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VHF/UHF AMPLITUDE SCINTILLATION OBSERVED BY THE LOW-LATITUDE IONOSPHERIC TOMOGRAPHY NETWORK (LITN)

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ABSTRACT

Electron density irregularities in the ionosphere that cause rapid fluctuations in radio signals or scintillation has been studied using the Low-Latitude Ionospheric Tomography Network. The network uses Ionospheric Tomography System (ITS) receivers to retrieve VHF and UHF scintillation data from August 2008 to February 2011. Amplitude scintillation, which mostly occurred at the equatorial anomaly peak, varied with local time, solar activity and magnetic activity. Moreover, night-time scintillation occurred predominantly around local midnight (2100-0200 LT), while most of the daytime scintillation occurred at 0900-1500 LT. Generally, the scintillation occurred under quiet magnetic condition and the occurrence increases as the solar activity increases.

Keywords: scintillation, ionospheric irregularity.

INTRODUCTION

The ionosphere is the part of the upper atmosphere that lies between about 50 km to more than 1000 km. It acts as a reflector and distributor of radio waves. Electron density irregularities in the ionosphere cause a significant problem in radio wave propagation, where it generates rapid fluctuations of amplitude, phase, polarization and angle of arrival of a radio signal (Davis, 1990; Das *et al.*, 2010). This effect, called scintillation, can cause a crucial disturbance for radio systems using satellite to ground links near the magnetic equator and at high-latitudes, which includes the polar caps and auroral regions (Bernhardt *et al*., 2000). These significant effects of scintillation at equatorial and low latitude regions attracted many researchers to study the scintillation phenomenon.

Scintillation is usually quantified through the S4 scintillation index or simply the S4-index, where it describes the variance of the received power fluctuations. Specifically, it is defined as the square root of the variance of received signal intensity fluctuations over the time-averaged received signal intensity in dB $\langle P \rangle$ (Bernhardt *et al*., 2000):

$$S4 = \frac{\sqrt{\langle P^2 \rangle - \langle P \rangle}}{\langle P \rangle} \qquad (1)$$

In this study, this parameter, commonly known as amplitude scintillation, is calculated over a 60-s period at 50-Hz sampling frequency from the very high frequency (VHF) and ultra high frequency (UHF) bands of the Low-Latitude Ionospheric Tomography Network (LITN). S4-index is related to diurnal and seasonal variations, as well as to geomagnetic and solar activity.

The low-latitude ionospheric tomography network

The LITN is a network of ground beacon receivers along the 120-130° East longitude. It was re-established in 2006 by the Ionospheric Sounding Laboratory of the Center for Space and Remote Sensing Research, National Central University in Taiwan after the original LITN was retired in 1997 (Hsiao *et al*., 2009). The LITN ground stations is spread from 34°N to 1°S latitude, as shown in Figure-1. Each station is equipped with an Ionospheric Tomography System (ITS) coherent receiving system from Northwest Research Associates, Inc. (NWRA). It can receive mutually coherent signals (150 MHz, 400 MHz and 1066.7 MHz) from low-earth orbit (LEO) satellites, such as the FORMOSAT3/COSMIC satellites and other NNSS-like satellites such as C/NOFS, OSCAR, GFO, RADCAL, and COSMOS.

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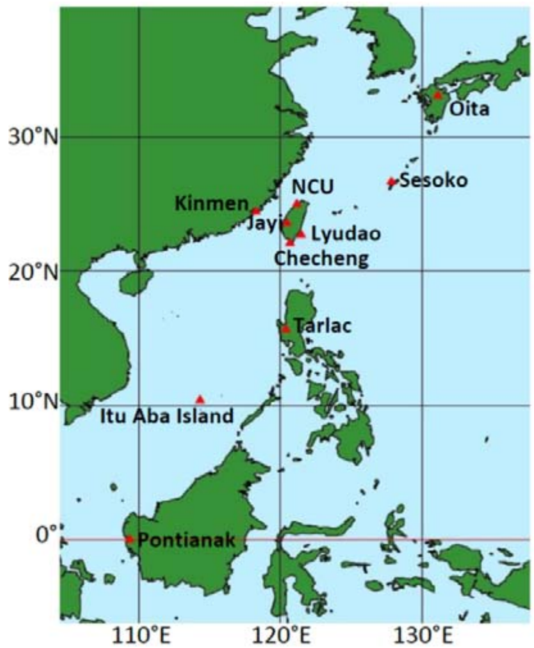

Figure-1. The LITN ground stations.

The ITS uses cross dipole antennas fixed above a ground screen, delivering between -132 and -109 dBm of power at each VHF and UHF frequencies. It outputs the in-phase and quadrature components of the VHF (150 MHz), UHF (400 MHz), and L-band (1066 MHz) signal at a rate of 50 Hz. The mean and S4-index (Equation (1)) are also provided. However, in this study, only the VHF and UHF signals are used.

RESULTS AND DISCUSSIONS

VHF and UHF scintillation, using the their calculated S4 indices, are observed from August 2008 to February 2011 using the ITS receiving stations of the LITN. This period happened during the onset of solar cycle 24 from the late deep solar minimum of 2008 to the increased solar activity in early 2011. During this period, there were 178 days of scintillation found, while 206 amplitude scintillation occurrences were recorded. Figure-2 shows the monthly scintillation events. Most scintillation events happened during spring equinox (Mar-May) of 2009 and 2010 with 24 and 49 events recorded, respectively. This corresponds to 31% and 47% of the total yearly occurrences, respectively. Moderate occurrence of scintillation happened during summer solstice and autumn equinoxes for both years which accounts for seasonal percentage of 28% at the most. But among the 2 seasons, scintillation occurs more often during autumn than summer. Scintillation occurrence was very low during the winter solstice of 2009 and 2010 where yearly percent occurrence is only 9% and 13%, respectively. On the other hand, scintillation occurrence generally increases with as solar activity.

As shown in Figure-2, scintillation occurrence varies with season and solar activity. Generally, increased background ionization generally favours the formation of irregularities in the ionosphere (Gwal *et al*., 2004). This implies that scintillations takes place most often during spring and autumn equinoxes during moderate and high solar activity. But this does not hold true during low solar activity because of low background ionization throughout the year (Ray and DasGupta, 2006). In addition, variations of equatorial scintillations with respect to seasonal and solar activity can be described in terms of the variation of pre-reversal enhancement (PRE) of the zonal electric field during local F-region sunset with season and solar activity. PRE is said to an indicator that ionospheric irregularities along the magnetic equator will be generated. Fejer *et al*. (1979) observed that PRE occurs more often during high solar activity than low solar activity. Moreover, the height of the F region decreases resulting in sparse scintillation occurrence during solar minimum. On the other hand, the asymmetry in occurrence between equinoxes, i.e. lower occurrence during autumn equinox than in the spring equinox, may be credited to the difference in background ionization between the two which is an effect of ionospheric composition changes, such as atomic oxygen density, among others (DasGupta *et al*., 1985; Patel *et al*, 2005; Ray and DasGupta, 2006).

Figure-3 shows that scintillation generally occurred under quiet magnetic condition. A total of 201 events have been recorded when Kp ≤ 3, which is 98% of the total events. There were only 5 scintillation events observed during active magnetic condition (Kp > 3), which accounts to only 2% of the total observed scintillation events. As mentioned by Patel *et al*. (2005), the increase in geomagnetic activity subdues occurrences of scintillation. However, disturbances in the ionosphere, such as solar or geomagnetic storms can enhance electrodynamic processes in the ionosphere, such as the equatorial electrojet and the equatorial ionization anomaly (EIA). These may cause significant increase background ionization that may provide the necessary conditions in order for irregularities to be generated (Abdu, 2005).

The local time distribution of scintillation events is shown in Figure-4. Night-time scintillations (deep green filled) occurred predominantly around 2100-0200 LT with 103 events during this time or 50% of the total events. Peak occurrence happens around midnight time. On the other hand, most of the daytime scintillation (light green filled) occurred at 0900-1500 LT and accounts for 61 events or 30% of the total events. Peak daytime scintillation occurred during 0900-1000 LT. However, scintillation rarely emerges near sunrise (0500-0800 LT) and before sunset (1600-1800 LT) with less than 10 events during these periods.

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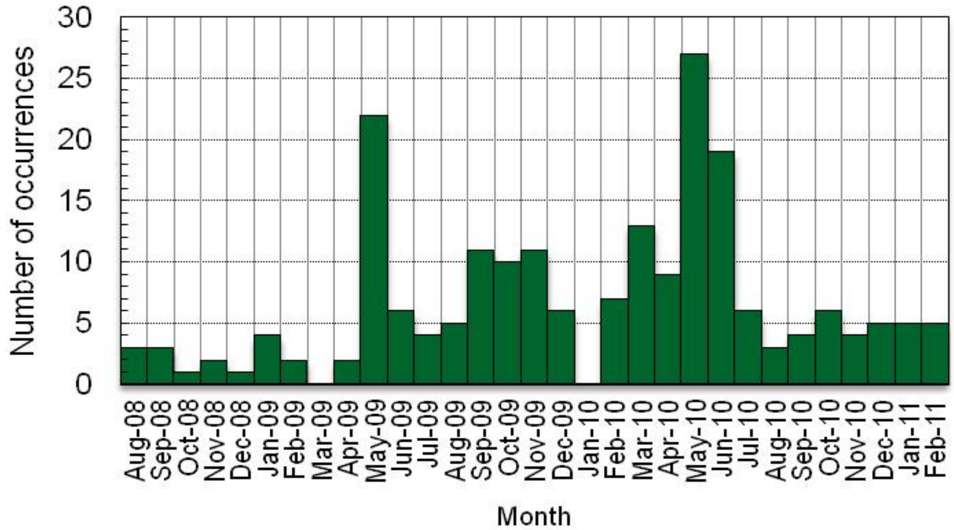

Figure-2. Monthly amplitude scintillation occurrences from August 2008 to February 2011.

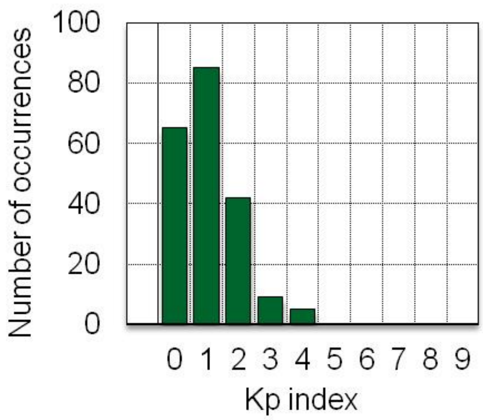

Figure-3. Magnetic activity variations of scintillation occurrence from August 2008 to February 2011.

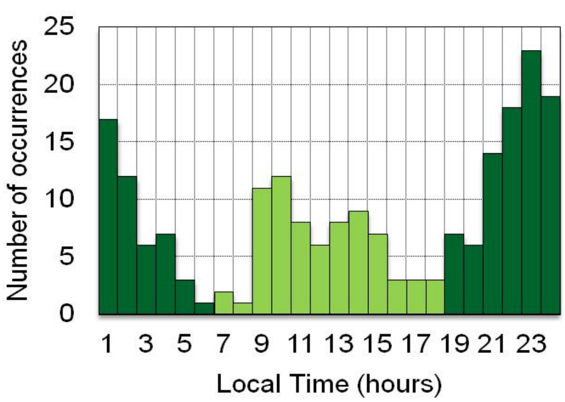

Figure-4. Local time distribution of scintillation events from August 2008 to February 2011.

At low latitude regions, night-time scintillations are generally associated with the generation and growth of F region irregularities over the magnetic equator (Zou, 2011). These irregularities, commonly known as spread-F irregularities, are formed at the bottom side of the F region after the PRE during sunset where PRE may provide the initial density perturbation in the formation of plasma bubbles. That is, if the height of the PRE reached a threshold altitude the bottom side ionosphere would produce a large electron density gradient. If this is large enough, recombination effect is overcome and the Rayleigh-Taylor instability process will initiate the growth of the plasma density perturbation. Once the primary bubbles are formed, they penetrate through the topside ionosphere and develop into plumes (Gwal *et al*. 2004). These irregularities are mapped poleward towards the EIA region along the magnetic flux tubes until it reach the region of EIA crests.

On the other hand, scintillation occurrence rate during daytime is relatively low. It is commonly attributed to sporadic E (Es) layer irregularities. The Es layer appears periodically in the altitude range between 90 and 120 km with enhanced electron density, where it contains a significant quantity of long-lived metallic ions. Its formation is said to be due to gradient drift instability in the low- and mid-latitude regions (Zou, 2011). These irregularities can be a several meters to a few kilometres and they can cause strong scintillations especially in the UHF and VHF bands especially during daytime. On the other hand, night-time Es may add to the effects of spread-F irregularities in the radio wave propagation.

Figure-5 shows the geographic distribution of scintillation event map from August 2008 to February 2011. The occurrence points were projected from 350 km height, which is considered as the average of the F-layer peak density height. Scintillation mostly occurred at the

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EIA peak. Gwal *et al*. (2004) observed that scintillation activity increases from the magnetic equator to the EIA region because of the increase in background ionization.

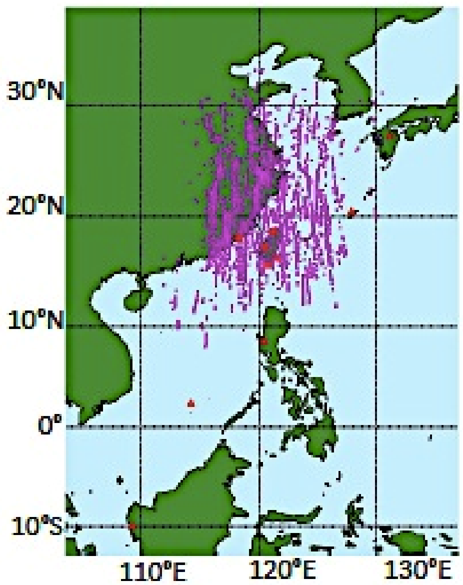

Figure-5. Geographical distribution of VHF and UHF scintillation.

CONCLUSIONS

The amplitude VHF and UHF scintillations show variations with local time, geographical location, solar activity, and magnetic activity. Increase in solar activity is found to promote scintillation occurrence. Scintillation occurrences were increasing from low solar activity (2008-2009) to higher solar activity (2010-2011). However, scintillations are observed more frequently during the equinoctial months, especially during high solar activity. The relation between scintillation occurrences and magnetic activity is also found where scintillation mostly occurred during quiet magnetic activity (Kp $\leq$ 3). The local time variations of the amplitude scintillation showed that night-time scintillations are more predominant than daytime scintillations. However, scintillations rarely occur near sunrise (0500-0800 LT) and before sunset (1600-1800 LT). Scintillation mostly occurred at the EIA peak.

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