

GNSS BASED IONOSPHERIC CHARACTERIZATION IN THE INDIAN SUBCONTINENT REGION

Kalyan Chatterjee¹, Sandip Nandy²

¹Assistant Professor, Amity University Kolkata, India

²Associate Professor, Kalyani Govt. Engineering College, India

Abstract – Due to the formation of irregularities in the electron density distribution, amplitude and phase of the satellite links fluctuates. Magnetic equator passes through the southern tip of Indian peninsula and as a result high ionospheric activity is observed in the Indian region. Quality of the satellite links passing through these irregularities degrades and it presents a very challenging situation for high dynamic platforms such as aircraft or trains. In this paper, the authors tried to identify:

1. Specific regions of the sky where scintillation is maximum, while observing from Calcutta.
2. Proposed the possibility of better Quality of Service (QoS) in the presence of GNSS satellites compared to GPS satellites.

Key Words: GNSS, Scintillation, GPS, GLONASS, Fading

1. INTRODUCTION

Scintillations are fluctuations of amplitude and phase of radio waves from satellites passing through the irregularities in electron density distribution in the ionosphere. The ionosphere is embedded in the earth's magnetic field and this situation influences the distribution of the ionized constituents [1]. A clear indication of this may be seen in the worldwide distribution of electron density in the upper atmosphere that tends to be best organized by geomagnetic rather than geographic coordinates. Moreover, being a magneto-ionic medium, the ionosphere has a profound impact upon radio waves that interact with the medium.

The most severe scintillation occurrences in the world are recorded at low latitude region [2]. In the equatorial region, scintillation occurrences maximize during the post sunset to midnight local time intervals of equinoctial months around the sunspot number maximum years. The equatorial ionosphere is somewhat characterized by two very important features: Equatorial Ionization Anomaly (EIA), Intense fluctuations in the electron density distribution of the ionosphere.

The morphology of equatorial ionosphere is quite different than at other latitudes because the geomagnetic field B is nearly parallel to the Earth's surface. During daytime, the region dynamo electric field E is eastward and resulting EXB drift transports the ionospheric F-region plasma upward at the magnetic equator. The uplifted plasma then moves along

B on response to gravity and pressure-gradient forces and forms the equatorial ionization anomaly with minimum F-region ionization density at the magnetic equator and maxima at approximately 15° to 20° magnetic latitude to the north and south. This upwelling of ionization at the magnetic equator and its subsequent redistribution at off-equatorial locations is often referred as the 'Fountain Effect' [1].

Near sunset, plasma densities and dynamo electric fields in the E-region decreases, and the equatorial anomaly begins to weaken. However, at this local time, a dynamo develops in the F- region. Polarization charges within conductivity gradients at the terminator enhance the eastward electric field after sunset. The post-sunset electric field moves the ionospheric plasma upward, allowing the equatorial anomaly crests to intensify. After sunset, F-region dynamo currents are no longer subjects to the shorting effect of the conducting E-layer to the north and south of the magnetic equator. Polarization fields are thus able to drive the F-layer upwards. Eventually the electric field turns westward, causing plasma to drift downward. Just before the reversal at the time of sunset, the field is much enhanced. This is called the post-sunset or the pre-reversal [4] enhancement of the eastward electric field. Scattering of signals from irregularities embedded in the ionosphere are obtained in the form of spread F on radar maps. Occurrence of spread F is more or less a daily phenomenon in the equatorial and low-latitudes during the equinoctial months of high sunspot number years. However, no prediction is available for occurrence of ESF on any particular evening. Recent efforts have been directed toward prediction of the day-to-day variability in terms of the seed mechanism or precursors. This prediction service has become very important in view of the deleterious effect of ESF on modern space-based communication and navigation systems.

When trans-ionospheric satellite links passes through these irregularities, intense, fast and random change of the amplitude and phase of the satellite signal takes place [2]. This creates a huge problem for high dynamic platforms such a moving aircraft or submarines. In this paper, the authors tried to identify specific regions of the sky, as observed by using a ground based GNSS receiver during October 2013 to March 2014, where occurrence of amplitude scintillation is most frequent. This identification leads to the application of spatial diversity techniques under such conditions.

2. AMPLITUDE SCINTILLATION

Amplitude scintillation is measured by S_4 parameter which is defined as the square root of the normalized variance of signal intensity over a given interval of time. It mathematically expressed as follows:

$$S_4 = \sqrt{\frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}}, \text{ where } I \text{ is the signal intensity.}$$

S_4 is a dimensionless number with theoretical upper limit of 1.0 and below 0.3 is likely to cause any impact on S_4 navigation satellite system. S_4 more than 0.4 will cause severe impact on the performance of satellite based navigation systems.

3. PROPOSED METHOD

In this paper, authors proposed a novel technique to characterize specific regions of sky, as observed from a ground based receiver from Calcutta, where maximum occurrences of intense scintillation is found.

Depending on the values of S_4 index, scintillation has been divided in three bins:

- A. Mild Scintillation ($0.4 < S_4$)
- B. Moderate Scintillation ($0.4 \leq S_4 < 0.6$)
- C. Intense Scintillation ($0.6 \leq S_4$).

4. RESULT ANALYSIS

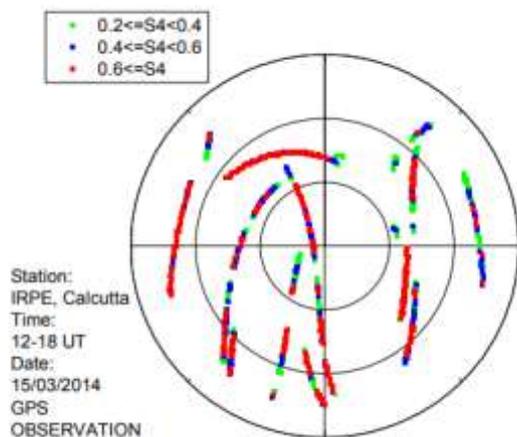


Fig -1: Spatial Distribution of Scintillation Index observed for GPS Satellites from IRPE, Kolkata.

Fig -1 shows spatial distribution of amplitude scintillation index observed by GPS satellites from IRPE, Calcutta on 15th March 2014. Intense amplitude scintillations were noted in the north near the overhead of the station and in the south during 12-18 UT. High scintillations were noted bear the overhead of the station even in midnight.

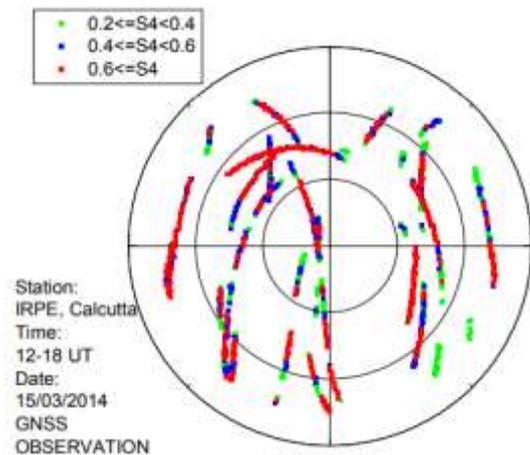


Fig -2: Spatial Distribution of Scintillation Index observed for GNSS Satellites from IRPE, Kolkata.

Fig -2 shows spatial distribution of amplitude scintillation index observed by GPS, GLONASS and GALILEO satellites from IRPE, Calcutta on 15th March 2014. Intense amplitude scintillations were noted in the north near the overhead of the station and in the south during 12-18 UT. High scintillations were noted bear the overhead of the station even in midnight.

Denser configuration in this plot suggests the possibility of application of spatial diversity techniques under adverse ionospheric conditions.

5. CONCLUSIONS

Occurrences of intense space weather events affecting trans-ionospheric L-band communication and navigation systems may pose a serious threat to the high dynamic platforms such as airplane, trains etc. that rely on space based navigation and communication systems. The present paper reports amplitude scintillations observed on GPS, GLONASS and GALILEO links from Calcutta during October 2013 to March 2014. The present station is situated near the northern crest of EIA in the Indian sector and presents worst case figures in relation to the outages of satellite signals.

Amplitude scintillations have been noted mainly between 12-18 UT during the period of observation and occurrences of intense amplitude scintillations in the late midnight hasn't been observed. Two regions have been identified where most intense amplitude scintillations occurred: in the north near the overhead of the station and in the south forming "banana" structure in the north-south direction. For a

receiving station located near the northern crest of Equatorial Ionization Anomaly, high scintillation is observed near the north during sunset hours due to pre-reversal enhancement and 'Fountain effect'. On the other hand, from a station like this, high amplitude scintillations are often noted in the southern sky during the late evening hours when satellite links are viewed "end-on" through the field aligned "plasma depleted bubbles".

Denser configuration in the combined GNSS plot suggests the possibility of application of spatial diversity techniques when occurrence of high amplitude scintillation is very frequent.

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