

Contents

Preface	xvii
Publisher Acknowledgments	xxiv
Editors and Contributors	xxvii
List of Acronyms	xxxii
List of Common Symbols	xxxiv

PART I Overview

1	Introduction and Radar Overview	3
1.1	Introduction	3
1.2	The Radar Concept	4
1.3	The Physics of EM Waves	5
1.4	Interaction of EM Waves with Matter	11
1.5	Basic Radar Configurations and Waveforms	18
1.6	Noise, Signal-to-Noise Ratio, and Detection	25
1.7	Basic Radar Measurements	27
1.8	Basic Radar Functions	33
1.9	Radar Applications	36
1.10	Organization of This Text	54
1.11	Further Reading	55
1.12	References	55
1.13	Problems	56

2	The Radar Range Equation	59
2.1	Introduction	59
2.2	Power Density at a Distance R	61
2.3	Received Power from a Target	62
2.4	Receiver Thermal Noise	64
2.5	Signal-to-Noise Ratio and the Radar Range Equation	66
2.6	Multiple-Pulse Effects	66
2.7	Summary of Losses	67
2.8	Solving for Other Variables	72

- 2.9 Decibel Form of the Radar Range Equation 72
- 2.10 Average Power Form of the Radar Range Equation 73
- 2.11 Pulse Compression: Intrapulse Modulation 74
- 2.12 A Graphical Example 75
- 2.13 Clutter as the Target 76
- 2.14 One-Way (Link) Equation 78
- 2.15 Search Form of the Radar Range Equation 79
- 2.16 Track Form of the Radar Range Equation 80
- 2.17 Some Implications of the Radar Range Equation 83
- 2.18 Further Reading 84
- 2.19 References 84
- 2.20 Problems 85

3 Radar Search and Overview of Detection in Interference 87

- 3.1 Introduction 87
- 3.2 Search Mode Fundamentals 89
- 3.3 Overview of Detection Fundamentals 95
- 3.4 Further Reading 111
- 3.5 References 111
- 3.6 Problems 112

PART II External Factors

- 4 Propagation Effects and Mechanisms 117
 - 4.1 Introduction 117
 - 4.2 Propagation Factor 118
 - 4.3 Propagation Paths and Regions 119
 - 4.4 Atmospheric Attenuation and Absorption 121
 - 4.5 Atmospheric Refraction 130
 - 4.6 Turbulence 137
 - 4.7 Exploiting the Ionosphere 138
 - 4.8 Diffraction 140
 - 4.9 Multipath 142
 - 4.10 Skin Depth and Penetration: Transmitting Through Walls 156
 - 4.11 Commercial Simulations 158
 - 4.12 Summary and Further Reading 160
 - 4.13 References 161
 - 4.14 Problems 163

5	Characteristics of Clutter	165
5.1	Introduction and Definitions	165
5.2	General Characteristics of Clutter	172
5.3	Clutter Modeling	202
5.4	Concluding Remarks	206
5.5	Further Reading	207
5.6	References	207
5.7	Problems	210
<hr/>		
6	Target Reflectivity	211
6.1	Introduction	211
6.2	Basic Reflection Physics	212
6.3	Radar Cross Section Definition	219
6.4	Three Scattering Regimes	224
6.5	High-Frequency Scattering	227
6.6	Examples	236
6.7	Further Reading	244
6.8	References	244
6.9	Problems	245
<hr/>		
7	Target Fluctuation Models	247
7.1	Introduction	247
7.2	Radar Cross Section of Simple Targets	248
7.3	Radar Cross Section of Complex Targets	251
7.4	Statistical Characteristics of the RCS of Complex Targets	253
7.5	Target Fluctuation Models	263
7.6	Doppler Spectrum of Fluctuating Targets	267
7.7	Further Reading	269
7.8	References	269
7.9	Problems	270
<hr/>		
8	Doppler Phenomenology and Data Acquisition	273
8.1	Introduction	273
8.2	Doppler Shift	274
8.3	The Fourier Transform	276
8.4	Spectrum of a Pulsed Radar Signal	277
8.5	Why Multiple Pulses?	286

8.6	Pulsed Radar Data Acquisition	287
8.7	Doppler Signal Model	291
8.8	Range-Doppler Spectrum for a Stationary Radar	293
8.9	Range-Doppler Spectrum for a Moving Radar	296
8.10	Further Reading	303
8.11	References	303
8.12	Problems	303

PART III **Subsystems**

9	Radar Antennas	309
9.1	Introduction	309
9.2	Basic Antenna Concepts	310
9.3	Aperture Tapers	314
9.4	Effect of the Antenna on Radar Performance	317
9.5	Monopulse	320
9.6	Reflector Antennas	322
9.7	Phased Array Antennas	326
9.8	Array Architectures	339
9.9	Further Reading	343
9.10	References	343
9.11	Problems	345
10	Radar Transmitters	347
10.1	Introduction	347
10.2	Transmitter Configurations	351
10.3	Power Sources and Amplifiers	356
10.4	Modulators	371
10.5	Power Supplies	373
10.6	Transmitter Impacts on the Electromagnetic Environment	375
10.7	Operational Considerations	381
10.8	Summary and Future Trends	384
10.9	Further Reading	385
10.10	References	385
10.11	Problems	388
11	Radar Receivers	391
11.1	Introduction	391
11.2	Summary of Receiver Types	392

11.3	Major Receiver Functions	396
11.4	Demodulation	400
11.5	Receiver Noise Power	404
11.6	Receiver Dynamic Range	406
11.7	Analog-to-Digital Data Conversion	409
11.8	Further Reading	414
11.9	References	414
11.10	Problems	415

12 Radar Exciters 417

12.1	Introduction	417
12.2	Exciter-Related Radar System Performance Issues	418
12.3	Exciter Design Considerations	429
12.4	Exciter Components	440
12.5	Timing and Control Circuits	452
12.6	Further Reading	454
12.7	References	454
12.8	Problems	455

13 The Radar Signal Processor 459

13.1	Introduction	459
13.2	Radar Processor Structure	460
13.3	Signal Processor Metrics	462
13.4	Counting FLOPs: Estimating Algorithm Computational Requirements	464
13.5	Implementation Technology	472
13.6	Fixed Point versus Floating Point	480
13.7	Signal Processor Sizing	482
13.8	Further Reading	488
13.9	References	488
13.10	Problems	491

PART IV Signal and Data Processing

14 Digital Signal Processing Fundamentals for Radar 495

14.1	Introduction	495
14.2	Sampling	496
14.3	Quantization	504
14.4	Fourier Analysis	506

14.5	The z Transform	522
14.6	Digital Filtering	523
14.7	Random Signals	532
14.8	Integration	536
14.9	Correlation as a Signal Processing Operation	538
14.10	Matched Filters	540
14.11	Further Reading	543
14.12	References	543
14.13	Problems	544
<hr/>		
15	Threshold Detection of Radar Targets	547
15.1	Introduction	547
15.2	Detection Strategies for Multiple Measurements	548
15.3	Introduction to Optimal Detection	552
15.4	Statistical Models for Noise and Target RCS in Radar	557
15.5	Threshold Detection of Radar Signals	560
15.6	Further Reading	584
15.7	References	584
15.8	Problems	585
<hr/>		
16	Constant False Alarm Rate Detectors	589
16.1	Introduction	589
16.2	Overview of Detection Theory	590
16.3	False Alarm Impact and Sensitivity	592
16.4	CFAR Detectors	593
16.5	Cell Averaging CFAR	597
16.6	Robust CFARs	607
16.7	Algorithm Comparison	616
16.8	Adaptive CFARs	618
16.9	Additional Comments	619
16.10	Further Reading	620
16.11	References	620
16.12	Problems	622
<hr/>		
17	Doppler Processing	625
17.1	Introduction	625
17.2	Review of Doppler Shift and Pulsed Radar Data	626
17.3	Pulsed Radar Doppler Data Acquisition and Characteristics	627

- 17.4 Moving Target Indication 629
 - 17.5 Pulse-Doppler Processing 644
 - 17.6 Clutter Mapping and the Moving Target Detector 665
 - 17.7 Pulse Pair Processing 668
 - 17.8 Further Reading 673
 - 17.9 References 673
 - 17.10 Problems 674
-

18 Radar Measurements 677

- 18.1 Introduction 677
 - 18.2 Precision and Accuracy in Radar Measurements 678
 - 18.3 Radar Signal Model 683
 - 18.4 Parameter Estimation 685
 - 18.5 Range Measurements 690
 - 18.6 Phase Measurement 695
 - 18.7 Doppler and Range Rate Measurements 696
 - 18.8 RCS Estimation 699
 - 18.9 Angle Measurements 700
 - 18.10 Coordinate Systems 709
 - 18.11 Further Reading 710
 - 18.12 References 710
 - 18.13 Problems 711
-

19 Radar Tracking Algorithms 713

- 19.1 Introduction 713
 - 19.2 Basics of Track Filtering 719
 - 19.3 Kinematic Motion Models 746
 - 19.4 Measurement Models 751
 - 19.5 Radar Track Filtering 757
 - 19.6 Measurement-to-Track Data Association 760
 - 19.7 Performance Assessment of Tracking Algorithms 766
 - 19.8 Further Reading 767
 - 19.9 References 768
 - 19.10 Problems 770
-

20 Fundamentals of Pulse Compression Waveforms 773

- 20.1 Introduction 773
- 20.2 Matched Filters 774
- 20.3 Range Resolution 782

20.4	Straddle Loss	786
20.5	Pulse Compression Waveforms	787
20.6	Pulse Compression Gain	788
20.7	Linear Frequency Modulated Waveforms	789
20.8	Matched Filter Implementations	794
20.9	Sidelobe Reduction in an LFM Waveform	797
20.10	Ambiguity Functions	800
20.11	LFM Summary	808
20.12	Phase-Coded Waveforms	808
20.13	Biphase Codes	817
20.14	Polyphase Codes	824
20.15	Phase-Code Summary	829
20.16	Further Reading	830
20.17	References	830
20.18	Problems	833
<hr/>		
21	An Overview of Radar Imaging	835
21.1	Introduction	835
21.2	General Imaging Considerations	837
21.3	Resolution Relationships and Sampling Requirements	843
21.4	Data Collection	852
21.5	Image Formation	856
21.6	Image Phenomenology	875
21.7	Summary	888
21.8	Further Reading	888
21.9	References	889
21.10	Problems	890
<hr/>		
Appendix A: Maxwell's Equations and Decibel Notation		893
A.1	Maxwell's Equations	893
A.2	The Ubiquitous dB	895
A.3	Reference	897
Appendix B: Answers to Selected Problems		899
Index		905