UNIT 3 GPS SURVEY AND APPLICATIONS

Structure

3.1 INTRODUCTION

In Unit 1, you have studied about the basic functions of GNSS, features of GNSS satellites, accuracy and types of GPS. You have also studied about the principles of GPS operation; and its space, control and user segments in Unit 2. In this unit, we will concentrate basically in planning a GPS survey, GPS measuring techniques, the generalised steps for carrying out GPS survey and some of the basic applications of GPS.

Where you are and how do you get to your destination? These questions are as old as the history of mankind and form the basis of evolution of present day satellite navigation system. You know that every aspect of human life is affected to a great extent due to rapid advancement in electronic system. Field of advanced surveying and navigation has tremendously benefited by use of these electronic devices. GPS technology is rapidly changing the lives of common people.

Many of the critical situations in surveying or navigation are now easily and precisely solved to acceptable limits of accuracy. Surveying is the science and technique of accurately determining the terrestrial or three-dimensional space position of points, the distances and angles between them. Surveying with GPS can be extremely productive and GPS has the advantage that the accuracy of the collected data is not dependent on the skill of the instrument operator.

However, you should keep in mind that GPS is not the solution for every survey task. Proper planning and preparation are essential ingredients of a successful GPS based survey, an awareness of the capabilities and limitations of GPS.

Objectives

After reading this unit, you should be able to:

- differentiate between GPS Navigation and GPS Survey;
- plan a GPS survey task and explain about GPS field survey procedures;
- describe the GPS measuring techniques;
- list the generalised steps for carrying out GPS survey; and
- discuss the applications of GPS in various field.

3.2 ADVANTAGES AND DISADVANTAGES OF GPS OVER CONVENTIONAL SURVEYING METHODS

Like any other approach, GPS based method also has advantages and disadvantages. It is simply one of the many tools that should be in the surveyor's tool box. Let us now discuss about some of the advantages and disadvantages of GPS over conventional surveying methods.

3.2.1 Advantages

The several advantages of the GPS satellite surveying technique over conventional surveying are listed below:

- Intervisibility between stations is not necessary.
- Operations are weather independent because GPS uses radio frequencies to transmit the signals.

- Because of the generally homogeneous accuracy of GPS surveying, the survey points are placed wherever they are required and need not be located at evenly distributed sites to satisfy intervisibility or network geometry.
- GPS can be used round-the-clock for data logging purposes.
- GPS provides three-dimensional information for the user point coordinates.
- High accuracies can be achieved with relatively less effort. In general, GPS survey results are more accurate.
- GPS surveying is most efficient, more flexible and less time consuming because of not requiring intervisibility of stations and of network-independent site selection procedure.

3.2.2 Disadvantages

However, along with the above advantages, some disadvantages are also associated with GPS surveying listed below:

- GPS cannot tolerate sky obstruction, therefore GPS surveying cannot be used where obstructions exist to the signals by overhanging structures (although the antenna can be raised above the obstruction). GPS surveying cannot be used for underground sites and have limited application in densely settled urban or forest areas.
- High efficiency has its price. Efficient use of GPS requires that travel time between stations is cut in order to match the savings in on-site time.
- GPS is an attractive technology for use in rugged and inhospitable terrain as station intervisibility is not necessary for GPS surveying. However, the logistical problems of transporting and supporting several field parties are still difficult. Helicopters may be necessary for surveying the cost of the survey will definitely raise.
- GPS survey is generally targeted to satisfy a specific survey need.
- GPS would have to establish two intervisible stations in order to satisfy the requirement for azimuth data for use by conventional survey methods.
- Horizontal and vertical coordinates from GPS must be transformed, if they are useful for conventional survey applications.
- GPS survey requires strategies for planning field operations for data collection along with the different data analysis methods to be developed.

3.3 GPS NAVIGATION VERSUS GPS SURVEYING

Many people are not able to differentiate between *GPS navigation and GPS surveying*. The distinctions between the two can be made based on a number of criteria which are as follows:

- GPS surveying is mostly associated with the traditional functions of establishing geodetic control, supporting engineering construction, cadastral surveys and making of maps whereas GPS navigation supports the safe passage of a vessel or aircraft from the port of departure, while underway and to its point of arrival.
- According to operational aspects, such as the real-time absolute positioning aspects of navigation is very essential, as opposed to the post-processed relative positioning characteristics of GPS surveying.
- Based on the type of measurement made and the GPS instrumentation used, GPS surveying receivers are expensive. Whereas GPS navigation type receivers are comparatively low cost.
- The primary measurement in GPS navigation is the pseudorange which is dealt in a casual and a relaxed manner. GPS surveying requires a more careful treatment of the biases during the data processing.

Spend 5 mins

Check Your Progress I

1) List out the distinctions between GPS Navigation and GPS Surveying.

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3.4 PLANNING GPS SURVEY

GPS survey requires careful different planning, execution and processing techniques, since it is different from conventional surveying. A systematic planning maximises the chances of the survey achieving the desired accuracy, within a reasonable time and budget. Before commencing the planning of a GPS survey one must decide the ultimate purpose of the survey and the accuracy of the desired results.

Elements of GPS Survey Planning Process

Unlike the conventional surveying technologies, generally there is not sufficient time for the surveyor to have combined the conventional wisdom needed to reliably execute GPS surveys. Therefore, careful planning is a critical issue and consists of the following elements:

- Project Design
- Observation Scheduling
- Instrumentation and Personal Consideration
- Logistical Consideration
- Reconnaissance

Let us now discuss about them in detail.

3.4.1 Project Design

One of the most important planning tasks of the GPS surveyor is designing the project layout. While designing a project the surveyor must take the following factors into account.

- **Definition of the Network:** This includes the size and the shape of the overall network, the number of stations and their spacing, intervisibility requirements, new and existing (known) stations.

- **Spacing of the Existing Stations:** This comprises the need for densification of existing control station, for the determination of transformation parameters, etc.

- **Accuracy and Standards:** This consists of the aspects of accuracy requirements as defined by the client and the standards as defined by the geodetic control authorities. While designing a GPS survey project both vertical and horizontal surveys should be kept in mind.

Once the number of GPS stations has been decided and their approximate locations have been determined, some other considerations that may be influencing the overall performance of the GPS-based calculations need to be taken care e.g., where additional stations may be located, or where refinements to the network design could also be made, etc.

3.4.2 Observation Scheduling

You will read that in order to prepare an observation schedule for a GPS survey there are three considerations:

- Relating to the various parameters of observation, i.e., how many to observe and for how long to observe, etc.

- Relating to satellite receiver geometry or the distribution of satellites in the sky.

- Relating to logistical design such as the number of observation sessions per day, number of multiple site occupancies, etc.

Satellite Consideration: Need for an observation schedule for a GPS survey; it is necessary to first define the satellite constellation to be tracked which include the following:

- Rise and set times of satellites above the observing horizon of a site. GPS satellites are not normally tracked at elevations less than 15° to 20° above the horizon due to atmospheric refraction.

- Each satellite broadcasts a health status with history of health problem indicator within its navigation message which should be avoided if at all possible.

- The minimum length of observation period per station should be determined, which is dependent on the satellite constellation to be observed and the length of the baseline, etc.

- Estimating the appropriate length of an observing session is very difficult, as it is a function of baseline length and environmental factors, as well as being dependent on the satellite constellation.

Satellite Receiver Geometry: The accuracy of GPS derived coordinates is a function of the measurement precision, the systematic errors present, the processing strategy used and the receiver satellite geometry during the observing session. Satellite geometry or the distribution of satellites in the sky affects the computation of the positional accuracies. This is referred to as *Position Dilution of Precision* (PDOP) which is determined by your geographic location, the time of day you are working and any obstruction in site, which might block the view of satellites. When the satellites are spread out, PDOP is low, hence good, whilst when the satellites are closer together, PDOP is high meaning that weak signals received.

3.4.3 Instrumentation and Personal Consideration

Project planning process includes the following instrumentation and personal consideration-

- **Number of Available GPS Receivers:** In a session for a better network, the number of receivers and the number of directly connected stations should be large, so that the progress in surveying is faster. The optimum number of receivers appears to be of the order of four to six.
- **Receiver Type:** In principle, all geodetic GPS receivers produce similar datasets and similar final accuracies. Thus mixing of different bands of receivers for the same network calculations could cause problems.
- **Single or Dual Frequency GPS Receivers:** For high accuracy applications dual frequency instruments are preferred as they permit compensation for the ionospheric delays based on the GPS signals.

Before GPS signals reach your antenna on the Earth, they pass through a zone of charged particles called the *ionosphere*, which changes the speed of the signal.

3.4.4 Logistical Consideration

The logistical considerations (source: www.gmat.unsw.edu.au/snap /gps/gps_survey/chap5/521.htm) of a GPS project increase enormously with the increase in the number of:

- Stations to be surveyed,
- Receivers deployed,
- Common stations occupied between sessions,
- Fixed stations to be occupied, and
- Sessions per day.

These logistical considerations are made complicated by some factors such as:

- The terrain and the nature of the transport link to be considered, whether four wheeler vehicle or helicopter is used.
- Instrumental factors such as requirement of special equipment for receivers to download data.
- Requirement of contingency plans in case of any mishaps.
- The quality control checking is required and partial processing of field data in the field office each day, hence the need for data from all receivers to be transferred to the field office on a daily basis.

- Availability of accommodation near the study area to minimise travel time, etc.

3.4.5 Reconnaissance

After the GPS points have been plotted on map and descriptions of how to reach the existing control has been obtained; now it is the time to perform a field reconnaissance. Easy access of the site is desired to save the time between the sessions. Sites that have many obstructions require additional considerations. Thus proper field reconnaissance is a prerequisite for any control survey. This should include a review of existing control networks, mark recovery and maintenances, station selection and setting of new monuments, as necessary.

3.5 GPS MEASURING TECHNIQUES

There are several measuring techniques that can be used by most GPS Survey Receivers are listed below. You will read about the techniques a surveyor should choose for the application in the following sections.

3.5.1 Static

This is used for measuring long base lines usually 20 km or more. This survey offers high accuracy over long distances but is comparatively slow. In static survey one receiver is placed on a point whose coordinates are known accurately in WGS84 and is known as the *Reference Receiver*. The other receiver is placed on the other end of the baseline and is known as *Rover Receiver*. Then at both the stations data is recorded simultaneously at the same rate. The data collection rate may be typically set to 15, 30 or 60 seconds. The receivers have to collect data for a certain length of time. The time is influenced by the number of satellites observed and the satellite geometry or dilution of precision (DOP) and by the length of the line. As a rule of thumb, the observation time is a minimum of 1 hour for a 20 km line with 5 satellites. Longer lines require longer observation times. Once enough data has been collected, the receivers can be switched off. The Rover receiver can then be moved to the next baseline. The following example will give you a better idea of static survey. You should read this section along with the Fig. 3.1.

Step 1: UVWXY is the network that has to be measured with three receivers that are placed on U, V and Y. The coordinates of U are known in WGS84. GPS data is recorded for the required length of time. After the required length of time, the receiver that was at Y moves to X and V moves to W. Now the triangle UWX is measured (Fig. 3.1a).

Step 2: Again receiver at U moves to Y and receiver at W moves to V and the triangle VXY is measured (Fig. 3.1b).

Step 3: Then receiver at V moves back to W and the line YW is measured (Fig. 3.1c).

Step 4: Finally, the network UVWXY is measured (Fig. 3.1d).

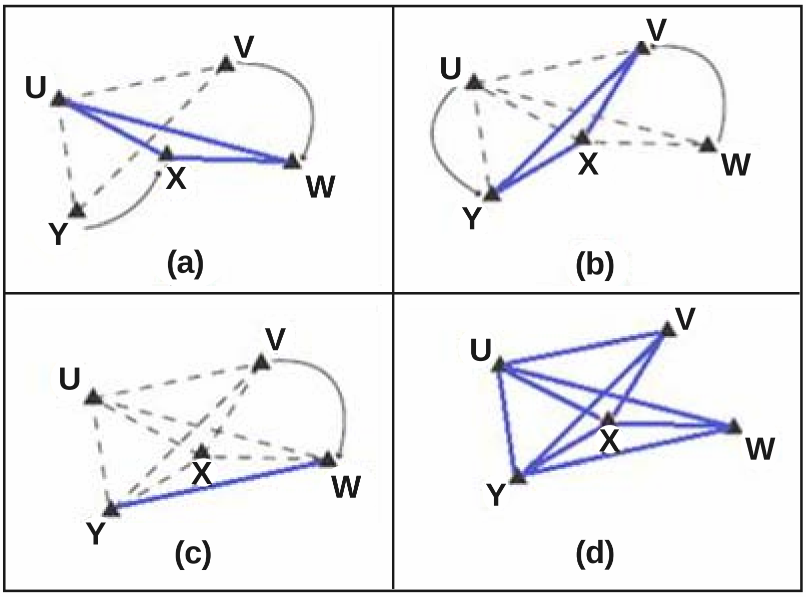


Fig. 3.1: Steps describing the Static measuring technique; (a) describes Step 1, (b) describes Step 2, (c) describes Step 3 and (d) describes Step 4 (source: modified from Leica Geosystems AG, 1999)

3.5.2 Rapid Static

Rapid Static Survey is used for densifying existing networks and establishing local control networks. It offers high accuracy on baselines upto 20km and is much faster than the static technique. In this type of survey, a Reference Point is chosen and one or more Rovers operate with respect to it. When starting work in an area where no GPS surveying has previously taken place, the very first task is to observe a number of points, whose coordinates are accurately known in the local system. At least 4 known points on the perimeter of the area of interest should be observed. The Reference Receiver is usually set up at a known point. If no known point is available, it can be set up anywhere within the network. The Rover Receivers then visit each of the known points. The length of the time that the Rovers must observe for at each point is related to the baseline length from the Reference and the GDOP (Geometric Dilution of Precision). Let us consider an example. You should read this example along with Fig. 3.2.

Step 1: The network UVWXY has to be measured from Reference station R with three GPS receivers (Fig. 3.2a).

Step 2: The reference station is setup and one Rover occupies point U whilst the other Rover occupies point W (Fig. 3.2b).

Step 3: After the required length of time, one Rover moves to point V whilst the other moves to point X (Fig. 3.2c).

Step 4: Then one Rover can return whilst the other measures point Y (Fig. 3.2d).

Step 5: The end result is shown in Fig. 3.2(e).

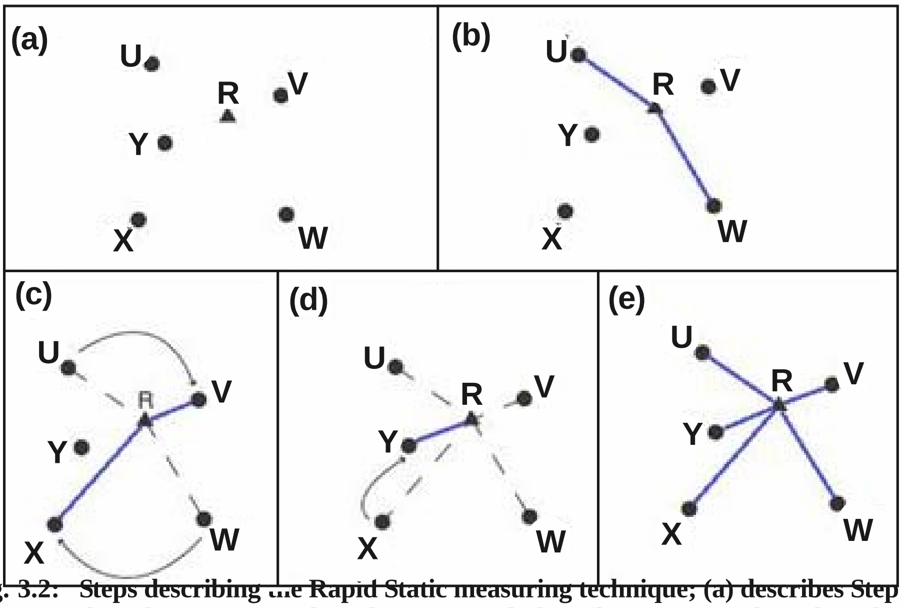


Fig. 3.2: Steps describing the Rapid Static measuring technique; (a) describes Step 1, (b) describes Step 2, (c) describes Step 3, (d) describes Step 4 and (e) describes Step 5 (source: modified from Leica Geosystems AG, 1999)

3.5.3 Kinematic

The Kinematic Survey technique is typically used for detail surveying and recording trajectories. It is very efficient way of measuring many points that are close together. This technique involves a moving Rover whose position can be calculated relative to the Reference. Firstly, the Rover has to perform what is known as an initialisation. This is essentially the same as measuring a Rapid Static point. The Reference and Rover are switched on and should remain absolutely stationary for 5-20 minutes. After this period, the Rover may then move freely. The user can record positions at a predefined recording rate, can record distinct positions, or record a combination of the two. This type of measurement is called kinematic chain. If at any time, less than four satellites are tracked by the Rover receiver, you must stop and move into a position where 4 or more satellites are tracked and perform an initialisation again before continuing. An example is shown in the Fig. 3.3(a-c).

Step 1: Initialisation is performed from the Reference R to the Rover r (Fig. 3.3 a).

Step 2: After initialisation the Rover can move and the positions can be recorded at a predefined interval r1 (Fig. 3.3 b).

Step 3: Positions can also be recorded at distinct point r2 (Fig. 3.3 c) if required.

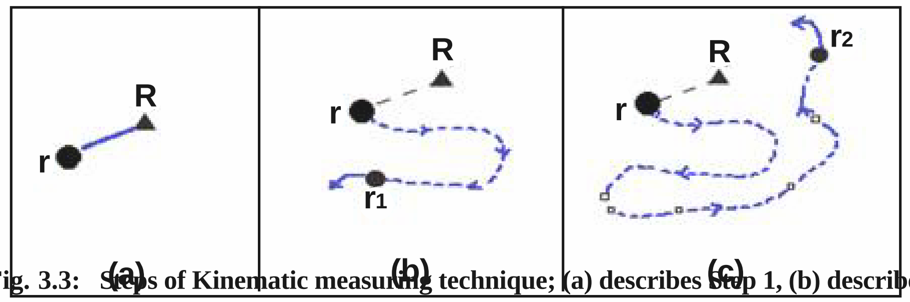


Fig. 3.3: Steps of Kinematic measuring technique; (a) describes Step 1, (b) describes Step 2 and (c) describes Step 3 (source: Leica Geosystems AG, 1999)

3.5.3 Real Time Kinematic (RTK)

Real Time Kinematic uses a radio data link to transmit satellite data from the Reference to the Rover. This enables coordinates to be calculated and displayed in real time, as the survey is being carried out. In RTK Survey the Rover has a radio link and receives the signal broadcast from the Reference. The Rover also receives satellite data directly from the satellites. These two sets of data can be processed together at the Rover to resolve the ambiguity and therefore obtain a very accurate position relative to the Reference receiver. When it is tracking satellites and receiving data from the Reference, it can begin the initialisation process. After initialisation the Rover can record point with the coordinate data. At this time, baseline accuracies will be in the 1-5 cm range. It is important to maintain contact with the Reference Receiver.

3.5.4 Stop-and-Go

Stop-and-go surveying is also known as semi-kinematic GPS surveying. Both methods are the same in principle; however, kinematic surveying requires no stops at the unknown points. The positional accuracy is expected to be higher with the stop-and-go surveying, as the errors are averaged out when the receiver stops at the unknown points.

The survey starts by determining the initial integer ambiguity parameters, known as *receiver initialisation*. Once the initialisation is performed successfully, positioning accuracy of centimetre-level can be obtained instantaneously. Following initialisation, the rover moves to the first unknown point and after collecting about 30 seconds of data, the rover moves, without being switched off, to the second point and the procedures are repeated. It is of utmost importance that at least four satellites are tracked, even during the move, otherwise the initialisation process must be repeated again by, reoccupying the previous point.

Now let us study about some of the GPS field survey procedures.

3.6 GPS FIELD SURVEY PROCEDURES

The following are some general GPS field survey procedures that should be performed at each point on a GPS survey. These general procedures apply to either static or kinematic observation methods and to either real-time or post-processed data collection.

1) **Receiver Setup:** GPS receiver can be set up in accordance with the manufacturer’s specifications prior to beginning of any survey task. Base station antennas are typically mounted on a tripod and kinematic rover receivers and antenna are mounted on fixed-height range poles. If real-time kinematic observations are being collected, then radio or satellite communication links needs to be set up.

2) **Antenna Setup:** All tribrachs used on a project should be calibrated and adjusted prior to the beginning of any survey. Dual use of both optical plummets and standard plumb bobs is strongly recommended since centering errors represent a major error source in all survey work, not just GPS surveying.

3) **Height of Instrument Measurements:** Height of instrument (HI) refers to the correct measurement of the distance of the GPS antenna above the reference mounted over which it has been placed. HI measurements should be made both before and after each observation session.

4) **Observation Recording Procedures:** Field recording books, log sheets, log forms should be completed for each station and/or session. The amount

of record keeping detail is project dependent. The following typical data should be included on these fields logging records.

i) Project name, and/or order number, etc.

ii) Station designation.

iii) Station file number.

iv) Date, weather conditions, etc.

v) Time start/stop session (local and UTC).

vi) Receiver, antenna, data recording unit and tribrach make, model and serial numbers.

vii) Antenna height: vertical or diagonal measures in inches (or feet) and meters (or centimeters).

viii) Space vehicle (SV) designations of satellites observed during sessions.

ix) Sketch of station location.

x) Approximate geodetic location and elevation.

xi) Problems encountered.

5) **Calibration and Initialisation:** When kinematic surveys are performed, it is necessary to calibrate the base station to a known local coordinate point and reference datum. An initialisation process is also required for some types of kinematic surveys. This can be checked with manufacturer's recommendations on specific techniques for calibrating RTK surveys to a local datum. These calibrations should be clearly noted on log records for the survey.

6) **Processing and Verification:** It is strongly recommended that GPS data processing and verification should be performed in the field where applicable. This is to identify any problems encountered during the survey period so that it can be corrected before returning from the field.

7) **Session Designations:** In GPS terminology a survey session refers to a single period of observations. Sessions and station designations are usually denoted and input into the data collector using alphanumeric characters. The station and session designations should be clearly correlated with entries on the log forms. The date of each survey session should be recorded during the survey. In addition to determination of station/session designations before the survey begins, the surveyor should consider or review some of the following factors:

- Satellite visibility for each station.
- Site reconnaissance data for stations to be occupied. Remember the same person who performed the initial site reconnaissance may not be the individual performing the survey; therefore, previous site reconnaissance data may require clarification before survey commencement.
- Explicit instructions on when each session is to begin and end, and follow-up sessions.
- Providing observers with data logging sheets for each occupied station.

8) **Station Log Forms:** Fig. 3.4 contains a sample log form used by various agencies. Standard bound field survey books may be used in lieu of separate log/work sheets.

Station Log Form

Project Name ________________________

Agency /Organisation ___________

Locality ________________________

Observer ______________________

Receiver ______________________ Serial No: ________________________________

Antenna ________________________ Serial No: ________________________________

Data Recording Unit _____________ Serial No: ________________________________

Tribrach ______________________ Serial No: ___________ Last Calibrated ______

	Session 1	**Session 2**	**Session 3**
Station Name	________	________	________
Station Number	________	________	________
Date MM/DD/YY	________	_______	________
UTC Time of Observation	________	________	________
Latitude	________	________	________
Longitude	________	________	________
Local Time Start	________	________	________
Local Time Stop	________	________	________
Weather Condition	________	________	________

Antenna Height Measurements

	Session 1	**Session 2**	**Session 3**
Slope Beginning	________	________	________
Slope End	________	________	________

Sketch Of Site

Session 1 **Session 2** **Session 3**

Describe any abnormalities and/or problems encountered during the survey; include session number, time of occurrence and duration.

Fig. 3.4: A Sample Station Log Form

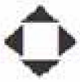
3.7 STEPS FOR CARRYING OUT GPS SURVEY

You should know about the basic steps for carrying out a survey with a handheld GPS Receiver.

There are different types of GPS receivers available in the market. But this section refers to a basic GPS device with its basic functions (Fig. 3.5).

There are several different keys on the GPS receiver that you need to become familiar with. Following are the basic keys that any basic GPS would have.

Power/Backlight Key: Power is used to turn the unit on and off. Press and release again to adjust the back lighting.



Up/Down/Right/Left Keys: The arrow keys let you select different items on the screen.

ENTER/MARK Key: To select or change something highlighted in the screen press the ENTER key. Enter key can be used any time to mark or record your current location.

PAGE/COMPASS Key: To move to a different screen, such as the map or the main menu or to close the on-screen keyboard, press the PAGE key.

QUIT: To go to the previous screen or to exit a page press QUIT key.

Fig. 3.5: A Typical GPS

Now let us study about how a GPS is used for finding a location, how to get from one location to another, etc.

1) **Finding your Location:** Now, turn on the GPS by pressing and releasing the POWER key. The main menu screen appears (Fig. 3.6a). A screen will appear that tells you about the satellites that are in range giving the GPS a good signal (Fig. 3.6b). This screen also tells you how much battery power

is left. Now hold the GPS at eye level and little away so that the top part has an unobstructed view of the sky. Now when the GPS has fixed its location, a new screen will appear (Fig. 3.6c) automatically the coordinates are displayed. If the GPS cannot fix its location then either top part of the GPS is obstructed to have a clear view of the sky or the GPS is in the wrong datum. (It is very important that you check the datum and the units you are using.) Move into a more open area and try again or change the datum.

2) **Saving Location:** After the GPS has displayed the coordinates of the location you can save the location in the displayed screen (Fig. 3.6d) by pressing the MARK key**.** A new screen (Fig. 3.6e) will appear with a number at the top of the screen that represents your location which is called a *WAYPOINT* in the GPS. Now the waypoint is saved and you can access this location at any time by switching the GPS on, pressing the PAGE key when the main menu screen appears, select the WAYPOINT LIST (Fig. 3.6f) using UP/DOWN arrow keys and press ENTER key, the coordinates of that location will appear on the screen.

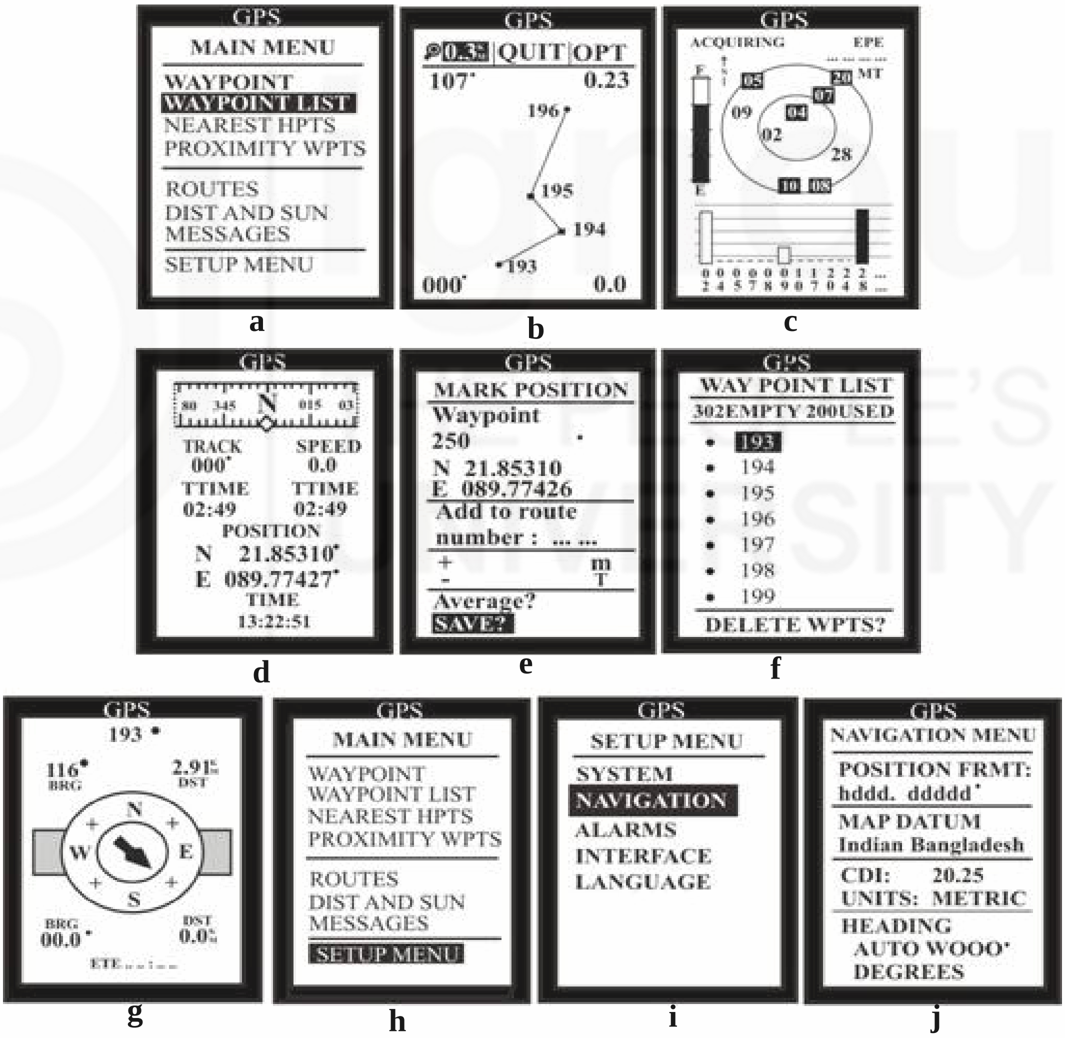


Fig. 3.6: Various screens of a GPS; (a) main menu screen, (b) satellites in range with good signals, (c) displaying coordinates, (d) saving the location by MARK key, (e) waypoint, (f) waypoint list, (g) direction of the way point, (h) set up menu, (i) navigation and (j) displaying datum

3) **Getting from One point (A) to Another (B):** Now if you press the GOTO button a list will appear of all the saved waypoints. You can use the UP/DOWN arrow keys to select the waypoint you are interested in and press the ENTER key. A new screen (Fig. 3.6g) will appear that will tell the

direction of the waypoint you have selected and how far it is from the location where you are standing. The distance is normally measured in kilometres (km).

4) **Changing Units and Datum:** If you need to change the units, press the PAGE key to get back to MAIN MENU screen (Fig. 3.6h) and now use the DOWN arrow key unit SETUP is highlighted and then press ENTER key and select the units part of the screen (Fig. 3.6i). If it is in the correct units then leave it as it is, if not then you can change the units by pressing ENTER key and use UP/DOWN arrow keys to select the right unit. To change or correct the datum (WGS84 or India/Bangladesh) (Fig. 3.6j) you can do in the same way that you have done for units using ENTER and UP/DOWN arrow keys. Once everything is set then press the QUIT key to return to the previous screen.

Check Your Progress II

Spend 5 mins

1) List out the basic steps to find the user location details using a GPS device.

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3.8 APPLICATIONS OF GPS

One of the most significant and unique features of the GPS is the fact that the positioning signals are available to users in any position worldwide at any time. GPS applications range from specialised fields like military, resource managers, surveyors and anyone else who wants to know their location, e.g., the nearest airport, nearest hospital, or locate points of interest. GPS is extensively used in defence, navigation and surveying applications. In addition to geo-science for measuring accurate time and frequency required for ionospheric and atmospheric studies, global climate changes, observing polar motion and Earth rotation rate, mapping the gravity field, detecting seismo-ionospheric effects, transport and communications, environment management, etc. GPS will soon be a part of the overall utility of technology. GPS is today being used for a wide spectrum of applications in India by various organisations. There are countless applications of GPS. You will read a few important ones covered in this section.

3.8.1 Military

GPS was originally developed for real time military positioning. Military applications include airborne, marine, and land navigation. Military aircraft, ships, submarines, tanks, jeeps and equipment use GPS technology for many purposes including basic navigation, target designation, close air support, weapon technology and rendezvous. GPS is also used in the combatants, vehicles, aircrafts and missiles are deployed over unfamiliar and non-uniform terrain. It is also suitable for marking the position of minefields and underground depots.

3.8.2 Navigation

Navigation using GPS can save countless hours in the field. GPS technology helps with marine navigation, traffic routing, underwater surveying, navigation in hazardous locations and their mapping. GPS navigation in helicopters, vehicles or ship can provide an easy means of navigation with substantial savings. Any feature, even if it is under water, can be located up to one hundred meters simply by scaling coordinates from a map, entering waypoints and going directly to the site. Examples include road intersections, corner posts, plot canters, accident sites, geological formations and so on. Commercial fishing fleets use it to navigate to optimum fishing locations and to track fish migrations. GPS technology helps with an automatic vehicle location and in-vehicle navigation systems. Many navigation systems show the vehicle's location on an electronic street map, allowing drivers to keep track of where they are and to look up other destinations. Some systems automatically create a route and give turn-by-turn directions. The car navigation system allows drivers to receive navigation instructions without taking their eyes off the road, via voice commands. GPS technology also helps to monitor and plan routes for delivery vans and emergency vehicles.

3.8.3 Surveying and Mapping

Using GPS technology, highly accurate surveying and mapping results can be rapidly obtained by reducing the amount of equipment and labour hours that normally are required for other conventional surveying and mapping techniques; especially over wide-areas for a geo-resource. Using GPS accurately and timely mapping of almost anything can be carried out. GPS provides accurate three-dimensional positioning information for natural and artificial features that can be displayed on maps and models of everything in the World Mountains, rivers, forests, endangered animals, precious minerals and many other resources. The GPS is used to map cut blocks, road alignments, and environmental hazards such as landslides, forest fires, and oil spills. Applications, such as cadastral mapping, needing a high degree of accuracy also can be carried out using high grade GPS receivers. Continuous kinematic techniques can be used for topographic surveys and accurate linear mapping.

3.8.4 Remote Sensing and GIS

GPS position information serves as a prime input to geographic information systems (GIS), that assemble, store, manipulate, and display geographically referenced information in a particular format. GPS has long been considered a technology that compliments GIS operations. It is also possible to integrate GPS positioning into remote-sensing methods such as mapping of geo-resources using photogrammetry and aerial scanning, and video technology. Today GPS has an established place in photogrammetry. Apart from determining the coordinates for ground reference points, GPS is regularly used to determine aerial survey navigation and camera coordinates. GPS is becoming very effective tool for GIS data capture. The GIS user community have benefited from the use of GPS for locational data capture in various GIS applications. The GPS can easily be linked to a laptop/computer in the field, and, with the help of appropriate software, users can also have all their data on a common base with every little distortion. The use of GPS within a GIS environment has already been well accepted and proven especially for data collection, and now data maintenance and information. Thus, GPS can help in several aspects of construction of accurate and timely GIS databases.

3.8.5 Aviation

Aviators throughout the world use the GPS to increase the safety and efficiency of flight. Aircraft pilots use GPS technology for enroute navigation and airport approaches. Satellite navigation provides accurate aircraft location anywhere on or near the Earth. The continuous global coverage capability of GPS permits aircraft to fly directly from one location to another, provided factors such as obstacle clearance and required procedures are adhered to. Incorporation of a data link enables the transmission of aircraft location to other aircraft and to air traffic control. New and more efficient air routes made possible by GPS are continuing to expand.

3.8.6 Environment

GPS technologies help survey disaster areas and map the movement of environment phenomena (such as forest fires, oil spills or hurricanes). It is even possible to find locations that have been submerged or altered by natural disasters. In land surveying, GPS has virtually become an exclusive method for pinpointing sites in basic networks. GPS has played a vital role in relief efforts for global disasters such as the tsunami that struck in the Indian Ocean region in 2004. Aerial studies of some of the world's most impenetrable wilderness are conducted with the aid of GPS technology to evaluate an area's wildlife, terrain, and human infrastructure.

3.8.7 Geodesy

GPS-based approach has become a widely used tool in geodetic studies of Earth. For geodetic surveying, the GPS with its economy and ease of operation has become the most preferred positioning method. Geodetic mapping and other control surveys can be carried out effectively using high-grade GPS equipment. Especially when helicopters are used or when the line of sight is not possible, GPS can set new standards of accuracy and productivity and it is used in order to carry out surveys (satellite geodesy) quickly and efficiently to achieve data well within an accuracy of a millimetre.

3.8.8 Time Measurement

In addition to longitude, latitude, and altitude, the GPS provides us with the opportunity of measuring time exactly on a global basis. Each GPS satellite contains multiple atomic clocks that contribute very precise time data to the GPS signals. GPS receivers decode these signals, effectively synchronising each receiver to the atomic clocks. This enables users to determine the time to within 100 billionths of a second, without the cost of owning and operating atomic clocks. Globally precise time measurements are necessary for synchronising control and communications facilities, for example, wireless telephone and data networks use GPS time to keep all of their base stations in perfect synchronisation. This allows mobile handsets to share limited radio spectrum more efficiently.

3.8.9 Land Survey Applications

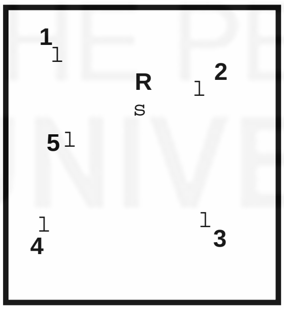
GPS does not need to be competitive against conventional techniques of surveying but can be employed for a wide range of activities. The advantages (and disadvantages) of GPS for land surveying applications can be classified into three categories. It is assumed that single receiver point positioning is not accurate enough to satisfy these applications. These three classes of applications (source: www.gmat.unsw.edu.au /snap/gps/gps_survey/chap2/ 232.htm) can be identified on the basis of range of relative accuracies:

- **Scientific** (better than 1ppm): surveys primarily encompass those surveys undertaken for precise engineering, deformation analysis, and geodynamic applications.
- **Geodetic** (1 to 10 ppm): surveys include geodetic surveys undertaken for the establishment, densification and maintenance of control networks to support mapping.
- **General Surveying** (lower than 10ppm): surveys primarily encompass lower accuracy surveys, primarily undertaken for urban, cadastral, geophysical prospecting, GIS and other general purpose mapping applications.

Users in the geodetic and general surveying categories form the majority of the GPS user community, while scientific category users often provide the primary "technology-pull" for the development of new instrumentation and processing strategies.

3.9 ACTIVITY

Looking at the following figure you list out the steps to measure a network 12345 by setting up two reference stations and use one rover to occupy the points.



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3.10 SUMMARY

In the present unit, you have studied that:

- High accuracies from GPS technology can be achieved with relatively less effort. GPS survey results are, in general, more accurate.
- The major advantage of GPS survey over conventional surveying technique is that the line of sight does not have to be established between two stations.

- GPS survey requires different planning, execution and processing techniques. Planning a GPS survey has to consider several parameters, such as site or satellite configurations, the number and type of receivers to be used and also the economic aspects.
- The application of GPS are endless, ranging from surveying properties, shipping, aviation, navigation to even charting the ocean depth, aerial survey, agriculture and forestry, etc.
- GPS can save lives by preventing transportation accidents, aiding search and rescue efforts, and speeding the delivery of emergency services and disaster relief.
- There are certain limitations for the usages of the GPS units which are actually guided more by the location parameters.

3.11 UNIT END QUESTIONS

Spend 30 mins

1) What are the elements of GPS survey planning process?
2) What is the difference between Static and Rapid Static Survey techniques?
3) Write in brief about applications of GPS.

3.12 REFERENCES

- Leica Geosystems AG, (1999), *GPS Basics* 1.0.0en, Heerbrugg, Switzerland, 64p.
- www.gmat.unsw.edu.au/snap/gps/gps_survey/chap5/521.htm.
- www.gmat.unsw.edu.au/snap/gps/gps_survey/chap2/232.htm.

(Data from above websites have been retrieved between 20th August and 20th September 2011.)

3.13 FURTHER/SUGGESTED READING

- Ahmed El-Rabbany, A.El. (2002), *Introduction to GPS: The Global Positioning System*, Artech House, 176p.
- Kaplan, E.D. and Hegarty, C. (2005), *Understanding GPS Principle and Applications*, Artech House Publishers, Norwood, 706p.
- Mc Namara J. (2008), *GPS for Dummies*, 2nd Ed., Willey Publishing Inc., River Street Hoboken, 408p.
- www.gps.gov/applications.

3.14 ANSWERS

Check Your Progress I

1) Refer to section 3.3.

Check Your Progress II

1) Refer to section 3.7.

Unit End Questions

1) **Hints**: You have to describe in brief about the planning elements- project design, observation scheduling, logistical considerations and reconnaissance.

2) Static survey is used for measuring long baselines in geodetic networks and offers a high accuracy whereas Rapid Static is used for densifying existing networks and establishing local control networks and is much faster than the Static technique.

3) The introduction of GPS has truly revolutionized the field of modern surveying, mapping and navigation tasks. From precision positioning to mapping, commercial applications to scientific studies, navigational and positioning applications, including navigation on land, in air and on sea, small scale maps to large scale maps, determining the precise coordinates of important geographical features as an essential input to mapping and Geographical Information System (GIS), precise cadastral surveys, earthquake and landslide monitoring, surveying, geodetic control networks, vehicle guidance in cities and on highways using GPS-GIS integrated systems, crustal and structural deformation studies.

GLOSSARY

- **Antispoofing (AS):** It is the mechanism of encrypting the P-code by W-code to produce a new Y-code, in order to prevent replication by potentially hostile forces

- **Atmospheric Propagation Delay:** It is the time delay affecting satellite signals due to tropospheric layers of the Earth's atmosphere.

- **Azimuth:** It is the geographic orientation of a line given as an angle measured in degrees clockwise from north.

- **Bandwidth:** It is a measure of the width of the spectrum of a signal (frequency domain representation of a signal) expressed in Hertz.

- **Baseline:** It is the length of the three-dimensional vector between a pair of stations for which simultaneous GPS data has been collected and processed with differential techniques.

- **Binary Biphase Modulation:** GPS signals are biphase modulated. Phase changes of either 0° or 180° (to represent binary 0 or 1, respectively) on a constant frequency carrier.

- **C/A-Code:** It is the standard (Clear/Acquisition) GPS PRN code, also known as the Civilian Code or S-Code.

- **Carrier:** It is a radio wave having at least one characteristic (e.g., frequency, amplitude, phase) that can be varied from a known reference value by modulation.

- **Constellation:** It is the specific set of satellites used in calculating a position, or all the satellites visible to a GPS receiver at one time, or the entire ensemble of GPS satellites comprising the Space Segment.

- **Deception Jamming:** It is a technique in which an adversary would replicate one or more of the satellite ranging codes, navigation data signal(s), and carrier frequency

- **Delay Lock:** It is the technique whereby the received code (i.e. generated by the satellite clock) is compared with the internal code (i.e. generated by the receiver clock) and the latter shifted in time until the two codes match.

- **Differential GPS:** It is a technique to minimise the error in GPS derived positions by using extra data from a reference GPS receiver at a known location in order to enhance the accuracy of measurements made by other GPS receivers within the same general geographic area.

- **Dithering:** It is the introduction of digital noise into the system.

- **Doppler Shift:** It is the apparent change in frequency of a received signal due to the rate of change of the range between the transmitter and receiver.

- **Ellipsoid:** In geodesy, unless otherwise specified, it is a mathematical figure formed by revolving an ellipse about its minor axis (sometimes also referred to as spheroid).

- **Ephemeris:** It is a list of positions or locations of a celestial object as a function of time.

- **GNSS:** It is a global navigation satellite system made up a network of satellites that transmit ranging signals used for positioning and navigation anywhere around the globe as well as air or sea.

- **Ionosphere:** It is the portion of the Earth's external atmosphere where ionisation caused by incoming solar radiation changes the propagation of radio waves. It extends from about 70 km to 1000 km above the Earth surface.

- **Kinematic Positioning:** It refers to applications in which the position of a non-stationary object (vehicle, ship, aircraft) is determined.

- **L1 Frequency:** It is the 1575.42MHz GPS carrier frequency which contains the C/A-Code, the encrypted P-Code (or Y-Code) and the Navigation Message.

- **L2 Frequency:** It is the 1227.60MHz GPS carrier frequency which contains only the encrypted P-Code (or Y-Code) and the Navigation Message.

- **Local Area Augmentation System:** It is a plan by which Local Area Differential GPS (LADGPS) generates and transmits differential corrections to appropriately equipped aircraft users.

- **National Marine Electronics Association:** It is U.S. standards body that defines message structure, content and protocols to allow electronic equipment installed within ships and boats to communicate with each other.

- **Optical Plummets:** It is a device used to center the instrument over a point, in place of a plumb bob, which moves in a strong wind.

- **Payload:** It is the carrying capacity of an aircraft or space ship including cargo, munitions, scientific instruments or experiments.

- **P-Code:** It is a very long sequence of PRN binary biphase modulations on the GPS L1 and L2 carrier at a chip rate of 10.23MHz, which repeats about every 267 days.

- **Plumb Bob:** It is a weight, usually with a pointed tip on the bottom that is suspended from a string and used as a vertical reference line.

- **Pseudorandom Noise (PRN) Code :** It is any group of binary sequences that appear to be randomly distributed like noise, but which can be exactly distributed.

- **Pseudorange:** This refers to the calculated range from the GNSS receiver to the satellite found out by taking the difference between the measured satellite transmit time and the receiver time of measurement, and multiplying by the speed of light.

- **Real Time Kinematic:** It is the Relative Positioning procedure whereby carrier phase measurements (or corrections) are transmitted in real-time from a Reference or Base Station to the user's roving receiver.

- **Real-Time DGPS:** It is a Base Station that computes, formats, and transmits pseudorange corrections via some sort of data communication link.

- **Receiver Independent EXchange Format:** It is a set of standard definitions and formats to promote the free exchange of GPS data and facilities the use of data from any GPS receiver with any post-processing software package.

- **Rover:** It is any mobile GPS receiver collecting data during a field session.
- **Satellite Ephemeris:** It is the data which contains orbital information and allows the receiver to calculate the position of the satellite.
- **Satellite-Based Augmentation System:** It is a geo-stationary satellite based system that enhances the accuracy, integrity, and availability of the basic GNSS signals.
- **Selective Availability:** It is the intentional degradation of the absolute positioning performance capabilities of the NAVSTAR satellite system for civilian use by the US military.
- **Solution Independent Exchange Format:** It is a solution output format developed by geodesists to permit the exchange of solution information between organisations, from which the original normal equation systems for precise GPS adjustments can be reconstructed.
- **Static Positioning:** It is the location determination when the receiver's antenna is presumed to be stationary on the earth.
- **Tribrach:** It is the detachable base of all total stations, and they are also used to attach prism to a tripod**.**
- **Trilateration:** It is the mathematical process of calculating the position of any geo-object in terms of latitude, longitude, altitude, speed, direction and time from signals received by GNSS receivers.
- **Tripod:** It is a portable three-legged frame used as a platform for supporting the weight and maintaining the stability of some other object.
- **Troposphere:** It is the most important layer of the atmosphere with the average height is 13 km. The air we breathe exists here.
- **Universal Coordinated Time**: It is the time standard by which the world regulates clocks and time.
- **Waypoint:** It is a (usually two-dimensional) coordinate that is input into a navigation device, such as a GPS receiver, representing a position that a vessel, aircarft, vehicle or person has to navigate to, with the aid of GPS.
- **WGS84:** It is an Earth fixed global reference frame used for defining coordinates when surveying and by GPS systems.
- **Wide Area Augmentation System:** It is a US Federal Aviation Authority (FAA) funded system of equipment and software that augments GPS accuracy, availability and integrity.
- **World Geodetic System 1984:** It is a global Geodetic Datum defined and maintained by the US Department of Defense.
- **Y-Code:** It is the term used to refer to the encrypted P-Code, generated within the satellites and transmitted on both the L1 and L2 carrier signals under the policy of "Anti-Spoofing".

ABBREVIATIONS

AS	:	Antispoofing
BBS	:	Bulletin Board System
C/A Code	:	Coarse/Clear Acquisition Code
CDMA	:	Code Division Multiple Access
CS	:	Commercial Services
DGPS	:	Differential GPS
ES	:	EGNOS Services
EU	:	European Union
FDMA	:	Frequency Division Multiplex Access
FOC	:	Full Orbit Constellation
GAGAN	:	Geo Augmented Navigation system
GBAS	:	Ground Based Augmentation Systems
GCC	:	Galileo Control Center
GCS	:	Galileo Combined Services
GLAS	:	Galileo Locally Assisted Services
GLONASS	:	GLObal NAvigation Satellite System or GLObalnaya NAvigatsionnaya Sputnikovaya Sistema
GNSS	:	Global Navigation Satellite System
GPS	:	Global Positioning System
GSOS	:	Galileo Satellite Only Services
LAAS	:	Local Area Augmentation System
LORAN	:	Long Range Aid to Navigation
NMEA	:	National Marine Electronics Association
OS	:	Open Services
P Code	:	Precise code
PPS	:	Precise Positioning System
PRS	:	Public Regulated Services
RINEX	:	Receiver INdependent EXchange format
RTK	:	Real-Time Kinematic Float
S/A	:	Selective Availability
SBAS	:	Satellite Based Augmentation Systems
SINEX	:	Solution Independent Exchange format
SoL	:	Safety to Life Services
SPS	:	Standard Positioning System
TOA/ToA	:	Time of Arrival
UT	:	User Terminal
UTC	:	Universal Coordinated Time
WAAS	:	Wide Area Augmentation System
WADGPS	:	Wide Area DGPS