Corresponding Authors

Analyzing Phase Scintillation Observations Made by a Static Triple Frequency GPS-based Monitor
Located near the Equatorial Ionization Anomaly Peak


1) INPE São José dos Campos, SP, Brazil email:auricio@iae.inpe.br, 2) IAE, São José dos Campos, SP, Brazil, 3) CETUC-PUC-Rio de Janeiro, RJ, Brazil, 4) UTD, Dallas, TX, USA, 5) ITA, São José dos Campos, SP, Brazil, 6) IPECT Golaia, GO, Brazil

1) Introduction:
Insonospheric scintillation is a manifestation of space weather effects that seriously affect the performance and availability of space-based navigation and communication systems. This paper presents results from an investigation on the characteristics of the phase and amplitude scintillation of Global Positioning System signals at the L1, L2C and L5 frequencies. Field data obtained by a scintillation monitor installed in São José dos Campos (23°1°30"E, 45°56"S, dip latitude 17°33", declination 21°W), Brazil, a station located near the southern crest of the Equatorial Ionization Anomaly, was used for this purpose. The analyzed data was collected during 150 nights from November 2014 to March 2015, an epoch when the solar activity is close to the recent solar maximum. Only measurements corresponding to an elevation mask of 30° and values above standard threshold levels were used in the analysis. The study emphasizes phase scintillation (σφ), but also involves comparisons with amplitude scintillation (S4). The different characteristics of scintillation focused in this study include: (1) the day-to-day variation in the diurnal average and maximum intensity; (2) the local time distribution of phase scintillation at different intensity levels; (3) azimuthal (solar) distributions at different levels of the standard deviation of phase fluctuations; (4) the relationship between amplitude and phase scintillation parameters for the L1, L2C, and L5 carriers of the Global Positioning System; and (5) the frequency dependence of amplitude and phase scintillation parameters. Important results on these different characteristics are presented. A brief summary of the main results and some conclusions are presented below. The experimental set up is described in detail in a recent paper (Rodrigues et al., 2016).

A most noteworthy aspect is that no significant scintillation cases could be observed from the southern quadrants (180° - 270°) of the receiver, which is an indication that during these periods, the scintillation values (2014-March 2015), which is close to the recent solar maximum, the EPIBs did not rise up to the levels of 220 km over the equator, the apex (E), and the magnetic field line mapping to the F region over São José dos Campos.

2) Phase Scintillation (σφ) Daily Variation:
The daily average values of σφ varied from approximately 10° to 60°, the corresponding values reached 270°. Their day-to-day variation was more pronounced. The daily average values also showed a similar tendency. Furthermore, the results also showed that, considering only the satellites that transmitted the three signals, phase scintillation events with σφ > 8° at the L5 frequency lasted longer than those at the L1 and L2C frequencies in 87.3% and 58.9% respectively. The average time of occurrence at the L1 frequency were 9 and 2 minutes longer than the ones associated with the L1 and L2C frequencies, respectively. These results clearly indicate that the L5 and L2C GPS frequencies are more susceptible to scintillation than the L1 frequency.

3) Local Time Distribution:
For different intensity range, more than 75% of the cases corresponded to σφ < 30°. Additionally, the absolute peak intervals for moderate phase scintillation of 5%, 10%, and 20% of the cases are such that σφ < 30° for the L1, L2C and L5 frequencies, respectively. Scintillation with σφ < 30° starts around 1930 LT (Figure 3), to reach its peak occurrence from 2200 LT to 2330 LT at the L1 frequency. However, the peak occurrence shifts to later hours (from 2300 LT to 2330 LT) at the lower frequencies L2C and L5. The stronger scintillation (σφ > 30°) started around 0000 LT, the occurrence of which is elongated at 0200 LT and 0300 LT, one hour sooner than the peak in weak scintillation. During the peak occurrence, the percentage of the strong cases is 34.8% at L1 and this percentage increased with the decrease in frequency, being 38.2% at L2C and 55.8% at L5.

4) Spatial Distribution:
In order to illustrate the distribution of phase scintillation, as seen from the receiver location, we examined those for different frequencies of phase scintillation activity and the three frequencies. Panels (a), (b) and (c) display the corresponding σφ indices for the L1, L2C and L5 signals, respectively.

5) S4 and σφ comparison:
Each of the three frequencies showed a well-defined relationship between their σφ and S4 values. This shows that there is a high correlation between the σφ and S4 values at all levels of phase scintillation at all three frequencies. Figure 5 displays the correlation plot for the L1, L2C and L5 frequencies, respectively. The highest values of S4 and low values of σφ were observed. A strong linear relationship between S4 and σφ was observed. However, it should be noted that the correlation coefficient for S4 at low frequency (L1) is slightly higher than those for the higher frequency (L5). Furthermore, it was noticed that, for small S4 values, the number of σφ cases decreases with σφ at a rate that is significantly lower than the corresponding rate of σφ for small S4 values. This observation seems to indicate that the combination of intense amplitude scintillation and weak phase scintillation is more common than the opposite.

6) Amplitude and Phase Correlation:
A detailed study showed that, although most of the σφ and S4 are highly correlated, there is a substantial number of examples of poor correlation.

7) Frequency Dependence of Scintillation:
A more direct analysis on the frequency dependence of σφ and S4 was carried out (Figure 7) with the objective of verifying the validity of theoretically expected ratios of the scintillation indices at the different frequencies. This investigation was carried out to support evaluations of the severity of phase scintillation at new lower frequency L5 (standard applications in space science) and higher order (most of the applications based on the values at the more widely used L1 frequency). The result showed that the ratios of the phase scintillation indices were in excellent agreement with their expected values (that is, the corresponding ratios) until a transition value of σφ = 105° is reached. In the case of amplitude scintillation (for which the expected ratio was the frequency ratio raised to the power 3/2) the transition occurred at S4 = 0.6. Above these transition values, the ratios decrease with increasing in scintillation intensity. In other words, the relationship tended to saturate with further increase in the scintillation intensity at L1. However, the scintillation ratio between the two closer frequencies L2C and L5 maintained its expected value at all levels of scintillation intensity.

Reference: