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Analysis of Ionospheric Scintillations Measurement on NavIC Signals

Kaitha Praveena, Perumalla Naveen Kumar, D. Krishna Reddy

Abstract**:** ***Ionospheric scintillation is a rapid change in amplitude and phase of an electromagnetic signal in the ionospheric environment. Amplitude scintillations indicated by S_4 index and phase scintillations by (σ_ϕ). Low latitude regions are prone to ionosphere scintillation. Since India is a low latitude region, ionospheric scintillations must be analysed. Indian NavIC or IRNSS planned and implemented by the Indian Space Research Organization (ISRO). In this paper S_4 index is investigated for NavIC L5 (1.17645 GHz) and S1 (2.492028 GHz) signals (1B,1C,1D,1E,1F,1G). For the analysis Guntur station (Lat:16.44N, Lon:80.62E) and Hyderabad station (Lat:17°24'28.10"N, Lon: 78°31'4.22"E) IGS receiver data is considered. The S_4 index is calculated using carrier to noise ratio of IRNSS L5 and S band signals. From the results it is observed that S_4 index is more for L5 band signals compared to S band signals, as ionospheric scintillations are frequency dependent. Guntur station S_4 average value is low for all (L5 and S) band satellite signals compared to Hyderabad station satellite signals. Over Indian region, it shows latitude-dependent scintillations.***

Keywords**:** ***IRNSS, S4 Index, C/N0, Signal Intensity.***

I. INTRODUCTION

The Indian Regional Navigation Satellite System (IRNSS) is a regional navigation satellite system developed by Indian Space Research Organization (ISRO). IRNSS providing reliable position, navigation, and timing services over India and its surroundings is the main objective of the system. This system operates at frequencies L5 (1.17645 GHz) and S1 (2.492028 GHz). While GPS is able to pinpoint location to an estimated accuracy of 20-30 metres, NavIC can pinpoint location from a distance of under 20 metres. While there are many errors, Ionospheric delays degrade NavIC's performance. The ionosphere is a propagation medium that affects signals in terms of scintillations. Rapid changes in the radio signal's amplitude and phase are known as Ionospheric scintillations. Variations in the ionospheric electron density cause the scintillation effects and it also depends on seasons, latitude and longitude, time of the day etc. The amplitude scintillations and the phase scintillations are used to represent S_4 index and (σ_ϕ) respectively. Amplitude scintillations are characterized by using S_4 index with the range (0-1), depending on the range it is classified as quiet, moderate, disturbed and severe scintillations. Severe scintillations lead to loss of lock of the signal, which may affect the user position calculation. There is a discussion of ionospheric effects at low latitudes [1]. For GPS data, amplitude scintillation index variation for various latitude and longitude regions is carried out, and latitude-based scintillations are explained [2]. The variation of amplitude scintillations over low latitude regions have already been investigated using GPS data by many authors. Scintillations are more likely to occur during this time around the pre-midnight hours of equinox months, with very little activity occurring during the post-midnight hours [3]. Amplitude scintillations for GNSS signals are investigated by researchers. Not much amount of work reported on regional navigation system.

It is necessary to investigate the scintillation effects in Indian region. Amplitude scintillations are investigated for NavIC, L5 and S band 1A,1B,1C satellite signals. L band frequencies have a greater impact on scintillations than higher frequencies [4]. Amplitude scintillation effects due to VHF signals and UHF frequency signals are discussed [5]. Electron density and plasma drift velocity are high in low-latitude regions and scintillations are high [6]. Post-sunset periods result in severe scintillation effects [7]. Scintillations are also effected in high latitude regions but less severe when compared to equatorial region [8][9]. It is important that the ionospheric process plays a role in positioning accuracy [10]. Amplitude scintillation index (S_4) is carried out for different stations using quiet and disturbed days [11]. Amplitude scintillations are calculated using signal intensity [12].

II. DATA AND METHDOLOGY

For the analysis 26th May, 2017 receiver data is obtained from ISRO IGS (IRNSS/GPS/SBAS) receiver of Guntur station and Hyderabad station. From the IGS receiver data file (Comma Separated Value) the required parameters of C/N0, time for every one minute (60sec) samples is obtained. From the C/N0 measurements signal intensity (I) is calculated and using signal intensity (S_4) index is calculated for each signal. For analysing the amplitude scintillation index, three geostationary satellite signals (1C, 1G, and 1F) and four geosynchronous satellite signals (1B, 1D, 1E, and 1I) are taken into consideration (S_4).

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*****Correspondence Author (s)

Kaitha Praveena*, AGRL LAB, Department of Electronics and Communication Engineering, Osmania University, Hyderabad (Telangana), India. Email: kaithapraveena@gmail.com, ORCD ID: https://orcid.org/0000-0002-9302-9106

Prof. Perumalla Naveen Kumar, AGRL LAB, Department of Electronics and Communication Engineering, Osmania University, Hyderabad (Telangana), India. Email: drnaveenkumarp9@gmail.com, ORCD ID: https://orcid.org/0000-0003-2023-4755

Prof. D. Krishna Reddy, Department of Electronics and Communication Engineering, Chaitanya Bharathi Institute of Technology (CBIT), Hyderabad (Telangana), India. Email: dkreddy@cbit.ac.in, ORCD ID: https://orcid.org/0000-0002-0279-2115

A. Amplitude Scintillation Index(S_4)

Amplitude scintillation index is calculated using carrier to noise ratio (C/N0) received from the receiver data. Signal intensity (I) is calculated using C/N0. By using signal intensity S_4 index is calculated. Signal intensity, it is defined as eqn (2) [10].

Steps to calculate the ionospheric Amplitude scintillation (S_4) using NavIC data

Step1: NavIC data extracted from IGS receiver using IRNSS utility software.

Step2: Signal intensity is calculated using C/N0 parameter from .csv data.

Step3: Calculate for S_4 index, S_4 mean and S_4 max for IRNSS L5 and S band signals.

Step4: Calculation of S_4 index using the following equations.

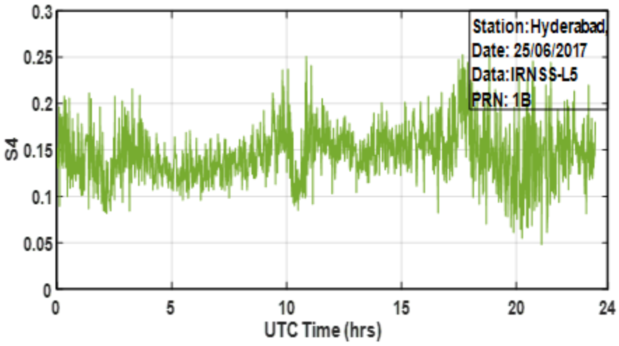
$$S_4 = \sqrt{\frac{<I^2> - <I>^2}{<I^2>}} \quad (1)$$

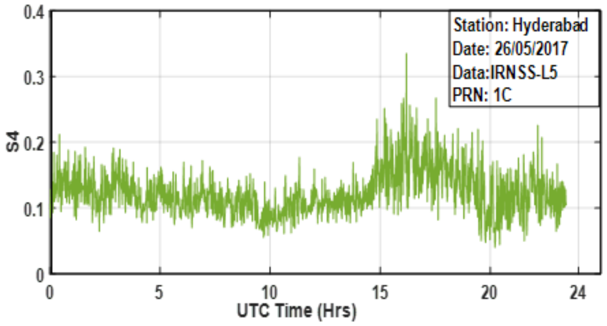
Where $I = 10^{(0.1 * \frac{C}{N0})}$ (2)

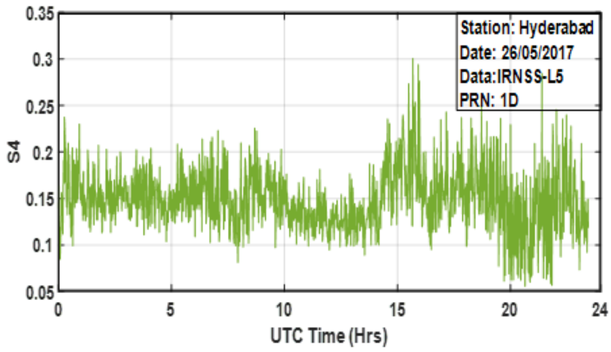
Where signal intensity is (I), <> symbol indicates the average value of SI. By collecting an average of 60 samples per minute, S4 index is calculated.

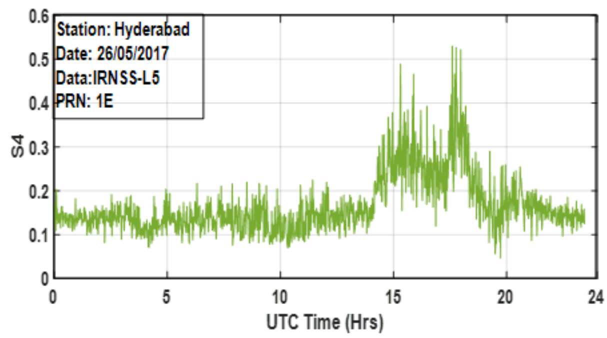
III. RESULTS AND DISCUSSION

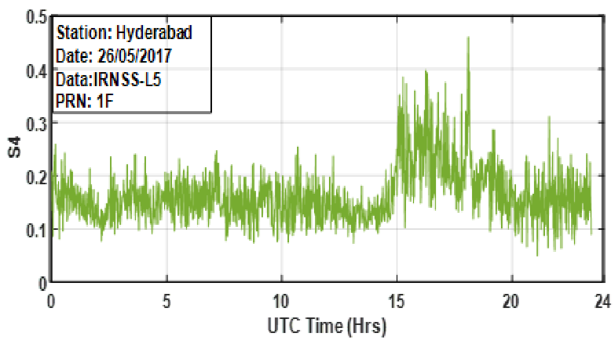
IGS receiver data of Guntur and Hyderabad stations on 26th May 2017 is considered for the analysis**.** As per the literature "amplitude scintillation index S_4 is classified as Quiet ($S_4 \leq 0.25$), Moderate $0.25<S_4\leq1$, disturbed $0.5<S_4\leq1$ and Severe $S_4>1$" [3]. Table 1. Shows that the Guntur station L5 band maximum S_4 index value is 0.793 for 1D satellite and minimum S band value is 0.494 for 1D satellite. For (1B,1F,1G) satellites moderate scintillations and (1C,1D,1E) disturbed scintillations are observed for L5 band signals. For Guntur station maximum S_4 average value for L5 band is 0.200 for 1B satellite and minimum S_4 average value is 0.169 for 1G satellite. For S band maximum S_4 average value is 0.133 for 1B satellite and minimum S_4 average value is 0.122 for 1G satellite. From Table1 and Table2 it is observed that S band scintillations are lower than L5 band scintillations. Table 2. Shows that the Hyderabad station maximum L5 band S_4 index value is 0.530 for 1E satellite and minimum L5 band value is 0.252 for 1B satellite. For (1B) satellite Quiet scintillations and (1C,1D,1E,1F,1G) moderate scintillations are observed for L5 band signals. Hyderabad station maximum S_4 average value for L5 is 0.165 for 1E satellite and minimum S_4 average value is 0.123 (1C satellite). For S band maximum S_4 average value is 0.0906 (1G satellite) and minimum S_4 average value is 0.065 for1C satellite. The Guntur station average value of S_4 is low for all (L5 and S) band satellite signals compared to Hyderabad station satellite signals. Over the Indian region, it shows latitude-dependent scintillations. It is found that due to the high frequency of S band signals, L5 band scintillations are severe compared to S band scintillation. Figure1. Shows the variation of S_4 index of 7 satellite signals for Hyderabad station. It can be concluded that Guntur station average values of all signals are low compared to the Hyderabad station. Where it is showing the latitude dependent variations in lowtatitude region (LR). Figure2. Shows the Guntur and Hyderabad station average S_4 index value for both L5 and S band signals. It is found that L5 band S_4 average value is high compared to the S band signals for both the stations.











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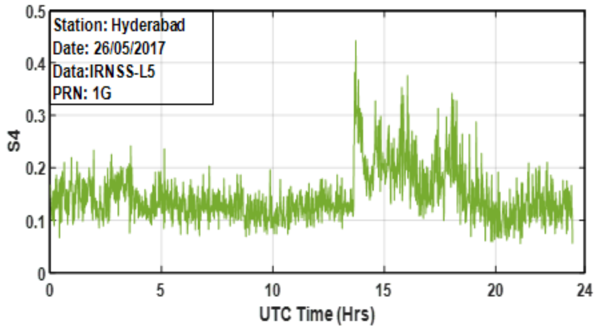
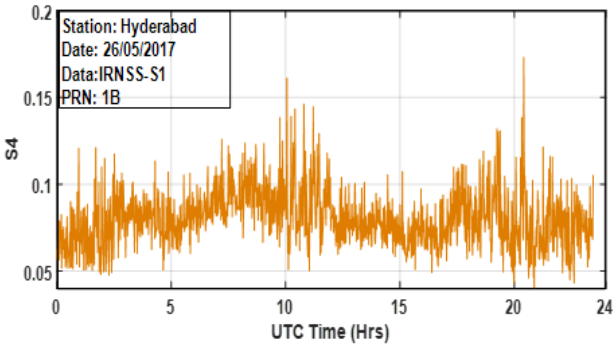
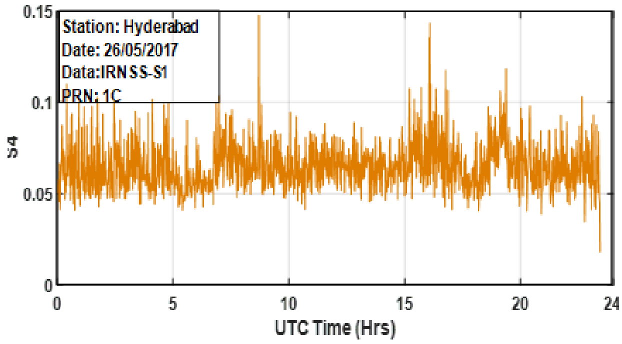
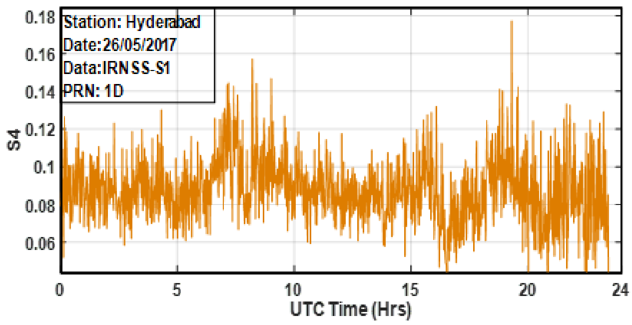
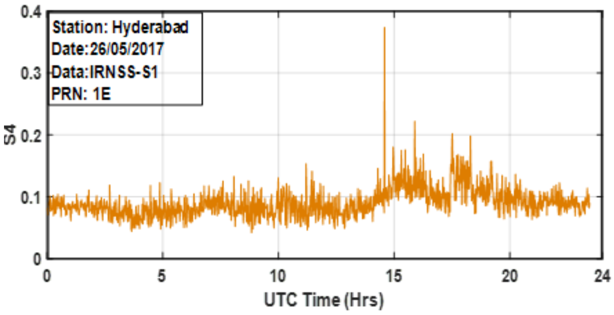
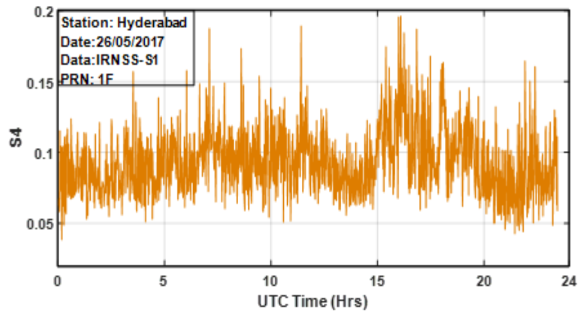












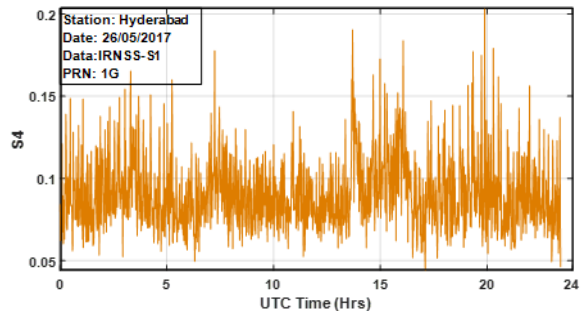


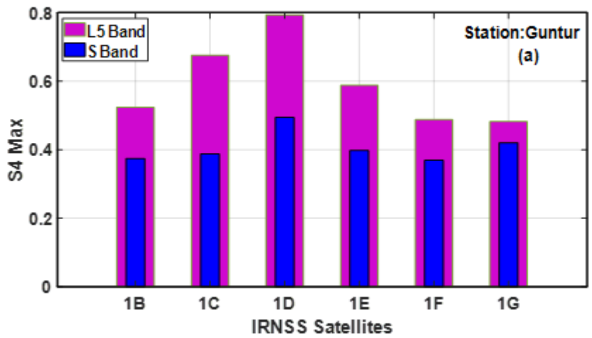
Figure 1. S_4 index variation of L5 and S signals for Hyderabad station

Table 1. Variation of S4 average and maximum values due to NavIC L5 and S signals

PRN	S4 Max	S4 Mean	S4 Max	S4 Mean
	L5 BAND		S BAND	
1B	0.5238225	0.2005397	0.3744833	0.1337785
1C	0.6757449	0.1953567	0.3875033	0.1272829
1D	0.7936268	0.7936268	0.4941201	0.1249691
1E	0.5882059	0.1923368	0.3975887	0.1257996
1F	0.4878037	0.1939812	0.3691376	0.1311211
1G	0.4825477	0.1699229	0.4203256	0.1227172

Table 2. Variation of S_4 average and maximum values due to NavIC 5 and S signals

PRN	S4 Max	S4 Mean	S4 Max	S4 Mean
	L5 BAND		S BAND	
1B	0.25266	0.1463097	0.1730904	0.0806328
1C	0.3349093	0.1230946	0.1477139	0.0652978
1D	0.3005634	0.1499188	0.1773492	0.0874985
1E	0.5300463	0.165324	0.3735755	0.0906714
1F	0.4599637	0.1638541	0.1961177	0.0934322
1G	0.4421007	0.1461024	0.2032682	0.0906886



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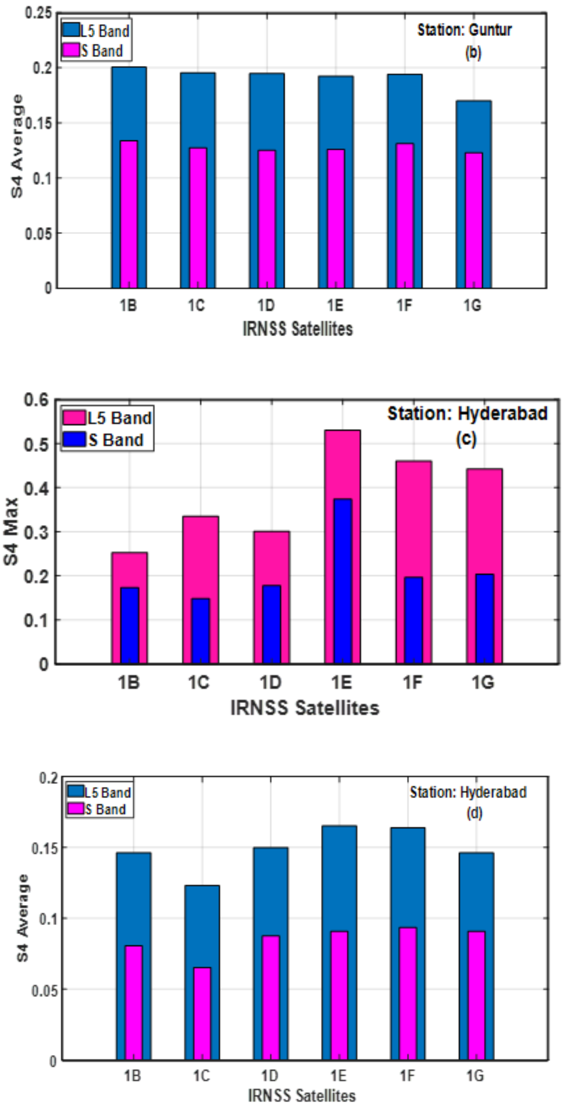

Figure 2. S4 variation of (a) S4 maximum values of IRNSS satellites Guntur station (b) S4 average of NavIC L5 and S signals Guntur station (c) S4 maximum values of IRNSS satellites Hyderabad station (d) S4 average of NavIC L5 and S signals Hyderabad station

IV. CONCLUSION

In this work Ionospheric amplitude scintillation index (S_4) variations of NavIC L5 and S band signals are investigated for low latitude Indian region. From the results it is observed that S band scintillations are low for both the Hyderabad and Guntur station compared to L5 band scintillations. The maximum S_4 value for Guntur station is 0.79 for L5 signal and 0.494 for S band signals for Guntur station. For Hyderabad station, S4 maximum value for L5 signal is 0.530 and 0.373 for S band signal. The Guntur station average value of S_4 is low for all (L5 and S) band satellite signals compared to Hyderabad station satellite signals. Over Indian region, it shows latitude-dependent scintillations.

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DECLARATION

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Authors Contributions	Author-1 carried out the study, simulated results included in manuscript and drafted the manuscript. Author-2 and Author-3 reviewed the manuscript suggested the modifications which were incorporated in the manuscript.
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AUTHORS PROFILE

Praveena Kaitha, completed B.Tech and M.Tech from GNITS, Hyderabad. She is presently doing her Full time PhD in Osmania University. She is having teaching experience. Her Research interest includes GNSS/NavIC applications.

Prof. D. Naveen Kumar, has obtained BE and PhD in Electronica and Communication Engineering from Osmania University, Hyderabad. He obtained his ME from JNTUH. Having 22 years of teaching experience and research experience. Presently he is professor in Electronics and Communication Engineering, Osmania University. He is having more than 95 publications to his credit in both national and international journals and conferences. Successfully completed SAC, ISRO project. His area of interest includes GNSS, NavIC and Satellite based Augmentation system.

Prof. D. Krishna Reddy, has obtained B.E. degree in ECE from Andhra University, Waltair in 1990 with distinction. In 1995, he obtained his M.E. degree. Awarded Ph.D degree in 2008 from Osmania University, Hyderabad. Having 26 years of experience in teaching and R&D organizations. Presently he is Head & Professor in ECE dept. of CBIT. He has about 67 publications to his credit both in national and international journals. Successfully completed one DST Project and one consultancy project sponsored by RCI, DRDO in the area of GNSS and NavIC. His areas of research interest include Navigation Systems, 5G and mobile communications