www.cafetinnova.org

ISSN 0974-5904, Volume 10, No. 04

DOI:10.21276/ijee.2017.10.0420

International Journal of Earth Sciences and Engineering

August 2017, P.P. 868-872

Data Analysis for Ionospheric Divergence and Glittering by using NavIC Receiver

THANGADURAI N, VASUDHA MP AND RAJU G

Department of Electronics and Communication Engineering, School of Engineering and Technology, Jain University, Bangalore, INDIA

Email: *mrgoldjain2015@gmail.com, mp.vasudha@gmail.com*

Abstract: *The Indian Regional Navigational Satellite System (IRNSS) renamed as NavIC is used in both the military and civilian communities for navigation, surveying, remote sensing, asset management and precise timing. A number of environmental factors are known to affect the performance of NavIC including electromagnetic interference, multipath, foliage attenuation, atmospheric delays and ionospheric effects. In this paper, the effects of the ionosphere on NavIC will be examined. Ionospheric effects are the most significant disturbance that can affect NavIC users during high sunspot activity. In the presence of glittering, ionospheric modeling can be rendered impractical and receiver performance can be severely degraded. The influence of the ionosphere and a strategy to isolate its effect are a major concern for NavIC positioning and navigation applications. It is also stronger from local sunset until just after midnight, and during periods of high solar activity. If sufficiently intense, these fluctuations can dramatically impact the performance of space-based communication and navigation systems. Therefore, it is desirable to obtain further understanding of ionosphere and its effects on NavIC.*

Keywords: *Ionospheric Refraction, Iono Delay, Position Error, C/No Ratio*

1. Introduction

NavIC is an autonomous regional navigational satellite system being developed by Indian Space Research Organization (ISRO). The objective is to implement an indigenous regional spaceborne navigation system for national applications. The proposed NavIC system will consist of seven satellites and a supporting ground segment. Three of the satellites in the constellation will be placed in a geostationary orbit positioned over 32.5^0, 83^0 and 131.5^0 and the remaining four in a geosynchronous inclined orbit of 29° positioned over longitudes of 55^0 and 111.75^0 relative to the equatorial plane. The NavIC receiver design requires position accuracy less than 20m throughout the Indian region and also extending about 1500km from its bourndary[1]. The orbital characteristics used for the purpose of the simulation are given in Table 1 and figure 1 shows the polar plot of the entire 7 satellites constellation.

The 4 satellites in inclination orbit trace a figure of "8" on earth where 3 of 7 satellites are at equator axis and other are at extreme positions. This system is expected to provide accurate real-time position, velocity and time observables for users on a variety of platforms with 24x7 service availability under all weather conditions [2].

Table 1. *Orbital Characteristics of IRNSS*

Satellites	Eccentricity	i	RAAN (deg)	AOP (deg)	True Anomaly
IRNSS1A	0.002	29°	241°	84.557°	266.941°
IRNSS1B	0.002	29°	61°	84.557°	86.941°
IRNSS1C	0.002	0°	86°	84.557°	90°
IRNSS1D	0.002	29°	310°	84.557°	255°
IRNSS1E	0.002	29°	130°	84.557°	75°
IRNSS1F	0.002	0°	32.5°	84.557°	94.5°
IRNSS1G	0.002	0°	131.5°	84.557°	94.5°

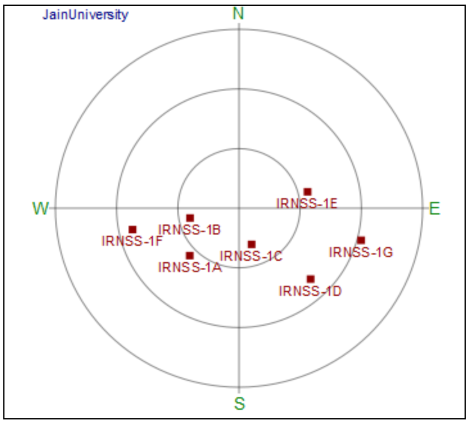
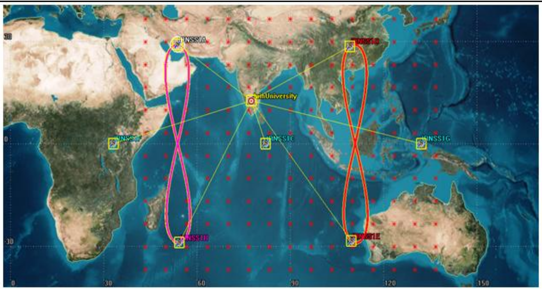


Figure 1: *Polar plot of all the NavIC satellites*

2. Location Targeting Jain University

In the simulation, a user target with the coordinates of IRNSS SPS-GPS User Receiver kept at Jain University is chosen for the coverage analysis and the access report is generated to verify the coverage. It is observed that all the seven satellites are looking at that point all the time. Figure 2 shows the screenshot of coverage report of the NavIC constellation for a period of 24 hours and Figure 3 shows the sample data of access time of coverage target from STK tool [7].

Received: February 19, 2017; Accepted: June 21, 2017; Published: August 30, 2017
International Journal of Earth Sciences and Engineering, 10(04), 868-872, 2017, DOI:10.21276/ijee.2017.10.0420



Map shows the Target marked as Jain university with line of access from corresponding all 7 constellation satellites and red (*) mark indicates the coverage area of India from satellites.

Figure 2: *Jain University as Target*

Coverage for Target1

Access	Access Start (UTCG)	Access End (UTCG)	Duration (sec)	Asset Full Name
1	24 Mar 2015 06:30:00.000	25 Mar 2015 06:30:00.000	86400.000	IRNSS1A
2	24 Mar 2015 06:30:00.000	25 Mar 2015 06:30:00.000	86400.000	IRNSS1C
3	24 Mar 2015 06:30:00.000	25 Mar 2015 06:30:00.000	86400.000	IRNSS1E
4	24 Mar 2015 06:30:00.000	25 Mar 2015 06:30:00.000	86400.000	IRNSS1G
5	24 Mar 2015 06:30:00.000	25 Mar 2015 06:30:00.000	86400.000	IRNSS1F
6	24 Mar 2015 06:30:00.000	25 Mar 2015 06:30:00.000	86400.000	IRNSS1D
7	24 Mar 2015 06:30:00.000	25 Mar 2015 06:30:00.000	86400.000	IRNSS1B

Figure 3: *Sample Data from STK Tool*

But practically the NavIC Constellation does not provide 24 hours coverage due to the space weather effects. Figure 4 shows the relationship between latitude and longitude motion which creates ‘figure of 8’ structure.

The different types of space weather effects are tropospheric effects, Ionospheric refractive effects and Ionospheric glittering effects. The IRNSS signals gets affected more by the Ionospheric refractive effects which introduce a range error and Ionospheric glittering effects which leads to loss of signals. The accuracy of the NavIC navigation solution is influenced by several kinds of error factors, among which the signal delay by the ionosphere is the greatest [12]. The data used for this analysis has been collected from IRNSS SPS-GPS User Receiver installed at the Department of Electronics and Communication Engineering, School of Engineering and Technology, Jain University, Kanakpura, India.

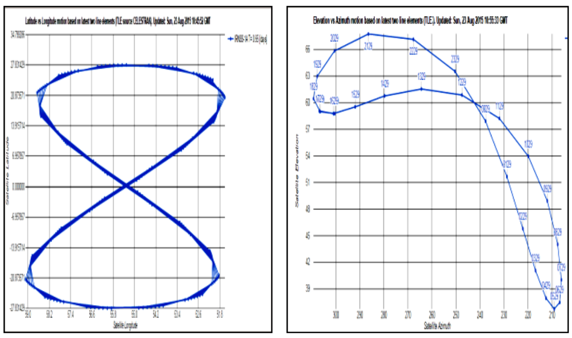


Figure 4: *IRNSS Latitude v/s longitude motion*

3. Ionospheric Distinctive

A. Total Electron Content

Total electron content (or TEC) is an important descriptive quantity for the ionosphere of the Earth. TEC is the total number of electrons integrated between two points, along a tube of one meter squared cross section, i.e., the electron columnar number density. It is often reported in multiples of the so-called TEC unit (TECU), defined as 1 TECU=$10^{16}\cdot m^{-2}$.

TEC is significant in determining the glittering and delays of a radio wave through a medium. Ionospheric TEC is characterized by observing delays of received radio signals transmitted from satellites located above the ionosphere. TEC is strongly affected by solar activity [6][9].

B. Ionospheric Divergence

The ionosphere is a layer of the atmosphere containing charged particles ionized by solar radiation. The ionosphere is a dispersive medium, in which radio frequency signals are refracted by an amount dependent upon signal frequency and ionospheric electron density [8]. The ionospheric radio effect is directly proportional to the TEC and inversely proportional to the square of the frequency. The ionospheric delay is given below:

$$\Delta Iono = {}^{40.3}/_{f_2}\, TEC \qquad (1)$$

C. Ionospheric Glittering

Satellites are in orbits hundreds of kilometers away from the earth. Signals that travel such distances are susceptible to path loss which reduces the received Signal to Noise Ratio (SNR). The electron concentration is affected primarily by the solar wind, solar flares, and electromagnetic radiation from the sun [4]. Solar flares and the solar wind carry charged particles from the sun. When they reach the Earth, some of them are trapped in the Earth’s magnetic field, thus adding to the total electron count. The intensity of solar flares since the electron concentration is not consistent throughout the path of the radio signal, the refractive index changes at different locations. This refractive index variation causes a phenomenon known as glittering, the rapid fluctuations in signal strength (amplitude) and phase and the solar wind is closely related to the number of sunspots which fluctuates on the eleven-year solar cycle. Thus, the effects of ionospheric glittering are increased during the solar maximum and decreased during the solar minimum [5].

Ionospheric losses are rapid variations in the amplitude and phase of trans-ionospheric radio signal resulting from density irregularities in the ionosphere. Glitterings have the capacity to affect both the accuracy and reliability of NavIC systems by compromising the performance of the code and carrier tracking loops of a receiver. Glitterings occur predominantly in the equatorial band that extends from about 20^0S to 20^0N of the magnetic equator and in the auroral and polar cap regions [3].

Glitterings are produced by changes in the phase velocity of sections of a satellite signal wavefront as it propagates through irregularities in the ionosphere. As absorption in the ionosphere is negligible at L-band frequencies, the amplitude of the emergent wave is unaffected by the irregularities. However, as the wave propagates towards the ground, interference across the wavefront creates complex amplitude and phase diffraction patterns that are a function of both the range to the irregularities and the cross-range position. Glitterings are produced when these spatial diffraction patterns are transformed into temporal ones, either through relative motion between the receiver and the patterns or by changes in the structure of the irregularities with time. Although diffraction is the principal cause of glitterings, weak focusing and defocusing through refraction can introduce additional amplitude and phase variations. However, for refractive effects to be significant at L-band frequencies, the density gradients in the ionosphere must be extremely large [10][11].

4. Results and Conclusion

This section provides the results of the investigation about the ionospheric refraction and ionospheric glittering effects on NavIC signals. The data used for this study is collected for a period of 3 months.

a. Ionospheric Delay Analysis

The analysis is carried out based on the following

1. Ionodelay Comparison Analysis for L5 and S-band and TEC comparison.
2. Position Error Comparison for IRNSS, GPS, and Hybrid.

b. Ionospheric Glittering Analysis

The analysis is carried out based on the following

1. Glittering duration for 1 day, 1 week, 1 month for showing repeativity in the time of occurrence.
2. Expanded view analysis for 2 hours

c. Ionodelay and Glittering Comparison

The Figure 5 shows the NavIC satellite L5 signals coverage over Indian region and Figure 6(a) shows the Iono-delay plot of the L5 band for 3 satellites on March $1^{st,}$ 2015 for a period of 24 hours. It is observed that the maximum Iono delay is around 70 m at 11.30pm and Iono-delay is around 30m at 11.45 am.

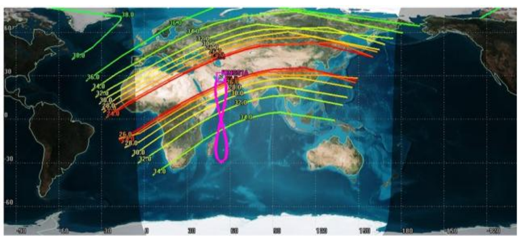


Figure 5: *Coverage range of NavIC L5 band signal*

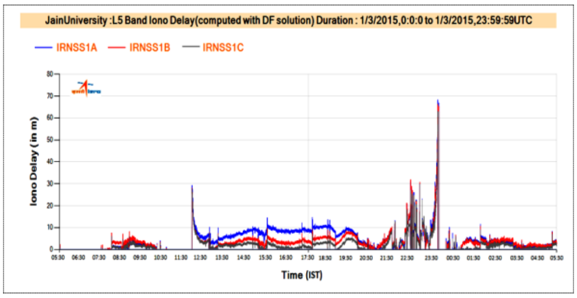


Figure 6(a): *Iono Delay L5 Band*

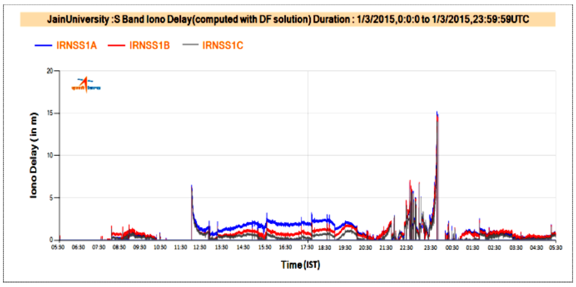


Figure 6(b): *Iono Delay S1 Band*

The Figure 6(b) shows the Iono delay plot of the S1 band for 3 satellites on March $1^{st,}$ 2015 for a period of 24 hours. From Table.2 it is observed that the maximum Iono delay is around 15m at 11.30 pm and Ionodelay is around 7m at 11.45 am.

Table.2 *Comparison of Ionodelay*

Time of Observation	Ionodelay for L5 band	Ionodelay for S1 band
11.45 AM	30 m	7 m
11.30 PM	70 m	15 m

Refraction increases in the presence of higher electron content and lower frequency signals are refracted more than higher frequency signals. The Iono delay will result in range error. Hence the calculated position will be in error.

Pseudo Range = CT

True Range = (Pseudo Range) – (Ionodelay) – (Tropo delay) – (other errors)

It is observed that L5 band signals are more prone to depletions than S-band frequency signals. Hence Ionospheric depletions are more severe with radio signals of low frequency. The maximum Iono Delay in L5 band signal is 70 m at 11.30 pm and the maximum iono delay in S signal is 15m at 11.30 pm.

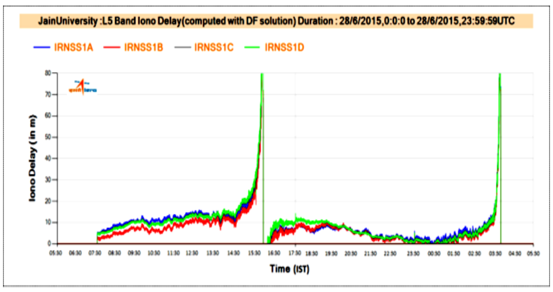


Figure 7(a): *Iono delay of L5 band signal*

Figure 7(a) and (b) shows the comparison between Iono delay of L5 band and NavIC L5 position error of 28th June 2015. It is observed the same in Table.3, that when the iono delay is increase position error is also increased.

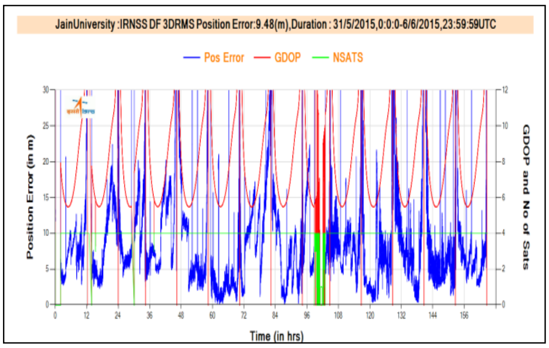


Figure 7(b): *Position Error of L5 band signal*

Table.3 *L5 band Iono Delay and Position Error Comparison*

Time of Observation	Iono delay for L5 band	Position error of L5 band
7.30AM	5 m	1 m
9.30AM	10 m	2 m
12.30 PM	15 m	5 m
02.45PM	20 m	12 m
03.30PM	80 m	30 m

Table.4 *Position Error Results*

	L5+S1 PE	GPS PE	Hybrid PE
Week 1	8.84m	8.29m	8.06m
Week 2	8.3m	8.03m	7.84m
Week 3	9.34m	7.79m	7.33m
Week 4	8.55m	8.34m	8.18m
Week 5	11.05m	9.04m	8.34m
Week 6	10.12m	7.83m	7.57m
Week 7	8.74m	7.43m	7.39m
Week 8	8.98m	8.24m	8.38m
Week 9	6.67m	6.27m	6.11m
Week 10	6.76m	6.42m	6.41m

From the Table.4, it can be observed that the position error in Hybrid is minimum than the L5 or S1 alone. The Table.4 concurs with the expected accuracy of L5+S1 (8m) and the same has been found in the above most of the time, the positional error accuracy is around 8m.

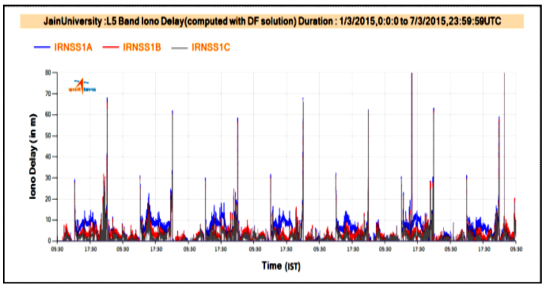


Figure 8(a): *Iono Delay L5 band for 1 week period*

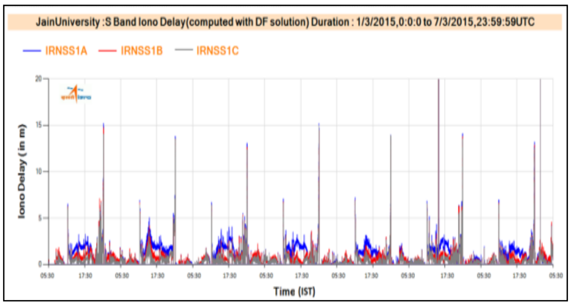


Figure 8(b): *Iono Delay S1 band for 1 week period*

The Figure 8(a) and (b) shows the iono delay for L5 and S1 band for a period of 1 week from March 1st 2015 to March 7th 2015. It is observed that the iono delay is maximum after the local sunset hours to midnight. The maximum Iono Delay in L5 signal is almost 70 m at 11.30 pm and the maximum iono delay in S signal is almost 15 m at 11.30 pm every day.

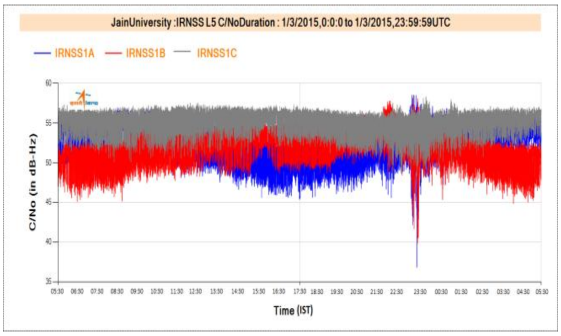


Figure 9: *C/N$_0$ variation for 1 day*

Figure 9 shows the C/N$_0$ variation for a period of 24 hours on March 1st 2015. It is observed that there is a sudden drop in the C/N$_0$ signal below 32dB for all NavIC satellites around 11.30pm which is due to glittering.

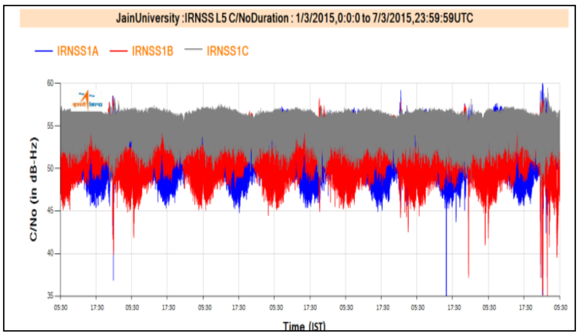


Figure 10: *C/N$_0$ variation for 1 week*

Figure10 shows the C/N$_0$ variation for a period of 1 week from March 1st 2015 to March 7th 2015. It is observed that the glittering occurs only after the post sunset hours every day.

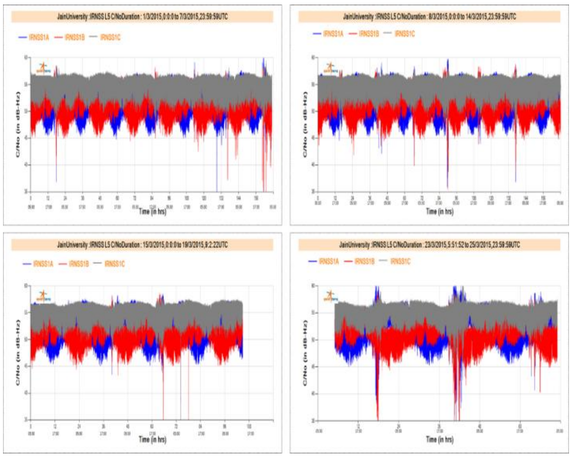


Figure 11: *C/N$_0$ variation for Month 1*

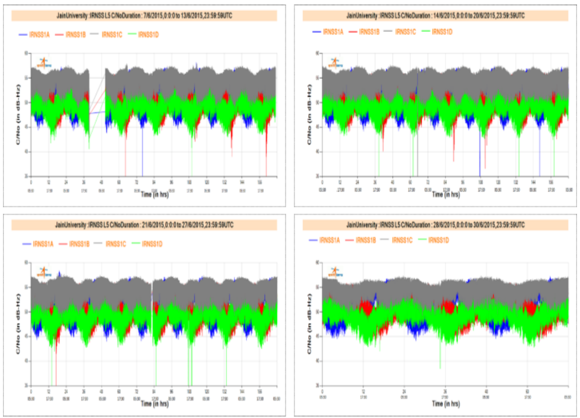


Figure 12: *C/N$_0$ variation for Month 2*

Similarly Figure 11 and 12 shows the C/N$_0$ variation for March month and June month respectively. It is observed that the glittering usually occurs after the post sunset hours every day. Note: The data is not available for analysis during due to back up power unavailability.

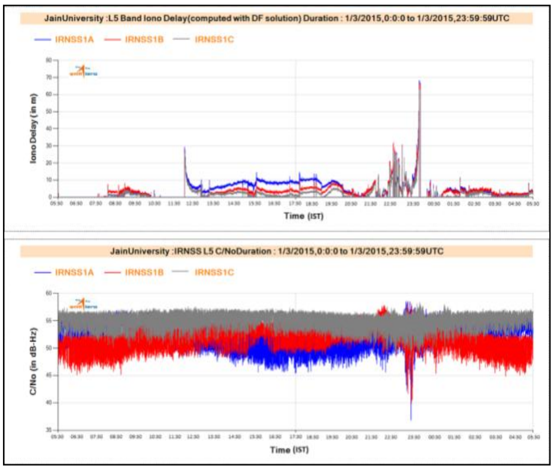


Figure 13: *Iono delay and Glittering Comparison*

Figure 13 shows the comparison between Iono delay L5 band and C/N$_0$ variation L5 band of March 1st 2015. It is observed that the maximum iono delay of 70 m is at 11.30 pm and there is also a drop in C/N$_0$ signal at 11.30 pm which is due to glittering.

Acknowledgement

The authors would like to express their sincere gratitude to Space Application Centre - Indian Space Research Organization (SAC- ISRO) for providing IRNSS (NavIC) receiver and encouraging on navigation studies. The authors acknowledge the necessary infrastructure and supporting facility provided by Jain University, Bangalore.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] Dana.J.Johnson Ph.D , “The Global Positioning Systems”, Analysis center papers, Northrop Grumman Analysis center, 2006.

[2] Thangadurai.N and Vasudha. MP, “A review of antenna design and development for Indian regional navigational satellite system” in Proc. of International Conference on Advanced Communication Control and Computing Technologies, Ramanathapuram, pp. 257-264, 2016.

[3] Presentation by S. Anandan, “Launch of first satellite for Indian Regional Navigation Satellite system next year”, 2010.

[4] IRNSS presentation by Mr K.N.Suryanarayana Rao (Project Director, ISRO)

[5] Vyasaraj Guru Rao. Gerard Lachapelle and Vijay kumar S B, “Analysis of IRNSS over Indian Subcontinent”, Proc. of ITM, The Institute of Navigation, Session B5, San Diego, CA, pp. 1-13, 2011.

[6] Dieter Bilitza, International reference ionosphere 2000, Radio Science 36 (2001), no. 2,261 – 275.

[7] Xu, G., GPS Theory, Algorithms and Application, Springer Verlag, 2nd edn, 2007.

[8] A.Bhaskarnarayana (ISRO), “Indian IRNSS and GAGAN”, presentation to COSPAR Meeting, Montreal, July 15, 2008.

[9] K. M. Gayathri, N. Thangadurai and M. P. Vasudha, "Positioning and signal strength analysis of IRNSS and GPS receiver in plain terrain along with foliage loss," Current Science, Vol. 112, Iss. 08, pp. 1738-1742.

[10] Rao, V. G., Lachapelle, G. and Vijay Kumar, S. B., Analysis of IRNSS over Indian Subcontinent. *J. Inst. Navigation*, San Diego, 2011.

[11] Rajan H Kapadia and Raj Hakani, "Design and Implementation of a Planar Array Antenna for L5 band of Indian Regional Navigational Satellite SYstem (IRNSS)", International Journal of Innovative Research in Technology, vol.2, Iss. 01, pp.10-14, 2015.

[12] Ganeshan A. S., Rathnakara S. C., Gupta R., Jain A.K.- Indian Regional Navigation Satellite System (IRNSS) Concept, ISRO Satellite Center Journal of Spacecraft Technology, 15(2):19-23, 2005