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IRNSS User Range Accuracy Evaluation for Receiver Autonomous Integrity

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Abstract

Civil aviation is one sector that immensely will get benefited from Indian Regional Navigation Satellite System (IRNSS) services. However, for safety of life applications, integrity of navigation solution is crucial. Integrity of the system depends on Signal-in-Space (SIS) errors. The user range accuracy (URA) transmitted in navigation message for each satellite is a conservative estimate of SIS error and can be mainly used for integrity monitoring. Therefore, investigation of URA is important. Further, for development of receiver autonomous integrity monitoring algorithm for IRNSS, the typical value of URA has to be defined. In this paper, the cumulative distribution of URA is analyzed to over bound SIS errors. The sigma URE for 68% over bound is 2.8m.

1. Introduction

Indian Regional Navigation Satellite System (IRNSS)[2], is an emerging and independent satellite based navigation system developed by India with a proposed constellation of 7 satellites (4 Geosynchronous with 290 inclination and 3 Geostationary) with L5 and S-band ranging payloads. It is also called as Navigation with Indian Constellation (NavIC)' system. Users of several applications including civil aviation get benefited from the standard Positioning Services (SPS) of this system. IRNSS is deployed to cover Indian subcontinent with extended service capability around 1500 km. At present the IRNSS constellation has 8 satellites (IRNSS-1A, 1B, 1C, 1D, 1E, 1F, 1G and 1I) on orbit. The present study is with respect to URA, which is a statistical indicator of range error obtained from a specific satellite and important parameter need to be defined precisely for implementation of RAIM or Advanced RAIM algorithms for IRNSS [1] [2].

2. IRNSS architecture

The architecture of IRNSS consists of three main segments namely, the space segment, ground segment and user segment [3].

Space Segment: It consists of three geostationary (GEO) and four geosynchronous (GSO) satellites located at 32.5º East, 83º East and 131.5º East longitude. At equator 55º East and 111.75º East, two GSO cross the plane.These satellites broadcast signals to the user segment for positioning, navigation, and timing (PNT).

Ground Segment: Space Craft Control Centre (SCC), IRNSS Navigation Centre (INC), IRNSS TTC & Up linking Stations (IRTTC), IRNSS Range and Integrity Monitoring Stations (IRIMS), IRNSS Timing Centre (IRNWT), IRNSS CDMA Ranging Stations, (IRCDR) Laser Ranging Station (ILRS) and Data Communication Network (IRDCN) are a part of ground segment. The SCC and the INC predict and provide IRNSS satellite positions, calculate integrity, Ionospheric and clock corrections as well.

User segment: As the IRNSS satellites transmit signals on L5 and S band. Dual-frequency receivers (L5 and S band frequencies) or single frequency (L5 only frequency) are being developed.

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3. Signal-in-space errors

The integrity of IRNSS is required for many applications including civil aviation, vehicle tracking, fleet management, disaster management etc. It is desired to monitor the satellite performance to maintain integrity. This requires SIS measurement, to identify the satellite failures of the systems. If SIS error exceeds 4.42*URA, it can be considered as a major service failure. Therefore, evaluation of URA is critical [4][5].

4. RAIM

Receiver autonomous integrity monitoring (RAIM) is the ability of the receiver to check or assess the integrity of the satellite system (IRNSS) at receiver/user level. For applications with stringent accuracy requirements IRNSS system does not provide any integrity information of transmitting signals. There is a possibility, that a satellite broadcast slightly incorrect information which will cause the navigation information to be incorrect. However, there are no standard techniques to check for integrity. Conventional RAIM techniques/algorithms are based on least square approach using redundant signals to determine whether or not a fault is associated with any of the signals of single constellation. Advanced RAIM is a proposed extension of RAIM to multi-constellations of GNSS [4]. This is to enhance horizontal guidance coverage and eventually provide regional/global coverage of vertical guidance.

Either RAIM or ARAIM, their performance is affected by the various errors, especially the SIS (Signal-In- Space) errors. To bound these errors user range accuracy has to be determined precisely.

5. Methodology

To over bound the user range errors in real time. The cumulative distribution of URA values is calculated for each satellite of IRNSS. 68% over bound and 95% over bound values of URA for the satellites are identified. And an overall URA value for use in RAIM algorithm for IRNSS is specified. The descriptive statistics such as minimum, maximum, mean and standard deviation of satellite specific URAs are calculated.

6. Data acquisition and processing

The satellite specific URA values of IRNSS system are obtained from the navigation data. The broadcast ephemeris data is acquired from Crustal Dynamics Data Information System (CDDIS) archives maintained by NASA. The daily files are accessed from the following ftp://cddis.gsfc.nasa.gov/gnss/data/daily/2018/. The navigation data, is not specific to any location and contains satellite ephemeris. The daily navigation file for period of 15 days during September-October, 2018 is considered.

7. Results and Discussion

Depending upon availability of data, the cumulative distribution function of broadcast URAs of IRNSS satellites PRN I02, I03, I04, I05 and I06 are depicted in Figs.1-5. The PRN I01 and I08 encountered system clock failure. I07 and I09 are not evaluated due to data inadequacy. Table 1 shows the minimum, maximum, mean and standard deviation of URAs and also satellite specific 68% and 95% URA bound. It cane be observed from the table that maximum URA of 48m is observed for satellite PRN06. This indicates the instances of integrity failure.

The least maximum URA of 0.48m is observed for I02 satellite. The maximum URA of the satellites I03, I04, I05 is in between 5m to 7m.

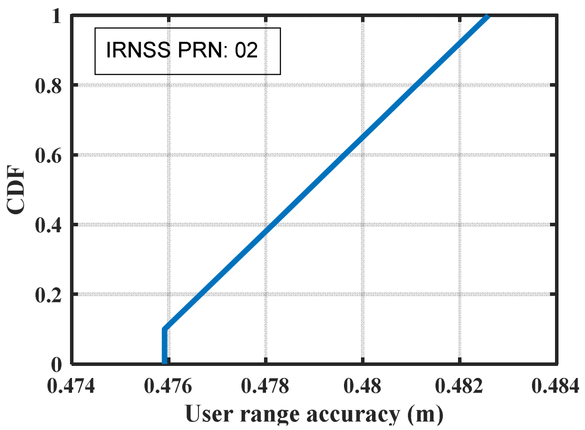

Figure 1 CDF plot of URA of IRNSS satellite I02

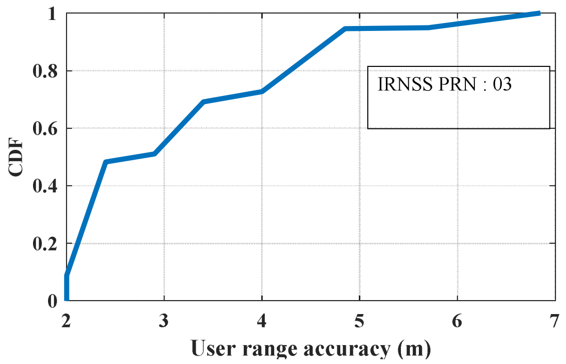

Figure 2 CDF plot of URA of IRNSS satellite I03

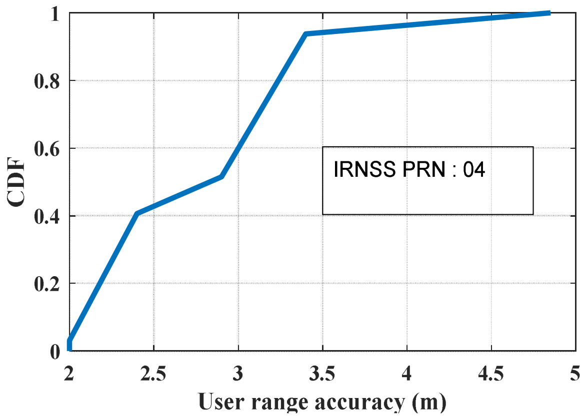

Figure 3 CDF plot of URA of IRNSS satellite I04

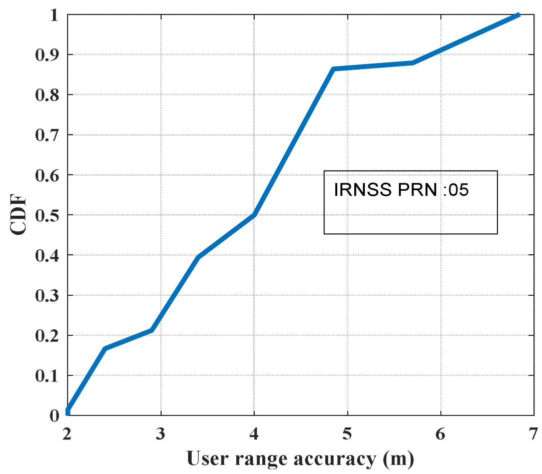

Figure 4 CDF plot of URA of IRNSS satellite I05

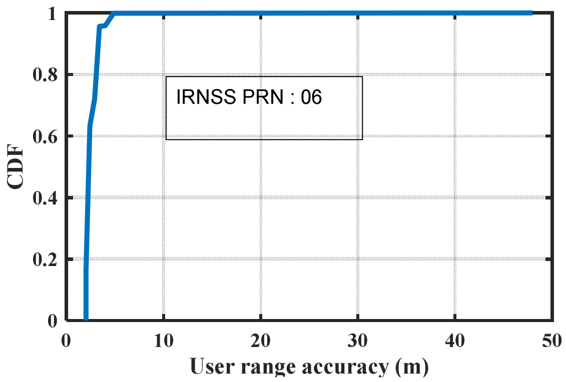

Figure 5 CDF plot of URA of IRNSS satellite I06

Table1: Minimum value, Maximum value, Mean, Standard deviation, 68% value and 95% value of various IRNSS satellites.

PRN	I02	I03	I04	I05	I06
Minimum value of URA (m)	0.47	2	2	2	2
Maximum Value of URA(m)	0.48	6.85	4.85	6.85	48
Mean of URA(m)	0.47	3.38	3.01	4.24	2.74
Standard deviation of URA(m)	0.0022	1.29	0.67	1.35	1.33
68% of URA(m)	0.47	3.4	2.4	5.7	2.4
95% of URA(m)	0.48	5.7	3.4	6.7	4

The 68% over bound of sigma URA is around 2.8 m, which is an average value of all satellites considered. To arrive at more precise value, User Range Error (URE) also have to evaluated, which is considered to be **future scope**. The 95% over bound is an important confidence level for integrity monitoring.

7. Conclusions

To verify the performance of IRNSS satellite signals, URA has been evaluated and 68% of URA over bound is observed to be around 2.8 m. This typical value can be used with the RAIM/ARAIM algorithms for IRNSS integrity monitoring. However, the analysis can be extended with actual URE errors to obtain more precise URA value, and its effect on availability and probability of false alarm (P_{fa}).

8. Acknowledgements

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9. References

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