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Ionospheric scintillation impact on the performance of communication satellites

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Satellite-mediated radio communication links are impacted by ionospheric propagation effects. Communication outage can result from a cumulative effect of ionospheric absorption, Faraday rotation of wave polarization components, random fading of signal amplitude, and of the random phase modulation due to scattering on ionospheric irregularities. The latter two effects, referred to as the scintillation phenomena, are highly variable in spatial and temporal domains and also depend on space weather conditions. As we show in Ref. [1], the modeling of ionospheric scintillation can facilitate the planning and the optimization of CubeSat low budget scientific missions. Such LEO CubeSat-type satellites collect and process scientific data and transmit these via radio transceivers to ground stations. For the ground stations in regions with high scintillation activity, the estimates of communication outage correlate with enhanced amplitude scintillation indices. As illustrated exemplary for the low-latitude stations in Brazil we show that the design the parameters of transceiver antennas, such as power characteristics and gains, can be optimized in advance aiming to minimize the risk of scintillation impact.

As the scintillation-causing ionospheric irregularities are usually field-aligned and anisotropic, the scintillation levels exhibit spatial anisotropy as well. For specific communication geometries, when the signal ray path crosses an irregularity along the direction of its largest spatial extension, the signal attains additional distortion. In this case scintillation is geometrically enhanced and can be an additional source of communication outage. We treat this enhancement effect in Ref. [2] and illustrate its importance by considering an exemplary GEO communication satellite over the equator. For this link configuration scintillation effects are geometrically enhanced at mid-latitudes as has been observed in Ref. [3]. The modeled enhancement effect presented in Figure 1 is in good agreement with the empirical observations.

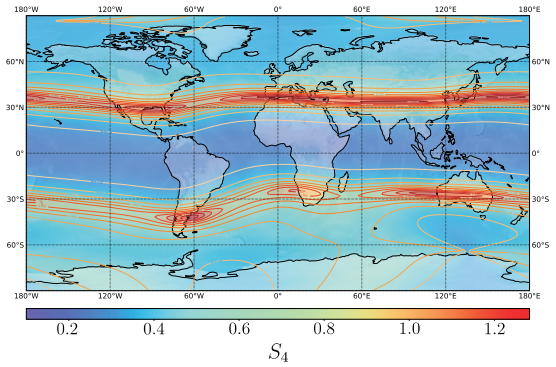

Figure 1. Regions of geometrically enhanced scintillations for communication links with GEO satellite over the equator. The values of S_4 are calibrated by the condition that the integrated irregularity strength parameter is constant, $C_s L = \text{const}$.

References

[1] A.A. Ferreira, R. A. Borges, L. R. Reis, C. Borries, D. Vasylyev, "Investigation of ionospheric effects in the planning of the AlfaCrux UHF satellite communication system," *IEEE Access*, **10**, 14, June 2022, pp. 65744–65759, doi:10.1109/ACCESS.2022.3183152.

[2] D. Vasylyev, Y. Béniguel, V. Wilken, M. Kriegel, and J. Berdermann, "Anisotropic scintillation indices for weak scattering regime," submitted to *Radio Science*.

[3] K. Sinno, H. Minakoshi, "Experimental results on satellite scintillations due to field-aligned irregularities at mid-latitudes," *J. Atm. Terr. Phys.*, **45**, August 1983, pp. 563–567, doi.org/10.1016/S0021-9169(83)80071-3.