Course 439:

GPS High Precision Kinematic Carrier Phase Techniques

Achieving decimeter & centimeter level positioning

On-Site Only

	Day 1	Day 2	Day 3
	High accuracy GPS positioning provides users accuracies down to the cm level very effectively. This day describes the basic concepts involved, and the various receiver technologies and observables available to obtain high accuracy positions.	***This day addresses the various errors affecting GPS, and how to estimate many of them using simple field experiments. It also presents some fundamental aspects of estimation theory; and describes the various DGPS methods and approaches, with real-time implementation implications.***	***This day focuses on using GPS in a variety of applications environments with high precision requirements. Numerous case studies are presented to illustrate the principles involved.***
8:30	**GPS Description and Status** GPS characteristics, ranging concepts Space, control and user segments and status Dilution of Precision User Equivalent Ranging Error (UERE) SPS and PPS positioning accuracies Overview of GPS Modernization	**GPS Observables and Estimation I** Pseudorange, carrier phase & instantaneous Doppler observables Point positioning methods & related equations; DGPS Single, double & triple differencing methods Cycle slip detection and correction	**Land Case Studies** L1 vs. L1/L2 ambiguity resolution in kinematic mode Meter & sub-meter level precision farming application Ambiguity float solutions for long baselines Under foliage and urban canyon applications Aiding with self-contained sensors Stand-alone positioning using post-mission data
9:45	**GPS Accuracy Enhancements** PPS improvements with improved orbital & clock data Post-mission orbits Static and kinematic single point performance L1 vs. L1/L2 performance Differential GPS concepts; GLONASS, Galileo	**GPS Observables and Estimation II** Carrier phase smoothing of the code Carrier phase ambiguities Linear phase combinations (widelaning) Accuracy measures, Dilution of Precision (DOP) Statistical internal and external reliability issues	**Airborne Case Studies** High accuracy DGPS aircraft positioning OTF ambiguity resolution for decimeter accuracy Velocity determination using carrier phase measurements High dynamics simulations Airborne positioning using an on-board pseudolite
11:00	**Signal Structure and Measurements** Definitions, req's, carrier phase ambiguity GPS signal characteristics, PRN code generation/properties Bi-phase modulation, spread spectrum, power levels, signal interference	**GPS Biases and Errors I** Effect of orbital errors on DGPS Use of precise orbits Satellite and receiver clock errors Effect of station coordinate errors	**Marine Case Studies** Ship positioning at the 1-2 meter level using post-mission data Water level profiling to centimeter level accuracy Low cost receivers for sonobuoy positioning Use of pseudolites for marine navigation
12:00	Characteristics of code & carrier meas'ments		
	Lunch is on your own		
1:30	**GPS Navigation Message** Broadcast message, satellite coordinate calculations Ephemeris records, almanac GPS time system	**GPS Biases and Errors II** Code & carrier phase noise estimation & examples Multipath: occurrence, estimation & examples, detection, correlation, reduction Narrow vs. wide correlator spacing Case study: Gaussian and non-Gaussian error distribution in DGPS kinematic mode	**GNSS Case Studies** Advantages and limitations of system integrations Single and double differencing issues for code and carrier measurements Availability and reliability of integrated solutions under signal masking, urban canyons, etc. Additional augmentation options
2:45	**WGS 84 and Relationship to Other Reference Systems** World Geodetic System 84; ITRF System Relationship between reference systems and datums Horizontal and vertical datums Geoid accuracies	**Atmospheric Effects** Atmospheric structure and characteristics Tropospheric & ionospheric effects & modeling L1/L2 corrections and survey results Code/carrier phase ionospheric divergence Absolute and relative numerical results	**Attitude Determination with GPS** Multi-antenna GPS technology using carrier phase techniques for attitude determination Dedicated vs. non-dedicated receivers Multi-receiver configurations Fuselage and wing flexing effects Marine applications; antenna separation effects GPS/GLONASS heading determination
4:00	**GPS Antennas & Receivers** Antenna types, gain patterns, ground planes Rcvr. design, tracking loops Code correlation and autocorrelation C/A code Narrow Correlator® spacing Codeless & semicodeless methods Receiver specs; frequency and time standards	**Differential Positioning & Nav Methods** DGPS static positioning for high accuracy applic's Semi-kinematic and kinematic modes Initial ambiguity resolution techniques Kinematic methods for 1-10m & sub-m accuracies On-the-fly (OTF) carrier phase ambiguity resolution Ambiguity float approach for decimeter accuracy DGPS message types and services	**Integrated GPS/INS** Advantages of GPS/INS integration Hardware vs. software integration Error sources and integration strategies Kalman filtering techniques GPS cycle slip detection with INS Bridging the gap with INS during GPS signal outages Integration of INS with twin-antenna GPS receiver
5:00			

Who Should Attend

Engineers, scientists and others concerned with using differential GPS or carrier phase technology for achieving centimeter and decimeter positioning accuracies and/or milliradian level attitude determination, in real time. Also for those involved in the development of high precision components and systems, as well as precision applications in this rapidly evolving field. This is a fast-paced highly practical course that will prepare you to understand when and how to use the various methodologies available to you for covering different accuracy requirements.

Materials You Will Keep

- A notebook containing copies of all ~1000 vugraphs presented
- A copy of selected papers and references

Prerequisites

- A basic knowledge of GPS system operation is assumed, as well as familiarity with engineering analysis methods.
- **Understanding of GPS principles, as in Course 122**

Instructors: Either of this University of Calgary team is emminently qualified to teach this course.

Dr. Gérard Lachapelle

Dr. M. Elizabeth Cannon

To register, or for more information, call Navtech at 1-800-NAV-0885 or 703-256-8900, or fax to 703-256-8988, or e-mail to courses@navtechgps.com. For updated information, look on our home page: www.navtechgps.com