Relation of multi-frequency GNSS signal scattering with equatorial ionospheric irregularity dynamics at VHF

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The performance of satellite-based communication and navigation links are often severely compromised in the equatorial region during intersection with ionospheric irregularities. These irregularities, of different scale sizes, primarily affect frequencies over a wide spectrum ranging from HF through VHF, UHF to L-band. Institute of Radio Physics and Electronics, University of Calcutta operates satellite beacon receiving systems at different frequencies, namely, Low Earth Orbiting (LEO) Coherent RAdio Beacon EXperiment (CRABEX) of Indian Space Research Organization at 150, 400MHz, SCIntillation Network Decision Aid (SCINDA) spaced-aerial VHF receiver of US Air Force Research Laboratory at 250MHz, and multi-frequency GNSS receivers at L1, L2 and L5 frequencies. The dynamical characteristics of equatorial ionospheric irregularities, like, zonal drift velocity, characteristic velocity and decorrelation time measured at VHF using spaced-aerial experiment may be mapped to L-band and serve as proxy indicators of L-band scintillations.

The present paper aims to understand decorrelation of multi-frequency GNSS signals at L1, L2 and L5 during periods of ionospheric scintillations with corresponding irregularity dynamics at VHF during the high-to-moderate solar activity periods of 2011-2012 and 2014-2015. During October 26-29, 2015, some cases of depletions in relative Total Electron Content (TEC) were observed by CRABEX on COSMOS2407 passes. SCINDA VHF link and GNSS links also noted patches of patches of scintillations on the geostationary FLEETSATCOM (FSC) link at 250 MHz. VHF zonal drift and characteristic velocities have been calculated from the SCINDA VHF spaced-aerial measurements. The decorrelation times of the VHF signals are provided by the VHF receiver. Functional relations have been developed to relate the VHF irregularity dynamics as mentioned above with GNSS S4 indices. In addition, variations in the Position Dilution of Precision (PDOP) measured from GNSS have been found to degrade with smaller decorrelation times of the signals at VHF.

Different nature of fading characteristics of the three GPS signals at L-band could possibly be attributed to different scattering mechanisms with respect to coherence distance. Scattering coefficients have been defined and calculated for each pair of GNSS L-band frequencies and their variations with irregularity zonal drift and characteristic velocities studied. A functional relation has been developed between irregularity drift velocity measured at VHF and S4 at L band during February–April 2011, and validation of measured S4 and predicted values performed during August–October 2011 and February–April 2012. Similar exercise has been performed for the equinoctial periods of 2014-2015. Significant improvement in L band scintillation prediction and consequent navigational accuracy will result using such relations derived from VHF irregularity measurements which are much simpler and inexpensive.