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Role and Challenges of Space Weather on Human Society, & its Management with the help of Ionospheric TEC

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Abstract

Space weather affects spacecrafts as well as ground based systems and in the worst case leads to loss of property and life. The main cause of space weather effects is our sun. It emits a continuous stream of particles which is called the solar wind. The energy that has evolved on the sun, when reaches the earth, disturbs the conventional ionosphere. The ionosphere is that part of the earth's atmosphere which is capable of reflecting electromagnetic waves due to the presence of free ions. These free electrons can absorb radio signals, but these electrons typically reradiate the signal. This results in the group or propagation velocity. If the electron density changes without the user's knowledge, the navigation system miscalculates the distance of the signal path due to signal delay, creating navigational error. The study of number of these ions present in the atmosphere is done in terms of TEC in the ray path from the satellite to the receiver in a unit cross-sectional area. Since the number of ions distribution in the atmosphere do not remains uniform throughout the year but are found to vary with the variation of the position of the sun as well as the amount of energy reaching the earth from the sun (i.e. according to Solar Activity), henceforth the study becomes very important. In the present paper we have tried first to calculate the TEC and then the delay caused in the signal transmission. Both, the TEC and the Delay have been plotted and the graphs have been discussed in detail. The pros and cons of the signal delay could be devastating for human health and life.
Keywords- Space Weather; Ionosphere; Delay; TEC; Solar Activity.

1. Introduction

The study of space weather, the result of solar activity, is important as it affect spacecrafts by charging (surface charging and deep discharges) and single event effects. The effects on humans in space are also to be considered (radiation, particles). Space weather effects also play a role on high altitude / high latitude air-flight; cosmic rays penetrate to the lower atmosphere and pose problems to humans and electronic components. Other influences of space weather include radio wave propagation, satellite-ground communications, global satellite-based navigation systems, power transmission systems on the earth.

The ionosphere, broadly a heterogeneous medium, is the main source of signal transfer. It is the Ionosphere which makes possible radio communication over large distances through one or more ionospheric reflection. Therefore estimating the ionospheric conditions in real time would be of great use to communication and navigation system operators, since ionospheric disturbances can adversely affect radio propagation. The work on TEC of the ionosphere by using Geo-stationary satellite

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beacons have been carried out by many workers (Titheridge, 1966; Walker and Ting, 1972).

2. Methodology

The code measurement technique is used in GPS system receiver's for computing TEC. It measures an apparent transit time of the signal from the satellite to the receiver. It is the difference between the signal reception time as determined by the clock in the receiver and the transmission time at the satellite as marked on the signal. It is the amount of time shift required to align the C/A code replica generated at the receiver with the signal received from the satellite Pseudorange is defined as the transit time so measured multiplied by the speed of light in vacuum. TEC can be calculated by the pseudorange measurements using dual frequency as $\rho_{L1} - \rho_{L2}$, where ρ_{L1} and ρ_{L2} are the pseudorange measured on L1 frequency and L2 frequency respectively (Klobuchar J.A., 1996).

$$\Delta t = \frac{k}{f^2} TECU$$

The delay Δt is given by
Where k=40.3 and 'f' is the signal carrier frequency. For the GPS L1 frequency where fL1=1575.42 MHz one TECU corresponds to a delay of approximately 0.16237 meters.

3. Experimental Data and Analysis

The systematic and appropriate data for a year of the TEC in the low latitude station (Bhopal, 23.2°N Lat. 77.4°E Long.) of Indian sector was collected by logging the GPS receiver. The average of the slant TEC for all the visible satellite was done for every 60 sec value, with the cut off elevation of 30 degree. The average of the slant TEC measured at every 60 second intervals was then converted to vertical TEC for the study of temporal variation of TEC. For the TEC analysis purpose the days were chosen such that they were quiet in terms of solar and magnetic activity. Later the delay was calculated from VTEC.

4. Result and Discussion

The study of the ionospheric variability was carried out by the beacon from the American series of the LEO satellites. The plots in the Fig.-1, is of VTEC

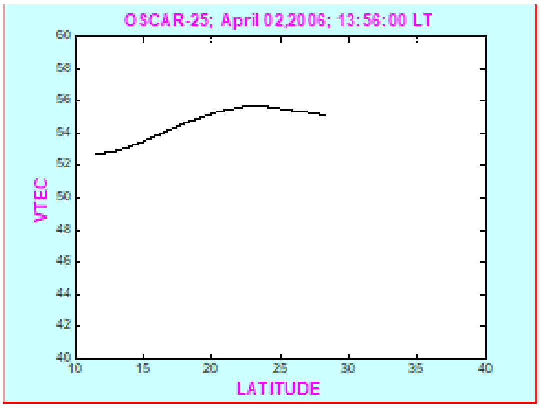

Fig. 1:- TEC records from the Oscar-25 satellites which passed during 1356 LT hours on April 02, 2006 recorded at Bhopal.

calculated from beacon of Oscar-25 satellite which passed during 13:56 LT hours on April 02, 2006. The X-axis of the plot represents the sub-ionospheric latitude crossed by the satellite ray path and Y-axis shows the dispersion of VTEC as per the ionization distribution along the different latitudes. The pass of the satellite so observed from the Bhopal station has shown the maximum coverage of about 20º latitude i.e. from 10ºN to 30º N latitude. The TEC at Bhopal (low latitude station) is found to be more compared to the latitude towards equator. This is evident of the presence of Equatorial ionization anomaly, as Bhopal is situated at the crest of anomaly. The ionospheric total electron content for the Malaysian region was carried out using GPS satellite (Wahi et al., 2005). From Fig.1, it is also clear that the latitudinal belt, for the sort duration of time remains stable as the plot of TEC of the ionosphere between the satellite and ground receiver is found to be smooth at all the latitudes. Some disturbance if arrives may be due to the presence of some irregularities or may be basically due to loss of lock problem.

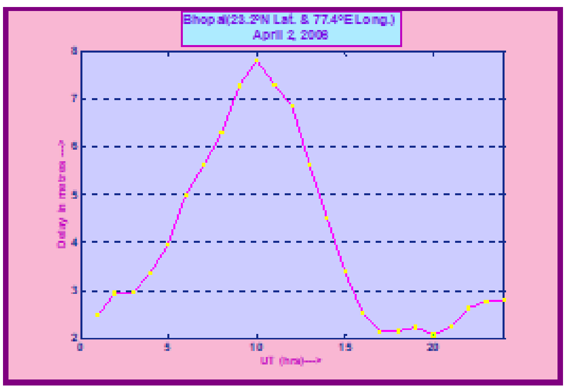

Fig. 2:- Delay in meters recorded on April 02, 2006 from GPS receiver at Bhopal.

On the day of pass of Oscar-25 satellite i.e. on April 02, 2006, a GPS receiver was also logged and the delay calculated has been shown in Fig. 2. The plot of delay reflects the same morphology as that of vertical TEC. The maximum delay was found to be 7.8 meters during 10 UT, this was also the pass period of Oscar-25 satellite. Thus we can infer that the Oscar-25 passed at the time when the amount of ionosphere was at maximum. Doherty et al. (2004) showed July 2000 storm presented the highest range delays. The peak value of the TEC recorded at crest of anomaly was about 55 TECU (Fig.1). The minimum delay recorded was 2 meters during 20 UT (Fig.2).

5. Conclusion

The following conclusions are drawn from the work as summarized below:-

- The ionosphere remains quiet during the short duration of time
- A pronounced maxima of the Total Electron Content is found at over head which gives the picture that the Bhopal is situated at the crust of anomaly.
- The peak value of TEC recorded at crest of Anomaly was about 55TECU.
- The maximum value of delay was found to be 7.8 meters during 10 UT

Thus studying the TEC in detail and predicting it in advance will help to forecast the space weather variation. This will be very much helpful in overcoming the navigational errors and early alarming of magnetic storms, which in turn will prove to be a boon to human civilization.

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