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Research Article

## Study of Ionospheric Amplitude Scintillation during Geomagnetic Activities of 2012 at Low Latitude Region

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**Abstract.** The impact of scintillation on radio communications, geodesy, radar system and navigation cannot be underemphasized. The first evident effect of space weather in the phase of radio signals and amplitude that passes over ionosphere is fluctuations. If there are intense fluctuations in the quality of the signals received, such signals might degrade or attenuate in quality. This phenomenon is referred to as scintillations. To study the effects of magnetic activity on scintillations, the percentage occurrence of scintillations has been separated for the five international quiet (Q) days and five international disturbed (D) days over Ilorin for the year 2012 which was obtained from world data centre Kyoto. The occurrences of S<sub>4</sub> were recorded during quiet days than the disturbed days in the study area. Generally, occurrence of S<sub>4</sub> was enhanced during pre-midnight hours but was suppressed during post-midnight hour both at quiet and disturbed days in Ilorin, Kwara State, Nigeria.

**Keywords.** Geomagnetic activities; Pre-midnight; Post-midnight; Scintillations' occurrence; Low latitude; Ionosphere

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## 1. Introduction

Occasionally, if radio signal propagates through a disturbed ionosphere, the signal received would fluctuate in phase and amplitude that are inconsistent with the modulation or signal strength from the source. This fluctuation in radio signal is referred to as scintillation. Aquino *et al.* (2005) stated that ionospheric scintillation tends to affect global navigation satellite system's receivers diversely. It ranges from degradation of signal's accuracy to signal loss. So far ionospheric scintillation causes significant communication hazard on radio systems, it is however needs attention from scientists (Banerjee *et al.*, 1992).

Li *et al.* (2010) stated that ionospheric scintillation is likely to disturb auroral and equatorial regions. At low latitude where Ilorin, Nigeria is inclusive, scintillation is majorly controlled by irregularities increment over the equator. Li *et al.* (2007) and (2010) further stated that ionospheric irregularities and scintillations usually occur in the pre-midnight period in most low latitude regions. In this paper, effect of geomagnetic activity on the occurrence of ionospheric amplitude scintillations ( $S_4$ ) during the ascending phase solar cycle 24 in the year 2012 over Ilorin (a low latitude zone) in Nigeria is analyzed.

The  $S_4$  index indicates the amount of variation in the amplitude of received signal power over an interval of time, typically one minute (Dyrud *et al.*, 2008). The dimensionless index is estimated using Equation (1).

$$S_4 = \sqrt{\left[ \frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2} \right]}. \quad (1)$$

Where  $I$  is the signal intensity, and  $\langle I \rangle$  is the mean intensity.

## 2. Materials and Methods

The data used in this study were obtained from the *Global Positioning System (GPS) Scintillation / Total Electron Content (TEC)* monitoring equipment installed at the department of Physics University of Ilorin, Ilorin, Nigeria (Geo Lat: 8.48° N, Long: 4.67° E, Geomagnetic Lat: 1.2° S) (Figure 1) through the Low Latitude Ionospheric Sensor Network (LISN) database for the year 2012. The Five international quiet days and disturbed days were got from the World Data Centre (WDC), Kuyoto, Japan.

The magnetic disturbed and quiet days of each month were calculated from the Global Magnetic Storm index (Kp index) based on the three criteria stated by Johnston *et al.* (1943): “the sum of the eight Kp values; the sum of the square of the eight Kp values; and the maximum of the eight Kp values”. In reference to each of these criteria, a relative order number is given to each day of the month, the mean of the three order numbers are calculated and the days with the lowest and the highest mean order numbers are selected as the five quietest and the five most disturbed days. It should be noted that these selection criteria give only a relative indication of the character of the selected days with respect to the other days of the same

month. As the general disturbance level may be quite different for different years and also for different months of the same year, the selected quietest days of a month may sometimes be rather disturbed or vice versa. The Ap index value is also obtained from WDC. The Ap index measures the daily average level of geomagnetic activity. The Ap-index is thus a geomagnetic activity index where days with high levels of geomagnetic activity have a higher daily value.

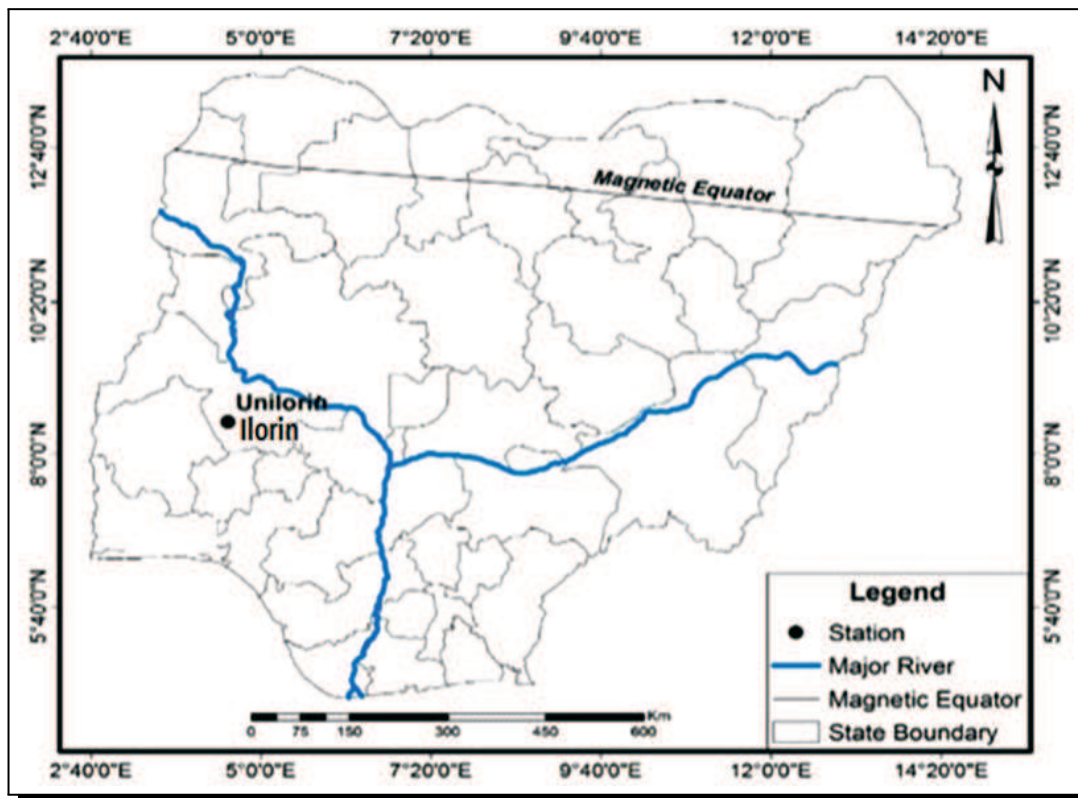


Figure 1. Location of the LISN GPS receiver in Ilorin, Nigeria

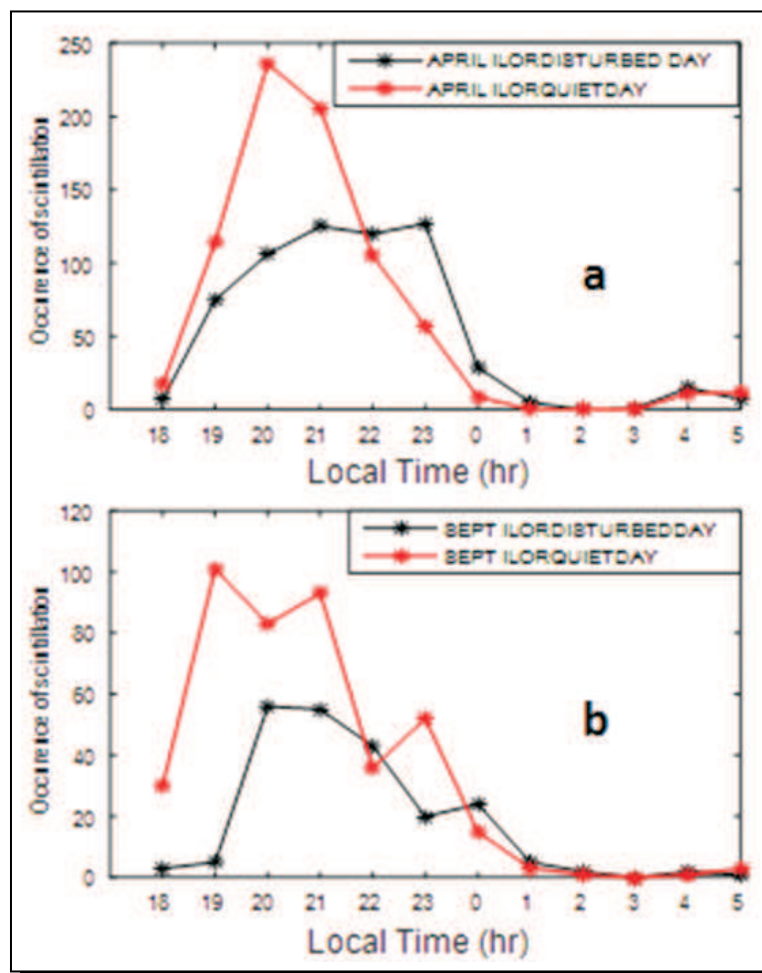
### 3. Results and Discussion

The occurrence of scintillations in the months of April and September in the year 2012 are shown in the Figure 2. In April scintillations, the amplitude of  $S_4$  was suppressed at the post-midnight hour while it was enhanced during pre-midnight hours. The results correlate with that of Tiwari *et al.* (2013). During the quiet period the trend reverses. That is, there are more  $S_4$  during magnetic Quiet days than magnetic disturbed days. It was further revealed that the occurrence of  $S_4$  was enhanced during pre-midnight hours and suppressed during post-midnight hours for magnetic quiet and disturbed period.

Around Equinox, the occurrence of  $S_4$  was enhanced at the pre-midnight hours on the quiet days than the disturbed days but these occurrences were suppressed during post-midnight in the study area. The suppression and enhancement of the asymmetries during geomagnetic perturbations can be traced to variations in the ring current (Aarons, 1991).

During the pre-sunset period, the eastward electric field is increased, causing F-layer height to increase. A negative drive of ring current during this period would lower the local eastward electric field and reduce the F-height. The result may sometimes be too large enough to reverse the rising movement of F-layer during the post-sunset period, thereby inhibiting the creation of irregularities. This may cause suppression of pre-midnight scintillations over most longitude during periods of high magnetic activity (Tiwari *et al.*, 2013).

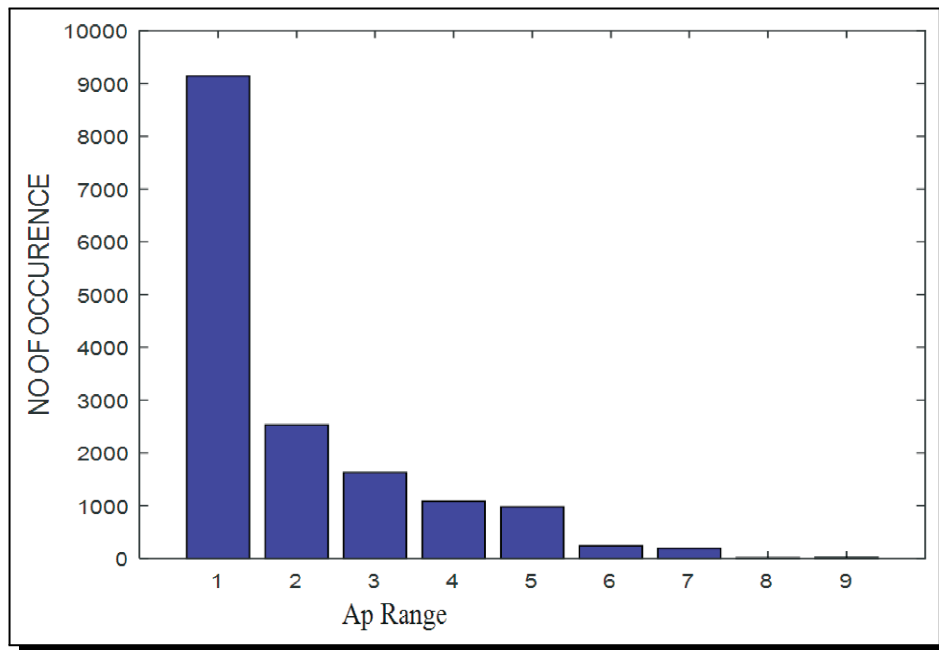
At pre-midnight and the post-midnight period when the electric field is eastward and the F-layer height is falling, the ring current may create a short-lived eastward electric field. Due to this, scintillations may continue to come into view at some other longitudes. For this reason, the F-layer height may rise temporarily before it falls again. Such a situation may create asymmetries and this might be the cause of scintillations during pre-midnight and post-midnight periods (Tiwari *et al.*, 2013).



**Figure 2.** Occurrence of Scintillations over Ilorin in the year 2012 for (a) quiet and disturbed nights in April and (b) September

$A_p$  values measures global level of magnetic disturbance. Figure 3 shows the plot of  $A_p$  values against the amplitude scintillation index ( $S_4$ ) observed at Ilorin, Nigeria during the year

2012. It is clear that the occurrence of  $S_4$  was mainly confined to periods of lower  $A_p$  values, and for periods with higher  $A_p$  group 8–9 (corresponding to values 47–150), there are nearly no  $S_4$  occurrences. The results showed that scintillation may easily occur during geomagnetic quiet days at Ilorin and geomagnetic disturbance may not trigger the  $S_4$  occurrence. This result is in agreement with the result got by Shewta *et al.* (2012).



**Figure 3.** The percentage of occurrence of scintillation with  $A_p$  range over Ilorin in 2012

## 4. Conclusion

It has been inferred from this study that:

- (i) Pre-midnight amplitude scintillations events were localized within the hours of 19:00 – 22:00 local time in Ilorin.
- (ii) The  $S_4$  occurrence was mainly confined to periods of lower  $A_p$  values, and for periods with higher  $A_p$  values (47–150), there are nearly no  $S_4$  occurrences. Increase in geomagnetic activity inhibits the Occurrence of  $S_4$ .
- (iii) Occurrence of  $S_4$  was enhanced in both disturbed and quiet days during pre-midnight night hours and it was suppressed in the post-midnight night hours. Although there were more occurrence of  $S_4$  during quiet days than disturbed days.

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## Competing Interests

The authors declare that they have no competing interests.

## Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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