Positioning and Signal Strength Analysis of IRNSS and GPS Receiver in Plain and Vegetation area

Gayathri K M,
Department of Electronics and Communication Engineering,
School of Engineering and Technology,
Jain University, Bangalore, India

Thangadurai N,
Department of Electronics and Communication Engineering,
School of Engineering and Technology,
Jain University, Bangalore, India

Vasudha M P
Department of Electronics and Communication Engineering,
School of Engineering and Technology,
Jain University, Bangalore, India.

Abstract: **Navigation system such as GPS plays a significant role in determining the user position. Similar to GPS, IRNSS is a navigation system indigenously developed by India to meet the country needs. Presently six satellites are in orbit three in inclined geosynchronous orbit and three in geostationary earth orbit. It is essential to evaluate and upgrade the performance of the IRNSS continuously for various applications. One such assignment has taken up to characterize the IRNSS performance is mapping of a Jain University global campus geographical area. The area for mapping includes a terrain with different features such as plain fields, vegetation fields, power distribution substation, dense trees and a terrain with altitude variation. The purpose of the study is to analyse the performance of both IRNSS and GPS with respect to carrier to noise ratio, altitude variation, satellite visibility, GDOP and corresponding observations are recorded and plotted with avaliable maps.**

Keywords: IRNSS, Mapping, C/N_0 ratio, Satellite Visibility, GDOP.

I. INTRODUCTION

Indian Regional Navigation Satellite System (IRNSS) is a satellite – based navigation system being developed by Indian Space Research Organization [1]. It is developed to provide position information to users in India and region extending up to 1500 km from its boundary. In September 2014, signal in space interface control document was released, which contains the information of its system architecture, frequency spectrum, satellite constellation, signal structure, modulation scheme and information of the navigation payload. IRNSS consists of 3 segments namely: Space segment, Ground Segment and User Segment. The Space segment consists of seven satellites, 3 in geostationary (GEO) orbit positioned over 32.5°, 83° and 131.5 ° E respectively and 4 in inclined geosynchronous (IGSO) orbits are positioned over longitudes of 55º and 111.75º E (two in each plane) respectively. Six of the seven satellites are already in space, but this mission has been carried out when only four satellites in space.

The ground segment consists of the IRNSS Ranging and Integrity Monitoring stations (IRIM) and Navigation control centre (INC). IRIM receives the data from the space and transmits to navigation control centre. INC controls the IRNSS system and also maintains the accurate time reference with IRNSS network timing centre. Using CDMA ranging and Laser ranging, the position of the satellites in the orbit monitored continuously. The navigation uplink centres which are part of Spacecraft Control Facility (SCF) updates the navigation data using Telemetry, Tracking and Command (TT&C).

The user segment consists of IRNSS receivers operating in different modes – Single Frequency mode (L5 or S band) – Dual Frequency mode (L5 and S band). It offers two services to the users: Standard Positioning Service (SPS) which is at free of cost to the users by using unencrypted data and Restricted Service (RS) which uses encrypted data for authorised users. The SPS signal uses Code Division Multiple Access (CDMA) modulation with Binary Phase Shift Keying (BPSK). The navigation data rate is 50 Hz and Pseudo Random Noise (PRN) code rate is 1.023 MHz with duration 1ms. The navigation data is modulo-2 added with the PNR code sequence followed by modulation with the Radio Frequency (RF) carrier at the L5 frequency.

Some applications of IRNSS are: Terrestrial navigation support for hikers and travellers, Aerial and Marine Navigation, Disaster Management, Vehicle tracking and fleet management, Integration with mobile phones, Precise Timing, Mapping and Geoditic data capture.

II. EXPERIMENTAL SETUP

One of the major applications in remote sensing is to generate database required for studying the geographical features and drawbacks such as water bodies, vegetations, disaster occurrence and so on. In order to demonstrate, the Jain University global campus geographical area has been considered as a location for mapping from the view point of logistic approach. The data obtained pertaining to GPS [2], IRNSS and GPS plus IRNSS (Hybrid mode) for the chosen location. The IRNSS User Receiver (UR) is taken for field survey with antenna mounted on top of mobile vehicle in open space.

The mission started from School of

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Engineering and Technology block as a starting point (latitude 12o38'27.95" N, longitude 77o26'23.22" E), moved towards Munchies, IIAEM block, Sai Temple, Medical Centre, Hostel, Canteen, Pipeline Road and building. The boundary of entire campus covering an area of 366 acres approximately surveyed using IRNSS receiver. The surveyed area includes various terrain features such as vegetation, plain fields, high and low altitude regions, power house and of different size buildings.

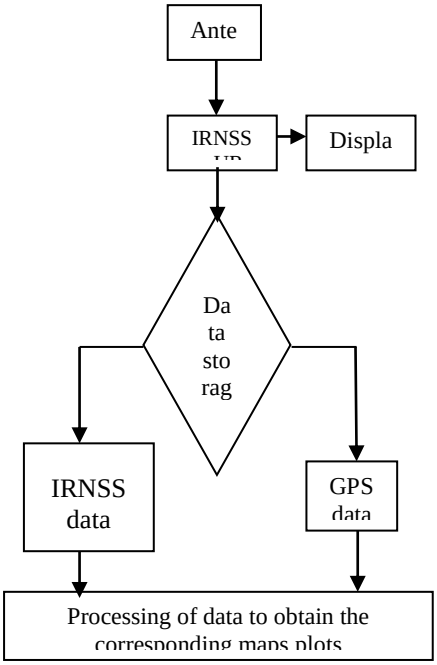

Fig. 1 Data Flow of IRNSS User Receiver

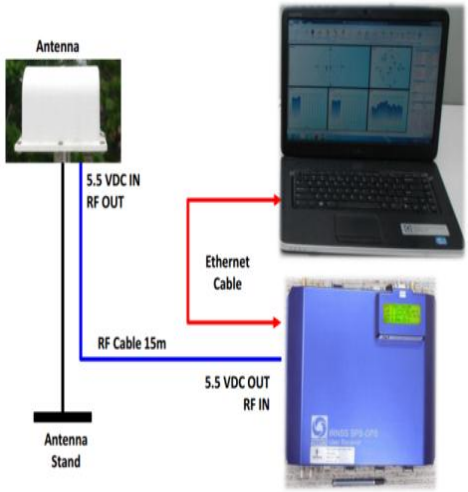

Fig. 2 Experimental setup of IRNSS User Receiver

The data for various parameters such as position, carrier to noise ratio, satellite visibility and GDOP was collected for all three modes: IRNSS, GPS and Hybrid. The altitude variation and interference due to vegetation at the different locations have been observed in this study.

The Fig 1 represents the data flow of our user receiver system. The GPS and IRNSS satellite signals are tracked by using user receiver.

From the experimental setup shown in Figure 2 the data is continuously logged with receiver and later processed using IRDAS software and algorithms to obtain the maps and plots of the area surveyed. Figure 3 shows the mobile vehicle where the experimental setup kept inside and antenna is mounted on the top.

Fig. 3 Antenna mounted on vehicle top.

III. MAPPING

The objective is to determine the location of Jain University global campus by using IRNSS User Receiver and plot it with available map. Mapping is one of the graphical representations of the geographical area on the surface of the earth. Navigation is a field of study that focus on the process of monitoring and controlling the movement of a craft or vehicle from one place to another. The purpose is to acquire spatial knowledge on geographical areas from maps and navigation data. They data give the latitude, longitude and altitude information of the position of interest in the geographical area.

The phases involved in this mapping mission are:

- Initialization of the IRNSS-User Receiver
- Serial Interfacing of IRNSS UR with PC
- Log the data into the PC.
- File Management & filtering of IRNSS and GPS data
- Accommodate to plot the map.
- Analysis of the data.

The mission took 2 hours 45 minutes to map the entire boundary of Jain University global campus with a vehicle speed not exceeding 20kmph. The Figure 4a shows the mapped area of Jain University global campus from data obtained by using GPS. For most of the parts it is tracking the boundaries with position accuracy of 3m. In the regions of dense trees, tall

buildings and near power distribution centre due to interference, the signal is attenuated with position values and data are missing for few locations.

Fig. 4a Jain University global campus mapping in GPS mode

The Fig 4b shows the mapped area of Jain University global campus from data obtained by using IRNSS receiver. For most of the parts it is tracking the boundaries with a position accuracy variation of 6 – 8m. The same regions, missed for GPS and not tracked by the IRNSS also. Apart from these there are some more regions that shows deviations from the actual tracked path i.e., near vegetation fields and in dense trees region.

Fig. 4b Jain University global campus mapping in IRNSS mode

Fig.4c Jain University global campus mapping in Hybrid mode

Due to multipath effects, the recorded position values are not accurate. In this area the performance of the IRNSS needs to be upgraded probably by adding the remaining satellites in to the constellation. Fig. 4c shows the Jain University global campus map done in Hybrid mode. The performance of IRNSS mode in Figure 4b is almost equivalent to GPS mode in Figure 4a even with only 4 satellites in orbit for Indian geographical region.

IV. RESULTS AND DISCUSSION

A. Altitude Variation

Even the terrain which is considered for the studying of plain area altitude may not be same for all location. The observed altitude variation have been plotted in the map for IRNSS and GPS as shown in the Fig 5a and Fig 5b respectively, which illustrates the mapped area between points P1 and P2 and Figure.5c illustrates its altitude variation plot.

Fig. 5a Altitude variation observed with IRNSS

Fig.5 Altitude variation observed with GPS

Fig.5c Altitude variation observed with IRNSS - UR

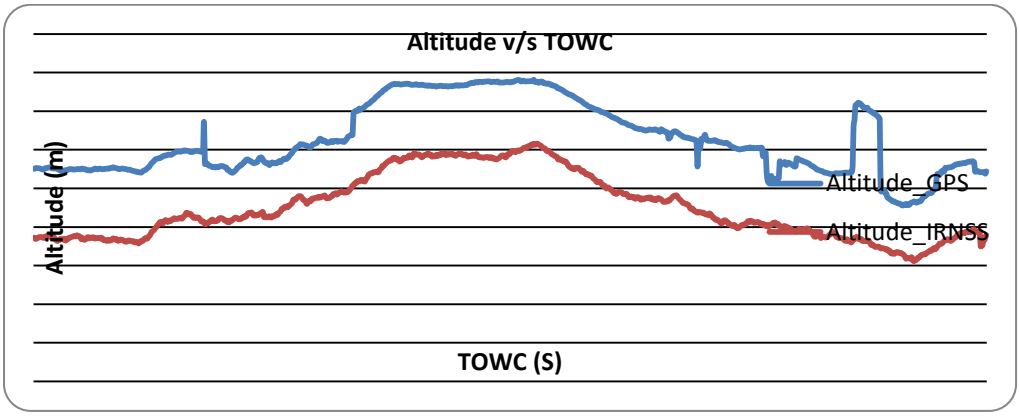

Fig. 6 Altitude v/s TOWC of GPS and IRNSS

The Figure.6 shows the relationship between altitude and TOWC of IRNSS and GPS for the area shown in the Fig. 5a and Fig. 5b. Here the mobile vehicle started from a low attitude point of 581.91m (IRNSS) and 595.58m (GPS) at point P1 reached to the high altitude point of 611.58m (IRNSS) and 628.13m (GPS) at point P2. There is a difference of 20m approximately in the altitude has been observed throughout the survey between IRNSS and GPS.

B. Vegetation Effect

The signal strength has been tested near dense vegetation region (Coconut Groove) as shown in Figure 7a. The observation shows the variation in satellite visibility in GPS at point P1 and IRNSS at point P2. Geometric Dilution of Precision (GDOP) and Number of Satellite (NSAT) visible have been plotted with respect to time travelled along the Jain University global campus from 1:30 pm to 03:15 pm.

Fig. 7a Vegetation area mapping

Figure 7b shows GDOP and NSAT visibility variation with respect to the observation time. From this plot the observation showing that the NSAT decreases, GDOP increases.

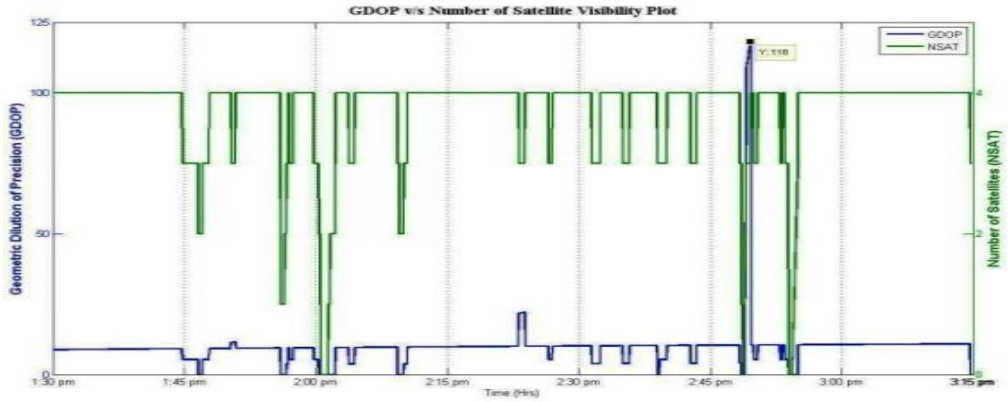

Fig. 7b GDOP and NSAT with respect to time

C. Carrier to Noise Ratio

The relationship between carrier to noise ratio and time has been shown in the Figure 8a for IRNSS satellites. The observation shows that the carrier to noise ratio has dropped down to 0dB-Hz due to attenuation of signal in vegetation area. Carrier to noise ratio has not dropped simultaneously in all the three satellites. Minimum three satellites are required to determine the position of location. Sometimes a fall in the position accuracy, which have shown as the deviation in the maps.

The Figure 8b shows carrier to noise ratio with respect to time for GPS satellites PRN 1, 5, 6, 9.

Though we can observe the drop of the C/N0 down to zero dB-Hz has occurred several times compared to IRNSS due to attenuation of signal in vegetation area, but still its performance in tracking the boundary, is superior to IRNSS as more number of satellites are visible for tracking. Out of 12 GPS channels available any 4 strong signals are sufficient for tracking the position.

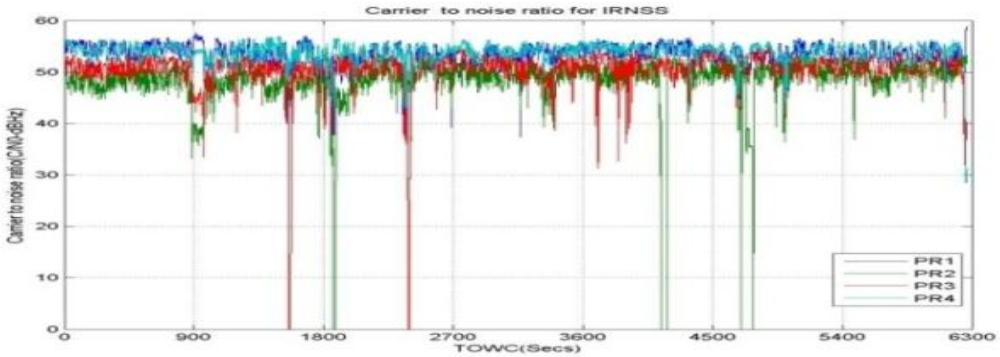

Fig. 8a C/N_0 of various satellites of IRNSS

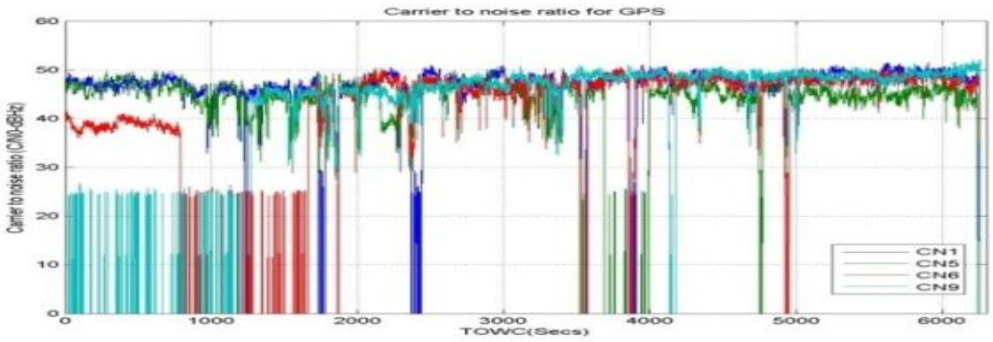

Fig. 8b C/N_0 of various satellites of GPS

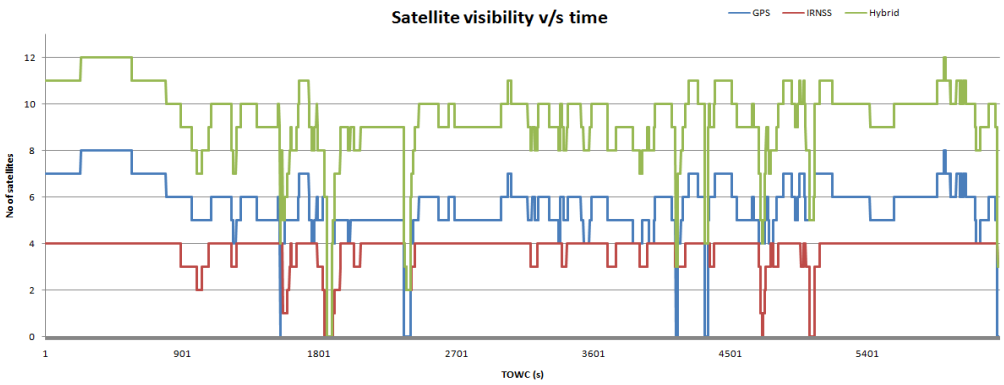

Fig. 9 Satellite visibility with respect to TOWC across the Jain University global campus

D. Satellite visibility

The satellite visibility data for the three different modes of UR are shown in the Figure 9. The satellite visibility of IRNSS can be rated above the GPS as signal blockages has occurred fewer times in IRNSS compared to GPS in Indian geographical region. There is an improvement in the hybrid mode as there are less signal blockages and can be used for improving the position accuracy. The signal experiences the attenuation in vegetation area as coconut groove, maize field. In all three modes UR fails to capture the signal from different satellite channels due to vegetation.

V. CONCLUSION

Indian Regional Navigation Satellite System is a satellite based navigation system being developed by Indian Space Research Organization. Mapping is one of the applications of navigation system. In this paper the mapping of Jain University global campus is completed successfully with the observed region data by using IRNSS UR. The data is anglicised and the plots are obtained for altitude variation, carrier to noise ratio and satellite visibility. The observed result shows that GDOP and satellite visibility is closely related. The carrier to noise ratio is dropped to zero when the receiver experiences a dense vegetation and

interference. The accuracy of position and altitude of both IRNSS and GPS have been presented with the corresponding results.

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REFERENCES

[1]. Indian Regional Navigation Satellite System Signal In Space ICD for Standard Positioning Service (Version 1.0, ISRO-IRNSS-ICD-SPS-1.0), Indian Space Research Organization, 2014.

[2]. Guochang Xu, “GPS Theory, Algorithms and Application”, Second Edition, Springer Verlag, 2007.

[3]. MV. Chandrasekar et. al., "Modernized IRNSS Broadcast Ephemeris Parameters", Journal of Control Theory and Informatics, vol. 5, no. 2, 2015.

[4]. “Indian Regional Navigation Satellite system Navigation Software Design Document”, ISRO-ISAC-IRNSSRR- 0900.

[5]. Anand Dwivedi, "Indian Regional Navigation Satellite System- An Overview," United Nations International Meeting on the Applications of Global Navigation Satellite Systems, Vienna, Austria, 2011

[6]. Vyasaraj Guru Rao, Gérard Lachapelle, Vijay Kumar S B, “Analysis of IRNSS over Indian Subcontinent”, Journal of Institute of Navigation, San Diego, 2011.

[7]. 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.

[8]. Surendra Pal, A. S. Ganeshan, K. N. S. Rao, L. Mruthyunjaya, "Indian Regional Navigation Satellite System," Proceedings of the 58th International Astronautical Congress, International Space Expo, Hyderabad, 2007.

[9]. Dr. Dru A. Smith, “ The Future of Global Navigation Satellite Systems: Anyone, Anywhere, Anytime, Any Accuracy by 2027”, http://celebrating200years.noaa.gov/visions/gnss, 2012.