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Latitudinal Variation Of Occurrence Of Amplitude Scintillations Over Lagos And Ilorin

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***Abstract:** This research investigated the occurrence of dual GPS L-band (L1: 1575.42Hz, L2: 1227.6Hz) amplitude scintillations at the equatorial anomaly region. The data used in this study were obtained from the GPS Scintillation/Total Electron Content (TEC) monitoring equipment installed at the space physics laboratory of the University of Lagos, (geo lat: 6.52°N, long: 3.4°E, dip lat. -3.04°) and the department of physics, University of Ilorin (geo lat: 8.48°N, long: 4.67°E, geomagnetic lat: 1.2°S), Nigeria, via the website of the Low Latitude Ionospheric Sensor Network (LISN, www.lisn.gop.pe) for the year 2012.*

Greater number of amplitude scintillations occurred over Lagos than over Ilorin. Over Lagos, 20,784 occurrences were recorded and 14,930 numbers of occurrences were recorded over Ilorin. Greater number of amplitude scintillations (S_4) were recorded during quiet days in both Lagos and Ilorin than during disturbed days, except in September where there were more S_4 in Lagos during disturbed days than quiet days. Generally, occurrence of S_4 was enhanced during pre-midnight hours at both stations but was suppressed during post-midnight hours, both at quiet and disturbed days at both stations.

I. INTRODUCTION

Radio waves propagating through an irregular, ionized medium exhibit turbulent change in the refraction index and may experience signal scintillation, or randomization in the signal phase and amplitude. The plasma density determines the refractive index for radio waves. The radio waves are particularly sensitive to irregularities in the plasma density within the ionosphere. The electron density change during scintillation events may be as high as 10% in the worst case. The effect of density irregularities as scattering centres is influenced strongly by the relative size of the irregularities compared to the signal's wavelength (Lanzerotti *et al*, 2001).

Scintillation effects are characterized by changes in amplitude and phase (Yeh and Liu, 1982). In this study we discuss the amplitude measure of scintillation, the S_4 index. The S_4 index indicates the amount of variation in the amplitude of received signal power over an interval of time, typically one minute (Lars Dyrud *et al*., 2007). The dimensionless index is given by the expression (Briggs and Parkins, 1963):

$$S_4 = \frac{\left(\langle I^2\rangle - \langle I\rangle^2\right)^{1/2}}{\langle I\rangle} \qquad (1)$$

where I is the signal intensity and $< I >$ is its mean value.

The latitudinal variation of amplitude ionospheric scintillations (S_4) were compared between two stations, namely, Ilorin (Geo Lat: 8.48°N, Long: 4.67°E, Geomagnetic Lat: 1.2°S) and Lagos (Geo Lat: 6.52°N, Long: 3.4°E, Dip lat. -3.04°) respectively during 2012 which is a year of ascending solar activity. The occurrences of the S4 during geomagnetically quiet and disturbed period were also compared and the results are interpreted at the section 2.0.

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II. DATA

The processed data was downloaded from the website of the Low Latitude Ionospheric Sensor Network and was analyzed by using statistical software. The amplitude scintillation data were acquired at two Nigerian equatorial GPS stations, namely; Lagos (Geo Lat: 6.52°N, Long: 3.4°E, Dip lat. -3.04°) and Ilorin (Geo Lat: 8.48°N, Long: 4.67°E, Geomagnetic Lat: 1.2°S). each of the GPS receiver at the two stations is a NovAtel GSV4004B GPS receiver, with a capability of measuring amplitude scintillations at a sampling rate of 50Hz. Typically, amplitude scintillation is quantified by the S_4 index (the standard deviation of the factor $I/\langle I \rangle$ over a *60*s period, where *I* is the intensity of the received signal and *I* is its average value). The receiver at Lagos and Ilorin stations were donated to the University of Lagos and University of Ilorin, Nigeria by the Institute for Scientific Research (ISR), Boston College, USA.

Figure 1 shows the location of the GPS receivers on the map of Nigeria, West Africa. The data covers one year (2012{Zurich sunspot number} (R_Z)): 57.6. The year 2012 is a year of ascending phase of solar cycle 24. In order to be sured that the data used were reliable ionospheric amplitude scintillation data, satellites with elevation angles greater or equal to 30° were taken into consideration, so as to reject signal fluctuations from non-ionospheric origins such as multipath. The scintillation index of the satellite with highest S4 index was taken into account (maxterm).

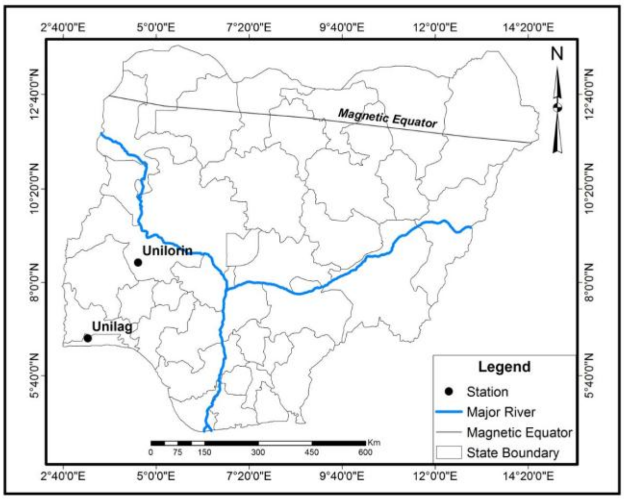

Figure 1: The location of the GPS receivers at Lagos and Ilorin, Nigeria

In order to study the threshold of scintillation three distinct thresholds, namely, moderate, strong and saturated, Gwal et al.., (2004) were considered: Moderate ($0.4 \leq S4 \leq 0.6$); Strong ($0.6 \leq S4 \leq 1.0$); Saturated ($1.0 \leq S4 \leq 1.4$). We also investigated the behaviour of the ionospheric irregularities at the two equatorial anomaly stations during geomagnetically quiet and disturbed conditions.

To study the effect of geomagnetic activity with occurrence of scintillation, geomagnetic index Ap is considered. The Ap index was obtained from the geomagnetic data service of Kyoto at www.kugi.kyoto-uac.jp. The Ap values are divided into nine different categories on the basis of their ranges as tabulated below.

Group	Range
1	0-5
2	6-8
3	9-12
4	13-18
5	19-26
6	27-36
7	37-46
8	47-66
9	67-150

Table 1.0: Ap Group and Ranges

III. RESULTS AND DISCUSSION

Figure 2-3 show the monthly variation and sum total of S4 over Lagos and Ilorin. There were no data for the months of January, May, June, July at Ilorin and also data were absent for the months of September and December at Lagos. The months of February, March and October at Ilorin have more amplitude ionospheric scintillations (S4) than Lagos for the months whose data were present for statistical comparison. But for the months of April, August and November, there were more amplitude ionospheric scintillations in Lagos than Ilorin. Considering the over all, Lagos recorded the highest number of moderate, strong and saturated scintillation than Ilorin. The sum total showed that Lagos had 15,386 number of occurrences and Ilorin had 12,579 number of occurrences. These results further established that the scintillation strength and occurrence probability become larger in proceeding from magnetic equator to the equatorial ionization anomaly (Kil et al, 2002). Lagos' magnetic latitude is 3.04°N while Ilorin's magnetic latitude is 1.2°S.

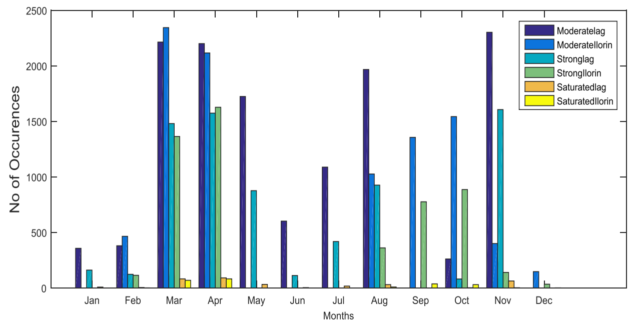

Figure 2: Monthly variation of S4 between Lagos and Ilorin in 2012

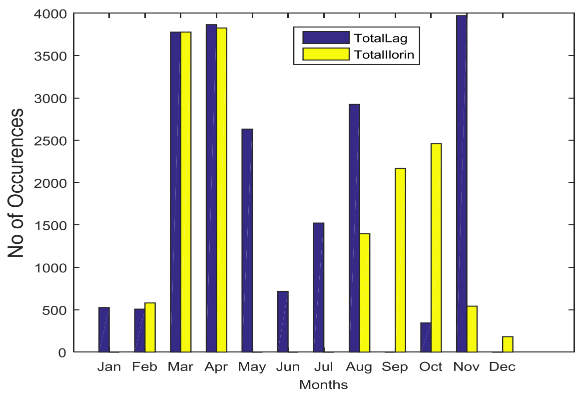

Figure 3: Total sum of Monthly variation of S4 over Lagos in 2012

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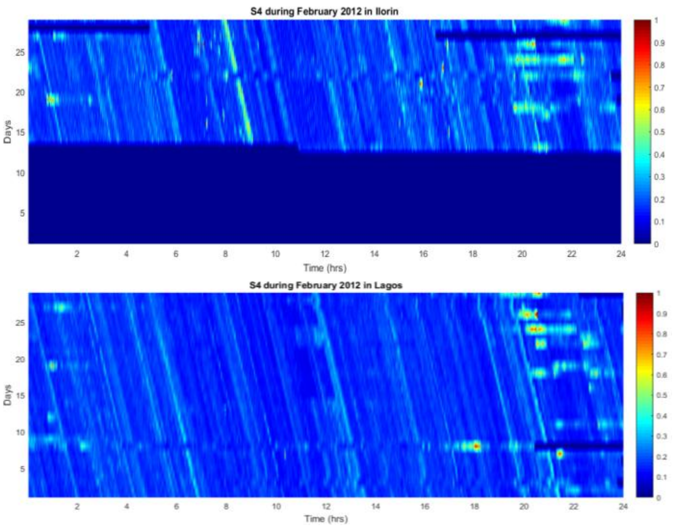
Figure 4.0a-4.0d, show local time variations of amplitude scintillation during different months, February, March, April, August, September, and November over Lagos and Ilorin. At the two stations pre-midnight amplitude scintillations events were localized within the hours of 19:00 – 22:00 local time in Lagos and Ilorin but the month of February is not intense as the other months.

During the day at both stations in the month of March, moderate and strong S4 was observed between 12:00 and 14:00 local time in Lagos and moderate plume was recorded at Ilorin but at different day of the month. At Ilorin, the moderate plume was recorded on the 10th and 19th day of the month of March and over Lagos it was recorded in the 29th day of the month of March. The month of April also recorded intense amplitude scintillation during the daytime at about 7:00 local time over Lagos and the month of August at 8:00 to 11:00 local time on the third day of the month of August.

The post-midnight occurrence of moderate and strong amplitude Scintillations were localized between 0.00 – 2:00 local time in all the months at the both stations. There were no data to compare the months of January, May, June, July, November and December.

During the evening hours, ionospheric density is largely dependent on the electric fields, recombination rate, and neutral winds. At these hours in the equatorial region, the zonal neutral wind and the rapid decay of the E region density interact to develop an enhanced eastward electric field on the day-side of the terminator and a westward electric field on the nightside (Tsunoda 1985, 2010). The enhanced eastward electric field causes vertical upwelling of the F region, and steepens the bottomside density gradient to trigger the Rayleigh–Taylor (RT) instability (Kelley 1989). Consequently, the low-density plasma from the bottomside percolates into the topside ionosphere to develop a plethora of plasma bubbles. Some of these bubbles are short-lived, while the surviving ones transform to a cascade of irregularities of different scale sizes, causing radio signals to scintillate.



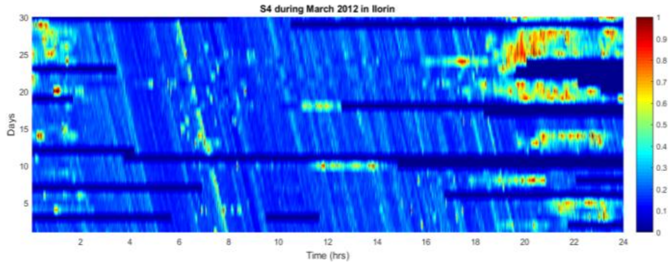


Figure 4.0a: Local time variation of amplitude scintillations

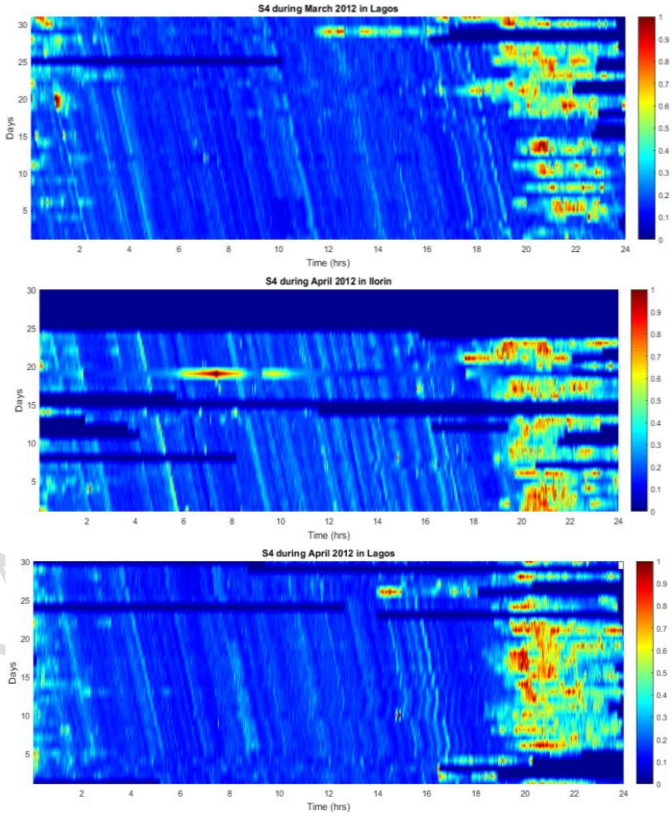
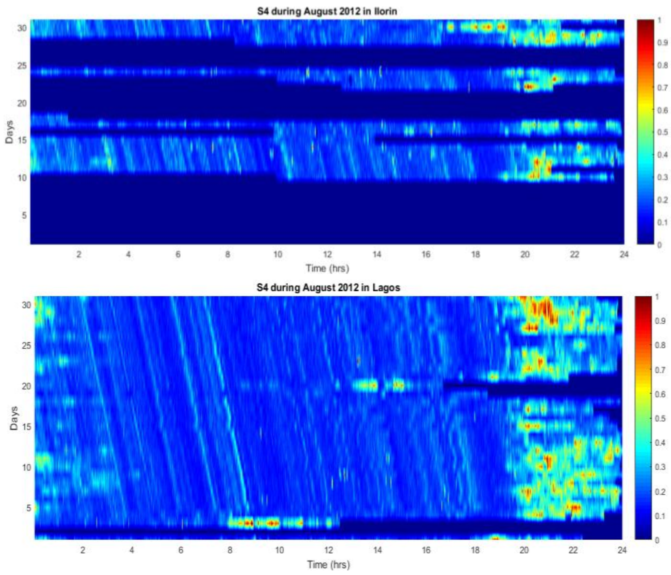


Figure 4.0b: Local time variation of amplitude scintillations



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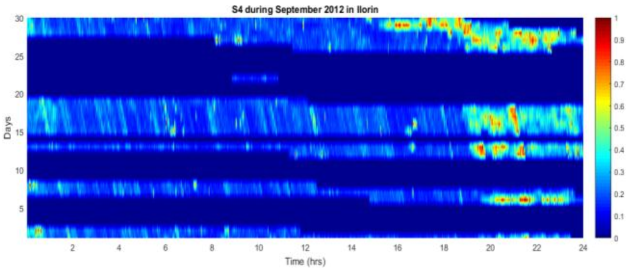

Figure 4.0c: Local time variation of amplitude scintillations

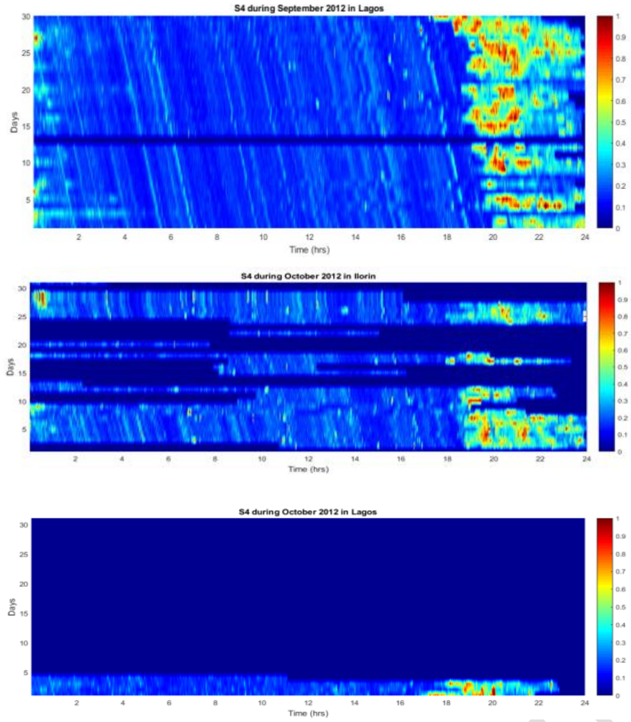

Figure 4.0d: Local time variation of amplitude scintillations

Figure 5.0 shows Variability of S4 index with different groups of Ap index**.** 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.

The Ap values are plotted against the amplitude scintillation index (S4) observed at Lagos and Ilorin during the year 2012. From the figure we can see that the S4 occurrence is mainly confined to periods of lower Ap values, and for periods with higher Ap values (47-150), there are nearly no S4 occurrences. The results showed that scintillation may easily occur during geomagnetic quiet days at Lagos and Ilorin and geomagnetic disturbance may not trigger the S4 occurrence. This result is in agreement with the result got by shewta et al, 2012.

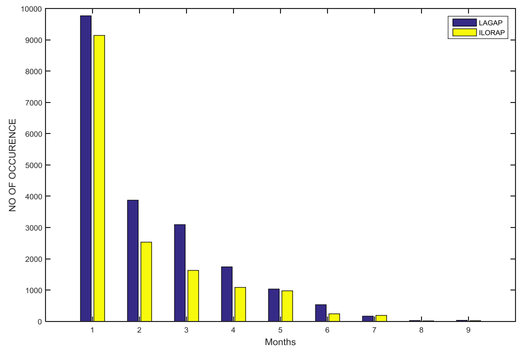

Figure 5.0: Variability of S4 index with different groups of Ap index

Figure 6.0 shows the impact of magnetic activity on occurrence of ionospheric amplitude scintillation was examined at the two stations (Lagos and Ilorin) by comparing S4 occurrence rate on Five international quiet (Q) and five international disturbed (D) days derived from the data downloaded from the website of world data centre (http//swdcwww.kugi.kyoto-uac.jp.). The number of occurrence of S4 for each month of April and September are shown the Figure 6.0.

On disturbed days in April over Ilorin and Lagos, the amplitude of S4 was more enhanced at Lagos during pre-midnight hours than at Ilorin although one can categorically say that at both stations S4 was enhanced during pre-midnight hours and was suppressed at the post-midnight hour this result is in agreement with Sunital *et al* (2013). However, the rate of suppression and enhancement at the both stations were not the same. During the quiet period, the trend reversed; S4 over Ilorin was more enhanced than S4 over Lagos. Generally,, there were more S4 during magnetic quiet days than magnetic disturbed days at both stations and the occurrence of S4 was enhanced during pre-midnight hours at both stations and suppressed during post-midnight hours for magnetically quiet and disturbed periods.

During September at Ilorin, on quiet days the occurrence of S4 was enhanced at the pre-midnight hours than on the disturbed days but it (i.e the occurrence of S4) was suppressed during post-midnight over Ilorin but different event occurred over Lagos in September, the occurrence of S4 was enhanced during disturbed days at pre-midnight even till 24:00LT and after which it was suppressed from 1:00 – 5:00LT.

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. (Sunital et al, 2013).

Although, scintillations may continue to come into view at some other longitudes. At pre-midnight and during 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. The F-layer height may rise temporarily because of this before falling again. Such a situation may create asymmetries and this might be the cause of scintillations during pre-midnight and post-midnight periods (Sunital et al, 2013).

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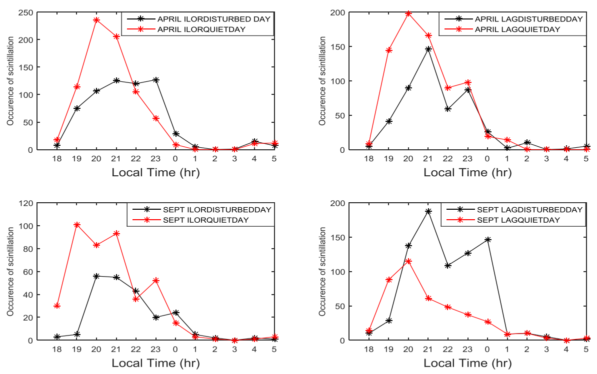

Figure 6.0: Local time occurrence of Ionospheric Amplitude scintillations on geomagnetically quiet and disturbed nights for months of April and September over Ilorin and Lagos

IV. CONCLUSION

The following conclusions may be drawn from the study of the occurrence of L-Band ionospheric scintillation over Lagos and Ilorin, Nigeria within equatorial anomaly region (Lagos Geo Lat: 6.52°N, Long: 3.4°E, Dip lat. -3.04°) and (Ilorin Geo Lat: 8.48°N, Long: 4.67°E, Geomagnetic Lat: 1.2°S).. The data used consist of one minute index of amplitude ionospheric scintillations (S_4) for the period of January 2012 to December 2012.

- ✓ The total number of occurrence of Ionospheric amplitude scintillations (S_4) was higher in Lagos than the number of S4 recorded over Ilorin.
- ✓ The results obtained from this research further established that the scintillation strength and occurrence probability become larger in proceeding from the magnetic equator to the equatorial ionization anomaly (Kil et al, 2002). Note that Lagos' magnetic latitude is 3.04°N while Ilorin's magnetic latitude is 1.2°S.
- ✓ Pre-midnight amplitude scintillations events were localized within the hours of 19:00 – 22:00 local time in Lagos and Ilorin
- ✓ The S4 occurrence is mainly confined to periods of lower Ap values, and for periods with higher Ap values (47-150), there are nearly no S4 occurrences. Increase in geomagnetic activity inhibits the occurrence of S_4.
- ✓ 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 S4 during quiet days than disturbed days.

The ionospheric process such as Equatorial electric field, Rayleigh-Taylor mechanism, pre-reversal enhancement that develops at F region height, the E×B drifts and the fountain effects were suggested to be responsible for the observed dependence.

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