Catalog

5.1Total Station:

Basic Principle

Although taping and theodolites are used regularly on site - total stations are also used extensively in surveying, civil engineering and construction because they can measure both distances and angles.

A typical total station is shown in the figure below

Fig 3.1 Total Station

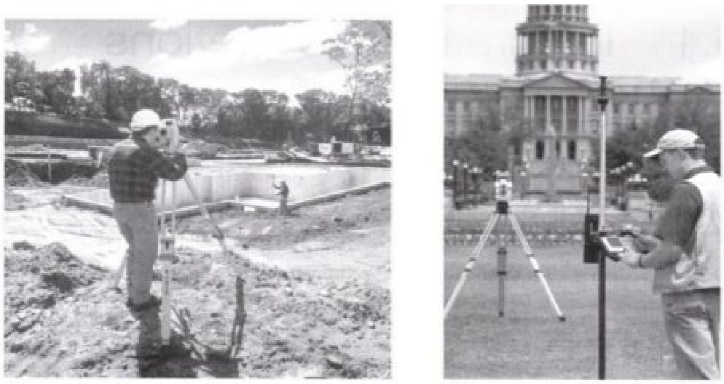
(https://www.brainkart.com/article/Total-Station--Basic-Principle_4649/)

Because the instrument combines both angle and distance measurement in the same unit, it is known as an integrated total station which can measure horizontal and vertical angles as well as slope distances. Using the vertical angle, the total station can calculate the horizontal and vertical distance components of the measured slope distance.

As well as basic functions, total stations are able to perform a number of different survey tasks and associated calculations and can store large amounts of data. As with the electronic theodolite, all the functions of a total station are controlled by its microprocessor, which is accessed thought a keyboard and display. To use the total station, it is set over one end of the line to be measured and some reflector is positioned at the other end such that the line of sight between the instrument and the reflector is unobstructed (as seen in the figure below).

- The reflector is a prism attached to a detail pole
- The telescope is aligned and pointed at the prism
- The measuring sequence is initiated and a signal is sent to the reflector and a part of this signal is returned to the total station
- This signal is then analysed to calculate the slope distance together with the horizontal and vertical angles.
- Total stations can also be used without reflectors and the telescope is pointed at the point that needs to be measured
- Some instruments have motorized drivers and can be use automatic target recognition to search and lock into a prism - this is a fully automated process and does not require an operator.

Some total stations can be controlled from the detail pole, enabling surveys to be conducted by one person.



Measuring with a total station

Robotic total station

Fig 3.2 Measuring with a Total Station

(https://www.brainkart.com/article/Total-Station--Basic-Principle_4649/)

Most total stations have a distance measuring range of up to a few kilometers, when using a prism, and a range of at least 100m in reflector less mode and an accuracy of 2-3mm at short ranges, which will decrease to about 4-5mm at 1km.

Although angles and distances can be measured and used separately, the most common applications for total stations occur when these are combined to define position in control surveys.

As well as the total station, site surveying is increasingly being carried out using GPS equipment. Some predictions have been made that this trend will continue, and in the long run GPS methods may replace other methods.

Although the use of GPS is increasing, total stations are one of the predominant instruments used on site for surveying and will be for some time. Developments in both technologies will find a point where devices can be made that complement both methods.

CLASSIFICATION OF TOTAL STATIONS

1.Electro- Optical System

2.Distance Measurement

When a distance is measured with a total station, am electromagnetic wave or pulse is used for the measurement - this is propagated through the atmosphere from the instrument to reflector or target and back during the measurement.

Distances are measured using two methods:

- ➔ the phase shift method, and
- ➔ the pulsed laser method.

This technique uses continuous electromagnetic waves for distance measurement although these are complex in nature, electromagnetic waves can be represented in their simplest from as periodic waves.

The wave completes a cycle when moving between identical points on the wave and the number of times in one second the wave completes the cycle is called the frequency of the wave. The speed of the wave is then used to estimate thedistance.

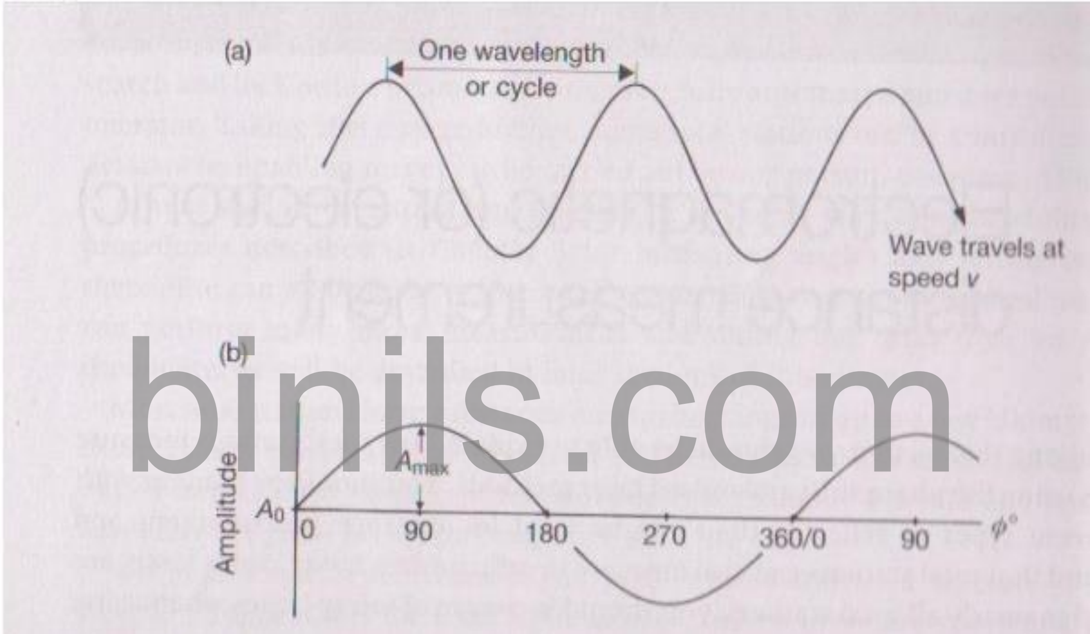


Figure 5.4 ● Sinusoidal wave motion: (a) as a function of distance or time (b) a tion of phase angle ϕ.

Fig 3.3 Sinusoidal wave motion

(https://www.brainkart.com/article/Classification-of-Total-Stations_4650/)

2 Laser Distance Measurement

In many total stations, distances are obtained by measuring the time taken for a pulse of laser radiation to travel from the instrument to a prism (or target) and back. As in the phase shift method, the pulses are derived an infrared or visible laser diode and they are transmitted through the telescope towards the remote end of the distance being measured, where they are reflected and returned to the instrument.

Since the velocity *v* of the pulses can be accurately determined, the distance *D* can be obtained using $2D = vt$, where *t* is the time taken for a single pulse to travel from instrument - target - instrument. This is also known as the timed-pulse or time-of-flight measurement technique. The *transit time t* is measured using electronic signal processing techniques. Although only a single pulse is necessary to obtain a distance, the accuracy obtained would be poor. To improve this, a large number of pulses (typically 20,000 every second) are analysed during each measurement to give a more accurate distance.

The pulse laser method is a much simpler approach to distance measurement than the phase shift method, which was originally developed about 50 years ago.

Slope and Horizontal Distances

Both the phase shift and pulsed laser methods will measure a slope distance *L* from the total station along the line of sight to a reflector or target. For most surveys the horizontal distance *D* is required as well as the vertical component *V* of the slope distance.

Horizontal distance $D = L \cos\Theta = L \sin z$

Vertical distance = $V = L \sin \Theta = L \cos z$

Where Θ is the vertical angle and

z is the is the zenith angle.

As far as the user is concerned, these calculations are seldom done because the total station will either display *D* and *V* automatically or will display *L* first and then *D* and *V* after pressing buttons

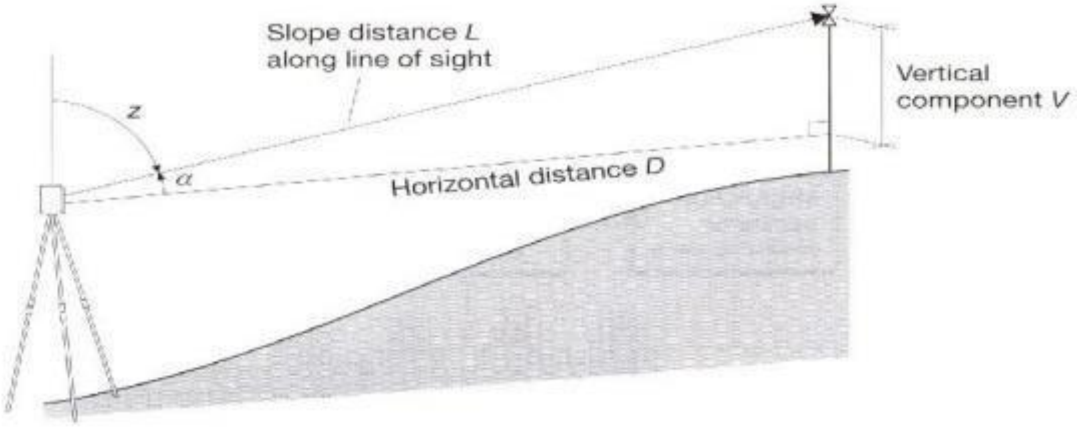


Fig 3.4 Slope and Distance Measured

(https://www.brainkart.com/article/Classification-of-Total-Stations_4650/)

How accuracy of distance measurement is specified All total stations have a linear accuracy quoted in the form (a mm + b ppm) The constant a is independent of the length being measured and is made up of internal sources within the instrument that are normally beyond the control of the user. It is an estimate of the individual errors caused by such phenomena as unwanted phase shifts in electronic components, errors in phase and transit time measurements.

The systematic error b is proportional to the distance being measured, where 1 ppm (part per million) is equivalent to an additional error of 1mm for every kilometer measured. Typical specifications for a total station vary from (2mm + 2ppm) to (5mm+ 5 p.m.).

For example:

(2mm + 2pm), at 100m the error in distance measurement will be 2mm but at 1.5km, the error will be (2mm + [2mm/km * 1.5km]) = 5m m

Reflectors used in distance measurement

Since the waves or pulses transmitted by a total station are either visible or infrared, a plane mirror could be used to reflect them. This would require a very accurate alignment of the mirror, because the transmitted wave or pulses have a narrow spread. To get around this problem special mirror prisms are used as shown below.

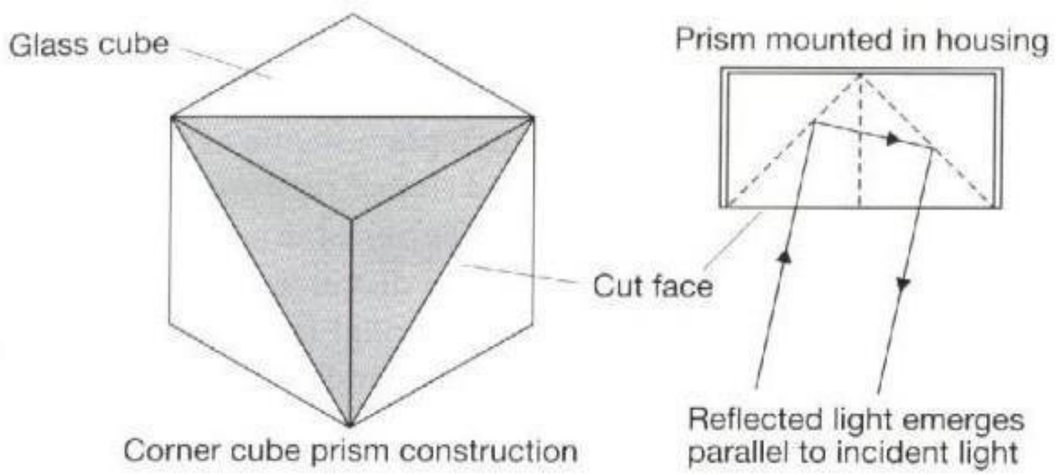


Fig 3.5 Reflector used in total station

(https://www.brainkart.com/article/Classification-of-Total-Stations_4651/)

Features Of Total Stations

Total stations are capable of measuring angles and distances simultaneously and combine an electronic theodolite with a distance measuring system and a microprocessor.

Angle Measurement

All the components of the electronic theodolite described in the previous lectures are found total stations. The axis configuration is identical and comprises the vertical axis, the tilting axis and line of sight (or collimation). The other components include the tribatch with levelling foot screws, the keyboard with display and the telescope which is mounted on the standards and which rotates around the tilting ais.

Levelling is carried out in the same way as for a theodolite by adjusting to centralize a plate level or electronic bubble. The telescope can be transited and used in the face left (or face I) and face right (or face II) positions. Horizontal rotation of the total station about the vertical axis is controlled by a horizontal clamp and tangent screw and rotation of the telescope about the tilting axis. The total station is used to measure angles in the same way as the electronic theodolite.

Distance measurement

All total stations will measure a slope distance which the onboard computer uses, together with the zenith angle recorded by the line of sight to calculate the horizontal distance. For distances taken to a prism or reflecting foil, the most accurate is precise measurement.

For phase shift system, a typical specification for this is a measurement time of about 1-2s, an accuracy of (2mm + 2ppm) and a range of 3-5km to a single prism.

Although all manufacturers quote ranges of several kilometers to a single prism. For those construction projects where, long distances are required to be measured, GPS methods are used in preference to total stations. There is no standard difference at which the change from one to the other occurs, as this will depend on a number of factors, including the accuracy required and the site topography.

Rapid measurement reduces the measurement time to a prism to between 0.5 and 1's for both phase shift and pulsed systems, but the accuracy for both may degrade slightly.

Tracking measurements are taken extensively when setting out or for machine control, since readings are updated very quickly and vary in response to movements of the prism which is usually pole-mounted. In this mode, the distance measurement is repeated automatically at intervals of less than 0.5s. For reflector less measurements taken with a phase shift system, the range that can be obtained is about 100m, with a similar accuracy to that obtained when using a prism or foil.

KEYBOARD AND DISPLAY

A total station is activated through its control panel, which consists of a keyboard and multiple line LCD. A number of instruments have two control panels, one on each face, which makes them easier to use. In addition to controlling the total station, the keyboard is often used to code data generated by the instrument - this code will be used to identify the object being measured.

On some total stations it is possible to detach the keyboard and interchange them with other total stations and with GPS receivers. This is called integrated surveying.

(a) (b)

Fig 3.6 Key Board and Display
(https://www.brainkart.com/article/Classification-of-Total-Stations_4652/)

Software Applications

The microprocessor built into the total station is a small computer and its main function is controlling the measurement of angles and distances. The LCD screen guides the operator while taking these measurements. The built in computer can be used for the operator to carry out calibration checks on the instrument.

The software applications available on many total stations include the following: Slope corrections and reduced levels Horizontal circle orientation Coordinate Measurement Traverse Measurements Resection (or free stationing) Missing line measurement Remote elevation measurement areas Setting out.

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Sources Of Error For Total Stations

Calibration Of Total Stations

To maintain the high level of accuracy offered by modern total stations, there is now much more emphasis on monitoring instrumental errors, and with this in mind, some construction sites require all instruments to be checked on a regular basis using procedures outlined in the quality manuals.

Some instrumental errors are eliminated by observing on two faces of the total station and averaging, but because one face measurements are the preferred method on site, it is important to determine the magnitude of instrumental errors and correct for them.

For total stations, instrumental errors are measured and corrected using electronic calibration procedures that are carried out at any time and can be applied to the instrument on site. These are preferred to the mechanical adjustments that used to be done in labs by technician.

Since calibration parameters can change because of mechanical shock, temperature changes and rough handling of what is a high-precision instrument, an electronic calibration should be carried our on a total station as follows:

Before using the instrument for the first time After long storage periods. After rough or long transportation After long periods of work. Following big changes in temperature Regularly for precision surveys. Before each calibration, it is essential to allow the total station enough to reach the ambient temperature.

Horizontal Collimation (Or Line Of Sight Error)

This axial error is caused when the line of sight is not perpendicular to the tilting axis. It affects all horizontal circle readings and increases with steep sightings, but this is eliminated by observing on two faces. For single face measurements, an on-board calibration function is used to determine *c*, the deviation between the actual line of sight and a line perpendicular to the tilting axis. A correction is then applied automatically for this to all horizontal circle readings

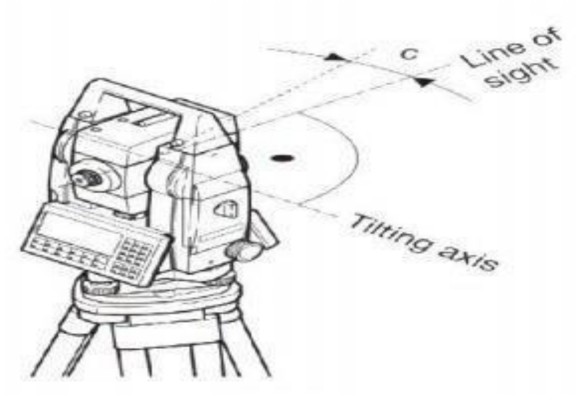


Fig 3.7 Line of Sight error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)

Tilting Axis Error

This axial errors occur when the titling axis of the total station is not perpendicular to its vertical axis. This has no effect on sightings taken when the telescope is horizontal, but introduces errors into horizontal circle readings when the telescope is tilted, especially for steep sightings. As with horizontal collimation error, this error is eliminated by two face measurements, or the tilting axis error a is measured in a calibration procedure and a correction applied for this to all horizontal circle readings - as before if a is too big, the instrument should be returned to the manufacture

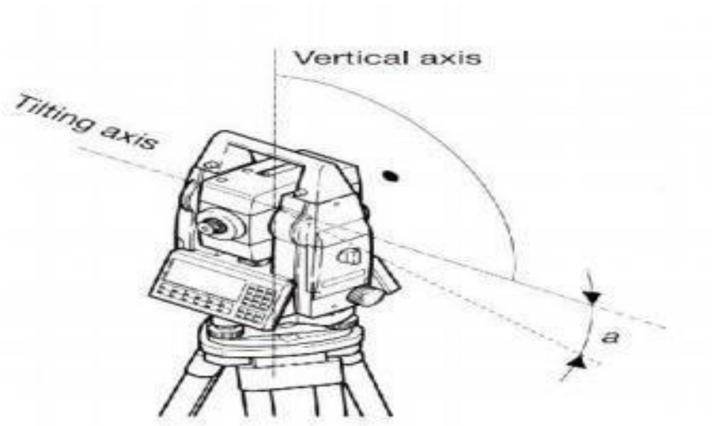


Fig tilting axis error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)

Compensator Index Error

Errors caused by not levelling a theodolite or total station carefully cannot be eliminated by taking face left and face right readings. If the total station is fitted with a compensator it will measure residual tilts of the instrument and will apply corrections to the horizontal and vertical angles for these.

However, all compensators will have a longitudinal error *l* and traverse error *t* known as zero-point errors. These are averaged using face left and face right readings but for single face readings must be determined by the calibration function of the total station.

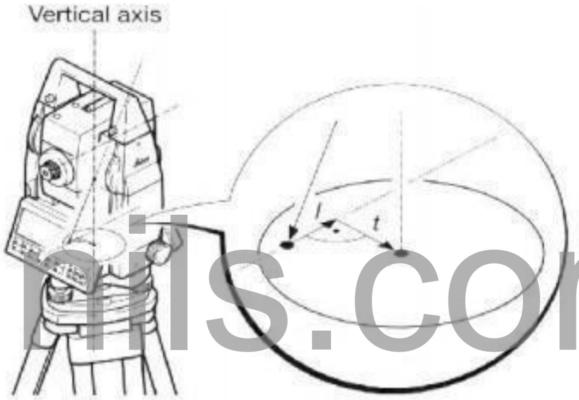


Fig 3.8 Compensator Index Error

(*https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/*)

A vertical collimation error exists on a total station if the 0^{0} to 180^{0} line in the vertical circle does not coincide with its vertical axis. This zero-point error is present in all vertical circle readings and like the horizontal collimation error, it is eliminated by taking FL and FR readings or by determining i

For all of the above total station errors (horizontal and vertical collimation, tilting axis and compensator) the total station is calibrated using an in-built function. Here the function is activated and a measurement to a target is taken as shown below. Following the first measurement the total station and the telescope are each rotated through 180^o and the reading is repeated.

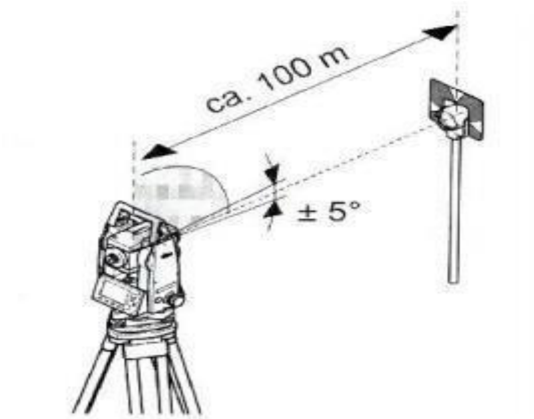


Fig 3.9 Compensator Index Error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)

Any difference between the measured horizontal and vertical angles is then quantified as an instrumental error and applied to all subsequent readings automatically. The total station is thus calibrated and the procedure is the same for all of the above error type.

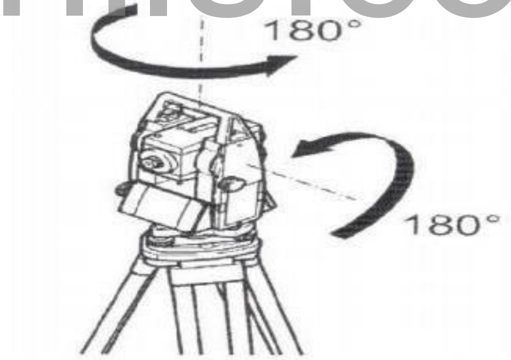


Fig 3.9 Compensator Index Error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)

5.2 GPS SURVEYING

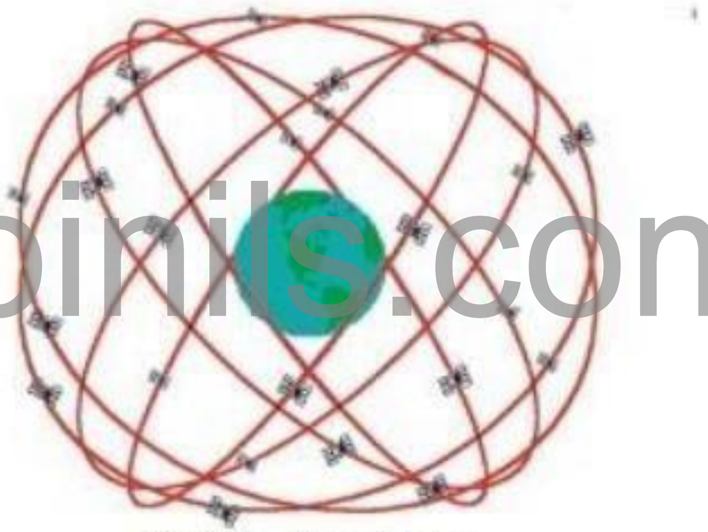
INTRODUCTION

Traditional methods of surveying and navigation resort to tedious field and astronomical observation for deriving positional and directional information. Diverse field conditions, seasonal variation and many unavoidable circumstances always bias the traditional field approach. However, due to rapid advancement in electronic systems, every aspect of human life is affected to a great deal. Field of surveying and navigation is tremendously benefited through electronic devices. Many of the critical situations in surveying/navigation are now easily and precisely solved in short time.

Astronomical observation of celestial bodies was one of the standard methods of obtaining coordinates of a position. This method is prone to visibility and weather condition and demands expert handling. Attempts have been made by USA since early 1960's to use space based artificial satellites. System TRANSIT was widely used for establishing a network of control points over large regions. Establishment of modern geocentric datum and its relation to local datum was successfully achieved through TRANSI T. Rapid improvements in higher frequently transmission and precise clock signals along with advanced stable satellite technology have been instrumental for the development of global positioning system.

The NAVSTAR GPS (Navigation System with Time and Ranging Global Positioning System) is a satellite-based radio navigation system providing precise three- dimensional position, course and time information to suitably equipped user. GPS has been under development in the USA since 1973. The US department of Defense as a worldwide navigation and positioning resource for military as well as civilian use for 24 hours and all-weather conditions primarily developed it.

In its final configuration, NAVSTAR GPS consists of 21 satellites (plus 3 active spares) at an altitude of 20200 km above the earth's surface (Fig. 1). These satellites are so arranged in orbits to have at least four satellites visible above the horizon anywhere on the earth, at any time of the day. GPS Satellites transmit at frequencies L1=1575.42 MHz and L2=1227.6 MHz modulated with two types of code viz. P-code and C/A code and with navigation message. Mainly two types of observable are of interest to the user. In pseudo ranging the distance between the satellite and the GPS receiver plus a small corrective term for receiver clock error is observed for positioning whereas in carrier phase techniques, the difference between the phase of the carrier signal transmitted by the satellite and the phase of the receiver oscillator at the epoch is observed to derive the precise information.



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

Fig 4.1 The Global Positioning System (GPS), 21-satellite configuration

(https://www.brainkart.com/article/GPS-Surveying_4655/)

The GPS satellites act as reference points from which receivers on the ground detect their position. The fundamental navigation principle is based on the measurement of pseudo ranges between the user and four satellites (Fig.)

Ground stations precisely monitor the orbit of every satellite and by measuring the travel time of the signals transmitted from the satellite four distances between receiver and satellites will yield accurate position, direction and speed. Though three- range measurements are sufficient, the fourth observation is essential for solving clock synchronization error between receiver and satellite. Thus, the term 'pseudo ranges' is derived. The secret of GPS measurement is due to the ability of measuring carrier phases to about 1/100 of a cycle equaling to 2 to 3 mm in linear distance Moreover the high frequency L1 and L2 carrier signal can easily penetrate the ionosphere to reduce its effect. Dual frequency observations are important for large station separation and for eliminating most of the error parameters.

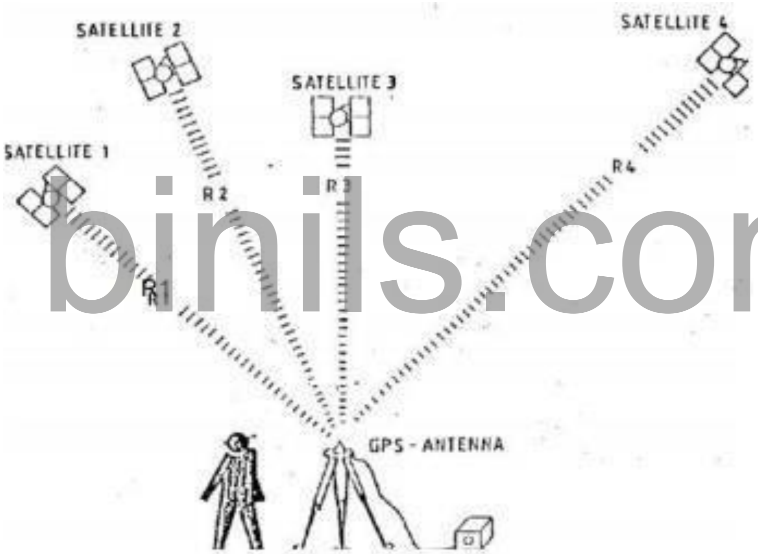
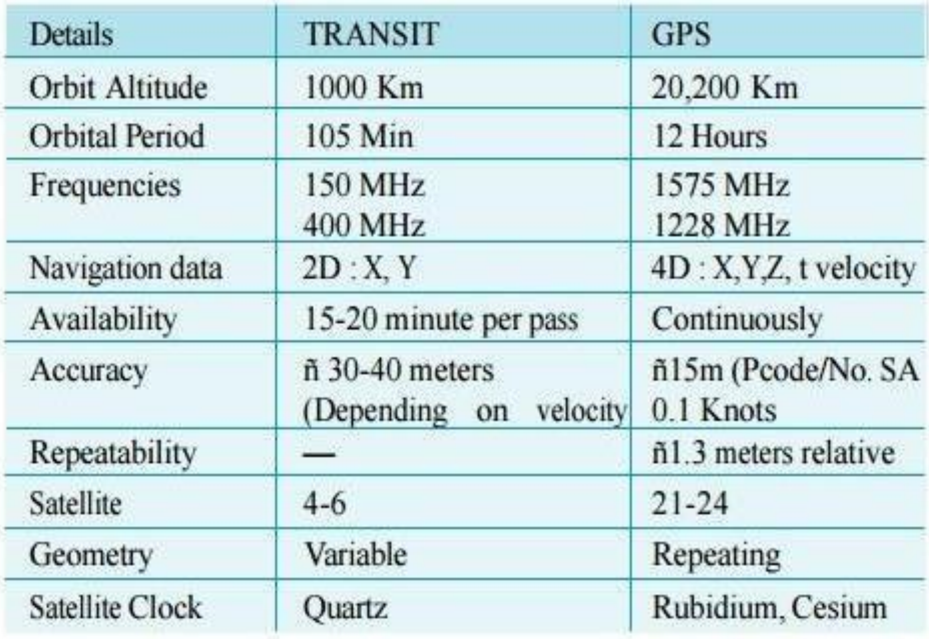


Figure 4.2: Basic principle of positioning with GPS

(https://www.brainkart.com/article/GPS-Surveying_4655/)

There has been significant progress in the design and miniaturization of stable clock. GPS satellite orbits are stable because of the high altitudes and no atmosphere drag. However, the impact of the sun and moon on GPS orbit though significant, can be computed completely and effect of solar radiation pressure on the orbit and tropospheric delay of the signal have been now modeled to a great extent from past experience to obtain precise information for various applications.

Comparison of main characteristics of TRANSIT and GPS re veal technological advancement in the field of space-based positioning system (Table1).



Details	TRANSIT	GPS
Orbit Altitude	1000 Km	20,200 Km
Orbital Period	105 Min	12 Hours
Frequencies	150 MHz 400 MHz	1575 MHz 1228 MHz
Navigation data	2D : X, Y	4D : X,Y,Z, t velocity
Availability	15-20 minute per pass	Continuously
Accuracy	ñ 30-40 meters (Depending on velocity	ñ15m (Pcode/No. SA 0.1 Knots
Repeatability	—	ñ1.3 meters relative
Satellite	4-6	21-24
Geometry	Variable	Repeating
Satellite Clock	Quartz	Rubidium, Cesium

Table 1 Transit vs GPS *(https://www.brainkart.com/article/GPS-Surveying_4655/)*

GPS has been designed to provide navigational accuracy of 1 0 m to 15 m. However, sub meter accuracy in differential mode has been achieved and it has been proved that broad varieties of problems in geodesy and geodynamics can be tackled through GPS.

Versatile use of GPS for a civilian need in following fields have been successfully practiced viz. navigation on land, sea, air, space, high precision kinematics survey on the ground, cadastral surveying, geodetic control network densification, high precision aircraft positioning, photogrammetry without ground control, monitoring deformations, hydrographic surveys, active control survey and many other similar jobs related to navigation and positioning. The outcome of a typical GPS survey includes geocentric position accurate to 10 m and relative positions between receiver locations to centimeter level or better.

Traditional methods of surveying and navigation resort to tedious field and astronomical observation for deriving positional and directional information. Diverse field conditions, seasonal variation and many unavoidable circumstances always bias the traditional field approach. However, due to rapid advancement in electronic systems, every aspect of human life is affected to a great deal. Field of surveying and navigation is tremendously benefited through electronic devices. Many of the critical situations in surveying/navigation are now easily and precisely solved in short time.

SEGMENTS OF GPS

For better understanding of GPS, we normally consider three major segments viz.

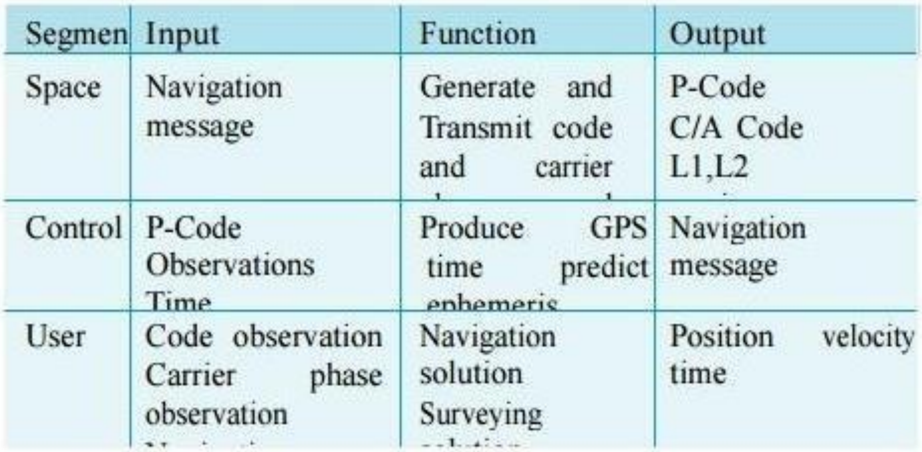
- space segment,
- Control segment and
- User segment.

Space segment deals with GPS satellites systems, Control segment describes ground based time and orbit control prediction and in User segment various types of existing GPS receiver and its application is dealt .

Table 2 gives a brief account of the function and of various segments along with input and output information.

GLONASS (Global Navigation & Surveying System) a similar system to GPS is being developed by former Soviet Union and it is considered to be a valuable complementary system to GPS for future application.

Table 2. Functions of various segments of GPS (https://www.brainkart.com/article/GPS-Surveying_4656/)



Segmen	Input	Function	Output
Space	Navigation message	Generate and Transmit code and carrier	P-Code C/A Code L1,L2
Control	P-Code Observations Time	Produce GPS time predict ephemeris	Navigation message
User	Code observation Carrier phase observation	Navigation solution Surveying	Position velocity time

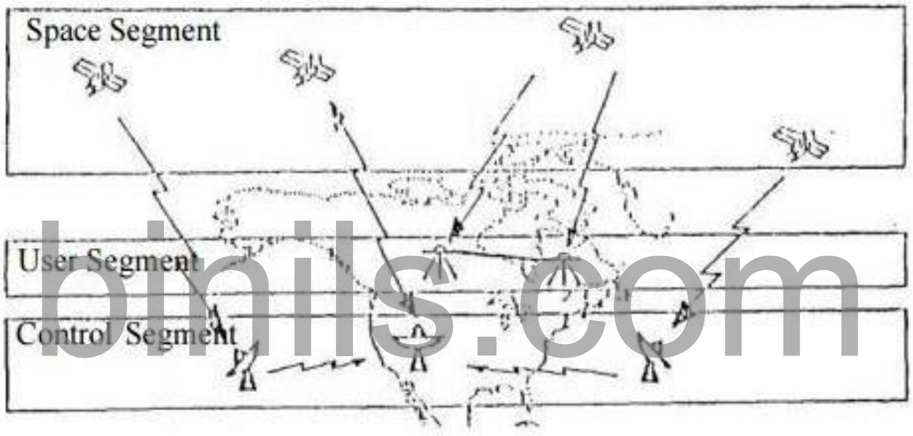


Figure 4.3: The Space, Control and User segments of GPS

(https://www.brainkart.com/article/GPS-Surveying_4656/)

SPACE SEGMENT

Space segment will consist 21 GPS satellites with an addition of 3 active spares. These satellites are placed in almost six circular orbits with an inclination of 55 degree. Orbital height of these satellites is about 20,200 km corresponding to about 26,600 km from the semi major axis. Orbital period is exactly 12 hours of sidereal time and this provides repeated satellite configuration every day advanced by four minutes with respect to universal time.

Final arrangement of 21 satellites constellation known as 'Primary satellite constellation' is given in Fig. 4. There are six orbital planes A to F with a separation of 60 degrees at right ascension (crossing at equator). The position of a satellite within a particular orbit plane can be identified by argument of latitude or mean anomaly M for a given epoch.

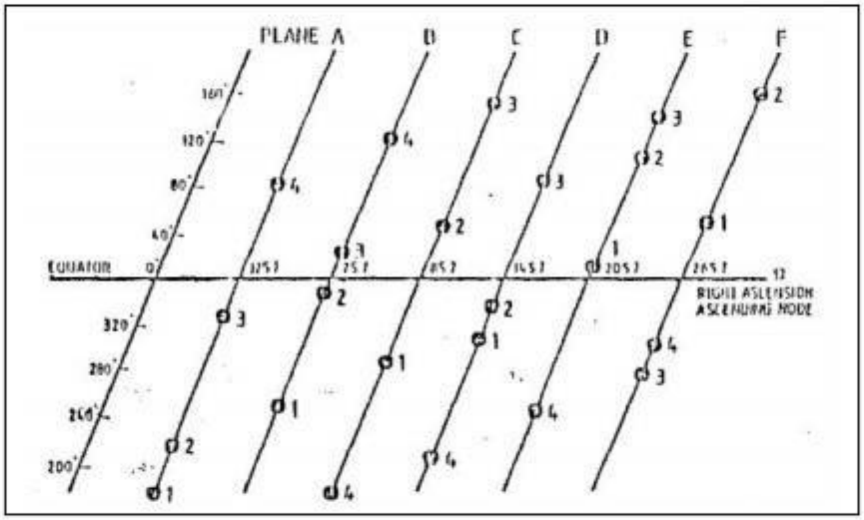


Figure 4. 4: Arrangement of satellites in full constellation

(https://www.brainkart.com/article/GPS-Surveying--Space-Segment_4657/)

GPS satellites are broadly divided into three blocks: Block-I satellite pertains to development stage, Block II represents production satellite and Block IIR are replenishment/spare satellite.

Under Block-I, NAVSTAR 1 to 11 satellites were launched before 1978 to 1985 in two orbital planes of 63-degree inclination. Design life of these prototype test satellites was only five years but the operational period has been exceeded in most of the cases.

The first Block-II production satellite was launched in February 1989 using channel Douglas Delta 2 booster rocket. A total of 28 Block-II satellites are planned to support 21+3 satellite configuration. Block-II satellites have a designed lifetime of 5-7 years.

To sustain the GPS facility, the development of follow-up satellites under Block-II R has started. Twenty replenishment satellites will replace the current block-II satellite as and when necessary. These GPS satellites under Block-IR have additional ability to measure distances between satellites and will also compute ephemeris on board for real time information gives a schematic view of Block-II satellite. Electrical power is generated through two solar panels covering a surface area of 7.2 square meter each.

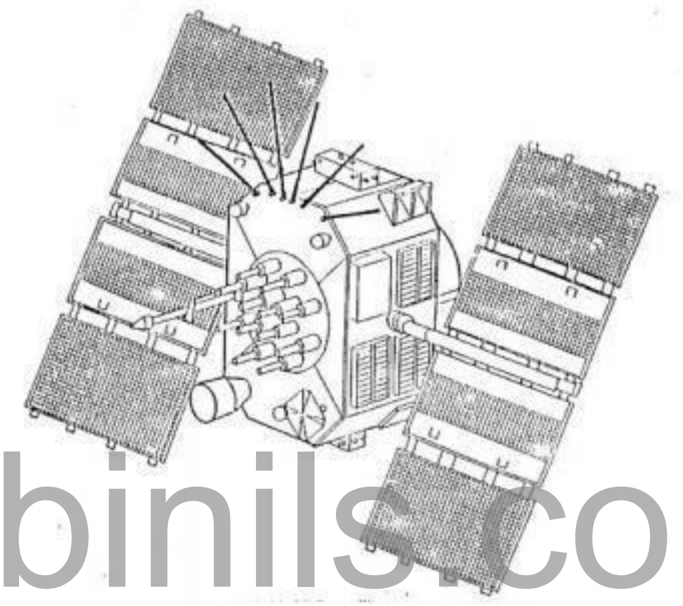


Fig 4.5 Schematic view of a Block II GPS satellite

(https://www.brainkart.com/article/GPS-Surveying--Space-Segment_4657/)

However, additional battery backup is provided to provide energy when the satellite moves into earth's shadow region. Each satellite weighs 845kg and has a propulsion system for positional stabilization and orbit maneuvers.

GPS satellites have a very high-performance frequency standard with an accuracy of between $1X10^{-12}$ to $1X10^{-13}$ and are thus capable of creating precise time base. Block- I satellites were partly equipped with only quartz oscillators but Block-II satellites have two cesium frequency standards and two rubidium frequency standards. Using fundamental frequency of 10.23 MHz, two carrier frequencies are generated to transmit signal codes.

OBSERVATION PRINCIPLE AND SIGNAL STRUCTURE

NAVSTAR GPS is a one-way ranging system i.e. signals are only transmitted by the satellite. Signal travel time between the satellite and the receiver is observed and the range distance is calculated through the knowledge of signal propagation velocity. One way ranging means that a clock reading at the transmitted antenna is compared with a clock reading at the receiver antenna. But since the two clocks are not strictly synchronized, the observed signal travel time is biased with systematic synchronization error. Biased ranges are known as pseudo ranges. Simultaneous observations of four pseudo ranges are necessary to determine X, Y, Z coordinates of user antenna and clock bias

Real time positioning through GPS signals is possible by modulating carrier frequency with Pseudorandom Noise (PRN) codes. These are sequence of binary values (zeros and ones or +1 and -1) having random character but identifiable distinctly. Thus, pseudo ranges are derived from travel time of an identified PRN signal code. Two different codes viz. P-code and C/A code are in use. P means precision or protected and C/A means clear/acquisition or coarse acquisition.

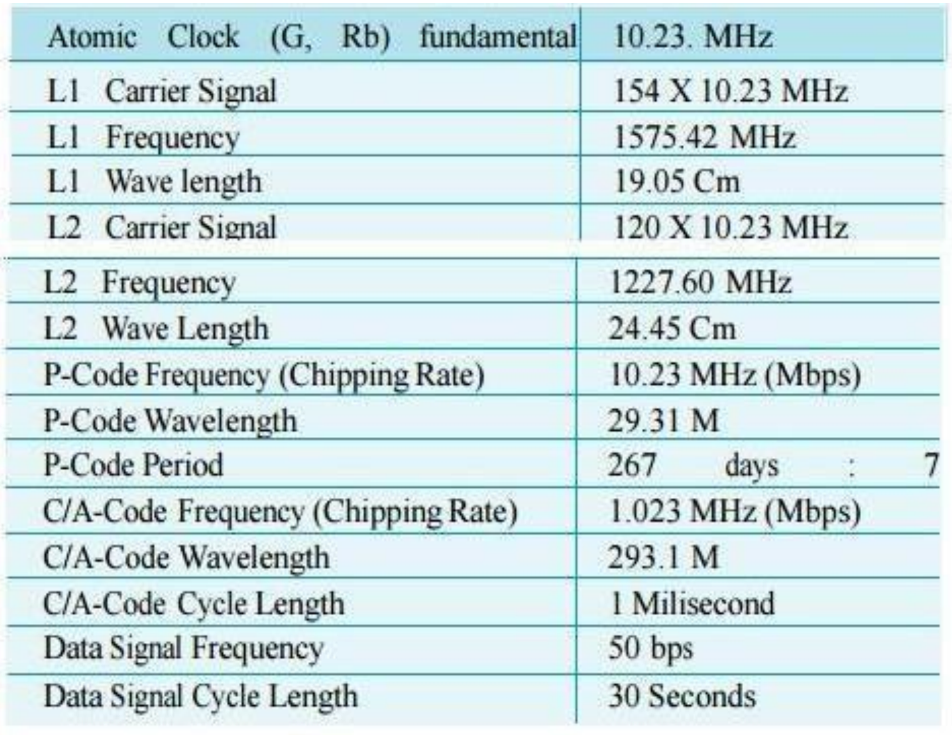
P- code has a frequency of 10.23 MHz This refers to a sequence of 10.23 million binary digits or chips per second. This frequency is also referred to as the chipping rate of P-code. Wavelength corresponding to one chip is 29.30m. The P-code sequence is extremely long and repeats only after 266 days. Portions of seven days each are assigned to the various satellites. As a consequence, all satellite can transmit on the same frequency and can be identified by their unique one-week segment. This technique is also called as Code Division Multiple Access (CDMA). P-code is the primary code for navigation and is available on carrier frequencies L1 and L2.

The C/A code has a length of only one millisecond; its chipping rate is 1.023 MHz with corresponding wavelength of 300 meters. C/A code is only transmitted on L1 carrier. GPS receiver normally has a copy of the code sequence for determining the signal propagation time. This code sequence is phase-shifted in time step- by-step and correlated with the received code signal until maximum correlation is achieved. The necessary phase-shift in the two sequences of codes is a measure of the signal travel time between the satellite and the receiver antennas. This technique can be explained as code phase observation.

For precise geodetic applications, the pseudo ranges should be derived from phase measurements on the carrier signals because of much higher resolution. Problems of ambiguity determination are vital for such observations.

The third type of signal transmitted from a GPS satellite is the broadcast message sent at a rather slow rate of 50 bits per second (50 bps) and repeated every 30 seconds. Chip sequence of P-code and C/A code are separately combined with the stream of message bit by binary addition ie the same value for code and message chip gives 0 and different values result in 1. The main features of all three signal types used in GPS observation viz carrier, code and data signals are given in Table 3.

Table 3 GPS Satellite Signals *(https://www.brainkart.com/article/GPS-Surveying--Observation-Principle-and-Signal-Structure_4658/)*



Atomic Clock (G, Rb) fundamental	10.23. MHz
L1 Carrier Signal	154 X 10.23 MHz
L1 Frequency	1575.42 MHz
L1 Wave length	19.05 Cm
L2 Carrier Signal	120 X 10.23 MHz
L2 Frequency	1227.60 MHz
L2 Wave Length	24.45 Cm
P-Code Frequency (Chipping Rate)	10.23 MHz (Mbps)
P-Code Wavelength	29.31 M
P-Code Period	267 days : 7
C/A-Code Frequency (Chipping Rate)	1.023 MHz (Mbps)
C/A-Code Wavelength	293.1 M
C/A-Code Cycle Length	1 Milisecond
Data Signal Frequency	50 bps
Data Signal Cycle Length	30 Seconds

The signal structure permits both the phase and the phase shift (Doppler effect) to be measured along with the direct signal propagation. The necessary bandwidth is achieved by phase modulation of the PRN code as illustrated in Fig. 6.

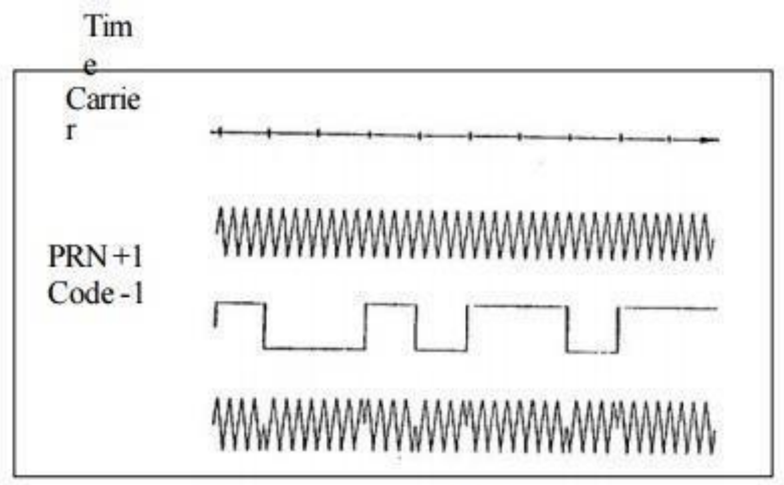


Fig 4.6 Generation of GPS Signals

(https://www.brainkart.com/article/GPS-Surveying--Observation-Principle-and-Signal-Structure_4658/)

STRUCTURE OF THE GPS NAVIGATION DATA

Structure of GPS navigation data (message) is shown in Fig. 7. The user has to decode the data signal to get access to the navigation data. For on line navigation purposes, the internal processor within the receiver does the decoding. Most of the manufacturers of GPS receiver provide decoding software for post processing purposes. With a bit rate of 50 bps and a cycle time of 30 seconds, the total information content of a navigation data set is 1500 bits. The complete data frame is subdivided into five subframes of six-second duration comprising 300 bits of information. Each subframe contains the data words of 30 bits each. Six of these are control bits. The first two words of each subframe are the Telemetry Work (TLM) and the C/A-P-Code Hand over Work (HOW). The TLM work contains a synchronization pattern, which facilitates the access to the navigation data. Since GPS is a military navigation system of US, a limited access to the total system accuracy is made available to the civilian users. The service available to the civilians is called Standard

Positioning System (SPS) while the service available to the authorized users is called the Precise Positioning Service (PPS). Under current policy the accuracy available to SPS users is 100m, 2D- RMS and for PPS users it is 10 to 20 meters in 3D. Additional limitation viz. Anti-Spoofing (AS), and Selective Availability (SA) was further imposed for civilian users. Under AS, only authorized users will have the means to get access to the P- code. By imposing SA condition, positional accuracy from Block-II satellite was randomly offset for SPS users.

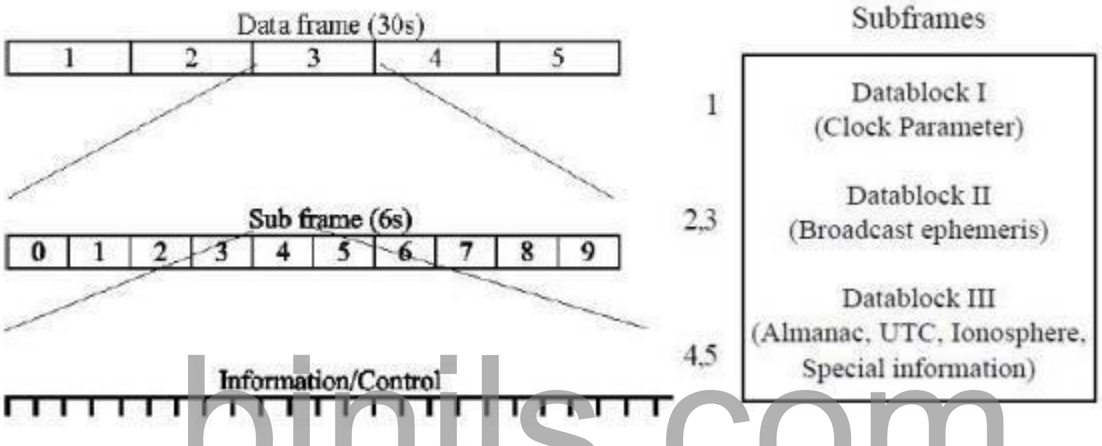


Fig 4.7 Data block

(https://www.brainkart.com/article/GPS-Surveying--Observation-Principle-and-Signal-Structure_4659/)

The navigation data record is divided into three data blocks:

- Data Block I appear in the first subframe and contains the clock coefficient/bias.
- Data Block II appears in the second and third subframe and contains all necessary parameters for the computation of the satellite coordinates.
- Data Block III appears in the fourth and fifth subframes and contains the almanac data with clock and ephemeris parameter for all available satellite of the GPS system.

This data block includes also ionospheric correction parameters and particular alphanumeric information for authorized users. Unlike the first two blocks, the subframe four and five are not repeated every 30 seconds.

International Limitation of the System Accuracy

The GPS system time is defined by the cesium oscillator at a selected monitor station. However, no clock parameter is derived for this station. GPS time is indicated by a week number and the number of seconds since the beginning of the current week. GPS time thus varies between 0 at the beginning of a week to 6,04,800 at the end of the week. The initial GPS epoch is January 5, 1980 at 0 hours Universal Time. Hence, GPS week starts at Midnight (UT) between Saturday and Sunday. The GPS time is a continuous time scale and is defined by the main clock at the Master Control Station (MCS). The leap seconds is UTC time scale and the drift in the MCS clock indicate that GPS time and UTC are not identical. The difference is continuously monitored by the control segment and is broadcast to the users in the navigation message. Difference of about 7 seconds was observed in July, 1992.

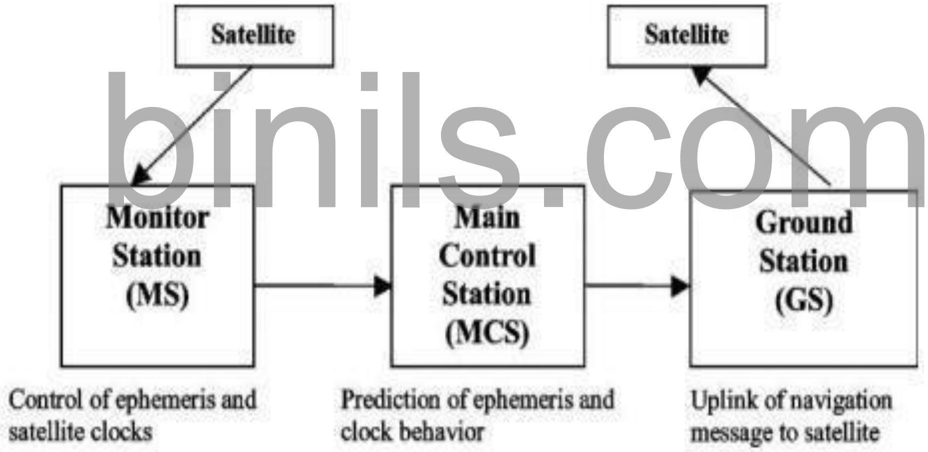


Figure 4.8 Data Flow in the determination of the broadcast ephemeris

(https://www.brainkart.com/article/GPS-Surveying--Observation-Principle-and-Signal-Structure_4659/)

GPS satellite is identified by two different numbering schemes. Based on launch sequence, SVN (Space Vehicle Number) or NAVSTAR number is allocated. PRN (Pseudo Random Noise) or SVID (Space Vehicle Identification) number is related to orbit arrangement and the particular PRN segment allocated to the individual satellite. Usually the GPS receiver displays PRN number.

CONTROL SEGMENT

Control segment is the vital link in GPS technology. Main functions of the control segment.

- Monitoring and controlling the satellite system continuously
- Determine GPS system time
- Predict the satellite ephemeris and the behavior of each satelliteclock.
- Update periodically the navigation message for each particular satellite.

For continuous monitoring and controlling GPS satellites a master control stations (MCS), several monitor stations (MS) and ground antennas (GA) are located around the world (Fig. 9). The operational control segment (OCS) consists of MCS near Colorado Springs (USA), three MS and GA in Kwajaleian Ascension and Diego Garcia and two more MS at Colorado Spring and Hawai.

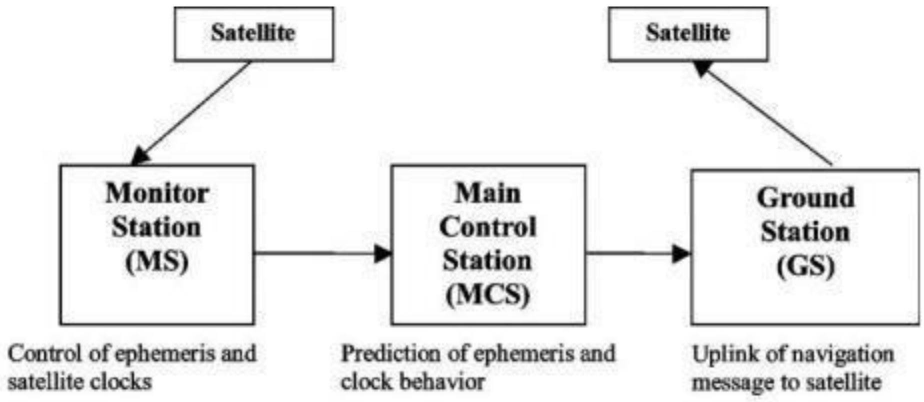


Figure 4.8 Data Flow in the determination of the broadcast ephemeris

(https://www.brainkart.com/article/GPS-Surveying--Observation-Principle-and-Signal-Structure_4659/)

GROUND CONTROL SEGMENT

The monitor station receives all visible satellite signals and determines their pseudo rages and then transmits the range data along with the local meteorological data via data link to the master control stations. MCS then precomputes satellite ephemeris and the behavior of the satellite clocks and formulates the navigation data. The navigation message data are transmitted to the ground antennas and via S-band it links to the satellites in view. Fig. 9 shows this process schematically. Due to systematic global distribution of upload antennas, it is possible to have at least three contacts per day between the control segment and each satellite.

USER SEGMENT

Appropriate GPS receivers are required to receive signal from GPS satellites for the purpose of navigation or positioning. Since, GPS is still in its development phase, many rapid advancements have completely eliminated bulky first-generation user equipment and now miniature powerful models are frequently appearing in the market.

BASIC CONCEPT OF GPS RECEIVER AND ITS COMPONENTS

The main components of a GPS receiver are shown in Fig. 10. These are:

- Antenna with pre-amplifier
- RF section with signal identification and signal processing
- Micro-processor for receiver control, data sampling and data processing
- Precision oscillator
- Power supply
- User interface, command and display panel
- Memory, data storage

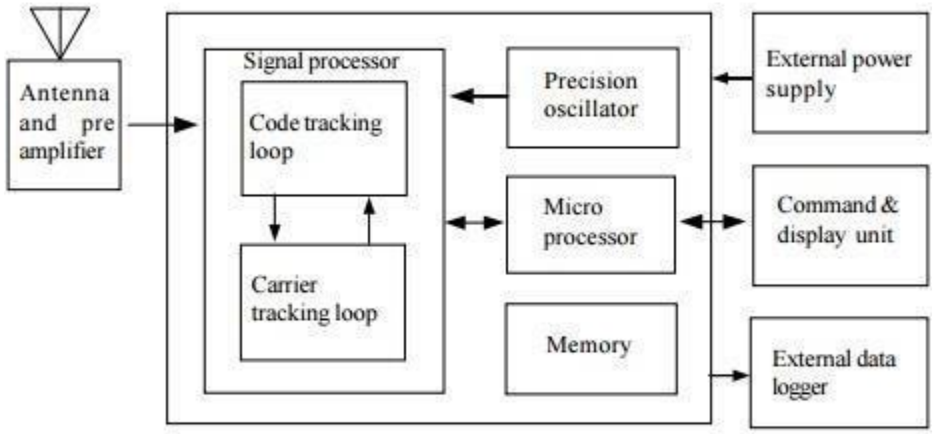


Fig 4.9 Major components of a GPS receiver

(https://www.brainkart.com/article/GPS-Surveying--Ground-Control-Segment-and-User-Segment_4661/)

ANTENNA

Sensitive antenna of the GPS receiver detects the electromagnetic wave signal transmitted by GPS satellites and converts the wave energy to electric current] amplifies the signal strength and sends them to receiver electronics.

Several types of GPS antennas in use are mostly of following types (Fig.).

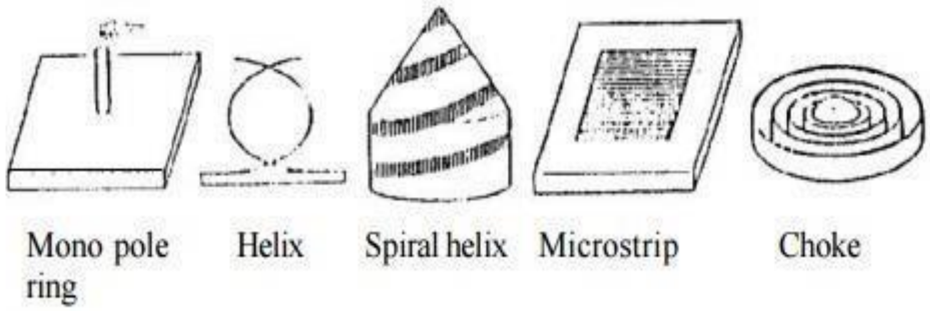


Fig Mono pole, Helix, Spiral helix, Microstrip, Choke ring

(https://www.brainkart.com/article/GPS-Surveying--Ground-Control-Segment-and-User-Segment_4661/)

Types of GPS Antenna

- Mono pole or dipole
- Quadrifilar helix (Volute)
- Spiral helix
- Microstrip (patch)
- Choke ring

Microstrip antennas are most frequently used because of its added advantage for airborne application, materialization of GPS receiver and easy construction. However, for geodetic needs, antennas are designed to receive both carrier frequencies L1 and L2. Also they are protected against multipath by extra ground planes or by using choke rings. A choke ring consists of strips of conductor which are concentric with the vertical axis of the antenna and connected to the ground plate which in turns reduces the multipath effect.

RF Section with Signal Identification and Processing The incoming GPS signals are down converted to a lower frequency in the RS section and processed within one or more channels. Receiver channel is the primary electronic unit of a GPS receiver. A receiver may have one or more channels. In the parallel channel concept each channel is continuously franking one particular satellite. A minimum of four parallel channels is required to determine position and time. Modern receivers contain up to 12 channels for each frequency.

In the sequencing channel concept, the channel switches from satellite to satellite at regular interval. A single channel receiver takes at least four times of 30 seconds to establish first position fix, though some receiver types have a dedicated channel for reading the data signal. Now days in most of the cases fast sequencing channels with a switching rate of about one-second per satellite are used.

In multiplexing channel, sequencing at a very high speed between different satellites is achieved using one or both frequencies. The switching rate is synchronous with the navigation message of 50 bps or 20 milliseconds per bit. A complete sequence with four satellites is completed by 20 millisecond or after 40 milli second for dual frequency receivers. The navigation message is continuous; hence first fix is achieved after about 30 seconds.

Though continuous tracking parallel channels are cheap and give good overall performance, GPS receivers based on multiplexing technology will soon be available at a cheaper price due to electronic boom.

Microprocessor

To control the operation of a GPS receiver, a microprocessor is essential for acquiring the signals, processing of the signal and the decoding of the broadcast message. Additional capabilities of computation of on-line position and velocity, conversion into a given local datum or the determination of waypoint information are also required. In future more and more user relevant software will be resident on miniaturized memory chips.

Precision Oscillator

A reference frequency in the receiver is generated by the precision oscillator. Normally, less expensive, low performance quartz oscillator is used in receivers since the precise clock information is obtained from the GPS satellites and the user clock error can be eliminated through double differencing technique when all participating receivers observe at exactly the same epoch. For navigation with two or three satellites only an external high precision oscillator is used.

Power Supply

First generation GPS receivers consumed very high power, but modern receivers are designed to consume as little energy as possible. Most receivers have an internal rechargeable. Nickel-Cadmium battery in addition to an external power input. Caution of low battery signal prompts the user to ensure adequate arrangement of power supply.

Memory Capacit

For port processing purposes all data have to be stored on internal or external memory devices. Post processing is essential for multi station techniques applicable to geodetic and surveying problems. GPS observation for pseudo ranges, phase data, time and navigation message data have to be recorded. Based on sampling rate, it amounts to about 1.5 Mbytes of data per hour for six satellites and 1 second data for dual frequency receivers. Modern receivers have internal memories of 5 Mbytes or more. Some receivers store the data on magnetic tape or on a floppy disk or hard-disk using external microcomputer connected through RS-232 port.

Most modern receivers have a keypad and a display for communication between the user and the receivers. The keypad is used to enter commands, external data like station number or antenna height or to select a menu operation. The display indicates computed coordinates, visible satellites, data quality indices and other suitable information. Current operation software packages are menu driven and very user friendly.

CLASSIFICATION OF GPS RECEIVERS

GPS receivers can be divided into various groups according to different criteria. In the early stages two basic technologies were used as the classification criteria viz. Code correlation receiver technology and sequencing receiver technology, which were equivalent to code dependent receivers and code free receivers. However, this kind of division is no longer justifiable since both techniques are implemented in present receivers.

Another classification of GPS receiver is based on acquisition of data types e.g.

- C/A code receiver
- C/A code + L1 Carrier phase

- C/A code + L1 Carrier phase + L2 Carrier phase
- C/A code + p_code + L1, L2 Carrier phase
- L1 Carrier phase (not very common)
- L1, L2 Carrier phase (rarely used)

Based on technical realization of channel, the GPS receivers can be classified as:

- Multi-channel receiver
- Sequential receiver
- Multiplexing receiver

GPS receivers are even classified on the purpose as:

- Military receiver
- Civilian receiver
- Navigation receiver
- Timing receiver
- Geodetic receiver

For geodetic application it is essential to use the carrier phase data as observable. Use of L1 and L2 frequency is also essential along with P-code.

Examples of GPS Receiver

GPS receiver market is developing and expanding at a very high speed. Receivers are becoming powerful, cheap and smaller in size. It is not possible to give details of every make but description of some typical receivers given may be regarded as a basis for the evaluation of future search and study of GPS receivers.

Classical Receivers

Detailed description of code dependent T1 4100 GPS Navigator and code free

Micrometer V1000 is given here:

T1 4100 GPS Navigator was manufactured by Texas Instrument in 1984. It was the first GPS receiver to provide C/A and P code and L1 and L2 carrier phase observations. It is a dual frequency multiplexing receiver and suitable for geodesist, surveyor and navigators. The observables through it are:

- P-Code pseudo ranges on L1 and L2
- C/A-Code pseudo ranges on L1
- Carrier phase on L1 and L2

The data are recorded by an external tape recorder on digital cassettes or are downloaded directly to an external microprocessor. A hand-held control display unit (CDU) is used for communication between observer and the receiver. For navigational purposes the built-in microprocessor provides position and velocity in real time every three seconds. T1 4100 is a bulky instrument weighing about 33 kg and can be packed in two transportation cases. It consumes 90 watts energy in operating mode of 22V - 32V. Generator use is recommended. The observation noise in P-Code is between to 1 m, in C/ A code it ranges between 6 to 10 m and for carrier phase it is between 2 to 3 m.

T1 4100 has been widely used in numerous scientific and applied GPS projects and is still in use. The main disadvantages of the T1 4100 compared to more modern GPS equipment's are

- ☆ Bulky size of the equipment
- ☆ High power consumption
- ☆ Difficult operation procedure
- ☆ Limitation of tracking four satellites simultaneously
- ☆ High noise level in phase measurements

Sensitivity of its antenna for multipath and phase centre variation if two receivers are connected to one antenna and tracking of seven satellites simultaneously ispossible. For long distances and in scientific projects, T1 4100 is still regarded useful. However, due to imposition of restriction on P- code for civilian, T1 4100 during Anti Spoofing (AS) activation can only be used as a single frequency C/A code receiver.

The MACROMETER V 1000, a code free GPS receiver was introduced in 1982 and was the first receiver for geodetic applications. Precise results obtained through it has demonstrated the potential of highly accurate GPS phase observations. It is a single frequency receiver and tracks 6 satellites on 6 parallel channels. The complete system consists of three units viz.

- ✓ Receiver and recorder with power supply
- ✓ Antenna with large ground plane
- ✓ P 1000 processor

The processor is essential for providing the almanac data because the Macrometer V 1000 cannot decode the satellite messages and process the data. At pre-determined epochs the phase differences between the received carrier signal and a reference signal from receiver oscillator is measured. A typical baseline accuracy reported for up to 100 km distance is about 1 to 2 ppm (Parts per million).

Macrometer II, a dual frequency version was introduced in 1985. Though it is comparable to Macrometer V 1000, its power consumption and weight are much less. Both systems require external ephemerides. Hence specialized operators of few companies are capable of using it and it is required to synchronize the clock of all the instruments proposed to be used for a particular observation session. To overcome above disadvantages, the dual frequency Macrometer II was further miniaturized and combined with a single frequency C/A code receiver with a brand name MINIMAC in 1986, thus becoming a code dependent receiver.

Examples of present Geodetic GPS Receivers

Few of the currently available GPS receivers that are used in geodesy surveying and precise navigation are described. Nearly all models started as single frequency C/A-Code receivers with four channels. Later L2 carrier phase was added and tracking capability was increased. Now a days all leading manufacturers have gone for code-less, non- sequencing L2 technique. WILD/ LEITZ (Heerbrugg, Switzerland) and MAGNAVOX (Torrance, California) have jointly developed WM 101 geodetic receiver in 1986. It is a four channel L1 C/A code receiver. Three of the channels sequentially track upto six satellites and the fourth channel, a house keeping channels, collects the satellite message and periodically calibrates the inter channel biases. C/A-code and reconstructed L1 carrier phase data are observed once per second.

The dual frequency WM 102 was marketed in 1988 with following key features:

- L1 reception with seven C/A code channel tracking upto six satellites simultaneously.
- L2 reception of up to six satellites with one sequencing P- code channel Modified sequencing technique for receiving L2 when P-code signals are encrypted.

The observations can be recorded on built in data cassettes or can be transferred on line to an external data logger in RS 232 or RS 422 interface. Communication between operator and receiver is established by alpha numerical control panel and display WM 101/102 has a large variety of receiver resident menu driven options and it is accompanied by comprehensive post processing software.

In 1991, WILD GPS system 200 was introduced. It’s hardware comprises the Magnavox SR 299 dual frequency GPS sensor, the hand held CR 233 GPS controller and a Nicd battery. Plug in memory cards provide the recording medium. It can track 9 satellites simultaneously on L1 and L2. Reconstruction of carrier phase on L1 is through C/A code and on L2 through

P-code. The receiver automatically switches to codeless L2 when P-code is encrypted. It consumes 8.5 watt through 12-volt power supply.

TRIMBLE NAVIGATION (Sunny vale, California) has been producing TRIMBLE 4000 series since 1985. The first generation receiver was a L1 C/ A code receiver with five parallel channels providing tracking of 5 satellites simultaneously. Further upgradation included increasing the number of channels up to twelve, L2 sequencing capability and P-code capability. TRIMBLE Geodetic Surveyor 4000 SSE is the most advanced model. When P-Code is available, it can perform following types of observations, viz.,

- ➔ Full cycle L1 and L2 phase measurements
- ➔ L1 and L2, P-Code measurements when AS is on and P-code is encrypted
- ➔ Full cycle L1 and L2 phase measurement
- ➔ Low noise L1, C/A code
- ➔ Cross-correlated Y-Code data

Observation noise of the carrier phase measurement when P-code is available is about 0-2mm and of the P-code pseudo ranges as low as 2cm. Therefore, it is very suitable for fast ambiguity solution techniques with code/ carrier combinations.

ASHTECH (Sunnyvale, California) developed a GPS receiver with 12 parallel channels and pioneered current multi-channel technology. ASHTECH XII GPS receiver was introduced in 1988. It is capable of measuring pseudo ranges, carrier phase and integrated doper of up to 12 satellites on L1. The pseudo ranges measurement is smoothed with integrated Doppler. Position velocity, time and navigation information are displayed on a keyboard with a 40-characters display. L2 option adds 12 physical L2 squaring type channels.

ASHTECH XII GPS receiver is a most advanced system, easy to handle and does not require initialization procedures. Measurements of all satellites in view are carried out automatically. Data can be stored in the internal solid plate memory of 5 Mbytes capacity. The minimum sampling interval is 0.5 seconds. Like many other receivers it has following additional options viz.

- 1 ppm timing signal output
  Photogrammetric camera input
- Way point navigation
- Real time differential navigation and provision of port processing and vision planning software

In 1991, ASHTECH P-12 GPS receiver was marketed. It has 12 dedicated channels of L1, P-code and carrier and 12 dedicated channels of L2, P-code and carrier. It also has 12 L1, C/A code and carrier channels and 12 code less squaring L2 channels. Thus the receiver contains 48 channels and provides all possibilities of observations to all visible satellites. The signal to noise level for phase measurement on L2 is only slightly less than on L1 and significantly better than with code-less techniques. In cases of activated P-code encryption, the code less L2 option can be used.

TURBO ROGUE SNR-8000 is a portable receiver weighing around 4 kg, consumes 15-watt energy and is suitable for field use. It has 8 parallel channels on L1 and L2. It provides code and phase data on both frequencies and has a codeless option. Full P- code tracking provides highest precision phase and pseudo rages measurements; codeless tracking is automatic 'full back' mode. The code less mode uses the fact that each carrier has identical modulation of P-code/Y-code and hence the L1 signal can be cross-correlated with the L2 signal. Results are the differential phase measurement (L1-L2) and the group delay measurement (P1-P2)

Accuracy specifications are :

- P-Code pseudo range 1cm (5 minutes integration)
- Codeless pseudo range 10cm (5 minutes integration)
- Carrier phase 0.2 - 0.3 mm
- Codeless phase 0.2 - 0.7 mm

One of the important features is that less than 1 cycle slip is expected for 100 satellite hours.

Navigation Receivers

Navigation receivers are rapidly picking up the market. In most cases a single C/A code sequencing or multiplexing channel is used. However, modules with four or five parallel channels are becoming increasingly popular. Position and velocity are derived from C/A code pseudo ranges measurement and are displayed or downloaded to a personal computer. Usually neither raw data nor carrier phase information is available. Differential navigation is possible with some advanced models.

MAGELLAN NAV 1000 is a handheld GPS receiver and weighs only 850 grams. It was introduced in 1989 and later in 1990, NAV 1000 PRO model was launched. It is a single channel receiver and tracks 3 to 4 satellites with a 2.5 seconds update rate and has a RS 232 data port.

The follow up model in 1991 was NAV 5000 PRO. It is a 5-channel receiver tracking all visible satellites with a 1-second update rate. Differential navigation is possible. Carrier phase data can be used with an optional carrier phase module. The quadrifocal antenna is integrated to the receiver. Post processing of data is also possible using surveying receiver like ASHTECH XII located at a reference station. Relative accuracy is about 3 to 5 meters. This is in many cases sufficient for thematic purposes.

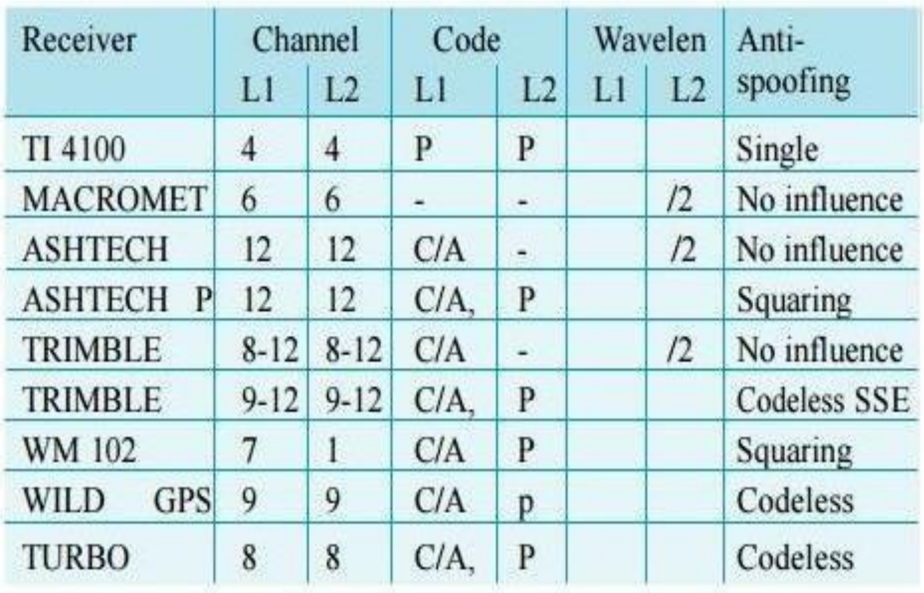
Many hand held navigation receivers are available with added features. The latest market situation can be obtained through journals like GPS world etc.

For most navigation purpose a single frequency C/A code receiver is sufficient. For accuracy requirements better than 50 to 100 meters, a differential option is essential. For requirement below 5 meters, the inclusion of carrier phase data is necessary. In high precision navigation the use of a pair of receivers with full geodetic capability is advisable.

The main characteristics of multipurpose geodetic receiver are summarized in Table 4.

Table 4. Overview of geodetic dual-frequency GPS satellite receiver (1992)

(https://www.brainkart.com/article/Classification-Of-GPS-Receivers_4662/)



Receiver	Channel		Code		Wavelen		Anti-spoofing
	L1	L2	L1	L2	L1	L2	
TI 4100	4	4	P	P			Single
MACROMET	6	6	-	-		/2	No influence
ASHTECH	12	12	C/A	-		/2	No influence
ASHTECH P	12	12	C/A,	P			Squaring
TRIMBLE	8-12	8-12	C/A	-		/2	No influence
TRIMBLE	9-12	9-12	C/A,	P			Codeless SSE
WM 102	7	1	C/A	P			Squaring
WILD GPS	9	9	C/A	p			Codeless
TURBO	8	8	C/A,	P			Codeless

Some of the important features for selecting a geodetic receiver are :

- ★ Tracking of all satellites
- ★ Both frequencies
- ★ Full wavelength on L2
- ★ Low phase noise-low code noise
- ★ High sampling rate for L1 and L2
- ★ High memory capacity
- ★ Low power consumption
- ★ Full operational capability under anti spoofing condition

Further, it is recommended to use dual frequency receiver to minimize ion-spherical influences and take advantages in ambiguity solution.

5.3 DIFFERENTIAL THEORY

Differential positioning is technique that allows overcoming the effects of environmental errors and SA on the GPS signals to produce a highly accurate position fix.

ACCURACY

In general, an SPS receiver can provide position information with an error of less than 25 meter and velocity information with an error less than 5 meters per second. Up to 2 May 2000 U.S Government has activated Selective Availability (SA) to maintain optimum military effectiveness. Selective Availability inserts random errors into the ephemeris information broadcast by the satellites, which reduces the SPS accuracy to around 100 meters.

For many applications, 100-meter accuracy is more than acceptable. Forapplications that require much greater accuracy, the effects of SA and environmentally produced errors can be overcome by using a technique called Differential GPS (DGPS), which increases overall accuracy.

DIFFERENTIAL THEORY

Differential positioning is technique that allows overcoming the effects of environmental errors and SA on the GPS signals to produce a highly accurate position fix. This is done by determining the amount of the positioning error and applying it to position fixes that were computed from collected data.

Typically, the horizontal accuracy of a single position fix from a GPS receiver is 15 meter RMS (root-mean Square) or better. If the distribution of fixes about the true position is circular normal with zero mean, an accuracy of 15 meters RMS implies that about 63% of the fixes obtained during a session are within 15 meters of the true position.

5.4 TYPES OF ERRORS

There are two types of positioning errors: correctable and non-correctable. Correctable errors are the errors that are essentially the same for two GPS receivers in the same area. Non-correctable errors cannot be correlated between two GPS receivers in the same area.

CORRECTABLE ERRORS

Sources of correctable errors include satellite clock, ephemeris data and ionosphere and tropospheric delay. If implemented, SA may also cause a correctable positioning error. Clock errors and ephemeris errors originate with the GPS satellite. A clock error is a slowly changing error that appears as a bias on the pseudo range measurement made by a receiver. An ephemeris error is a residual error in the data used by a receiver to locate a satellite in space.

Ionosphere delay errors and tropospheric delay errors are caused by atmospheric conditions. Ionospheric delay is caused by the density of electrons in the ionosphere along the signal path. A tropospheric delay is related to humidity, temperature, and altitude along the signal path. Usually, a tropospheric error is smaller than an ionospheric error.

Another correctable error is caused by SA which is used by U.S Department of Defense to introduce errors into Standard Positioning Service (SPS) GPS signals to degrade fix accuracy.

The amount of error and direction of the error at any given time does not change rapidly. Therefore, two GPS receivers that are sufficiently close together will observe the same fix error, and the size of the fix error can be determined.

NON-CORRECTABLE ERRORS

Non-correctable errors cannot be correlated between two GPS receivers that are located in the same general area. Sources of non-correctable errors include receiver noise, which is unavoidably inherent in any receiver, and multipath errors, which are environmental. Multi-path errors are caused by the receiver 'seeing' reflections of signals that have bounced off of surrounding objects. The sub-meter antenna is multipath-resistant; its use is required when logging carrier phase data. Neither error can be eliminated with differential, but they can be reduced substantially with position fix averaging. The error sources and the approximate RMS error range are given in the Table.

Table- Error Sources *(https://www.brainkart.com/article/GPS-Surveying--Correctable-Errors_4664/)*

Error Sources

Error Source	Approx. Equivalent Range Error (RMS) in meters
Correctable with Differential	
Clock (Space Segment)	3.0
Ephemeris (Control Segment)	2.7
Ionospheric Delay (Atmosphere)	8.2
Tropospheric Delay (Atmosphere)	1.8
Selective Availability (if implemented)	27.4
Total	28.9
Non-Correctable with Differential	
Receiver Noise (Unit)	9.1
Multipath (Environmental)	3.0
Total	9.6
Total user Equivalent range error (all sources)	30.5
Navigational Accuracy (HDOP = 1.5)	45.8

DIFFERENTIAL GPS

Most DGPS techniques use a GPS receiver at a geodetic control site whose position is known. The receiver collects positioning information and calculates a position fix, which is then compared to the known co-ordinates. The difference between the known position and the acquired position of the control location is the positioning error.

Because the other GPS receivers in the area are assumed to be operating under similar conditions, it is assumed that the position fixes acquired by other receivers in the area (remote units) are subject to the same error, and that the correction computed for the control position should therefore be accurate for those receivers. The correction is communicated to the remote units by an operator at the control site with radio or cellular equipment. In post-processed differential, all units collect data for off-site processing; no corrections are determined in the field. The process of correcting the position error with differential mode is shown in the Figure.

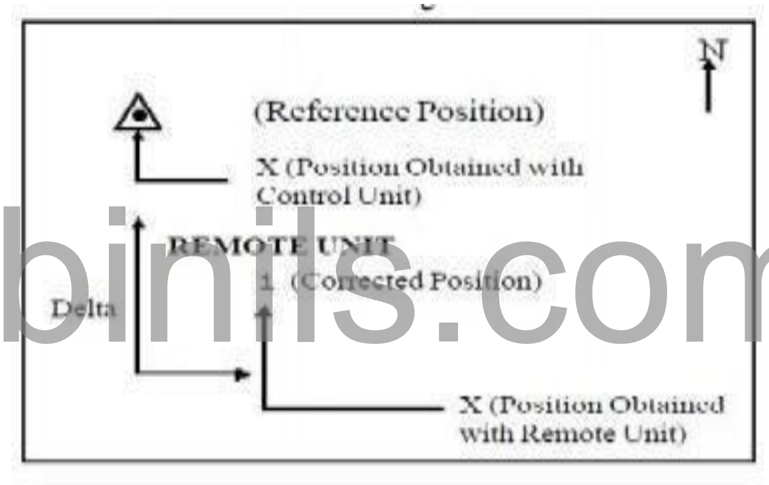


Fig Differential GPS

(https://www.brainkart.com/article/Differential-GPS_4665/)

The difference between the known position and acquired position at the control point is the DELTA correction. DELTA, which is always expressed in meters, is parallel to the surface of the earth. When expressed in local co- ordinate system, DELTA uses North-South axis (y) and an East-West axis (x) in 2D operation; an additional vertical axis (z) that is perpendicular to the y and x is used in 3D operation for altitude.

Applications of GPS

- z Providing Geodetic control.
- z Survey control for Photogrammetric control surveys and mapping.
- z Finding out location of offshore drilling.
- z Pipeline and Power line survey.
- z Navigation of civilian ships and planes. z Crustal movement studies.
- z Geophysical positioning, mineral exploration and mining.
- z Determination of a precise geoid using GPS data.
- z Estimating gravity anomalies using GPS.
- z Offshore positioning: shipping, offshore platforms, fishing boats etc.

Astronomical observation of celestial bodies was one of the standard methods of obtaining coordinates of a position. This method is prone to visibility and weather condition and demands expert handling. Attempts have been made by USA since early 1960's to use space based artificial satellites. System TRANSIT was widely used for establishing a network of control points over large regions. Establishment of modern geocentric datum and its relation to local datum was successfully achieved through TRANSIT. Rapid improvements in higher frequently transmission and precise clock signals along with advanced stable satellite technology have been instrumental for the development of global positioning system.

The **NAVSTAR GPS** (Navigation System with Time and Ranging Global Positioning System) is a satellite-based radio navigation system providing precise three- dimensional position, course and time information to suitably equipped user