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IONOSPHERIC DAY TIME AND NIGHT TIME AMPLITUDE SCINTILLATIONS ON L1 BAND

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ABSTRACT

A study on ionospheric amplitude scintillation with S4 index >0.17 was conducted by using L1-band of geostationary Indian satellites GSAT-8 (PRN 127) and GSAT-10 (PRN 128) over Delhi (Geomagnetic Latitude: 19.90^0 N, Geomagnetic Longitude: 151.89^0 E) during equinox (March, April, September, and October) of 2014. Here, the characteristics of scintillations (S4 index) was analysed separately for day time (06:00-18:00 IST) and night time (18:00-06:00 IST) sectors. The highest probability of occurrence of day time amplitude scintillations was during 06:00-10:00 IST and 14:00-18:00 IST for GSAT-8 and GSAT-10, respectively. It was found that most of the night time amplitude scintillation events were concentrated in pre mid-night hours for both satellites. The seasonal highest values of day time S4 index reported for GSAT-8 and GSAT-10 were 1.12 (at 07:44 IST) and 0.85 (at 07:08 IST), respectively. Similarly, the night time S4 index showed a highest value 1.54 at 21:10 IST (GSAT-8) and 1.38 at 21:15 IST (GSAT-10) in March. The separate analysis of day time and night time amplitude scintillation are of great importance, because day time amplitude scintillations are due to the ionospheric E region irregularities like sporadic E layer (Es), whereas equatorial F region irregularities like plasma bubbles produce night time amplitude scintillations.

KEY WORDS: Amplitude Scintillations, Equatorial Spread-F, Sporadic E Layer

The importance of trans-ionospheric radio communication for weather forecasting, air traffic control, space missions, positioning, and navigational system using satellites is increasing day by day. Disturbed ionosphere can be considered as the major source of vulnerabilities to the communication systems (Rao et al., 2006). Frequently generated electron density irregularities in the ionosphere may scatter the radio waves from satellites of different phases. When radio-frequency signals pass through ionosphere, the phase and/or amplitude of the signal get fluctuated due to electron density irregularities called scintillation (Aarons, 1982). The irregularities produce a region of fluctuating refractive index and may act as a source of subsequent differential diffraction (scattering) of the radio signals (Kintner et al., 2009). As the signal continuously pass through the ionospheric irregularities, phase and amplitude scintillation will develop through interference of multiple scattered signals. If the scintillation is strong, the signal becomes buried in noise, resulting in a signal loss and cycle slip (Aquino et al., 2005).

The equatorial ionosphere is different from other latitudes, because the magnetic field (B) at the equator is nearly parallel to the Earth's surface and the morphology of the equatorial ionosphere is different from other latitudes. For almost all Indian regions, the ionosphere falls under equatorial and low-latitude sectors. The magnetic field along with the daytime eastward electric field (E) produces E×B drift and as a result the up lift of F-region plasma over the magnetic equator occurs. This up lifted plasma moves along the magnetic field and it pushes the F-region ionization density at magnetic equator towards higher latitude (equatorial ionization anomaly), resulting in the increased ionization at the two anomaly crests around ±15^0 in magnetic latitude to the north and south of the magnetic equator (Rao et al., 2006). Sreeja (2016) showed that amplitude scintillation directly affects the signal to noise ratio (C/No) of signals in a GPS receiver, as well as the noise levels in code and phase measurements. Amplitude scintillation can be sufficiently severe that the received GPS signal intensity from a given satellite drops below the receivers tracking threshold, causing loss of lock of that satellite, and hence the need to re-acquire the GPS signal(s).

Objective of this work is to present a comparison between the characteristics of day time and night time amplitude scintillations with S4 > 0.17 on L1- band of GSAT-8 (PRN 127) and GSAT-10 (PRN 128) over Delhi (Geomagnetic Latitude: 19.90^0 N, Geomagnetic. Longitude: 151.89^0 E) during equinox (March, April, September, and October) of 2014.

MATERIALS AND METHODS

Figure 1 depicts the temporal variation of day time and night time amplitude scintillation on the L1 band (1575.42 MHz) of two geostationary Indian satellites

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GSAT-8 (PRN 127) and GSAT-10 (PRN 128) at the off crest station Delhi recorded on 05th March 2014 using Septentrio's polarRxS GNSS receiver.

Amplitude scintillation is quantified by the S4 index. PolaRxS is a multifrequency multiconstellation GNSS receiver that can generate 50 Hz signal data, which is post processed to get 60s scintillation indices. The S4 index can be calculated as follows:

$$\mathrm{S4} = \sqrt{\mathrm{S4t}^2 - \mathrm{S4c}^2} \quad (1)$$

Here S4t is the total scintillation from which thermal noise contribution S4c is eliminated. The S4 index is divided into three categories, namely weak (S4 index=0.17 to 0.3), moderate (S4 index=0.3 to 0.45) and strong (S4 index>0.45) scintillations, respectively. Here, 06:00 to 18:00 IST is considered as the day time and 18:00 to 06:00 IST as the night time sector for the present study.

RESULTS AND DISCUSSION

In Delhi, both the satellites, GSAT-8 and GSAT-10 have good elevation angle of 49^0 and 56^0, respectively. Therefore, the fluctuations due to multipath effects were completely neglected from the amplitude scintillation measurements.

Month Wise Analysis of Amplitude Scintillations

Figure 2 presented the month wise variation of percentage of occurrence of day and night time amplitude scintillations occurred for GSAT-8 and GSAT-10 signals during equinox of 2014 over Delhi. As per the data availability, for GSAT-8, all the available days of April and for GSAT-10, all the available days of March and April show day time amplitude scintillations. For both PRNs, the day time amplitude scintillation events were least in October (20 % and 19.35% for GSAT-8 and GSAT-10, respectively). Here, it is observed that for most of the days, during day time, if amplitude scintillations were occurred on L1-band signal of GSAT-8, the simultaneous observation of scintillation with nearly same value of S4 index would be observed for GAST-10 also. For example, on 05 March 2014, GSAT-8 suffers a severe form of amplitude scintillation of S4 index value 0.53 around 11:55 IST, and simultaneous to this, GSAT-10 also suffers scintillation of S4 value 0.56.

The highest percentage of occurrence of night time amplitude scintillation events were prominent during April and March for GSAT-8 (66.67%) and GSAT-10 (60%), respectively. For GSAT-10, night time amplitude scintillations were absent during April. The percentage of occurrence of day time and night time amplitude scintillations follow same pattern in September and October for both PRNs.

Percentage of Occurrence of Weak, Moderate, and Strong Amplitude Scintillations

During equinox, majority of day time and night time amplitude scintillation activities were belonged to strong type for GSAT-8 (60 % each for day time and night time scintillation) and GSAT-10 (51.62 % and 54.55 for day time and night time, respectively) (Figure 3). The weak and moderate day time amplitude scintillations were 22.50% and 17.50%, respectively for PRN 127 and that for PRN 128 were 30.23% and 18.60%. For GSAT-8, the lowest percentage of occurrence of night time amplitude scintillation events belonged to weak type (15%), where as that of GSAT-10 belonged to moderate type (13.64%).

Local Time Distribution of Day and Night Time Amplitude Scintillations in Equinox

The day time amplitude scintillations were most probable during morning (45%) and near sunset (51.63%) respectively for GSAT-8 and GSAT-10 (figure 4a). Compared with the morning (06:00-09:59 IST) and evening hours (14:00-17:59 IST), both the PRNs were showing lowest probability of occurrence during noon time (10:00-13:59 IST). For both the satellites as we go from morning to evening, the percentage of occurrence decreases towards noon reaching the minimum values at noon, and there after increases and reaches the maximum values around sun set. This is mainly due to the morphology of sporadic E layer and associated ionospheric disturbances, which would be minimum during noon time. It was found that most of the night time amplitude scintillation events were concentrated in pre mid-night hours for both satellites. At night time, ionospheric irregularities manifested as plasma bubbles are mainly responsible for night time amplitude scintillations. Previous studies (Li et al., 2008; Sridharan et al., 2012; Unnikrishnan et al., 2017) also support this observation that for equatorial stations, plasma bubbles are most probably occurred at pre midnight hours.

A seasonal highest value of day time S4 index reported for GSAT-8 and GSAT-10 were 1.12 (at 07:44 IST) and 0.85 (at 07:08 IST), respectively. Similarly, the night time S4 index showed a highest value 1.54 at 21:10 IST (GSAT-8) and 1.38 at 21:15 IST (GSAT-10) in March.

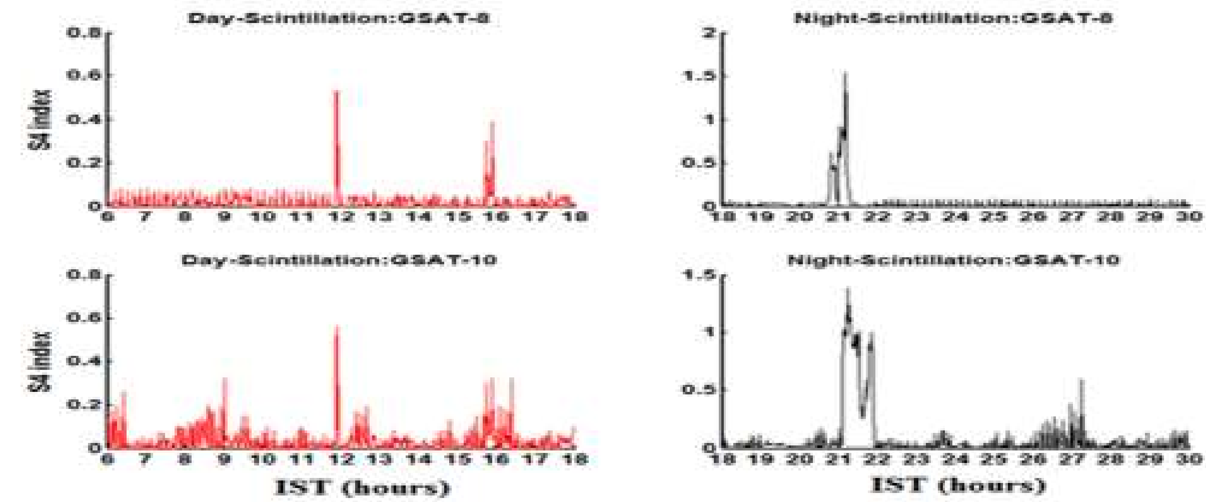

Figure 1: The typical examples of day time and night time amplitude scintillations of GSAT-8 and GSAT-10 on 05th March 2014.

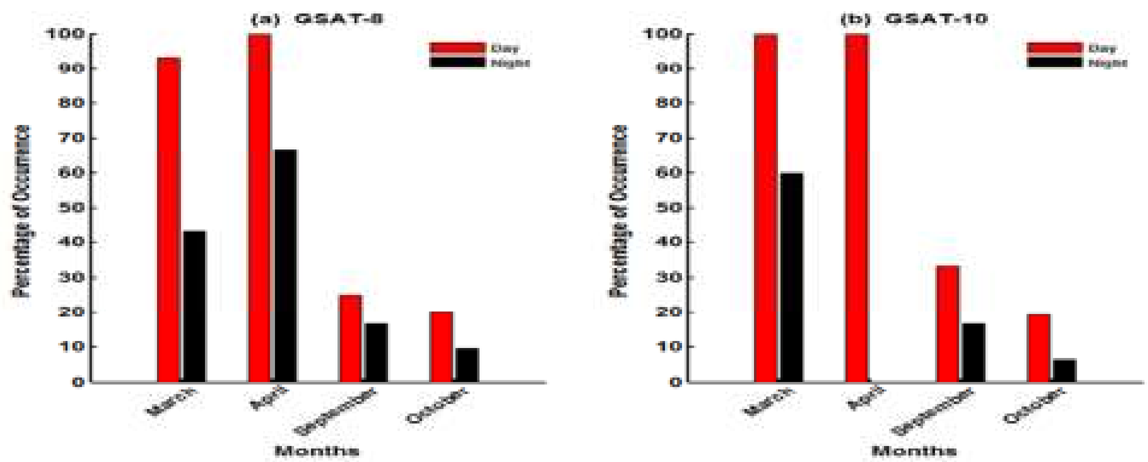

Figure 2: Month wise variation in percentage of occurrence of day and night time amplitude scintillation events for (a) GSAT-8 and (b) GSAT-10.

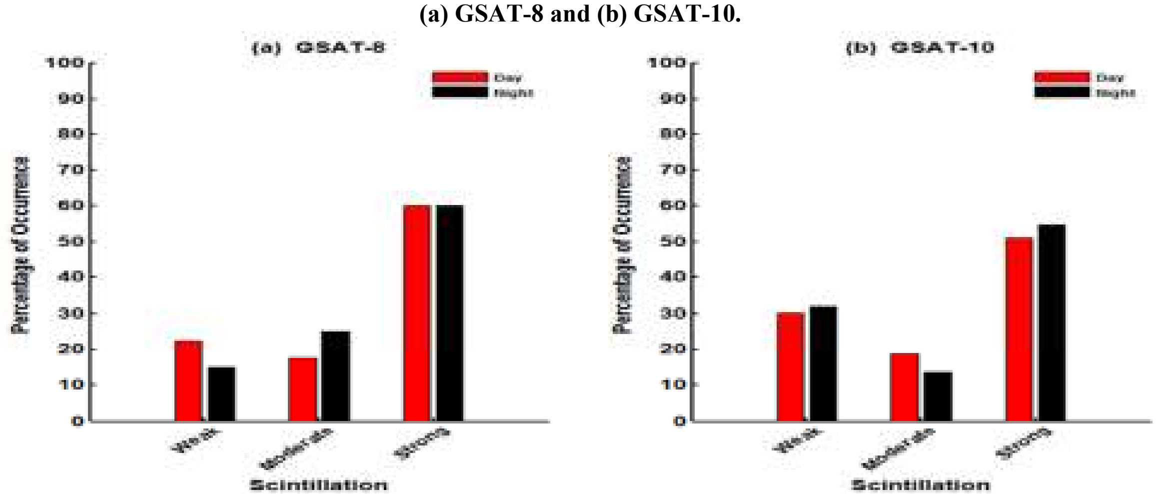

Figure 3: Percentage of occurrence of weak, moderate, strong day and night time amplitude scintillation events during equinox of 2014 for (a) GSAT-8 and (b) GSAT-10.

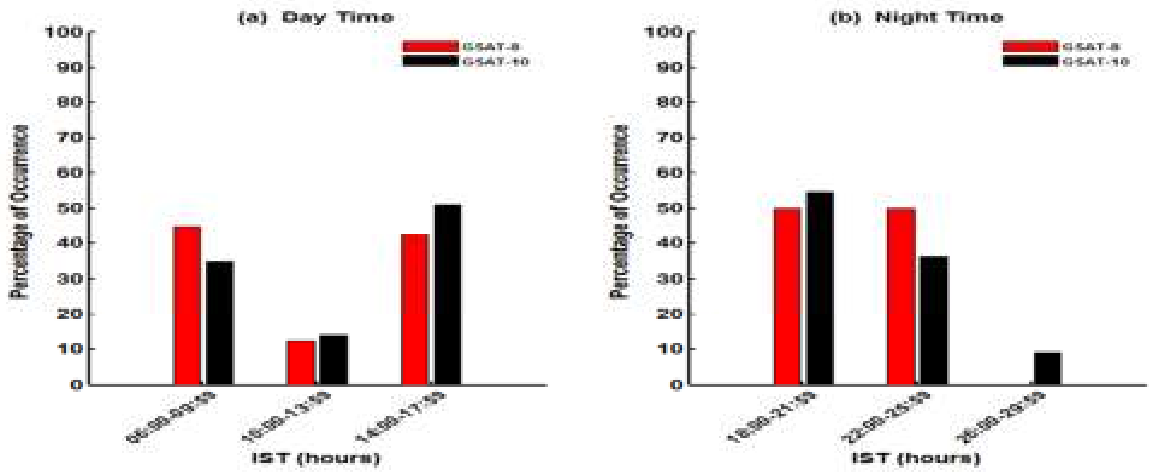

Figure 4: Local time distribution of percentage of occurrence of (a) day time and (b) night time amplitude scintillation for GSAT-8 and GSAT-10.

CONCLUSION

The separate analysis of day time and night time amplitude scintillations are of great importance because day time amplitude scintillations are due to the ionospheric E region irregularities like sporadic E layer (Es) (Zou, 2011), whereas equatorial F region irregularities like plasma bubbles produce night time amplitude scintillations. For both GSAT-8 and GSAT-10 daytime and night time amplitude scintillations were strong. These results are entirely different from the outcome of Seif et al. (2012) at UKM station, Malaysia using GPS satellites. According to them day time amplitude scintillations were much weaker as compared to night time scintillations. This may due to the altitude difference of two constellations. Seif et al. (2012) pointed out that day time amplitude scintillations are due to E region irregularities and night time amplitude scintillations are due to F region irregularities like plasma bubbles. As the plasma bubbles moving across the receiver satellite field of view, sometimes both the satellites exhibit identical scintillation pattern with definite time delay. By measuring the time delay, we can estimate the drift velocity and east-west width of plasma bubbles (Unnikrishnan et al., 2017).

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