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Spatial and stochastic analysis of scintillation data in the frame of absolute GNSS positioning algorithms

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The ionosphere has always been a major limitation for GNSS positioning applications. Free electrons in the ionosphere perturb the propagation of GNSS radio signals involving both refraction and diffraction effects. The ionospheric refraction mainly results in a modification of the propagation speed of the GNSS electromagnetic signals, inducing an error (propagation delay or phase advance depending on the observable) in GNSS measurements. In the frame of absolute positioning techniques, single-frequency algorithms usually exploit an ionospheric model to mitigate the ionospheric error while dual-frequency algorithms, such as the well-known Precise Point Positioning (PPP), take the benefit of the availability of two frequencies and the fact that the ionosphere is a dispersive medium to construct an ionosphere-free mathematical model. But these two strategies are not able to counteract the effect of the ionospheric diffraction which is due to small-scale irregularities in the free electron density. By scattering GNSS signals, these irregularities generate rapid fluctuations (scintillations) in the amplitude and phase of GNSS signals with critical consequences for GNSS applications: cycle slips, signal power fading, receiver loss of lock and poor resulting satellite geometry.

The goal of our research is to develop a strategy to mitigate the effect of ionospheric scintillations on absolute GNSS positioning techniques, in particular the SPP (Standard Point Positioning) and the PPP (Precise Point Positioning). The strategy is based on the adjustment of the stochastic model. In order to construct the stochastic model (diagonal and non-diagonal elements) and study the correlation between observables, we adopted a “spatial” and an “empirical” approach.

The spatial approach consists in a study of the spatial autocorrelation existing in scintillations effects on GNSS signals. The spatial autocorrelation is detected by using specific spatial analysis techniques applied on data from a network of ISMR (Ionospheric Scintillation Monitoring Receiver) stations located at equatorial and polar latitudes, where scintillations effects are most severe. The knowledge of how scintillation effects are spatially correlated is helpful for determining a coherent stochastic model. The empirical approach does not take into account the phenomenon spatiality and the locations of the measurements but only the observation data. Its objective is to determine the statistical correlation which exists between GNSS measurements during a scintillation event by using a moving filter applied on GNSS observation and scintillation data. The spatial approach exploits data and data locations while the empirical approach is based only the data itself.