PRIVATE GROUP LIVESTREAM REMOTE COURSE

Couses 356: GPS/GNSS and DGPS Operation for Engineers & Technical Professionals: Principles, Technology, Applications and DGPS Concepts (3.0 CEUs)

(Similar to Course 346, but with three additional hours of Differential GPS and two additional hours of Kalman filtering.)

DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
Dr. Chris Hegaty, MITRE				
Fundamentals of GPS operation. Overview of how the system works. U.S. policy and current status. **GPS System Description** • Overview and terminology • Principles of operation • Augmentations • Trilateration • Performance overview • Modernization **GPS Policy and Context** • Condensed navigation system history • GPS policy and governance • Modernization program • Ground segment • Other satellite navigation systems **GPS Applications** • Land • Marine • Aviation • Science • Personal navigation • Accuracy measures • Error sources	**GPS Principles and Technologies** **Clocks and Timing** • Importance for GPS • Timescales • Clock types • Stability measures • Relativistic effects **Geodesy and Satellite Orbits** • Coordinate frames and geodesy • Satellite orbits • GPS constellation • Constellation maintenance **Satellites and Control Segment** • GPS satellite blocks • Control segment components and operation • Monitor stations, MCS, and ground antennas • Upload operations • Ground control modernization	**Differential GPS Overview** • Local-area, regional-area, wide-area architectures • Code vs. carrier-phase based systems • Pseudolites • Performance overview **Differential Error Sources** • Satellite ephemeris errors • Satellite clock errors • Selective availability • Ionospheric, tropospheric delay • Multipath • Receiver internal noise, biases **Observable Modeling** • Code pseudorange and carrier-phase outputs • Code-minus-carrier observables • Carrier-smoothed code operation • Double difference operation • System error budgets	**GPS Signal Structure and Message Content** • Signal structures • Signal properties • Navigation message **GPS Receiver Overview** • Functional overview • Synchronization concepts • Acquisition • Code tracking • Carrier tracking • Data demodulation **GPS Antennas** • Antenna types • Antenna performance characteristics • Prefilters • Low-noise amplifiers (LNAs) • Noise figure	**Case Study: Tracing a GPS Signal Through a Receiver** • Received signal • Digitized signal • Correlator outputs • Code-phase estimate • Carrier-phase estimate • Data demodulation **GPS Navigation Algorithms: Point Solutions** • Pseudorange measurement models • Point solution method and example **Basics of Kalman Filtering** • Introduction to Kalman filtering • Filter structure • Simulation results
Lunch is On Your Own				
Legacy GPS Signals • Signal structure and characteristics • Modulations: BPSK, DSSS, BOC • Signal generation • Navigation data **Measurements and Positioning** • Pseudorange and carrier phase measurements • Least squares solution • Dilution of precision • Types of positioning solutions **GPS Receiver Basics** • Types of receivers • Functional overview • Antennas	**Error Sources and Models** • Sources of error and correction models • GPS signals in space performance • Ionospheric and tropospheric effects • Multipath • Error budget **Augmentations and Other Constellations** • Augmentations: local-area, satellite-based, and regional • Russia's GLONASS • Europe's Galileo • China's Compass (BeiDou) **Precise Positioning** • Precise positioning concepts • Reference station networks • RINEX data format	**Differential GPS Design Considerations** • Range vs. navigation domain corrections • Data links • Pseudolites • Reducing major error components • Ambiguity resolution **DGPS Case Studies I** • RTCM SC104 message format • USCG maritime DGPS and National DGPS (NDGPS) • Commercial satellite-based systems **DGPS Case Studies II** • Wide Area Augmentation System (WAAS) • Local Area Augmentation System (LAAS) • RINEX format • CORS&IGS network for precise positioning (survey) • Precise time transfer	**GPS Signal Processing** • In-phase and quadra-phase signal paths • Analog-to-digital (A/D) conversion • Automatic gain control (AGC) • Correlation channels • Acquisition strategies **Code Tracking, Carrier Tracking & Data Demodulation** • Delay locked loop (DLL) implementations; performance • Frequency locked loops (FLLs) • Phase locked loops (PLLs) • Carrier-aiding of DLLs • Data demodulation **Receiver Impairments and Enhancements** • Impairments - bandlimiting, oscillators, multipath, interference • Enhancements - carrier smoothing, narrow correlator, codeless/semicodeless tracking, vector tracking, external aiding	**Kalman Filtering for GPS Navigation** • Clock models and dynamic models • Integration with INS • Measurement and dynamic mismodeling **Practical Aspects I** • Types of GPS and DGPS receivers • Understanding specification sheets • Data links • Antennas **Practical Aspects II** • Receiver and interface standards • Connectors • Accessories • Test, evaluation, and signal performance

Course Objectives

- To give you a comprehensive introduction to GPS and DGPS technology, system concepts, design, operation, implementation and applications, including critical information on DGPS and Kalman filtering concepts.
- To provide detailed information on the GPS signal, its processing by the receiver, and the techniques by which GPS obtains position, velocity and time.
- To present current information on the status, plans, schedule and capabilities of GPS, as well as of other satellite-based systems with position velocity and time determination applications.
- To fill technical information gaps for those working in the GPS and GNSS fields.
- Note: This course encompasses Courses 122, 336 and 356B. If you have selected this course, do not separately select any of these course numbers.

Who Should Attend?

Excellent for engineering staff who need to be rapidly brought up to speed on GPS, and for those already working in GPS who need exposure to the system as a whole in order to work more effectively.

Prerequisites

Familiarity with engineering terms and analysis techniques. General familiarity with matrix operations is desirable for Thursday and Friday, and familiarity with signal processing techniques is desirable for Wednesday through Friday. (The materials for days 3, 4 and 5 of Course 356 are more in-depth than what is taught in Course 346.)

Materials You Will Keep

- A color electronic copy of all course notes provided in advance on a USB drive or CD-ROM.
- Ability to use Adobe Acrobat sticky notes on electronic course notes.
- NavtechGPS Glossary of GNSS Acronyms.
- A black and white hard copy of the course notes.
- A textbook from the list below.

Course Fee Entitles You to One of the Following Books

- *Understanding GPS: Principles and Applications,* 2nd ed., Elliott Kaplan & Chris Hegarty, Eds., Artech House, 2006, OR
- *Global Positioning System: Signals, Measurement and Performance,* P. Misra and P. Enge, 2nd ed., 2011.
- *GPS Basics for Technical Professionls,* P. Misra, 2019.
- *Introduction to GPS: the Global Positioning System,* 2nd Ed., A. El-Rabbany, 2006. .

What Attendees Have Said

[My objective was to] gain a better understanding of GPS operating principles with a focus on error sources and differential GPS. I thought [Dr. Hegarty's] teaching style was excellent. He specifically tailored his approach to the small classroom environment with significant student interaction: True teaching versus lecturing. [I would recommend this course to] system engineers requiring more than a black box knowledge of GPS.

— Name withheld upon request, March 2012

Instructor:

Dr. Chris Hegarty