
CONTENTS

Preface	xv
Acknowledgments	xvii
Useful Constants	xix
List of Acronyms and Abbreviations	xxi
About the Author	xxvii
1 INTRODUCTION	1
1.1 Satnav Revolution	2
1.2 Basic Principles of Satnav	5
1.3 Satnav Attributes	12
1.4 Book Structure and How to Use This Book	12
1.5 More to Explore	14
Reference	15
PART I SYSTEM AND SIGNAL ENGINEERING	17
2 SATELLITE ORBITS AND CONSTELLATIONS	19
2.1 Kepler's Laws	20
2.2 Orbital Deviations from Ideal	25
2.3 Constellations	26
2.4 Useful Geometry Calculations	30
2.5 Summary	35
Review Questions	35
References	36
3 SATNAV SIGNALS	37
3.1 Signals, Signal Processing, and Spreading Modulations	38
3.2 Effects of Doppler and of Ionospheric Propagation	59
3.3 Satnav Signal Characteristics	65
3.4 Satnav Signal Structure	86
3.5 Summary	92
Review Questions	92
References	99
	vii

4	LINK BUDGETS	102
4.1	Free-Space Path Loss	103
4.2	Calculating Maximum and Minimum Specified Received Power in Signal Specifications	107
4.3	Terrestrial Link Budgets	112
4.4	Building Penetration and Foliage Losses	116
4.5	Summary	119
	Review Questions	119
	References	120
5	CORRELATOR OUTPUT SNR, EFFECTIVE C/N_0, AND I/S	122
5.1	Channel Model and Ideal Receiver Processing	122
5.2	Correlator Output SNR With No Interference	125
5.3	Correlator Output SNR With Interference: Spectral Separation Coefficients and Processing Gain	127
5.4	Effective C/N_0	129
5.5	Interference-to-Signal Power Ratios and Effective C/N_0	130
5.6	A Deeper Look at Spectral Separation Coefficients	130
5.7	Multiple Access Interference and Aggregate Gain of a Constellation	133
5.8	Summary	135
	Review Questions	136
	References	138
6	ERROR SOURCES AND ERROR CHARACTERIZATION	139
6.1	Sources of Error in Satnav Positioning and Timing Calculation	140
6.2	Dilution of Precision and Error Measures	146
6.3	Positioning Errors for Standalone and Differential Satnav Receivers	150
6.4	Other Error Sources	152
6.5	Summary	153
	Review Questions	154
	References	155
PART II	SATNAV SYSTEM DESCRIPTIONS	157
7	NAVSTAR GLOBAL POSITIONING SYSTEM	163
7.1	GPS History and Plans	165
7.2	GPS Description	167
7.3	GPS Signals	168

7.4	Summary	196
	Review Questions	197
	References	198
8	SATELLITE-BASED AUGMENTATION SYSTEMS	201
8.1	SBAS History and Plans	202
8.2	SBAS Description	204
8.3	SBAS Signals	205
8.4	Summary	209
	Review Questions	210
	References	211
9	GLONASS	212
9.1	GLONASS History and Plans	213
9.2	GLONASS Description	214
9.3	GLONASS Signals	215
9.4	Summary	222
	Review Questions	224
	References	224
10	GALILEO	226
10.1	Galileo History and Plans	227
10.2	Galileo Description	228
10.3	Galileo Signals	230
10.4	Summary	248
	Review Questions	249
	References	250
11	BEIDOU SYSTEM	252
11.1	BDS History and Plans	253
11.2	BDS Description	254
11.3	BDS Signals	257
11.4	Summary	262
	Review Questions	264
	References	264
12	QUASI-ZENITH SATELLITE SYSTEM	266
12.1	QZSS History and Plans	267
12.2	QZSS Description	268

12.3	QZSS Signals	270
12.4	Summary	280
	References	281
13	INDIAN REGIONAL SATELLITE SYSTEM	282
13.1	IRNSS History and Plans	283
13.2	IRNSS Description	283
13.3	IRNSS Signals	284
13.4	Summary	289
	References	289
PART III	RECEIVER PROCESSING	291
14	RECEIVER FRONT END	297
14.1	Front-End Components	298
14.2	Front-End Noise Figure	321
14.3	Front-End Architectures and Frequency Plans	323
14.4	Summary	328
	Review Questions	329
	References	331
15	ANALOG-TO-DIGITAL CONVERSION	333
15.1	Introduction to Analog-to-Digital Conversion and Automatic Gain Control	334
15.2	Linear Analog-to-Digital Conversion	338
15.3	Precorrelator Analog-to-Digital Conversion—The Digitizing Correlator	340
15.4	Summary	362
	Review Questions	362
	References	363
16	ACQUISITION	364
16.1	Initial Conditions for Acquisition	367
16.2	Initial Synchronization Basics	370
16.3	Initial Synchronization Computation	383
16.4	Initial Synchronization Performance	392
16.5	Other Aspects of Acquisition	396
16.6	Summary	401

Review Questions	403
References	404
17 DISCRETE-UPDATE TRACKING LOOPS	406
17.1 Discrete-Update Tracking Loop Formulation	408
17.2 Discrete-Update Tracking Loop Design	412
17.3 Tracking Loop Characterization	416
17.4 Summary	426
References	427
18 CARRIER TRACKING AND DATA DEMODULATION	428
18.1 Signal Processing for Carrier Tracking	429
18.2 Frequency-Locked Loops	442
18.3 Costas Loops	447
18.4 Phase-Locked Loops	450
18.5 Data Message Demodulation	453
18.6 Summary	462
Review Questions	463
References	465
19 CODE TRACKING	467
19.1 Signal Processing for Code Tracking	468
19.2 Discriminators for Code Tracking	474
19.3 Carrier-Aided Code Tracking	480
19.4 Code Tracking Performance in White Noise	481
19.5 Code Tracking Performance in White Noise and Interference	489
19.6 Ambiguous Code Tracking	492
19.7 Summary	498
Appendix 19.A RMS Bandwidth	499
Review Questions	502
References	502
20 POSITION, VELOCITY, AND TIME CALCULATION	504
20.1 Forming Measurements	505
20.2 Reducing Pseudorange Errors	508
20.3 Standard Point Positioning	515
20.4 Blending Solutions From Multiple Satnav Systems	520
20.5 Velocity Calculation	522

20.6	Working with Disadvantaged Receivers	524
20.7	Precise Point Positioning	527
20.8	Integrity Monitoring: Receiver Autonomous Integrity Monitoring and Fault Detection and Exclusion	529
20.9	Summary	530
	Review Questions	531
	References	534
PART IV	SPECIALIZED TOPICS	537
21	INTERFERENCE	539
21.1	Interference Characteristics	540
21.2	Effects of Interference on Receiver Operation	541
21.3	Dealing with Interference	542
21.4	Summary	549
	References	550
22	MULTIPATH	551
22.1	Multipath Characteristics	552
22.2	Multipath Effects	556
22.3	Multipath Mitigation	560
22.4	Summary	567
	References	568
23	AUGMENTATIONS USING DIFFERENTIAL SATNAV	570
23.1	Overview of Differential Satnav	571
23.2	Code-Based Differential Systems	574
23.3	Carrier-Based Differential Systems	576
23.4	Summary	586
	References	586
24	ASSISTED SATNAV	588
24.1	Reducing IFU and ITU	590
24.2	Provision of Clock Corrections, Ephemeris, and Data Message Bits	591
24.3	Block Processing	592
24.4	Computing Pseudoranges and Position	592
24.5	Summary	593
	Reference	594

25	INTEGRATED RECEIVER PROCESSING	595
25.1	Kalman Filter Overview	596
25.2	Loosely and Tightly Coupled Sensor-Integrated Satnav Processing	599
25.3	Standalone Vector Tracking	603
25.4	Ultratightly Coupled Sensor-Integrated Satnav Processing	605
25.5	Summary	606
	References	607
A	THEORETICAL FOUNDATIONS	609
A.1	Some Useful Functions and Their Properties	610
A.2	Fourier Transforms	611
A.3	Signal Theory and Linear Systems Theory	611
A.4	Stochastic Processes	613
A.5	Some Results for Keyed Waveforms	615
A.6	Bandwidth Measures	619
A.7	Matrices and Matrix Algebra	621
A.8	Taylor Series and Linearization	623
A.9	Coordinate System Overview	624
	References	625
	Index	627