Physics of Satellite Navigation Systems

Enseignement en anglais donné à l'Observatoire de Paris le lundi de 9h à 12h15, du lundi 11 janvier au 22 mars 2021 (examen de 1re session semaine du 5 avril 2021)

Teachers

- Remi Geiger (SYRTE) : remi.geiger@observatoiredeparis.psl.eu
- Philp Tuckey (SYRTE) : philip.tuckey@observatoiredeparis.psl.eu

Overview

This course is strongly motivated by modern time-frequency and length metrology applied to positioning and navigation, and teaches various aspects of satellite navigation physics and engineering: orbits, on-board clocks, observational data, communication with ground stations... These topics are illustrated with the satellites of Global Navigation Satellite Systems (GNSS), but the concepts are easily applicable to other positioning and navigation systems, such as geodetic satellites, the Deep Space Network…

Detailed content

- Metrology of positioning: diferent methods available for positioning on Earth; analysis of positioning requirements for a given application; design of a positioning system that can satisfy such requirements.
- Orbits: physics of orbits and Kepler's laws; types of orbits around the Earth; orbit parametrization, Keplerian elements, perturbations…
- Atomic clocks: historical development of clocks; physics (quantum mechanics) of atomic clocks such as atomic energy levels, Schrödinger's equation, Rabi/Ramsey interrogation, analysis of interference signal in clocks; different types of atomic clocks.
- Time and frequency metrology of clocks: basic notions of uncertainty, stability and accuracy; Allan variance and power spectral density; systematic effects, in particular in atomic clocks.
- Relativistic chronometry: reference systems; space-time diagram and related concepts such as world line, light cone, proper time, space-time interval, simultaneity conventions... ; calculation of coordinate time and proper time for simple trajectories.
- Geodesy and geographic maps: notion of ellipsoid, geoid and map projection; conversion between geographic coordinates and Cartesian coordinates; classes of map projections.
- Physics of the atmosphere: influuence of different atmospheric layers on GNSS signal propagation, in particular the ionosphere and troposphere; modelling of dispersion; tropospheric and ionospheric delays, orders of magnitude; rejection of ionospheric effects; correction of tropospheric effects.
- Physics of signals: general concepts such as pseudo-random code, communication capacity of a channel, carrier and modulation; GNSS signals, structure, codes (C/A, P and navigation message), frequency bands, separation of signals from different satellites, RINEX file format; measurement of pseudo-distance, code and phase, differential positioning.
- GNSS data analysis: use of GNSS-Laboratory (gLab), study of two positioning solutions, Standard Point Positioning and Precise Point Positioning, and various corrections applied.