International Journal of Enhanced Research in Management & Computer Applications, ISSN: 2319-7471
Vol. 3 Issue 6, June-2014, pp: (32-37), Impact Factor: 1.147, Available online at: www.erpublications.com

# Indian GPS Satellite Navigation System: An Overview

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**Abstract: The GPS is satellite navigation system used to find location, position and much more. In this paper, INDIAN GPS Satellite System is introduced, described and explained with some results. Before 2008, USA GPS SYSTEM was the only source for navigation but after this INDIA come across and made its own GPS Satellite System for its security and civilian purposes. Indian Regional Satellite Navigation System(IRNSS) has launched its first two satellites IRNSS 1-A and IRNSS1-B .Two satellites have launched out of seven satellites of INDIAN GPS Satellite System. IRNSS will be fully operational by 2016.**

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## I. INTRODUCTION

Speeding down a highway or steering through the city lanes, if you tap your smartphone or in-car navigation device to locate a fuelling station, ATM, McDonald's, or the good old dhaba, the one service you rely on is the global positioning system (GPS). This stable clock in space is a set of satellites that beam radio signals to receivers on earth. Without it, flights cannot operate, communication networks won't function, drones can't fly, nor can bombs be dropped. In short, this dual-use technology is the global utility that the world has come to rely upon.

To ease India's dependence on America's GPS and even to some extent on Russia's Glonass, the Indian Space Research Organization (Isro) has built its own geo-spatial positioning system, a regional one at that, and called it Indian Regional Navigation Satellite System (IRNSS). The GPS aided geo augmented navigation or GPS and geo-augmented navigation system (GAGAN) is an implementation of a regional satellite-based augmentation system (SBAS) by the Indian government. It is a system to improve the accuracy of a GNSS receiver by providing reference signals [1]. The AAI's efforts towards implementation of operational SBAS can be viewed as the first step towards introduction of modern communication, navigation, surveillance/Air Traffic Management system over Indian airspace [2].The project has established 15 Indian Reference Stations, 3 Indian Navigation Land Uplink Stations, 3 Indian Mission Control Centers, and installation of all associated software and communication links [3]. It will be able to help pilots to navigate in the Indian airspace by an accuracy of 3 m. This will be helpful for landing aircraft in tough weather and terrain like Mangalore and Leh airports. The Indian Regional Navigation Satellite System (IRNSS) is an autonomous regional satellite navigation system being developed by the Indian Space Research Organization (ISRO) [4] which would be under complete control of the Indian government. The requirement of such a navigation system is driven by the fact that access to foreign government-controlled global navigation satellite systems is not guaranteed in hostile situations. The IRNSS would provide two services, with the Standard Positioning Service open for civilian use and the Restricted Service, encrypted one, for authorized users (military).


**Figure 1: IRNSS Satellites**

Instead of using the zero-crossing point of the back-EMF waveform to trigger a timer, the rectified back-EMF waveform is fed to an integrator, whose output is compared to pre-set threshold. The adoption of an integrator provides dual advantages of reduced switching noise sensitivity and automatic adjustment of the inverter switching instants according to changes in rotor speed [10]. IRNSS is an independent regional navigation satellite system being developed by India. It is designed to provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary, which is its primary service area. The Extended Service Area lies between primary service area and area enclosed by the rectangle from Latitude 30 degsouth to 50 deg North, Longitude 30 deg East to 130 degEast. The IRNSS System is expected to provide a position accuracy of better than 20 m in the primary service area.

## II. BACKGROUND THEORY

The Indian Regional Navigation Satellite System (IRNSS), a constellation of 7 satellites required to provide a regional navigational coverage. With successful launch, the Indian space agency becomes the sixth in the word to venture into the arena of space based navigational system. The basic purpose behind any space based navigation system is to identify the location of an object on earth and gathering information about it in real time. On ground these inputs are made available to the user in varying formats depending on the type of the receiver used. These inputs could be projected as a moving display or a digital information display, providing basic information in respect to latitude, longitude, altitude (elevation), and in some cases additional information like direction and speed. Such navigational systems are useful both for civilian and military purposes.

For many years the United States' Global Positioning System (GPS) has been singlehandedly dominating the global space navigational market. GPS services were available since early 1970s and the system was initially developed for assisting the US military. To ease India's dependence on other countries GPS, the Indian Space Research Organization (ISRO) has built its own geo-spatial positioning system, a regional one at that, and called it Indian Regional Navigation Satellite System (IRNSS). By early 2015, all seven satellites in this constellation will be up there, 35,000 km above the earth, to make the system fully operational. It will provide an all-weather absolute position over the Indian landmass and 1,500kmbeyond its geo-political boundary.

With 32 satellites in orbit, GPS pretty much serves as the global reference. The US doesn't share military grade signals with countries but civilian signals, in L1 (1575.4 MHz) and L2 (1227.6 MHz) frequencies, is free for all. But as is true with all innovators, it's believed the US practices 'selective denial'. In times of war, and sometimes even otherwise, the signals can be corrupted. Today, apart from the US system the only other globally available system is the Global Navigation Satellite System (GLONASS) of Russia. However, this system was only partially operational for almost the last two decades because the Russian government was not able to provide adequate financial support. The European Space Agency (ESA) is developing its own navigational system called Galileo but the progress is slow due to financial constraints. The most

remarkable investment into the space navigation sector has been made by the Chinese. They are developing a global constellation called Compass (Beidou) and presently the system has been declared operational over the Asia Pacific region. So the choice finally rests in building its own system. At a modest cost of Rs 1,420 crore, IRNSS has turned out a programme that the world is keenly watching.

For any navigational system, a minimum of three satellites are required to begin limited operations, while to provide global coverage, a constellation of minimum 24 satellites is required. Apart from India's IRNSS, the other constellations like GPS/GLONASS/Galileo/COMPASS are meant for global operations and have provisions (or have plans) for about 26 to 35 satellites each. Japan is also developing a three to four satellite regional system called the Quasi-Zenith Satellite System (QZSS). India appears to have made smart investments based on its immediate needs. Today, broadly India's strategic area of interest could be viewed as a region extending from the Persian Gulf to the Malacca Straits. It's obvious that India's interests are regional and from that perspective she has made limited investments. India is developing a unique system consisting of satellites mostly in the geostationary orbit (36,000 km above the earth's surface). Various space navigation satellites by other states are normally placed in a medium earth orbit (MEO). The Indian system is expected to provide an accuracy of about 15 to 20 meters. The entire system is expected to become operational by 2015 and subsequently four more satellites could be added into this to augment its efficiency and range. Also, this system is expected to be compatible with the US GPS.

As part of the project, ISRO opened a new satellite navigation center within the campus of ISRO Deep Space Network (DSN) at Byalalu near Bangalore in Karnataka on 28 May 2013 [5]. A network of 21 ranging stations located across the country will provide data for the orbit determination of the satellites and monitoring of the navigation signal. A goal of complete Indian control has been stated, with the space segment, ground segment and user receivers all being built in India. Its location in low latitudes facilitates coverage with low-inclination satellites. Three satellites will be in geostationary orbit over the Indian Ocean. Missile targeting could be an important military application for the constellation [6].

The total cost of the project is expected to be 1420 crore (US$241 million), with the cost of the ground segment being 300 crore (US$51 million) and each satellites costing 125 crore (US$21 million) [4].India's IRNSS is a regional system, not meant for offensive but defensive purposes. Military use is important but essentially 95 percent of the data one gets is for civilian use. From the time the project was sanctioned in July 2006 to July 2013, when the first launch will take place, it's been an exploration.

"From defining the signal structure to fixing ground infrastructure to determining the measurement system, everything had to be done ab initio. We didn't know how to do this, While other global systems have their satellites placed in middle earth, at a height of about 20,000 km, Isro chose to go up another 15,000 km. In that orbit, choosing how to place a minimum number of satellites at what degrees so as to cover the entire Indian region was a challenge. One of the hallmarks of ISRO programmes is their cost effectiveness. Its most-trusted rocket, Polar Satellite Launch Vehicle (PSLV), is being used to launch these satellites.

But the heart of IRNSS lies in the master clock. "The Americans, the Europeans… all have their standard time. We also had to establish our own standard time. A master clock provides the timing reference for the generation of the navigation signal. This atomic clock maintains accuracy of better than 20 nano-seconds with respect to any universal time. It provides stability of 0.4 or 0.5 nanoseconds variation in a day.

## III. DESCRIPTION AND METHOD

The proposed system would consist of a constellation of seven satellites and a support ground segment. In April 2010, it was reported that India plans to start launching satellites by the end of 2011, at a rate of one satellite every six months. This would have made the IRNSS functional by 2015.Seven satellites with the prefix "IRNSS-1" will constitute the space segment of the IRNSS. IRNSS-1A, the first of the seven satellites of the IRNSS constellation, on 1 July 2013[7]. IRNSS-1B was launched on 4 April 2014 at 17:14 IST on board the PSLV-C24 rocket. The satellite has been placed in geosynchronous orbit. In 2014, two more navigational satellites – IRNSS-1C and IRNSS-1D would be launched. Three more navigational satellites will be launched early 2015 and by middle of 2015, India will have the full navigational satellite system in place [8].

Three of the satellites in the constellation will be located in geostationary orbit at 32.5° East, 83° East, and 131.5° East longitude. Two of the GSOs will cross the equator at 55° East and two at 111.75° East [9].Such an arrangement would mean all seven satellites would have continuous radio visibility with Indian control stations. The satellite payloads would consist of atomic clocks and electronic equipment to generate the navigation signals.

IRNSS signals will consist of a Special Positioning Service and a Precision Service. Both will be carried on L5 (1176.45 MHz) and S band (2492.08 MHz). The SPS signal will be modulated by a 1 MHz BPSK signal. The Precision Service will use BOC(5,2). The navigation signals themselves would be transmitted in the S-band frequency (2–4 GHz) and broadcast through a phased array antenna to maintain required coverage and signal strength. The satellites would weigh approximately 1,330 kg and their solar panels generate 1,400 watts. The system is intended to provide an absolute position accuracy of better than 10 meters throughout Indian landmass and better than 20 meters in the Indian Ocean as well as a region extending approximately 1,500 km around India

The ground segment of IRNSS constellation would consist of a Master Control Center (MCC), ground stations to track and estimate the satellites' orbits and ensure the integrity of the network (IRIM), and additional ground stations to monitor the health of the satellites with the capability of issuing radio commands to the satellites (TT&C stations). The MCC would estimate and predict the position of all IRNSS satellites, calculate integrity, makes necessary ionospheric and clock corrections and run the navigation software. In pursuit of a highly independent system, an Indian standard time infrastructure would also be established.

Indian Regional Navigation Satellite System (IRNSS) successfully launched its first satellite on July 1 from the Satish Dhawan Space Centre at Sriharikota spaceport on the Bay of Bengal. An Indian-built Polar Satellite Launch Vehicle PSLV-C22, XL version, carried the 1,425-kg satellite aloft.

IRNSS-1A is the first of seven satellites that will make up the new constellation: four satellites in geosynchronous orbits inclined at 29 degrees, with three more in geostationary orbit. IRNSS-1A is one of the geosynchronous satellites.Following launch, the master control facility conducted five orbit maneuvers to position the satellite in its circular inclined geosynchronous orbit (IGSO) with an Equator crossing at 55 degrees east longitude. Reports indicate that orbit-raising maneuvers have been completed, and all the spacecraft subsystems have been evaluated and are functioning normally.
IRNSS-1A's drift eastward from 47 degrees east longitude on July 10 was gradually slowed, and the satellite achieved its assigned inclined geosynchronous orbit, with a 55-degree East equator crossing, by July 18. The orbit inclination is 27.03 degrees.

## IV. PAYLOAD RESULT

IRNSS-1A carries two types of payloads, navigation and ranging. The navigation payload will operate in L5 band (1176.45 MHz) and S band (2492.028 MHz), using a Rubidium atomic clock. The ranging payload consists of a C-band transponder that facilitates accurate determination of the range of the satellite. IRNSS-1A also carries corner-cube retro-reflectors for laser ranging. Its mission life is 10 years [10].

The spectrum recorded by the German Aerospace Center researchers appears to be consistent with a combination of BPSK (1) and BOC(5,2) modulation. This is the signal structure that ISRO announced would be used for IRNSS transmissions in the L-band: The IRNSS signals consist of two special services namely Standard Positioning Service (SPS) and a Restricted Service (RS) will be carried on L5 and S bands. The SPS will be modulated by a 1 MHz BPSK signal and RS will use BOC(5,2) modulation.

Scientists from the German Aerospace Center's Institute of Communications and Navigation in Oberpfaffenhofen, Germany, have received signals from IRNSS-1A, the first satellite in the Indian Regional Navigation Satellite System.Launched on July 1, 2013, the satellite reached its designated inclined geosynchronous orbit by July 18 with an inclination of 27 degrees and an equator crossing of 55 degrees east longitude [11]. Indian Space Research Organization (ISRO) announced on July 18 that testing of the satellite's navigation payload would begin within a week.On July 23, the German Aerospace Center scientists pointed their 30-meter dish antenna at Weilheim towards the satellite and found that it was already transmitting a signal in the L5 frequency band.

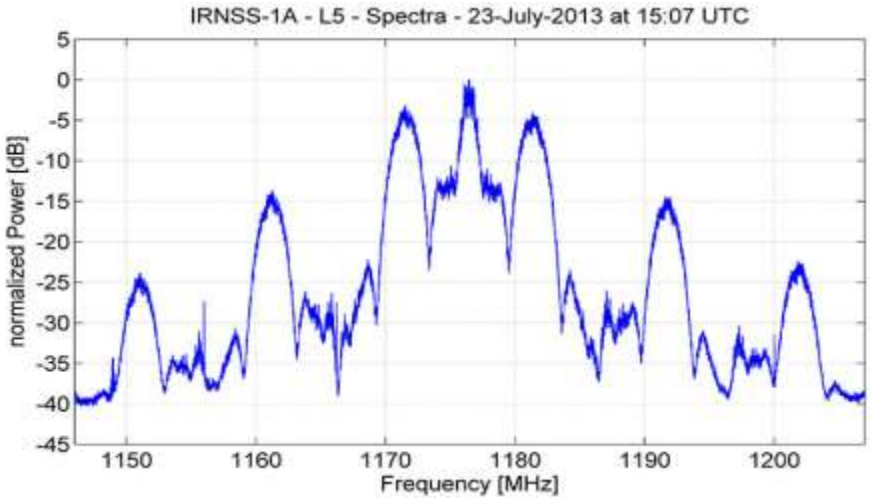


**Figure 2: Spectrum of IRNSS 1-A L-5 Signal**

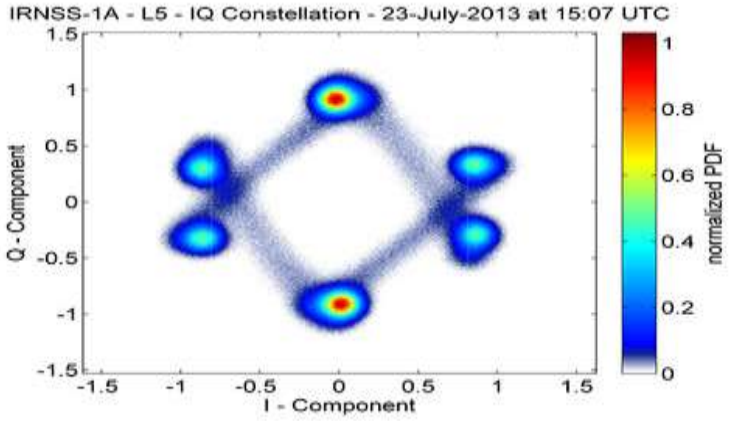


**Figure 3: IQ Constellation diagram of IRNSS 1-A L-5 Signal**

Figure 1 shows the spectrum of the received signal. Centered at 1176.45 MHz, the signal has a single symmetrical main lobe and a number of side lobes characteristic of a spread-spectrum signal. The corresponding IQ constellation diagram is shown in Figure 2 [12]. The signal structure appears to be unlike those used by the GPS, GLONASS, Galileo, or BeiDou constellations. Further analysis will be required to sleuth the signal details as ISRO, so far, has not publicly released an IRNSS interface control document (ICD). ICDs characteristically describe a satellite system's signal structure in detail
The German scientists caution that this is a very early snapshot of the current signal transmission and probably both the signal power and the signal quality will change and possibly improve during the in-orbit-testing phase of the satellite's operation.

India on April 4, 2014 successfully launched its second navigational satellite IRNSS-1B onboard PSLV C-24, taking a step closer to realizing its ambitious programme of establishing an independent regional space-based navigation system.
IRNSS-1B, the second of the seven satellites planned under the Indian Regional Navigation Satellite System (IRNSS), was placed in precise orbit by the workhorse Polar Satellite Launch Vehicle (PSLV) which completed its silver jubilee success mission.

Drawing a golden brush in the clear blue sky, the 44.4 metre tall PSLV-C24 lifted off from the Satish Dhawan Space Centre, Sriharikota, about 100 km from Chennai, at 5.14 pm and soared to its destination. About 19 minutes after the lift-off, PSLV C24 successfully placed the 1,432 kg IRNSS 1B in the intended orbit above the Earth, much to the jubilation of the ISRO scientists in the mission control room. The PSLV, in its 25th successive successful flight, precisely injected India's second regional navigational satellite IRNSS-1B very precisely. At a total budget of around Rs 1,420 crore, ISRO is in the process of putting in place the IRNSS, comprising a space, ground and user segments, which would provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary.

IRNSS is equivalent to Global Positioning System of the United States. IRNSS-1A, the first satellite of the IRNSS constellation, has already started functioning, having been launched in July last year.

## CONCLUSION

Thanking the entire ISRO team for this "major milestone" for the country, For the farthest distance we targeted was 20,650 kms plus or minus 20,675 kms, and what we got is 20,630 kms, just 20 kms less. As far as the inclination of the orbit, we are on the dot. Talking about the future projects, during the current year the space agency would launch two more navigational satellites IRNSS 1C and 1D.While the US' Global Positioning System (GPS) and Russia's GLONASS are the effective navigation systems worldwide presently, India is hoping to put all the seven satellites in space by 2015. However, the IRNSS could start functioning even with a minimum of four navigation satellites in space. IRNSS would help in terrestrial, aerial and marine navigation, disaster management, vehicle tracking and fleet management, integration with mobile phones, mapping and geodetic data capture and others.

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