Performance Analysis of IRNSS Receiver Signal Strength and Accuracy on a Moving Vehicle

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Abstract: **Indian Regional Navigation Satellite System (IRNSS) is a indigenous and autonomous satellite navigation system being developed by Indian Space Research Organization. IRNSS operates in two frequency bands namely L5 band (1176.45 MHz) and S1 band (2492.02 MHz). The Objective of IRNSS is to develop a regional navigation and positional accuracy system for Indian applications with 1500 kms. This paper describes a methodology for performance analysis of IRNSS receiver on a probe vehicle. A vehicle is equipped with IRNSS and GPS receiver and the data collected for every second throughout the test field. From the observed data an analysis has been done with vehicle speed, satellite visibility, precision and signal strength. The vehicle speed will not affect the signal strength and accuracy of IRNSS. The precision is consistent over the Indian geographical region when compared to GPS. Though the precision is better with GPS, it's not consistent with satellite visibility over the Indian geographical region.**

Keywords: **Navigation satellite, Carrier to noise ratio, GDOP, TOWC, Vehicle speed.**

I. INTRODUCTION

Indian Regional Navigation Satellite System (IRNSS) is a satellite – based navigation system being developed by Indian Space Research Organization. It is developed to provide position information to users in Indian region extending up to 1500 km from its boundary. In September 2014, signal in space interface control document was released. IRNSS consists of 3 segments namely: a Space segment, a Ground Segment and a User Segment. Fig 1 shows the experimental set up of IRNSS user receiver provided by ISRO with Accord Software and Systems.

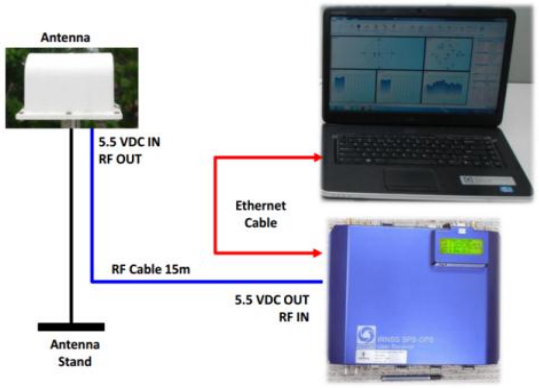

Fig 1 IRNSS and GPS hybrid user receiver

The Space Segment consists of seven satellites, 4 in geostationary (GEO) which are positioned over 34°, 83° and 132 ° East respectively and 3 in inclined geosynchronous (IGSO) orbits are positioned over longitudes of 55º E and 111.75º E respectively. Five of the seven satellites are already 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 satellite in orbit will be monitored. The navigation uplink centres which are part of Spacecraft Control Facility (SCF) update the navigation data using Telemetry, Tracking and Command (TT&C).

The User segment consists of IRNSS receivers operating in – Single Frequency (L5 or S1 band) – Dual Frequency (L5 and S1 band) IRNSS signals are transmitted. It offers two services to the users: Standard positioning Service (SPS) which is free of cost to the users and uses unencrypted data and Restricted Service 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 pseudorandom noise (PRN) code rate is 1.023 MHz with the duration of 1ms. The navigation data is modulo-2 added with the pseudorandom noise (PRN) code sequence followed by modulation with the Radio Frequency (RF) carrier at the L5 frequency. Some applications of IRNSS are: Terrestrial, Aerial and Marine Navigation, Disaster Management, Vehicle tracking and fleet management, Integration with mobile phones, Precise Timing, Mapping and Geodetic data capture, Terrestrial navigation aid for hikers and travellers, Visual and voice navigation for drivers

II. DATA AVAILABILITY

The satellite signal received by the antenna, and the data are logged in to the system. Fig 2 shows the signal strength chart of both GPS and IRNSS. GPS is has 12 channels and 12 Satellites can be seen in the constellation. The signal strength of both the bands of IRNSS can be seen and 5 satellites are visible in the constellation. Both IRNSS and GPS data are logged in

ISBN No.978-1-4673-9544-1

to the system for every one second so having the same TOWC counts. As we have two frequency bands in IRNSS both L5 and S band data are logged in separate file. The data is logged in to two separate folders namely GPS parameters and IRNSS parameters. In GPS parameters we have six different files namely POSB, DOPB, SATB. Fig 3 shows the file format of POSB which contains the position information and Fig 4 shows the file format of SATB which contains the information signal strength of the each satellite. IRNSS parameters also have same files for both L5 Band and S1 band namely POSB_L5, POSB_S, DOPB_L5, DOPB_S. The POSB of GPS and IRNSS provides the information of position. POSB file consists of following parameters such as latitude, longitude and altitude which gives the information about the position. SATB file consists of the following parameters such as Carrier to noise ratio, Doppler Azimuth, elevation and time. In GPS we have 12 Satellites and in IRNSS we have 5 Satellites. Hence for all the channels the above mentioned parameters are logged in to the CSV file. From this we can calculate the signal strength that we have received. The Doppler gives the velocity data about the objects at distance. Azimuth gives the angular measurement in a spherical coordinate. Elevation refers to the angle between the beam pointing direction, directly towards the satellite, and the local horizontal plane. It is the up-down angle. DOPB file gives the information about dilution of precision. DOP is an indicator of three dimensional positioning accuracy of relative position of Satellites with respect to a receiver. In literature different types of DOP designations are in use, for example, GDOP, PDOP, etc.

These are given below:

- GDOP: Geometrical dilution of precision (measure of accuracy in 3 –D position and time)
- PDOP: Position dilution of precision (measure of accuracy in 3 –D position) also called as Spherical DOP.
- HDOP: Horizontal dilution of precision (measure of accuracy in 2 –D position) example Latitude and longitude.
- VDOP: Vertical dilution of precision (measure of accuracy in 1 –D position) example Height.

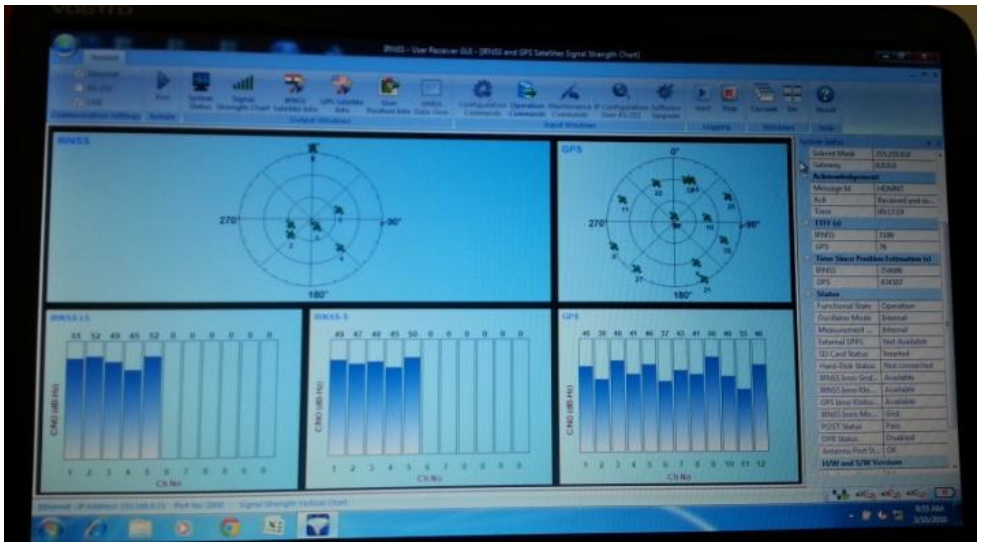

Fig 2 Screenshot of GPS and IRNSS Signal strength chart

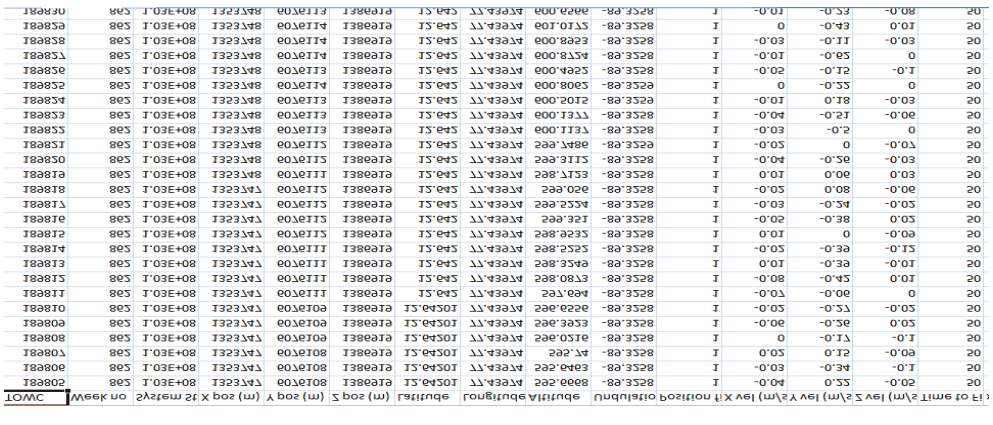

Fig 3 POSB file format

TOWC	Week no	System St	No of chai	Chan No-1	PRN-1	Channel T	Doppler-1	C/NO-1 (d	Azimuth-1	Elevation	PR-1 (m)	DR-1 (m)	Reject Co	Lock Time	Chan No-2	PRN-2
189806	862	1.03E+08	7	1	1	36370	-136.176	50.72	260.4317	65.91102	36104168	-34.7013	1	124	2	2
189807	862	1.03E+08	7	1	1	36370	-134.656	50.5	260.4267	65.91007	36104202	-34.3141	1	125	2	2
189808	862	1.03E+08	7	1	1	36370	-135.75	50.92	260.4217	65.9091	36104237	-34.5929	1	126	2	2
189809	862	1.03E+08	7	1	1	36370	-136.099	51.35	260.4167	65.90816	36104271	-34.6818	1	127	2	2
189810	862	1.03E+08	7	1	1	36370	-136.054	51.61	260.4117	65.9072	36104305	-34.6705	1	128	2	2
189811	862	1.03E+08	7	1	1	36370	-135.552	50.71	260.4067	65.90625	36104340	-34.5425	1	129	2	2
189812	862	1.03E+08	7	1	1	36370	-136.768	50.67	260.4017	65.9053	36104375	-34.8524	1	130	2	2
189813	862	1.03E+08	7	1	1	36370	-136.462	49.29	260.3967	65.90434	36104409	-34.7743	1	131	2	2
189814	862	1.03E+08	7	1	1	36370	-136.745	48.29	260.3917	65.90338	36104444	-34.8465	1	132	2	2
189815	862	1.03E+08	7	1	1	36370	-135.539	47.79	260.3867	65.90244	36104478	-34.5391	1	133	2	2
189816	862	1.03E+08	7	1	1	36370	-136.625	47.6	260.3817	65.90148	36104513	-34.8159	1	134	2	2
189817	862	1.03E+08	7	1	1	36370	-136.254	45.53	260.3767	65.90052	36104547	-34.7212	1	135	2	2
189818	862	1.03E+08	7	1	1	36370	-135.284	46.19	260.3717	65.89957	36104582	-34.4742	1	136	2	2
189819	862	1.03E+08	7	1	1	36370	-135.259	47.05	260.3667	65.89861	36104616	-34.4677	1	137	2	2
189820	862	1.03E+08	7	1	1	36370	-136.592	47.46	260.3617	65.89766	36104651	-34.8074	1	138	2	2
189821	862	1.03E+08	7	1	1	36370	-135.635	47.69	260.3567	65.89671	36104686	-34.5635	1	139	2	2
189822	862	1.03E+08	7	1	1	36370	-137.277	47.99	260.3517	65.89574	36104720	-34.9821	1	140	2	2
189823	862	1.03E+08	7	1	1	36370	-137.463	47.63	260.3467	65.89478	36104755	-35.0295	1	141	2	2
189824	862	1.03E+08	7	1	1	36370	-135.268	48.94	260.3417	65.89383	36104789	-34.4701	1	142	2	2
189825	862	1.03E+08	7	1	1	36370	-136.484	48.66	260.3367	65.89288	36104824	-34.7801	1	143	2	2
189826	862	1.03E+08	7	1	1	36370	-136.47	48.49	260.3317	65.89191	36104858	-34.7763	1	144	2	2
189827	862	1.03E+08	7	1	1	36370	-138.029	48.6	260.3267	65.89096	36104893	-35.1736	1	145	2	2
189828	862	1.03E+08	7	1	1	36370	-136.329	49.32	260.3217	65.89	36104928	-34.7405	1	146	2	2
189829	862	1.03E+08	7	1	1	36370	-137.361	49.13	260.3167	65.88905	36104962	-35.0035	1	147	2	2
189830	862	1.03E+08	7	1	1	36370	-136.73	48.99	260.3117	65.88808	36104997	-34.8426	1	148	2	2
189831	862	1.03E+08	7	1	1	36370	-136.064	49.29	260.3067	65.88712	36105032	-34.673	1	149	2	2

Fig 4 SATB file format

III. FIELD TEST

The IRNSS and GPS User Receiver is taken for field survey with antenna mounted on a mobile vehicle in open space as shown in Fig 5. The survey is done for 3.5 kms from Jain University, Jain Global Campus main entrance as a starting point and the Pipeline road joining to the Bangalore to Kanakapura Main road as an ending point as shown in map Fig 6. The surveyed area is a plain field without any dense vegetation and any possible interference. The data for various parameters such as position, carrier to noise ratio, satellite visibility and GDOP was collected for both GPS and IRNSS. The data is collected first at the eight identified static points. The data is collected for 10 km/Hr to 20 km/Hr and then the speed is increased to 30 to 40 km/Hr and the speed is increased till 80km/Hr. Hence for all the different speed the data has been logged into the system.

Fig 5 : Vehicle with mounted antenna

Fig 6 Mapping of test field

IV. RESULT AND DISCUSSION

The parameters received from the satellite are latitude, longitude, altitude, elevation, carrier to noise and many more. Table 1 show the signal strength and positioning data of identified at hot spots of pipeline road near Iain University where the data collected at different static points. The travel is planned with eight indentified hot spots. The vehicle is travelled from point P1 to P2, then P2 to P3, P3 to P4 and P4 to P5 and returned back from P5 to P6 and P6 to P7 and finally P7 to P8. At all the identified points the vehicle is stopped and the data is collected.

Table 1: Position and Signal strength in indentified hot spots of pipeline road, JAIN University, Bangalore

Points	TOWC	IRNSS					GPS			
		Latitude	Longitude	Altitude	C/N_O (dB-Hz)		Latitude	Longitude	Altitude	C/N_O (dB-Hz)
					L5 band	S1 band				
P1	190057	12.64157	77.4369	593.290	52.296	46.774	12.64158	77.4369	606.048	44.638
P2	190271	12.64479	77.43876	596.988	52.188	46.462	12.6448	77.43875	608.596	42.264
P3	190506	12.65009	77.44151	591.456	52.236	46.832	12.6501	77.44149	596.637	43.109
P4	190591	12.65225	77.44229	588.199	51.19	46.766	12.65226	77.44228	592.467	42.164
P5	190785	12.6583	77.44442	583.445	51.694	47.31	12.65831	77.4444	586.937	43.585
P6	190936	12.65295	77.44258	585.912	48.936	46.9	12.65296	77.44257	589.575	44.476
P7	190975	12.65009	77.44153	591.173	50.256	47.542	12.65011	77.44152	595.853	43.515
P8	191092	12.64159	77.43693	594.703	50.37	46.568	12.6416	77.43692	599.157	43.976

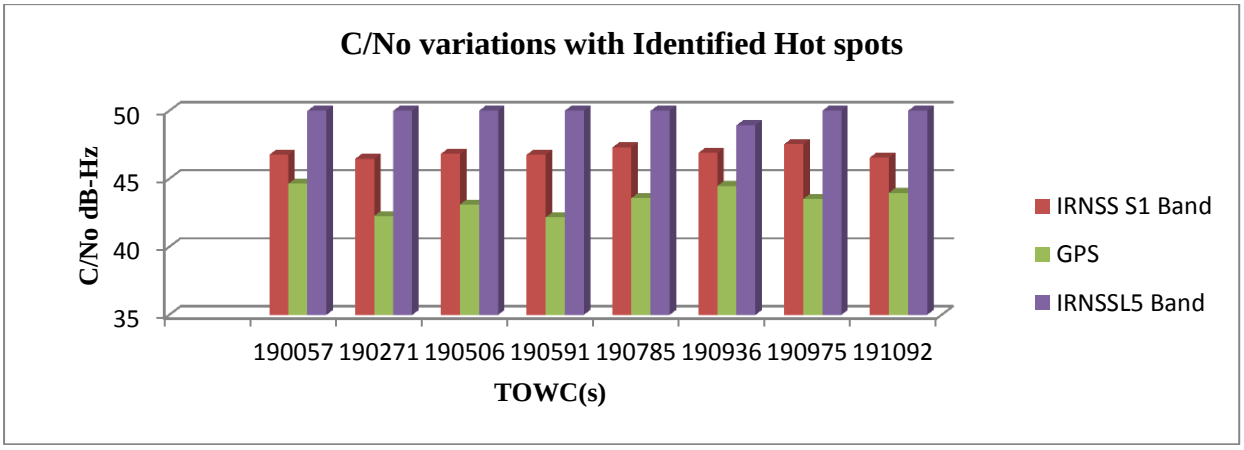

Fig-7: C/No variations in identified hot spots

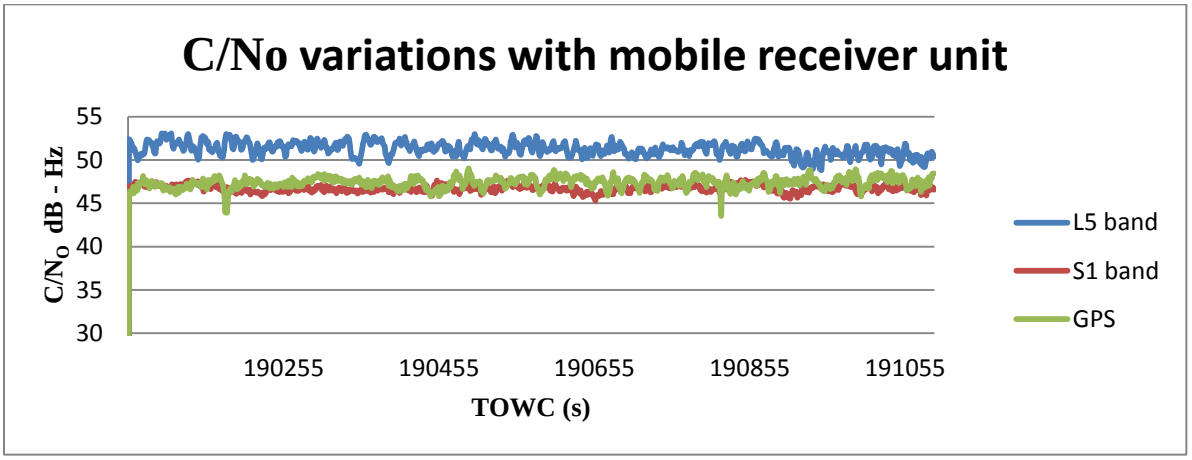

Fig-8: C/No variations for entire surveyed area

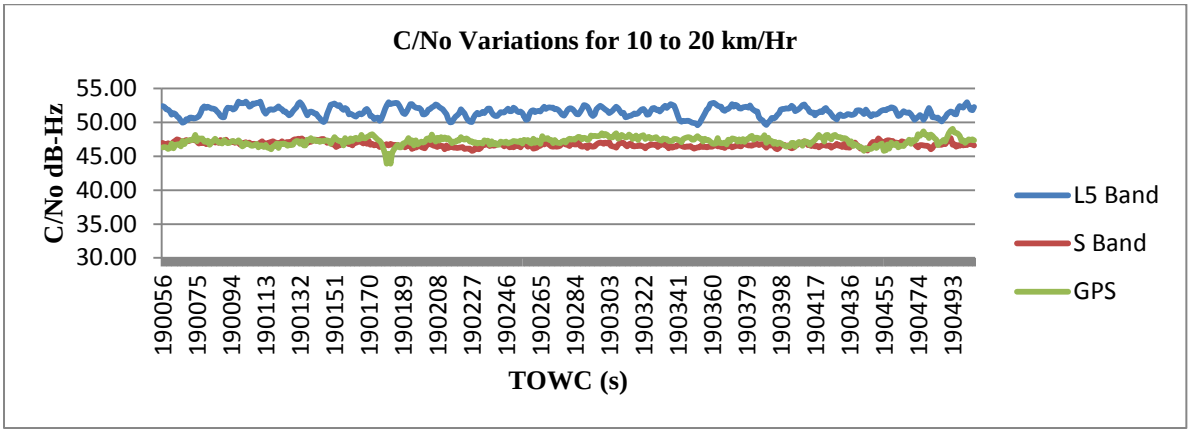

Fig-9a: C/No variations for 10 to 20 km/Hr

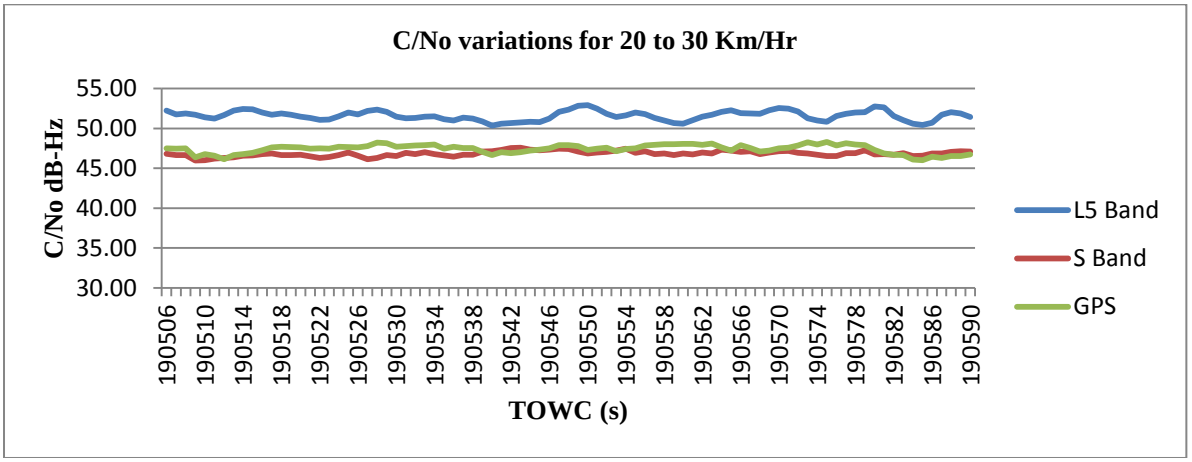

Fig-9b: C/No variations for 20 to 30 km/Hr

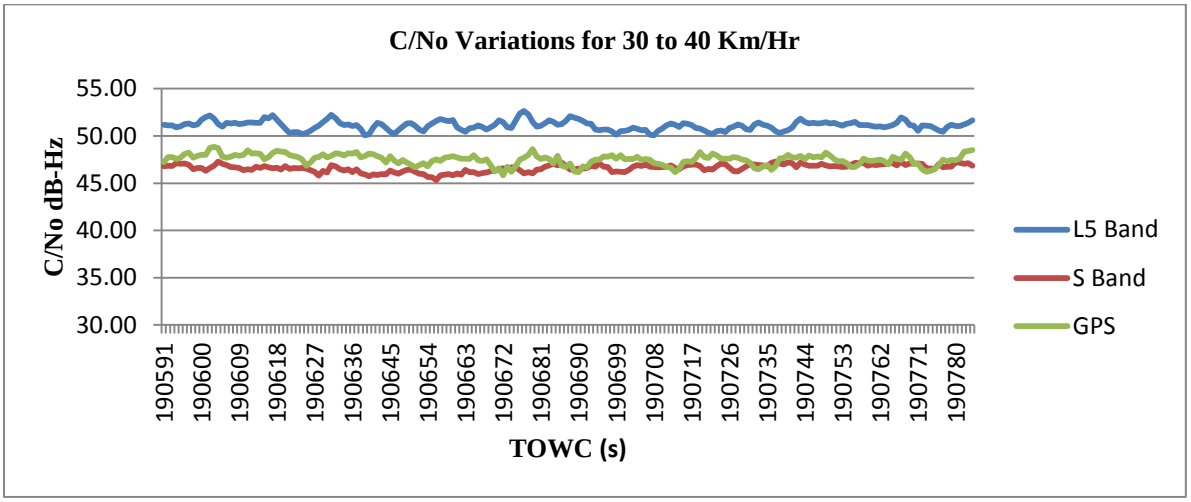

Fig-9c: C/No variations for 30 to 40 km/Hr

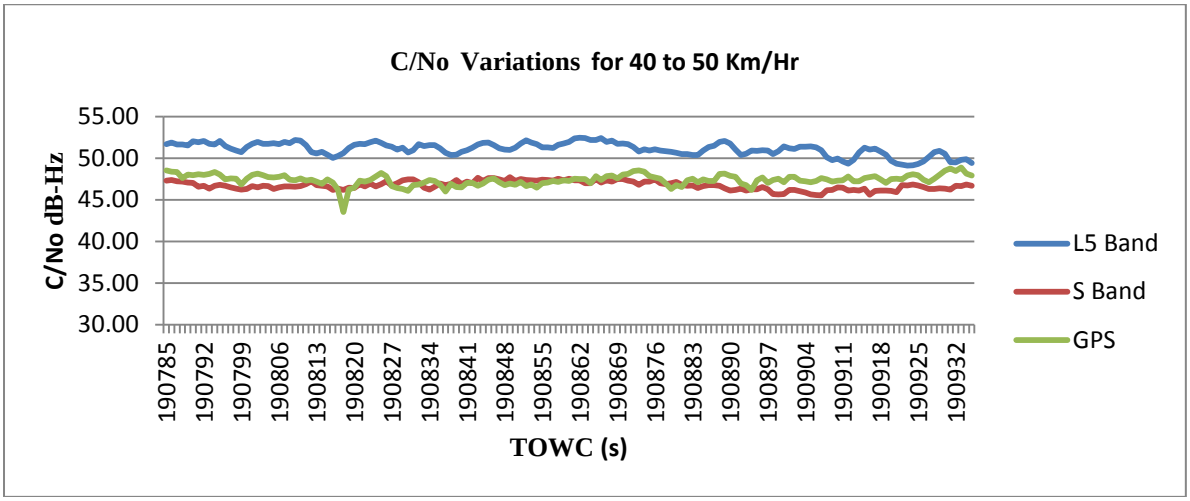

Fig-9d: C/No variations for 40 to 50 km/Hr

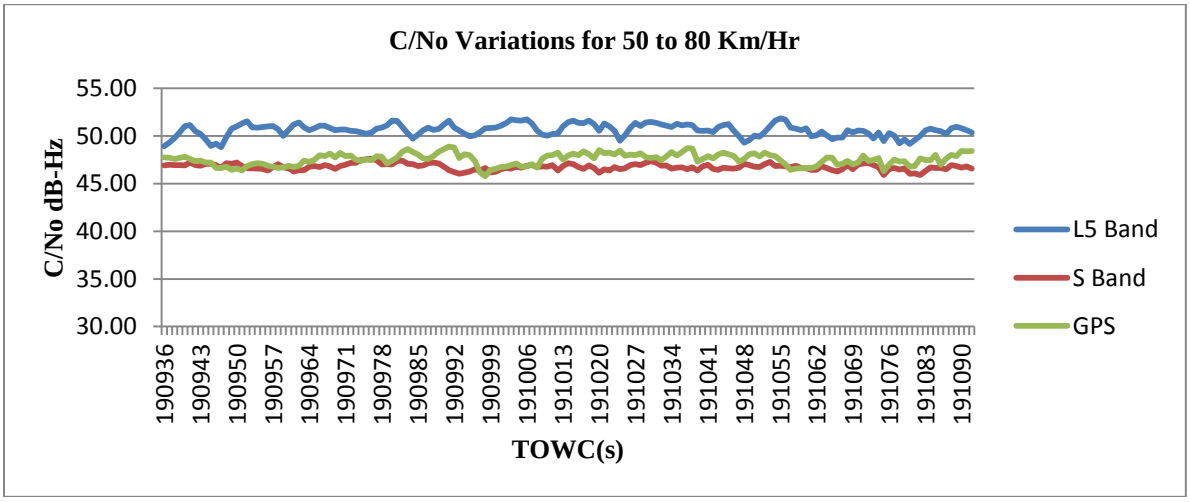

Fig. 9 e C/N_0 variations for 50 to 80 Km/hr

Fig 7 shows the carrier to noise ratio of the identified static hot spots in the test field for all the three L5, S1 and L1 bands.

The vehicle is travelled with a speed of 10 to 20 km/hr from point P1 to P2. From P1 the vehicle is started and moves towards P2, when the vehicle is travelled from P1 to P1a the speed is increased and when the vehicle come to the point P11 it gains a constant speed and travel towards point P1b and from point P1b the vehicle speed stars reducing as it stops. Hence we can conclude that the vehicle attains a constant speed from Point P1a to P1b so the data is collected. So the same is repeated for others point P3 to P8.

Fig 8 shows the carrier to noise ratio plots for all the three L5, S1 and L1 bands continually throughout the total time for the entire data of surveyed area. The TOWC is counted from 190057 to 191092. The observation is made that there is no outage of signal in the test field for different speed respect to TOWC. Here we can observe that there is no outage of signal. Hence speed will not reduce the signal strength.

Figure 9(a-e) shows the carrier to noise ratio for different speed from 10km/hr to 80km/hr.

Fig 10 shows the number satellite visible to the receiver at out test field. Here we can observe that IRNSS all five satellites are visible constantly throughout the Indian region but there is variations of GPS satellite visibility in the Indian region.

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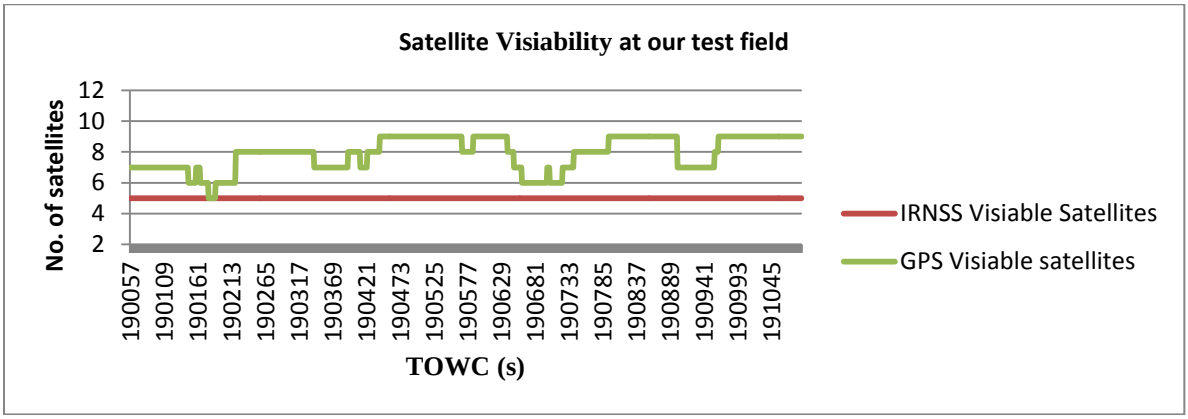

Fig 10: Satellite visibility at our test field

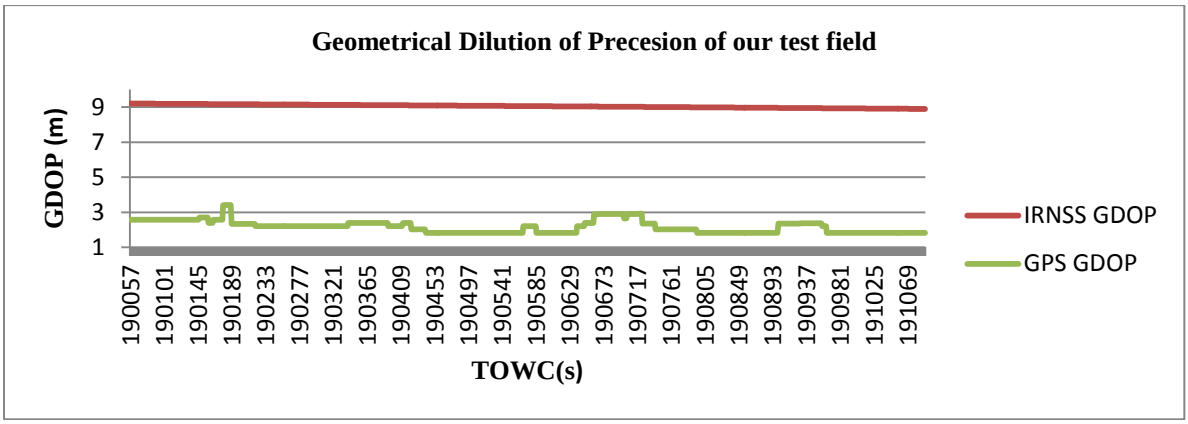

Fig 11: GDOP of our test field

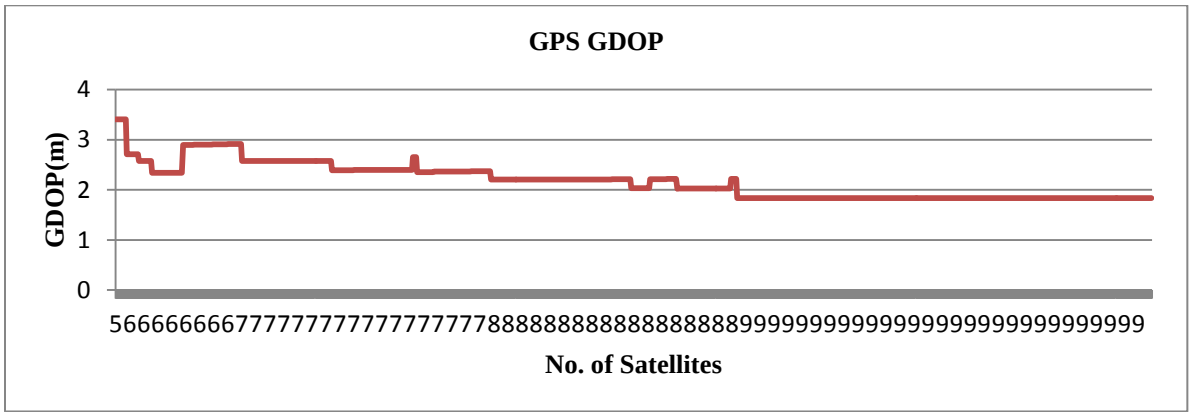

Fig 12: GDOP of GPS

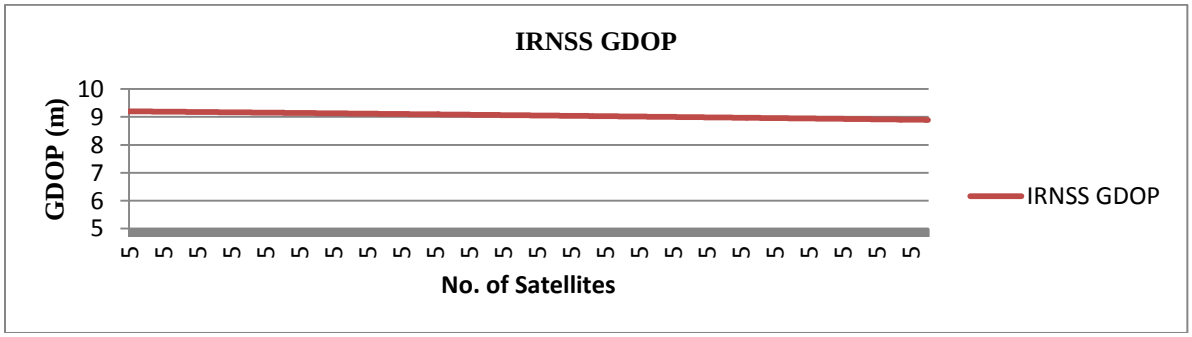

Fig 13: GDOP of IRNSS

Fig 11,12,13 shows the geometric dilution of precision of our test field for both GPS and IRNSS. From Fig 8a we can say that the precision of IRNSS is consistent throughout the surveyed area. Thought the GPS is giving better precision but it has some variations. Fig 8b shows the plot of No. Of satellites with GDOP of GPS here we can observe that as the number of satellite increases the precision is better. The maximum precision is 3.41m with 5 number of visible satellite. The minimum precision is 1.83m with a visibility of 9 number of satellite. Fig 8c shows GDOP of IRNSS where the precision varies from 8.89m to 9.20m.

V. CONCLUSION

The IRNSS and GPS hybrid User Receiver is taken for field survey with antenna mounted on a mobile vehicle in open space. The survey is done for 3.5 kms with Jain University, Jain Global campus entrance gate as a starting point and the Pipeline road as an ending point. The survey has done for different vehicle speed staring from 10 km/Hr to 80 km/Hr, where the observation is made that there is no signal outage at any point. Hence the signal strength does not depend on the speed of the vehicle. The precision of the GPS is better but not consistent for Indian geographical region. Even though the IRNSS precision is higher than GPS but there is consistent in Indian geographical region. Make a note that only five satellites have been launched for IRNSS. Once remaining two satellites placed in the orbit will get better precision which even can compete with GPS. All five satellites are visible in IRNSS, but in GPS there is a variation of visible satellite from 5 to 9. From the GPS observations number of visible satellite plays an important role in position accuracy.

ACKNOWLEDGEMENT

The authors hereby acknowledge ISRO-SAC, Ahemdabad and Jain University, Bangalore for the successful completion of this work. Also acknowledges Dr. G. Raju, Professor, Jain University, and Bangalore for his support and motivation towards this work with his valuable inputs.

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