International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Application of Navigation with Indian Constellation (NavIC) Signals for Ionosphere Irregularities Measurement

K.C.T.Swamy, M.A. Farida, M. Jyothirmai, S. Towseef Ahmed

Abstract: ***Soon Indian's mobile phones and cars are to be installed with new and indigenous satellite technology, i.e. Navigation with Indian Constellation (NavIC) developed by ISRO. After successful completion of NavIC, India has become fifth nation in the sequence of countries with independent navigation technology/system. The NavIC technology will be used mainly for terrestrial, aerial and marine navigation along with tracking and disaster management. Here we are proposing the application of NavIC signals for measuring and montoring ionosphere layer behaviour leading accuracy degradation of satellite based navigation and communication systems. This paper presents the computation of ionosphere parameters such as TEC, ROTI and scintillation index (S_4) using pseudo range and Carrier to Noise density ratio (C/N_o) measurements of NavIC L_5 and S-band signals. ROTI and S_4 results revealed that the impact of ionosphere irregularity is more on L_5 than that of S-band signals.***

Keywords **:** ***NavIC, ROT, ROTI, S_4.***

I. INTRODUCTION

Navigation with Indian Constellation (NavIC) is an indigenous satellite navigation system planned and implemented by the Indian Space Research Organization (ISRO) for position, navigation and time (PNT) applications with a limited service region. It is fully operational with three Geostationary orbital (GEO) satellites and four Geosynchronous orbital (GSO) satellites, details are given in Table 1. The arrangement of satellites in the orbits was planned in such a way that users from the Indian subcontinent could receive signals from atleast four satellites. The NavIC satellites transmit navigation signals, based on Code Division Multiple Access (CDMA) on L_5 (1176.45MHz) with a Binary Phase-Shift Keying (BPSK (1)) modulation for standard positioning service (SPS) users. Restricted service user get signals with a Binary Offset Carrier (BOC(5,2)) modulation on S-band(2492.028 MHz) [1].

The ionosphere, a propagation medium for the satellite based communication and navigation systems affects signals in terms of refraction, absorption, Faraday rotation, scintillation, propagation time delay, Doppler frequency shift, etc. Moreover, Ionosphere scintillations are hazardous to the wide range of radio frequencies and is therefore of great practical interest. In the beginning, researchers have been published the reviews of ionospheric scintillations [2]-[5]. Further, Global Positioning System (GPS) signals were used to study the irregularities of ionosphere. Swamy et al. (2013) & Sarma et al. (2014) studied ionospheric scintillations and developed mathematical models for predicting ionospheric scintillations over the Indian region using GPS signals [6]-[7].

Pi et. al., (1997) introduced a parameter, Rate of TEC Index (ROTI) to study ionosphere irregularity, later the relation between ROTI and S4-index (ROTI/S_4) was analyzed by Basu et al. (1999) [8]-[9]. Sujimol and Shahana (2017) have done a preliminary study on the amplitude scintillation effect of NavIC signals and found frequent loss of lock on L_5 signals at Delhi station [10].

Table 1: NavIC satellites details
(https://www.isro.gov.in/launchers/pslv)

	Satellite	Orbit	Longitude	Orbit Inclination	Launch Date	Status
1	IRNSS-1A	GSO	55^{0}E	29	Jul 01, 2013	Clocks Failed
2	IRNSS-1B	GSO	55^{0}E	31	Apr 04, 2014	Operational
3	IRNSS-1C	GEO	83^{0}E	-	Oct 16, 2014	Operational
4	IRNSS-1D	GSO	111.75^0 E	30.5	Mar 28, 2015	Operational
5	IRNSS-1E	GSO	111.75^0 E	28.1	Jan 20, 2016	Operational
6	IRNSS-1F	GEO	32.5^{0}E	-	Mar 10, 2016	Operational
7	IRNSS-1G	GEO	129.5^{0}E	-	Apr 28, 2016	Operational
8	IRNSS-1H			-	Aug 31, 2017	Launch Failed
9	IRNSS-1I	GSO	55^{0}E	290	Apr 12, 2018	Operational

Manuscript published on 30 September 2019.
*Correspondence Author(s)
Dr. K.C.T.Swamy*, Department of Electronics and Communication Engineering, G.Pullaiah College of Engineering & Technology, Kurnool, India. kctswamy@gmail.com
Mohammed Abdul Farida, Department of Electronics and Communication Engineering, G.Pullaiah College of Engineering & Technology, Kurnool, India. mafarida01@gmail.com

In this paper the availability of NavIC dual frequencies (L_5 and S-band) was taken as the advantage to compute ionosphere medium irregularities over an Indian low latitude station. Signals from a typical IRNSS-1B satellite were used to compute a parameter, Total Electron Content (TEC) which is the indicator of ionosphere condition. Then, critical analysis of ionosphere irregularities was carried out with parameters ROTI and S_4-index by collecting data from all the available NavIC satellites at different elevation angles.

II. DATA AND METHODOLOGY

To measure ionosphere irregularities, NavIC satellite signals were received by establishing a receiver station at GPCET (15.790N, 78.070E), Kurnool, India. A dual-band receiving antenna was mounted on the roof of a 5 floor building with clear sky view and connected to the receiver through a 15 meter low loss RF cable TNC-M to TNC-M. The received signal binary data were extracted using a tool *'IrnssUR'*, subsequently ROTI and S_4-index were computed.

A. *Rate Of TEC Index (ROTI)*

The irregularity level of ionosphere medium can be measured by computing two parameters -Rate of change of TEC (ROT) and ROT Index (ROTI), which is function of TEC. ROTI is defined as the standard deviation of Rate of change of TEC over a 5 minutes time interval. ROTI characterizes small-scale and/or rapid variations in TEC [8]. For a satellite 'i', ROTI can be computed as follows,

$$ROTI_i = < ROT_i^2 > - < ROT_i >^2 \qquad (1)$$

Where, ROT is the rate of TEC/minute and is given by eqn. (2),

$$ROT_i(t) = \left[\frac{\left(TEC_i(t) - TEC_i(t-\tau) \right)}{\tau} \right] \qquad (2)$$

$$TEC(t) = \frac{L_5^2 S^2}{S^2 - L_5^2}(P_1 - P_2) \qquad (3)$$

Where, P_1 and P_2 are pseudo ranges on S and L_5 band respectively.

B. *S_4-index*

Amplitude scintillation (S_4) refers to rapid fluctuations in the received signal carrier to noise ratio $\left(C/N_O \right)$ or signal intensity (*SI*). The parameter used to represent amplitude scintillations is S_4-index and it can be measured by computing the square root of the normalized variance of signal intensity over 60 seconds (Eqn.4) [11],

$$S_4 = \sqrt{\frac{(< SI^2 > - < SI >^2)}{< SI >^2}} \qquad (4)$$

The signal intensity in the above mathematical expression can be represented in terms of carrier-to-noise density ratio $\left(C/N_O \right)$ measured in dB-Hz. The relation between these two quantities is as given below,

$$S/N_O = 10^{(0.1 * C/N_O)} \qquad (5)$$

However, the above measured S_4 -index suffers from the ambient noise which degrades the signal quality; hence it must be removed by proper calculations. For a given C/N_O in dB-Hz, the ambient noise effect on index can be calculated as,

$$AmbientNoise = \sqrt{\frac{100}{S/N_O}\left[1 + \frac{500}{19 * S/N_O}\right]} \qquad (6)$$

Therefore, the corrected S_4 index,

$$S_4 \text{ index}_{\text{corrected}} = S_4 - ambient \text{ noise factor}$$

$$S_4 \text{ index}_{\text{corrected}} = \sqrt{\frac{(< SI^2 > - < SI >^2)}{< SI >^2} - \frac{100}{S/N_O}\left[1 + \frac{500}{19 * S/N_O}\right]} \qquad (7)$$

Based on the S_4 value scintillations can be categorized as weak ($0.15 \le S_4 < 0.3$), moderate ($0.3 \le S_4 < 0.5$) and strong ($0.5 \le S_4 \le 1$).

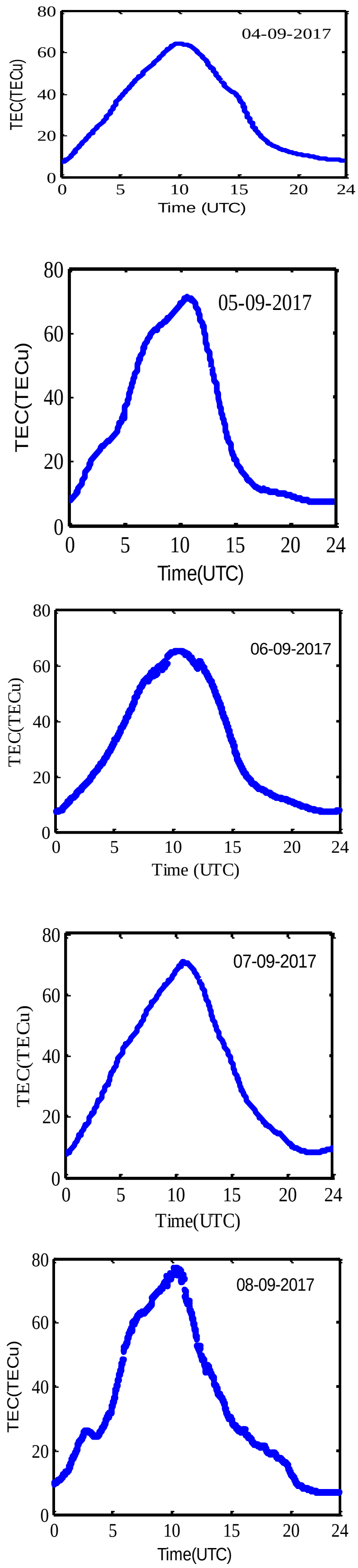
III. RESULTS AND DISCUSSION

In this paper ROTI and S_4-index, the indicators of ionosphere irregularities are measured from the active NavIC satellite (IRNSS-1B, IRNSS-1C, IRNSS-1D, IRNSS-1E, IRNSS-1F and IRNSS-1G) signals. Since the TEC is basic parameter, qualitative discussion of it presented below..

Fig.1 shows daily TEC variations of IRNSS-1B for the period Sep 4,2017 to Sep 10, 2017. In figure time on x-axis was represented in UTC (Hrs) and it can be converted into Indian Standard Time (IST) by adding 5:30 Hrs. TEC increases gradually with time and reaches peak at midday then decreases gradually. The peak value was occurred in between UTC 10:30 Hrs and UTC 11:30 Hrs. The highest peak (78 TECu) has been observed on 08-09-2017 which is due to the solar flares of type M8.1. The diurnal variation of TEC measured in this work is synchronized with typical low latitude ionosphere behavior studied elsewhere [12] -[14]. Also, it is clearly observed that the variations in TEC are more during daytime, whereas the variations are less during the night time.

Retrieval Number: K20330981119/19©BEIESP
DOI: 10.35940/ijitee.K2033.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)



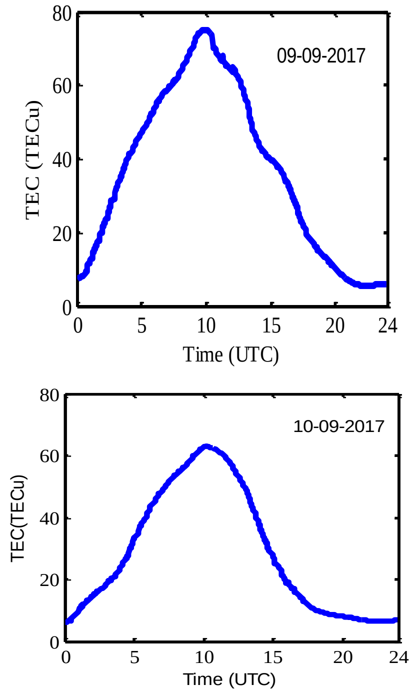
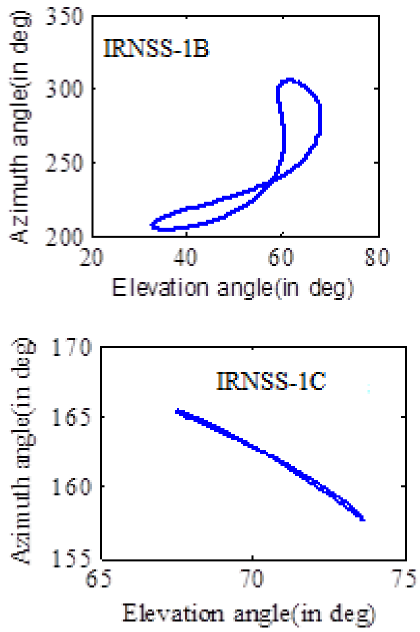


Fig. 1. TEC variability during solar flares days

Since, the NavIC constellation is new, it is more interesting to know the satellite's path over a period of 24 Hrs. Fig.2 shows the NavIC satellites visibility in terms of elevation and azimuth angles. From, the figure it is understood that IRNSS-1C, IRNSS-1F and IRNSS-1G are GEO satellites with elevation and azimuth angle variation is within 10^0. And the remaining satellites IRNSS-1B, IRNSS-1D and IRNSS- 1E are geosynchronous (GSO) satellites with azimuth and elevation angle variation approximately 100^0 and 30^0 respectively. It can be concluded that the receiver station has been acquiring signals from 3 GSO and 3 GEO NavIC satellites.



Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

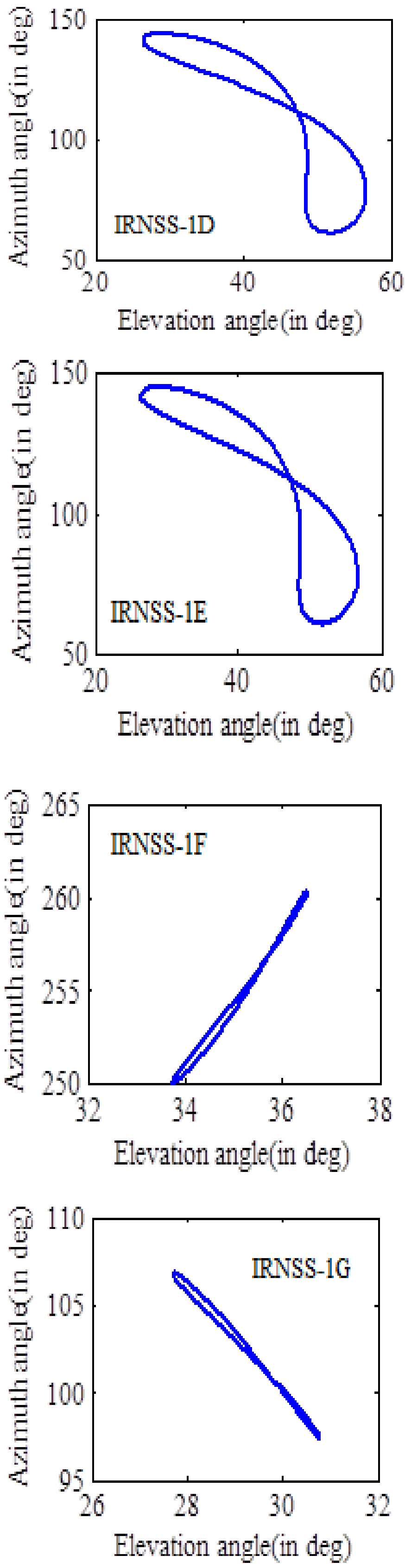
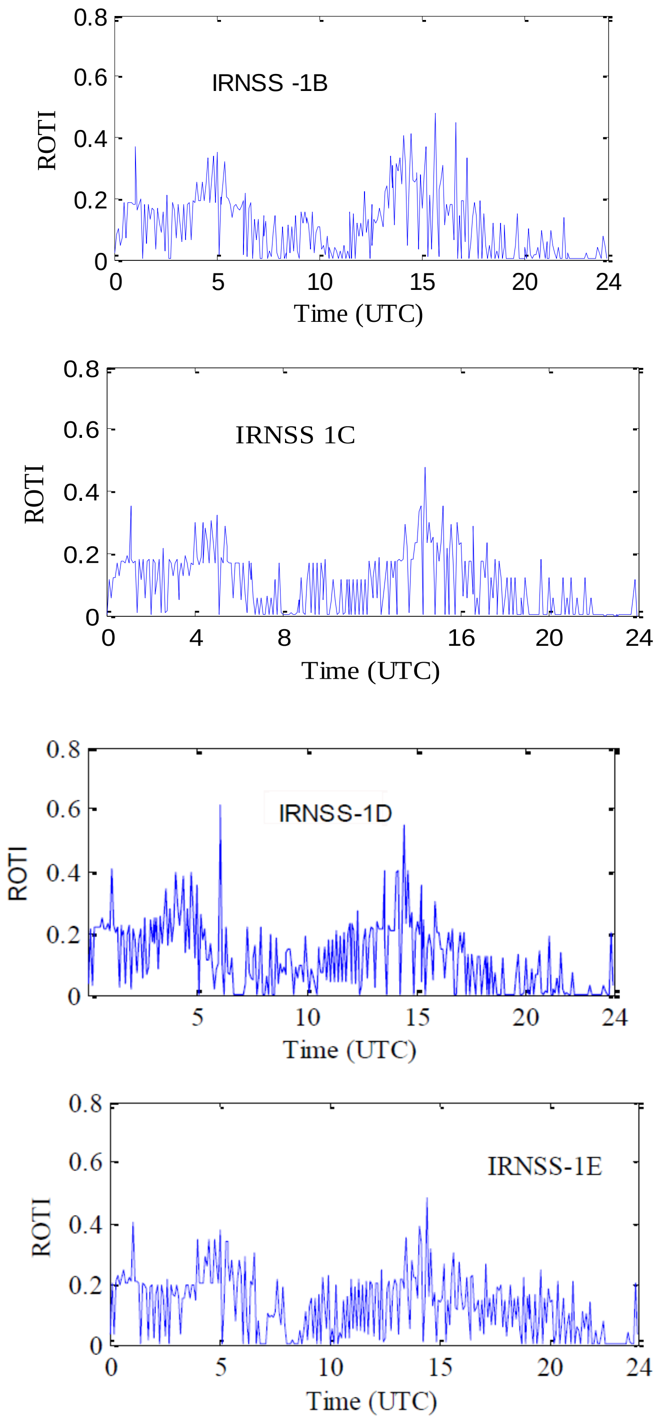


Fig.2 NavIC satellites path with respect to a lower latitude receiver station

Fig.3, shows ROTI variation measured with all available satellites data and the Fig.4, shows S_4-index variation measured from the respective satellite signals. The peak ROTI is observed 0.48, 0.47, 0.62, 0.48, 0.79 and 1.1 for IRNSS-1B, IRNSS-1C, IRNSS-1D, IRNSS-1E, IRNSS-1F and IRNSS-1G respectively. From the results, we could see the greater ROTI values for IRNSS-1G and lesser ROTI values for IRNSS-1C which are located above the equator at longitude 129.5^0 E and 83^0 E respectively. Since, the receiver is located at the longitude of 78.07^0E, IRNSS-1C is almost in the zenith direction with high elevation angles (short path length), whereas IRNSS-1G is at low elevation with longer path length. As the signal path length increases TEC and ROTI also increases. From S_4-index variations it is understood that the L_5 signal is more sensitive to the ionosphere variations than that of S-band signals.



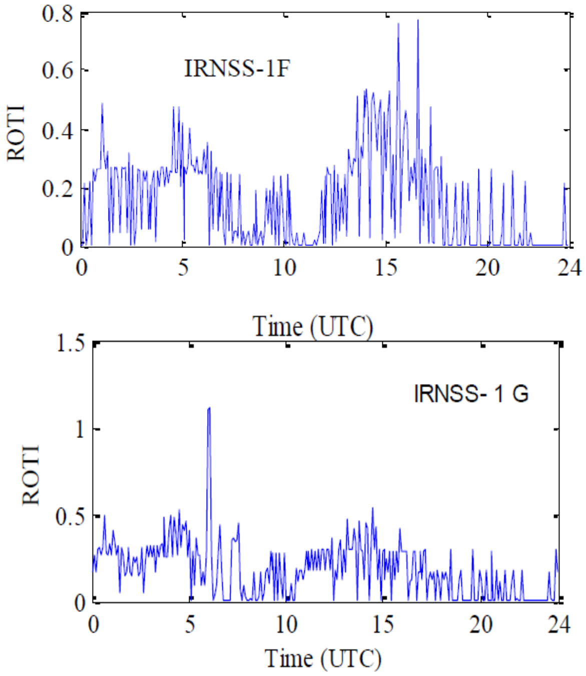
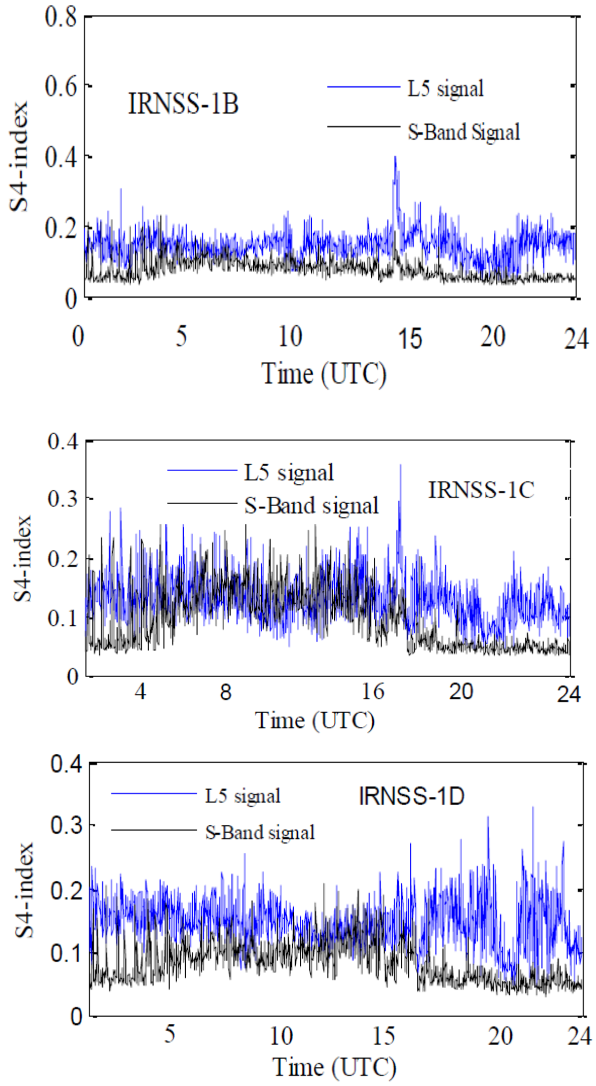


Fig.3 ROTI variations measured by different NavIC satellites on 08-09-2017



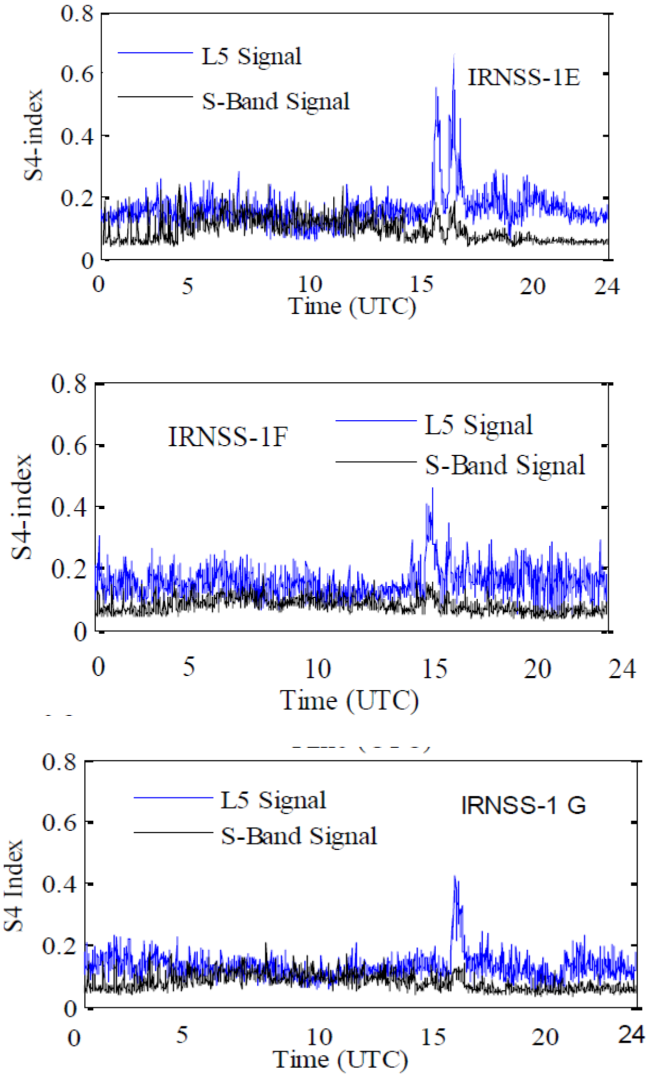


Fig.4 ROTI and S4-index variations measured by different NavIC satellites on 08-09-2017

IV. CONCLUSIONS

In this paper, we have explained measurement and analysis of ionosphere irregularities using NavIC signals. Pseudo ranges based TEC and ROTI measurement approach can be used for both real-time and post processing analysis of ionosphere irregularities. In this contribution, presented a step-by-step procedure for S_4-index measurement with removal of ambient noise effect. We found that the ionosphere fluctuations impact is more on the low elevation GEO satellite signals. Further, low frequency (L_5) signals are highly sensitive to the ionosphere fluctuations.

ACKNOWLEDGMENT

The research work presented in this paper has been carried out under the project entitled "Investigation of Indian Ionosphere Irregularities Correlation with Space Weather Parameters for Navigation Applications" funded by SAC (ISRO), NavIC-GAGAN Utilization Programme, Project ID: NGP-12, Dated: 23 January, 2017.

REFERENCES

1. Indian Space Research Organisation (ISRO). Indian Regional Navigation Satellite System: Signal in Space ICD for Standard Positioning Service, Version 1.0; ISRO Satellite Centre: Bengaluru, India, 2014.W.-K. Chen, *Linear Networks and Systems* (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.
2. Aarons J, Global morphology of ionospheric scintillation, Proc IEEE (USA), 70(4) 360, 1982.
3. Aarons J, The longitudinal morphology of equatorial F-layer irregularities relevant to their occurrence, Space Sci Rev (USA), 63 , 209 , 1993.
4. Basu S & Basu S, Equatorial scintillations: Advances since ISEA-6, J Atmos Terr Phys (UK), 47, 753, 1985.
5. Basu S & Basu S, Remote sensing of auroral E region plasma structures by radio, radar, and UV techniques at solar minimum, Journal of Geophysical Research Atmospheres, 98(A2):1589-1602,1993.
6. K.C.T. Swamy, A. D Sarma & A. Supraja Reddy, V. Satya Srinivas, P.V.D. Somasekhar Rao, Modelling of GPS signal scintillations with polynomial coefficients over the Indian region, Indian Journal of Radio & Space Physics (IJRSP) IJRSP, vol. 42, no. 3, 2013.
7. AD Sarma, KCT Swamy & PVD Somasekhar Rao, Forecasting of ionospheric scintillations of GPS L-band signals over an Indian low latitude station, 2014 IEEE Antennas and Propagation Society International Symposium (APSURSI), 265-266, 2014.
8. Pi X, Manucci A J, Lindqwister U J & Ho C M, Monitoring of global ionospheric irregularities using worldwide GPS network, Geophs Res Lett (USA), 24, 2283, 1997.
9. Sunanda Basu & Ceasar Valladares, Global aspects of plasma structures, Journal of Atmospheric and solar –Terrestrial Physics 61, 127-139, 1999.
10. M R Sujimol & K Shahana, Ionospheric scintillation characterisics in IRNSSL5 and S- band signals, Indian Journal of Radio & Space Physics ,Vol 45, March 2017 ,pp 15-19, 2018.
11. Wernik A.W, Alfonsi L & Materassi M, Scintillation modeling using in situ data, 36 Radio Sci. 42, 1–21. doi:10.1029/2006RS003512, 2007.
12. Swapna Raghunath & D Venkata Ratnam, Detection of ionospheric spatial and temporal gradients for ground based augmentation system applications, Indian Journal of Radio & Space Physics, Vol 45, March 2016, pp 11-19, 2016.
13. Swamy K.C.T, Sarma A.D, Satya Srinivas V, Accuracy evaluation of estimated ionospheric delay of GPS signals based on Klobuchar and IRI-2007 models in low latitude region, IEEE Geosci. Remote Sens, Lett., , 10, (6), pp. 1557–1561 (doi: 10.1109/LGRS.2013.2262035), 2013.
14. Smita Dubei, Rashmi Wahi, Ekkaphon Mingkhwan & A K Gwal, Study of amplitude and phase scintillation at GPS frequency, Indian Journal of Radio & Space Physics, Vol. 34, pp. 402-407, 2005.

AUTHORS PROFILE

Dr.K.C.T. Swamy, Obtained his Ph.D. from JNTUH, Hyderabad in 2016. He published more than 20 papers in reputed journals and conferences. He has been working for two research projects funded by ISRO and SERB- New Delhi. His research interest includes GNSS and NavIC signal delay and scintillations estimation and modeling. Presently he is working as an associate professor in the ECE department, GPCET, Kurnool, India.

Mohammed Abdul Farida has obtained B.Tech in ECE and M.Tech in VLSI-SD from JNTUH, yderabad. Presently, working as Assistant Professor in ECE department, GPCET, Kurnool and area of research interest includes communication and DOP.

M.Jyothirmai has obtained B.Tech in ECE and M.Tech in Communications and Signal Processing from JNTUA, Ananthapur. Presently, working as Assistant Professor in ECE department, RCEW, Kurnool and area of research interest includes communication and GNSS.

S. Towseef Ahmed has obtained B.Tech in ECE and M.Tech Embedded Systems from JNTUA, Ananthapur. Presently, working as Junior Research Fellow in ECE department, GPCET, Kurnool and area of research interest includes GNSS, Communication and Embedded Systems.

Retrieval Number: K20330981119/19©BEIESP
DOI: 10.35940/ijitee.K2033.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)