PRIVATE GROUP COURSE

Course 338: Ionospheric Effects, Monitoring, and Mitigation Techniques (1.8 CEUs)

DAY 1	DAY 2	DAY 3
Introduction to Ionospheric Effects • Fundamental properties of ionosphere impacting satellite navigation • Ionospheric refraction effects in GNSS measurements: code delay, carrier advance, and total electron content (TEC) • TEC broadcast models for single-frequency receivers • TEC estimation using dual-frequency receiver measurements • TEC estimation using multi-frequency receiver measurements • TEC estimation using single-frequency receiver measurements	**Ionospheric Scintillation – Concepts, Theory, Modeling, and Monitoring** • Distinctions between refraction and diffraction effects • Scintillation theory: phase screen models • GNSS signal scintillation indicators • Scintillation model for GPS-like signals transmitted from LEO satellites • Scintillation model for VHF, UHF, L, C, and S band signals transmitted from LEO satellites	**Recent advances in ionospheric effects monitoring and forecasting** • GNSS radio occultation • GNSS reflectometry • Ionospheric effects on signals transmitted from LEO satellites • Machine learning (ML) for ionospheric disturbance detection, classification, and forecasting.
Ionospheric Effects Correction Method • Vertical TEC (VTEC) and mapping function • IGS VTEC products • Network-based VTEC mapping methods • TEC estimation using low-cost receivers • TEC estimation using cell phone measurements • Higher-order ionospheric errors	**Ionospheric scintillation effects and mitigation techniques** • Scintillation effects • Scintillation signal tracking algorithms: architecture, implementations, and performance assessment	A detailed version of the outline for this course can be found at navtechgpscom/338-outline

Instructor

Dr. Jade Morton,

Dr. Jade Morton is Helen and Hubert Croft Professor in the Aerospace Engineering Sciences Department at the University of Colorado Boulder. Her research interests lie at the intersection of satellite navigation technologies and remote sensing of Earth's ionosphere, atmosphere, and surface. She received her PhD in electrical engineering (EE) from Penn State. Dr. Morton was a president and Satellite Division Chair of the US Institute of Navigation (ION), and a recipient of ION Thurlow, Burka, Kepler, IEEE PLANS Kershner, and AGU SPARC award. She is a fellow of IEEE, ION, and RIN.

Note that this course is scheduled to be presented over three days. The start of each lecture is expected to begin later than outlined based on the time added by attendee questions

Course Objectives

- To provide a comprehensive review of fundamentals of ionospheric effects on GNSS
- To present ionospheric correction techniques to improve GNSS measurement accuracy
- To showcase the latest receiver signal processing techniques to mitigate ionospheric scintillation effects
- To highlight recent advances in ground and spaceborne ionospheric monitoring systems, machine learning algorithms, and simulation models to improve current and future navigation systems performance.

Who Should Attend?

This course is designed for students, engineers, researchers, and managers interested in satellite navigation and remote sensing technologies and applications.

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 GNSS textbook of your choosing from our list of recommended companion texts

New Course for 2024! 2025 Public Presentations to be Determined

Course Description:

Ionospheric effects are major threats to the availability, continuity, and accuracy of GNSS solutions and other satellite-based radio systems. Models, global networks of GNSS stations, and LEO satellite-based radio occultation constellations have been established to monitor and predict the ionospheric effects. This course will present the current state-of-art understanding of the various ionospheric effects on GNSS-based navigation systems and their mitigation techniques. The course consists of five lectures. The first lecture introduces the fundamental properties of the ionosphere that impact satellite navigation signals and PVT solutions, discusses the ionospheric refractive effects, broadcast models from various GNSS service provides, and the Total Electron Content (TEC) estimation techniques for single, dual-, and multi-frequency GNSS receivers. The second lecture focuses on ionospheric error correction methods, including IGS TEC products, network-based TEC mapping techniques, low-cost ionospheric monitoring system, and the latest developing in using cell phone measurements to map ionosphere. Higher order refraction errors and correction techniques will also be covered. Lecture 3 covers ionospheric scintillation effect, with a focus on the concepts, theory, modeling, and indicators for monitoring. Scintillation signal models for current GNSS L-band signals and potential future LEO satellite-based navigation systems at multiple bands ranging from VHF to S band will be discussed. Lecture 4 takes a deeper look into GNSS receiver signal processing algorithms designed to combat ionospheric scintillation effects. Part 5 will provide an update on the latest development in ionospheric effects monitoring and forecasting using machine learning algorithms, worldwide ground-based and space-based GNSS observations, the ionospheric effects on signals transmitted from LEO satellites. We will finish the course with an outlook for outstanding challenges in the field.