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Ionospheric Scintillation During Night Time Beyond EIA, Using GPS

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Abstract

Ionospheric scintillation is the rapid change in the phase and/or the amplitude of a radio signal as it passes through small scale plasma density irregularities in the ionosphere. These scintillations not only can reduce the accuracy of GPS receiver pseudo-range and carrier phase measurement but also can result in a complete loss of lock on a satellite. Scintillation in the ionosphere varies as the sun spot number (SSN), Geomagnetic index (o < Kp < 9), time of year, time of day, geographical position. Most scintillation occurs for a few hours after sunset during the peak years of the solar cycle. Typically delay locked loop/phase locked loop designs of GPS receivers enable them to handle moderate amount if scintillations. Consequently, any attempt to determine the effects of scintillations on GPS must consider both predictions of scintillation activity in the ionosphere and residual effect of this activity after processing by a receiver. In this work dual frequency (f1 = 1.5 GHz, f2 = 1.2 GHz) GPS data recorded at mid latitude station Palampur (Geographic latitude 32.117 ^{0} N, longitude 76.533^0 E) have been analyzed to monitor the amplitude scintillation index (S4) for April 2014. The analyzed data is used to study the ionospheric scintillation at mid latitude. It is found that at mid latitude there is the ionospheric scintillation in 28 days in pre night hours and one day in post night hours.

Keywords: Equatorial Ionization Anomaly and Ionospheric Scintillation

Introduction:

Ionospheric scintillation is the rapid change in the phase and/or the amplitude of a radio signal as it passes through small scale plasma density irregularities in the ionosphere. These scintillations not only can reduce the accuracy of GPS receiver pseudo-range and carrier phase measurement but also can result in a complete loss of lock on a satellite. Small-scale structures in the electron content of the ionosphere can range from a few meters to a few kilometers in extent which can cause both refraction and diffraction effects on the electromagnetic waves propagating through the ionosphere. Ionospheric scintillation on GPS radio links is a phenomenon originating in the Earth's upper atmosphere which has both theoretical and practical interest. Indeed, scintillation is the footprint on radio links of complex plasma dynamics and hence it can be used for remote sensing of ionospheric irregularities (Wernik et al. 2003). On the other hand, scintillation may affect radio communications severely, harming their information content and can even cause the loss of the signal by a receiver (Yeh and Liu, 1982). In any case, it is desirable to have statistical tools to single out scintillation events and identify their characteristics as effectively as possible. The percentage of irregularities in these fluctuations is usually very small, but it can be as large as nearly 100% near the equator .Variability of ionospheric irregularities are of serious concern to radio communications because these irregularities affect the amplitude and phase of satellite signals. Amplitude variations may induce signal fading, and when depth of fading exceeds the fade margin of a receiving system, message errors are encountered. If navigation is dependent on the GPS, then amplitude fluctuations may lead to data loss and cycle slips. Sudden phase changes may cause a loss of phase lock in GPS receivers (Basu et al., 1993). Equatorial scintillations during a high solar activity period have been found to be sufficiently intense to disable many communication and navigation systems (Groves et al., 1997). Hence, it is necessary to understand the role of space-weather events on scintillations. The amplitude scintillation during high solar activity times at the equatorial region can reach 20 dB at 1.5 GHz (Bishop et al., 1996). The phase scintillations are rapid changes in signal phase that can be attributed to rapid but very small changes in the ionospheric electron content. The scintillations vary widely with frequency, time of the day, season, geographical place and magnetic as well as solar activity, (*Aarons,* 1982; *Das Gupta et al.,* 1983). According to (*Sripathi et al.,(*2012) if irregularities are confined to a layer of less than ~100 km thickness, only phase fluctuations get emerged and further propagation of radio waves to the plane of the receiver produces amplitude fluctuations also.

Nighttime equatorial F-region is a seat of intense plasma density irregularities encompassing scales from about 1000 km to a fraction of a meter. These plasma density irregularities are associated with the phenomenon of equatorial spread-F as seen in radio soundings of the ionosphere, radio wave scintillation in trans-ionospheric propagation. Amplitude scintillation

Amplitude Scintillation

Amplitude scintillation is quantified by the S4 parameter which is defined as the square root of the normalized variance of signal intensity over a given interval of time.

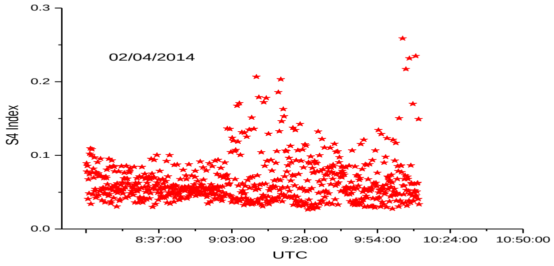
$S_4 = \sqrt{\frac{<SI^2>-<SI>^2}{<SI>^2}}$ Where SI is signal intensity and <> represents the expected value of the signal intensity. S4 is a dimensionless number with a vertical upper limit of 1.0, commonly estimated over an interval of 60 seconds. There are two defined regions of amplitude scintillation weak and strong which roughly correspond to the type of scattering associated with each. Strong scintillation is greater than ~ 0.6 and is associated with strong scattering of signal in the ionosphere. Below this is weak scintillation. An S_4 level below 0.3 is unlikely to have a significant impact on GPS.

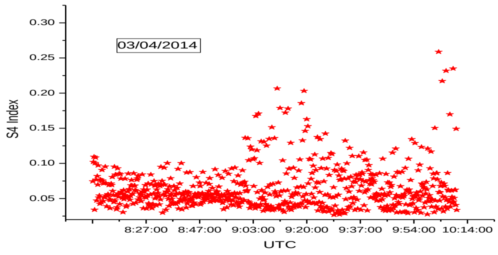
Data Selection and Methodology: Scintillation has been monitored by employing GPS receiver at Department of Physics, Sri Sai University, Palampur, Himachal Pradesh, India, since 1st April, 2014. The amplitude scintillation was monitored by computing the S4 index, which is defined as the standard deviation of the received signal power normalized to the average signal power. It is calculated for each 1-minute period based on a 50-Hz sampling rate. The GISTM also computes the S4 index due to ambient noise in such a way that a corrected S4 index (without noise effects). It measures phase and amplitude (at 50-Hz rate) and code/carrier divergence (at 1Hz rate) for each satellite being tracked on L1 and computes TEC from combined L1 and L2 pseudorange and carrier phase measurements. The primary purpose of the GSV4004A GISTM is to collect ionospheric scintillation and TEC data for all visible GPS satellites (up to eleven). In this research paper we have taken only one month data for the study of scintillation and S4 index is taken in which the amplitude is greater than 0.2000. All scintillation data is analyzed with an elevation angle of 35^0.The occurrence of ionospheric scintillation events has been noted down starting from 2nd April to 30 April 2014.

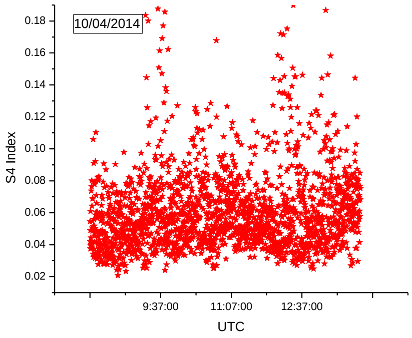
Results and Discussion:

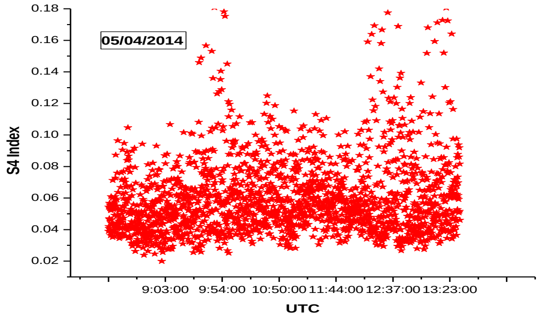
Here in the present work we have taken the numerical value of S4 index 0.2000 as the threshold value of the ionospheric amplitude scintillation. In this paper we have studied only the night time scintillation. **PRN 7** shows the scintillation during 18 days out of 29 days of value of 0.2-0.4 in pre night time and PRN 9 also show the scintillation in pre night hours during 6 days as shown in table 1 and day wise graphical representation. PRN 22, 14, and 20 show the scintillation during pre night hours where as only PRN 21 shows the scintillation of value 0.34 in post night hours. The prn-7 has observed 18 days their values of scintillation lies between 0.2-0.4 at time 8:00-14:00 UT. The prn-9 has 6 days their values of scintillation lies between 0.2-0.4 at time 12:00-16:00 UT. The prn-5, prn-21 and prn-6 has one day their value of scintillation lies between 0.2-0.4 at time 18:18 , 21:37 and 6:36. The prn-20 has one day and their value of scintillation lies >0.6. The prn-22 has one day and their value lies between 0-0.2 having no scintillation, so the maximum value lies between 0.2 -0.4 having mild scintillation in pre night. A station like Palampur which is located beyond the northern crest of EIA the scintillation occurrence found is low. The results presented highlight the pattern of occurrence of scintillation at this region which shows that rate of occurrence is more at post midnight hours then the pre -midnight hours(reverse in case). The cause of this pattern observed here is Propagation Geometry Effect with respect to the magnetic field direction. That means the scintillation pattern observed depends more upon propagation geometry effect than ionization density irregularities. In the late night hours the intense scintillation are observed on GPS links which are at low elevation angles towards the south i.e., the satellite which are viewed end-on through the field- aligned plasma bubbles, traversing a greater distance through the bubble . Therefore during this local time period moderate to intense amplitude scintillations are observed on GPS links.

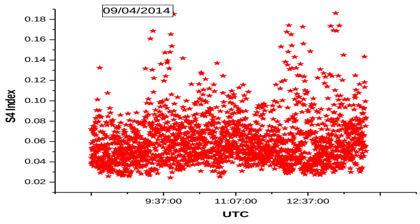
Graphically some plots of PRN 7 and 9 are shown by graphical representation as

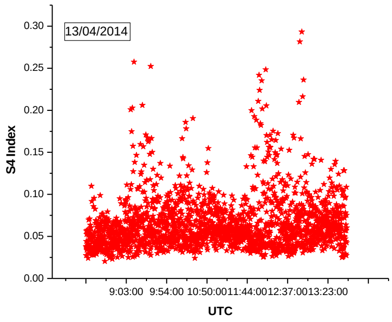

02/04/2014
S4 Index
0.3
0.2
0.1
0.0
8:37:00
9:03:00
9:28:00
9:54:00
10:24:00
10:50:00
UTC

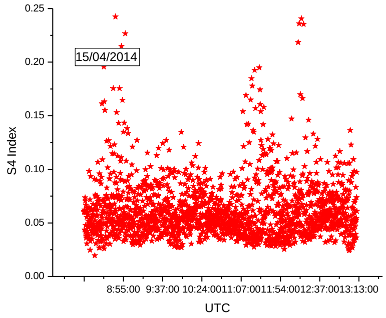

03/04/2014
S4 Index
0.30
0.25
0.20
0.15
0.10
0.05
8:27:00
8:47:00
9:03:00
9:20:00
9:37:00
9:54:00
10:14:00
UTC

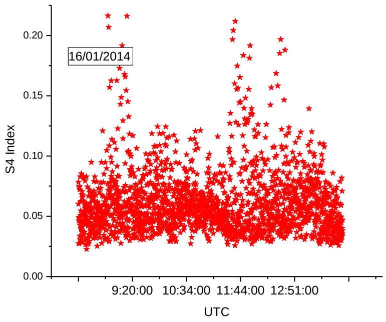

10/04/2014
S4 Index
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
9:37:00
11:07:00
12:37:00
UTC

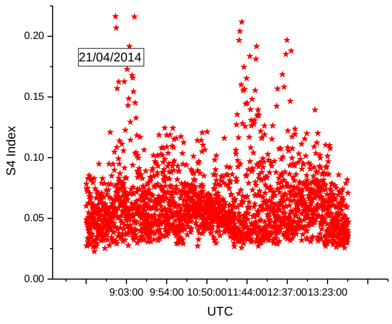

05/04/2014
S4 Index
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
9:03:00
9:54:00
10:50:00
11:44:00
12:37:00
13:23:00
UTC

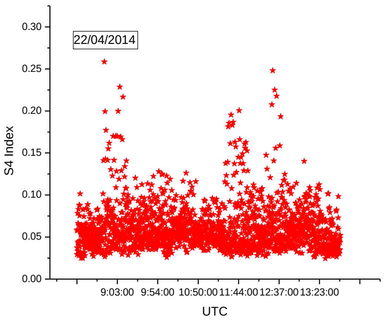

09/04/2014
S4 Index
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
9:37:00
11:07:00
12:37:00
UTC


13/04/2014
S4 Index
0.30
0.25
0.20
0.15
0.10
0.05
0.00
9:03:00
9:54:00
10:50:00
11:44:00
12:37:00
13:23:00
UTC

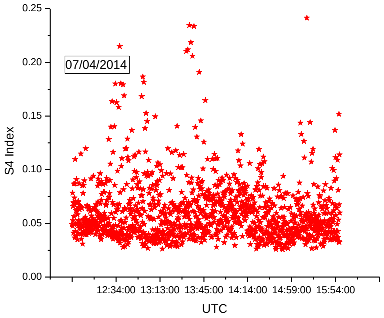

15/04/2014
S4 Index
0.25
0.20
0.15
0.10
0.05
0.00
8:55:00
9:37:00
10:24:00
11:07:00
11:54:00
12:37:00
13:13:00
UTC

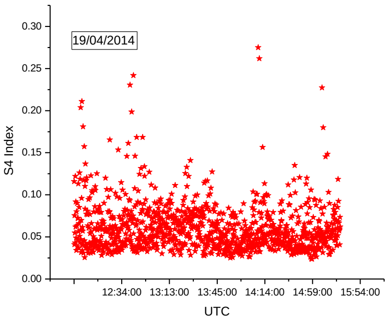

16/01/2014
S4 Index
0.20
0.15
0.10
0.05
0.00
9:20:00
10:34:00
11:44:00
12:51:00
UTC

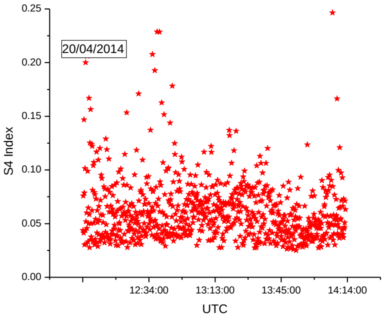

21/04/2014
S4 Index
0.20
0.15
0.10
0.05
0.00
9:03:00
9:54:00
10:50:00
11:44:00
12:37:00
13:23:00
UTC

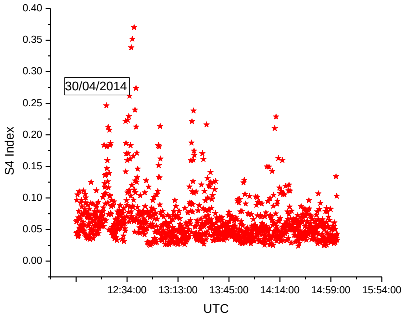

22/04/2014
S4 Index
0.30
0.25
0.20
0.15
0.10
0.05
0.00
9:03:00
9:54:00
10:50:00
11:44:00
12:37:00
13:23:00
UTC

PRN 9:









DAY	UTC	PRN 7 (S4)	DAY	UTC	PRN 9 (S4)	DAY	UTC	PRN 5 (S4)	DAY	UTC	PRN 16 (S4)
2	13:55	0.259	4	15:27	0.261	17	18:18	0.367	14	06:36	0.214
3	13:55	0.259	7	15:15	0.263						
5	13:44	0.281	8	15:11	0.296						
9	13:27	0.263	19	14:22	0.275						
10	09:52	0.278	20	14:18	0.278						
11	09:48	0.311	30	12:32	0.370						
13	13:07	0.293									
15	09:28	0.274									
16	09:23	0.256									
21	08:53	0.299									
22	08:59	0.291									
23	08:55	0.283									
24	08:50	0.272									
25	08:46	0.312									
26	08:42	0.320									
27	08:38	0.283									
28	08:24	0.259									
29	08:20	0.298									

Table 1: Table 1 Shows all the month with Day , UTC and S4 for every PRN.

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