Observations of Scintillations and TEC at Palampur Himachal Pradesh beyond the Northern Crest of the EIA

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Abstract: *A dual-frequency GPS receiver has been operational at the Department of Physics, Sri Sai University, Palampur (32^0 N, 76^0 E) installed by the Space Weather and Satellite Beacon Group of the Institute of Radio Physics and Electronics, University of Calcutta, Calcutta on April 1, 2014 as part of a collaborative research program. The location of the station is beyond the northern crest of the EIA and very few ionospheric measurements are available in this region. This region is characterized by sharp latitudinal gradients of ionization, much greater than the equatorward gradient of EIA. TEC was analyzed for satellite links above an elevation of 60° to eliminate the effects of sharp spatial gradients of ionization existing in this region. S_4 records were analyzed above an elevation of 15° in order to remove the effects of multipath. Post-sunset amplitude scintillations were noted on April 2014 the whole month from this station. We got peak of the amplitude scintillation S4 (0.5-1) are 12 events and UTC range is 11:00-11:52 for 11 events and for one it is 10:46. S4 (0.2-0.5) are 3 events and UTC range is 11:10-11:15 for 2 events and for one it is 6:16. S4 (1-2) are 9 events and UTC range is 11:00-11:52 for 11 events and for one it is 10:46, pre-midnight local time hours respectively. It is important to note that all the satellite links showing scintillations were located south of the station near the northern crest of the EIA.*

Keywords: TEC, Scintillation and EIA

1.Introduction

Ionospheric scintillation on Global Positioning System (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 [1]. 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 [2]. 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 [3]. Equatorial scintillations during a high solar activity period have been found to be sufficiently intense to disable many communication and navigation systems. Hence, it is necessary to understand the role of space-weather events on scintillations.

At mid-latitudes, the threat comes during magnetic storms when sharp ionospheric gradients are formed. These gradients threaten augmentation systems directly and sometimes they form irregularities that cause GPS signals to scintillate. Unfortunately, we know very little about this threat because during the last solar maximum very few resources were applied to understanding scintillation at mid-latitudes. Despite the low level of ionospheric activity at mid-latitudes implied, one should not assume that no activity exists there.

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, Himachal Pradesh (Geographic latitude 32.12° N, 76.53° E) have been analyzed to monitor the amplitude scintillation index (S4) from 1 April 2014 to30 April 2014. These analyzed data is used to study the daily variation of ionospheric scintillation at mid latitude.

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 transionospheric propagation [4]. It is well established now that large-scale plasma depletions are generated first in post-sunset period through Rayleigh-Taylor Instability and the depleted regions rise fast to cover the entire F region including topside ionosphere. Plasma processes then give rise to instabilities acting on the steep gradients available and generate smaller and smaller scale sizes in a cascade process . Since the equatorial spread-F irregularities

extend along the field lines, higher the altitude of plasma depletion, wider the latitudinal extent of the irregularities. Although the ionospheric delay is the biggest error source for GPS navigation, it can be directly measured by future dual frequency GPS avionics and higher order ionospheric errors are not problematic for Localizer Performance with Vertical guidance i.e. LPV-200 [5]. However deep and frequent GPS signals fade due to electron density irregularities in the ionosphere raise a concern about the operational availability of LPV-200. Trans-ionospheric radio waves interfere constructively and destructively when they pass through electron density irregularities. This phenomenon can be understood as multipath inside the ionosphere. As a result a receiver experiences amplitude fading and phase jitter of the received signal. This phenomenon referred to as ionospheric scintillation [6]. Many researchers have been studied the geomagnetic control over the occurrence of scintillations at mid latitude.

In this work we have studied the occurrence of night time amplitude scintillation for April month 2014 using GPS data of ground station at Palampur, Himachal Pradesh station. In the present paper we are showing the initial results of GPS installed in Palampur campus.

2.Data and Method of Analysis

Employing a GPS receiver we have monitored scintillation (S4) index at mid latitude station Palampur, Himachal Pradesh (Geographic latitude 32.12° N, 76.53° E), India of month of April 2014. In this work we have taken the condition of elevation of greater than 25^0 if S4 index is greater than 0.2000 then there is ionospheric scintillation. We have studied the occurrence of ionospheric scintillation events for complete one month. We used GSV400B GPS receiver. The two NovAtel GPSolution 4 or SLOG programs can be can be used to control the GSV400B operations, but SLOG is recommended for collecting scintillation logs.

Amplitude Scintillation:

The strength of amplitude scintillations is typically quantified by a metric called the S4 index. The S4 index is the ratio of the standard deviation of the signal power to the mean signal power computed over a period of time, which is given by

$$S_4 = \sqrt{\frac{<I^2>-<I>^2}{<I>^2}}$$

Where I = A*A, and the brackets indicate ensemble averaging, which can be approximated by the time averages of I. This time period is nominally 60 s but could be arbitrarily larger or smaller, keeping in mind that the time period must be long compared to the Fresnel length divided by the irregularity drift speed.

GPS Scintillations at Mid latitudes

The definition of mid latitude is somewhat arbitrary. The effects associated with equatorial spread F have certainly been observed to move poleward beyond the equatorial

anomalies and produce GPS scintillations in locations such as Hawaii [7], and during magnetic storms there appears to be extended activity from the anomalies poleward as the storm evolves [8] in locations. Here in the present work we have taken the numerical value of S4 index greater than 0.2000 as the threshold value of the ionospheric amplitude scintillation. In this paper we have studied only the night time scintillation. We have started our study with the study of the amplitude scintillation in April 2014. On first April it is found that the S4 index is recorded 1.2 by PRN 17 at 13:20 UTC, second highest value of S4 is 1.17 given by PRN 7 at 14:51 UTC, and third peak is of value 1.02 by PRN 8 at 16: 02 UT. The TEC value is 28.05 TECU at 12:01UT as shown in Figure 1 with three panels.

2nd April is represented by figure 2 and in first panel s4 index is 0.36 at 11:10 UT given by PRN 8 and TEC value is 271.45 at 8:56 UT shown by panel 3and panel 2. Figure 3 shows the 3rd April, first panel is S4 index and the value is 0.98 given by PRN 26 at 13:06 UT and TEC is 304.9 TECU at 9:41 UT the second peak is of value 0.8 at 12:28 shown by second panel.

4th April, the S4 index is 1.96 at 12:22 UT presented by PRN and TEC is 222.88 at 8:48 UT shown by figure 4. Figure 5 is 6th April 2014 the S4 index is 0.99 given by PRN 9 at 11:17 with TEC value 323.9 TECU at 9:36 UT. On 7th April the S4 index is 1.2 at 11:12 UT given by PRN 9 the TEC value is 358.28 TECU at 8:42 UT shown in figure 6. S4 index is 1.46 at11:08 UT shown by PRN 9 and TEC value is 312.47 TECU at 8:32 UT on 8th April 2014 as shown in figure 7. On 9th April 2014 S4 index is 0.73 at 11:04 UT given by 9 PRN and TECU is 232.96 at 8:28 UTC represented in figure 8. Rests of the values of April month are given in **table 1**.

S4 (0.5-1) =12 events and UTC range is 11:00-11:52 for 11 events and for one it is 10:46.
S4 (0.2-0.5) =3 events and UTC range is 11:10-11:15 for 2 events and for one it is 6:16.
S4 (1-2) =9 events and UTC range is 11:00-11:52 for 11 events and for one it is 10:46.

From the above table it is clear that S4 index increases after some time of TEC high value.

3.Discussion

The F-region irregularities generally associated with the spread-F have been considered to be the main cause of intense night-time scintillations [9]. Most of the major causes of satellite communication outages are satellite signal fading due to many factors such as climatically, atmosphere and amplitude scintillation. That cause of amplitude scintillation fluctuation is enhancement and fading rapidly, it has result in worsening of accurate data. The study of the amplitude scintillation occurrence, the diurnal and seasonal variation is importance information for obtaining the communication planning via satellite link or system margin design appropriately to the real condition under scintillation effect in each station. At low latitude at the time of sunset an enhanced eastward electric field called the pre-reversal enhancement generally developed at

the F-regions heights. In future we will also study diurnal, seasonal and scintillation with solar activity.

4.Conclusion

Analyzing the GPS data of the month April 2014 for studying amplitude scintillation we have following points of remark:

1. We got peak of the amplitude scintillation S4 (0.5-1)=12 events and UTC range is 11:00-11:52 for 11 events and for one it is 10:46.
2. S4 (0.2-0.5) =3 events and UTC range is 11:10-11:15 for 2 events and for one it is 6:16.
3. S4 (1-2) =9 events and UTC range is 11:00-11:52 for 11 events and for one it is 10:46, pre-midnight local time hours respectively.
4. We have observed the maximum number of scintillation having amplitude scintillation index ranging from 0.20 to 0.5 and minimum scintillations whose S4 index is greater than 0.5-1. From this observation we are concluding here that at our location mid latitude, we have frequent occurrence of strong and intense ionospheric scintillatons.

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Table 1

| UTC	TECU	PRN	UTC	S4 Index	Date April 2014	S.N.
12:01	282.05	17	13:20	1.19	1	1
8:56	271.45	8	11:10	0.36	2	2
9:41	304.9	26	13:06	0.98	3	3
8:48	222.87	11	12:22	1.96	4	4
					No	5
9:36	323.9	9	11:17	0.99	6	6
8:42	358.28	9	11:12	1.2	7	7
8:32	312.47	9	11:08	1.46	8	8
8:28	232.96	9	11:04	0.73	9	9
8:30	343.81	9	11:00	0.8	10	10
8:20	340.24	11	11:54	0.92	11	11
9:03	215.96	9	10:51	1.02	12	12
12:15	227.96	11	11:47	0.719	13	13
8:55	309.60	23	6:16	0.26	14	14
11:45	316.62	9	10:19	1.43	20	15
10:20	256.25	11	11:15	0.37	21	16
7:42	236.10	26	11:52	0.83	22	17
11	419.23	26	11:47	0.8	23	18
10:19	258.30	1	11:44	1.05	24	19
8:12	233	26	11:39	0.90	25	20
8:08	278	26	11:41	0.78	26	21
8:04	274.96	26	11:31	1.09	27	22
10:02	315.18	11	10:46	0.926	28	23
9:58	197.88	1	11:23	0.911	29	24
9:53	245.88	19	11:07	1.14	30	25

Figure Caption:

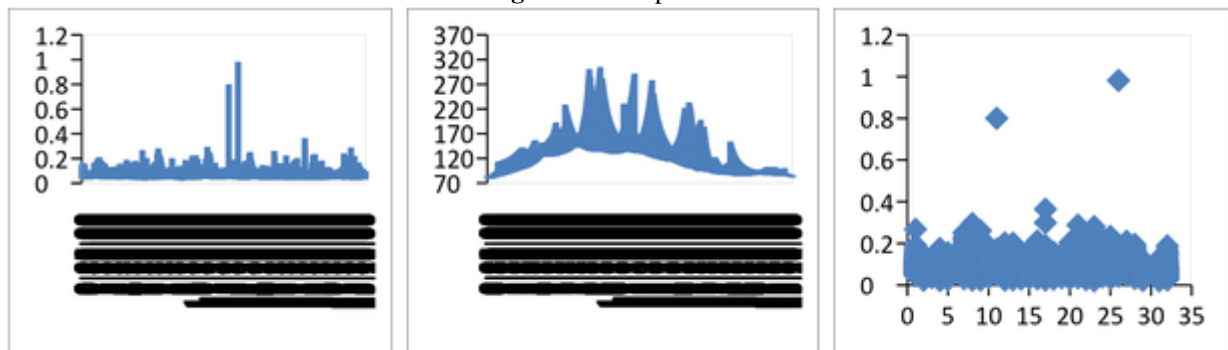In All Figures we have three panels first is S4 index, second is Tec in TECU and third is S4 verses PRN.

Along X axis in first panel is UTC and along Y axis is S4 index, Along X axis in second panel is UTC and along Y axis TEC in TECU and in third panel along X axis PRN and along Y axis S4 index is there.
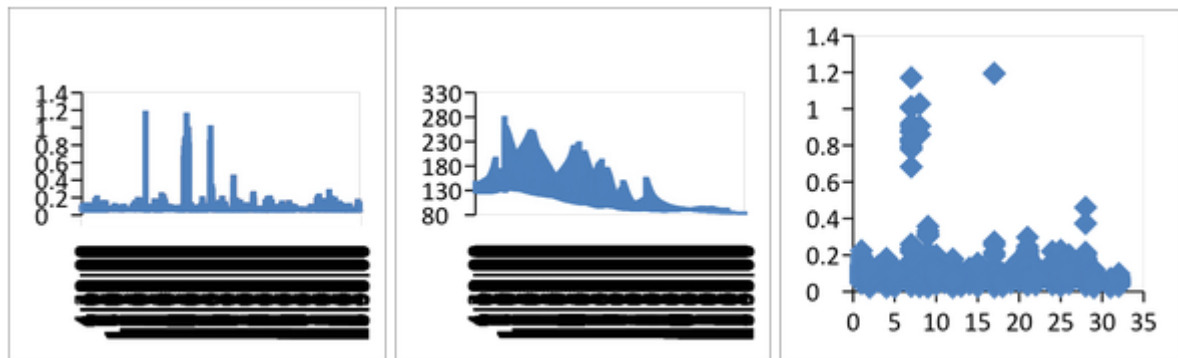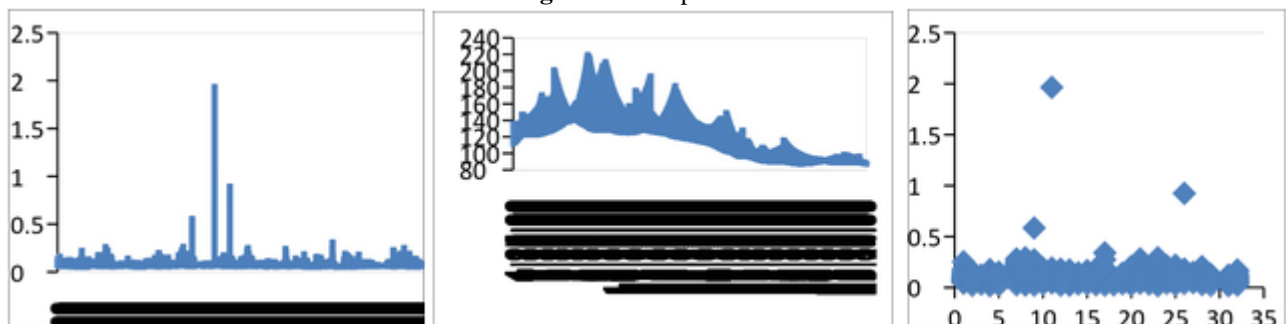

Figure 1: 1st April 2014
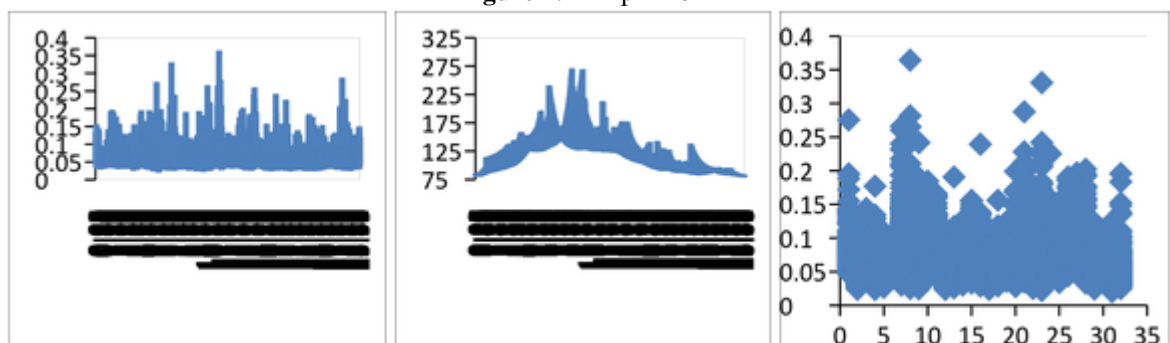
Figure 2: 2nd April 2014

Figure 3: 3rd April 2014

Figure 4: 4th April 2014

Figure 5: 6th April 2014

Figure 6: 7th April 2014

Figure 7: 8th April 2014

Figure 8: 9th April 2014

Figure 9: 10th April 2014