URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

Large-to-small ionization scales measured by means of EISCAT/ESR and their effects on GNSS signals in the auroral and polar ionosphere

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Ionospheric plasma irregularities in the electron density spatial distribution can scatter radio waves causing fluctuations in their amplitude and phase. Whilst large-scale irregularities induce phase fluctuations, small-scale irregularities induce scintillation in both intensity and phase of radio waves.

A way to model radio wave scintillation is to assume the presence of a phase-changing screen along the ray path. The change in phase produced by small-scale irregularities distributed within the screen causes different parts of the radio wavefront to interfere, hence causing the radio wave to scatter and the observation of scintillation at the receiver.
Weak scattering through ionospheric irregularities can be described with the presence of a single phase screen where the distribution and size of irregularities within the screen need to be assumed in order to model the propagation problem [1,2]. On the other hand, multiple scattering requires the presence of several phase screens which introduce additional assumptions about the distance between the screens and the electron density distribution in each of the screens [2].

Ionospheric plasma irregularities associated with phase-changing screens are characterized by a spatial spectrum with an energy cascade from larger to smaller scales following plasma instability mechanisms. The knowledge of the irregularities spatial spectrum is an essential feature for the modeling of scintillation when propagating through plasma density irregularities.

A multi-instrument experiment was designed and conducted involving the European Incoherent SCATter (EISCAT), the EISCAT Svalbard Radar (ESR) and geodetic/ionospheric Global Navigation Satellite Systems (GNSS) ground stations in the auroral and polar ionosphere. The purpose of the experiment was to study the distribution of electron density in the E and F regions along hypothetical phase screens across ray paths of Global Positioning System (GPS) signals. The effects of plasma structures detected by EISCAT/ESR on GPS signals were evaluated in terms of fluctuations in the intensity and phase of GPS signals of relevance.
The experiment provided information such as the outer scale of the irregularities, the thickness of the phase screens, the distribution of the electron density structures, their spatial spectrum, the origin of the irregularities, their temporal and spatial evolution, and the corresponding effects that these structures induce on GPS signals in the auroral and polar ionosphere.

References

[1] Yeh K. C. and C.-H. Liu (1982), Radio wave scintillation in the ionosphere, *Proceedings of the IEEE*, 70(4), 324-360.

[2] Knepp, D. L. and L. J. Nickisch (2009). Multiple phase screen calculation of wide bandwidth propagation. *Radio Science*, 44(1), doi:10.1029/2008RS004054.