Positioning and signal strength analysis of IRNSS and GPS receiver in plain terrain along with foliage loss

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Navigation systems such as Global Positioning System (GPS) play a significant role in determining the user position. Similar to GPS, Indian Regional Navigation Satellite System (IRNSS) is a navigation system indigenously developed by India to meet the country's 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 IRNSS continuously for various applications. One such assignment to characterize the performance of IRNSS is mapping of the Jain University global campus geographical area in Bengaluru. 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 variation in altitude. The purpose of this study is to analyse the performance of both IRNSS and GPS with respect to carrier-to-noise ratio, altitude variation, satellite visibility and GDOP, and the corresponding observations are recorded and plotted with available maps.

Keywords: Altitude variation, navigation system, satellite visibility, vegetation effect.

INDIAN Regional Navigation Satellite System (IRNSS) is a satellite-based navigation system being developed by the Indian Space Research Organisation (ISRO) to provide position information to users in India and the region extending up to 1500 km from its boundary[1–3]. In September 2014, Signal-in-Space Interface Control Document was released, which contains information on its system architecture, frequency spectrum, satellite constellation, signal structure, modulation scheme and navigation payload. IRNSS consists of three segments, namely space segment, ground segment and user segment. The space segment consists of seven satellites, three in geostationary (GEO) orbits positioned over 32.5°, 83° and 131.5°E respectively, and four in inclined geosynchronous (IGSO) orbits positioned over long. 55°E and 111.75°E (two in each plane) respectively. Six of the seven satellites are already in space, but this analysis has been carried out when only four satellites are in space[4–6].

The ground segment consists of the IRNSS Ranging and Integrity Monitoring stations (IRIM) and Navigation Control Centre (INC). IRIM receives data from the space and transmits them to INC. This Centre 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 orbit is monitored continuously. The navigation ground stations which are part of the Spacecraft Control Facility (SCF) update 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) and dual-frequency mode (L5 and S band). It offers two services to the users: standard positioning service (SPS) which is free of cost and uses unencrypted data, and restricted service (RS) which uses encrypted data for authorized 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 1 ms duration. The navigation data are 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 and precise timing, mapping and geoditic data capture.

One of the major applications in remote sensing is to generate database required for studying the geographical features and drawbacks such as water bodies, vegetation occurrence of disasters, etc. The Jain University global campus geographical area in Bengaluru has been considered for mapping using the logistic approach. The data were obtained pertaining to GPS, IRNSS and GPS plus IRNSS (hybrid mode) for the chosen location. The IRNSS user receiver (UR) is used for field survey with antenna mounted on top of mobile vehicle in open space[7–9].

The mission began from the school of Engineering and Technology Block as a starting point (lat. 12°38′27.95″N, long. 77°26′23.22″E), moved towards Munchies, IIAEM block, Sai Temple, Medical Centre, Hostel, Canteen, Pipeline Road and main building. The boundary of the entire campus covering an area of ~366 acres was surveyed using IRNSS UR. The surveyed area includes various terrain features such as vegetation, plain fields, high- and low-altitude regions, powerhouse and different sized buildings.

The data for various parameters such as position, carrier-to-noise (C/N) ratio, satellite visibility and GDOP were 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 the study.

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Figure 1 represents the data flow of our IRNSS UR system. The GPS and IRNSS satellite signals are tracked using UR.

From the experimental set-up (Figure 2), the data are continuously logged with the 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 with experimental set-up inside and antenna mounted on the top.

The objective of the study is to determine the location of Jain University global campus using IRNSS UR and plot it with available maps. Mapping is one of the graphical representations of the geographical area on the surface of the earth. Navigation is a field of study that focuses 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. The data provide the latitude, longitude and altitude information of the position of interest in the geographical area.

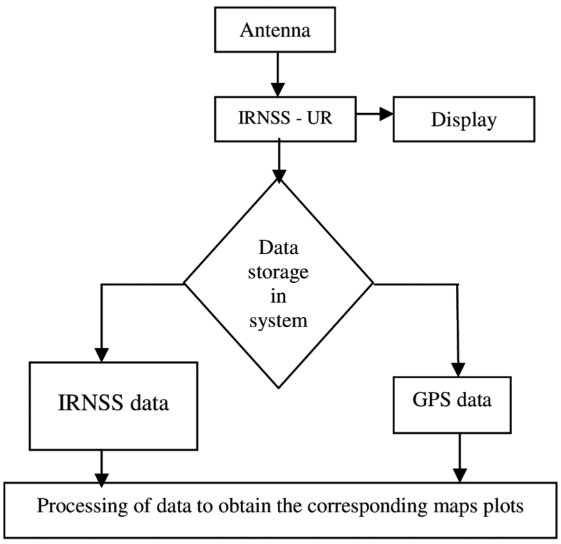

Figure 1. Data flow of Indian Regional Navigation Satellite System (IRNSS) user receiver.

The phases involved in this mapping mission are:

- Initialization of the IRNSS-UR.
- Serial interfacing of IRNSS UR with a personal computer (PC).
- Logging the data into the PC.
- File management and filtering of IRNSS and GPS data.
- Accommodate to plot the map.
- Analysis of the data.

The mission took 2 h and 45 min to map the entire boundary of Jain University global campus with a vehicle speed not exceeding 20 kmph. Figure 4 *a* shows the mapped area from the data obtained using GPS. For most parts of the area, it tracks the boundaries with a position accuracy of 3 m. In the regions with dense trees, tall buildings and near the power distribution centre, due to interference the signal is attenuated with position values and data are missing for a few locations.

Figure 4 *b* shows the mapped area from data obtained using IRNSS UR. For most parts of the area, it tracks the boundaries with a position accuracy variation of 6–8 m. The same regions missed by GPS are not tracked by IRNSS as well. Apart from these, there are some regions that show deviations from the actual tracked path, i.e. near vegetation fields and those with dense trees.

Due to multipath effects, the recorded position values are not accurate. Thus the performance of IRNSS needs to be upgraded probably by adding the remaining satellites into the constellation. Figure 4 *c* shows the mapping done in hybrid mode. The performance of IRNSS mode is almost equivalent to GPS mode even with only four satellites in orbit for the Indian geographical region.

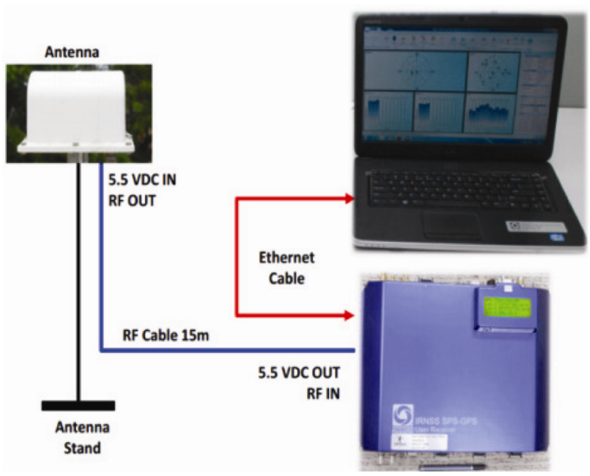

Figure 2. Experimental set-up of IRNSS user receiver.

Figure 3. Antenna mounted on vehicle top.

Figure 4. Jain University global campus mapping in: (***a***) GPS mode; (***b***) IRNSS mode and (***c***) hybrid mode.

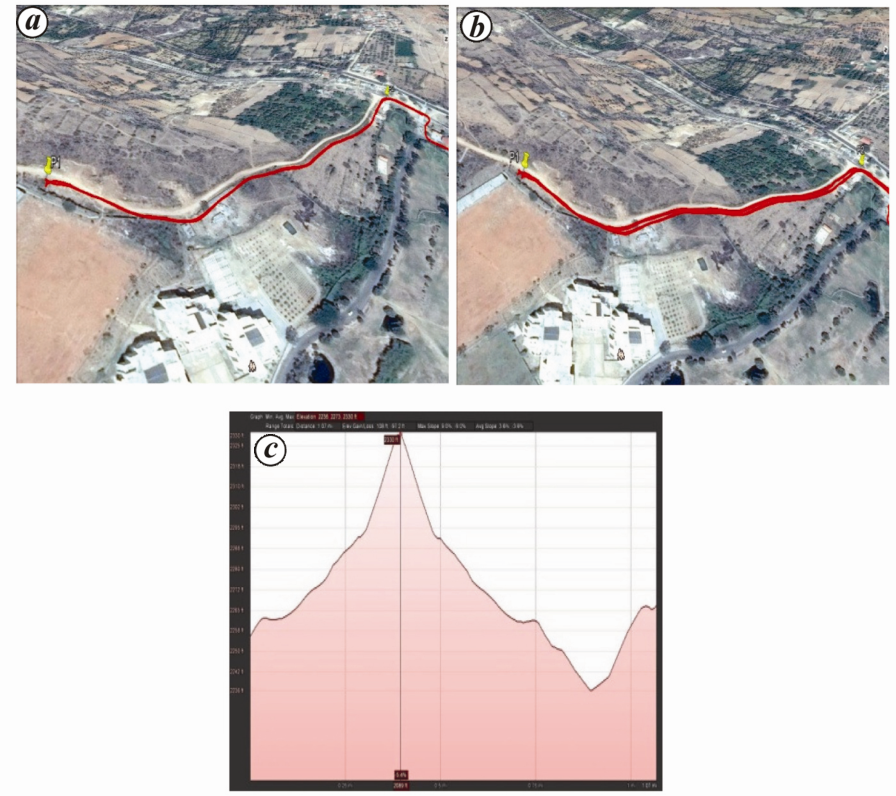

Figure 5. Altitude variation observed with: (***a***) IRNSS, (***b***) GPS and (***c***) IRNSS–UR.

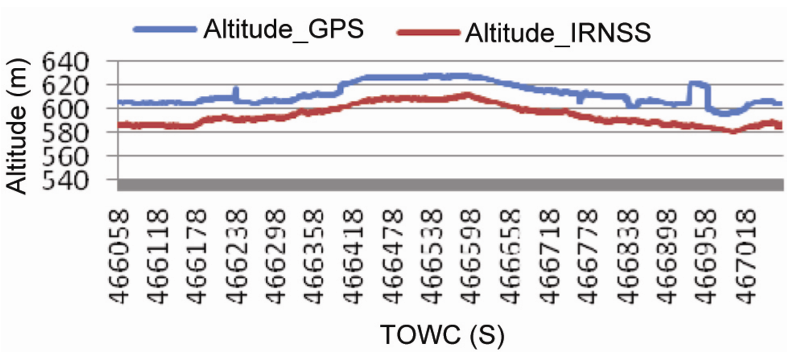

Figure 6. Altitude versus time of week count (TOWC) of GPS and IRNSS.

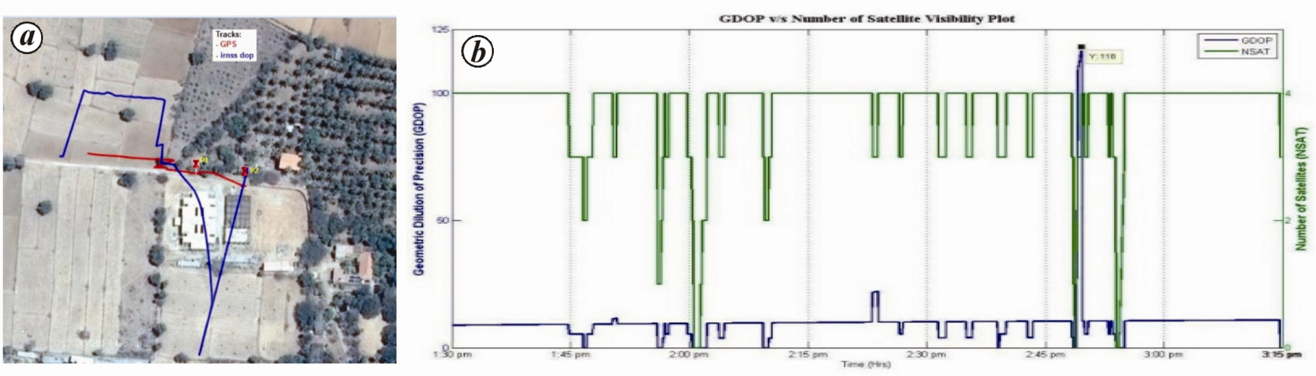

Figure 7. ***a***, Vegetation area mapping. ***b***, GDOP and NSAT with respect to time.

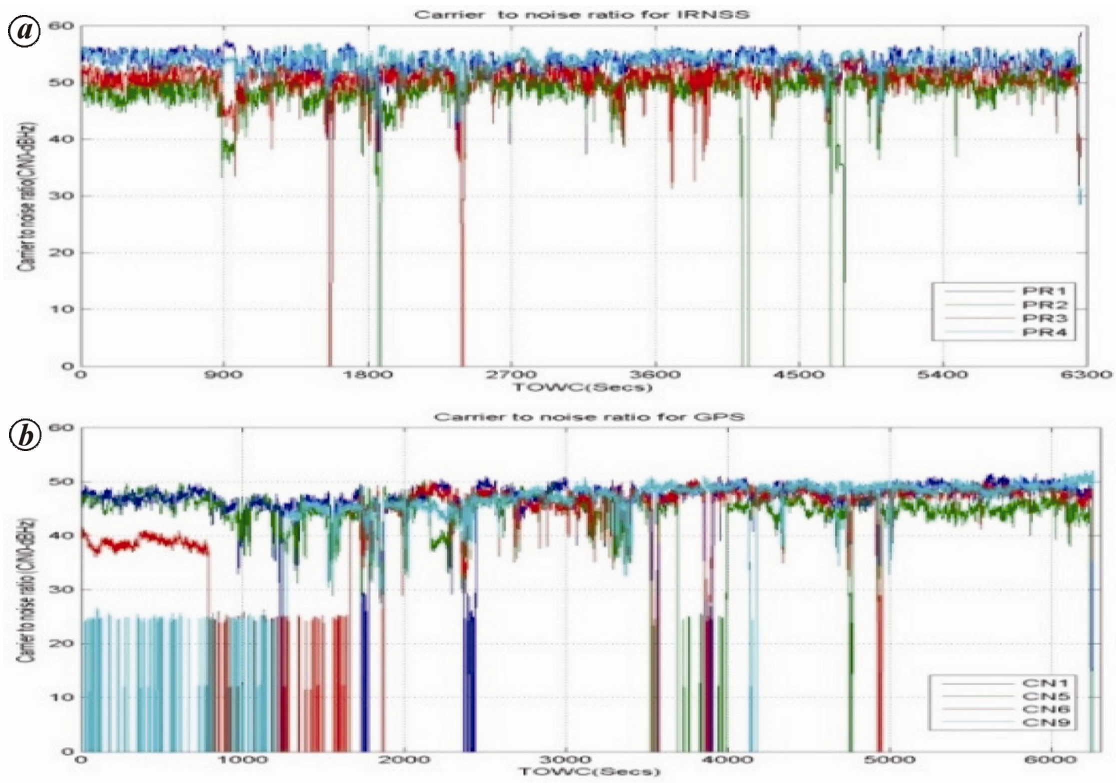

Figure 8. Carrier-to-noise ratio of various satellites of (***a***) IRNSS and (***b***) GPS.

The terrain considered for studying the altitude of plain areas may not be the same for all locations. The observed altitude variation has been plotted for IRNSS and GPS in Figure 5 *a* and *b* respectively, which illustrates the mapped area between points P1 and P2. Figure 5 *c* shows the altitude variation plot through our survey area.

The Figure 6 shows the relationship between altitude and TOWC of IRNSS and GPS for the area shown in Figure 5 *a* and *b*. The mobile vehicle started from a low altitude point of 581.91 m (IRNSS) and 595.58 m (GPS) at point *P*1 and reached the high-altitude point of 611.58 m (IRNSS) and 628.13 m (GPS) at *P*2. A difference of ~20 m in the altitude has been observed throughout the survey between IRNSS and GPS.

The signal strength has been tested near dense vegetation region (coconut groove). Figure 7 *a* shows the variation in satellite visibility in GPS at point *P*1 and IRNSS at point *P*2. The geometric dilution of precision (GDOP) and number of satellites (NSAT) visible have been plotted in Figure 7 *b* with respect to time travelled along the Jain University global campus from 1 : 30 to 03 : 15 pm.

The figure shows a decrease in NSAT and an increase in GDOP. The relationship between C/N ratio and time is shown in Figure 8 *a* for IRNSS satellites. The figure

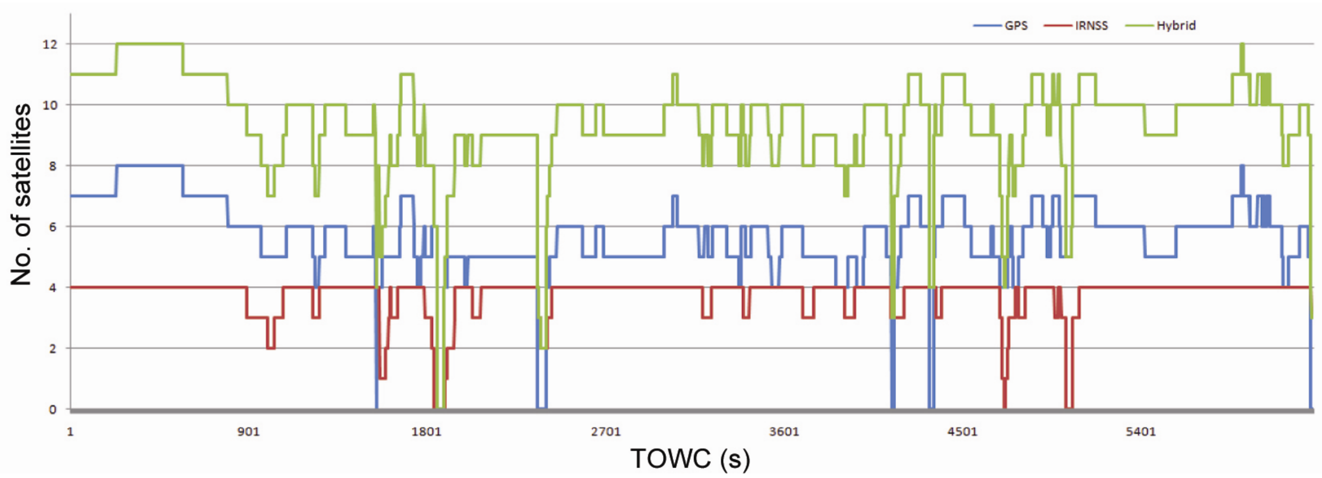

Figure 9. Satellite visibility with respect to TOWC across the Jain University global campus.

shows that the ratio drops down to less than 35 dB due to attenuation of the signal in the vegetation area. The ratio drops simultaneously for all the three satellites. A minimum of three satellites are required to determine the position of an area. Sometimes there is decrease in the position accuracy, which is shown as a deviation in the maps.

Figure 8 *b* shows the C/N ratio with respect to time for GPS satellites PRN 1, 5, 6, 9. Though we can observe a drop in the ratio less than 35 dB several times compared to IRNSS due to attenuation of the signal in the vegetation area, its performance in tracking the boundary is superior to IRNSS as more number of satellites is visible for tracking. Out of 12 GPS channels available, any four strong signals are sufficient for tracking the position.

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

In this study, mapping of the Jain University global campus has been successfully completed with the observed region data using IRNSS UR. Based on the receiver data plots are obtained for altitude variation, C/N ratio and satellite visibility. The results showed that GDOP and satellite visibility are closely related. The C/N ratio drops to zero when the receiver experiences dense vegetation and interference. The accuracy of position and altitude of both IRNSS and GPS are presented with the corresponding results.

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