# TABLE OF CONTENTS

## VOLUME I

Contemplating a National Capability to Detect, Locate and Mitigate GNSS Interference .............................................. 1  
*Milt Clary, Doug Taggart*

Challenges to Implementation of GNSS for Aviation Applications in African Continent ............................................. 7  
*Andrew O. Akala, Patricia H. Doherty, Charles S. Carrano, Larry L.N. Amaeshi*

The Low-Latitude Ionosphere Sensor Network (LISN) ........................................................................................................ 16  
*Cesar E. Valladares, Patricia H. Doherty*

The Igliniit (Trails) Project: Inuit Hunters and Geomatics Engineering Students Collaborating to Develop an Interactive GPS Tracking System in Nunavut, Canada ........................................ 25  
*Kyle O’Keefe, Shari Gearheard, Gary Aipellee, David Igqapialu, Laimikie Palluq, Jacopie Panipak, Apiessie Apak, Brandon Culling, Josiah Lau, Tina Mosstajiri, Trevor Phillips, Michael Brand, Ryan Enns, Edward Wingate*

Deep Space Navigation Augmentation Using Variable Celestial X-Ray Sources ............................................................... 34  
*Suneel I. Sheikh, John E. Hanson, John Collins, Paul Graven*

An Investigation into the Feasibility of using a Modern Gravity Gradiometer Instrument for Passive Aircraft Navigation and Terrain Avoidance ................................................................. 49  
*Marshall M. Rogers, Richard E. Huffman Jr., Christopher M. Shearer*

*Jamie R. Morrison, John F. Raquet, Michael J. Veth*

Intelligent Multi-Sensor Measurements to Enhance Vehicle Navigation and Safety Systems .................................................. 74  
*John W. Allen, Jordan H. Britt, Christopher J. Rose, David M. Bevly*

Physical Pseudo Random Function in Radio Frequency Sources for Security ................................................................. 84  
*Di Qi, Dave De Lorenzo, Sherman Lo, Dan Boneh, Per Enge*

Long-Term Accuracy of Camera and IMU Fusion-based Navigation Systems ................................................................. 93  
*Clark N. Taylor*

Vehicle Lane Position Estimation with Camera Vision using Bounded Polynomial Interpolated Lines .................................................. 102  
*Christopher Rose, David M. Bevly*

Distributed Multi-Sensor Fusion for Improved Collaborative GPS-Denied Navigation .................................................. 109  
*Shunguang Wu, Jim Kaba, Siun-Chuon Mau, Tao Zhao*

Receiver-Autonomous Spoofing Detection: Experimental Results of a Multi-Antenna Receiver Defense against a Portable Civil GPS Spoofer .................................................................................. 124  
*Paul Y. Montgomery, Todd E. Humphreys, Brent M. Ledvina*

Adaptive Replica Code Synthesis for Interference Suppression in GNSS Receivers ........................................................ 131  
*Chun Yang, Jade Morton*

Ground Testing Installed Systems for Interference at the Air Combat Environment Test and Evaluation Facility ............. 139  
*Phyllis Cook*

Modeling C/A on C/A Interference ................................................................................................................................. 142  
*Alessandro P. Cerruti, Joseph J. Rushanan, David W. Winters*
Temporal and Spatial Decorrelation Error Reduction by a Compact Network RTK
Byungwoon Park, Changdon Kee ................................................................. 341

Practical Evaluation of RTCM Network RTK Messages in the SWEPOS™ Network
Dan Norin, Gunnar Hedling, Daniel Johansson, Soren Persson, Mikael Lilje
................................................................. 353

Real Time UWB Error Estimation in a Tightly-Coupled GPS/UWB Positioning System
Glenn D. MacGougan, Kyle O’Keefe ........................................................ 360

Ground Based LiDAR Georeferencing using Dual GPS Antenna Attitude
Ben Wilkinson, Ahmed Mohamed ................................................................. 375

Zero Mean Noise Processes that Do Not Appear to be Zero Mean
Victor S. Reinhardt ........................................................................... 384

A Novel Scalar Adaptive Filter for Mitigating the Cycle Slip
Jun Kyu Lim, Chan Gook Park, Min Su Lee ................................................. 391

New BPSK, BOC and MBOC Tracking Structures

Ambiguity Removal Method for any GNSS Binary Offset Carrier (BOC) Modulation
Phillip W. Ward, Walter E. Lillo ................................................................. 406

Bayesian Receiver Autonomous Integrity Monitoring Technique
Henri Pesonen, Robert Piche .................................................................... 420

Improving Optimality of Deeply Coupled Integration of GPS and INS
Siva Sivananthan, Jay Weitzen .................................................................... 426

Multiple Branch Delay Lock Loop Comparison for SinBOC(1,1) Signal Tracking in
Multipath Environments
Xuan Hu, Elena Simona Lohan, Ingmar Groh, Stephan Sand, Markku Renfors ................. 434

A Novel Wireless Network-Based Carrier-Aided DGPS Algorithm Design and
Implementation

eNavigation - A Standards Perspective
Bob Markle ............................................................................................... 447

The Problem with Integration is Interfacing
Joseph F. Ryan .......................................................................................... 465

USCG Development, Test and Evaluation of AIS Binary Messages for Enhanced VTS
Operations
Gregory Johnson, Ruslan Shalaev, Irene Gonin, Lee Alexander, Brian Tetreault .................. 473

Developing Standards for the eLoran System
Benjamin Peterson ....................................................................................... 510

Federal Aviation Administration - Position, Navigation, and Time Services
Mitch Narins .................................................................................................. 531

A Portable Multi-Sensor Navigation System for In-Vehicle and On-Foot Navigations
X. Zhao, Z. Syed, N. El-Sheimy ................................................................. 578

Robust Location Tag Generation from Noisy Location Data for Security Applications
Di Qiu, Dan Boneh, Sherman Lo, Per Enge ................................................. 586

Algorithms for Eliminating User Position Biases Caused by Satellite Constellation Changes
or Differential Signal Gain or Loss in Kalman Filter and Weighted Least Squares
Solutions
Hassan I. Abou Ghaida, Scott R. Smith .................................................. 598
A Genetic Fuzzy and Kalman Filtering Model for MEMS-IMU/GPS Integration
Tamer Abdelazim, Walid Abdel-Hamid, Naser El-Sheimy

A New Paradigm for using GNSS for Road Tolling
Bern Grush, Preet Khalsa

Low Elevation Measurements of GPS Ocean Reflections
Per Hoeg, Laust Olsen, Anders Carlstrom

Lane Tracking using Multilayer Laser Scanner to Enhance Vehicle Navigation and Safety Systems
Jordan H. Britt, David M. Bevly

A Novel Attitude and Motion Determination Algorithm Based on Dual Quaternion
Chen-Ying Kao, He-Sheng Wang, Szu-Kai Wang

Modified LAMBDA for Absolute Carrier Phase Positioning in the Presence of Biases
P. Henkel, V. Gomez, C. Gunther

A New Method for Partial Ambiguity Resolution
David G. Lawrence

Real Time Precise GPS Constellation Orbits and Clocks Estimation using Zero-Difference Integer Ambiguity Fixing
D. Laurichesse, F. Mercier, J.P. Berthias

A Low-Cost Precise Navigation Solution using Single-Frequency GPS Receiver
C. Wang, Y. Shao, L. Dai, D. Eslinger

Evaluation of Wavelet Multipath Mitigation Technique in the Final Measurement Domain
Mohamed Elhabiby, Ahmed El-Ghazouly, Naser El-Sheimy

A Solution to the Full State Formulated Navigation State Vector Estimation Problem
Charles Shapiro

GPS/IMU Integrated Navigation System Case Study with Unscented Kalman Filtering
Hang Guo, Lixun Wang, Min Yu

Recent and Anticipated Changes to the International Earth Rotation and Reference Systems Service (IERS) Conventions
Brian Luzum

On the Use of Ground and Space Based GPS Measurements in the Electron Density Assimilative Model (EDAM)
Matthew Angling, Natasha Jackson-Booth

Efficient Ionospheric Model using Wavelet for Geomagnetic Storm
Kyoungho Sohn, Byungwoon Park, Changdon Kee

Interplanetary Scintillations as a Tool for Synoptic Monitoring of Space Weather
Peter Duffett-Smith, Graham Woan

Space Weather Monitoring by Ground and Space Based GNSS Measurements
N. Jakowski, C. Mayer, C. Borries, V. Wilken

A Constrained GPS/INS Integration Based on Rotation Angle for Attitude Update and Dynamic Models for Position Update
Ezzaldeen Edwan, Stefan Knedlik, Junchuan Zhou, Otmar Loffeld

An Improved Low-cost GPS/INS Integrated System Based on Embedded DSP Platform
Jieying Zhang, Stefan Knedlik, Otmar Loffeld
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detecting Systematic Biases and GNSS/INS Drifts in LiDAR Data</td>
<td>753</td>
</tr>
<tr>
<td>Ayman Habib, Ana Paula Kersting, Ki-In Bang</td>
<td></td>
</tr>
<tr>
<td>Integration of Video Camera with 2D Laser Scanner for 3D Navigation</td>
<td>767</td>
</tr>
<tr>
<td>Andrey Soloviev, Nicholas Gans, Maarten Uijt de Haag</td>
<td></td>
</tr>
<tr>
<td>Satellite-to-Indoor Broadband Channel Measurements at 1.51 GHZ</td>
<td>777</td>
</tr>
<tr>
<td>Thomas Jost, Wei Wang</td>
<td></td>
</tr>
<tr>
<td>Design and Performance of a Minimum-Variance Hybrid Location Algorithm Utilizing</td>
<td>784</td>
</tr>
<tr>
<td>GPS and Cellular Received Signal Strength for Positioning in Dense Urban Environments</td>
<td></td>
</tr>
<tr>
<td>David S. De Lorenzo, Sherman C. Lo, Per K. Enge, Marty Feuerstein, Tarun K. Bhattacharya, Steve Spain, Zhengjiu Kang</td>
<td></td>
</tr>
<tr>
<td>Efficient Fingerprint DB Generation Method for Indoor Wireless Location using the</td>
<td>793</td>
</tr>
<tr>
<td>Environment Analysis Tool</td>
<td></td>
</tr>
<tr>
<td>Seong Yun Cho, Sung Jo Yun</td>
<td></td>
</tr>
<tr>
<td>Feasibility Study of Pseudolite Techniques using Signal Transmission Delay and Code</td>
<td>798</td>
</tr>
<tr>
<td>Offset</td>
<td></td>
</tr>
<tr>
<td>Sung-Hyuck Im, Gyu-In Jee</td>
<td></td>
</tr>
<tr>
<td>Vision-Aided, Cooperative Navigation for Multiple Unmanned Vehicles</td>
<td>804</td>
</tr>
<tr>
<td>Jason K. Bingham, Michael J. Veth</td>
<td></td>
</tr>
<tr>
<td>Exploration of Two Position Adjustment Methods for Underground Mine Tracking</td>
<td>814</td>
</tr>
<tr>
<td>Systems</td>
<td></td>
</tr>
<tr>
<td>Jingcheng Li, David P. Snyder, Nicholas W. Damiano</td>
<td></td>
</tr>
<tr>
<td>WPI Precision Personel Locator System: Antenna Geometry Estimation using a Robust</td>
<td>822</td>
</tr>
<tr>
<td>Multilaterization Technique</td>
<td></td>
</tr>
<tr>
<td>B. Woodacre, D. Cyganski, R.J. Duckworth, V. Amendolare</td>
<td></td>
</tr>
<tr>
<td>New 3D Four Constellation High Performance Wideband Choke Ring Antenna</td>
<td>829</td>
</tr>
<tr>
<td>Lennon Bedford, Neil Brown, Justin Walford</td>
<td></td>
</tr>
<tr>
<td>An Improved Method to Decode GPS L2C/L5 Navigation Message: Combination of the</td>
<td>836</td>
</tr>
<tr>
<td>Inner and the Outer Channel Codes</td>
<td></td>
</tr>
<tr>
<td>Axel Garcia Pena, Marie-Laure Boucheret, Christophe Macabiau, Anne-Christine Escher, Lionel Ries, Jean-Louis Damidaux, Stephane Corazza</td>
<td></td>
</tr>
<tr>
<td>Synthetic Aperture GPS Signal Processing: Concept and Feasibility Demonstration</td>
<td>851</td>
</tr>
<tr>
<td>Andrey Soloviev, Frank van Graas, Sanjeev Gunawardena, Mikel Miller</td>
<td></td>
</tr>
<tr>
<td>Wave Measurement System Using GPS Software Receiver and Arrayed Antenna</td>
<td>864</td>
</tr>
<tr>
<td>Shigeyuki Okuda, Yasuo Arai, Cui Jian, Nobayoshi Koguchi</td>
<td></td>
</tr>
<tr>
<td>A Miniature LORAN H-Field Antenna for Low-Profile Conformal Hybrid Applications</td>
<td>869</td>
</tr>
<tr>
<td>David Lee, Steven Best, Drayton Hanna, Eddie Rosario</td>
<td></td>
</tr>
<tr>
<td>Improved Iono PHMI Calculation for SBAS Systems</td>
<td>875</td>
</tr>
<tr>
<td>Christoph Mayer, Juan Blanch</td>
<td></td>
</tr>
<tr>
<td>WAAS Performance Improvement in Mexico</td>
<td>881</td>
</tr>
<tr>
<td>Ephrem Paredes, Nitin Pandya, Timothy Schempp</td>
<td></td>
</tr>
<tr>
<td>New Tools to Assess the User Domain SBAS Integrity</td>
<td>894</td>
</tr>
<tr>
<td>M. Hernandez-Pajares, J.M. Juan, J. Sanz, F. Toran, J. Ventura-Traveset, C. Lopez, D. Flament</td>
<td></td>
</tr>
<tr>
<td>GBAS GAST-D (CAT IIIB) Aircraft Monitor Performance Requirements for Single</td>
<td>903</td>
</tr>
<tr>
<td>Referene Receiver Faults</td>
<td></td>
</tr>
<tr>
<td>Curtis A. Shively</td>
<td></td>
</tr>
</tbody>
</table>
The Innovations of WAAS Navigation Data Decoding and Signal Quality Monitoring in NovAtel WAAS-GII Receiver ................................................................. Minmin Lin, Hua Huang, Michael Clayton 917

Dynamic Phase Lock Loop for Robust Receiver Carrier Phase Tracking ................................................................. Karl Shallberg, Tom Morrissey, Joe Grabowski, Michael Olynik 924

Optimizing the Evaluation of Estimation Algorithm about the Fault Detection and Exclusion (FDE) in the WAAS ................................................................. R.B. Zhao, Rui Li, Bo Shao, ZhiGang Huang 937

Development of an Ionospheric Delay Model with Plasma Bubbles for GBAS ................................................................. Susumu Saito, Takayuki Yoshihara, Naoki Fujii 947

Researches on the AIS Information Sharing and Serving System ............................................................................. 954

Optimizing the Evaluation of Estimation Algorithm about the Fault Detection and Exclusion (FDE) in the WAAS ................................................................. R.B. Zhao, Rui Li, Bo Shao, ZhiGang Huang 937

Development of an Ionospheric Delay Model with Plasma Bubbles for GBAS ................................................................. Susumu Saito, Takayuki Yoshihara, Naoki Fujii 947

Researches on the AIS Information Sharing and Serving System ............................................................................. 954

Performance Analysis of a Closely Coupled GPS/INS Relative Positioning Architecture for Automated Ground Vehicle Convoys ................................................................. William Travis, David M. Bevly 999

A Closed-Form Method for the Attitude Determination using GNSS Doppler Measurements ................................................................. Byangwoon Park, Sanghoon Jeon, Changdon Kee 1009

Deeply-Integrated Feature Tracking for Embedded Navigation ............................................................................. 1018

Cycle Ambiguity Reacquisition in UAV Applications using a Novel GPS/INS Integration Algorithm ................................................................. Steven E. Langel, Samer M. Khanafseh, Fang-Cheng Chan, Boris S. Pervan 1026

Guided K-9 Tracking Improvements using GPS, INS, and Magnetometers ................................................................. 1038

Comparing Non-Linear Filters for Aided Inertial Navigators ............................................................................. 1048

Improved MAV Attitude Estimation through Coupled Acceleration Estimation ................................................................. 1054

Performances of a New Correlation Algorithm for a Platform-Independent GPS Software Receiver ................................................................. Gregoire Waelchli, Cyril Botteron, Pierre-Andre Farine, Marcel Baracchi-Frei 1062
Standardization of Definitions for Weapons-Based GPS Receiver Timelines .................................1068
Walter Trach Jr., Marty R. McGregor, Jonathan M. Sebast, Ronald L. Lessman

Vector Delay/Frequency Lock Loop Implementation and Analysis .............................................1073
Matthew Lashley, David M. Bevly

U.S. Activities to Promote Global Use of GNSS ........................................................................1087
Kenneth Hodgkins

GettingThere..... Without Getting Lost .........................................................................................1113
Dozie Ezigbalike

National Positioning, Navigation, and Timing Architecture ......................................................1140
Karen Van Dyke

Scientific Applications of the Galileo System .............................................................................1153
B. Arbesser-Rastburg

The International Federation of Surveyors (FIG) - Our Role and How FIG and ION can
Co-Operate .........................................................................................................................1194
Mikael Lilje

Author Index