UNIT 1 INTRODUCTION TO GNSS

Structure

1.1 INTRODUCTION

You all know that since the beginning of civilisation, humans wandered on the Earth and had found many simple ways to locate themselves on it. For example, the Early man of the Stone age started navigation by leaving stones, marking trees or referencing mountains. On the other hand, early mariners used the angular measurements of the celestial bodies such as the Sun and the stars to calculate their positions. Now with the rapid advancement of space technology, navigation on the Earth has become very easy. A constellation of navigation satellites commonly known as Global Navigation Satellite System (GNSS) has made it possible to determine three dimenisional position of the object on any part of the Earth or in space. The most widely used operational GNSS is the Global Positioning System (GPS).

Navigation is the process of monitoring and controlling the movement of a craft or vehicle or a person from one place to another within a specified framework.

Satellite-based positioning is the determination of positions of observing sites on land or at sea, in the air and in space by means of artificial satellites.

Initially, GNSS was mainly used for defence purposes. But recently, its usage has increased and now, it is being widely incorporated by the civilians for different purposes like in tracking systems, navigation, intelligent transportation systems, weather forecasting, precise positioning and emergency services. In this unit, we shall discuss the concepts, history and the components of GNSS. We will also discuss the main GNSS systems of the world including GPS. At the end of the unit, we will compare GPS with other global navigation systems.

You have been introduced to GPS in Unit 1, *Introduction to Geoinformatics* of MGY-001.

Objectives

After reading this unit, you should be able to:

- discuss the basics of GNSS;
- describe the history of GNSS;
- outline various global navigation systems;
- compare the GPS with other navigation systems;
- explain the accuracy of differential GPS and sources of errors; and
- elaborate GNSS in Indian context.

1.2 BASICS OF GNSS

In simple words, GNSS are a constellation of satellites designed to determine positioning and timing information for users on the Earth or in space. In 1970, International Civil Aviation Organisation defined *GNSS* as "a worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation". At present, there are mainly two core constellations for GNSS namely United States of America (USA) Global Positioning System commonly known as GPS and Russian Federation's Global Navigation Satellite System abbreviated as GLONASS. In addition, Galileo - an European satellite navigation system, GAGAN - an Indian GPS aided geo-augmented navigation and Compass System - a China navigation satellite system are the emerging satellite constellations which will evolve into global constellations in the coming years. The operational GNSS such as GPS and GLONASS are combined into a single category known as GNSS-1. The underdeveloping second generation GNSS system e.g. Galileo, Chinese compass, Japanese quasi-zenith satellite system and Indian regional navigational satellite system are grouped as GNSS-2. When GPS is used with corrections from ground or space based augmentation systems then it is called as a Differential GPS (DGPS). Currently, the complete navigation satellite technology is known GPS because it is the only fully functional GNSS with constellation of 32 satellites and most of existing global applications are related to it.

Components of GNSS

GPS, GLONASS and Galileo are the three main GNSS systems and all these technologies consist of three main segments/components. These segments are space, control and user.

- **Space Segment:** It consists of GNSS satellites like space vehicles that send radio signals from space.
- **Control Segment:** It consists of a system of tracking stations located around the world like master control and monitor network.
- **User Segment:** It consists of the GNSS receivers and user community. GNSS receivers convert space vehicle(s) signals into

position, velocity and time estimates which are used by GNSS user for navigation, positioning, time dissemination and other research.

The current generation of navigation systems such as GPS and GLONASS and those under development like Galileo determine the user terminal position through the time of arrival and mode of ranging. In general, this kind of ranging technique is based on the measurement of time interval employed by a signal transmitted by an emitter (e.g., satellite, radio signal) at a known location to arrive at the user receiver.

Here you will read about a simple formula that gives distance of the receiver from each satellite. In fact, time is the most important parameter required to know the distance between the satellites and the receiver. The distance from a known position of a satellite to the receiver end is equal to the velocity of transmitted signal multiplied by travel time of radio waves transmitted from the satellites to reach the receiver. In this case, distance is calculated as:

Distance = Velocity of light × Travel time of the satellite signal

Let us discuss this with a common example of a thunderstorm. If you work out the phenomenon of thunderstorm such as how far you are from a bolt of lightning, you would make the following calculations. This distance can be established quite easily (Fig. 1.1). Distance is the time of the lightning flash perceived (start time) until the thunder is heard (stop time), multiplied by the speed sound of at approx. 330m/s. The difference between the start and stop time is referred as the *Signal Travel Time*. In this case, signal is the sound wave travelling through air.

Hence,

Distance = Travel time × Speed of sound

Now you can see that GPS works on the same principle, called '*Time of Arrival*'(**TOA** or **ToA**), sometimes known as *Time of Flight* (ToF). Time of arrival is the travel time of a radio signal from a single transmitter to a remote signal receiver. Time of arrival of the signal measured by the user receiver is as given below:

TOA = Time instant of arrival – Time instant of transmission

You have read about thunderstorm, where speed of sound is considered but in the case of satellite navigation, electromagnetic signals are used which propagate at the speed of light ($\sim 3 \times 10^8$ m/s). If the user receiver knows the speed of signal, then he/she is only able to determine the distance from the emitter, simply by multiplying the time of arrival with signal speed value. By considering the relationship between the speed of light in vacuum and carrier frequency of a signal, the time represents a measure for the distance between transmitter and receiver.

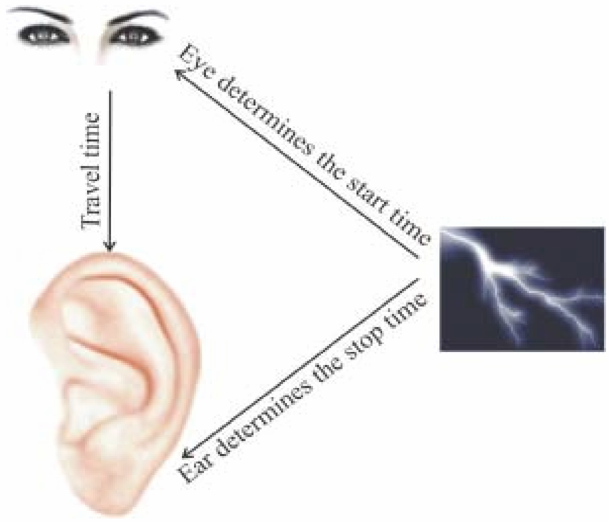


Fig. 1.1: Determining the Distance of a Lightning Flash

You can obtain geometric distance between the satellite and receiver by calculating the true time of arrival. This implies that the receiver has a precise knowledge of time instant of arrival and time instant of transmission of the satellite signal. The time instant of arrival can be achieved through direct reading of the receiver clock whereas time instant of transmission is embedded in the signal, which is scheduled *navigation signal*.

To achieve a true difference between these time instants, discussed above, the satellite and receiver clocks have to be synchronised to the same time scale. Once the user receiver has a sufficient number of distance values from multiple satellites with known locations, it can specify its position, according to theoretical considerations. You shall read about this in Unit 2 *GNSS and its Components*, of MGY-003. In satellite-based navigation, transmitters are not having fixed points, as in the case of terrestrial. We have discussed that the receiver is able to determine satellite position for each distance measurement. For this purpose, each navigation signal modulates a message that includes satellite orbital parameters. Satellite orbital parameters are generally known as *satellite ephemeris* data. This enables the receiver to propagate satellite orbit and then to evaluate transmitter position at each time instant. Orbital parameters are updated by the master control station and transmitted to the satellites once or twice a day.

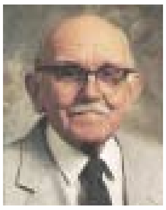
Satellite ephemeris data contains orbital information and allows the receiver to calculate the position of the satellite.

1.3 HISTORY OF GNSS

In this section, we shall discuss about the history of GNSS. You have studied in the earlier section that leaving stones, marking trees or referencing mountains were some of the ways used by early humans for finding their locations. Later on, with the discovery of constellations the relative positions of Sun, Moon and Stars were considered as point of reference. With the advancement of communication technology, radio signals were used for finding location by measuring time taken for special radio signals.

The primitive navigation system which is known as LORAN (Long Range Navigation) was developed in early 1940s by USA. It became operational in 1943. LORAN was the first radio navigation system that provided aid to the marine radio navigation. It was based on the principle of time difference between the receipt of signals from a pair of radio transmitters. It covered only 5% of the

Earth's surface and just provided 2 dimensional information (latitude and longitude) with an accuracy up to 250 m. During the early 1960s, the importance of GNSS was first realised by the US Department of Space. As a consequence, several US Government agencies started putting efforts for designing and developing satellite system for the determination of three dimensional positions. The result of such efforts led to the development of navigation system named *Omega*. It became operational in 1971 and was shut down in 1997. It was the first radio navigation system for the aircraft which was operated by US in cooperation with six partner countries such as Argentina, Norway, Liberia, France, Japan and Australia. It enabled ships and aircraft to determine their position by receiving very low frequency radio signals.



John Alvin Pierce, the "Father of Omega" (source: http://jproc.ca/hyperbolic/omega.html)

During the same time US developed and deployed first satellite based navigation system known as *TRANSIT*. This system is also known as NAVSAT (Navy Navigation Satellite System) because it was primarily used by U.S. Navy for determining accurate location information. TRANSIT provided continuous navigation satellite service from 1964 to 1996 initially for Polaris submarines and later on for civilian usage. It was also used for geodetic and hydrographic surveying. The advent of GPS made TRANSIT as an obsolete system. As a consequence, its navigation service ceased in 1996.

Polaris submarine was a two-stage solid-fuel nuclear-armed submarine built during the Cold War by the United States Navy.

Geodetic survey involves large area of land surveys in which corrections are made to report for the curvature of the earth.

Hydrographic survey encompasses the measurement and description of features which affect marine navigation, construction, dredging and exploration.

Delhi government has agreed the usage of GPS in autorickshaws and taxis in Delhi and National Capital Region (NCR). This would enable the customers to have uniformity in fares and reach the precise location.

The swift growth in civilian use of GNSS took place only twenty years ago which was limited to merchant ships' crews and surveyors. The major breakthrough came with the introduction of American NAVSTAR, more commonly known as GPS. The roots of GPS are closely connected to the launch of the Sputnik satellite by the former Soviet Union in 1957. But a modern GPS came into existence in 1973 when US Department of Defense decided to develop satellite navigation system based on its previous systems like TRANSIT. When the first satellite was launched in 1978, the GPS was only intended for US military applications. Today, millions of GPS receivers are being used in transport, commerce and variety of recreational activities. In mid 1980s, the system was made available for civilian uses especially in aviation industry. By 1994, a complete constellation of 24 satellites was in orbit initiating the GPS system's full operational capability. The 'Cold War' rivalry between the USA and the former Soviet Union led to the 'Space Race' and almost parallel development of GLONASS – the Soviet system.

1.4 GNSS SYSTEMS: EXAMPLES

You have already been introduced to the three examples of GNSS viz., GPS, GLONASS and Galileo. In this section we will further discuss about them. The two main satellite-based navigation systems operational today are GPS and GLONASS. Both systems were originally military networks, with each one based on constellations of 24 operational satellites in order to give the user an accurate position. Despite of their military origins, GPS and GLONASS had innumerable civilian applications that was far beyond the original contemplation. Satellite navigation has completely changed the lives of common man. The civil aviation sector has greatly benefitted from this technology. Civilians like hikers, private pilots and boat owners are making extensive use of satellite positioning. It is estimated that nine out of every ten new satellite navigation receivers are currently being sold for civilian or commercial use. Let us discuss about the different operational and under development navigational systems.

1.4.1 Global Positioning System

GPS satellites were developed under NAVSTAR programme of US. Hence, NAVSTAR is commonly known as NAVSTAR-GPS (NAVigation System with Timing And Ranging Global Positioning System). It is planned for both civilian and military use. NAVSTAR GPS was developed in 3 phases. They are:

- Phase 1: 1973-1979 - Concept Validation
- Phase 2: 1979-1985- Full development and tests
- Phase 3: 1985-till date - Production and Deployment

GPS is based on GNSS (Fig. 1.2) and maintained by US government. It is freely accessible by anyone with a GPS receiver. In 1978, the first experimental Block I, GPS satellite was launched. By 1985, eleven more experimental Block I satellites had been launched to validate the concept (Table 1.1). On February 14, 1989, a new type of satellite was activated and the first modern Block II satellite was launched. By December 1993, GPS achieved initial operational capability, indicating a full constellation of 24 satellites was available and provided the *Standard Positioning Service* (SPS). In 1995, Full Operation Capacity (FOC) was achieved and five years later accuracy for civilian users increased from about 100 m to 20 m as the result of deactivation of *Selective Availability*.

Block refers to the satellites associated with each phase of development of global navigation satellite system.

SPS is a positioning and timing service that will be available to all GPS users on a continuous, world-wide basis with no direct charge.

Selective Availability is the intentional degradation of the absolute positioning performance capabilities of the NAVSTAR satellite system for civilian use by the U.S. military.

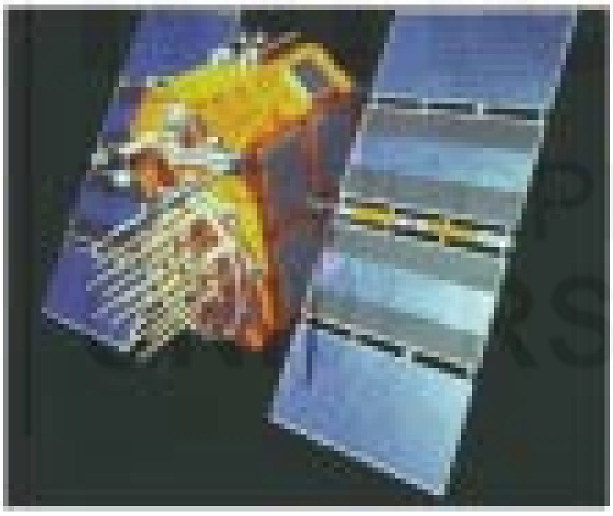


Fig. 1.2: GPS Satellite Artist's Impression
(source: www.zogg-jm.ch/Dateien/ GPS_ CompendiumGPS-X-02007.pdf)

In 2005, the modernisation of GPS system began by launching the first satellite of type IIR-M, which supported a new military signal on L1 and L2 and the addition of the second civil code (C/A) on L2 frequency. As of 12 February 2007 the space segment was built-up by 30 operational satellites of Block IIA, 12 satellites of Block IIR and 3 satellites of Block IIR-M (Crews, 2007). The addition of third civil signal L5 at 1176.45 MHz in Block II F satellite has given an entirely different and more efficient structure. We will discuss about the GPS survey in the next unit.

The fully operational capability of GPS was acheived by April 1995, signifying full availability of the military's secure *Precise Positioning Service* (PPS). The oldest GPS satellite was launched on November 26, 1990 and became operational on December 10, 1990. The recent operational GPS satellite was launched on

PPS is a highly accurate military positioning, velocity and timing service which is available continuously, worldwide to users authorized by the U.S.

May 28, 2010. Currently, we have 31 operational satellites providing signals. Table 1.1 shows different blocks of satellites and their availability.

We will read about GPS in Unit 3, *GPS Survey and Applications* of MGY-003.

Table 1.1: Summary of GPS satellites

Block	Launch Period	Satellite Launches		Currently in orbit
		Success	Failure	
I	1978–1985	10	1	0
II	1989–1990	9	0	0
IIA	1990–1997	19	0	10
IIR	1997–2004	12	1	12
IIR-M	2005–2009	8	0	7
IIF	2010–2011	2	0	2
Total		60	2	31

1.4.2 GLONASS

GLONASS is satellite based radio navigation system which provides the positioning and timing information to users, similar to GPS (Fig. 1.3). It is operated by the Ministry of Defense of the Russian Federation. During the period of over three decades GLONASS has gone through numerous improvements which can be divided into three generations:

- the original GLONASS is out of service (since 1982)
- GLONASS-M (since 2003)
- GLONASS-K are operational now (since 2011)

The most important specifications of this system were:

- 24 planned satellites (21 standard + 3 reserve satellites)
- 3 orbital levels with an angle of 64.8° from the equator
- orbital altitude of 19,100 km
- orbital period of 11h 15.8 min

Every GLONASS satellite transmits two codes (C/A and P-Code) on two frequencies. Every satellite transmits the same codes PRN (Pseudorandom noise), but at different frequencies in the vicinity of 1602 MHz and 1246 MHz.

Fig. 1.3: GLONASS Satellite (source: www.esa.int/SPECIALS/ ESA_Permanent_Mission_in_Russia/SEMWMIW4QWD_0.html)

You will read about the space, control and user segments in detail in Unit 2, *GNSS and its Components*, of MGY-003

You have earlier read that there are three segments in GNSS satellite systems.

GLONASS also comprises three segments as discussed below:

1) space segment

2) control segment

3) user segment

- ***Space Segment*** consists of satellites located in the middle of the circular orbit at 19,100 km altitude with a 64.8° inclination and a period of 11 h and 15 min. The constellation operates in three orbital planes with 8 evenly spaced satellites on each. A fully operational constellation with global coverage consists of 24 satellites, while 18 satellites are necessary for covering the territory of Russia. GLONASS is especially suited for usage in the northern latitudes.

Ephemerides is a table of values that gives the positions of astronomical objects in the sky.

Universal Coordinated Time (UTC) is the primary time standard by which the world regulates clocks and time.

- ***Control Segment*** consists of the system control center and a network of command tracking stations across Russia. Its control segment is similar to GPS that monitors the status of satellites and determines the ephemerides and satellite clock offsets with respect to GLONASS time and Coordinated Universal Time (UTC). It uploads the navigation data to the satellites twice a day.

- ***User Segment*** consists of equipment that tracks and receives the satellite signals. This equipment is capable of simultaneously processing the signals from a minimum of four satellites to obtain accurate position, velocity and timing measurements. Like GPS, GLONASS has a dual military and civilian usage.

1.4.3 Galileo

Galileo aims to provide a high-precision positioning system upon which European nations can rely, independently from the US GPS, Russian GLONASS and chinese Compass systems, which can be disabled in times of war or conflict.

Galileo is the European Union radio navigation program that was launched by the European Commission and developed jointly with the European Space Agency. It is named after the famous Italian astronomer Galileo Galilei. It will open the door to a revolution comparable to that generated by mobile phones. In addition, Galileo promises a new generation of universal services in various sectors, such as transport, telecommunications, agriculture and fisheries. The Galileo program will be managed and controlled by civilians and will offer a guarantee of quality and continuity of service that is essential for many applications.

Galileo provides the provision of a large variety of services. Some of the services will be provided autonomously by Galileo and others will result from the combined use of Galileo and other systems. Galileo will provide multiple levels of service to users throughout the world. Five services are planned:

1. An *open* service will be free of direct user charges;

2. A *commercial* service will combine value-added data to a high-accuracy positioning service;

3. *Safety-of-life* (SOL) service for safety critical users;

4. *Public regulated* service strictly for government-authorised users requiring a higher level of protection;

5. Support for *search and rescue*.

Like GPS, the Galileo system also consists of following three components, namely:

1) Space Segment

2) Control Segment

3) User Segment

- **Space Segment:** It comprises a constellation of 27 satellites with 3 operational inorbit spares, in medium height circular orbits at 23,616 km above the Earth's surface. Orbits have 56° inclination and a 14 hr 22 min period. Satellites are located in three orbital planes, where nine operational satellites are equally spaced in each orbital plane and 1 spare satellite per plane is provided. Therefore, orbital and constellation parameters of Galileo and GPS will be different; at any time and any location on the Earth. The maximum number of visible satellites is 25 (13 from Galileo and 12 from GPS), 21 (11 from Galileo and 10 from GPS) and 17 (9 from Galileo and 8 from GPS).

- **Control Segment's:** It's main functions are *satellite* and *mission control*. Satellite control includes constellation management through monitoring and control. It also determines and disseminates integrity information (warning alerts within time-to-alarm requirements) on a global basis. The Galileo control center is the core of the system and includes all control and processing facilities. Further components of the ground control segment are the Galileo sensor stations, which collect navigation data from the Galileo satellites as well as meteorological and other required environmental information.

- **User Segment:** This includes the family of different types of user receivers, with different capabilities of using the Galileo signals according to the various services. Users must be equipped with adequate multifunctional terminals to take full benefit from all Galileo services (global, local, and combined). The functions implemented in the user terminal should allow the user to receive directly the actual Galileo receiver.

Check Your Progress I

Spend 5 mins

1) What is TRANSIT system?

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2) What are the four basic levels of accuracy in GPS?

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1.5 COMPARISON OF DIFFERENT GNSS SYSTEMS

You have read in the above sections that there are currently three main GNSS systems in different stages of development. US NAVSTAR GPS is the only fully operational GNSS. The Russian Federation GNSS, GLONASS is in the process of being restored to full operation. The European Union's Galileo positioning system is a second generation GNSS in the initial deployment phase. The full Orbit Constellation (FOC) will be reached in 2015. See in Table 1.2 which summarises some of the key features of these three different GNSS systems.

Table 1.2: Comparison of the most important properties of three existing GNSS systems-GPS, GLONASS and Galileo (source:www.zoggjm.ch/ Dateien/GPS_CompendiumGPS-X-02007.pdf)

Properties	GPS	GLONASS	Galileo
Start of development	1973	1972	2001
1st Satellite Launch	February 22, 1978	October 12, 1982	December 28, 2005
Number of Satellites	Minimum: 24 / Maximum: 32	Planned: 24 + 3 passive reserves	Planned: 27 + 3 active reserves
Orbitals	6	3	3
Inclination	55°	64.8°	56°
Altitude	20,180 km	19,100 km	23,616 km
Orbital Period Time System	11 hr 58 min GPS-Time	11 hr 15.8 min GLONASS-Time	14 hr 5 min GST (Galileo System Time)
Signal Characteristic	CDMA	FDMA	CDMA
Frequencies	2 frequencies, with a 3rd frequency planned	2 frequencies, with a 3rd frequency planned	2 frequencies, with a 3rd frequency planned
Encryption	Military Signal	Military Signal	OS, CS, SoL and PRS services
Services	2 (civilian+military)	2 (civilian+military)	5
Responsibility	US Department of Defense	Russian Defense Ministry	Civilian Governments of the EU
Integrity Signal	Currently none but planned	None	Planned

1.6 DIFFERENTIAL GPS

Differential GPS is a method of increasing the accuracy of positions derived from GPS receivers. With DGPS receivers, position accuracy is improved from 30 m to better than 10 m.

Differential GPS (DGPS) was developed to meet the requirements of positioning and distance measuring applications that required the best accuracies. In this section, you will read about Differential GPS. The principle of DGPS is that any two receivers, relatively close together will experience similar atmospheric errors. It is necessary requirement for DGPS that a GPS receiver be set up on a precisely known location. GPS receiver is the *base* or *reference station* (Fig. 1.4). The base station receiver calculates its position based on satellite signals. Thereafter this location is compared to the known location. The difference is applied to GPS data recorded by the second GPS receiver, which is known as the *roving receiver***.** The corrected information can be applied to data from the roving receiver in real time in the field using radio signals. DGPS involves the use of a *control* or *reference receiver* at a known location to measure the systematic GPS errors.

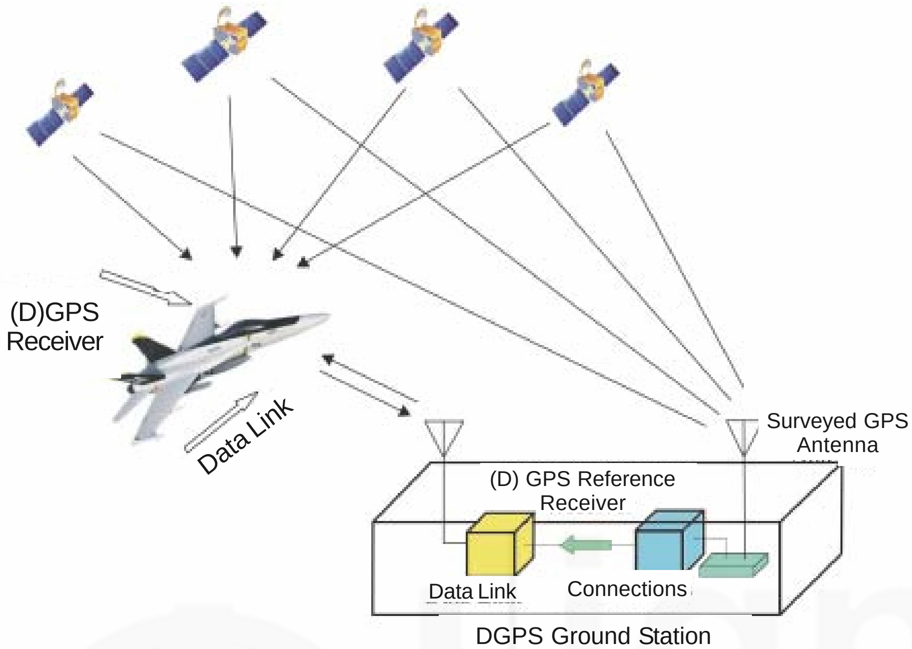

Fig. 1.4: A typical architecture of DGPS (source: http://ftp.rta.nato.int/public// PubFullText /RTO/AG/RTO-AG-160-V21///AG-160-V21-01.pdf)

Real-time DGPS occurs when on receiving data, the base station calculates and broadcasts corrections for each satellite. Further, the corrections are received by the roving receiver via a radio signal, if the source is land based or via a satellite signal, if it is satellite based. This correction is then applied to the position it is calculating. Real-time differential corrections usage allows navigation within 1 to 2 m of any location depending on the service and GPS receiver.

The differential correction of GPS data by postprocessing uses a base GPS receiver that logs positions at a known location and a rover GPS receiver that collects positions in the field. The files from the base and rover are transferred to the office processing software, which computes corrected positions for the rover's file. This resulting corrected file can be viewed in or exported to a Geographic Information System (GIS).

There are many permanent GPS base stations currently operating throughout the world that provide data necessary for differentially correcting GPS data. This data can be downloaded from the internet or via a Bulletin Board System (BBS), depending on the technology preferred by the base station owner. Sources of base station data for postprocessing fall into four categories namely:

- public sources
- commercial sources
- web-based services
- base station ownership

The various DGPS services available are categorised according to broadcast range of the correction signals:

- Local DGPS are, basically, the Local Area Augmentation System (LAAS) but sometimes also called as the Ground Based Augmentation Systems (GBAS).
- Regional DGPS
- Wide Area DGPS (WADGPS) or Satellite Based Augmentation Systems (SBAS) employ satellites to transmit DGPS correction data.

1.7 ACCURACY OF DGPS AND SOURCES OF ERROR

In this section, we will discuss about the accuracy levels exhibited and sources of errors in DGPS data. The controlled tests and quite recent extensive operational use of DGPS have repeatedly demonstrated that DGPS results exhibit an accuracy to the order of about 10 m. Many recent applications of DGPS use C/A code (Coarse Acquisition) pseudorange as the only observable with achieved accuracies of 1 to 5 m in real-time. It allows the civilian user to increase position accuracy from 1 to 100m making it more useful for many civilian applications.

Pseudorange is a measure of range or distance between the GPS receiver and the GPS satellite.

Sources of Errors of DGPS

The major sources of errors affecting DGPS are the following:

- **Ephemeris Error**: They are the errors present in the ephemeris data. They range from few metre to decimetre level.
- **Ionospheric and Tropospheric Propagation Delay**: When the satellite signal passes through the ionosphere and troposphere, it is slowed down, as the velocity of the signal is affected. These propagation delays can introduce an error.
- **Satellite Clock Drift**: Even though the clocks in the satellite are very accurate (to about 3 nanoseconds) and slight drift in this clock causes small errors which have a considerable affect on the accuracy of the position.
- **Multipath**: Multipath error occurs when the receiver antenna is positioned close to a large reflecting surface such as a lake or building.
- **Selective Availability (S/A)**: It is a process applied by US Department of Defense to GPS signal. This is intended to deny full accuracy of GPS to the civilian and hostile foreign powers by subjecting the satellite clocks to a process known as "*dithering*", which alters their time slightly.
- **Anti-Spoofing:** It is similar to S/A in that its intention is to deny civilian and hostile powers access to the P-code part of GPS signal.

Multipath effect describes the reflection of satellite signals from terrestrial objects such as buildings.

Dithering is the process of introduction of digital noise into the system.

Spend 5 mins

Check Your Progress II

1) List the categories of DGPS services available.

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2) List the major sources of error affecting DGPS.

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1.8 INDIAN SCENARIO

After reading about the current generation and under development GNSS systems, you must be curious to know about the Indian scanario of GNSS. GAGAN, which is a GPS Aided Geo-Augmented Navigation is a planned implementation of a regional Satellite Based Augmentation System (SBAS) of the Indian government. It is a system to improve the accuracy of a GNSS receiver by providing reference signals. Wide Area Augmentation System (WAAS) codes for L1 frequency and L5 frequency were obtained from US Air Force and US Department of Defense in November 2001 and March 2005, to begin implementing SBAS over the Indian airspace. The system will use eight reference stations located in Delhi, Guwahati, Kolkata, Ahmedabad, Bangalore, Jammu, Thiruvananthapuram and Port Blair and a master control center at Bangalore.

The next major milestone in GAGAN is the conduct of Preliminary System Acceptance Testing (PSAT). It was successfully completed in December 2010. The first GAGAN navigation payload GSAT-8 was launched on May 21, 2011. The second GAGAN payload is scheduled to be launched on GSAT-10 in the first quarter of 2012. The third GAGAN payload is planned on another geostationary satellite. GAGAN after its final operational phase completion, will provide seamless air navigation service across regional boundaries. While the ground segment will have subsystems such as data communication network, SBAS correction and verification, operations and maintenance, performance monitoring display and payload simulator.

The project costing ₹ 774 crore is being implemented in three phases from 2008 by the Airport Authority of India with the help of the Indian Space Research Organisation’s (ISRO) technology and space support. The goal is to provide navigation system for all phases of flight over the of Indian airspace and in the adjoining area. It is applicable to safety-of-life operations and meets the performance requirements of international civil aviation regulatory bodies.

1.9 SUMMARY

In this unit, we have discussed about GNSS basics and various current generation and under development GNSS and their comparisons. In addition to this, you have also learnt about the operation of DGPS which gives high accurate measurement. You have learnt about the status of GNSS in Indian context.

Let us recall the important points covered in this unit:

- Navigation during the Stone Age was done by leaving stones, marking trees or referencing mountains by early humans. With the advancement of technology, we are currently using the satellites for locating ourselves on the Earth.

- The fundamental equation of satellite navigation is :
  Distance = Velocity of light × Time of the satellite signal.
- Currently operational GNSS are American GPS and Russian Federation GLONASS.
- GPS is having 31 operational satellites in space.
- GLONASS revolves in middle circular orbit at 19,100 km altitude with a 64.8 ^{o} inclination in a period of 11 h and 15 min.
- Galileo is a GNSS of the European Union, which is underdevelopment. Galileo will provide multiple levels of service to users throughout the world viz., Open service, Commercial service, Safety-of-life (SOL), Public regulated service and Support for search and rescue.
- DGPS are essential to achieve high accuracies at a level of few centimeters level.
- DGPS work as real-time DGPS when the base station calculates and broadcasts corrections for each satellite as it receives data. Post processing correction is required on DGPS data to achieve more accurate measurement.
- India's augmentation service is known as GAGAN.

Spend 30 mins

1.10 UNIT END QUESTIONS

1) Discuss the three GNSS satellites.
2) Compare the most important properties of three existing GNSS systems viz., GPS, GLONASS and GALILEO.
3) Give an account of status of GNSS system in India.

1.11 REFERENCES

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- www.zogg-jm.ch/Dateien/ GPS_ CompendiumGPS-X-02007.pdf

Data from above websites has been retrieved between 20th August and 15th September 2011.

1.12 FURTHER/SUGGESTED READING

- Kaplan, E.D. and Hegarty, C. (2005), *Understanding GPS Principle and Applications*, Artech House Publishers, Norwood, 706p.
- Leica Geosystems A.G. (1999), *GPS Basics*, Heerbrugg 1.0.Oen, Switzerland, 64p.
- McNamara J. (2008), *GPS for Dummies*, 2nd Ed, Willey Publishing Inc., Indiana, 408p.

1.13 ANSWERS

Check Your Progress I

1) The TRANSIT system also known as NAVSAT (for Navy Navigation Satellite System), was the first satellite navigation system to be used operationally. The system was primarily used by the US Navy to provide accurate location information to its Polaris ballistic missile submarines and also for hydrographic and geodetic surveying.

2) The four types of Differential GPS accuracy are : Autonomous Accuracy, Differential GPS Accuracy (DGPS), Real-Time Kinematic Accuracy and Float (RTK Float), Real-Time Kinematic Accuracy

Check Your Progress II

1) The various DGPS services available are categorized according to the broadcast range of the correction signals. They are Local DGPS: Local Area Augmentation System (LAAS) sometimes called Ground Based Augmentation Systems (GBAS), Regional DGPS and Wide Area DGPS (WADGPS) or Satellite Based Augmentation Systems (SBAS).

2) The major sources of error affecting DGPS are- Ephemeris Error, Ionospheric Propagation Delay, Tropospheric Propagation Delay, Satellite Clock Drift, Multipath, Receiver Noise and clock drift and Selective Availability.

Unit End Answers

1) Refer to subsections 1.4.1, 1.4.2 and 1.4.3 of the section on GNSS satellites.

2) Refer to section 1.5 and Table 1.2

3) Refer to section 1.8