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Design Considerations of an In house Developed Tri-band Reference Receiver for NavIC Ground Segment

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Abstract

As with any other satellite navigation system the Navigation with Indian Constellation (NavIC) satellite navigation system has three segments namely the space segment, ground segment and the user segment. The ground segment of NavIC is responsible for the house keeping of the NavIC satellites as well as for performing the Orbit Determination and Time Synchronization (ODTS) of the NavIC constellation. One of the important elements of NavIC ground segment is the network of IRNSS Range and Integrity Monitoring Station (IRIMS). The IRIMS network is dedicated for continuous one way ranging of the NavIC satellites, signal quality monitoring of the constellation and for determining the ionospheric, tropospheric errors and other biases.

NavIC at present operates in L5 and S bands and it is possible that in the near future there could be additional signals. Any augmentation of the NavIC signal in space warrants an augmentation of the ground segment also. It is therefore planned to augment the NavIC ground segment with an in house developed reference receiver that will cater to the augmented signal in space and provide continued support for the existing signals. This paper addresses some of the design considerations of the reference receiver that is being developed for the NavIC ground segment.

1 Introduction

NavIC is a regional navigation satellite constellation realized by the Indian Space Research Organization consisting of 7 satellites placed in geostationary and geosynchronous orbits such that they provide navigation services over the Indian landmass and in the region extending to 1500 kilometers beyond the Indian geopolitical boundary. Three of the NavIC satellites are in geostationary orbit (32.5 E, 83E and 125.5E) while four of the satellites are in two geosynchronous orbits having an inclination of 29 degrees. While one of the geosynchronous orbit planes crosses the equator at 55 degrees east longitude, the other geosynchronous orbit crosses the equator at 111.75 degrees east longitude. The NavIC constellation along with the other segments such as the ground segment and the user segment is depicted in Figure-1. The NavIC satellites provide the navigation signals in two frequency bands namely the L5 (11.76.45 MHz) and S band (2492.028 MHz) and in tow services namely the Standard Positioning Service (SPS) and the Restricted Service (RS). It is planned to augment the NavIC Signal in Space (SIS) with additional signals and the NavIC ground segment will need to be augmented to handle the additional signals.

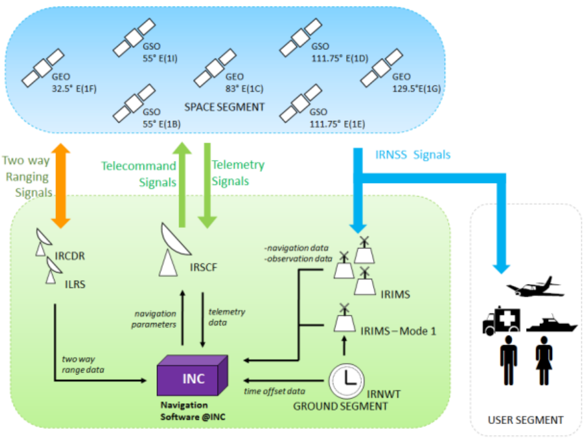

Figure 1. Concept of NavIC Satellite Navigation System

The NavIC ground segment consists of a network of IRNSS Range and Integrity Monitoring Stations (IRIMS), a network of IRNSS CDMA Ranging stations (IRCDR). While the IRIMS perform one way ranging to the NavIC constellation, the IRCDR stations perform two way CDMA ranging to the NavIC constellation. Laser ranging of the NavIC constellation is carried out on a best effort basis by the International Laser Ranging Service (ILRS). At the heart of the NavIC ground segment is the ISRO Navigation Center (INC) which also houses the IRNSS Network Timing facility (IRNWT) and performs the ODTS of the NavIC constellation.

The NavIC reference receiver is the core component of the IRIMS station and performs the following functions[1] :

1. Performs one way ranging to the NavIC constellation and provides accurate measurements for the ODTS of the NavIC constellation
2. Acts as the measurement sensor and enables the signal quality monitoring of the downlink signals

3. Enables integrity monitoring of the broadcast ephemeris
4. Acts as the fundamental interface between the precise timing facility where the NavIC reference time is generated and the ODTS system

A NavIC user receiver is a positioning/timing receiver which calculates the user's position and time through the trilateration method. The outputs of a user receiver are the corrected position and time. The NavIC reference receiver is different from a NavIC user receiver in the following ways:

1. The reference receiver does not compute a solution but forwards the raw measurements to the navigation center
2. The reference receiver has a significantly better G/T when compared to a user receiver
3. The reference receiver is a stationary receiver and the tracking loops are optimized for low antenna dynamics.
4. The reference receiver is equipped with state of the art multipath mitigation techniques, RFI mitigation techniques and provides very precise ranging measurements.
5. The reference receiver reports its own health before it reports the health of the downlink signals that it tracks
6. The reference receiver is capable of operating in multiple timing modes
7. The reference receiver is expected to operate continuously on a 24X7 basis

2 Design Considerations of the Antenna and the RF subsystem

The antenna and the RF subsystem needs to be designed to cater to the existing downlink signals of NavIC namely the L5 (1176.45 MHz) and the S Band (2492.028 MHz)[2]. Apart from this, the next generation NavIC satellites are designed to have additional downlink signals. Therefore the antenna needs to be designed for tracking the augmented SIS. The NavIC constellation consists of GEO and GSO satellites and the constellation is symmetric about 83 degrees east longitude Since the NavIC constellation currently consists of seven satellites in the GEO and GSO orbits spanning about a 100 degrees of longitude separation near the equator, the antenna coverage pattern has been designed so as to optimize the gain of the antenna. An analysis was carried out to arrive at an optimal coverage pattern for the antenna and it is seen that a directional pattern with a half cone angle of 65 degrees is sufficient to cater to the NavIC constellation as shown in Figure-2. However, the antenna would need to be mounted such that the antenna bore sight axis coincides with the line of sight of the satellite at 83 degrees east. As compared to an omni directional antenna, such an antenna would provide a 3-4dB gain advantage at the peak and about a 2 dB advantage at the end of coverage. This tradeoff is shown in Table-1. Any improvement in gain of the antenna improves the signal strength of the received signal and thereby the measurement accuracy of the reference receiver. The RF subsystem needs to be designed to ensure that the various downlink frequencies are processed separately.

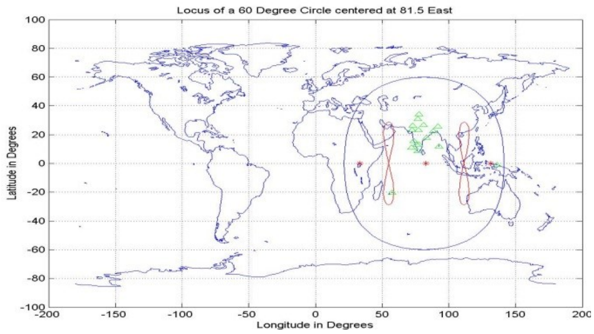

Figure 2. Coverage of the NavIC constellation by a directional antenna having an half cone angle of 65 degrees

Table 1. Options in the improvement in gain of a directional antenna

	Coverage	Gain (dBi) (Peak)	Gain (dBi) (at 65 °)	Gain (90 °)
1.	± 65°	5.1	2.1	-1.5
2.	± 65°	6.1	2.1	-2.9
3.	± 65°	6.9	1.9	-4.3
4.	± 65°	7.6	1.6	-6.0

The reference receiver needs to have effective multipath mitigation techniques as multipath is a major source of ranging error. There is a two pronged approach as far as multipath mitigation is concerned. At the RF stage, multipath is mitigated by making the antenna insensitive to signals emanating from low elevations. For these purposes choke ring antennas are generally used. Two approaches have been made with respect to the design of the antenna. Three individual patches have been designed and integrated into a single antenna package in the first approach. The gain patterns for the L5 and S bands using two individual patches are shown in Figure-3. The second approach involves the design of a stacked patch solution for making the antenna resonate at three different frequencies.

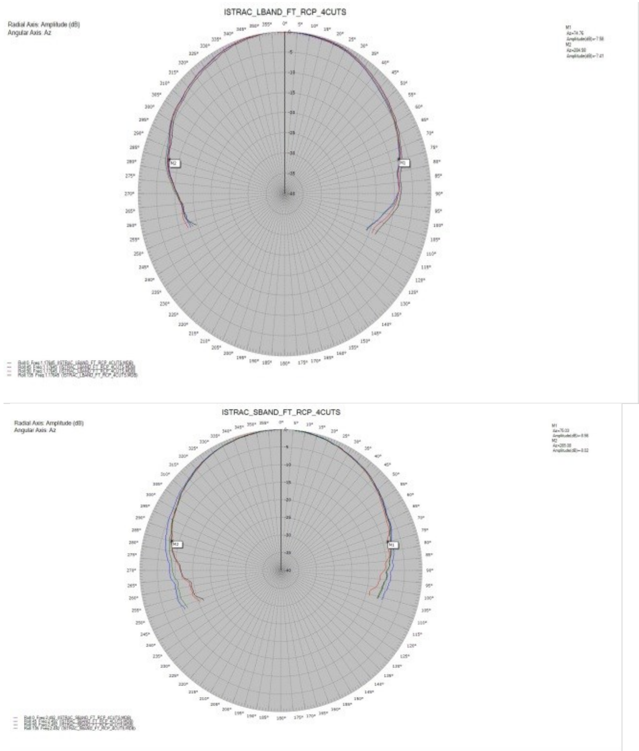

Figure 3. Gain patterns of a directional antenna (L5 and S) designed for the IRIMS reference receiver

3 Design Considerations of the Baseband Subsystem

The reference receiver is required to provide very precise pseudorange measurements to the orbit determination and time synchronization system in terms of code phase and carrier phase and Doppler information. At the co-relator level, multipath mitigation is taken care of by using narrow chip widths. The baseband subsystem handles the signals at the IF level and handles the signals in different chains. The receiver consists of acquisition and tracking loops and the PLL and DLL bandwidths need to be tuned with care to ensure the precision of the measurements. The receiver is equipped to take in time and frequency inputs in the form of a 10 MHz and 1 PPS signals. The reference receiver is designed to operate in various timing modes and provides all the information including the demodulated broadcast ephemeris in the form of logs to the navigation center with minimal latency.. The reference receiver needs to be designed with provisions for field upgrade, and for tracking additional services in future. The reference receiver should be capable of supporting remote monitoring and control and should time stamp the measurements with an accuracy of better than 100ns. The receiver that has been designed is currently providing pseudo range measurements with an accuracy of about 15cm. A typical code phase jitter that happens in the pseudo range measurements in shown in Figure-4. The receiver design is being currently tuned to ensure that the pseudo range measurements are provided with an accuracy of better than 10cm in three different bands.

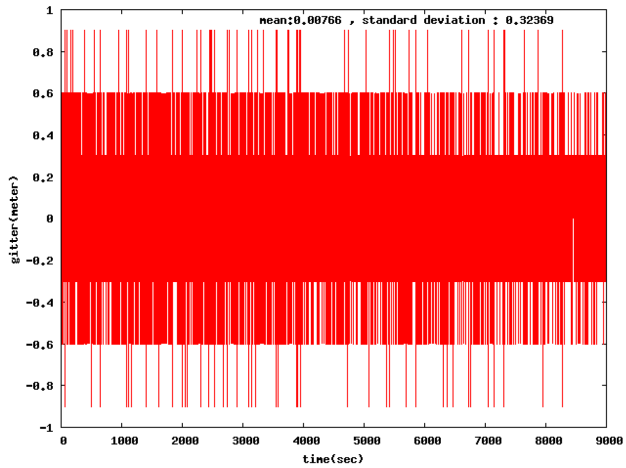

Figure 4. Code Noise Performance of the Indigenous Reference Receiver

4 Conclusions

An in house designed reference receiver is being developed for the NavIC ground segment. The reference receiver apart from being capable of tracking the existing downlinks is capable of tracking the newer signals of the next generation NavIC constellation. It is also capable of being upgraded to handle additional signals and services. The design is being tuned to meet the overall project goals. Once realized the in house designed reference receiver shall act as the fundamental measurement sensor of the NavIC ground segment in the near future. The in house design of the NavIC reference receiver has helped master a critical technology required for the satellite navigation ground segment.

6 Acknowledgements

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7 References

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