An Inverse Diffraction Method for Mapping the Deterministic Structure of Ionospheric Scintillations from One Frequency to Another

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To predict the impact of ionospheric scintillations on communications, navigation, and space radar systems it can be useful to simulate the RF conditions under which these systems must operate. Several beacon satellites currently in orbit broadcast radio signals that can be monitored by receivers on the ground to specify scintillations at one or more frequencies. In this paper, we present an inverse diffraction technique for mapping the deterministic structure of scintillations observed using these beacons to other frequencies. There are several reasons one may want to do this. For example, GNSS satellites can be used to monitor scintillations at L-band but it can be desirable, from a system impacts point of view, to know how these scintillations would map to a SATCOM system operating at UHF or a space-radar operating at X-band. For the case of weak scatter, a theory for scaling the S_4 index from one frequency to another is well established (Rino, Radio Sci., 14, 1135, 1979). However, this statistical scaling breaks down when the S_4 index at either frequency saturates due to multiple scatter effects. Furthermore, in some applications the deterministic structure of scintillations is required, not just statistics such as S_4.

The inverse diffraction method does not suffer from these shortcomings, and it works as follows. The complex signal fluctuations on the ground are back-propagated up to ionospheric altitudes to infer an equivalent phase screen. Forward-propagation through an appropriately scaled version of this screen provides a realization of the complex fluctuations at the desired operating frequency. This approach has a number of advantages. The statistical properties of the disturbed ionospheric medium need not be assumed *a-priori*. Instead, the ionospheric screen is derived from the scintillation measurements themselves. The method preserves the deterministic structure of the scintillations, whereas statistical scaling approaches provide only statistical predictions. Unlike the statistical scaling approach, the inverse diffraction method can be applied to measurements in the strong scatter domain. Finally, the method is simpler and computationally more efficient than 4th moment inverse techniques for inferring the screen parameters from scintillations in the strong scatter case (Carrano et al., Int. J. Geophysics, vol. 2012, 2012).

Using 50 Hz measurements of C/No and phase fluctuations on the GPS L1 and L2C carrier signals from Brazil, we validate the inverse diffraction method by predicting L1 scintillations from L2, and predicting L2 scintillations from L1. We quantify the accuracy of the frequency mapping by calculating the 2-norm of the difference between predicted and measured signals. We find that mapping to be most accurate for equatorial scintillations when the satellite scan is directed across the magnetic field lines. The reason for this is that the propagation calculations are necessarily restricted to the plane of the satellite scan, and when this scan is across highly field-aligned irregularities all structure with spectral content at the Fresnel scale is resolved.