<i>Beam Superposition</i>	381	11.5.2	Spherical Arrays	457
10.3.2	Beam Interpolation Circuits	383	Acknowledgments		458
10.4	Beam Orthogonality	385	References		458
10.4.1	Orthogonal Beams	385	12	Connected Arrays	465
10.4.1.1	<i>Meaning of Orthogonality</i>	385	12.1	History of Connected Arrays	465
10.4.1.2	<i>Orthogonality of Distributions</i>	386	12.2	Connected Array Principles	466
10.4.1.3	<i>Orthogonality of Arrays</i>	388	12.3	Connected Dipole Currents	467
10.4.2	Effects of Nonorthogonality	389	12.3.1	Simulation Results: Current Phases	467
10.4.2.1	<i>Efficiency Loss</i>	389	12.3.2	Simulation Results: Current Amplitudes	468
10.4.2.2	<i>Sidelobe Changes</i>	390	12.3.3	Simulation Results: SEP	474
	Acknowledgments	393	12.4	Connection by Reactance	474
	References	393			

12.5 Connected Array Extensions	476
References	476
13 Reflectarrays and Retrodirective Arrays	479
13.1 Reflectarrays	479
13.1.1 History of Reflectarrays	479
13.1.2 Geometric Design	480
13.1.3 Elements	481
13.1.4 Phasing of Elements	482
13.1.5 Bandwidth	484
13.1.6 Reflectarray Extensions	485
13.2 Retrodirective Arrays	486
13.2.1 History of Retrodirective Arrays	486
13.2.2 Recent Progress	487
13.2.3 Advanced Applications	491
References	491
14 Reflectors with Arrays	497
14.1 Focal Plane Arrays	497
14.1.1 Focal Plane Fields and Coma	497
14.1.2 Recovering Coma Scan Loss	502
14.1.3 Coma Correction Limitations	502
14.2 Near-Field Electromagnetic Optics	503
14.2.1 Near-Field Cassegrain	503
<i>14.2.1.1 System Trades and Restrictions</i>	507
14.2.2 Near-Field Gregorian	507
References	510
15 Measurements and Tolerances	513
15.1 Measurement of Low-Sidelobe Patterns	513
15.2 Array Diagnostics	516
15.3 Waveguide Simulators	518
15.4 Array Tolerances	524
15.4.1 Directivity Reduction and Average Sidelobe Level	524
15.4.2 Beam Pointing Error	526
15.4.3 Peak Sidelobes	527
Acknowledgment	529
References	529
Author Index	533
Subject Index	543