

Understanding GPS: Principles and Applications Second Edition

For more information or to order click HERE

Elliott Kaplan and Christopher Hegarty ISBN 1-58053-894-0 Approx. 680 pages

Navtech Part #1024

This thoroughly updated second edition of an Artech House bestseller brings together a team of leading experts who provide you with a current and comprehensive treatment of the Global Positioning System (GPS). The book covers all the latest advances in technology, applications, and systems. The second edition includes new chapters that explore the integration of GPS with vehicles and cellular telephones, new classes of satellite broadcast signals, the emerging GALILEO system, and new developments in the GPS marketplace.

This single-source reference provides both a quick overview of GPS essentials and an indepth treatment of advanced topics. The book guides you in developing new applications and shows you how to evaluate their performance. It explains all the differential GPS services available to let you decide which is best for particular applications. You learn how to build GPS receivers and integrate them into navigational and communications equipment. Moreover, this unique volume helps you determine how technology is affecting the marketplace and where best to invest your company's resources.

Author Bio

Elliott Kaplan is a principal engineer at the MITRE Corporation, Bedford, Massachusetts. He is the New England Section Officer of the Institute of Navigation.. He earned his M.S. in electrical engineering from Northeastern University.

Christopher Hegarty is a senior principal engineer at the MITRE Corporation, Bedford, MA. He received a D.Sc. in electrical engineering from The George Washington University and currently serves as editor of the Institute of Navigation's quarterly journal, NAVIGATION, and as a member of RTCA, Inc.'s Program Management Committee.

Contents

Prefa	Preface		XV
Ackn	Acknowledgments		xvii
CHA	APTER	1	
	ductio		1
1.1	Introd	uction	1
		ensed GPS Program History	2
		Overview	3
1.0	1.3.1		4
	1.3.2	SPS	4
1.4	GPS N	Modernization Program	5
1.5		LEO Satellite System	6
1.6	Russia	nn GLONASS System	7
1.7	Chine	se BeiDou System	8
1.8	Augm	entations	10
1.9	Mark	ets and Applications	10
	1.9.1	Land	11
	1.9.2	Aviation	12
		Space Guidance	13
		Maritime	14
1.10		inization of the Book	14
	Refere	ences	19
CHA	APTER	2	
Func	lament	als of Satellite Navigation	21
2.1	Conce	ept of Ranging Using TOA Measurements	21
	2.1.1	Two-Dimensional Position Determination	21
	2.1.2	Principle of Position Determination Via	
	Satelli	te-Generated Ranging Signals	24
2.2	Reference Coordinate Systems		26
	2.2.1	Earth-Centered Inertial Coordinate System	27
	2.2.2	Earth-Centered Earth-Fixed Coordinate System	28
	2.2.3	World Geodetic System	29
	2.2.4	Height Coordinates and the Geoid	32
2.3	Funda	mentals of Satellite Orbits	34
	2.3.1	Orbital Mechanics	34
		Constellation Design	43
2.4	Position Determination Using PRN Codes		50
		Determining Satellite-to-User Range	51
	242	Calculation of User Position	54

viii Contents

2.5	Obtaining User Velocity	58
2.6	Time and GPS	61
	2.6.1 UTC Generation	61
	2.6.2 GPS System Time	62
	2.6.3 Receiver Computation of UTC (USNO)	62
	References	63
CH	APTER 3	
GPS	System Segments	67
3.1	Overview of the GPS System	67
	3.1.1 Space Segment Overview	67
	3.1.2 Control Segment (CS) Overview	68
	3.1.3 User Segment Overview	68
3.2	1 0 1	68
	3.2.1 GPS Satellite Constellation Description	69
	3.2.2 Constellation Design Guidelines	71
	3.2.3 Space Segment Phased Development	71
3.3	Control Segment	87
	3.3.1 Current Configuration	88
	3.3.2 CS Planned Upgrades	100
3.4	User Segment	103
	3.4.1 GPS Set Characteristics	103
	3.4.2 GPS Receiver Selection	109
	References	110
CH	APTER 4	
GPS	Satellite Signal Characteristics	113
4.1	Overview	113
4.2	Modulations for Satellite Navigation	113
	4.2.1 Modulation Types	113
	4.2.2 Multiplexing Techniques	115
	4.2.3 Signal Models and Characteristics	116
4.3	Legacy GPS Signals	123
	4.3.1 Frequencies and Modulation Format	123
	4.3.2 Power Levels	133
	4.3.3 Autocorrelation Functions and Power Spectral Densities	135
	4.3.4 Cross-Correlation Functions and CDMA Performance	140
4.4	Navigation Message Format	142
4.5	Modernized GPS Signals	145
	4.5.1 L2 Civil Signal	145
	4.5.2 L5	147
	4.5.3 M Code	148
	4.5.4 L1 Civil Signal	150
4.6	Summary	150
	References	150

<u>Contents</u> ix

CHA	APTER S		
		nal Acquisition, Tracking, and Data Demodulation	153
5.1	Overvi	iew	153
		eceiver Code and Carrier Tracking	155
	5.2.1		158
		Baseband Signal Processing	159
		Digital Frequency Synthesis	161
		Carrier Aiding of Code Loop	162
		External Aiding	164
5.3	Carrie	r Tracking Loops	164
		Phase Lock Loops	165
	5.3.2	Costas Loops	166
	5.3.3	Frequency Lock Loops	170
5.4	Code 7	Fracking Loops	173
5.5	Loop I	Filters	179
5.6	Measu	rement Errors and Tracking Thresholds	183
	5.6.1	PLL Tracking Loop Measurement Errors	184
	5.6.2	FLL Tracking Loop Measurement Errors	192
	5.6.3	C/A and P(Y) Code Tracking Loop Measurement Errors	194
	5.6.4	Modernized GPS M Code Tracking Loop Measurement Errors	199
5. 7	Formation of Pseudorange, Delta Pseudorange, and Integrated Doppler		
	5.7.1	Pseudorange	201
		Delta Pseudorange	216
		Integrated Doppler	218
5.8	_	Acquisition	219
		Tong Search Detector	223
		M of N Search Detector	227
	5.8.3	, 8	229
		nce of Initial Receiver Operations	231
		Demodulation	232
5.11		al Baseband Functions	233
		Signal-to-Noise Power Ratio Meter	233
		Phase Lock Detector with Optimistic and Pessimistic Decisions	
- 10	5.11.3	1 ,	235
5.12		of Digital Processing	235
5.13		iderations for Indoor Applications	237
5.14		less and Semicodeless Processing	239
	Refere	nces	240
CHA	APTER (
Inter	ference	, Multipath, and Scintillation	243
6.1	Overvi	ew	243
6.2	Radio	Frequency Interference	243
	6.2.1	Types and Sources of RF Interference	244
	6.2.2	Effects of RF Interference on Receiver Performance	247
		Interference Mitigation	278
63	Multir	nath	2.79

x Contents

	6.3.1 Multipath Characteristics and Models	281
	6.3.2 Effects of Multipath on Receiver Performance	285
	6.3.3 Multipath Mitigation	292
6.4	Ionospheric Scintillation	295
	References	297
СН	APTER 7	
	ormance of Stand-Alone GPS	301
7.1		301
	Measurement Errors	301
7.2	7.2.1 Satellite Clock Error	304
	7.2.2 Ephemeris Error	305
	7.2.3 Relativistic Effects	306
	7.2.4 Atmospheric Effects	308
	7.2.5 Receiver Noise and Resolution	319
	7.2.6 Multipath and Shadowing Effects	319
	7.2.7 Hardware Bias Errors	320
	7.2.8 Pseudorange Error Budgets	321
7.3	PVT Estimation Concepts	322
	7.3.1 Satellite Geometry and Dilution of Precision in GPS	322
	7.3.2 Accuracy Metrics	328
	7.3.3 Weighted Least Squares (WLS)	332
	7.3.4 Additional State Variables	333
	7.3.5 Kalman Filtering	334
7.4	GPS Availability	334
	7.4.1 Predicted GPS Availability Using the Nominal 24-Satellite	
	GPS Constellation	335
	7.4.2 Effects of Satellite Outages on GPS Availability	337
7.5	GPS Integrity	343
	7.5.1 Discussion of Criticality	345
	7.5.2 Sources of Integrity Anomalies	345
	7.5.3 Integrity Enhancement Techniques	346
7.6	Continuity	360
7.7	Measured Performance	361
	References	375
CH	APTER 8	
	erential GPS	379
8.1	Introduction	379
8.2	Spatial and Time Correlation Characteristics of GPS Errors	381
0.2	8.2.1 Satellite Clock Errors	381
	8.2.2 Ephemeris Errors	382
	8.2.3 Tropospheric Errors	384
	8.2.4 Ionospheric Errors	387
	8.2.5 Receiver Noise and Multipath	390
8.3	Code-Based Techniques	391
	8.3.1 Local-Area DGPS	391

<u>Contents</u> <u>xi</u>

	8.3.2 Regional-Area DGPS	394
	8.3.3 Wide-Area DGPS	395
8.4	Carrier-Based Techniques	397
	8.4.1 Precise Baseline Determination in Real Time	398
	8.4.2 Static Application	418
	8.4.3 Airborne Application	420
	8.4.4 Attitude Determination	423
8.5	Message Formats	425
	8.5.1 Version 2.3	425
	8.5.2 Version 3.0	428
8.6	Examples	429
	8.6.1 Code Based	429
	8.6.2 Carrier Based	450
	References	454
CH	APTER 9	
	gration of GPS with Other Sensors and Network Assistance	459
9.1	Overview	459
9.2	GPS/Inertial Integration	460
	9.2.1 GPS Receiver Performance Issues	460
	9.2.2 Inertial Sensor Performance Issues	464
	9.2.3 The Kalman Filter	466
	9.2.4 GPSI Integration Methods	470
	9.2.5 Reliability and Integrity	488
	9.2.6 Integration with CRPA	489
9.3		491
	9.3.1 Introduction	491
	9.3.2 Review of Available Sensor Technology	496
	9.3.3 Sensor Integration Principles	515
9.4	Network Assistance	522
	9.4.1 Historical Perspective of Assisted GPS	526
	9.4.2 Requirements of the FCC Mandate	528
	9.4.3 Total Uncertainty Search Space	535
	9.4.4 GPS Receiver Integration in Cellular Phones—Assistance Data	
	from Handsets	540
	9.4.5 Types of Network Assistance	543
	References	554
CH	APTER 10	
GAL	ILEO	559
10.1	GALILEO Program Objectives	559
10.2		559
	10.2.1 Open Service (OS)	560
	10.2.2 Commercial Service (CS)	562
	10.2.3 Safety of Life (SOL) Service	562
	10.2.4 Public Regulated Service (PRS)	562
	10.2.5 Support to Search and Rescue (SAR) Service	563

xii Contents

10.3 GALILEO Frequency Plan and Signal Design	563
10.3.1 Frequencies and Signals	563
10.3.2 Modulation Schemes	565
10.3.3 SAR Signal Plan	576
10.4 Interoperability Between GPS and GALILEO	577
10.4.1 Signal in Space	577
10.4.2 Geodetic Coordinate Reference Frame	578
10.4.3 Time Reference Frame	578
10.5 System Architecture	579
10.5.1 Space Segment	581
10.5.2 Ground Segment	585
10.6 GALILEO SAR Architecture	591
10.7 GALILEO Development Plan	592
References	594
CHAPTER 11	
Other Satellite Navigation Systems	595
11.1 The Russian GLONASS System	595
11.1.1 Introduction	595
11.1.2 Program Overview	595
11.1.3 Organizational Structure	597
11.1.4 Constellation and Orbit	597
11.1.5 Spacecraft Description	599
11.1.6 Ground Support	602
11.1.7 User Equipment	604
11.1.8 Reference Systems	605
11.1.9 GLONASS Signal Characteristics	606
11.1.10 System Accuracy	611
11.1.11 Future GLONASS Development	612
11.1.12 Other GLONASS Information Sources	614
11.2 The Chinese BeiDou Satellite Navigation System	615
11.2.1 Introduction	615
11.2.3 Program History	616
11.2.4 Organization Structure	617
11.2.5 Constellation and Orbit	617
11.2.6 Spacecraft	617
11.2.7 RDSS Service Infrastructure	618
11.2.8 RDSS Navigation Services	621
11.2.9 RDSS Navigation Signals	622
11.2.10 System Coverage and Accuracy	623
11.2.11 Future Developments	623
11.3 The Japanese QZSS Program	625
11.3.1 Introduction	625
11.3.2 Program Overview	625
11.3.3 Organizational Structure	626
11.3.4 Constellation and Orbit	626
11.3.5 Spacecraft Development	627

Contents

	11.3.6 Ground Support	628
	11.3.7 User Equipment	628
	11.3.8 Reference Systems	628
		628
	11.3.9 Navigation Services and Signals	
	11.3.10 System Coverage and Accuracy	629
	11.3.11 Future Development	629
	Acknowledgments	630
	References	630
	References	050
CH/	APTER 12	
	S Markets and Applications	635
12.1	GNSS: A Complex Market Based on Enabling Technologies	635
	12.1.1 Market Scope, Segmentation, and Value	638
	12.1.2 Unique Aspects of GNSS Market	639
	12.1.3 Market Limitations, Competitive Systems, and Policy	640
12.2		641
12.2	Civil Navigation Applications of GNSS	
	12.2.1 Marine Navigation	642
	12.2.2 Air Navigation	645
	12.2.3 Land Navigation	646
12.3	GNSS in Surveying, Mapping, and Geographical Information Systems	647
	12.3.1 Surveying	648
	, 0	648
	12.3.2 Mapping	
	12.3.3 GIS	649
12.4	Recreational Markets for GNSS-Based Products	650
12.5	GNSS Time Transfer	650
12.6	Differential Applications and Services	650
12.0	12.6.1 Precision Approach Aircraft Landing Systems	651
	12.6.2 Other Differential Systems	651
	12.6.3 Attitude Determination Systems	652
12.7	GNSS and Telematics and LBS	652
12.8	Creative Uses for GNSS	654
	Government and Military Applications	654
	12.9.1 Military User Equipment—Aviation, Shipboard, and Land	655
	12.9.2 Autonomous Receivers—Smart Weapons	656
	12.9.3 Space Applications	657
	12.9.4 Other Government Applications	657
12.1	0 User Equipment Needs for Specific Markets	657
12.1		660
	References	661
	References	001
APP	ENDIX A	
	t Squares and Weighted Least Squares Estimates	663
	Reference	664
	Reference	007
APP	ENDIX B	
Stabi	ility Measures for Frequency Sources	665
B.1	Introduction	665

•	
XIV	Contents

B.2 Frequency Standard Stability	665
B.3 Measures of Stability	667
B.3.1 Allan Variance	667
B.3.2 Hadamard Variance	667
References	668
APPENDIX C	
Free-Space Propagation Loss	669
C.1 Introduction	669
C.2 Free-Space Propagation Loss	669
C.3 Conversion Between PSDs and PFDs	673
References	673
About the Authors	675
Index	683