December 10-14, 2018
Hyatt House Falls Church/Merrifield
8296 Glass Alley
Fairfax, Virginia, USA, 22031

Dr. John Betz, Instructor

Main objectives: To learn more about GPS/GNSS receiver algorithms. To learn more about GNSS signals. The course met and exceeded my objectives. I especially like the review questions. I also like the real-world examples and anecdotes from Dr. Betz's experience developing real systems.

-- Patrick Pitoscia, U.S. Army

COURSE 551 (3.0 CEUs)

Using Advanced GPS/GNSS Signals and Systems: In-Depth, 5 Days

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Dr. John Betz, The MITRE Corporation				
Day 1 Morning **Objectives: Review basics of satellite-based positioning and timing, establish common terminology and notation, explore satellite orbits and constellations, understand satnav signal fundamentals** **Introduction and Overview of the Course** **Satnav Orbits and Constellations** • Kepler's laws • Constellation design considerations • Useful geometry calculations **Satnav Signals** • Signal overview • Spreading modulations	**Day 2 Morning** **Objectives: Review Day 1 material, begin to explore details of GPS and its signals, both original and modernized** **Day 1 Review Questions and Answers** **GPS and SBAS Overview** **GPS Signals** • C/A signal • P(Y) signal • L2C signal • M signal • L5 signal	**Day 3 Morning** **Objectives: Review Day 2 material, address details of analog-to-digital conversion, introduce initial synchronization** **Day 2 Review Questions and Answers** **Analog to Digital Conversion** • Fundamentals • Linear ADC • ADC for the digitizing correlator • Replica aliasing **Initial Synchronization Overview** • Receiver states • Time-frequency search and the crossambiguity function • Widening BOC correlation functions	**Day 4 Morning** **Objectives: Review Day 3 material, address details of code tracking and data message demodulation** **Day 3 Review Questions and Answers** **Code Tracking** • RMS bandwidth and its influence on code tracking performance • Signal processing and discriminators for code tracking • Implementation and tradeoffs • Performance prediction • False lock points **Data Message Demodulation**	**Day 5 Morning** **Objectives: Review Day 4 material, complete description of Galileo signals, describe Galileo receiver processing** **Day 4 Review Questions and Answers** **Galileo System and Signals** • E5, E5a, E5b • E1 OS receiver processing • E5 receiver processing
LUNCH IS ON YOUR OWN				
Day 1 Afternoon **Objectives: Establish rigorous mathematical models of satnav signals, become proficient with systems engineering tools** **Satnav Signals** • Signal components **Effective C/N_0** **Link Budgets** • Space to Earth • Terrestrial • Building and vegetation effects **Errors in Satnav** • Error sources and error budgets • Dilution of precision • Error measures and relationships among error measures	**Day 2 Afternoon** **Objectives: Complete exploring details of GPS signals and SBAS signals, begin receiver engineering with an overview, followed by details of receiver front-end design** **GPS Signals** • L1C signal • Summary of GPS signal characteristics **SBAS Signals** • L1 SBAS • L5 SBAS **Overview of Receiver Processing** **Receiver Front End Design** • Noise figure • Receive antennas and filters • Active components • Architectures	**Day 3 Afternoon** **Objectives: Describe approaches for massively parallel initial synch and evaluating initial synch performance, describe procedures for tracking loop design and implementation, followed by carrier tracking** **Initial Synchronization Details** • Architectures for massively parallel computation • Code doppler • Initial synchronization performance Assessment • Other aspects of acquisition **Tracking Loops** • Design • Implementation and tradeoffs • Carrier tracking • Frequency-locked loop design and performance • Costas loop design and performance • Phase-locked loop design and performance • Tradeoffs	**Day 4 Afternoon** **Objectives: Describe algorithms and considerations for calculating position, velocity, and time; provide integrated view of dealing with interference; introduce Galileo system and signals** **Position, Velocity, Time Calculation** • Generating and refining observables • Correcting ionospheric, tropospheric, and clock errors • Position calculation • Underdetermined solutions **Dealing with Interference** • Interference effects • Interference mitigation **Galileo System and Signals** • Overview • E1 OS • E1 PRS • E6 CS • E6 PRS	**Day 5 Afternoon** **Objectives: Summarize other satnav systems and signals (GLONASS, BDS, QZSS), provide overviews of differential satnav, assisted satnav, and multipath considerations, wrap up course** **Other Satnav Systems and Signals** • GLONASS • BDS • QZSS **Differential Satnav** **Block Processing and Assisted Satnav** **Dealing with Multipath** **Course Wrap-up**

Description

This 5-day course enables attendees to achieve proficiency, not merely familiarity, with the essential aspects of using GPS/GNSS signals. Not only does it thoroughly address current and future GPS signals, but it also drills deeply into available details of signals from other satellite-based positioning and timing systems. As attendees understand similarities and distinctions among different systems and signals, they will become equipped to take advantage of signals from multiple systems.

Receiver processing techniques are described along with ways to characterize the performance of receiver processing. These processing techniques are customized to specific characteristics of signals from GPS and other satnav systems. Specialized topics, including dealing with interference and with multipath, differential satnav, and assisted satnav, are also addressed.

Attendees will be given review questions each day that will be reviewed in class the following morning. These review problems and solutions help attendees understand and apply key concepts.

Course Objectives

To develop proficiency with advanced receiver processing of modernized and new signals from GPS, GLONASS, Galileo, BeiDou, and QZSS, supplemented by systems engineering skills, integrated with techniques for assessing performance and performing design trades concerning receiver processing.

Prerequisites

Attendees should have a solid background in GPS and be ready to develop advanced skills. Prior exposure to basic signal processing techniques and terminology as well as familiarity with engineering mathematics is needed.

Materials You Will Keep

- A color electronic copy of all course notes will be provided on a USB Drive or CD-ROM.
- A black and white hard copy of the course notes will also be provided.

Book Allowance

Book allowances for on-site group contracts, if any, are negotiated as part of the contract. For your allowance, we encourage you to consider the new Book by John Betz, Ph.D., ***Engineering Satellite-Based Navigation & Timing: GNSS, Signals, & Receivers,*** Betz. Wiley-IEEE Press, 2015.

What Attendees Have Said

"He [Dr. John Betz] had a very methodical and logical way to present the material and build on it. It was very effective. He took questions well and answered them thoroughly and encouraged questions. Understanding the trade-offs that Dr. Betz presented in an elegant way helps us decipher when and how to use the different parameters for receiver design and signal processing and which techniques to use.

— Gina Guiducci, U.S. Army, Aberdeen Proving Grounds, January 2017