The position of stationary or moving object can be determined through GPS. When the position of a stationary or moving object is determined with respect to a well defined coordinate (x, y, z) by using a single GPS receiver and by making observations to four or more satellites, it is called *point positioning* or *absolute positioning* (Fig. 9.10). However, if the coordinates of an unknown point are determined with respect to a known point (taking this as origin of a local coordinate system), it is called *relative positioning*. In other words, relative positioning aims at determination of the vector between the two points, by observations to four or more satellites by two receivers placed at the two points simultaneously (Fig. 9.11). In case the object to be positioned is stationary, it is termed as *static positioning*, while if the object is moving, it is called *kinematic positioning*. GPS surveying implies the precise measurement

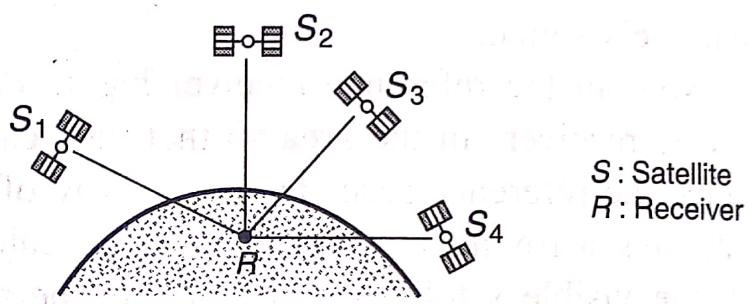
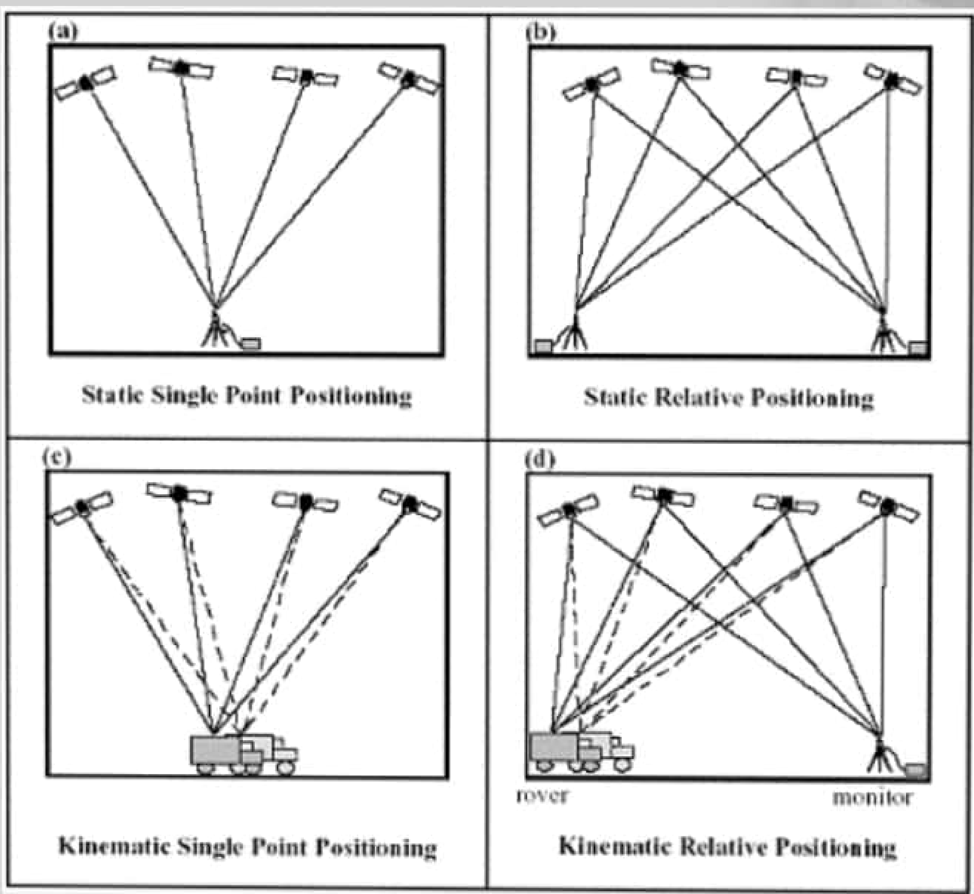


Fig. 9.10 *Point positioning*

Static Vs Kinematic Positioning

- GPS positioning may also be categorized as Static or Kinematic.
- In static positioning, a GPS receiver is required to be stationary whereas in Kinematic positioning a receiver collects GPS data while moving.
- For Kinematic relative positioning, one receiver, referred to as a monitor or base, is left stationary on a known point while a second receiver, referred to as a rover, is moved over the path to be positioned.



Static & Kinematic positioning for both single point and relative positioning

7. GPS 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.

7.1 Correctable Errors

Sources of correctable errors include satellite clock, ephemeris data and ionospheric and tropospheric delay, satellite geometry/shading. If implemented, SA (Selective Availability) may also cause a correctable positioning error.

7.1.1 Receiver Clock Errors

A receiver's built-in clock is not as accurate as the atomic clocks onboard the GPS satellites. Therefore, it may have very slight timing errors.

7.1.2 Orbital Error/Ephimeris Error

An ephemeris error is a residual error in the data used by a receiver to locate a satellite in space. These are inaccuracies of the satellite's reported location.

7.1.3 Ionosphere and Troposphere Delays

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 tropspheric delay is related to humidity, temperature, and altitude along the signal path. Usually, a tropospheric error is smaller than an ionospheric error.

7.1.4 Intentional Degradation of the Satellite Signal

Selective Availability (SA) is an intentional degradation of the signal once imposed by the U.S. Department of Defence. SA was intended to prevent military adversaries from using the highly accurate GPS signals. The government turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

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.

7.2 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.

7.2.1 Multipath Error

This occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.

The error sources and the approximate error range are given below:

Table 2: Sources of GPS error

Error Source	Approx. Equivalent Range Error in meters
Correctable with Differential	
Clock(Space Segment)	3.0
Ephemeris(Control Segment)	2.7
Ionospheric Delay	8.2
Tropospheric Delay	1.8
Selective availability(if implemented)	27.4
Non-Correctable with Differential	
Receiver Noise	9.1
Multipath (Environmental)	3.0

8. Differential GPS (DGPS)

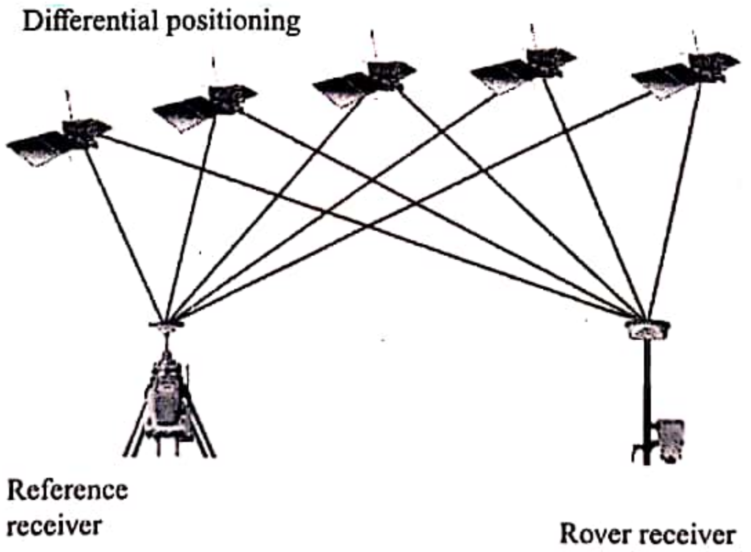
DGPS uses a second, stationary GPS receiver at a precisely measured spot (usually established through traditional survey methods). This receiver can correct many errors found in the GPS signals, including atmospheric distortion, orbital anomalies, Selective Availability (when it existed), and other errors. A DGPS station is able to do this because its processor already knows its precise location, and can easily determine the amount of error provided by the GPS signals by comparing its known location with the erroneous position data provided by the GPS.

DGPS corrects or reduces the effects of:

1. Orbital errors
2. Atmospheric distortion
3. Selective Availability
4. Satellite clock errors
5. Receiver clock errors

DGPS cannot correct for GPS receiver noise in the user's receiver, multipath interference, and user mistakes.

In order for DGPS to work properly, both the user's receiver and the DGPS station receiver must be accessing the same satellite signals at the same time. This requires that the user's receiver not be more than 300 miles from the DGPS station (100 miles or less is considered optimum). Let's take an example. Let a DGPS station receives GPS signals telling the station that its location is x+5, y-3. But the station already knows that its true location is x+0, and y+0. So it calculates a correction of x-5, y+3, and transmits this correction out to the field on its own frequency. The DGPS receiver in the field uses this correction factor to update the



same GPS radio signals its receiving. Here the GPS receiver triangulates its position with GPS as x+30, and y+60. The DGPS receiver provides the correction factor to the other GPS receiver's processor, which calculates its correct position by subtracting 5 from 'x' co-ordinate and adding 3 with the 'y' co-ordinate. The user can generally get accurate position fixes within a few meters or less using DGPS.

Many high-end GPS receivers have built in DGPS capability, while some low-end receivers (including some Garmin models) can be configured for DGPS using add on hardware. There are a number of free and subscription services available to provide DGPS corrections. The U.S. and Canadian Coast Guards and U.S. Army Corps of Engineers transmit DGPS corrections through marine beacon stations.

The Wide Area Augmentation System (WAAS) is being developed by the Federal Aviation Administration (FAA) as another kind of highly advanced DGPS.