Satellite-beacon Ionospheric-scintillation Global Model of the upper Atmosphere (SIGMA): GNSS Signal Propagation Modeling and Channel Mismatch Analysis

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Radio wave signals which propagate through the Ionosphere are vulnerable to scintillation caused by the existence of Ionospheric plasma irregularities. Scintillation, which is the temporal fluctuation in amplitude and phase of a signal, can result in severe channel fading and random phase variations that can interfere with the performance of global navigation satellite (GNSS), communication and radar systems. While various models have been developed for equatorial use, where the nature of the electron density structures are thought to be relatively well understood, there is still a need to advance simulation capabilities for the high latitude regions to better capture the complex anisotropic structures and more effectively evaluate their impact on GNSS system performance. In this paper, we present recent enhancements made to the signal simulation and analysis capabilities of the Satellite-beacon Ionospheric-scintillation Global Model of the upper Atmosphere (SIGMA) phase screen propagation model. The simulation improvements include the incorporation of Shkarofsky's spectrum to represent the wide range of electron density structures reported at high latitudes, and wideband signal propagation to more effectively simulate the legacy and recently available and more advanced GNSS signals. The data analysis enhancements include the development and application of a new Ionospheric GNSS channel mismatch evaluation approach that estimates the residual spectra in the presence of scintillation. This method, which produces a compact wideband performance metric using a least squares spectral estimation approach previously developed for adaptive array and digital beamforming applications, is subsequently used to explore the relationship between conditions and GNSS signal spectra characteristics. In exercising these new capabilities we demonstrate the potential impact that the satellite line-of-sight (LOS), irregularity orientation and degree of anisotropy can have on correlation processing of a received GNSS signal. The results from this study provide valuable physical insights into Ionospheric propagation which will aid in further validation of SIGMA as an Ionospheric propagation model.