Modern Surveying Techniques

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Lecture - 3

GPS Positioning Methods

The different types of GPS positioning methods can be broadly categorized into 2 categories. First, the standard positioning service and the second is precise positioning service. So, let us look at what actually a standard positioning service.

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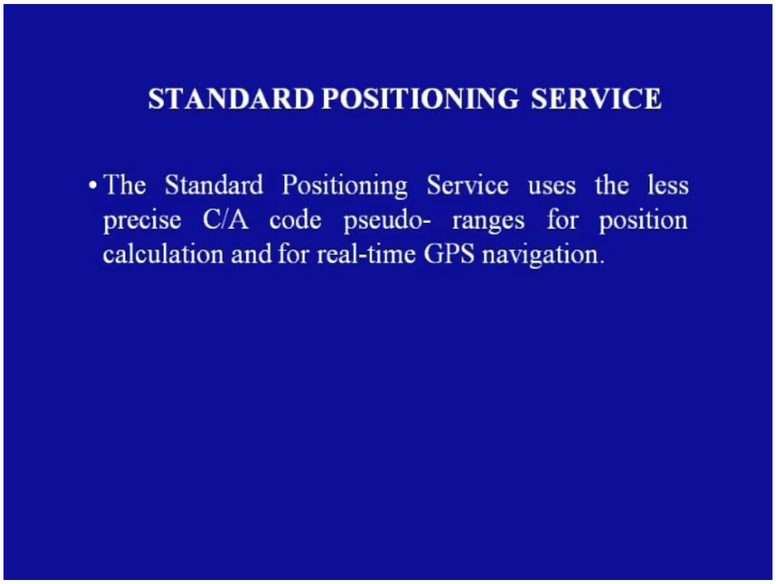

The standard positioning service uses the less precise C/A code pseudo-ranges for position calculation and for the real-time GPS navigation. This means that this is a low order data collection procedure. The accuracies obtained in this particular positioning system would be of a lower order.

The second type of positioning system is the precise positioning service, in short known as PPS.

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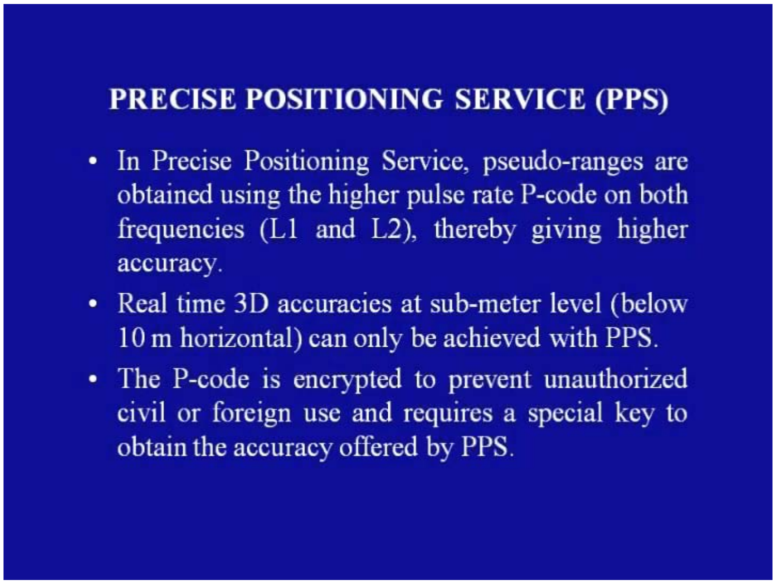

In precise positioning service, pseudo-ranges are obtained using high pulse rate P-code on both frequencies L1 and L2, thereby giving higher accuracy. Real time 3D coordinates at sub-meter level below 10 meter horizontal can be achieved with PPS.

The P- code is encrypted to prevent unauthorized civil or foreign use and requires a special key to obtain the accuracy offered by PPS. In order to understand the positioning system, let us look at the carrier phase measurement which actually helps us in identifying what is the time difference between the satellite transmission and the receiver obtaining the signal.

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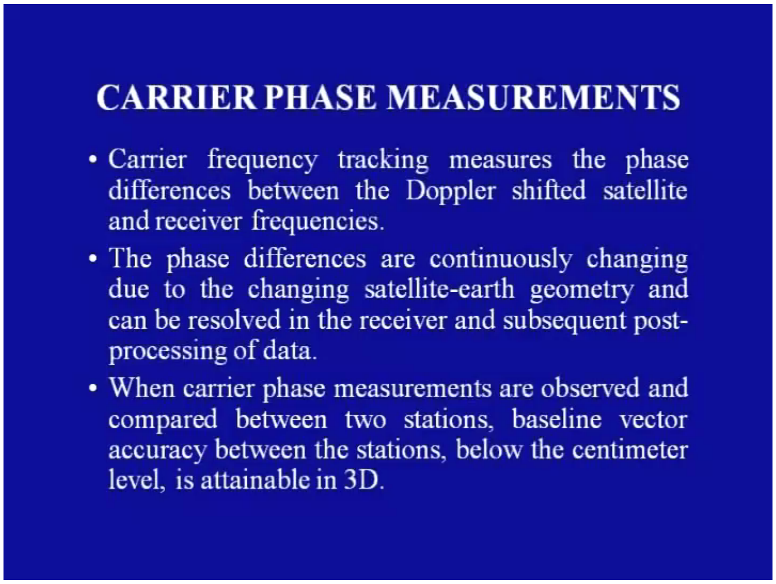

Carrier frequency tracking measures the phase differences between the Doppler shifted satellite and the receiver frequencies. The phase differences are continuously changing due to the changing satellite -earth geometry and can be resolved in the receiver and the subsequent post processing of the data. When carrier phase measurements are observed and compared between 2 stations, baseline vector accuracy between the stations below the centimeter level is attainable in 3 dimensions, that is x, y and z.

In order to understand the process of the data collection procedure using a GPS, it is important to understand what is the message which is being broadcasted by each of the satellite. For this, let us look at what does GPS broadcast.

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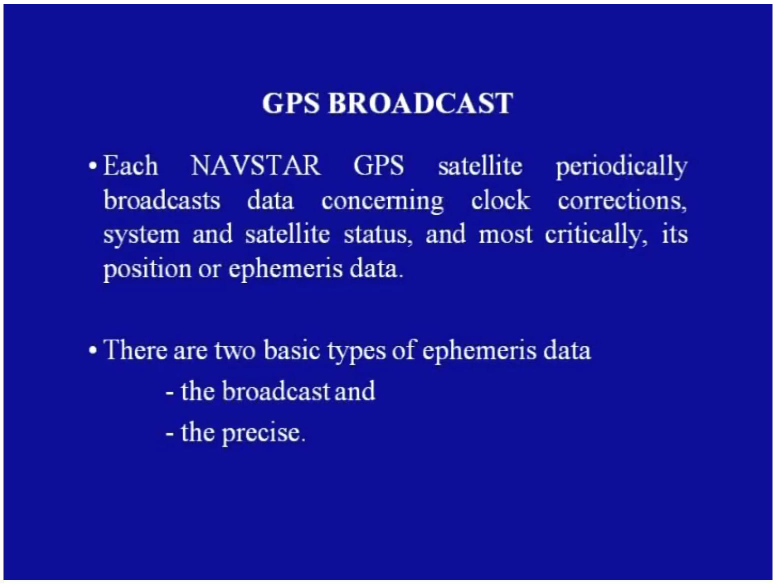

Each NAVSTAR GPS satellite periodically broadcast data concerning clock corrections, systems and satellite status and most critically, its position or ephemeris data. This is a very important information in GPS point calculation procedures. Without this 1 cannot expect a good result or an answer through a GPS observation set up.

So, let us look at what are the 2 basic type of ephemeris data's that we have. First is the broadcast and the second is the precise. So, let us look at each of them 1 by 1.

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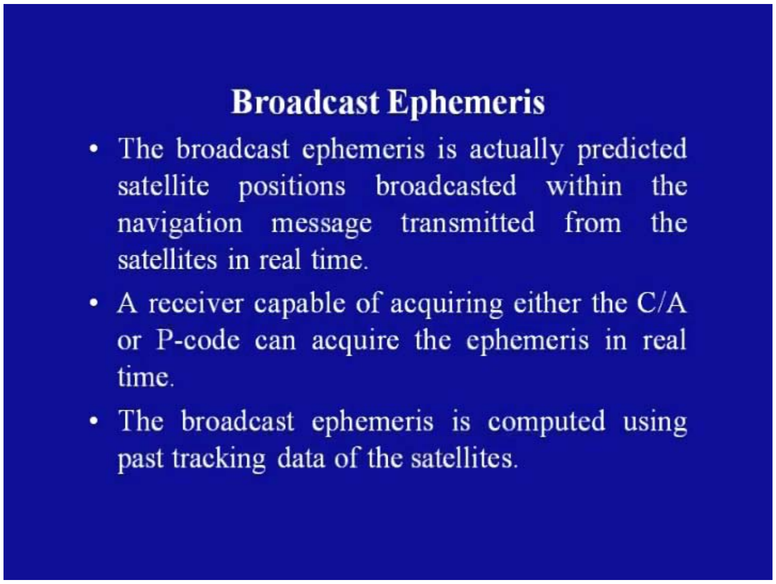

The broadcast ephemeris is the first which needs to be understood. The broadcast ephemeris is actually predicted satellite position, broadcasted within the navigation message transmitted from the satellite in real time. A receiver capable of acquiring either the C/A code or P code can acquire the ephemeris in real time. The broadcast ephemeris is computed using past tracking data of the satellites.

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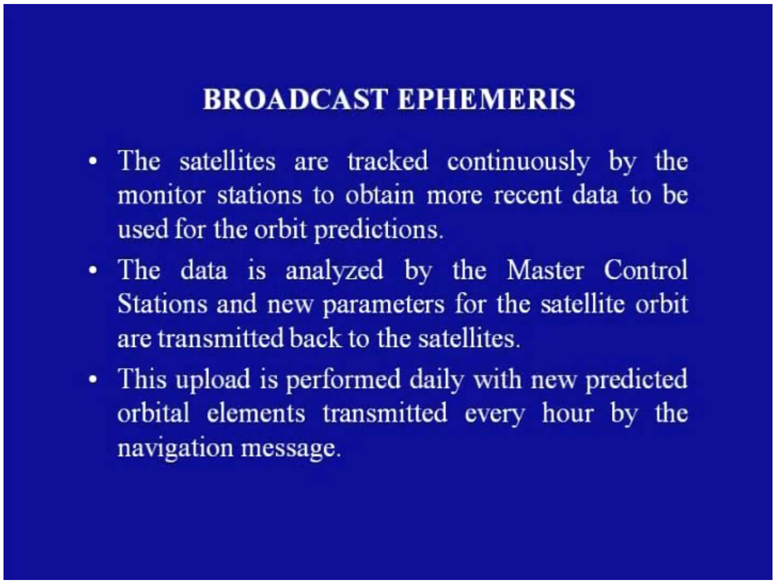

The satellites are continuously tracked by the monitor station to obtain more recent data to be used for the orbit predictions. The data is analyzed by the master control station and the new

parameters of the satellite orbit are transmitted back to the satellites. This upload is performed daily with new predicted orbital elements transmitted every hour by the navigation message.
The second GPS broadcast which is performed is the precise ephemeris.

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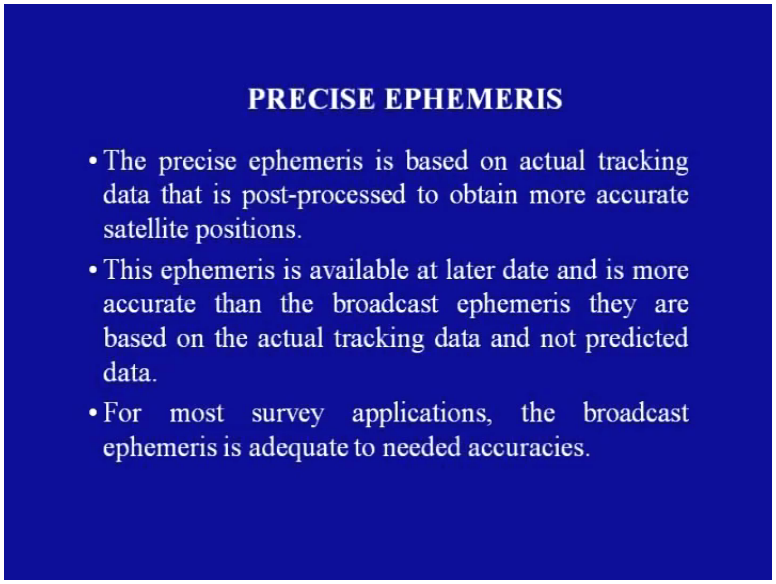

The precise ephemeris is based on actual tracking data that is post processed to obtain more accurate satellite position. This ephemeris is available at a later date and is more accurate than the broadcast ephemeris. They are based on the actual tracking data and not on the predicted data. Thereby, any user who is interested in obtaining very precise point position, coordinates of a point must use the precise ephemeris rather than the broadcast ephemeris which is available on a predicted basis of the satellite data.

For most survey applications, the broadcast ephemeris is adequate to needed accuracies. Another important data which is of importance to the user and that is the almanac data.

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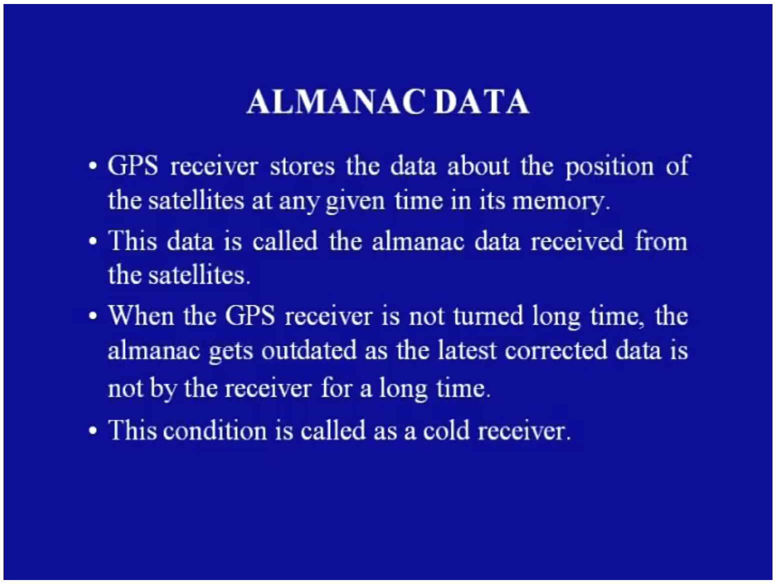

GPS receivers store the data about the position of the satellites at any given time in its memory. This data is called the almanac data received from the satellites. When the GPS receiver has not been turned on for a long time, the almanac gets outdated as the latest corrected data is not received by the receiver for a long time. This condition is called as a cold receiver.

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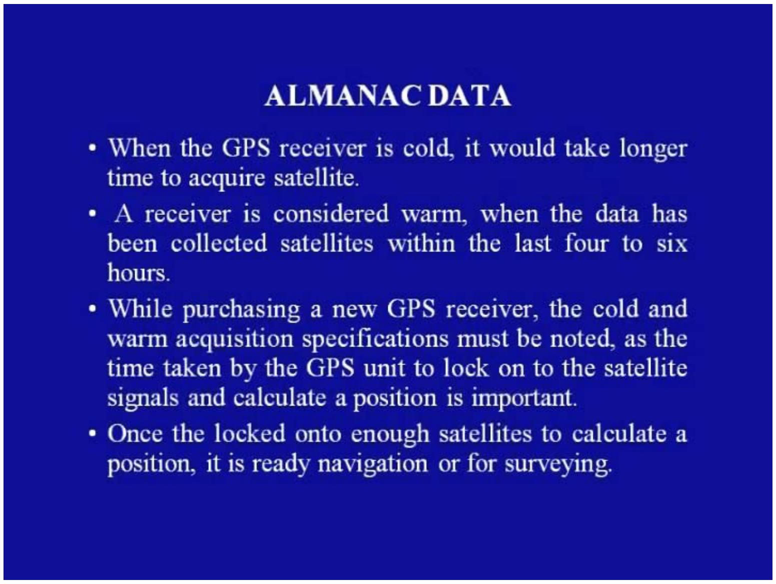

When the GPS receiver is cold, it would take longer time to acquire the satellite positions. A receiver is considered warm, when the data has been collected for satellites within the last 4 to 6 hours. While purchasing a new GPS receiver, the cold and the warm acquisition specifications must be noted as the time taken by the GPS unit to lock on to the satellite signals and to calculate a position is important. Once locked onto enough satellites to calculate a position, it is ready for navigation or for surveying activities.

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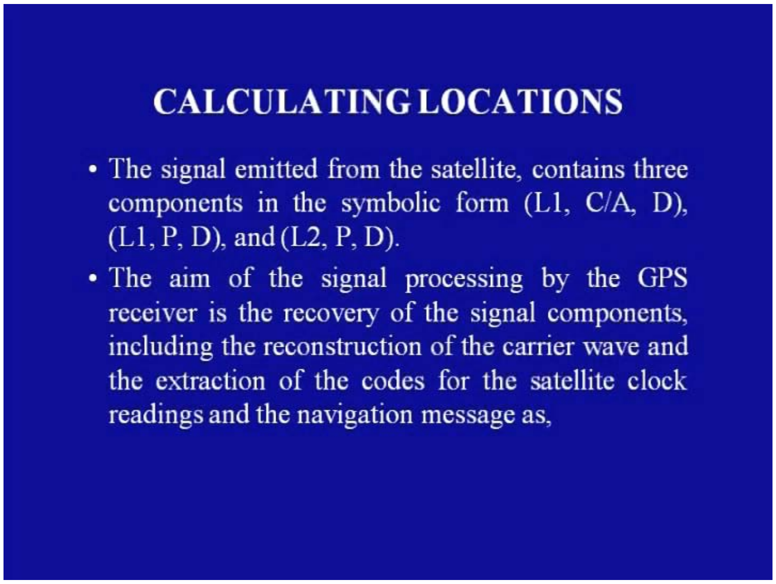

Now, let us look at how do we calculate the locations on the ground. The signal emitted from the satellite consist of 3 components in the symbolic form of L1, C/A and D, L1, P, D and L2, P and D. Basically, these are nothing but the specifications of the carrier waves; the type of code it is carrying and the distance that it has.

The aim of the signal processing by the GPS receiver is the recovery of the signal components, including the reconstruction of the carrier waves and the extraction of the codes of the satellite clock readings and the navigation message.

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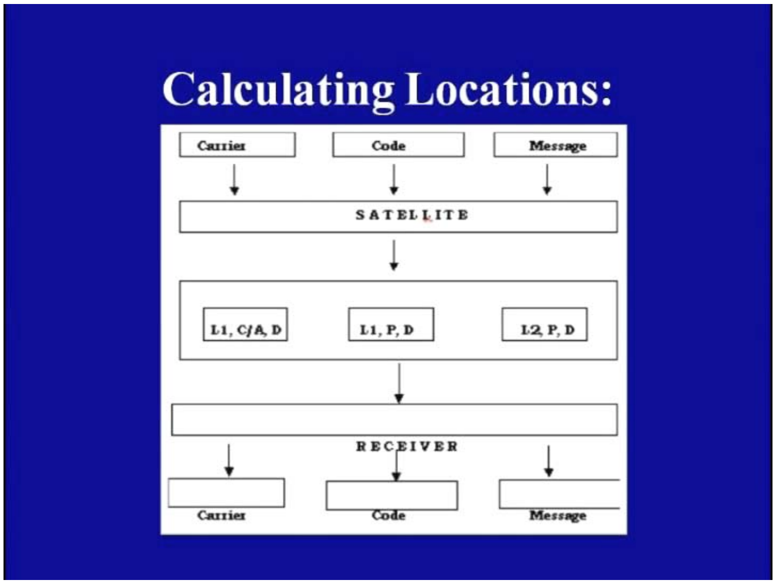

In this particular slide, a block diagram of calculating the location has been provided. One can see that a satellite will primarily have 3 basic informations. One is the carrier, the other is the code and the third is the message.

These are translated into L1, C/A, D, L1, P, D and L2, P, D. These are now recorded by the receiver which again reconstructs this information into carrier code and message for subsequent post-processing of the data.

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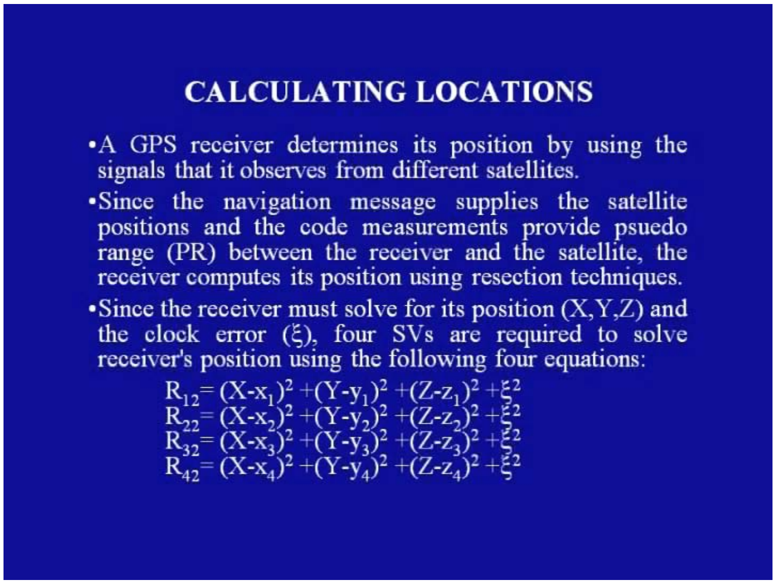

In order to calculate the locations of a point, a GPS receiver determines its position by using the signals that it receives from different satellites. Since, the navigation message supplies the satellite positions and the code measurements provides pseudo-range between the receiver and the satellite, the receiver computes its position using resection techniques.

Here, the receiver must solve for its position. That is X, Y and Z and the clock error xi from 4 satellite vehicles to solve the receiver's position using the following equation as given below. That is distance R_1, that is between the satellite 1 and the receiver is equal to X capital X minus x_1 whole square plus capital Y minus y_1 whole square plus capital Z minus z_1 whole square plus xi square. So, this gives the square of the distance between the satellite and the receiver position. Similarly, the other distances R_2, R_3 and R_4 can be computed on the similar basis as explained earlier.

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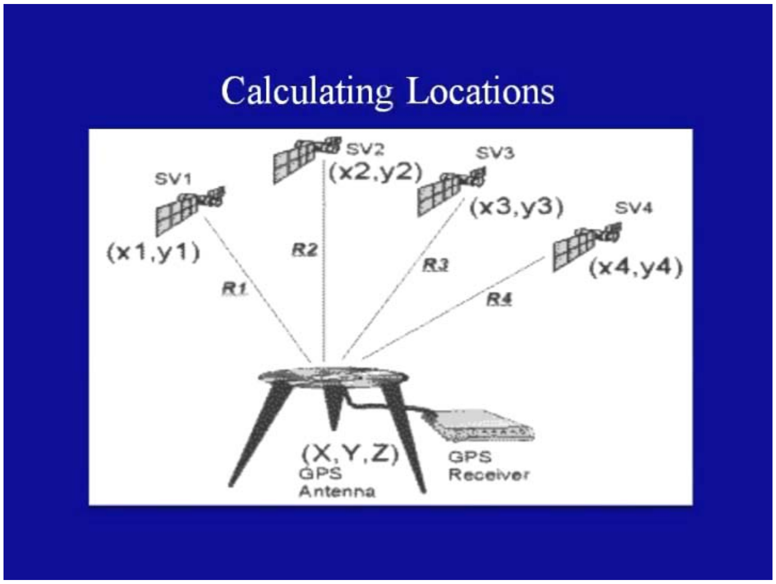

To give a better idea, let us look at this particular illustration which shows a GPS receiver located at a point whose values are unknown at this present point of time and they are designated as capital X, capital Y and capital Z.

Now, this particular receiver is in contact with minimum 4 satellite vehicles; in short we call them as SV1, SV2, SV3, SV4 having spatial coordinates X1 Y1, X2 Y2, X3 Y3, X4 Y4 respectively and the distance between the receiver and each of the satellite vehicles have been designated as R1, R2, R3, R4 and they can be computed by the equations as discussed.

By solving the 4 equations that we have, we can now find out the 4 unknowns which are there which will help us in determining the positions. That is X, Y and xi. That is the position or the location of the station is now calculated.

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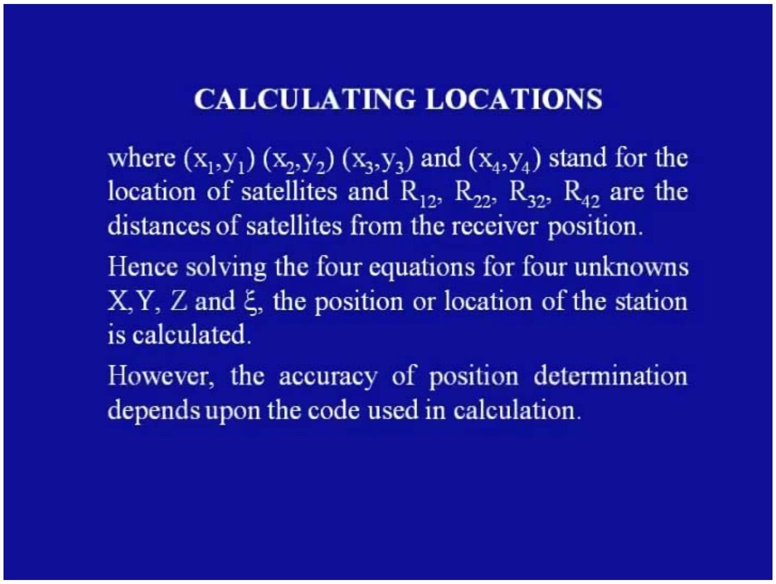

However, the accuracy of the position determination depends upon the code used in the calculation. When we are talking about the type of code which is there, let us look at what type of accuracies that we may have using different type of codes.

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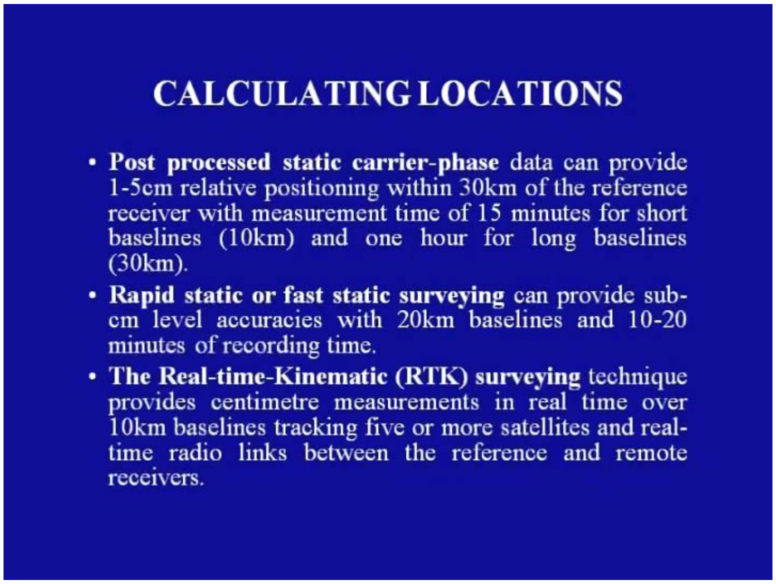

First is post processed static carrier - phase data which can provide us about 1 to 5 centimeter relative positioning within 30 kilometers of the reference receiver with measurement times of 15 minutes for short baselines of the length of 10 kilometers and 1 hour for long baselines of the order of 30 kilometers.

In rapid static or fast static surveying can provide sub-centimeter level accuracies with 20 kilometer baselines and 20 to 10 to 20 minutes of recording time. In real time kinematic surveying mode which we call in short as RTK technique, it provides centimeters measurements in real time over 10 kilometer baselines tracking 5 or more satellites and real time radio links between the reference and the remote receivers.

So, this identifies the procedure of computing the distance between the satellite vehicle and the GPS antenna which is located at an unknown position and also we have discussed the procedure in short regarding the type of accuracy that can be achieved and the time taken for the observation to achieve that level of accuracy.

We now, move ahead to look at different types of GPS positioning that we have.
Well, there are 2 main modes of GPS position.

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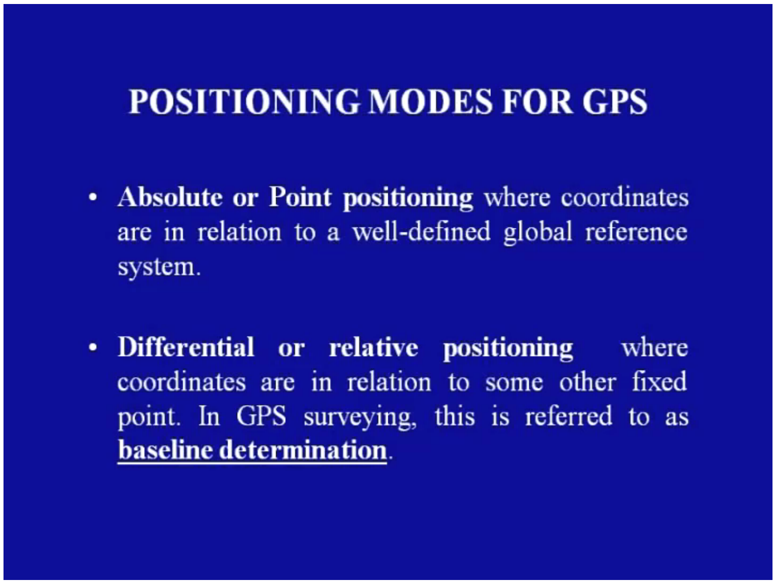

The first is absolute or point positioning where coordinates are in relation to a well defined global reference system. We all know that the word has a well defined coordinate system which is in terms of latitude and longitude, which defines the 2 dimensional spatial coordinate and Z defines the elevation.

If the user is interested in performing the GPS operation at a very small time without tying its observation to the real world then in that case, he may go for a differential or relative positioning where the coordinates are in relation to some fixed point. In GPS surveying this is referred to as baseline determination.

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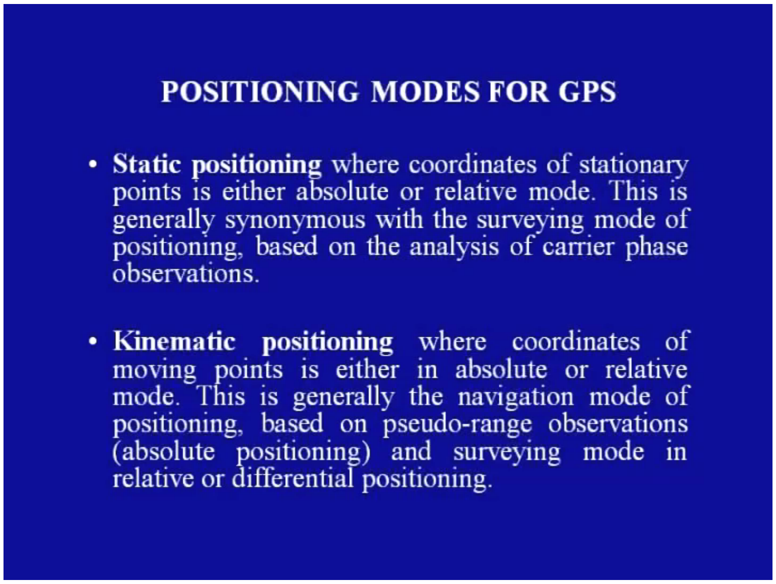

Another category of positioning mode is the static positioning where the coordinates of the stationary points are either absolute or in relative mode. This is generally synonymous with the surveying mode of positioning based on the analysis of the carrier phase observations. Other type is the kinematic position where the coordinates of moving points either in absolute or relative mode are to be determined.

This is generally the navigation mode of positioning based on the pseudo range observation that is absolute positioning and the survey mode in relative or differential positioning. So now, let us look at each of the mode that we have. First is the navigation mode and the next is the surveying mode.

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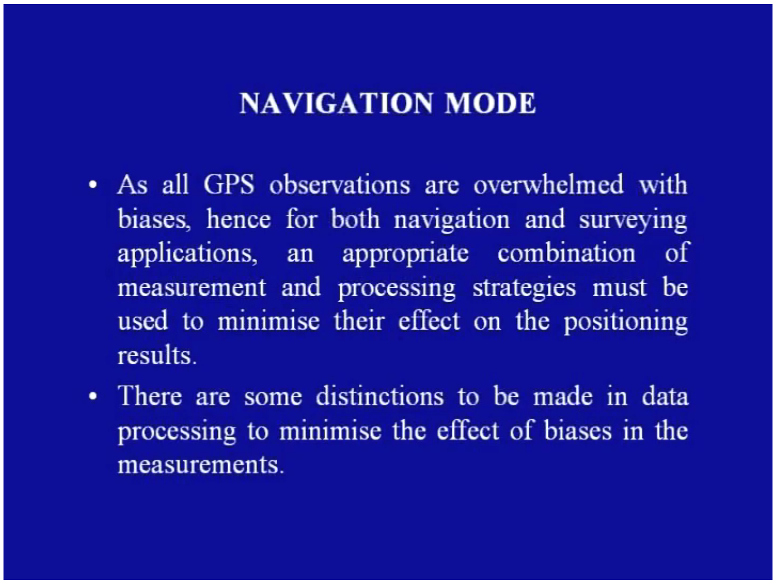

In navigation mode, GPS observations are generally found to be overwhelmed with biases. Hence, for both navigation and surveying applications, an appropriate combination of measurement and processing strategies must be used to minimize their effect on the positioning results. There are some distinctions to be made in data processing to minimize the effect of biases in the measurement techniques.

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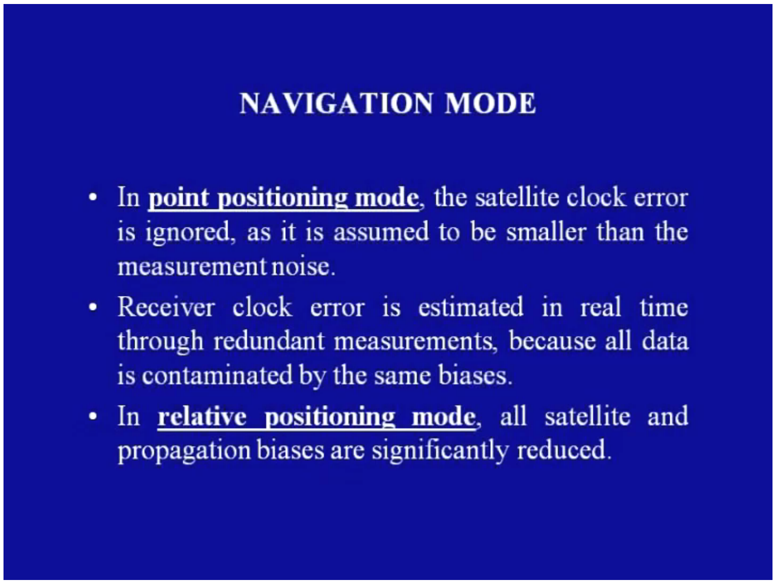

In point positioning mode, the satellite clock error is ignored as it is assumed to be smaller than the measurement noise. The receiver clock is estimated in real time through redundant measurements because all data is contaminated by the same amount of bias which is present in the observation. In relative positioning mode, all satellite and propagation biases are significantly reduced.

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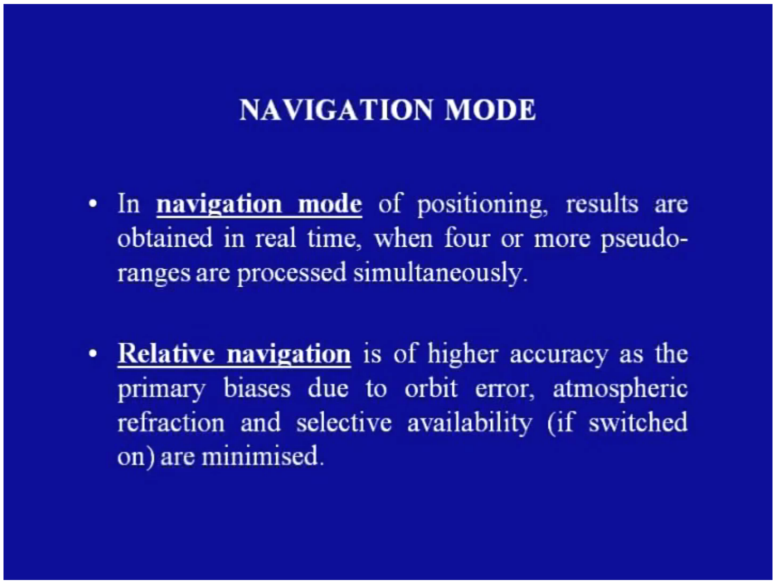

In navigation mode of positioning, results are obtained in real time when 4 or more pseudo ranges are processed simultaneously. Whereas, in relative navigation which is of a higher accuracy primarily as the primary biases due to the orbit error and atmospheric refraction and selective availability are minimized.

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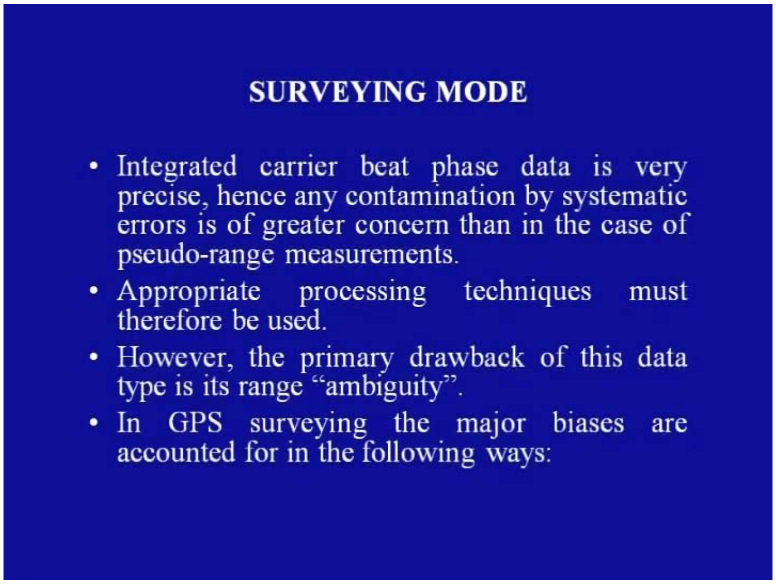

Coming to the surveying mode of GPS positioning; here, the integrated carrier beat phase data is very precise and any contamination by systematic error is of greater concern than in case of pseudo range measurements. Appropriate processing techniques must therefore be used. However, the primary drawback of this data type is its range ambiguity. In order to account for range ambiguity in GPS surveying, the major biases are accounted for in the following ways.

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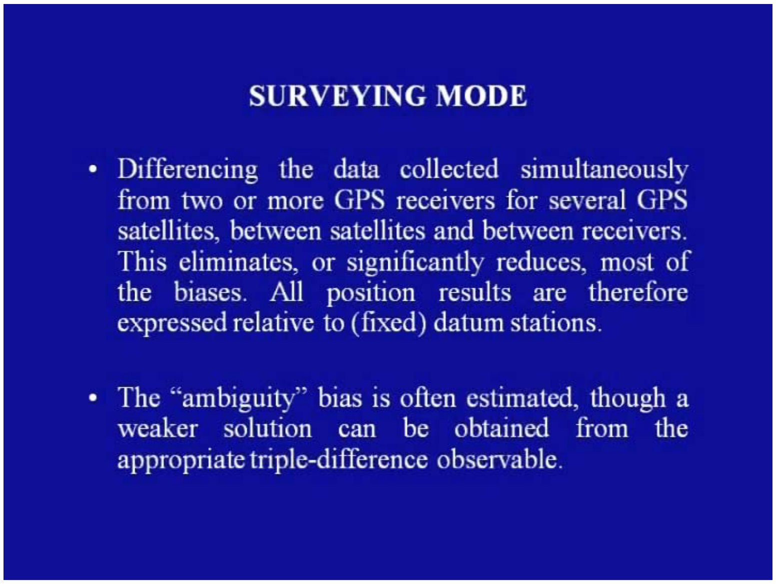

First, differencing the data collected simultaneously from 2 or more GPS receivers for several GPS satellites between the satellites and the receivers. This eliminates or significantly reduces most of the biases. All the positions results are therefore expressed relative to a fixed datum station. The ambiguity bias is often estimated though a weaker solution can be obtained from the appropriate triple difference observable quantities.

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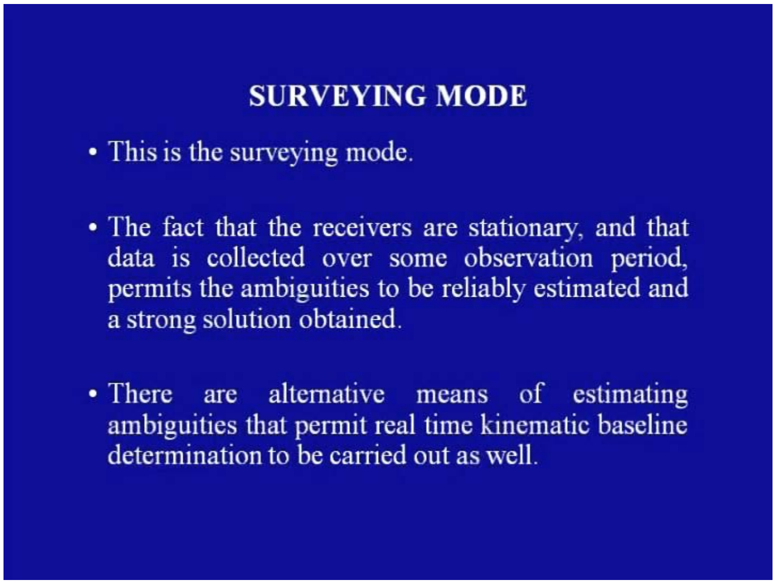

Fact that the GPS receivers are stationary and that the data is collected over some observation period, this permits the ambiguities to be reliably estimated and a strong solution can be obtained. There are alternative means of estimating ambiguities that permit real time kinematic baseline determination to be carried out as well.

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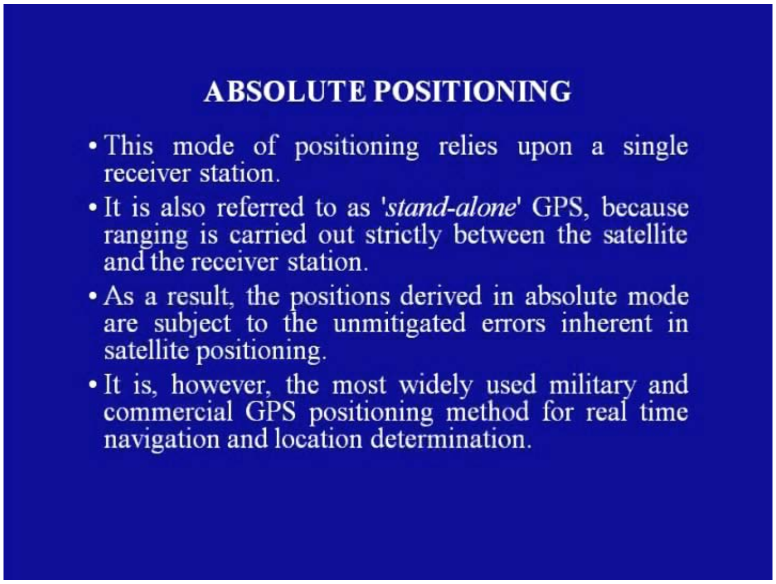

Coming to the next type of positioning which is the absolute positioning. In this mode of positioning, it relies upon a single receiving station. This is also referred to as a stand-alone GPS because ranging is carried out strictly between the satellite and the receiving station. As a result, the positions derived in absolute mode are subjected to unmitigated errors inherent in the satellite positioning.

It is however, most widely used in military and commercial positioning method for real time navigation and location determination.

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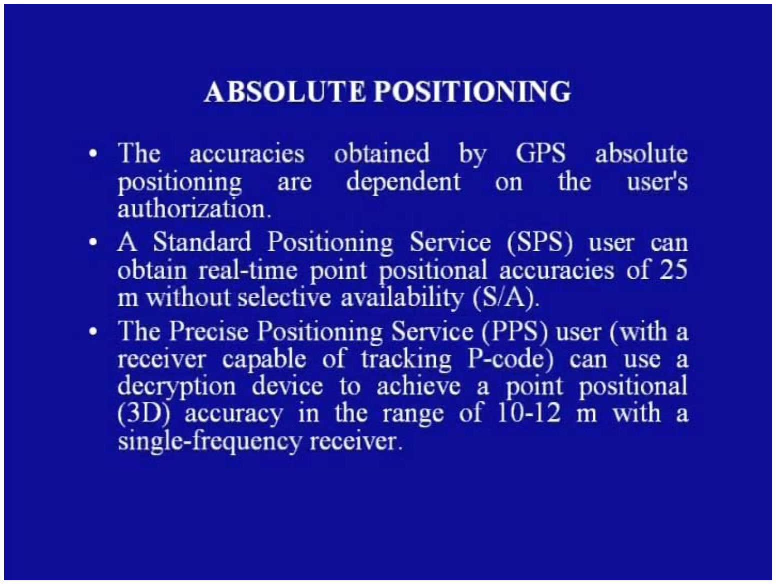

The accuracies obtained by GPS absolute positioning are dependent upon the user's authorization. A user may have 2 types of authorization as discussed earlier. That is the standard positioning service; in short we call it as SPS.

Here, the user can obtain real time point positional accuracies of 25 meters without selective availability. In the other mode, that is the precise positioning service or PPS, a user with a receiver capable of tracking P code can use a decryption device to achieve a point position in 3D accuracy in the range of 10 to 12 with a single frequency receiver.

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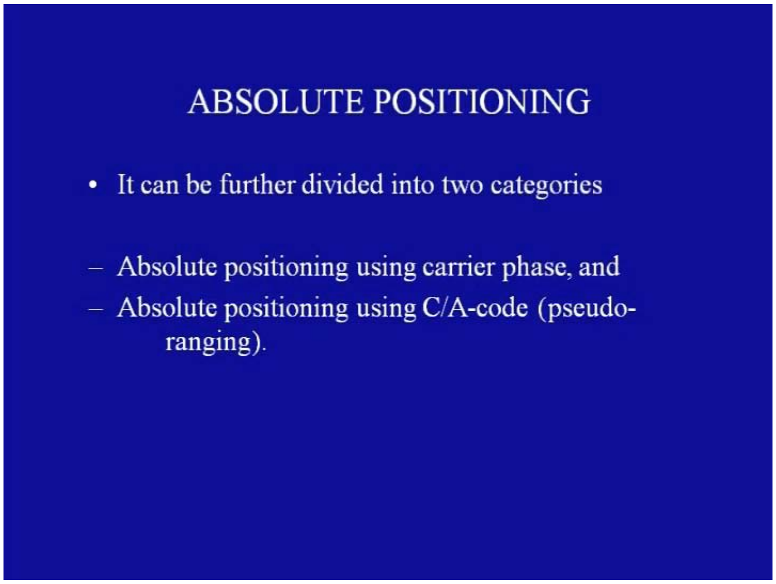

We can further sub divide this absolute positioning technique into 2 more categories. One is absolute positioning using carrier phase and absolute positioning using C/A code that is pseudo ranging. So, let us look at these 2 categories of point positioning method.

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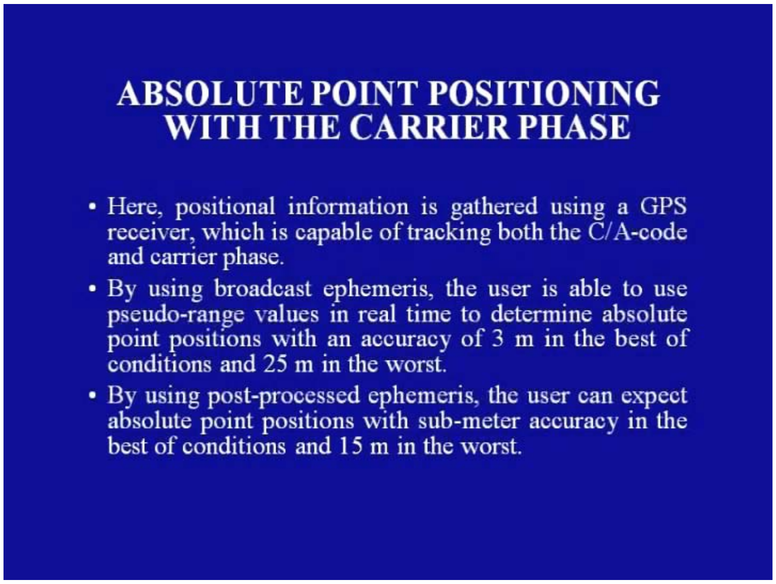

Absolute point positioning with carrier phase; here, in this technique, positional information is gathered using a GPS receiver which is capable of tracking both the C/A and P codes and the carrier phase.

By using broadcast ephemeris, the user is able to use pseudo-range values in real time to determine absolute point positions with an accuracy of 3 meter in the best of the conditions and 25 meters in the worst of the condition. By using post processing techniques wherein, the ephemeris data may be used; the user can expect absolute point positions with sub-meter accuracy in the best of the conditions and about 15 meters in the worst condition.

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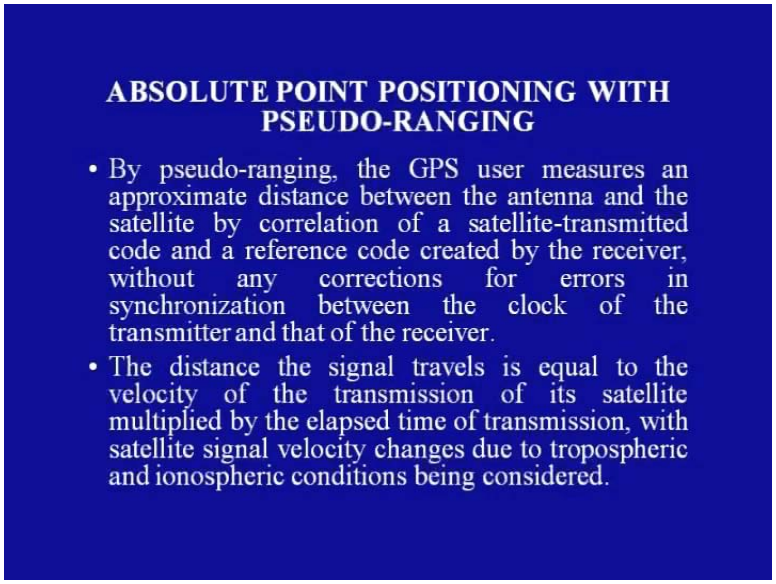

In the next method of absolute point positioning with pseudo ranging, the GPS user measures an approximate distance between the antenna and the satellite by correlation of a satellite transmitted code and a reference code created by the user without any corrections for the error in the synchronization between the clock of the transmitter and that of the receiver.

The distance of the signal traveled is equal to the velocity of the transmission of its satellite multiplied by the elapsed time of transmission with satellite signal velocity changes due to tropospheric and ionospheric conditions being considered.

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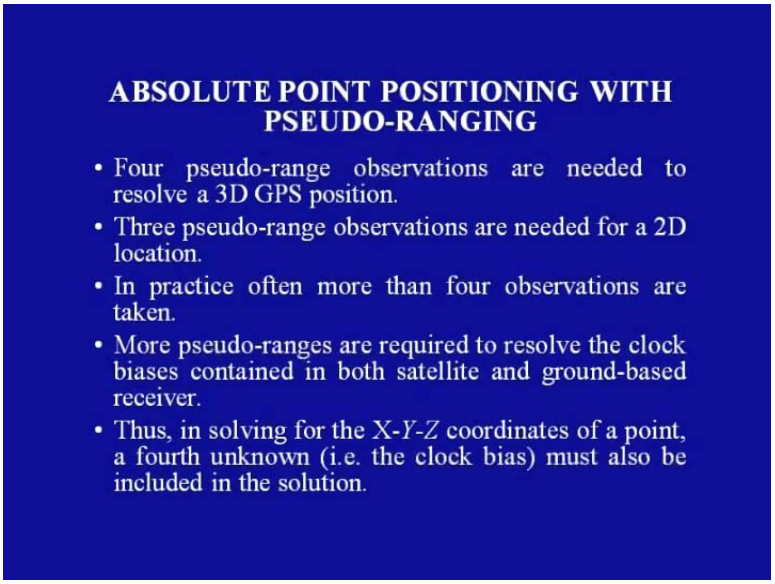

Here, 4 pseudo range observations are needed to resolve a 3D GPS position, that is X, Y and Z. The 3 pseudo range observations are required for a 2D location. That is if Z is not required, then we can go for 3 pseudo range observations.

In practice, more than 4 observations are generally taken in order to have a better solution for the point determination. More pseudo ranges are required to resolve the clock biases contained in both the satellite and ground based receivers. Thus, in solving for the X and Y coordinates of a point, a fourth unknown that is the clock bias must also be included into the solution.

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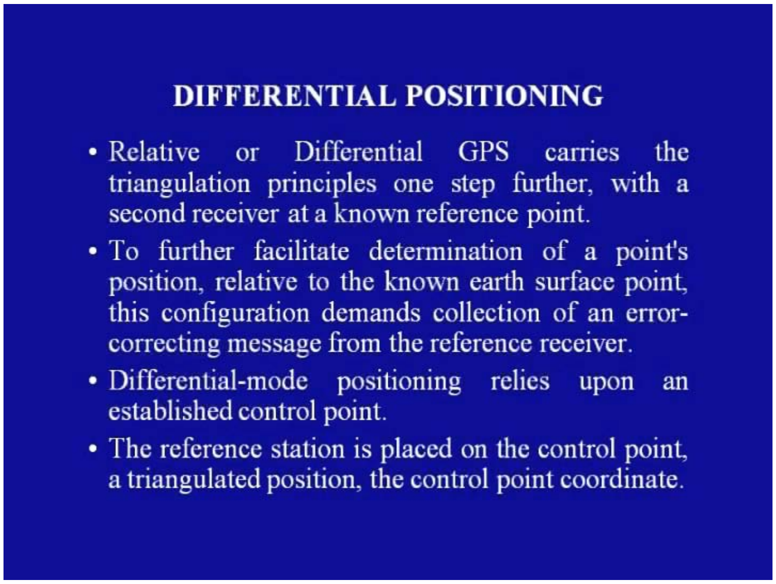

Now, we come to the next type of GPS position and that is the differential positioning. Relative or differential GPS carries the triangulation principles one step further with a second receiver at a known reference point. To further facilitate determination of a point’s position relative to the known earth surface point, this configuration demands collection of an error correcting message from the reference receiver.

Differential mode positioning relies upon an established control point. The reference station is placed on the control point which could be a triangulated position or it could be a control point coordinate.

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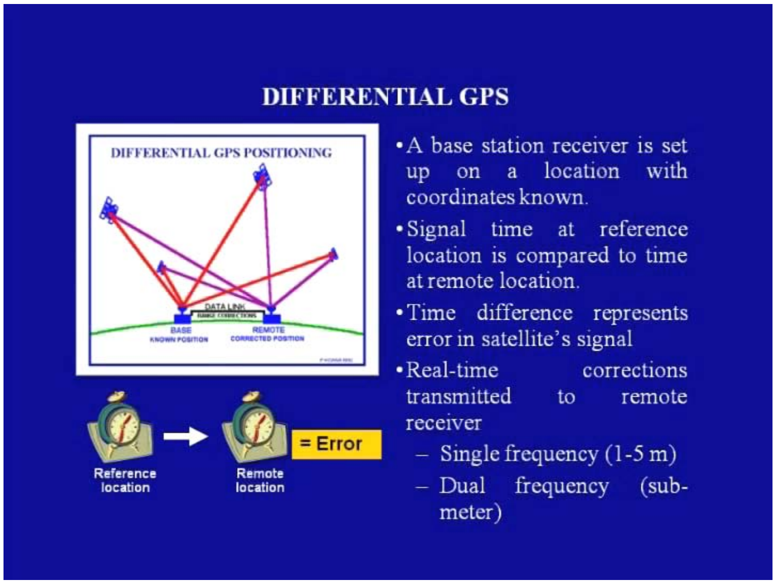

In this slide, a general configuration of differential GPS positioning has been shown. One can see that 1 GPS receiver has been placed at a known position which we call it as the base station and the second which is the unknown point, the GPS receiver has been placed and this is known as the remote location. Between these 2 GPS receivers, there is a data link so that range corrections can be carried out.

It may be observed that both the GPS receivers that is at the base and at the remote location are tracking the same satellite vehicles, a minimum of 4 is required. So, we can see that with the help of these four satellite stations, the error can be resolved between the reference location and the remote location in terms of clock time because this is important in terms of resolving the biases which may have come into existence.

Real time corrections transmitted to the remote sensing receiver may vary upon the type of frequency configurations that we may have. If one is using a single frequency GPS, then probably the corrections could be of the order of 1 to 5 meters. However, this can be reduced to sub-meter if dual frequency is where GPSs are being used for differential GPS.

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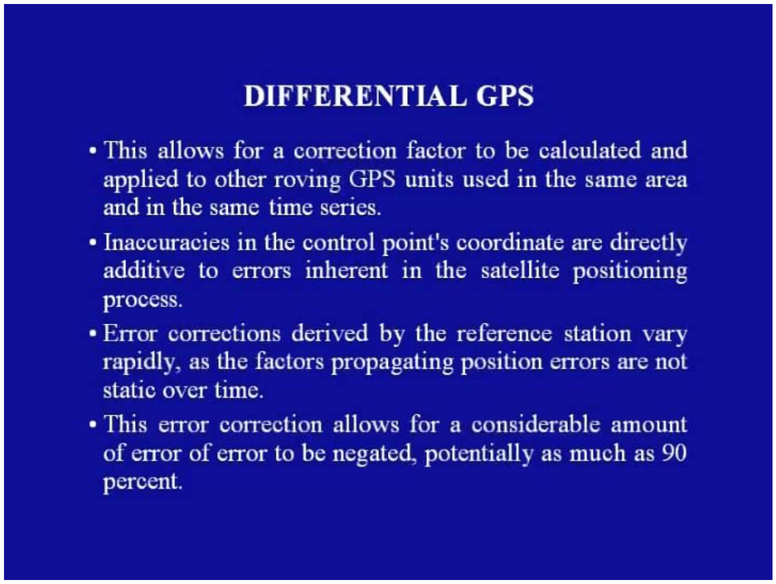

It may be noted that by allowing for a correction factor to be calculated and applied to the rovering GPS units used in the same area and in the same time series. Inaccuracies in the control point coordinates are directly additive to the errors inherent in the satellite positioning process. Error corrections derived by the reference stations vary rapidly as the factor propagating position errors are not static over time. This error correction allows for a considerable amount of error to be negated potentially as much as 90%.

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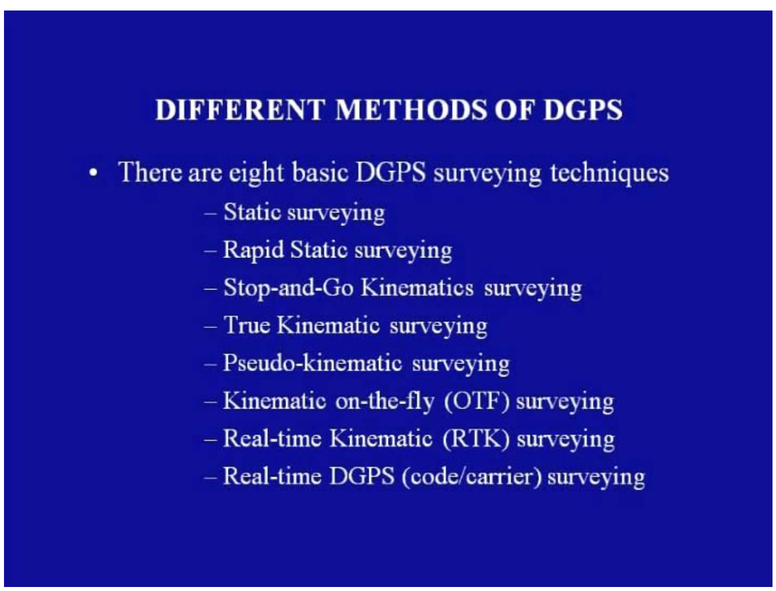

When we are talking about differential GPS positioning methods, there are many methods which are available to the user. In fact, there are 8 basic DGPS surveying techniques. These are; static surveying, rapid static surveying, stop and go kinematic surveying, true kinematic surveying, pseudo kinematic surveying, kinematic on the fly or we call it as OTF surveying, real time kinematic or RTK surveying and real time DGPS that is code slash carrier surveying.

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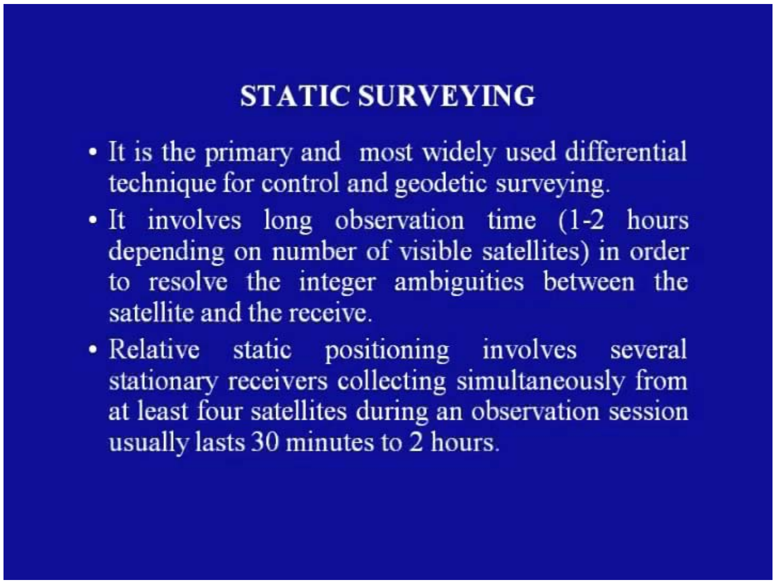

Now, let us look at each of these basic 8 basic DGPS surveying techniques that we have one by one. It is the primary and the most widely used differential technique for control and geodetic surveying. It involves long observation time of the order of 1 to 2 hours depending upon the number of visible satellites in order to resolve the integer ambiguities between the satellite and the receiver.

The relative static positioning involves several stationary receivers collecting simultaneously from at least 4 satellites during an observation session which may usually lasts between 30 minutes to 2 hours.

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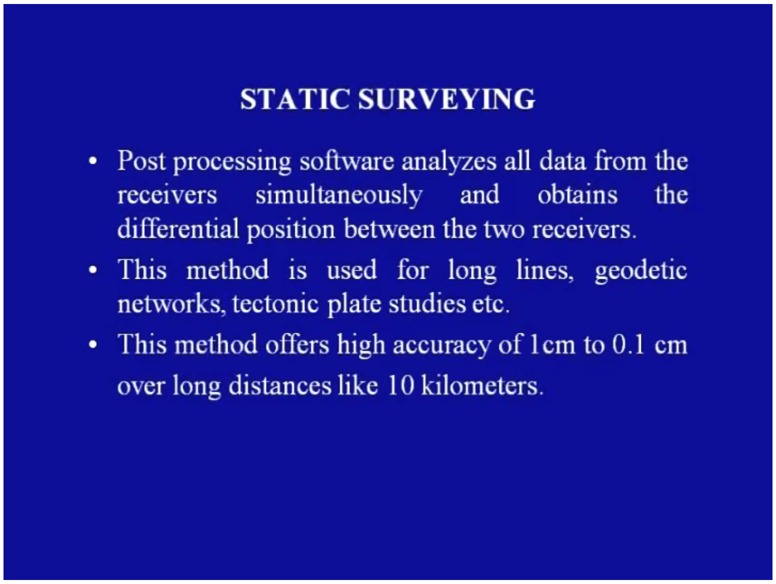

Post processing software analyzes all the data from the receiver simultaneously and obtains the differential positions between the 2 receivers. This method is used for long lines, geodetic networks, tectonic plate studies etc. This method offers high accuracy of 1 centimeter to about 0.1 centimeter over long distances of 10 kilometers.

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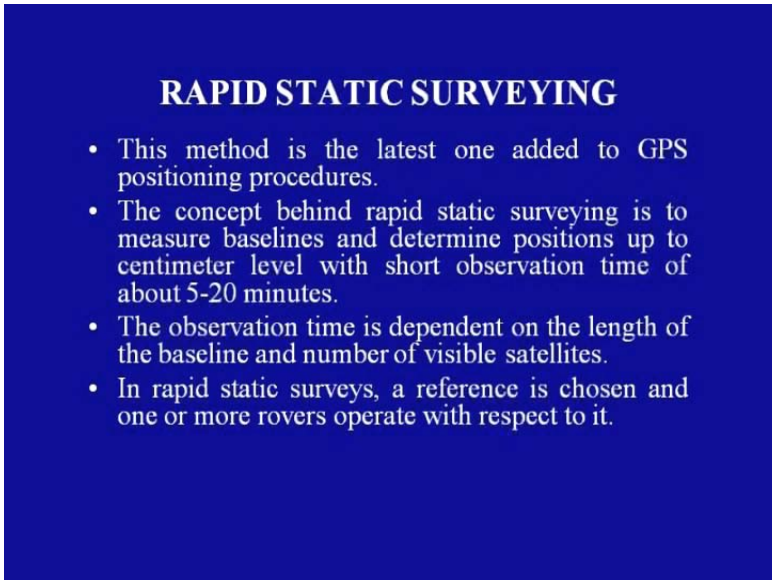

The next is the rapid static surveying. This method is the latest one added to GPS positioning procedures. The concept behind rapid static surveying is to measure baselines and determine positions up to centimeter level with short observation time of about 5 to 20 minutes.

The observation time is dependent upon the length of the baseline and the number of visible satellites which are available at that time. In rapid static surveys, a reference is chosen and one or more rover GPSs operate with respect to it.

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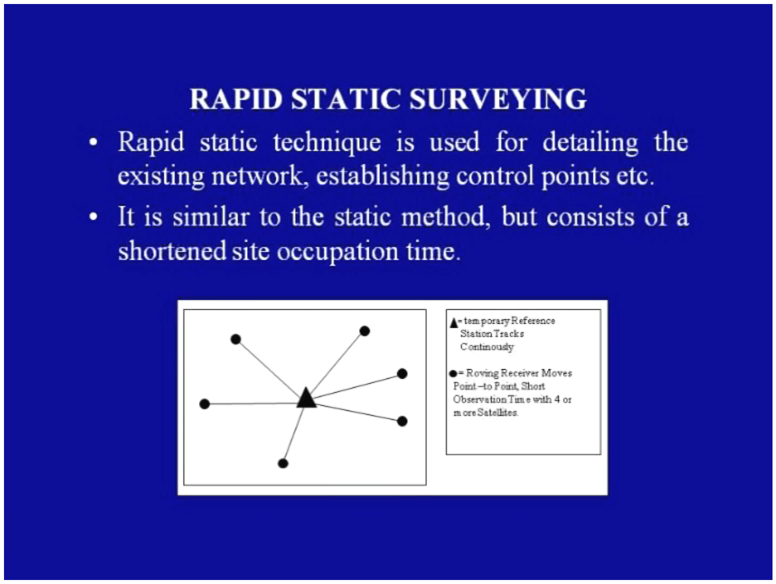

The rapid static technique is used for detailing the existing network establishing control points etc. It is similar to static method but consists of a shortened site occupation time.

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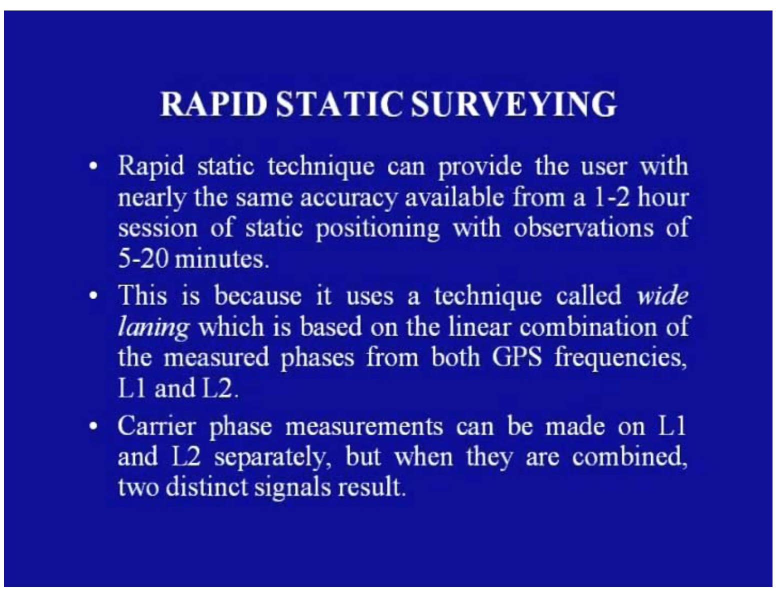

Rapid static technique can provide the user with nearly the same accuracy available from 1 to 2 hour session of static positioning with observations of 5 to 20 minutes. This is because it uses a technique called wide laning which is based on the linear combinations of the measured phases of both the GPS frequencies that is L1 and L2.

The carrier phase measurements can be made on L1 and L2 separately. But when they are combined, the two, it results in two distinct signals.

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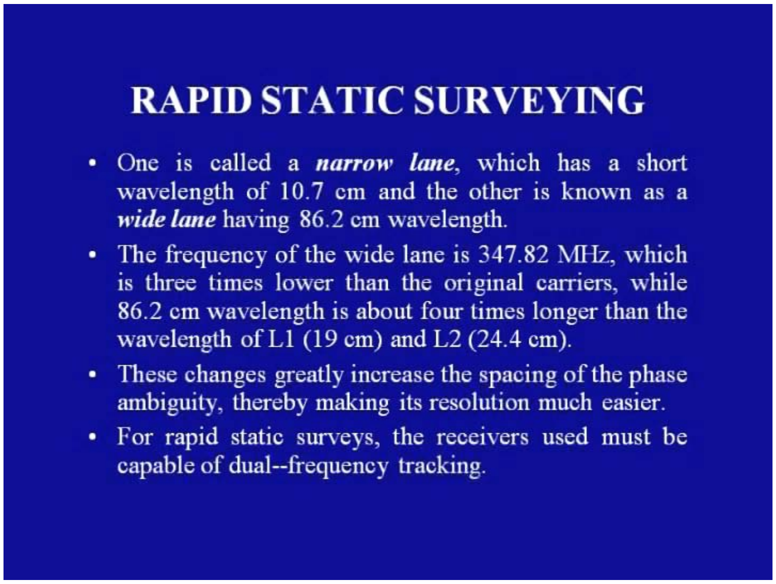

One is called a narrow lane which is a short wavelength of 10.7 centimeter and the other is known as the wide lane having 86.2 centimeter wavelength. The frequency of the wide lane is 347.82 megahertz which is 3 times lower than the original carriers while 86.2 centimeter wavelength is about 5, 4 times longer than the wavelength of L1. That is 19 centimeters and L2 which is 24.4 centimeters.

These changes greatly increase the spacing of the phase ambiguity, thereby making its resolution much easier. For rapid static surveys, the receivers used must be capable of dual frequency tracking.

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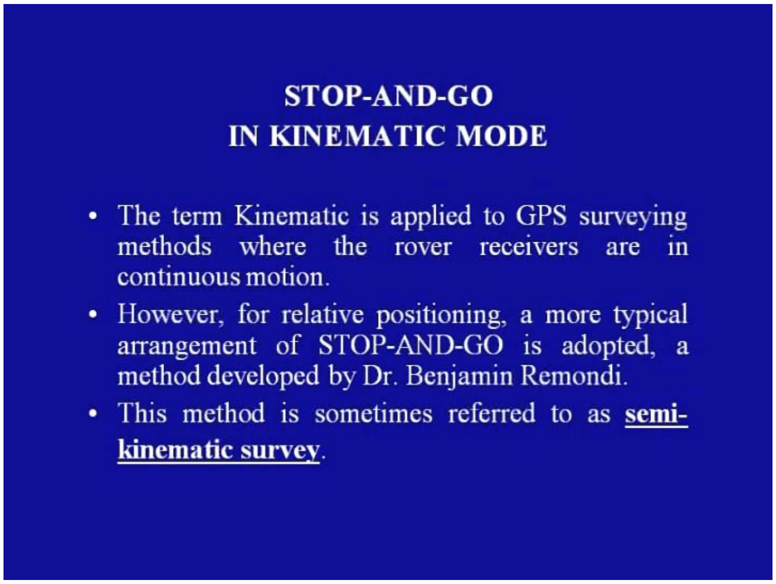

The next method is stop and go kinematic mode. The term kinematic is applied to GPS surveying methods where the rover receivers are in continuous motion. However, for relative positioning, a more typical arrangement of stop and go is adopted; a method developed by Doctor Benjamin Remondi. This method is sometimes referred as a semi kinematic survey.

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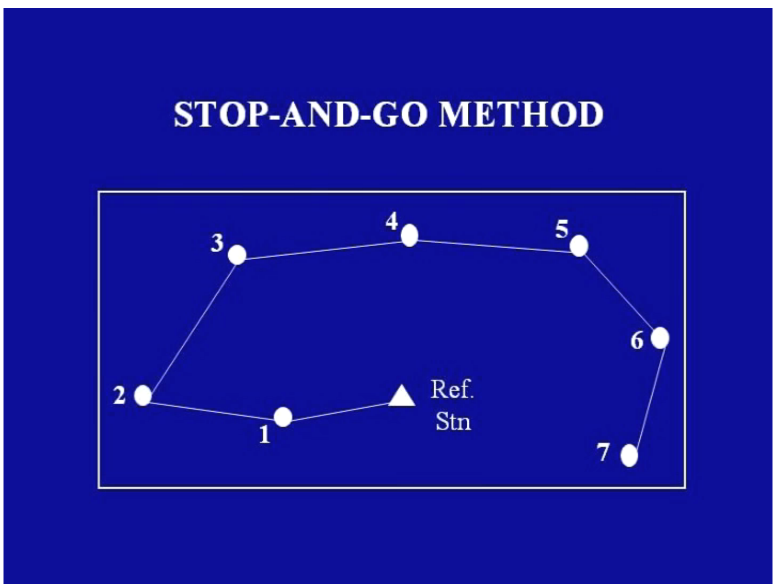

This slide shows the procedure of stop and go method wherein, we have a reference station and we take observations to the other points which are to be determined in a cyclic order.

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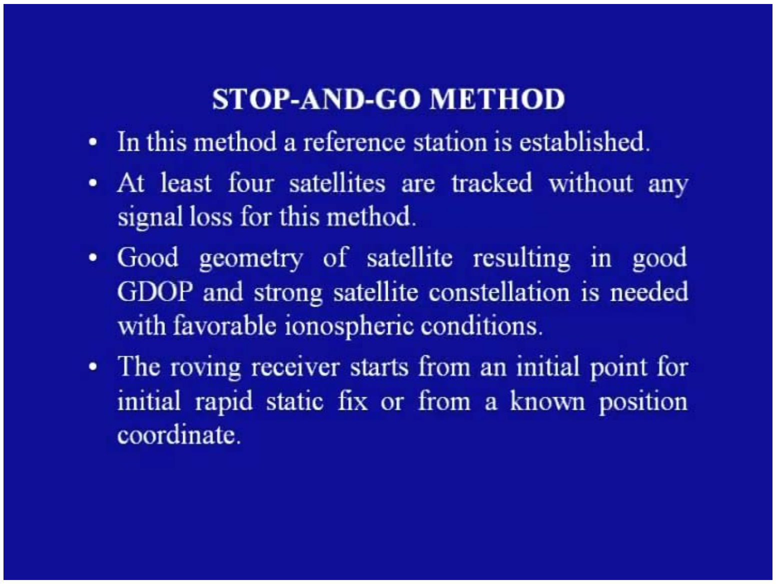

Here, at least 4 satellites must be tracked without any loss of signal during the whole observation period. Good geometry of satellite resulting in good GDOP and strong satellite constellation is needed with favorable ionospheric conditions. The rovering satellite starts from an initial point for initial rapid static fix or from a known position coordinate.

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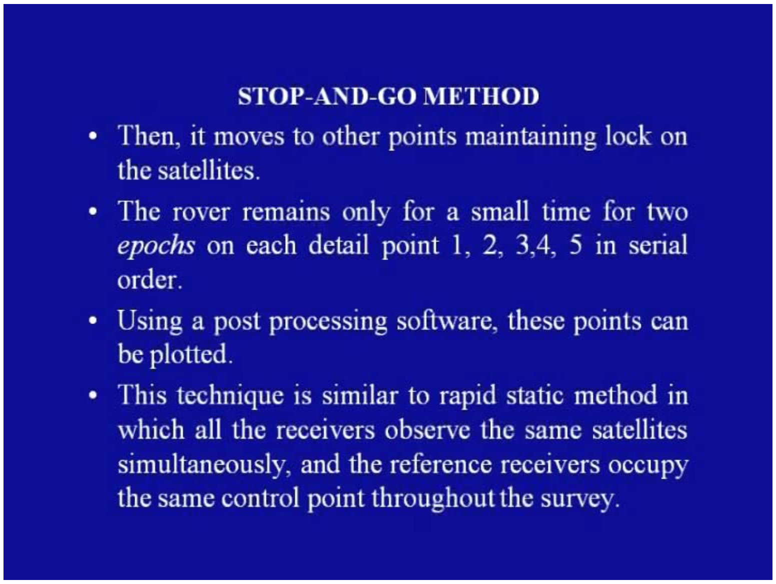

It then moves to other points maintaining lock on the satellites. The rover maintains only for a small time for 2 epochs on each detail points 1, 2, 3, 4 and 5 in the serial order. Using a post processing software, these points can be plotted. This technique is similar to rapid static method in which all the receivers observe the same satellite simultaneously and the reference receiver occupies the same control point throughout the survey.

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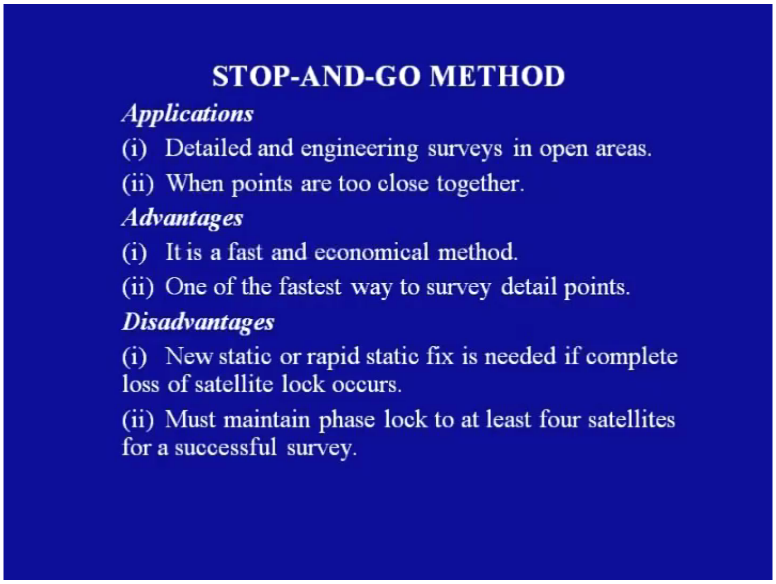

Applications wherein, detailed and engineering surveys in open areas are to be carried out and second, when the points of observations are too close to each other. The advantage of this particular method is that it is fast and economical and one of the fastest way to survey detail points.

However, it has some disadvantages and that is new static or rapid static fix is needed if there is a complete loss of satellite lock occurs. It must also maintain phase lock to at least 4 satellites for a successful survey to be performed.

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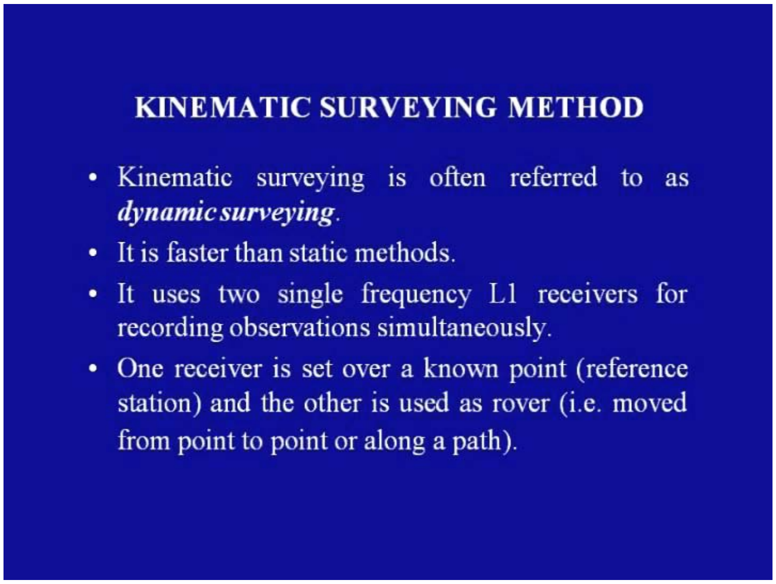

We come to the next method and that is the kinematic surveying method. Kinematic surveying is often referred to as dynamic survey. It is faster than static methods. It uses 2 single frequency L1 receivers for recording observations simultaneously. One receiver is set over a known point which is known as the reference station and the other is used as a rover that is which is moved from point to point or along a path.

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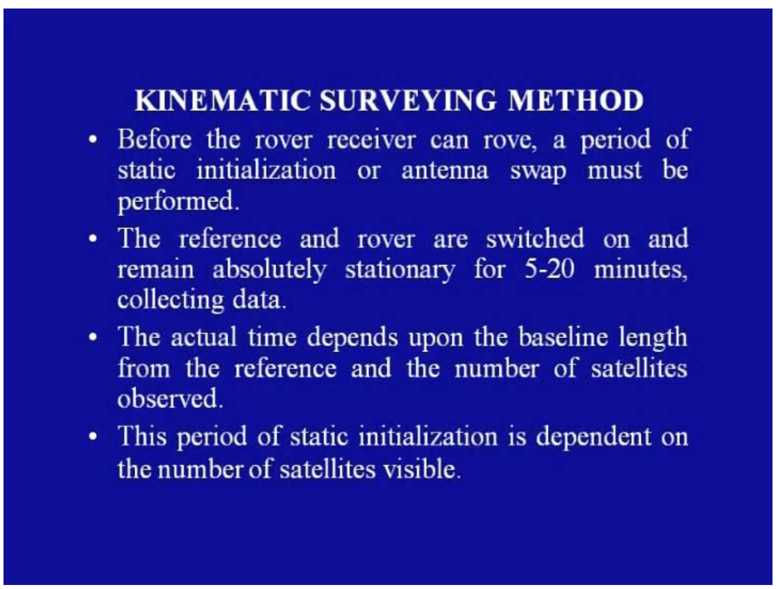

Before the rover receiver can rove, a period of static initialization or antenna swap must be performed. The reference and the rover are switched on and remain absolutely stationary for 5 to

20 minutes before collecting the data. The actual time depends upon the baseline length from the reference and the number of satellites observed. This period of static initialization is dependent upon the number of satellites which are visible at a given instant of time.

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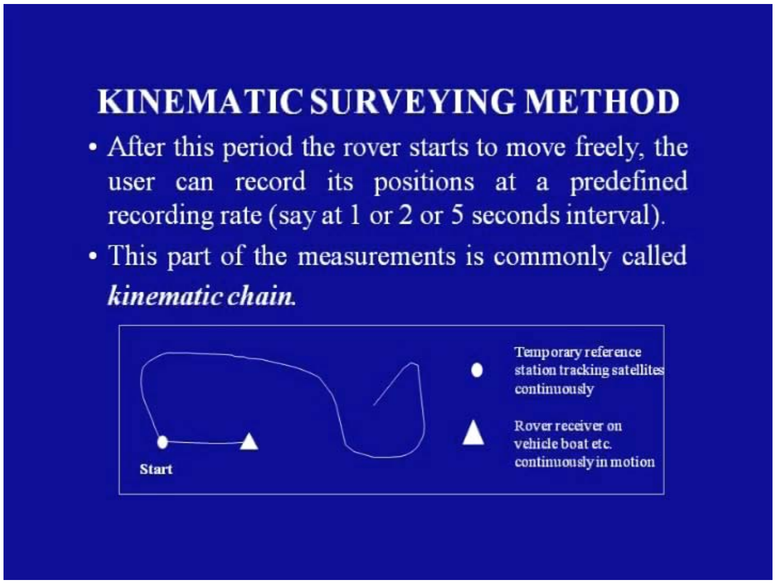

After this period, the rover now starts to move freely and the user can record its position at predefined recording rates; say, at 1 or 2 or 5 seconds interval. This part of the measurement is commonly called kinematic chain.

In the figure below, we have a control point and we have a start point where the rover is kept and now the rover starts to move and it moves in a continuous mode as if a line is being drawn on the ground and it is acquiring data at predefined intervals of time as 1 second or 2 second or 5 second depending upon the manner in which the ground information varies.

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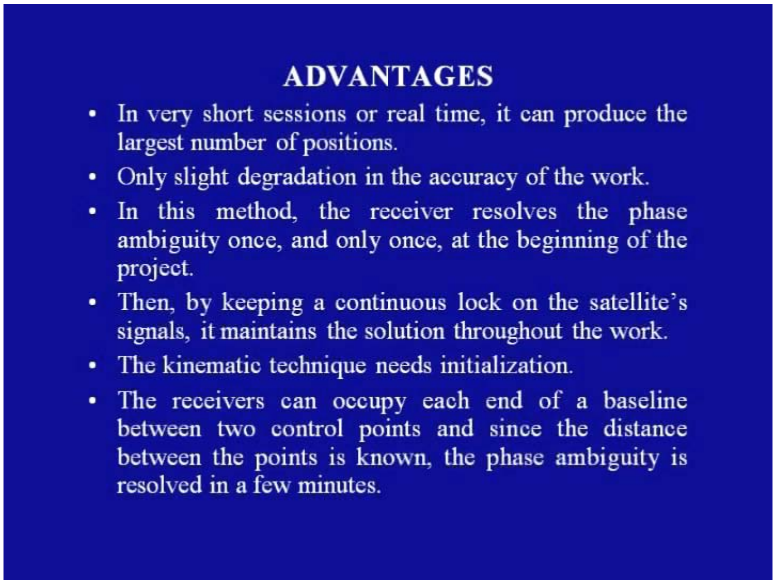

The advantage of kinematic surveying is that in very short sessions or real time, it can produce the largest number of positions. Only slight degradation in the accuracy of the work occurs. In this method, the receiver resolves the phase ambiguity once and only once at the beginning of the project.

Then by keeping a continuous lock on the satellite's signal, it maintains its solution throughout the work. The kinematic technique requires initialization. That is the receivers can occupy each end of the baseline between the 2 control points and since the distance between the points is known, the phase ambiguity is resolved in a few minutes time.

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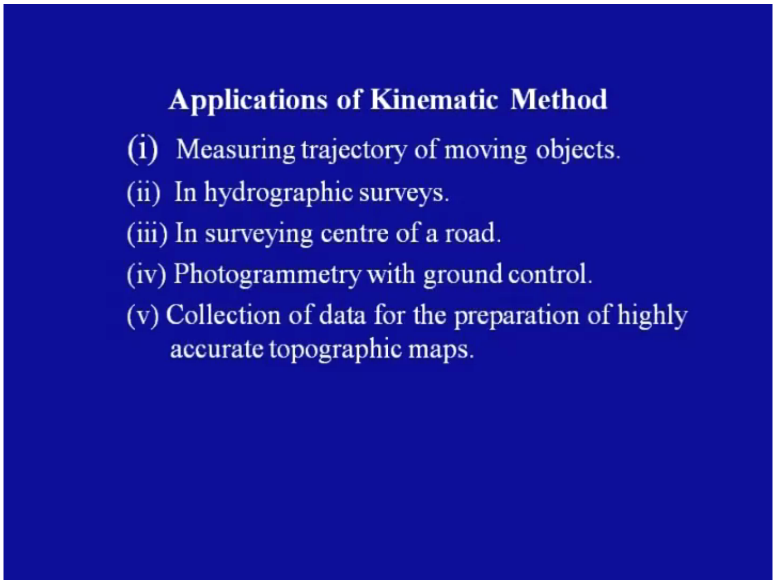

Applications of kinematics method could be for measuring trajectory of moving objects in hydrographic surveys, in surveying the center line of a road, photogrammetry for ground control provisions, collection of data for preparation of highly accurate topographical maps.

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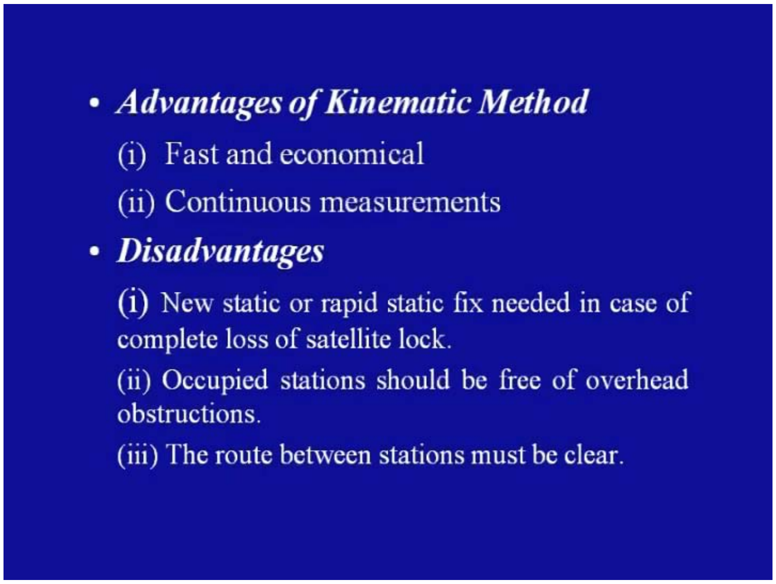

An advantage of kinematic method is that it is fast and economical and provides continuous measurements along a line or a chain. However, there are some disadvantages, that is it requires a static fix with a continuous chain of satellites. In case of break or loss of signal, then a new static or a rapid static fix is required. Occupied stations should be free of overhead obstructions that are there should be no tree or a building close by or electric wire should not pass. The route between the stations must also be clear, that is the there should be clear link between the between the reference and the rover receivers in the area.

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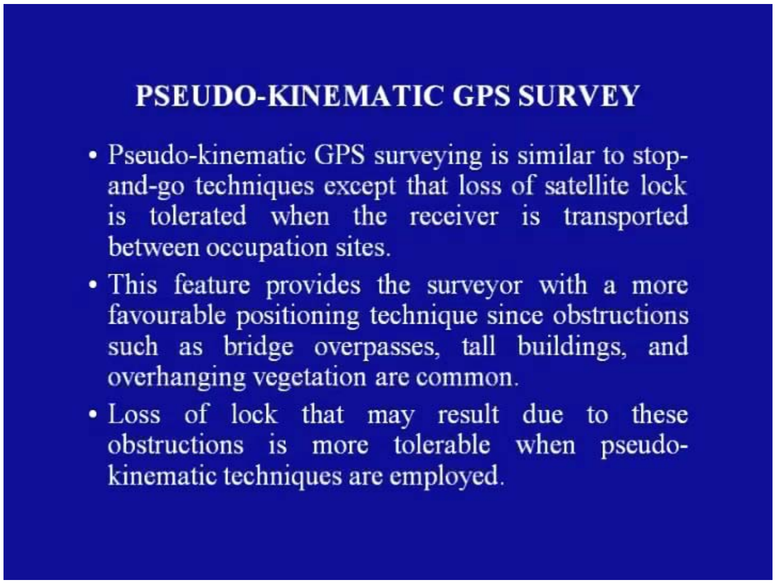

The next method is pseudo kinematic GPS surveying. Pseudo kinematic GPS survey is similar to stop and go techniques except that the loss of satellite lock is tolerated when the receiver is transported between occupation sites.

This feature provides the survey surveyor with a more favorable positioning technique, since obstruction such as bridge overpasses, tall buildings and overhanging vegetations are common. Lock of loss that may result due to these obstructions is more tolerable when pseudo-kinematic techniques are employed.

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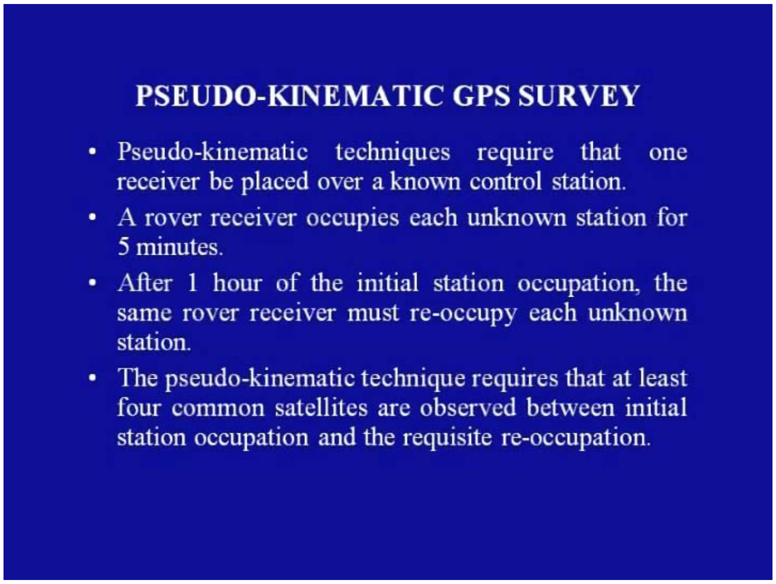

Pseudo kinematic techniques require that one receiver be placed over a known control station. A rover receiver occupies each unknown station for about 5 minutes. After 1 hour of initial station occupation, the same rover receiver must re-occupy each unknown station. The pseudo kinematic technique requires that at least 4 common satellites are observed between initial station occupation and the requisite re-occupation.

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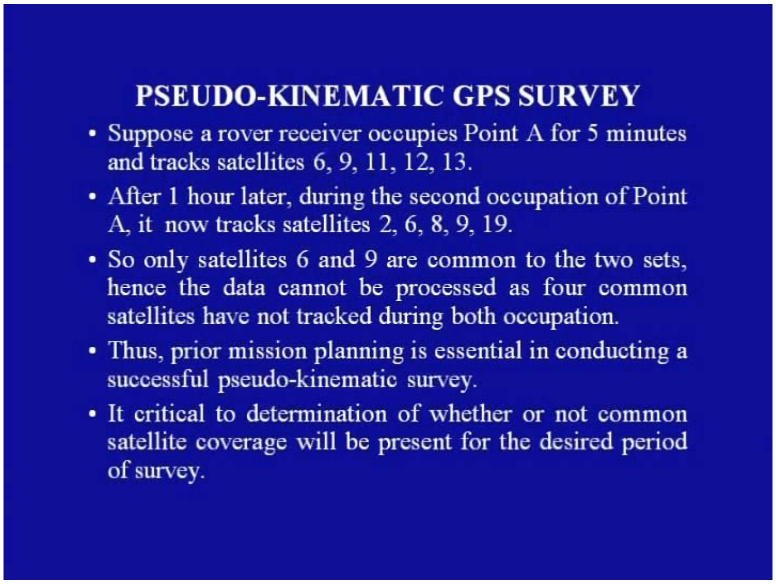

Suppose, a rover receiver occupies point A for 5 minutes and tracks satellites 6, 9, 11, 12 and 13. After 1 hour during the second occupation of point A, it now tracks satellites 2, 6, 8, 9 and 19. So, only the satellites 6 and 9 are common to the 2 sets. Hence, the data cannot be processed as 4 common satellites have not tracked during both occupations.

Thus, prior mission planning is essential in conducting a successful pseudo kinematic survey. It is critical to determine whether or not common satellite coverage will be present for the desired period of survey.

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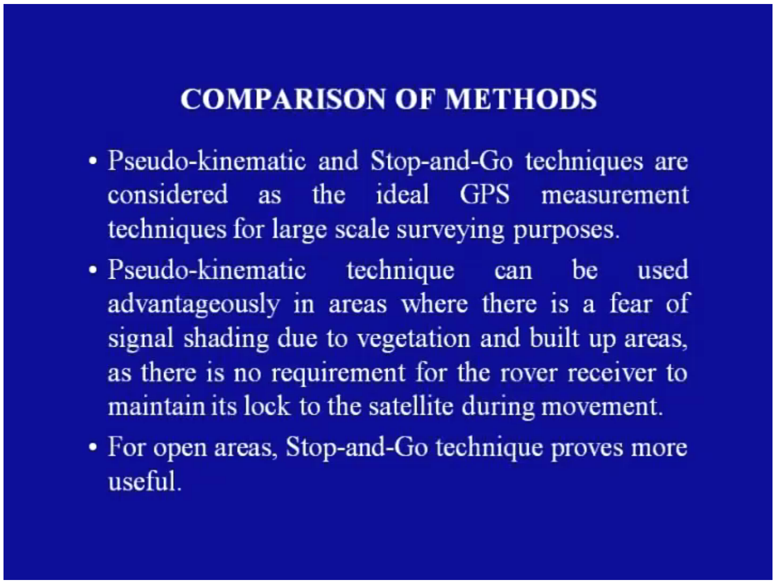

Now, let us look at the comparison between pseudo kinematic and stop and go techniques as these are considered as the ideal GPS measurement techniques for large scale surveying purposes.

Pseudo kinematic techniques can be used advantageously in areas where there is a fear of signal shading due to vegetation and built up areas as there is no requirement for the rover receiver to maintain its lock to the satellite during movement. For open areas stop and go techniques proves to be more useful.

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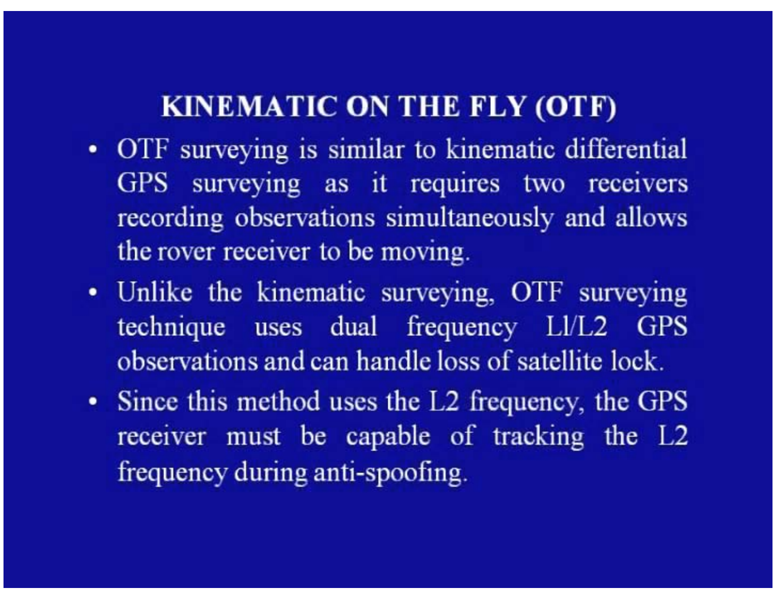

Now, we focus on the next method and that is kinematic on the fly or in short OTF. OTF survey is similar to kinematic differential GPS surveying as it requires 2 receivers recording observations simultaneously and allows the rover receiver to be moving.

Unlike kinematic surveying, OTF surveying techniques uses dual frequency L1/L2 GPS observations and can handle loss of lock. Since this method uses L2 frequency, the GPS receiver must be capable of tracking the L2 frequency during anti-spoofing.

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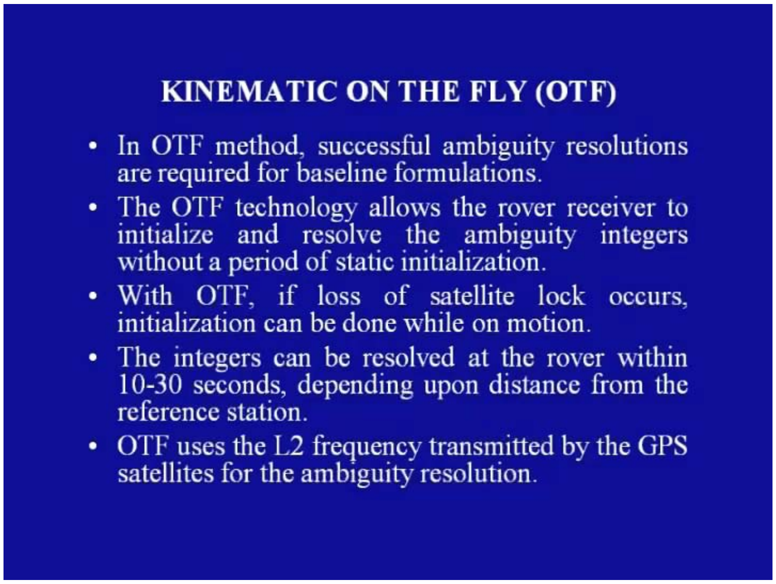

In OTF method, successful ambiguity resolutions are required for baseline formulations. The OTF technology allows the rover receiver to initialize and resolve the ambiguity integers without a period of static initialization.

With OTF, if loss of satellite lock occurs; initialization can be done on the motion. The integers can be resolved at the rover within 10 to 30 seconds depending upon the distance from the reference station. OTF uses L2 frequency transmitted by GPS satellites for ambiguity resolution.

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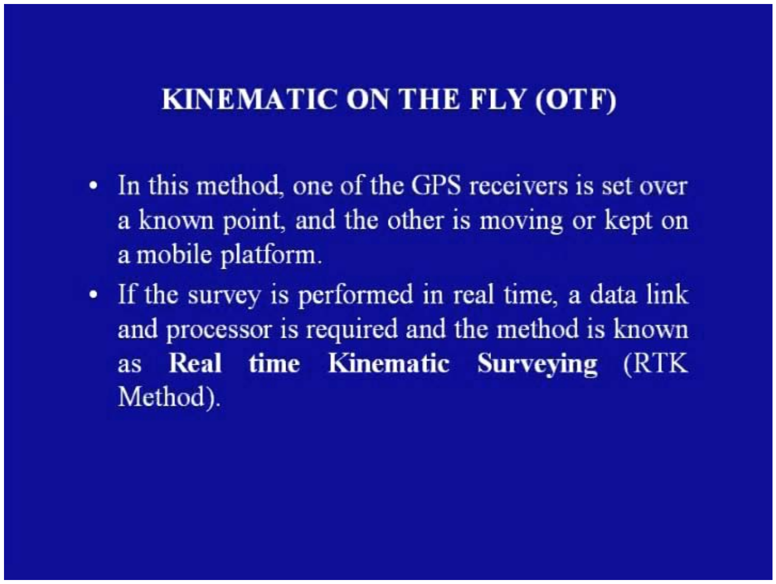

In this method, one of the GPS receivers is set over a known point and the other is moving or kept over a mobile platform. If the survey is performed in real time, a data link and a processor is required and the method is known as real time kinematic surveying or what we call it as RTK method.

So, let us look at what actually is RTK.

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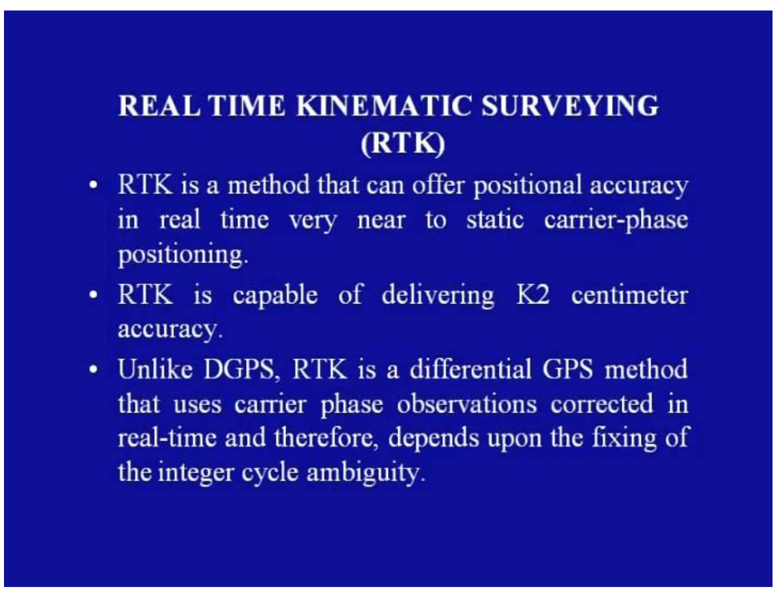

RTK is a method that can offer positional accuracy in real time very near to static carrier phase positioning. RTK is capable of delivering K2 centimeter accuracies. Unlike DGPS, RTK is a differential GPS method that uses carrier phase observations corrected in real time and therefore, depends upon the fixing of the integer cycle ambiguity.

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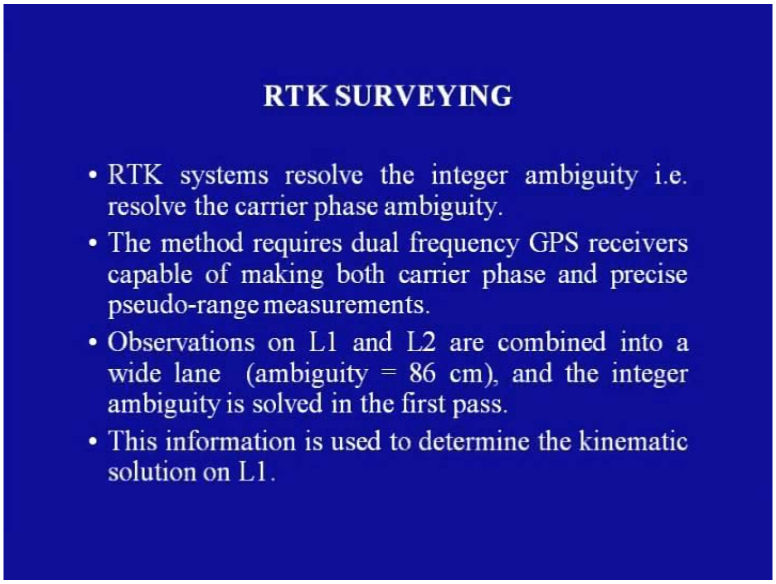

RTK systems resolve the integer ambiguity, that is resolve the carrier phase ambiguity. The method requires dual frequency GPS receivers capable of making both carrier phase and precise pseudo range measurements.

Observations on L1 and L2 are combined onto a wide lane with the ambiguity equal to about 86 centimeters and the integer ambiguity is resolved in the first pass. This information is used to determine the kinematic solution on L1.

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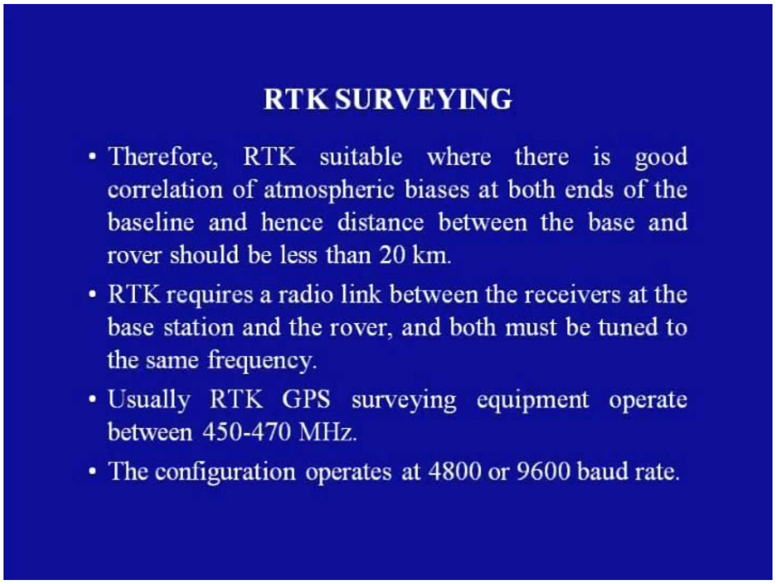

Therefore, RTK suitable where there is good correlation of atmospheric biases at both ends of the baseline and hence distance between the base and the rover should not be less than 20 kilometers. RTK requires a radio link between the receivers at the base station and the rover and both must be tuned to the same frequency.

Usually, RTK GPS surveying equipment operate between 450 to 470 megahertz. The configuration operates at 4800 or 9600 baud rate.

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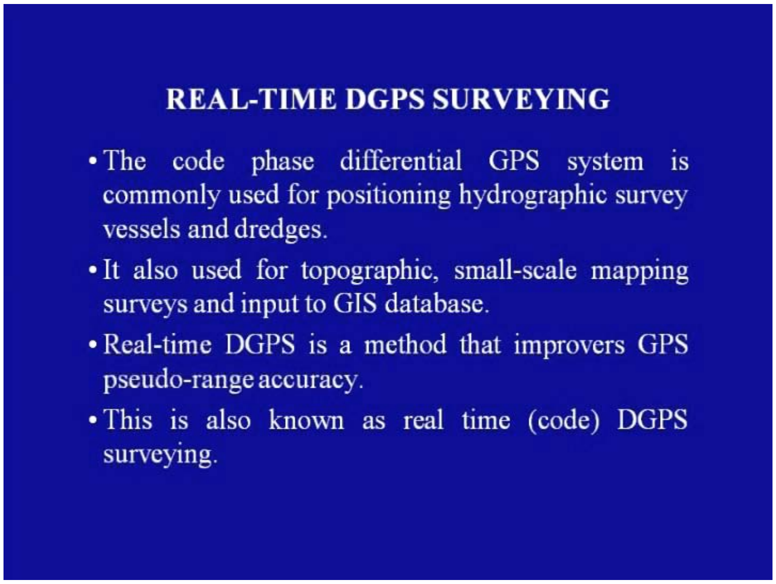

The code phase differential GPS system is commonly used for positioning hydrographic survey vessels and dredges. It is also used for topographic small scale mapping surveys and input into GIS data bases.

Real time DGPS is a method that improves GPS pseudo range accuracy. This is also known as real time DGPS surveying. So, let us look at real time DGPS surveying.

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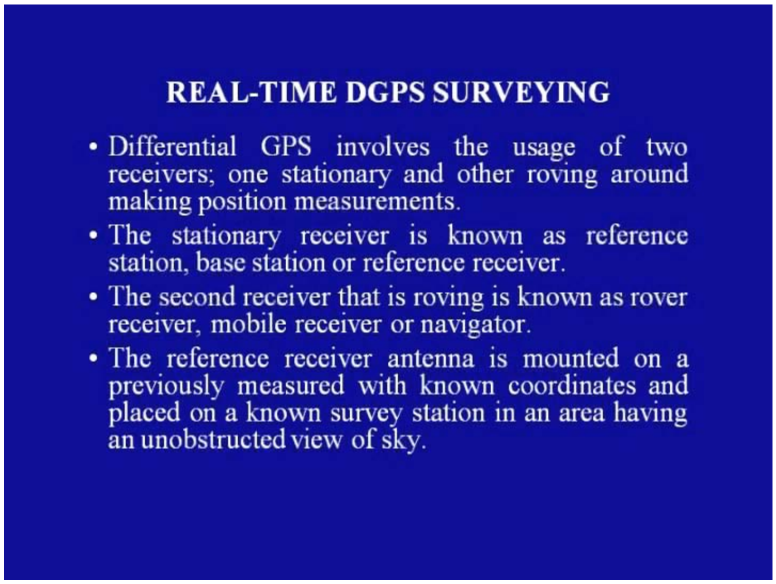

Differential GPS involves the usage of two receivers; one, stationary and the other rovering around making position measurements. The stationary receiver is known as reference station or base station or reference receiver. The second receiver that is roving is known as rover receiver or mobile receiver or navigator. The reference receiver antenna is mounted on a previously measured with known coordinates and placed on a known survey station in an area having unobstructed view of the sky.

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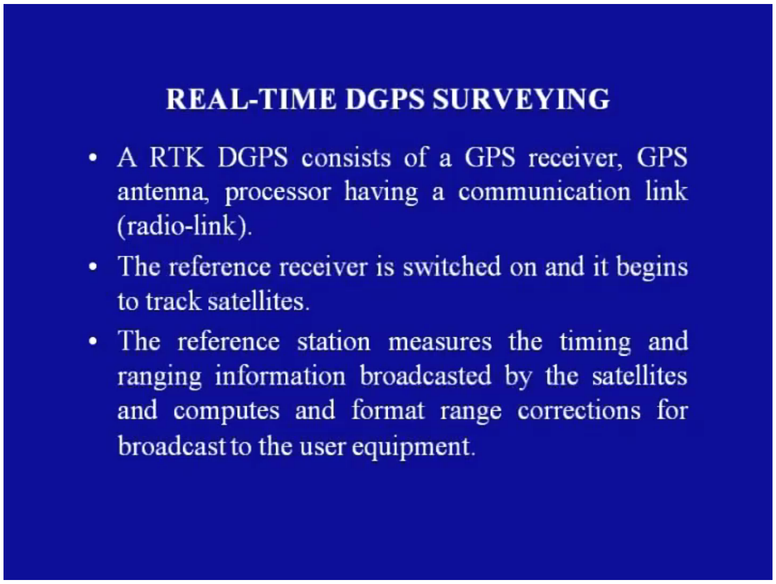

A RTK DGPS consists of a GPS receiver, GPS antenna, processor having a communication link that is a radio link between the two receivers. The reference receiver is switched on and it begins to track satellites. The reference station measures the timing and the ranging information broadcasted by the satellites and computes and format range corrections for broadcast to the user equipment.

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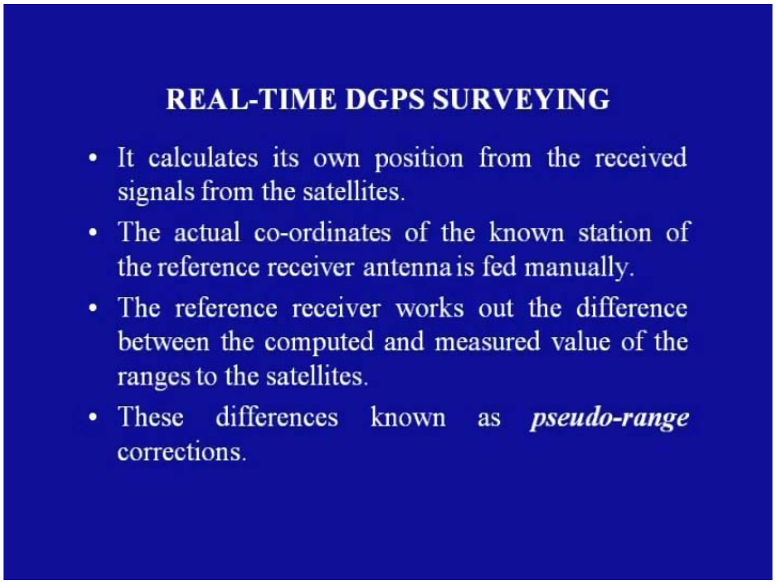

It calculates its own position from the received signals from the satellite. The actual coordinates of the known station of the reference receiver antenna is fed manually. The reference receiver works out the difference between the computed and the measured value of the ranges to the satellite. These differences are known as pseudo range corrections.

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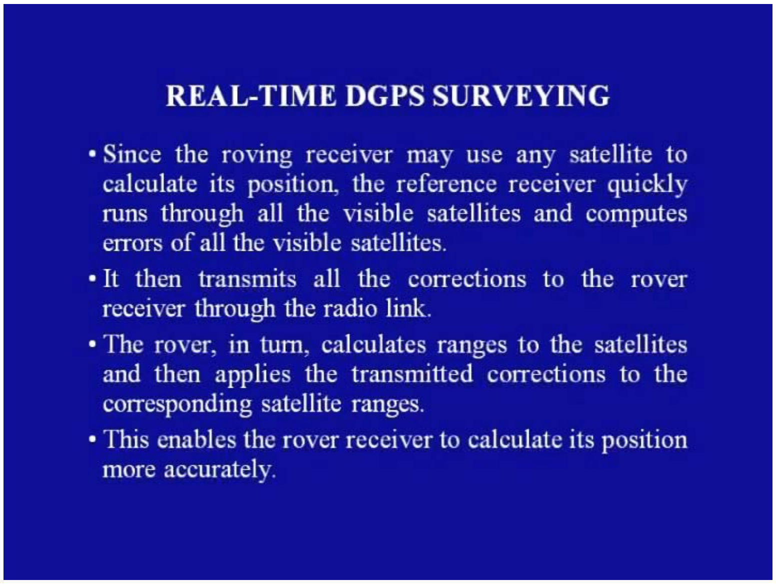

Since the rovering receiver may use any satellite to calculate its position, the reference receiver quickly runs through all the visible satellites and computes errors on all the visible satellites.
It then transmits all the corrections to the rover receiver through the radio link. The rover in turn calculates ranges to the satellites and then applies the transmitted correction to the corresponding satellite ranges. This enables the rover receiver to calculate its position more accurately.

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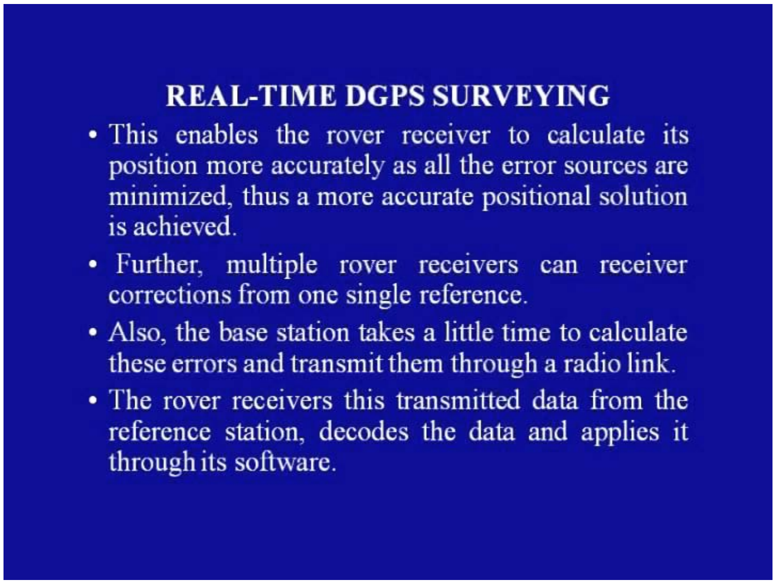

This enables the rover receiver to calculate its position more accurately as the error sources are minimized. Thus, a more accurate positional solution is achieved. Further, multiple rover receivers can receive corrections from one single receiver. Also, the base station takes a little time to calculate these errors and transmit them through a radio link.

The rover receiver transmits this data from the reference station, decodes the data and applies it through its software.

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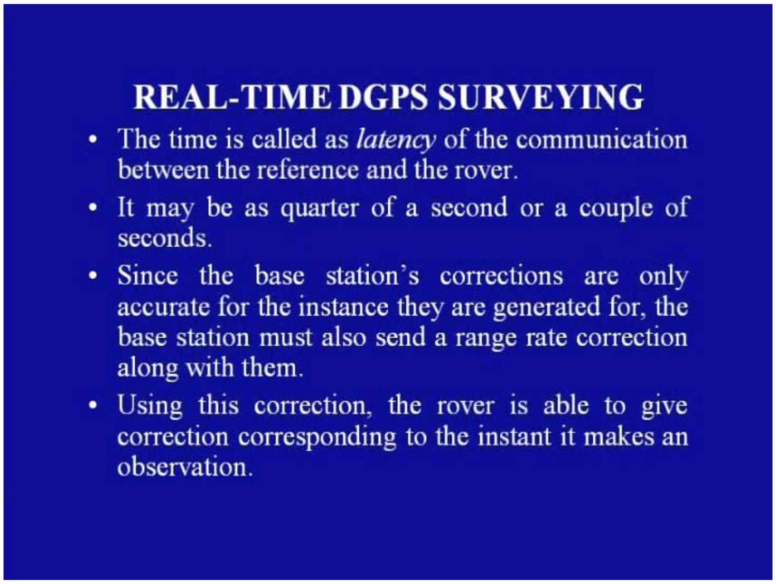

This time is called the latency of the communication between the reference and the rover. It may be as quarter of a second or a couple of seconds. Since, the base station corrections are only accurate for the instance they are generated for, the base station must also send a range rate correction along with them. Using this correction, the rover is able to give correction corresponding to the instant it makes an observation.

I come to the end of the different types of GPS positioning method which are there. Before I finish this lecture, it would be proved to record what are the accuracies that we can achieve with different types of GPSs methods which are there.

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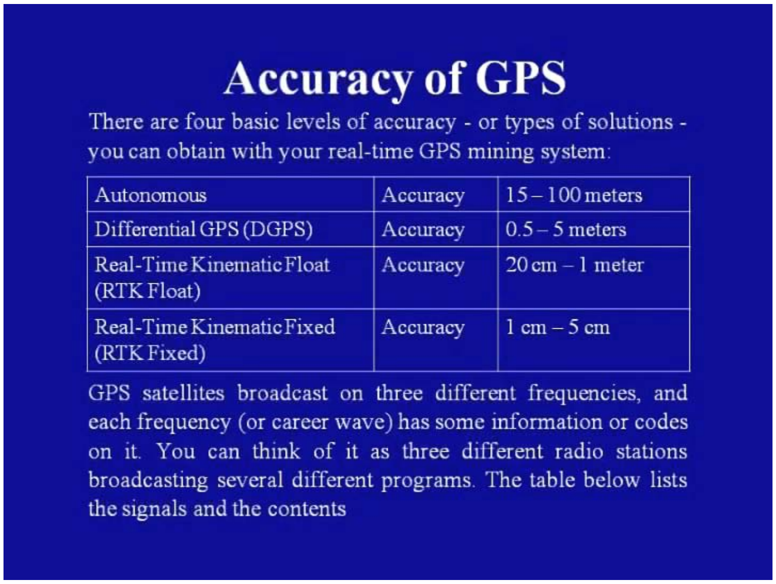

So, let us look at the accuracies which can be achieved. Differential GPS, it is very accurate and it can provide accuracy of the order of 0.5 to 5 meters. Real time kinematic float can provide 20 centimeter to 1 meter accuracy, real time kinematic fix can provide 1 centimeter to 5 centimeter accuracy.

GPS satellite broadcast on 3 different frequencies and each frequency has some information or codes on it. You can think these as to be 3 different radio stations broadcasting several different programs.

In our next mode session, we will focus on the different solution methods which can be obtained through a GPS observation procedure and what could be the possible sources of errors which could be there while taking an observation.

Thank you.