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Inferring Zonal Irregularity Drift from Single-Station Measurements of Amplitude (S4) and Phase (Sigma-phi) Scintillations

Abstract:
A complete characterization of field-aligned ionospheric irregularities responsible for the scintillation of transionospheric satellite signals includes not only their spectral properties (power spectral strength, spectral index, outer-scale, and anisotropy) but also their bulk motion, or drift. At low latitudes, the irregularity drift is predominantly zonal and controlled by the F region dynamo and regional electrodynamics. These physical processes are of considerable interest and are investigated using a variety of measurement techniques. The irregularity drift is important from a system impacts perspective because it affects the rate of signal fading and the level of phase fluctuations encountered by the receiver (both of which influence its ability to maintain lock on the satellite signals).

The zonal irregularity drift is most commonly measured at low-latitudes by cross-correlating observations of a satellite signal made by a pair of closely-spaced receivers. The AFRL-SCINDA network operates a small number of VHF spaced-receiver systems at low-latitudes for this purpose. A far greater number of GNSS scintillation monitors are operated by the AFRL-SCINDA network (25-30) and the Low Latitude Ionospheric Sensor Network (35-50), but the receivers are too widely separated from each other for cross-correlation techniques to be effective. Previous authors have attempted to measure the drift using a single GNSS receiver by cross-correlating the signals from different satellites, but differences in the satellite scan directions with respect to the field-aligned irregularities tend to degrade the correlation (thereby limiting the usefulness of this technique).

In this paper, we present an alternative approach that leverages the weak scatter scintillation theory [Rino, Radio Sci., 1979] to infer the zonal irregularity drift from single-station GNSS measurements of S4, Sigma-phi, and the propagation geometry alone. Unlike the spaced-receiver technique, this approach requires assumptions regarding the height of the scattering layer (which introduces a bias in the drift estimates) and the spectral index of the irregularities (which affects the spread of the drift estimates about the mean). Nevertheless, theory and experiment show that the ratio of Sigma-phi to S4 is less sensitive to these parameters than it is to the zonal drift. We validate the technique using VHF spacer-receiver measurements of zonal irregularity drift obtained from the AFRL-SCINDA network. While the spaced receiver technique remains the preferred way to monitor the drift when closely-spaced receiver pairs are available, our technique provides a new opportunity to monitor zonal irregularity drift using regional or global networks of widely separated GNSS scintillation monitors.