IGARSS 2009 Short Course

TITLE: Processing of Reflected and Occulted Global Navigation Satellite System (GNSS) Signals for Earth Remote Sensing

SESSION LENGTH: 20 Hours of Instruction

SUMMARY: Although designed for navigation, signals from the Global navigation satellite system (GNSS), ie., GPS, GLONASS, Galileo and COMPASS, pass through the Earth's atmosphere and reflect off of the Earth and ocean surface, where the effects of refraction and rough surface scattering change their properties. Several methods have been developed for inverting these effects to retrieve geophysical data, including ocean surface roughness (winds), soil moisture, and atmospheric refractivity profiles (from which water vapor profiles can be generated). Radio-occultation has been developed over the last decade, with numerous GPS receivers launched on small satellites (including Sunsat, by the University of Stellenbosch in South Africa). GNSS reflection measurements, however, are still in the development stage. Airborne experiments have been conducted in both the US and Europe. An extensive set of satellite data was recently collected on the UK-DMC satellite. The use of a small, passive, receiver enables GNSS instruments to be deployed cheaply on small satellites, light aircraft, and UAV's.

In this short course, we will develop models for reflected and occulted GNSS signals to show the influence of atmospheric and surface properties, and then show how these properties can be exploited for remote sensing of the Earth's oceans, land masses, and atmosphere. The course will focus on the signal processing aspects of these measurements and would be appropriate for those interested in the design and development of GNSS receivers, missions, or the processing of raw data. Several examples will be provided, to allow attendees to process actual GPS data (collected from an airborne receiver) using MATLAB code provided.

OUTLINE:

1. Introduction to the GNSS signal structure: Correlation properties of PRN codes; BPSK and BOC modulation; the Doppler effect; space to ground link budget; and the fundamentals of navigation receiver signal processing.
2. Models for the reflected GNSS signal: Geometric optics-based models for rough surface scattering, their limitations, and current attempts to improve upon them. Geometry of the bistatic radar problem. The link budget for reflected signals. Correlation properties of reflected signals, and the generation of delay-Doppler maps. Models for the polarization of reflected signals. Second-order moments of the reflected signal waveform as a stochastic process.
3. Geophysical model functions: forward models relating geophysical parameters to the scattering models. Ocean height spectrum models (Elfouhaily), and the generation of filtered mean square slope. Models for the slope statistics (Cox and Munk) and reduction of these models to account for the L-band wavelength of

GNSS-R signals. Surface reflection coefficients on land and water, and the relationship to soil moisture and ocean salinity.

4. Retrieval of geophysical data through inversion of scattering models. Direct inversion of scattering models, to estimate surface roughness from delay-Doppler waveform measurements. Non-linear least squares approaches and their sensitivity. Recent results on full-PDF retrievals. Faster computational methods, including series approximations, waveform peak tracking, and matched filters. Power calibration of the reflected signal.
5. Model for the radio-occultation of GNSS signals. Refraction in a layered atmosphere. Bending angle. The Abel transform and recovery of refractivity.
6. Processing of radio-occultation signals. Limitations of conventional tracking. Open-loop tracking. Frequency-domain methods.
7. Review of current research and missions.

INSTRUCTOR BIOGRAPHY: Prof. James L Garrison is an Associate Professor of Aeronautics and Astronautics at Purdue University, with a courtesy appointment in the School of Electrical and Computer Engineering. He also serves on the executive committee of the new Division of Environmental and Ecological Engineering at Purdue. He holds a PhD from the University of Colorado, Boulder, and degrees from Stanford and the Rensselaer Polytechnic Institute. He was at NASA's Langley Research Center and Goddard Space Flight Center, from 1988 through 2000, prior to joining the Purdue faculty. He has published 19 journal articles, 34 conference papers, and has been awarded 2 US patents.