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IRNSS Architecture and Applications

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***Abstract*— The Indian Regional Navigational Satellite System (IRNSS) is an autonomous regional satellite navigation system being developed by the Indian Space Research Organization (ISRO) 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 Global Navigation Satellite Systems, GPS, 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). Here in this paper we study architecture and applications very briefly.**

***Keywords*— IRNSS Constellation, Navigation, Architecture, Applications.**

I. INTRODUCTION

ISRO developed a satellite based navigation system, called Indian Regional Navigation Satellite System (IRNSS), with a constellation of 7 satellites and complementary round infrastructure. Two spare satellites are also planned. The IRNSS system was planned to be made operational by end of 2014. Government has approved the IRNSS project at a total cost of Rs. 1420.00 crores in May 2006 for both space and ground infrastructure. The IRNSS is expected to provide positional accuracies similar to the Global Positioning System (10 m over Indian landmass and 20 m over the Indian Ocean) in a region centered around the country with a coverage extending up to 1,500 km from India between longitude 40° E to 140° E and between latitude ± 40°.IRNSS was featured with highly accurate position, velocity and time information in real time for authorized users on a variety of vehicles. Data with good accuracy for a single frequency user with the help of Ionospheric corrections. All weather operation on a 24 hour basis.

Polar Satellite Launch Vehicle in its twenty fourth flight (PSLV-C22) have launched India's first dedicated navigational satellite system IRNSS-1A. Each IRNSS satellite weights about 1,380 kg and their solar panels generate 1,400 Watt of power. The satellites will be configured with an optimized I-1K bus (compatible for launch onboard PSLV) with a power handling capability of around 1600W.

Fig. 1 PSLV Flight

II. IRNSS SATELLITES

The satellite is designed for a nominal life of 7 years. Its payload will consist of electronic equipment to generate navigation signals and extremely accurate on-board atomic clocks. The navigation signals in S-band (2-4 GHz) are fed to a high performance phased array antenna for the required

coverage. There is a ranging payload consisting 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.

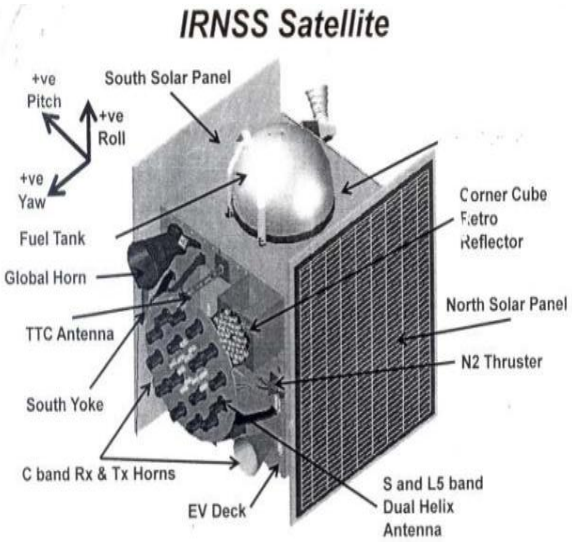

Fig. 2 IRNSS Satellite

III. ARCHITECTURE

The INRSS consist of three segments: space, ground and user. The space segment consists of a constellation of seven satellites: three (Geostationary Orbit) GEOs located at 34° E, 83° E and 131.5° E and four (Geosynchronous Orbit) GSOs at an inclination angle of 29° placed two each at with equator crossing at 55° and 111° East.

IRNSS ground segment consists ground stations for generation and transmission of navigation parameters, satellite control, satellite ranging and monitoring. A total of 20 stations are planned, most of them located at airports along with GAGAN ground elements. IRNSS will have the two Master Control Stations (MCS), which may be co-located with GAGAN INMCC.

IRNSS will have two types of signals in L5 (1176.45 MHz) & S (2492.028 MHz) band. Both L5 and S-band consists of two downlinks.

IRNSS provides two basic services such as Standard Positioning Service (SPS) for common civilian users and Restricted services (RS) for special authorized users. The system can be augmented with local area augmentation for higher accuracy

IRNSS is an autonomous regional satellite navigation system being developed by ISRO (Indian Space Research Organization).

The objective of the IRNSS is to implement an independent and indigenous regional space borne navigation system for national applications.

The IRNSS design requirements call for a position accuracy of < 20 m throughout India and within the region of coverage extending about 1500 km beyond. The system is expected to provide accurate real-time position, velocity and time observables for users on a variety of platforms with 24 hour x 7 day service availability under all weather conditions.

The IRNSS was being developed parallel to the **GAGAN** (GPS Aided GEO Augmented Satellite Navigation) program, the ISRO SBAS (Satellite Based Augmentation System) version of an overlay system for GNSS signal corrections.

The IRNSS system consists of a constellation of seven satellites and a supporting ground segment. Three of the satellites in the constellation will be placed in a geostationary orbit and the remaining four in a geosynchronous inclined orbit of 29º relative to the equatorial plane. Such an arrangement would mean all seven satellites would have continuous radio visibility with Indian control stations.

ISRO has filed for 24 MHz bandwidth of spectrum in the L5-band (1164 - 1189 MHz) for IRNSS and for the second signal in S-band (2483.5 - 2500 MHz).

The IRNSS constellation architecture consists of the following elements:

Space segment

The IRNSS satellites carry a navigation payload in a redundant configuration. A separate C-band transponder for precise CDMA ranging is included in the payload configuration. The important functions of the IRNSS payload are: Transmission of the navigational timing information in the L5 bands; transmission of navigation, timing information

in S-band; generation of navigation data on-board, CDMA ranging transponder for precise ranging.

The navigation payload will have the following subsystems: NSGU (Navigation Signal Generation Unit), Atomic clock unit, comprising of Rubidium atomic clocks, clock management and control unit, frequency generation unit, modulation unit, high power amplifier unit, power combining unit and navigation antenna.

The IRNSS spacecraft are dedicated for navigation services and they are configured to be of a class that can be launched by the Indian launcher PSLV. The design incorporates most of the proven subsystems available indigenously tailoring it is specifically for the navigation.

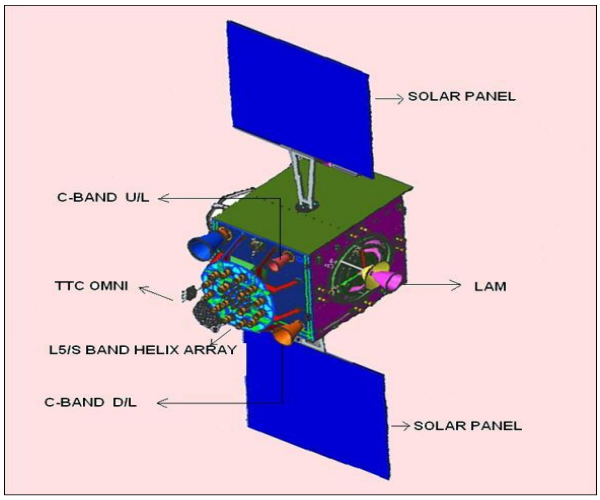

Fig. 3 Deployed IRNSS Spacecraft

The spacecraft are 3-axis stabilized. Attitude control of the satellite is provided with yaw steering, a capability to optimize the use of the solar panels and to support the thermal control of the satellite.

Launch mass	1425 kg, dry mass of 614 kg
Spacecraft size (launch configuration)	1.58 m x 1.5 m x 1.5 m
EPS (Electrical Power Subsystem)	Two solar panels generating 1660 W, one lithium-ion battery of 90 Ah capacity
ADCS (Attitude Determination and Control Subsystem)	Zero momentum system, orientation input from sun & star sensors and gyroscopes; reaction wheels, magnetic torquers and 22 Newton thrusters as actuators
Mission life	10 years
Propulsion	440 N LAM (Liquid Apogee Motor) with twelve 22 N thrusters

Table. 1 Parameter of IRNSS-1 Spacecraft

Orbit

The three GEO spacecraft are in the equatorial plane at an altitude of 20,650 km located at 32.5º, 83º and 131.5º E. The four GSO (Geosynchronous Orbit) spacecraft, with an inclination of 29º, are located in two planes with daily longitudinal equator crossings at 55º E and at 111.75º E. The coverage provided by the constellation encompasses a longitude from 30º to 130º and a latitude region of 30º S to 50º N

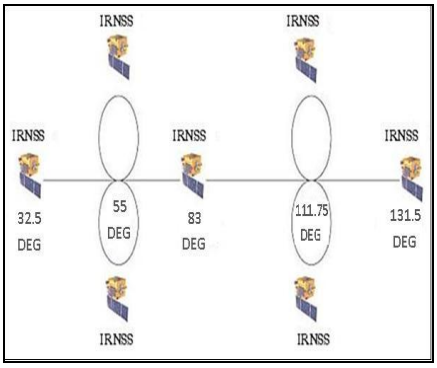

Fig. 4 Alternate Projection of IRNSS Spacecraft

Ground segment

The IRNSS ground segment includes the major systems for controlling the satellite constellation and will consist of the IRNSS Spacecraft Control Facility (IRSCF), IRNSS Navigation Control Facility, IRNSS Range and Integrity Monitoring Stations, ranging stations, a timing center, IRNSS TTC and uplink stations, and the IRNSS Data Communication Network.

IRNSS Ground Segment Elements:

· IRSCF (IRNSS Satellite Control Facility)

- IRTTC (IRNSS TTC and Land Uplink Stations)

- IRSCC (IRNSS Satellite Control Center)

· IRIMS (IRNSS Range and Integrity Monitoring Stations)

· IRNCF (IRNSS Navigation Control Facility)

· IRDCN (IRNSS Data Communication Network)

Seventeen IRIMS sites will be distributed across the country for orbit determination and ionospheric modeling. Four ranging stations, separated by wide and long baselines, will provide two-way CDMA (Code Division Multiple Access) ranging. The IRNSS timing center will consist of highly stable clocks. The navigation center will receive all this data through communication links, then process and transmit the information to the satellites.

IRNSS will have a network of 21 ranging stations geographically distributed primarily across India. They provide data for the orbit determination of IRNSS satellites and monitoring of the navigation signals. The data from the ranging/monitoring stations is sent to the data processing facility at INC where it is processed to generate the navigation messages. The navigation messages are then transmitted from INC to the IRNSS satellites through the spacecraft control facility at Hassan/Bhopal. The state of the art data processing and storage facilities at INC enable swift processing of data and support its systematic storage.

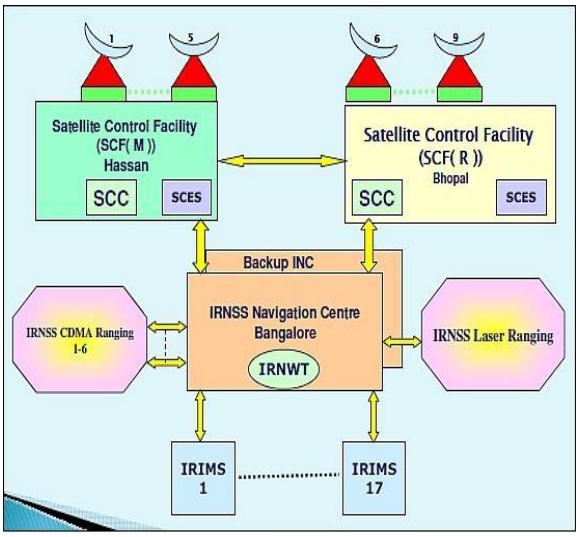

Fig. 5 IRNSS Ground Segment Architecture

User segment

The user segment consists of IRNSS receivers operating in:

· Single frequency (L5 at 1176.45 MHz or S-band at 2492.028 MHz)

· Dual frequency (L5 and S-band)

The single frequency and dual frequency receivers shall receive both SPS (Special Positioning System), which is provided to all users, and RS (Restricted/Authorized Service) signals, which is an encrypted service provided only to authorized users.

The IRNSS user receiver calculates its position using the timing information embedded in the navigation signal,

transmitted from the IRNSS satellites. The timing information being broadcast in the navigation signal is derived from the atomic clock onboard the IRNSS satellite.

The IRNWT (IRNSS Network Time) is determined from a clock ensemble composed of the cesium and hydrogen maser atomic clocks at the INC (Indian Navigation Centre) ground stations. As with UTC, IRNWT is also a weighted mean average time, but with two substantial differences. IRNWT will be made available in real time and is a continuous time without leap seconds. The IRNSS satellites carry a rubidium atomic frequency standard onboard. At INC through navigation software, these onboard clocks are monitored and controlled. The deviation between each of the satellite and IRNWT is modeled with a quadratic function of time, and the parameters of this model are calculated and transmitted as a part of the IRNSS broadcast navigation messages.

The parameters are often called as clock bias (A0) or the clock offset (in seconds), drift (A1) or the relative frequency instability (in seconds/second) and aging (A2), also referred to as relative frequency shift (in seconds/second^2). Apart from these corrections, any IRNSS users should consider the necessary relativistic time adjustment. With these adjustment parameters, which are usually calculated once per day, are then transmitted to the satellites, thus the satellite clock errors are expected to be well within 5^{-10}ns which fulfills the requirement.

The estimated accuracy is < 20 m over the Indian ocean region, and < 10 m over main land India.

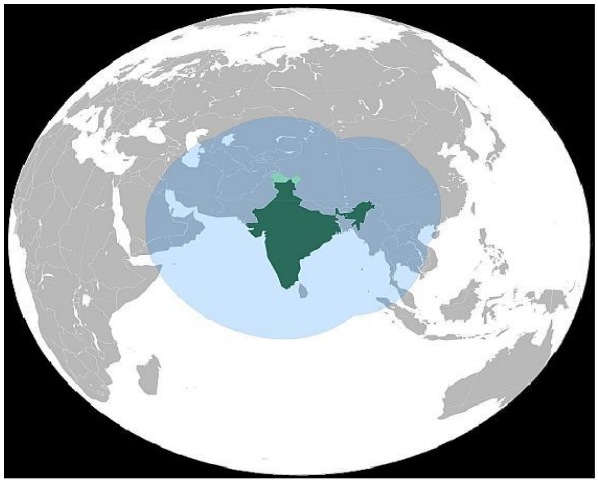

Fig. 6 IRNSS Coverage

Navigation payload

Each satellite has two payloads : the Navigation payload and the CDMA ranging payload in addition with a retroreflector array. The payload generates navigation signals at L5 and S-band. The design of the payload makes the IRNSS system interoperable and compatible with GPS and Galileo.

· A highly accurate Rubidium atomic clock is part of the navigation payload.

· The ranging payload of IRNSS-1A consists of a C-band transponder which facilitates accurate determination of the spacecraft range.

IRNSS Signals

The IRNSS constellation is expected to provide position accuracy (2¿) of better than 20 m over India and a region extending outside the Indian land mass to about 1,500 km. The system will provide two types of services:

1) SPS (Standard Positioning Service)

2) RS (Restricted/Authorized Service)

Both of these services will be provided at two frequencies, one in the L5 band and the other in S-band.

SPS will use bi-phase shift keying BPSK (1) modulation, whereas the RS service will employ binary offset carrier (BOC (5, 2)) modulation. An additional BOC pilot signal is being provided for the RS Service in order to help provide better acquisition and performance. As each L5-band and S-band contains three signals, the IRNSS design adds an interplex signal in order to maintain the constant envelope characteristic of the composite signal.

The transmission is done using the L-band and S-band helix array antenna to provide global coverage in right-hand circularly polarized (RHCP) signals. Thus, user receivers can operate in single-and/or dual-frequency mode.

Timing group delay

The time of radiation of the navigation signals on each carrier frequency and among frequencies is not synchronized due to the different digital and analog signal paths that each signal must travel from the IRNSS satellite signal generator to the transmit antenna. This hardware group delay is defined as a time difference between the transmitted RF signal (measured at the phase center of a transmitting antenna) and the signal at the output of the onboard frequency source.

Three different parameters comprise this group delay: a fixed/bias group delay, a differential group delay and a group delay uncertainty in bias and differential value.

The fixed delay or hardware group delay is a bias term included in the clock correction parameters transmitted in the navigation data and is, therefore, accounted for by the user computations of system time in the appropriate GPS interface specifications. More specifically, this delay represents the amount of time it takes the signal to start from the common clock, travel through each code generator, modulator, up-converter, transmitter, and finally emerge from the satellite antenna.

The hardware group delay uncertainty reflects the variability in the path delay due to changeable conditions in the operational environment and other factors. The effective uncertainty of the group delay will be in the range of few nanoseconds (on the order of 1-3 ns).

Each IRNSS navigation signal has two hardware paths - main and redundant. The hardware will each IRNSS navigation signal has two hardware paths - main and redundant. The hardware will be different for each path in terms of data generator, modulator, up converter, travelling-wave tube amplifier (TWTA), cable, and integration components.

In case of failure, the signal will be diverted from the main subsystem to the redundant subsystem. he delay of main and redundant subsystem will be different and thus cause a difference in the mean path delay based on the selected path for the navigation signal.

Differential group delay is the difference in delays between two navigation signals. It consists of random plus bias components. The mean differential is defined as the bias component and will be either positive or negative. For a given navigation payload redundancy configuration, the absolute value of the mean differential delay shall not exceed a few nanoseconds, i.e., on the order of 15 to 30 ns.

IRNSS-1A was the first of the seven satellites constituting the space segment of the Indian Regional Navigation Satellite System. IRNSS is an independent regional navigation satellite system designed to provide position information in the Indian region and 1500 km around the Indian mainland. IRNSS would provide two types of services, namely, Standard Positioning Services (SPS) - provided to all users - and Restricted Services (RS) provided only to authorize users.

A number of ground stations responsible for the generation and transmission of navigation parameters, satellite control, satellite ranging and monitoring, etc., have been established in as many as 15 locations across the country.

The entire IRNSS constellation of seven satellites is planned to be completed by 2015-16.

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