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Research Paper

Comprehensive Study of GNSS Systems

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Abstract:- *Almost every application these days relies on position of their user. The more accurate the position is, the more precise is service provided by the application. Also the faster one gets location, the faster is the response of application. This constant demand of positioning leads to an increasing number of applications of Global Navigation Satellite Systems (GNSS).In the light of these requirements GNSS will become more available, more accurate and more robust. In turn to this change, GNSS receiver architecture must also be enhanced to adapt to these technology changes. This paper presents the different kinds of GNSS systems available at present (which may not be fully functional) to find out the geographical location of a user around the globe.*

Keywords : *Global Navigation Satellite Systems (GNSS), satellite systems, Global Positioning System (GPS), GLONASS, Galileo, Beidou, navigation, tracking, space, control, map positioning.*

I. INTRODUCTION

Global Navigation Satellite System refers to a constellation of satellites revolving around the earth which transmits positioning data received by the GNSS receivers and GNSS receivers can estimate the location parameter based on the data encoded in these signals. GNSS provides global coverage that means this set of satellites can be used to find location of a GNSS receiver anywhere on the earth.

The GNSS technology is becoming pervasive day-by-day, this is leading to enhancements in GNSS satellite technologies and also makes GNSS receivers a major concern to focus on, particularly architecture, size and cost of the receivers. In addition to this, GNSS system must be robust to provide services required by the location based applications.

The modern GNSS systems provides variety of location based services such as single shot sessions, continuous navigation, location services based on distances, geo-fencing, etc. To simplify GNSS system and also to fulfill above mentioned requirements, GNSS systems are often made interoperable i.e. a GNSS receiver processing the data from different GNSS systems such as GPS, GLONASS, and Galileo. Multi-GNSS solutions can provide better availability and accuracy. However this kind of solution might increase the cost of the GNSS receiver which is a very important factor when market is considered.

To design such a system with multi-constellation support one must first study all the types of GNSS systems which they want to support and then proceed any further. This paper explains briefly the GNSS systems those are in operation at present and their signals characteristics used to calculate location parameters.

II. RELATED WORK

A. *GPS :*

GPS was launched in 1978 for US Department of defense with a 24 satellites used. GPS became fully functional in 1995 and provides location services with a precision of 5 meters. GPS was the first fully functional GNSS system and its functionality was available only for military use initially. GPS came for civilian usage in 1983.Applications those uses GPS are time-based applications, distance-based application, tracking etc. To provide location based results GPS depends upon a lot of factors such as satellite positions, weather, RF communication link, GPS antenna etc. To provide consistent and reliable service GPS consists of two segments: Space Segment and Control Segment as explained below:

Space Segment: GPS has a group of thirty one satellites(27 functional and 4 spares) revolving around the earth in Medium Earth Orbit(MEO) at an approximate altitude of 20,200 km and with an orbital inclination of 55 degrees(as shown in fig.1).

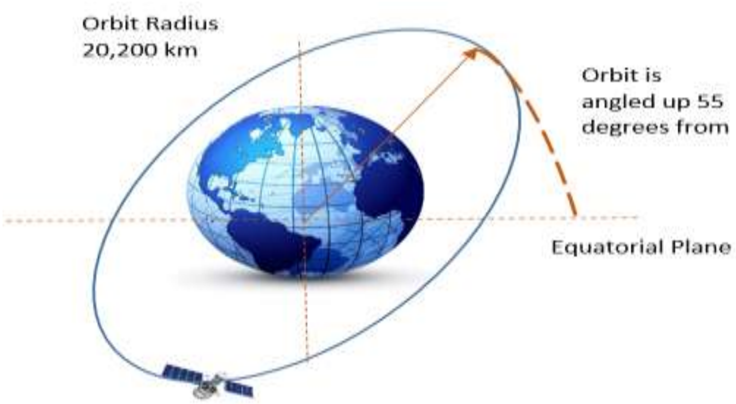

Fig.1. GPS Space Segment

These satellites broadcasts a navigation message which could be received by the GPS receiver on the earth and this message contains the data which can be used to identify a satellite(e.g. Satellite Vehicle Number) or to calculate the location of the receiver on the earth. GPS signals are based on Code Division Multiple Access (CDMA) and are described in table I.

TABLE I: GPS Control Segment

Designation	**Frequency(in MHz)**	**Description**
L1	1575.42	L1 is modulated by the C/A code (Coarse/Acquisition) and the P-code (Precision) which is encrypted for military and other authorized users.
L2	1227.60	L2 is modulated by the P-code and, beginning with the Block IIR-M satellites, the L2C (civilian) code. L2C has begun broadcasting civil navigation
L5	1176.45	L5, available beginning with Block IIF satellites, has begun broadcasting CNAV messages.

Control Segment: The GPS control segment comprises of a worldwide arrangement of ground amenities that assist in tracking the GPS satellites in the constellation, supervise their communication, execute analysis, and launch guidelines and orders, that facilitate the navigation services. The GPS control segment consists of a master control station (and a backup master control station), monitor stations, ground antennas and remote tracking stations (as shown in fig.2).

Fig.2. GPS Control Segment

The ground antennas are co-located with monitor Stations and used by the Master Control Station to communicate with and control the GPS satellites. The Air Force Satellite Control Network (AFSCN) remote tracking stations provide the Master Control Station with additional satellite information to improve telemetry, tracking and control. Details of these stations are provided in table II.

TABLE II: GPS Control Segment

Master Control Station	Schriever AFB
Alternate Master Control Station	Vandenberg AFB
Air Force Monitor Stations	Schriever AFB, Cape Canaveral, Hawaii, Ascension
AFSCN Remote Tracking Stations	Schriever AFB, Vandenberg AFB, Hawaii, New Hampshire,
NGA Monitor Stations	USNO Washington, Alaska, United Kingdom, Ecuador,
Ground Antennas	Cape Canaveral, Ascension Island, Diego Garcia, Kwajalein

B. GLONASS :

The formerly Soviet, now Russian, Global'naya Navigatsionnaya Sputnikovaya Sistema (Global Navigation Satellite System), or GLONASS, launched their fully functional satellite system in 1995. GLONASS provides real time position and velocity determination for military and civilian users with a precision of 5-10 meters. Though development of GLONASS began in 1970s, its first launch was in 1982. Initial launch was to provide regional coverage and in 2011 it started providing global coverage. GLONASS receiver can estimate position by collecting data from minimum four satellites visible to it at that point of time. Same as GPS, GLONASS also has two segments as described:

Space Segment: GLONASS has a total of 27 satellites 24 operational and 3 spares in three orbital planes (8 satellites per plane) inclined at 64.8 degrees and with orbit radius of 19,140km. GLONASS signal contains a unique identifier to each satellite and health of the satellite. It also includes almanac of all other satellites and positioning, timing, velocity for computing positions.

Control Segment: This has the system control center and a network of stations across Russia. Control segment monitors the satellites, determines the ephemeris and uploads corrections to satellites twice a day.

Signal transmission in GLONASS is slightly different than signal transmission in GPS i.e. instead of CDMA used by GPS, GLONASS uses FDMA i.e. satellites transmits same signals at different frequencies. Each GLONASS satellite transmits on a slightly different L1 and L2 frequency, with the P-code (HP code) on both

L1 and L2, and the C/A code (SP code), on L1 (all satellites) and L2 (most satellites). GLONASS signals are described in table III:

TABLE III: GLONASS Signals

Designation	Frequency (in MHz)	Description
L1	1598.0625 - 1609.3125	L1 is modulated by the HP (high precision) and the SP (standard precision) signals.
L2	1242.9375 - 1251.6875	L2 is modulated by the HP and SP signals. The SP code is identical to that transmitted on L1.

C. Galileo :

A European GNSS system, Galileo launched its first fully functional satellite 21 October 2011. Galileo is the first satellite system designed for civilian usage to provide highly reliable and accurate global positioning services which provides location services with a precision of 1m (public) and 1cm (encrypted). Galileo is designed in such a way that it is always compatible with GPS and it ensures to provide location services in extreme conditions. Galileo's first test satellite was launched in 2005 and four satellites in 2011 and 2012 were launched to check the basic functionalities of satellites with their base stations. At present Galileo has a total of 30 satellites, out of which 12 satellites are in space.

There are three components which constitutes Galileo system: global, regional and local. The global component is the heart of the system which has satellites and the ground stations providing timing and related data. The regional component has ERIS (External Region Integrity Systems) to satisfy legal constraints. Local components are for improving the performance of the system.

Galileo space segment consist of 30 Satellites (27 operational and 3 spares) at three orbital planes inclined at 56 degrees to the equatorial plane with orbital radius of 23,222km. Galileo signals are describes in table IV:

TABLE IV: Galieo Signals

Designation	Frequency	Description
E1A	1575.42 Mhz	Public Regulated Service Signal
E1B	1575.42 Mhz	Safety-Of-Life And Open Service Signal(Data)
E1C	1575.42 Mhz	Safety-Of-Life And Open Service Signal (Dataless).
E5a I	1176.45 Mhz	Open Service Signal (Data).
E5a Q	1176.45 Mhz	Open Service Signal (Dataless).
E5b I	1207.14 Mhz	Safety-Of-Life And Open Service Signal (Data).
E5b Q	1207.14 Mhz	Safety-Of-Life And Open Service Signal (Dateless).
Altboc	1191.795 Mhz	Combined e5a/E5b Signal.
E6 A	1278.75 Mhz	Public Regulated Service Signal.

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E6 B	1278.75 Mhz	Commercial Service Signal (Data).
E6 C	1278.75 Mhz	Commercial Service Signal (Dateless).

Broadly, Galileo provide four services, named: Free Open Services (OS), highly reliable Commercial Service (CS), Safety-of-Life Service (SOL), Government encrypted Public Regulated Service (PRS) which makes it choice of a GNSS system.

D. Beidou :

Beidou is a Chinese satellite System launched in 2000. Beidou's precision for location services is 10m (for civilian usage) and 0.1m (for military). Beidou was developed in two phases, first with the regional coverage in 2000(known as Beidou-1) and second one with global coverage which under process (known as Beidou-2).
Beidou-1 space segment has five satellites in GEO orbit, five in IGSO and four in MEO with an inclination of 55 degrees from equatorial plane and with 35,787km orbit radius for GEO and IGSO, and 21,528km for MEO. On the other hand, Beidou-2 is planned to have 5 satellites in GEO, 3 in IGSO and 27 in MEO in three orbital planes with an inclination of 55 degrees and orbit radius of 35,787km for GEO and IGSO, and 21,525km for MEO. Beidou signals are also based on CDMA (Code Division Multiple Access) and details are as shown in table V:

TABLE V: Beidou Signals

Designation	Frequency	Description
B1	1561.098 MHz	B1 provides both public service signals and restricted service signals.
B2	1207.140 MHz	B2 provides both public service signals and restricted service signals.
B3	1268.520 MHz	B3 provides restricted service signals only.

III. PROPOSED IDEA

GNSS has a huge impact on global market and is expected to grow reaching €200 billion by 2016. Such a huge demand requires fully functional, robust and sustainable solutions of location services. This demand can be fulfilled by Multi-GNSS solutions which can provide location services faster and accurate. Multi-GNSS means that GNSS receiver should be able to process signals coming from different GNSS satellites and use these signals to provide results for location queries.

Design of such system requires several considerations such as understanding the technologies used with different GNSS systems, technical aspects of signal processing, platform in which these receivers are going to be embedded, signal to noise ratio of the signals, power related issues etc. Also there are some non-functional characteristics need to be considered such as size and cost of the receiver.

A multi-GNSS system is different than traditional systems in a sense that it can have position accuracy improved as the number of satellites involved in position calculation has also increased. Another advantage of such a system is increase in availability i.e. if some satellites are not visible it can get data from satellites of other GNSS system. Last but not the least is resistance against interference. GNSS can use different frequency bands of different GNSS systems to get the signals to avoid interference issues occurred in case of signals coming at same frequency.

IV. CONCLUSION

This paper provides basic introduction of GNSS and what are the GNSS systems available as of now. It also describes the system architecture of each GNSS system containing space and control segments and also their signal characteristics. Though GPS is the most widely used GNSS system, other GNSS systems also provide robust features and these can also be merged to exploit characteristics of multiple GNSS systems. While choosing GNSS of your choice not only the precision matters but also the availability of satellite signals because even if precision is more but satellites are unavailable, it will not be a feasible solution. Thus this paper provides basics of all the GNSS and the comparison between them to facilitate an understanding of GNSS.

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