Variations of Ionospheric Scintillations Due to Solar Activity

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***Abstract* – This preliminary work focuses on the effect of solar activity on the ionospheric phase and amplitude scintillations. Data from a GISTM receiver at Parit Raja, Johor, Malaysia (1°52' N, 103°06'E) during February 2009 (daily SSN: 0-8) and February 2014 (daily SSN: 66-154) were analyzed. It is found that there is only small dependency of phase scintillations on the solar activity. Weak phase scintillations occurred in February 2014 (high solar activity) for about 0.06% of the time, whereby nothing significant was observed in 2009 (low solar activity). Meanwhile, for the amplitude scintillations, no dependency was observed. Weak amplitude scintillations occurred in February 2009 for about 0.923% of the time, whereby it decreased to 0.336% in 2014.**

***Index Terms* —Ionospheric scintillations, solat activity.**

I. INTRODUCTION

The earth's ionosphere is ever variable. It parameters can be affected by several factors, including the height above earth's surface, location, time of day, season, solar activity, and solar disturbances. Previous work has shown that the scintillations of the ionosphere somewhat vary with different solar activity, where the scintillations were higher during maximum solar activity, and lower during minimum solar activity.

The purpose of the work is to observe the variations of ionospheric scintillations (both amplitude and phase) due to the different solar activity; during minimum (daily SSN 0-8) and maximum (daily SSN 66-154) conditions. Data utilized in this work were obtained from a GPS Ionospheric Scintillation and TEC Monitor (GISTM) receiver located at Wireless and Radio Science (WARAS) Centre, Universiti Tun Hussein Onn Malaysia (UTHM) (1°52' N, 103°06'E).

II. DATA AND METHODOLOGY

The GISTM receiver is configured to measure amplitude and phase scintillation from the L1 frequency, and TEC from the L1 and L2 frequencies. Data from this receiver at UTHM from February 2009 and February 2014 were used for the analysis in this preliminary work.

The GISTM receiver is capable of measuring amplitude scintillation, which normally represented by its index, S4. The raw amplitude measurements are normalized by averaging the measurements over the 60-second interval. This produces the total S4, S_{4T} which includes the effects of ambient noise and multipath [2]:

$$S_{4T} = \sqrt{\frac{\langle P^2 \rangle - \langle P \rangle^2}{\langle P \rangle^2}} \tag{1}$$

where P is the received signal power.

S_{4T} contains ambient noise that causes a relatively high S4 at lower frequencies, such as at VHF and UHF. The effects of this noise can be removed by estimating the average of the signal-to-noise density, S/N_o over the same 60-second interval. The correction to the total S4 due to ambient noise, S_{4N_0} is [3]:

$$S_{4N_o} = \sqrt{\frac{100}{\overline{S/N_o}}\left(1 + \frac{500}{19\overline{S/N_o}}\right)} \tag{2}$$

where $\overline{S/N_o}$ represents the 60-second average of S/N_o

Next, the corrected S4 can be computed as follows [3]:

$$S4 = \sqrt{S_{4T}^2 - S_{4N_o}^2} \tag{3}$$

Low-to-moderate amplitude scintillation at lower elevation angles can be due to multipath. Even though the cut off elevation angle for the GISTM receiver is set to 5°, only data with the elevation angle greater than 25° are considered as meaningful. This is to make sure that multipath effect is minimized.

The GISTM receiver also collects phase measurements and then detrended with a 6th-order Butterworth high-pass filter with the cut-off frequency of 0.1 Hz. Then, the standard deviations, σ_φ of the phase over 1-second, 3-second, 10-second, 30-second and 60-second intervals are calculated by the receiver [2]. The 60-second σ_φ is normally used as the phase scintillation indicator, and hence will be used in this work.

In this preliminary work, data from this station for 3-28 February 2009 and 3-28 February 2014 were analyzed. This corresponds to low solar and high solar activity, respectively. The daily SSN for February 2009 is between 0 and 8, with the average of 1.4, and between 66 and 154 in February 2014, with the average of 102.8. The daily SSN data are produced by NGDC and downloaded from http://cdaweb.gsfc.nasa.gov.

III. Results and Analysis

Fig. 1 shows the amplitude scintillations for every minute for February 2009 and 2014. In both months, S4 did not exceed 0.35. S4 between 0 and 0.2 are usually considered as insignificant. In terms of percentage of occurrences, a total of 99.07% of the S4 were in the range of 0 and 0.2 in February 2009, and the values slightly increased to 99.66% in February 2014 (Refer Table I). Weak amplitude scintillations (in the range of 0.2 to 0.4) occurred in February 2009 for about 0.923% of the time, whereby it decreased to 0.336% in 2014.

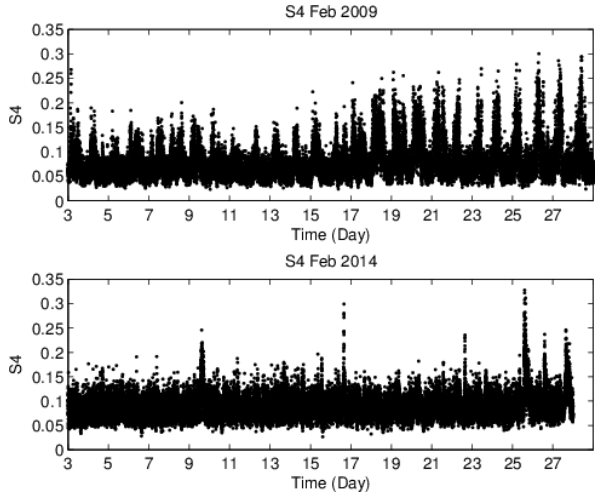

Fig. 1. Amplitude scintillation, S4 in February 2008 (top), and February 2014 (bottom).

TABLE I
Percentage of Occurrences of Amplitude Scintillation in February 2009 and February 2014

Range of S4	Percentage of occurrences (%)	
	Feb 2009	Feb 2014
0 – 0.1	81.92	76.07
0.1 – 0.2	17.15	23.59
0.2 – 0.3	0.92	0.32
0.3 – 0.4	0.003	0.016

Fig. 2 shows the phase scintillations for February 2009 and 2014. It can be seen in 2009, the phase scintillations did not exceed 0.2 rad, but reached up to around 0.33 rad in 2014. Similar to the amplitude scintillations, phase scintillations less than 0.2 rad are considered as insignificant. Weak phase scintillations occurred in February 2014 for about 0.06% of the time, whereby nothing significant were observed in 2009. (Refer Table II).

IV. Concluding Remarks

Based on the results, phase scintillations showed only small dependency on the solar activity. Weak phase scintillations occurred in February 2014 (high solar activity) for about 0.06% of the time, whereby nothing significant was observed in 2009 (low solar activity). Meanwhile, for the amplitude scintillations, no dependency was observed. Weak amplitude scintillations occurred in February 2009 for about 0.923% of the time, whereby it decreased to 0.336% in 2014. This preliminary work will be continued for longer period of observations.

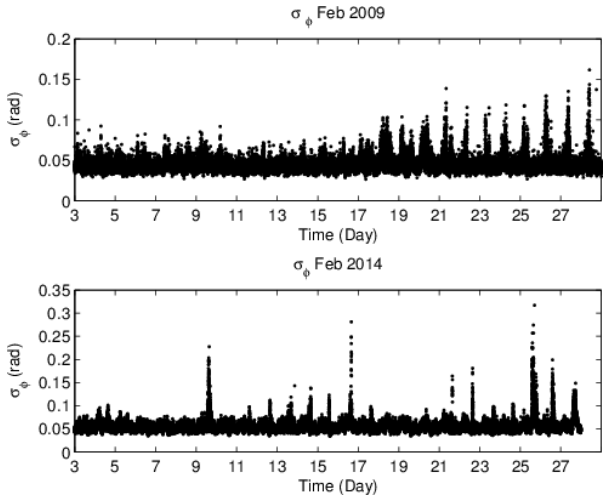

Fig. 2. Phase scintillation, σ_φ in February 2008 (top), and February 2014 (bottom).

TABLE II
Percentage of Occurrences of Phase Scintillation in February 2009 and February 2014

Range of σ_φ (rad)	Percentage of occurrences (%)	
	Feb 2009	Feb 2014
0 – 0.1	99.75	98.46
0.1 – 0.2	0.25	1.48
0.2 – 0.3	0	0.06
0.3 – 0.4	0	0.003

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