

---

# CONTENTS

---

<b>Contributors</b>	<b>xi</b>
<b>1 Introduction</b>	<b>1</b>
<i>Fulvio Gini and Muralidhar Rangaswamy</i>	
1.1 Organization of the Book / 3	
Acknowledgments / 7	
References / 7	
<b>2 Cognitive Radar</b>	<b>9</b>
<i>Simon Haykin</i>	
2.1 Introduction / 9	
2.2 Cognitive Radar Signal-Processing Cycle / 10	
2.3 Radar-Scene Analysis / 12	
2.3.1 Statistical Modeling of Statistical Representation of Clutter- and Target-Related Information / 13	
2.4 Bayesian Target Tracking / 14	
2.4.1 One-Step Tracking Prediction / 16	
2.4.2 Tracking Filter / 16	
2.4.3 Tracking Smoother / 18	
2.4.4 Experimental Results: Case Study of Small Target in Sea Clutter / 19	
2.4.5 Practical Implications of the Bayesian Target Tracker / 20	
2.5 Adaptive Radar Illumination / 21	
2.5.1 Simulation Experiments in Support of Adjustable Frequency Modulation / 22	
2.6 Echo-Location in Bats / 23	

- 2.7 Discussion / 25
  - 2.7.1 Learning / 27
  - 2.7.2 Applications / 27
    - 2.7.2.1 Multifunction Radars / 27
    - 2.7.2.2 Noncoherent Radar Network / 28
- Acknowledgments / 29
- References / 29

**3 Knowledge-Based Radar Signal and Data Processing: A Tutorial Overview** **31**

*Gerard T. Capraro, Alfonso Farina, Hugh D. Griffiths, and Michael C. Wicks*

- 3.1 Radar Evolution / 32
- 3.2 Taxonomy of Radar / 34
- 3.3 Signal Processing / 35
- 3.4 Data Processing / 37
- 3.5 Introduction to Artificial Intelligence / 38
  - 3.5.1 Why Robotics and Knowledge-Based Systems? / 39
  - 3.5.2 Knowledge Base Systems (KBS) / 39
  - 3.5.3 Semantic Web Technologies / 40
- 3.6 A Global View and KB Algorithms / 40
  - 3.6.1 An Airborne Autonomous Intelligent Radar System (AIRS) / 42
  - 3.6.2 Filtering, Detection, and Tracking Algorithms and KB Processing / 44
- 3.7 Future work / 49
  - 3.7.1 Target Matched Illumination / 49
  - 3.7.2 Spectral Interpolation / 49
  - 3.7.3 Bistatic Radar and Passive Coherent Location / 50
  - 3.7.4 Synthetic Aperture Radar / 50
  - 3.7.5 Resource Allocation in a Multifunction Phased Array Radar / 50
  - 3.7.6 Waveform Diversity and Sensor Geometry / 51
- Acknowledgments / 51
- References / 51

**4 An Overview of Knowledge-Aided Adaptive Radar at DARPA and Beyond** **55**

*Joseph R. Guerci and Edward J. Baranoski*

- 4.1 Introduction / 56
  - 4.1.1 Background on STAP / 56
  - 4.1.2 Examples of Real-World Clutter / 60

4.2	Knowledge-Aided STAP (KA-STAP) / 61	
4.2.1	Knowledge-Aided STAP: Back to “Bayes-ics” / 61	
4.2.1.1	Case I: Intelligent Training and Filter Selection (ITFS) / 62	
4.2.1.2	Case II: Bayesian Filtering and Data Pre-Whitening / 63	
4.3	Real-Time KA-STAP: The DARPA KASSPER Program / 67	
4.3.1	Obstacles to Real-Time KA-STAP / 67	
4.3.2	Solution: Look-Ahead Scheduling / 67	
4.4	Applying KA Processing to the Adaptive MIMO Radar Problem / 71	
4.5	The Future: Next-Generation Intelligent Adaptive Sensors / 72	
	References / 72	
<b>5</b>	<b>Space–Time Adaptive Processing for Airborne Radar: A Knowledge–Based Perspective</b>	<b>75</b>
	<i>Michael C. Wicks, Muralidhar Rangaswamy, Raviraj S. Adve, and Todd B. Hale</i>	
5.1	Introduction / 76	
5.2	Problem Statement / 77	
5.3	Low Computation Load Algorithms / 81	
5.3.1	Joint Domain Localized Processing / 82	
5.3.2	Parametric Adaptive Matched Filter / 84	
5.3.3	Multistage Wiener Filter / 85	
5.4	Issues of Data Support / 86	
5.4.1	Nonhomogeneity Detection / 87	
5.4.2	Direct Data Domain Methods / 89	
5.4.2.1	Hybrid Approach / 90	
5.5	Knowledge-Aided Approaches / 91	
5.5.1	A Preliminary Knowledge-Based Processor / 92	
5.5.2	Numerical Example / 94	
5.5.3	A Long-Term View / 98	
5.6	Conclusions / 99	
	References / 99	
<b>6</b>	<b>CFAR Knowledge-Aided Radar Detection and its Demonstration Using Measured Airborne Data</b>	<b>103</b>
	<i>Christopher T. Capraro, Gerard T. Capraro, Antonio De Maio, Alfonso Farina, and Michael C. Wicks</i>	
6.1	Introduction / 103	
6.2	Problem Formulation and Design Issues / 106	
6.3	KA Data Selector / 107	

- 6.4 2S-DSP Data Selection Procedure / 109
  - 6.4.1 Two-Step Data Selection Procedure (2S-DSP) / 112
- 6.5 RP-ANMF Detector / 113
- 6.6 Performance Analysis / 114
- 6.7 Conclusions / 123
- References / 123
- Appendix 6A: Registration Geometry / 127

**7 STAP via Knowledge-Aided Covariance Estimation and the FRACTA Meta-Algorithm**

129

*Shannon D. Blunt, Karl Gerlach, Muralidhar Rangaswamy, and Aaron K. Shackelford*

- 7.1 Introduction / 130
- 7.2 The FRACTA Meta-Algorithm / 132
  - 7.2.1 The General STAP Model / 132
  - 7.2.2 FRACTA Description / 134
    - 7.2.2.1 Reiterative Censoring / 135
    - 7.2.2.2 CFAR Detector / 137
    - 7.2.2.3 ACE Detector / 138
- 7.3 Practical Aspects of Censoring / 139
  - 7.3.1 Global Censoring / 139
  - 7.3.2 Censoring Stopping Criterion / 140
  - 7.3.3 Fast Reiterative Censoring / 141
  - 7.3.4 FRACTA Performance / 141
- 7.4 Knowledge-Aided FRACTA / 147
  - 7.4.1 Knowledge-Aided Covariance Estimation / 147
  - 7.4.2 Doppler-Sensitive ACE Detector / 149
  - 7.4.3 Performance of Knowledge-Aided FRACTA / 151
- 7.5 Partially Adaptive FRACTA / 156
  - 7.5.1 Reduced-Dimension STAP / 157
  - 7.5.2 Multiwindow Post-Doppler STAP / 157
    - 7.5.2.1 PRI-Staggered Post-Doppler STAP / 159
    - 7.5.2.2 Adjacent-Bin Post-Doppler STAP / 160
  - 7.5.3 Multiwindow Post-Doppler FRACTA / 160
  - 7.5.4 Multiwindow Post-Doppler FRACTA + KACE / 161
  - 7.5.5 Performance of Partially Adaptive FRACTA + KACE / 161
- 7.6 Conclusions / 163
- References / 163

**8 Knowledge-Based Radar Tracking** **167**

*Alessio Benavoli, Luigi Chisci, Alfonso Farina, Sandro Immediata,  
and Luca Timmoneri*

- 8.1 Introduction / 167
- 8.2 Architecture of the Tracking Filter / 169
  - 8.2.1 Filtering / 169
  - 8.2.2 Data Association / 172
  - 8.2.3 Track Initiation / 174
- 8.3 Tracking with Geographical Information / 176
  - 8.3.1 Processing of Geographical Maps / 178
  - 8.3.2 Hard Classification / 179
  - 8.3.3 Fuzzy Classification / 179
  - 8.3.4 Application of the KB to the Tracking System / 180
  - 8.3.5 Hard Classification: DMHC and DTPHC / 182
  - 8.3.6 Fuzzy Classification: DMLR and  $\alpha$ -NNCJPDA / 183
- 8.4 Knowledge-Based Target ID / 184
- 8.5 Tracking with Amplitude Information / 185
- 8.6 Performance Evaluation / 187
  - 8.6.1 Aircraft Simulation Results / 189
  - 8.6.2 Number of False Tracks and Tentative Tracks / 192
  - 8.6.3 The Use of Amplitude Information / 193
- 8.7 Conclusions / 194
- Acknowledgments / 194
- References / 195

**9 Knowledge-Based Radar Target Classification** **197**

*Igal Bilik and Joseph Tabrikian*

- 9.1 Introduction / 197
- 9.2 Database / 200
- 9.3 Target Recognition by Human Operator / 203
- 9.4 Classification Scheme / 203
  - 9.4.1 Knowledge-Based Models / 205
  - 9.4.2 Statistical Knowledge-Based Approach / 206
- 9.5 Physical Knowledge-Based Approach / 207
  - 9.5.1 Physical Model Construction / 208
  - 9.5.2 Indirect Concept / 213
  - 9.5.3 Direct Concept / 214

**x** CONTENTS

- 9.6 Combined Approach / 215
- 9.7 Experimental Results / 215
  - 9.7.1 Statistical Knowledge-Based Classifier for the Seven-Class Problem / 216
  - 9.7.2 Physical Knowledge-Based Classifier for the Three-Class Problem / 218
- 9.8 Conclusions / 222
- References / 223

**10 Multifunction Radar Resource Management** **225**

*Sergio Luis de Carvalho Miranda, Chris J. Baker, Karl Woodbridge, and Hugh D. Griffiths*

- 10.1 Introduction / 225
- 10.2 Simulation Architecture / 229
  - 10.2.1 Priority Assignment / 230
  - 10.2.2 Surveillance Manager / 230
  - 10.2.3 Track Manager / 230
  - 10.2.4 Radar Functions / 231
  - 10.2.5 Operator and Strategy / 231
- 10.3 The Schedulers / 231
  - 10.3.1 Orman et al. Type Scheduler / 231
  - 10.3.2 Butler-Type Scheduler / 232
- 10.4 Comparison of the Scheduling Algorithms / 232
  - 10.4.1 Underload Situations / 234
  - 10.4.2 Overload Situations / 238
- 10.5 Scheduling Issues / 243
- 10.6 Prioritization of Radar Tasks / 244
  - 10.6.1 Prioritization of Tracking Tasks / 245
  - 10.6.2 Prioritization of Sectors of Surveillance / 246
- 10.7 Examination of the Fuzzy Logic Method / 248
- 10.8 Comparison of the Different Prioritization Methods / 253
- 10.9 Prioritization Issues / 261
- 10.10 Summary and Conclusions / 262
- References / 262

**Index**