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Analytical Study of Nighttime Enhancements in TEC and related Amplitude Scintillation at Low Latitude Bhopal during Low Solar Activity Period

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Abstract

As the ionosphere is dispersive in nature, the delay in the GPS signals is proportional to the inverse of the squared frequency and directly proportional to the refractive index of TEC. The TEC in turn depends on the geographic latitude, longitude, local time, season, geomagnetic activity and viewing direction. Some natural perturbation termed as irregularities, are present in the form of electron density of the ionosphere that cause disruption in the radio and satellite communications. Therefore the study of the ionospheric irregularities is of practical importance, if one wishes to understand the upper atmosphere completely. In order to make these communications uninterrupted the knowledge of irregularities, which are present in the ionosphere are very important. These irregularities can be located and estimated with the help of Ionospheric Total Electron Content and Scintillation. Scintillation is generally confined to nighttime hours, particularly around equatorial and low latitudes. In order to emphasize the relationship between TEC enhancements and amplitude scintillation, an attempt has been made to investigate the association between TEC enhancement and amplitude scintillation. We have studied this relationship using TEC and scintillation data using GPS measurements at Bhopal (23.23° N, 77.54°E), a station near the anomaly crest region for the period March 2004 – February 2005 during low solar activity, which corresponds to ascending phase of 23rd solar cycle. The results are discussed in terms of the mechanisms believed to be responsible for the association of two phenomena.

Keywords: Nighttime TEC, Scintillation, Low solar activity, Ionosphere

Introduction

Irregularly structured ionosphere (i.e. inhomogenities in refractive index) can cause fluctuations (due to refraction effects) on the radio signal that is passing through it. These fluctuations are called ionospheric scintillations. Low latitude region is suitable for studying these scintillations. The influence of the ionosphere on the propagation of the radio wave becomes very marked with reference to communication or navigational radio system at very low frequency (VLF) to a high frequency (HF), which operate over the distances of 1000 km or more. Radio wave communication at different frequencies depends on structure of the ionosphere. With the advent of the artificial satellites, they are used as a prime mode of radio wave communication. Some natural perturbation termed as irregularities, are present in the form of electron density of the ionosphere that cause disruption in the radio and satellite communications. Therefore the study of the ionospheric irregularities is of practical importance, if one wishes to understand the upper atmosphere completely. In order to make these communications uninterrupted the knowledge of irregularities, which are present in the ionosphere are very important. These irregularities can be located and estimated with the help of Ionospheric Total Electron Content and Scintillation (Huang 1978).

Scintillation is generally confined to nighttime hours, particularly around equatorial and low latitudes. The electron content enhancements are attributed to changes in the bottom side ionosphere driven by dynamic mechanisms possibly of tidal origin. It is suggested that the reduced winds in the lower thermosphere allow the upward penetration of medium scale gravity waves from tropospheric sources resulting in scintillation-producing irregularities (Titheridge,1968).

Data and Method of Analysis

A GSV 4004A GPS receiver has been operational at the crest of the equatorial anomaly at Barkatullah University Bhopal, India since 3 December 2003. The receiver provides the total electron content data and the amplitude scintillation index, S_4. Both the amplitude scintillation and the enhancement in nighttime TEC are the irregular phenomena.

The Amplitude scintillation is measured by the S_4 parameter (defined as the normalized standard deviation of the temporal intensity fluctuations at the receiver), with a correction factor included to eliminate the effects of ambient noise (Dierendonck et al., 1996).

In characterizing nighttime TEC enhancement, the same criterion as that adopted by Unnikrishnan et al., 2002 was applied. Accordingly, a nighttime TEC enhancement was defined as the excess content

(ΔTEC), which remained after the exponentially decaying background of the diurnal content was subtracted from the total content. The maximum difference between the enhanced TEC and the background content gave the excess content, which is called the “amplitude”.

Only those days were considered on which enhancements and scintillation occurred together. Only those enhancements that have peak amplitude (ΔTEC_{max}) ≥ 20 % of the background content level and scintillation activity (SI_{max}) ≥ 0.25 units have been considered. Various parameters such as time of occurrence, time of peak, peak amplitude and duration of enhancement in TEC and that of scintillation activity have been determined; then average value of parameters during the course of the events are computed. Only those days were considered in study when scintillation and nighttime enhancement occurred together in order to study the relationship between the two irregular phenomena.

Results and Analysis

The hourly data of the total electron content and amplitude scintillation has been analyzed statistically and morphologically to explore the relationship between anomalous nighttime enhancement in TEC and amplitude scintillation using GPS measurements occurred for the period of March 2004 - February 2005 at Bhopal during low solar activity. The events were looked at in terms of their amplitude, probability of occurrence, time of occurrence, their duration, peak time and their dependence upon local time, solar and magnetic activity. All the characteristics of both the phenomena were analyzed in local time.

Figure 1 illustrates some exemplar of the nighttime enhancement in TEC and corresponding scintillation activity on certain nights observed during low solar activity at Bhopal from March 2004 – February 2005. We have considered that the increase in TEC is an excess content or mean peak amplitude (ΔTEC), as regards the nighttime bottom level in the diurnal TEC course. Irregularly structured ionospheric regions can cause diffraction and scattering of trans-ionospheric radio signals. When received at an antenna, these signals present random temporal fluctuations in both amplitude and phase known as ionospheric scintillation.

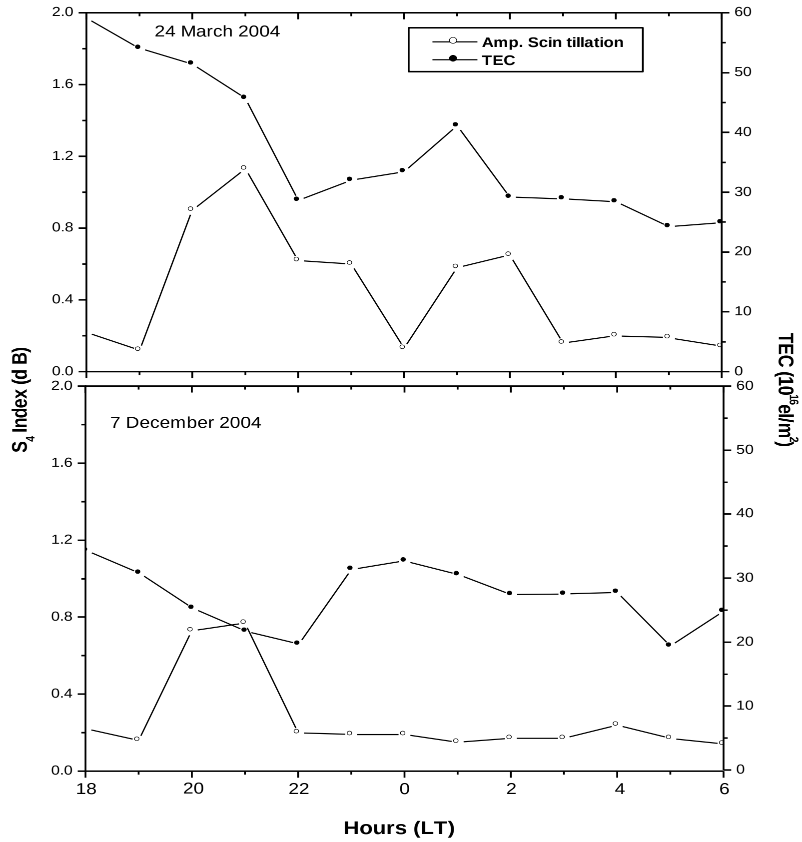

Figure-1: Examples of Amplitude Scintillation for the period March 2004 – February 2005 at Bhopal (low solar activity period)

The outcome indicates that

1. Both the phenomena occur in the pre midnight as well as during post midnight hours at Bhopal.
2. The TEC enhancements and associated scintillation activity occur more frequently during equinox months and seldomly in summer months.
3. Scintillations occur on average 1.5 to 2 hours before than the TEC enhancements at Bhopal.
4. There are some strong TEC increases, which have ΔTEC greater than 25% to background content and maximum scintillation observed is of 1.2 units.

5. The duration of enhancements is often large (about 5 hr and more) as compared to that of scintillation.
6. Some examples show a complex character of the nighttime increases in TEC and the associated scintillation activity.

Throughout the period of annotations, it is find that total 89 nights show enhancements in nighttime TEC of which 36 for equinox, 32 for winter, 21 for summer months. Out of total events, only 49 events of TEC enhancements were found to be associated with amplitude scintillation (21 for equinox, 15 for winter, 13 for summer) and used for the analysis. It is observed that the two phenomena occur frequently in equinox and seldomly in summer.

Figure 2 presents the month-to-month variation of occurrence of nighttime enhancements in TEC alone, scintillation activity alone and both the phenomena together observed at Bhopal from the period March 2004 - February 2005. Obviously, the frequent occurrences (both the phenomena together) are much less than the individual ones.

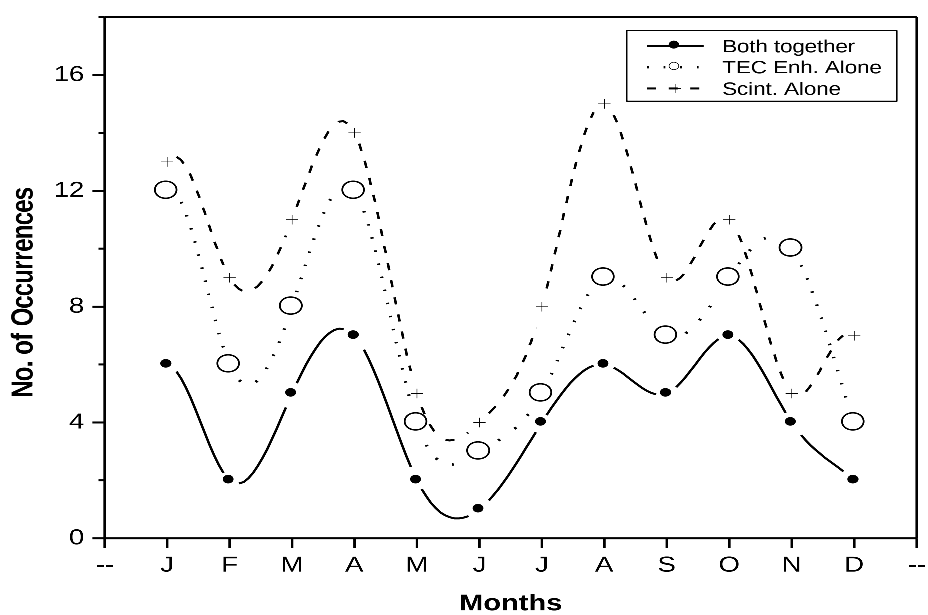

Figure 2: Month to month variation of total number of occurrences of the nighttime TEC enhancements, Amplitude Scintillation and both the phenomena together for the period March 2004 – February 2005 at Bhopal

From the figure, it is clear that all scintillation events are not related with nighttime enhancements in TEC while majority of events are associated with TEC enhancements. The maximum numbers of occurrences of both the phenomena in all the cases were observed in equinox months while minimum in summer months. Both the phenomena occurred together more frequently during equinox month while less during summer month as depict from Figure 2.

Discussion

The data analysis allows us to explore the relationship between nighttime enhancements in TEC and associated amplitude scintillation their characteristics at low latitude station, Bhopal (23.23° N, 77.54° E, Dip 18.5°), near the crest of anomaly using GPS measurements. The results presented above provide a convincingly comprehensive picture of monthly and local time variation, on various characteristics of nighttime enhancements and amplitude scintillation at Bhopal during low solar activity for the period March 2004 – February 2005. The results presented above clearly show that there is a good relationship between nighttime TEC enhancements and the amplitude scintillation i.e. both the phenomenon are well correlated.

Simultaneous occurrence of amplitude scintillation and nighttime enhancement in TEC near the equatorial region may have some relevance and govern by the similar processes responsible for these two phenomena. The post sunset enhancements in the upward equatorial **ExB** drift velocity combined with meridional neutral air wind is believed to be responsible for the nighttime enhancement in TEC around the crest of the equatorial anomaly. On the other hand nighttime amplitude scintillations in this region are mainly associated with Equatorial Spread F (ESF) irregularities. The reverse plasma fountain provides favourable condition for generation and propagation of plasma bubbles and spread F irregularities. Thus the nighttime enhancement in IEC and strong amplitude scintillation around the crest of equatorial anomaly region are controlled by **ExB** drift velocity and are modulated by neutral winds (Jain et al., 2000).

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