

Contents

Preface	IX
List of Main Symbols	XII
Abbreviations	XIV
Chapter 1. Introduction	1
1.1 Historical Survey	1
1.2 Adaptive Antenna Arrays	3
1.3 Adaptive Array Techniques for Sonar	4
1.4 Seismic Arrays	5
1.5 The Principle of the Adaptive Array	6
1.6 Adaptive Arrays—Tentative Classification	7
1.7 Narrowband and Broadband Adaptive Arrays	9
Chapter 2. Antenna Arrays	12
2.1 General	12
2.2 Antenna Arrays — Parameters and Features	12
2.3 Radiation Patterns	13
2.4 The Radiation Pattern of Uniform Arrays	14
2.5 Null Point Locations for Uniform Arrays	15
2.6 The Beamwidth of Uniform Arrays	16
2.7 Sidelobes of Uniform Arrays	17
2.8 Linear Equidistant Arrays and the z -Transform	18
2.9 Simple and Multiple Zeros for Linear Equidistant Arrays	19
2.10 Bandwidth Considerations for Linear Equidistant Arrays	20
2.11 Bandwidth of Simple and Double Nulls	21
2.12 Rectangular Arrays	23
Chapter 3. Retrodirective Arrays	25
3.1 General	25
3.2 Retrodirective Arrays — Redirective Arrays	25
3.3 Van Atta Retrodirective Arrays	27
3.4 Heterodyne Type Retrodirective Arrays	32
Chapter 4. Self-Cohering Antenna Arrays	36
4.1 General	36
4.2 Self-Cohering Arrays with Phase-Locked Loops	37
4.3 The Loop at Synchronism	38
4.4 Implementation Considerations	40
4.5 Self-Cohering Arrays with Phase Shifters	43
4.6 The Radio Camera Algorithm	44

Chapter 5. Sidelobe Cancellers	48
5.1 General	48
5.2 Single Sidelobe IF Canceller. The Classical Theory	49
5.3 SSLCs — Another Approach	53
5.4 Bandwidth Estimation for a SSLC	56
5.5 Multiple Sidelobe Cancellers	59
5.6 Sidelobe Cancellers — Open Loop Operation	62
Chapter 6. Theoretical Considerations Regarding the MSNR and LMS Algorithms	65
6.1 General	65
6.2 The MSNR Algorithm	65
6.3 The LMS Algorithm	71
6.4 The Covariance Matrix	73
6.5 The Covariance Matrix — Continuation	76
6.6 Optimal Weight Vector and SINR for MSNR and LMS Algorithms	77
6.7 The Radiation Pattern Behaviour	78
6.8 The Weight Vector Behaviour	80
6.9 The SINR — Performance Evaluation	80
6.10 The Power Inversion	82
6.11 The MSNR Algorithm. Effect of Beam Pointing Errors	83
6.12 Dynamic Range and Beam Pointing Errors for the MSNR Algorithm	86
6.13 The MSNR and LMS Algorithms vs Multiple Desired Signals	88
6.14 Eigenvalues and Eigenvectors of Covariance Matrices	91
6.15 SINR and Eigenvalues of the Covariance Matrix	93
6.16 The Effect of Jammer Bandwidth on the Array SINR	93
Chapter 7. The MSNR Algorithm — Implementation Considerations	97
7.1 General	97
7.2 Phase Conjugacy	97
7.3 Correlation Loops	98
7.4 Adaptive Arrays with Multiple Loops	104
7.5 Correlation Loops and the MSNR Algorithm	107
7.6 Ill-Conditioned Covariance Matrices	111
7.7 The Retrodirective Eigenvector Beam Concept	112
7.8 Bandwidth Effects	113
7.9 Hard Limitation in Correlation Loops	114
7.10 The Weight Jitter Phenomenon	116
7.11 Other Loop Arrangements	120
7.12 Digital Implementation Considerations	120
Chapter 8. The LMS Algorithm — Analogue Implementation Considerations	122
8.1 General	122
8.2 Analogue Implementation Background	122
8.3 The Transient Behaviour of an Analogue LMS Array	123
8.4 Artificial Noise in LMS Arrays	124
8.5 Effect of Pole Position on an LMS Array Performance	125
8.6 Effect of Multiplier Offset Voltages	126
8.7 Generation of the Reference Signal	128
8.8 Effect of Reference Signal Phase Shift	130
8.9 Effect of Differential Phase Delays	131
8.10 Bandwidth Considerations	132

Chapter 9. The LMS Algorithm; Gradient-Based Algorithms	135
9.1 General	135
9.2 The Steepest Descent Algorithm	135
9.3 The LMS Algorithm	138
9.4 The Improved LMS Algorithm	140
9.5 The MLMS Algorithm	141
9.6 The PAG Algorithm	143
9.7 A Recursive Method for Computing W_{opt}	145
9.8 Gradient Determination Using Weight Perturbations	146
9.9 The DSD Algorithm	147
9.10 Orthogonal Perturbation Sequences	148
9.11 MSLC Digital Implementation	150
9.12 Gradient-Based Algorithms Using Real Representation of Signals	151
Chapter 10. The SMI Algorithm	154
10.1 General	154
10.2 The Sample Covariance Matrix	154
10.3 Effect of Sample Covariance Matrix Use	156
10.4 Which Matrix to Sample: R or M ?	157
10.5 The Extended SMI Algorithm	159
10.6 Updating the Sample Covariance Matrix	159
10.7 Computational Load and Associated Problems	161
Chapter 11. Adaptation in the Beams Space and the Frequency Domain	164
11.1 General	164
11.2 Short Description of an MBA	164
11.3 Adaptive MBA Arrays	166
11.4 Adaptive Arrays for Satellite Communications	167
11.5 Adaptation in the Frequency Domain	169
Chapter 12. Adaptation in the Presence of Constraints	173
12.1 General	173
12.2 The One-Mode and Two-Mode Adaptations of the LMS Algorithm	173
12.3 The Pilot Signal Technique	175
12.4 Pre-adaptation Spatial Filters	176
12.5 Control Loop Spatial Filters	178
12.6 The Constrained LMS Algorithm	178
12.7 A First Alternative Approach to the Constrained LMS Algorithm	183
12.8 A Second Alternative Approach to the Constrained LMS Algorithm	185
12.9 Directional Constraints	187
12.10 Derivative Constraints	190
12.11 Quadratic Constraints	191
12.12 The Maximum Gain Algorithm	191
12.13 The Power Minimization Algorithm	193
12.14 The Power Optimization Algorithm	194
12.15 The Weight Vector Norm Upper Bound Constraint	195
12.16 The Only-in-Phase Adaptation	196
12.17 A Robust Adaptation Algorithm with Broadband Capabilities	198
12.18 Other Constrained Adaptation Algorithms	199
Chapter 13. Other Adaptation Algorithms	202
13.1 General	202
13.2 The PI Algorithm	202

13.3	The LRS Algorithm	204
13.4	The ARS Algorithm	205
13.5	The GARS Algorithm	205
13.6	An Improved Feedback Loop	206
13.7	The Signal Separation Algorithm	208
13.8	A Combined MSNR + LMS Algorithm	209
13.9	The Maximin Algorithm	210
13.10	The Kalman Filtering Algorithm	212
13.11	A Diagonalization Algorithm	216
Chapter 14.	Other Adaptation Techniques	219
14.1	Suboptimal Noise Suppression Before Beamforming	219
14.2	Suboptimal Processing Using Adaptive Subarrays	220
14.3	Nonadaptive Preprocessing	221
14.4	Adaptive Preprocessing — A First Approach	223
14.5	Adaptive Preprocessing — A Second Approach	226
14.6	Adaptive Preprocessing — A Third Approach	227
14.7	Adaptive Preprocessing — A Fourth Approach	230
14.8	Polarization — Sensitive Adaptive Arrays	231
14.9	Suboptimal Processing — Conventionally Combined Adaptive Subarrays	235
14.10	Suboptimal Processing — Partially Adaptive Arrays	236
14.11	Adaptive Nulling Using the Davies Beamformer	240
14.12	Reactively Controlled Adaptive Arrays	241
14.13	Optical Processing — Generalities	243
14.14	Background to COP Systems	245
14.15	Adaptive Array Using COP Systems — An Example	249
14.16	Background to IOP Systems	250
14.17	Adaptive Arrays — The Systolic IOP Approach	254
Chapter 15.	Some Applications of Adaptive Arrays	259
15.1	Superresolution Capabilities of Adaptive Arrays	259
15.2	The MEM Approach	260
15.3	The ML Approach	263
15.4	The Linear Prediction Method and Superresolution	264
15.5	Eigenvector Methods and Superresolution	266
15.6	Other Considerations Concerning Superresolution	267
15.7	Elevation Estimation Using Adaptive Arrays	270
Chapter 16.	Limitations of Adaptive Array Performances	274
16.1	Grating Nulls of Adaptive Arrays	274
16.2	The Required Precision for Adaptive Processing	276
16.3	Covariance Matrix Estimation Errors	277
16.4	Weight Quantization Errors	279
Appendix 1	281
Appendix 2	283
Appendix 3	284
Appendix 4	286
Appendix 5	287
Additional References	288
Subject Index	295