ANALYSIS OF FADING EFFECTS DUE TO IONOSPHERIC SCINTILLATIONS USING MODERN GNSS SIGNALS OBSERVED AT A NORTHERN LOW LATITUDE STATION

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ABSTRACT

The major threat to Global navigational system’s signal availability, accuracy, and processing is the signal fading caused due to ionospheric scintillations. In this paper the triple – frequency data of GPS signal collected at Koneru Lakshmaiah University, Guntur, India is processed to analyze the signal fading characteristics of GPS signal bands. Ionospheric scintillation parameter known as fade duration is calculated using GPS C/N0 measurements. It is observed that maximum fade duration is about 90 sec. It is evident that the L5 signal fading intensity is low as compared to L1 and L2 signals. The outcome of this work would be useful for developing inter-frequency aiding algorithms used in signal tracking and reacquisition in future GNSS receivers.

Keywords: ionospheric scintillations, fading characteristics, normalized signal intensity, fade events, fade duration.

1. INTRODUCTION

Ionospheric scintillation is the quick fluctuation of the amplitude or phase of the radio - frequency signal when the signal passes through the ionosphere plasma with irregular structures. Strong scintillations cause the received GNSS signal to attenuate for more than 30dB, which results degradation in signal strength [1].

It has been known that the ionospheric scintillations depend on the geographical position of the receiver and also on the signal frequency. These scintillation effects can be observed with a wide variety of characteristics in the low-latitude and high-latitude regions [2]. Further, the signals with low frequencies are also affected more in these regions [3], [4]. During a strong scintillation, it has been observed that the signals with different frequencies will becomes lesser correlated both in the time and also in the magnitude [5].

To understand the impact and the different characteristics of the ionospheric scintillations on the GPS signal, the data collected by the GPS receiver located at KL University is used. This paper deals with the calculation of signal intensity (SI) during scintillation activity, which includes fade duration of the multiple frequency bands based on the data that is collected.

2. IONOSPHERIC SCINTILLATION PARAMETER ANALYSIS

Global Positioning System is a satellite based communication system which has a receiver on the earth that can be used to determine the location, time and velocity. It is under the operation of the US, Department of Defense. The main problem in the GPS receiver tracking is due to the affects of the ionosphere. The irregularities in the ionosphere electron density cause the signal fading and this is called as the scintillation [10], [11].

The scintillation characteristics will help us to propose the tracking algorithms that can be used by the GPS receiver. A multiple number of signal fades are identified in the data that has been collected. The carrier to noise ratio (C/N0) is not accurate to the mark, as the averaging will be done during its calculations [12].

Normalized signal intensity can be a better parameter for the calculation of fade level and also the fade duration. Normalized signal intensity of a signal can be obtained by a 6th order Butterworth low pass filter with a cut-off frequency at 0.1 Hz and the nominal value after detrending is set to 0 dB [7], [8]. The fading events can be calculated by using two thresholds -10 dB and -15 dB. The signal intensity fading events can be extracted when the signal normalized intensity falls below the thresholds. The previous discussions are on calculation of fade duration modeling and characterizations based on the C/N0 analysis [13], [14].

The fade duration or the duration of the fade can be stated as the difference of time between the start of a normalized signal frequency dropping below the threshold and the start of the normalized signal frequency that is rising above a given threshold [9], [15].

3. RESULTS AND DISCUSSIONS

Koneru Lakshmaiah (KL) University, Vaddeswaram, Guntur district (16.31°N, 80.37°E), is a transition zone of equatorial ionization anomaly (EIA) of low latitude regions. The pseudo random noise (PRN) codes of 24 and 25 satellite signal data (1 Jan 2013, 17 March 2013, 1 June 2013) is used to analyze normalized signal intensity and fading characteristics. To avoid multipath fading effects, the signal with elevation angles greater than 30° was considered.

L1 (1575.42 MHz), L2 (1227.60 MHz) and L5 (1176.45 MHz) GPS signal frequencies are used for analyzing fading characteristics. The data of different
dates are taken and analyzed for the scintillation characteristics. The L1 and L2 signals are obtained by all the available satellites whereas the L5 signal is obtained only from a set of particular satellites those are PRN 24 and 25.

1 January 2013 PRN 25

17 March 2013 PRN 25

1 June 2013 PRN 25

1 June 2013 PRN 24
Figure 1(a) - 1(f) are the normalized signal intensity that is plotted for the L1, L2 and L5 signal frequencies. A threshold line of -10 dB is used to calculate the number of fades that are occurring in a signal. The normalized signal intensity is a better parameter to calculate the fade events effectively as there is no averaging methods that are used in its calculation.

Analysis of fade events
Fade events are the observations that are made when the signal falls below the given threshold. These are the events in order to know how much a signal is affected by the scintillation. A larger number of fade events imply more signal deterioration.

Table-1 discusses about the data that has fallen below the thresholds of -10 dB and -15 dB for PRN 24. Here it is observed that the data is more affected in dates where geo magnetic storms are observed, as more fade events are observed in 1 January and 1 June on L1 frequency. The L2 and L5 has considerably low fades.

Table-2 can be used to illustrate the fade events that are observed in 2013 for thresholds of -10 dB and -15 dB. The data corresponds to the observations made by the GPS receiver from the satellite with the PRN 24. It is observed that the L1 signal is affected as in the case of PRN 25 data. Here less number of fades is observed than the PRN 24. This is mainly due to the difference of positions of the satellites.
Table-2. Illustration of the fading events for L1, L2 and L5 frequencies for dates where storms are observed under the thresholds of -10dB and -15dB for PRN 24.

<table>
<thead>
<tr>
<th>Fading</th>
<th>L1</th>
<th>L2</th>
<th>L5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>-10dB</td>
<td>-15dB</td>
<td>-10dB</td>
</tr>
<tr>
<td>1 January 2013</td>
<td>108</td>
<td>109</td>
<td>3</td>
</tr>
<tr>
<td>17 March 2013</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>1 June 2013</td>
<td>60</td>
<td>66</td>
<td>3</td>
</tr>
</tbody>
</table>

Analysis of fade duration

The fade duration is the time difference for which the signal is falls below a threshold and the signal rising above a threshold. The fade duration helps in knowing how much time the signal has deviated from its original path.

Figure-2. The fade duration measurements that are observed in the L1, L2, L5 frequencies. Figure-2 indicates the fade durations that are observed in a signal. Figure 2(a) is the fade duration representation of the data collected on 1 January 2013 on PRN 25. In this larger fade duration of around 98 sec is
observed in L2 frequency but more number of fades and fade durations are observed in L1 frequency. 

Figure-2(b) represents the fade durations that are calculated for the data collected on 17 March 2013 from PRN 25. During middle hours of data collection, there is larger fade duration for L2 and L1 also has comparatively larger fade duration. Figure-2(c) describes the fade duration for data dated on 1 June 2013 and clearly larger fade duration is observed for L2 frequency.

The L2 tracking is a difficult process so when once the signal is affected by a strong scintillation the recovery may be a tough task. Hence larger fade duration are observed in L2 frequency. The L5 frequency has less fades and also we cannot observe fade duration for the data taken and the thresholds maintained. Here it is observed that larger fade duration of around 98 secs on 1 January 2013. It is observed that the fade duration that fall below 5 secs.

CONCLUSIONS
Ionospheric scintillations have a predominant effect on the GPS signals. The signals having more fades will lose their capacity to maintain the tracking algorithms followed by the GPS receiver. In order to understand how much a signal is affected by the scintillation we need to calculate the parameters that are define the extent of fades. Here we used the fade events and the fade duration to know the extent of the scintillation. The results here can infer that the signals are mostly affected by the scintillations in L1 frequency with respect to the fade events and the fade duration that have been observed than that of the L2 and L5 signal frequencies.

The signal fades at a maximum of 1319 are observed in the L1 frequency in 1 June 2013 and maximum fade duration of 2690 has been observed in the same L1 frequency on the same date. The signal is more adversely affected when there is an occurrence of solar storm .when compared to other frequencies we can observe that L1 is mostly affected. The signals L2 and L5 are very difficult to track during a strong scintillation. This could be a reason to have lesser fade events as the data availability of L2 and L5 is less compared to L1 during strong scintillation. It is also observed that the L2 had larger fade durations than L1. The L2 signal affected by scintillation has a greater possibility to lose the tracking capability.

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REFERENCES


