

# Course 331: Weak Signal Tracking & High-Sensitivity GPS for Indoors

Chateau Sonesta Hotel  
New Orleans, Louisiana  
January 10-12, 2005

	Monday	Tuesday	Wednesday
8:30	<p>Dr. Gerard Lachapelle &amp; Dr. Mark Petovello University of Calgary</p> <p><b>GPS Overview</b> <i>Review of Fundamental GPS Theory</i></p> <ul style="list-style-type: none"> <li>Origins of GPS</li> <li>Navigation fundamentals and requirements</li> <li>Space, control and user segments</li> <li>System errors and accuracies</li> <li>Geometry considerations</li> </ul> <p><b>GPS Signal Structure</b></p> <ul style="list-style-type: none"> <li>RF propagation; Fresnel zones, reflection</li> <li>Refraction; attenuation; modulation</li> <li>Pseudo-Random Noise (PRN) codes and their properties</li> <li>Frequency domain</li> <li>Overview, navigation information</li> </ul> <p><b>Observables</b></p> <ul style="list-style-type: none"> <li>Pseudorange</li> <li>Doppler</li> <li>Carrier phase</li> <li>Carrier phase ambiguity</li> </ul> <p><b>Satellite Ranging Concept</b></p> <ul style="list-style-type: none"> <li>Measurement overview</li> </ul> <p>• Pseudorange measurements using correlation</p> <p>• Dilution of Precision (DOP) and User Equivalent Range Error (UERE)</p> <ul style="list-style-type: none"> <li>Performance measures</li> </ul> <p><b>Link Budget</b></p> <ul style="list-style-type: none"> <li>Radiated power, free space loss</li> <li>Received power</li> <li>System specifications</li> </ul> <p><b>Reference System</b></p> <ul style="list-style-type: none"> <li>Definition of WGS-84</li> <li>Datum transformations</li> <li>Horizontal and vertical datums</li> </ul>	<p><b>GPS Receiver Operation #2</b> <i>Signal Acquisition</i></p> <ul style="list-style-type: none"> <li>Objectives and limitations</li> <li>Time and frequency search space</li> <li>Signal detection and acquisition thresholds</li> <li>Possible implementations</li> <li>Factors affecting acquisition</li> <li>Signal reacquisition</li> </ul> <p><b>Navigation Message Demodulation</b></p> <ul style="list-style-type: none"> <li>Bit synchronization</li> <li>Frame synchronization, parity decoding, obtaining GPS time</li> </ul> <p><b>Navigation Solution</b></p> <p><b>GPS In Weak Signal Environments (High Sensitivity GPS)</b> <i>Motivation &amp; Objectives</i></p> <ul style="list-style-type: none"> <li>E911/112 mandates</li> <li>Weak signals</li> <li>Typical Signal Attenuations</li> <li>Overview of How to Handle Weak Signals</li> </ul> <p><b>Extended Coherent Accumulation</b></p> <ul style="list-style-type: none"> <li>Navigation Data; Navigation Bit Prediction; Relevance of Frequency Errors</li> </ul> <p><b>Non-Coherent Accumulation</b></p> <ul style="list-style-type: none"> <li>Definition; Squaring Loss; Relevant Factors Affecting Squaring Loss; Weak Signal Exercises &amp; Examples</li> </ul> <p><b>Signal Acquisition in Weak Signal Environments</b></p> <ul style="list-style-type: none"> <li>Frequency Bin Size Requirements; Search Space Size; Massive Parallel Correlation</li> </ul> <p><b>Review of Current Technologies</b> <i>Assisted GPS &amp; Aiding Information</i></p> <ul style="list-style-type: none"> <li>Self Aiding; External Aiding Options; Overview of Aiding Standards</li> </ul>	<p><b>High Sensitivity GPS Receiver Implementation Issues</b></p> <p><i>Estimation and Reliability</i></p> <ul style="list-style-type: none"> <li>Review of estimation concept</li> <li>Measurement model</li> <li>Least squares</li> <li>Kalman filtering</li> <li>System model</li> <li>Estimated accuracy</li> <li>Residual testing</li> <li>Statistical reliability</li> <li>Multi-dimensional accuracy measures</li> </ul> <p><i>Possible Problems</i></p> <ul style="list-style-type: none"> <li>Overview</li> <li>Increased measurement uncertainty</li> <li>Poorer reliability</li> <li>Multipath</li> <li>Echo-only signals</li> <li>Cross-correlation</li> <li>Near-far problem</li> </ul> <p><i>Signal Modeling</i></p> <ul style="list-style-type: none"> <li>E-911 mandate</li> <li>Motivation, objectives, sample results</li> </ul> <p><b>High Sensitivity GPS Receiver Case Studies #1</b> <i>Performance Assessment In Urban Canyon</i> <i>Performance Assessment Under Forest Canopy</i></p>
9:45			
11:00			
12:00	<i>Lunch is on your own</i>		
1:30	<p><b>GPS Receiver Operation #1</b> <i>Overview</i></p> <ul style="list-style-type: none"> <li>GPS receiver block diagram</li> <li>Performance issues</li> <li>Classes of GPS receivers</li> </ul> <p><b>RF Front End</b></p> <ul style="list-style-type: none"> <li>Antenna</li> <li>Local oscillator</li> <li>Characterizing time scales, FTS, Allan Variance</li> <li>Preamplifier, Friis' Formula, <math>C/N_0</math> and its relevance</li> <li>Relationship between <math>C/N_0</math> and SNR</li> <li>Down conversion and frequency mixers</li> <li>Sampling</li> </ul> <p><b>Signal Processing Overview</b></p> <ul style="list-style-type: none"> <li>Overall objectives</li> <li>Signal acquisition &amp; tracking</li> <li>Navigation message</li> <li>Demodulation</li> <li>Measurement generation</li> <li>Nav solution</li> </ul> <p><b>Signal Tracking &amp; Meas. Generation</b></p> <ul style="list-style-type: none"> <li>Objectives and limitations</li> <li>Doppler removal</li> <li>Code correlation</li> <li>Coherent accumulation</li> <li>Tracking loops (DLL, FLL, PLL)</li> <li>Measurement generation</li> </ul>	<p><b>Differential GPS</b> <i>Overview</i></p> <ul style="list-style-type: none"> <li>Objectives</li> <li>Motivation</li> </ul> <p><b>Implementation</b></p> <ul style="list-style-type: none"> <li>Between satellite single differencing</li> <li>Between receiver single differencing</li> <li>Double differencing</li> </ul> <p><b>GPS Errors</b> <i>Satellite Errors</i></p> <ul style="list-style-type: none"> <li>Orbits</li> <li>Clocks</li> </ul> <p><b>Atmospheric Errors</b></p> <ul style="list-style-type: none"> <li>Ionosphere</li> <li>Troposphere</li> </ul> <p><b>Receiver and Antenna Errors</b></p> <ul style="list-style-type: none"> <li>Noise</li> <li>Multipath</li> <li>Clock</li> <li>Interference</li> </ul>	<p><b>High Sensitivity GPS Receiver Case Studies #2</b> <i>Performance Assessment Inside Various Buildings</i></p> <p><b>Hardware Simulator for HSGPS</b> <i>Description</i></p> <ul style="list-style-type: none"> <li>Motivation</li> </ul> <p><i>Testing Capabilities</i></p> <ul style="list-style-type: none"> <li>Tracking threshold; GPS fading channel model</li> <li>Acquisition threshold</li> <li>Re-acquisition threshold</li> <li>Dynamics testing</li> </ul> <p><b>Augmentation Options</b> <i>Overview</i></p> <ul style="list-style-type: none"> <li>Software options</li> <li>Sensor options</li> </ul> <p><i>Sample Results</i></p> <ul style="list-style-type: none"> <li>Inertial Measurement Unit (IMU)</li> <li>Gyroscopes</li> <li>Barometer</li> <li>Pedestrian Navigation</li> <li>Accelerometers</li> <li>Processing Options</li> </ul>
2:45			
4:00			
5:00			

Fee: \$1695  
1.8 CEUs

## About This Course

The ever-increasing demand for position availability has forced receiver manufacturers to adapt traditional signal tracking algorithms to operate in weak signal or indoor environments. This course covers the basic concepts of GPS receiver operation before explaining how these methods are improved upon for use in weak signal environments.

Where possible, concepts are described/presented from different perspectives in an attempt to improve comprehension and to accommodate different learning styles. In particular, heuristic, time domain and frequency domain explanations are given where appropriate. Numerical examples are also included to further illustrate certain ideas and concepts. Numerous real-world case studies are also presented to emphasize and clarify various topics.

This course can be given on-site and is typically taught over three days. However, course duration and content can be adjusted somewhat to address client requirements.



**Instructors:** Dr. Gérard Lachapelle Dr. Mark Petovello

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](mailto:courses@navtechgps.com). For updated information, look on our home page: [www.GPSetc.com](http://www.GPSetc.com).

## Prerequisites

An understanding of GPS principles, such as presented in *Course 122* is beneficial, but not required.

## Who Should Attend

This course is for engineers and analysts interested in acquiring knowledge of how weak signal tracking is implemented and/or achieved. The course provides both theoretical background information and practical examples to better illustrate important aspects, thereby providing a comprehensive approach to understanding and analyzing these systems.

## Materials You Will Keep

- A notebook with copies of all presentation materials.
- Navtech's CD-ROM containing a variety of GPS articles and references.

