Modern Surveying Techniques

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Lecture - 4

GPS Solutions and Errors

In the last session I had discussed the different types GPS techniques by which GPS data can be collected. In this session I would like to focus on the different types of solution that a GPS can provide followed by the different types of errors associated which GPS observations.

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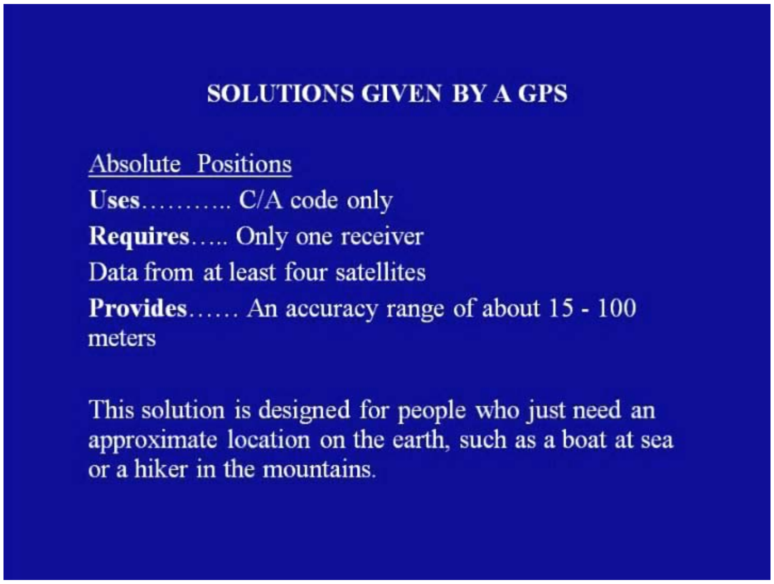

So, solutions given by a GPS: first, absolute position. Well, this uses the C/A code only and requires only one receiver. Data from at least 4 satellites are required for getting the observation and it provides an accuracy range of about 15 to 100 meters. This solution is designed for people who just need an approximate location on the earth such as a boat at sea or a hiker in the mountains.

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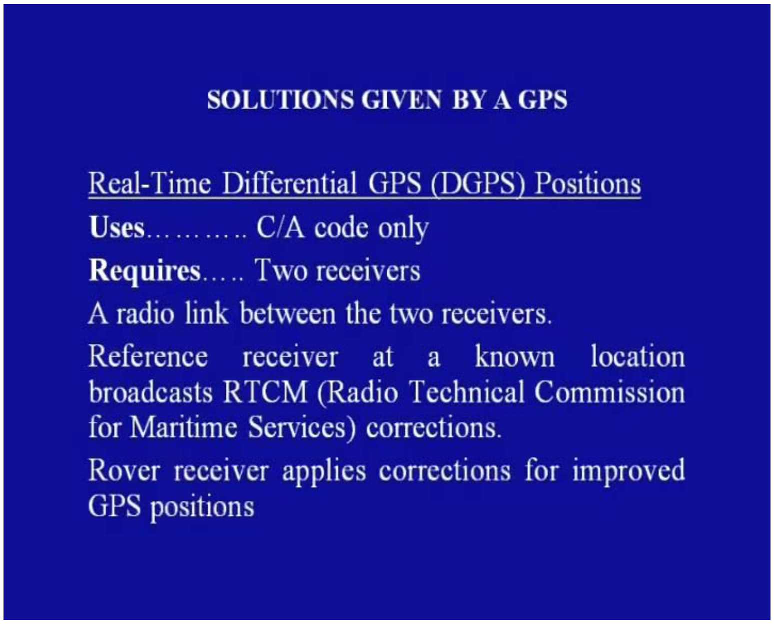

The next solution is real time differential GPS or DGPS position. Well, this type of solution uses a C/A code only and requires 2 receivers. Between the 2 receivers, a radio link is required. The reference receiver at a known location broadcast RTCM that is radio technical commission for maritime services corrections. The rover receiver applies corrections for improved GPS positions.

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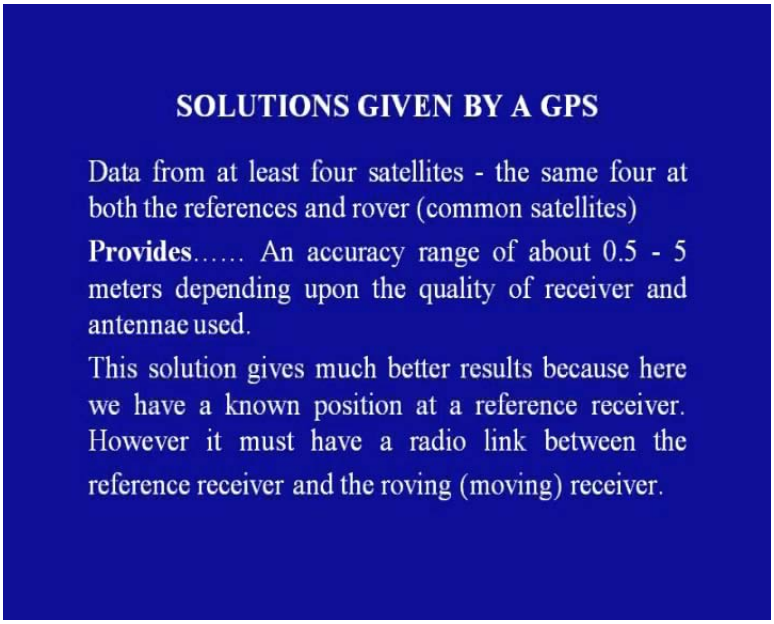

Data from at least 4 satellites; that is the same 4 at both the reference and rover receivers are required. It provides an accuracy range of about 0.5 to 5 meters depending upon the quality of the receiver and the antennae used. This solution gives much better results because here we have a known position at a reference receiver. However, it must have a radio link between the reference receiver and the rover; that is the moving receiver.

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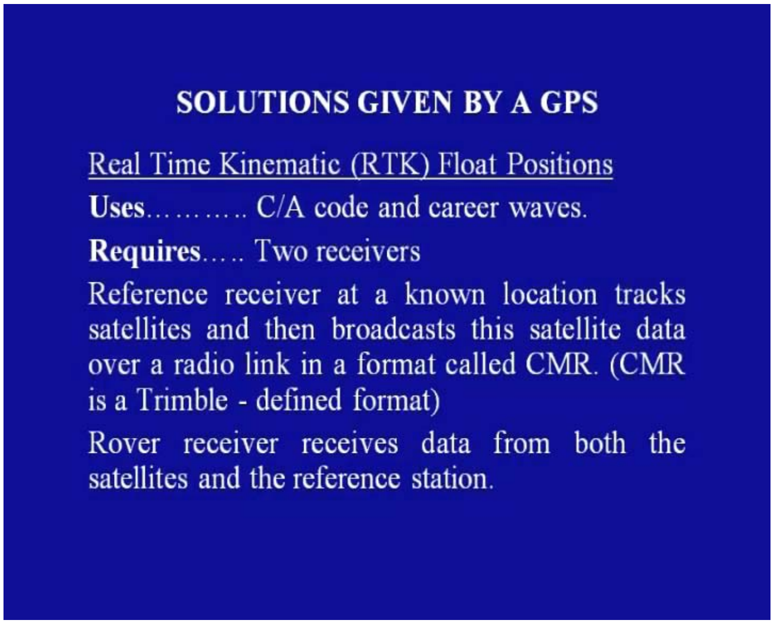

Next is real time kinematic; RTK float positions. Well, this solution requires C/A code along with carrier waves. It requires 2 receivers; the reference receiver at a known location tracks the satellites and then broadcasts this satellite data over a radio link in a format called CMR, CMR is Trimble - defined format. Rover receiver receives data both from the satellites and from the reference data.

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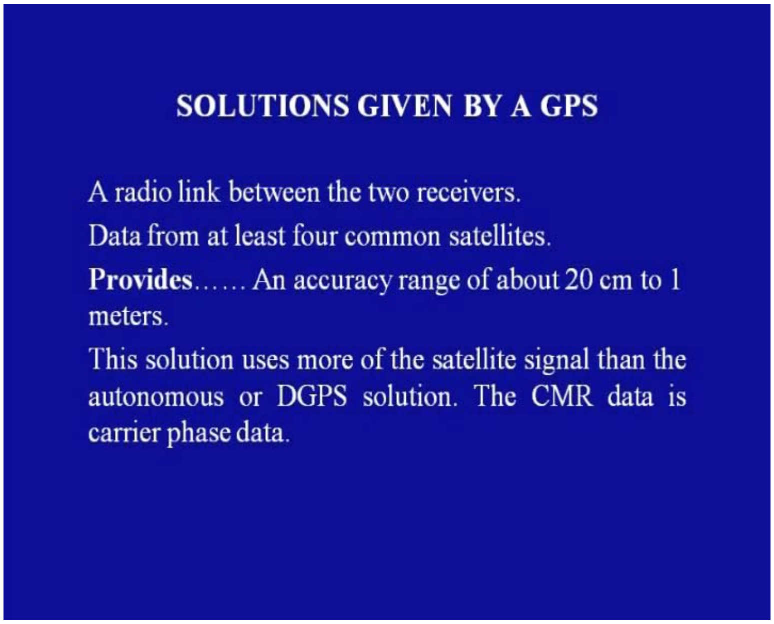

A radio link between the 2 receivers is required. Data from at least 4 common satellites need to be tracked both by the reference and the rover GPS receivers. This type of solution provides an accuracy range of about 20 centimeters to 1 meter. This solution uses more of the satellite signal than the autonomous or DGPS solution. The carrier data, this CMR data is a carrier phase data.

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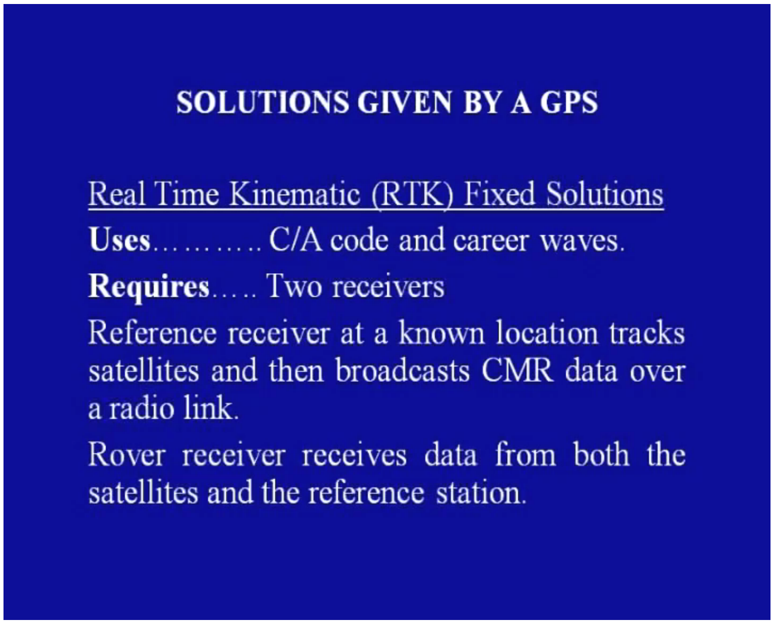

Then we have the next solution that is real time Kinematic fixed solutions. Well, again in this we use C/A code and carrier waves and require 2 GPS receivers. The reference receiver at a known location tracks the satellites and then broadcast the CMR data over a radio link. The rover receiver receives data from the both satellites and the reference station.

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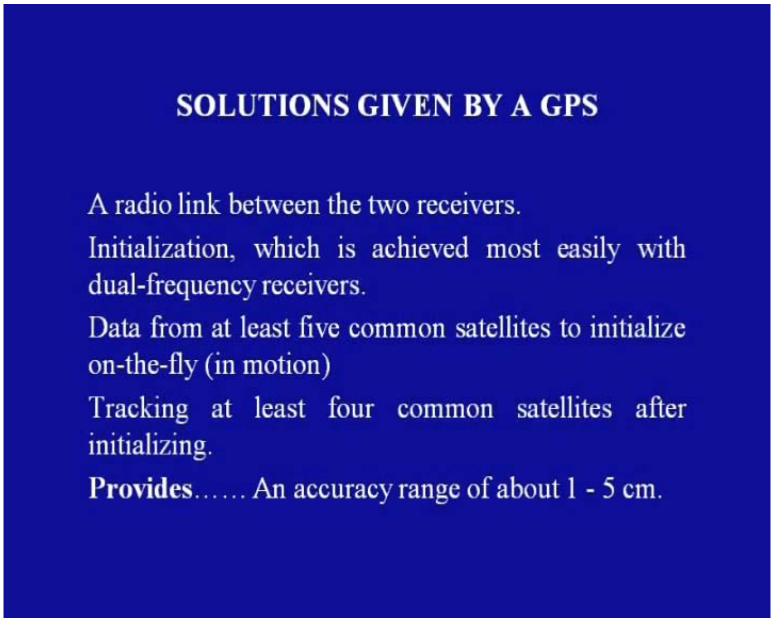

A radio link between the 2 receivers has to be maintained. Initialization, which is achieved most easily with dual - frequency receivers. Data from at least 5 common satellites to initialize on the fly that is in motion are required and one needs to track at least 4 common satellites after initialization procedure.

Well, this particular solution can provide an accuracy range ranging from 1 to 5 centimeters.
Having looked at now at the different types of solutions which are there, the next important factor is the type of errors which could be associated with a GPS.

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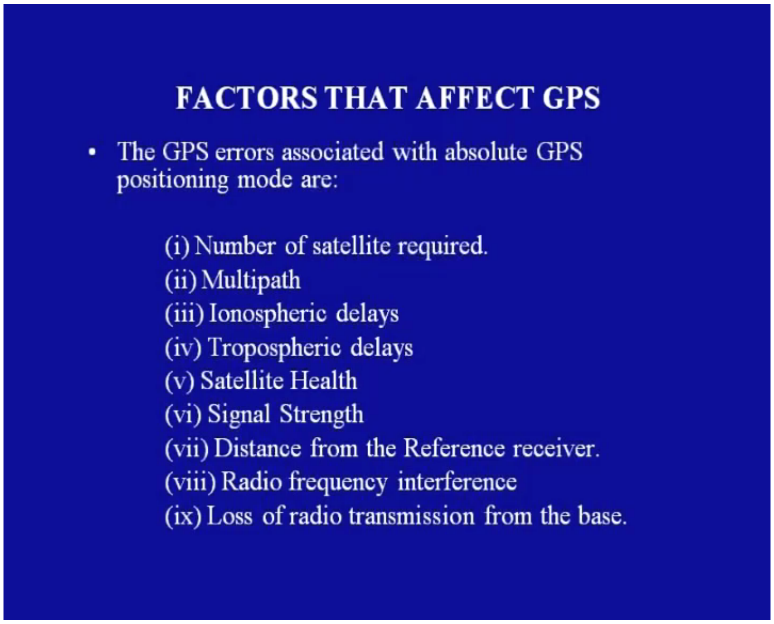

So, let us to look at what are the factors which affect GPS. The GPS errors associated with absolute GPS positioning modes are; 1.Number of satellites required, 2.Multipath, 3.Ionospheric delays, 4. Tropospheric delays, 5. Satellite data, 6.Signals strength, 7.Distance from the receiver, reference receiver, 8. Radio frequency interference and 9 is loss of radio transmission from the base.

Now, let us took at each of these errors one by one in detail.

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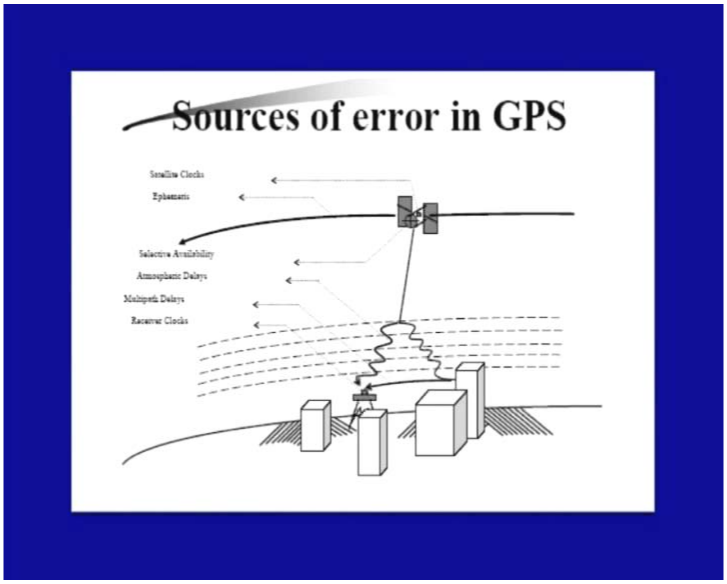

Before we proceed ahead, this particular slide shows a schematic diagram of the sources, radio sources of errors in GPS observations. First error which could be which needs be looked into is through cost by the number of satellites. As we know that apart from the spatial coordinate's x, y and z, time is another factor to be taken into consideration.

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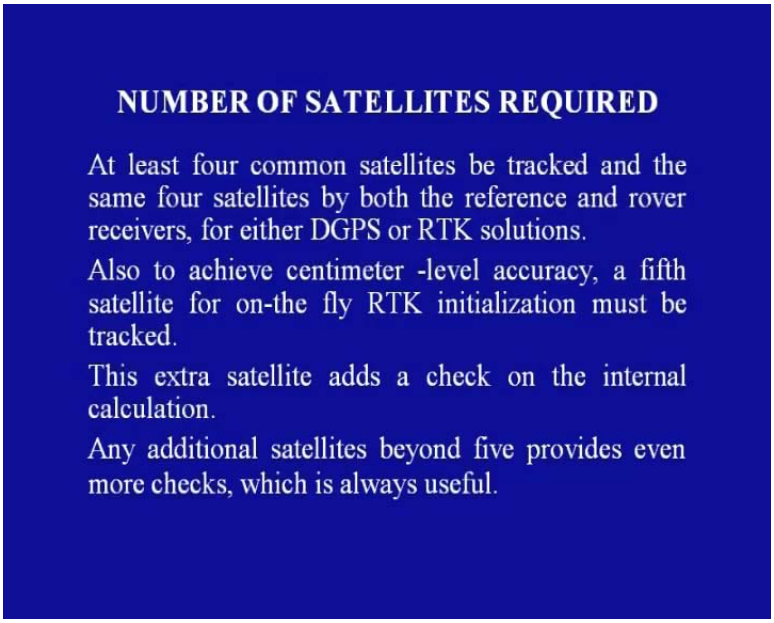

So, at least 4 common satellites be tracked and the same 4 satellites by both the reference and rover receivers either in DGPS or RTK solutions be there. Also, to achieve centimeter level accuracy, a fifth satellite on-the fly RTK initialization must be tracked. This extra satellite adds a check on the internal computations. Any additional satellite beyond 5 provides even more checks which is always useful.

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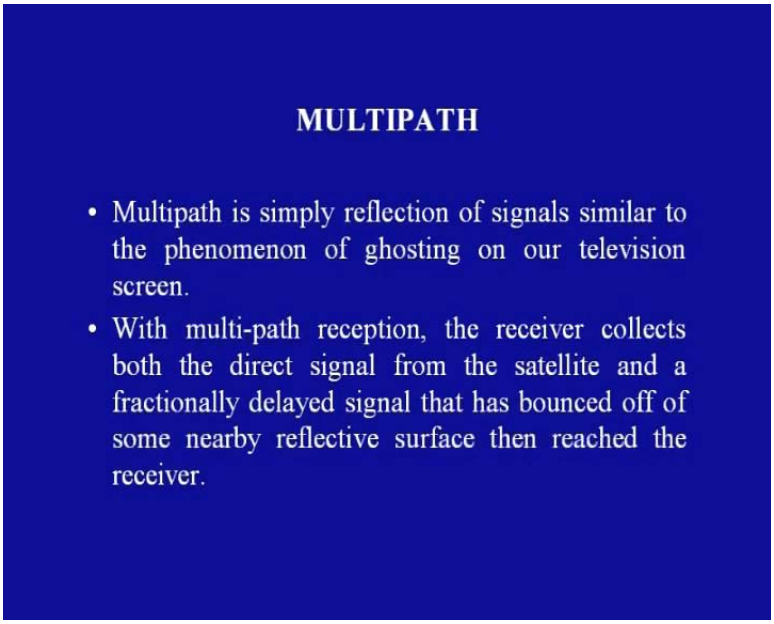

Then, multipath; multipath is simply reflection of the signals similar to the phenomena of ghosting on our television screens. With multipath reception, the receiver collects both the direct signals from the satellite and a fractionally delayed signal that has bounced off from some nearby reflective surface, then reaches the receiver.

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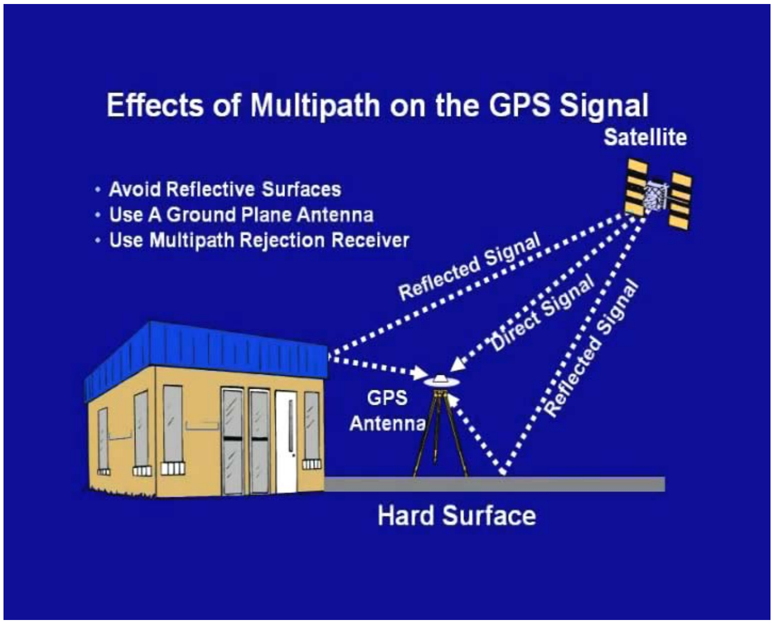

This particular slide shows the phenomena of multipath. We can see that the GPS antenna has been located on a hard surface and closed by there is building which has some reflective properties. So, what happens is there is one signal which is received by the GPS antenna which we call it as the direct signal and there are two other signals which are also recorded or tracked by the GPS receiver which may come from the road surface or may be from objects in the nearby vicinity of the GPS antenna where it had been placed.

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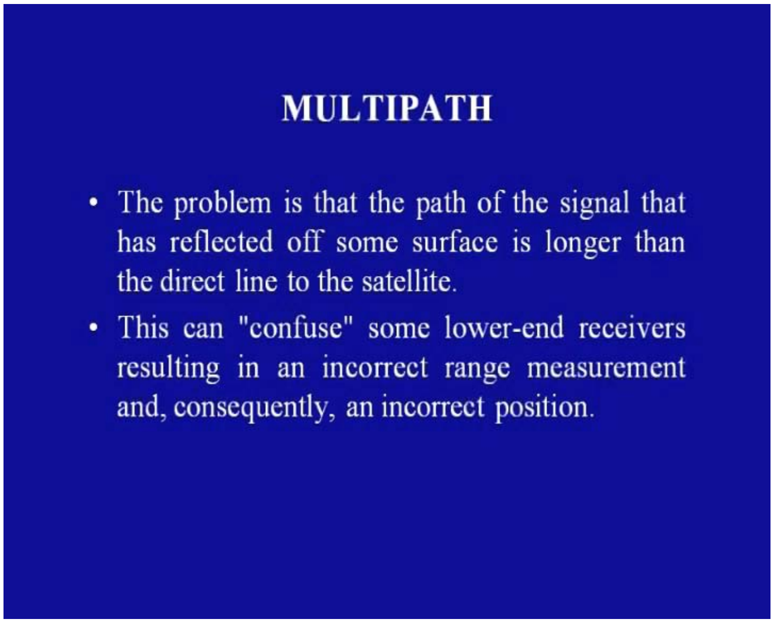

The problem is that the path of the signal that has reflected of some surface is longer than the direct line of the satellite. This can confuse some lower end receivers resulting in an incorrect range measurement and consequently an uncorrected position.

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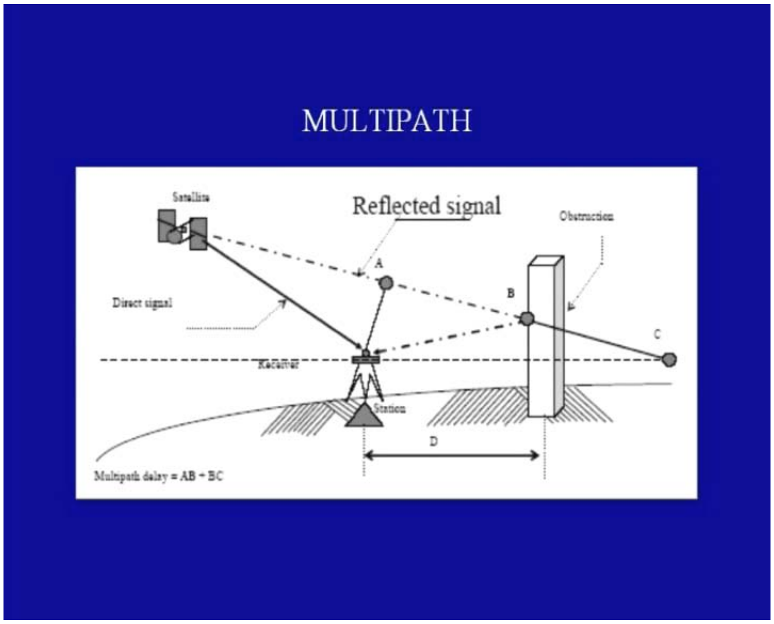

This particular slide it shows a line diagram as to how the multipath delay causes a difference in the times range of the signal being received at the GPS.

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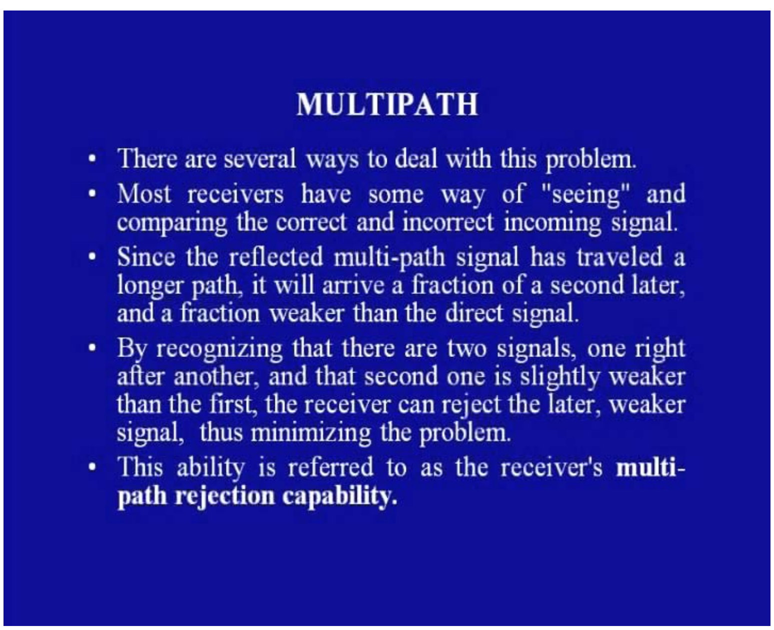

However, there are several ways to deal this problem most receivers have some way of seeing and comparing the correct and incorrect incoming signals. Since the reflected multipath signal has traveled a longer path, it will arrive if fraction of a second later and a fraction weaker than the direct signal. By recognizing that there are 2 signals, one right after another and that second one a slightly weaker than the first one, the receiver can reject the later or weaker signal thus minimizing the problem. This ability is referred to as the receiver's multipath rejection capability.

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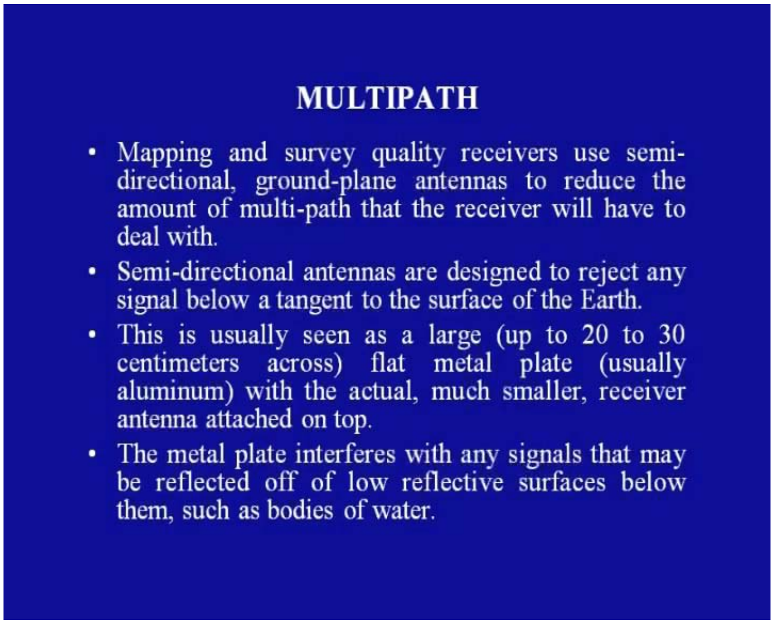

Mapping and surveying quantity quality receivers use semi directional ground plane antennas to reduce the amount of multipath that the receiver may have to deal with. Semi directional antennas are designed to reject any signal below a tangent of the earth of surface the earth. It this is usually seen as a large up to 20 to 30 centimeters across flat metallic plate, usually aluminum with the actual width much smaller, receiver antenna attached on the top. The metal plate interferes with any signal that may be rejected reflected off the low reflective surfaces below them such as bodies of water.

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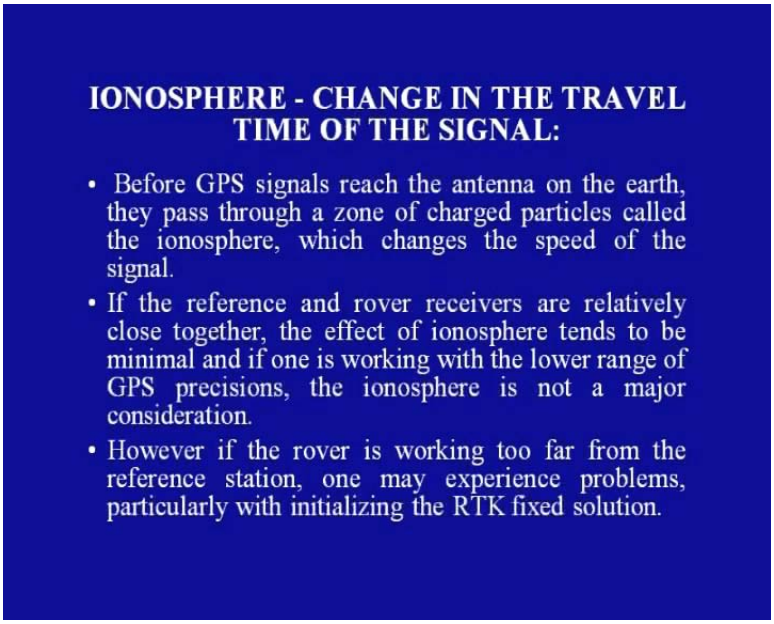

The next error could be due to ionosphere where this causes a change in the travel time of the signal. Before the GPS signals reach the antenna on the earth surface, they pass through a zone of charged particles called the ionosphere which changes the path of the signal.

If the reference and the rover receivers are relatively close together, the effect of ionosphere tends to be minimal and if one is working with a lower range of GPS precisions, the ionosphere is not a major consideration. However, if the rover is working too far from the reference station; one may experience problems, particularly with initialization of RTK fixed solutions.

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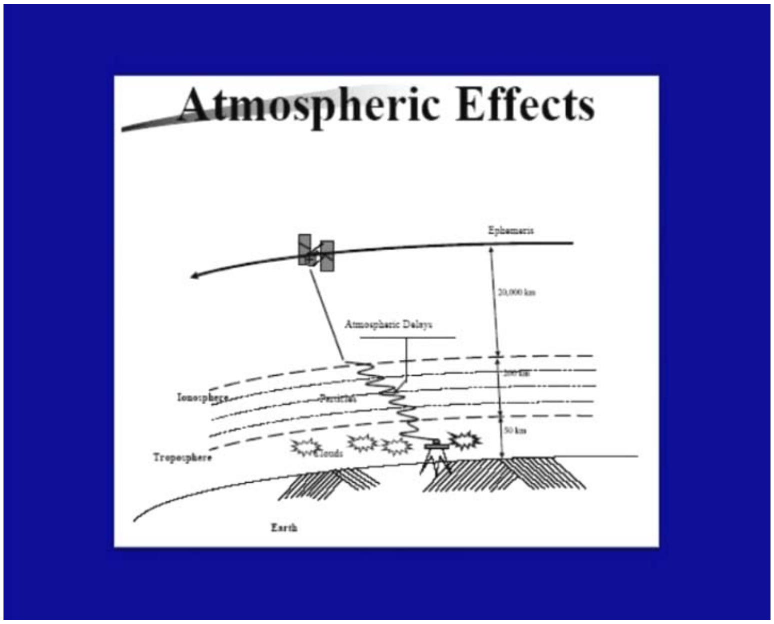

This particular slide, it shows the atmospheric effects on the signal, GPS signal which is received by the antenna. And, one can see there are two layers which cause this problem; ionosphere which is approximately 200 kilometers above the earth surface and troposphere which is the approximately 50 kilometers above the earth surface.

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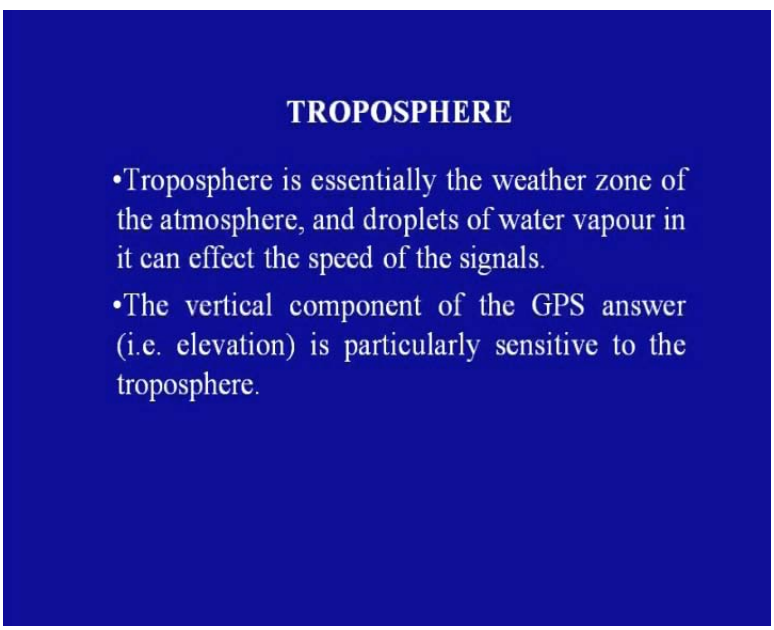

The next factor is troposphere. Troposphere is essentially the weather zone of the atmosphere and the droplets of water vapour in it can affect the speed of the signals. The vertical component of GPS answer that is elevation is particularly sensitive to the troposphere.

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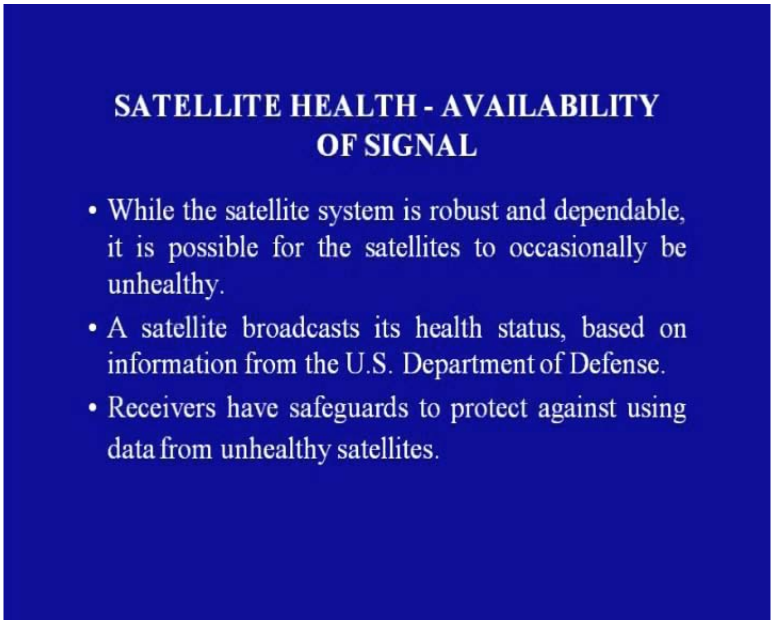

Ehen the satellite system is robust and dependable, it is possible that the satellites to occasionally be unhealthy. A satellite broadcasts its health status based on the information form the US department of defense. Receivers have safeguards to protect against using data from unhealthy satellites.

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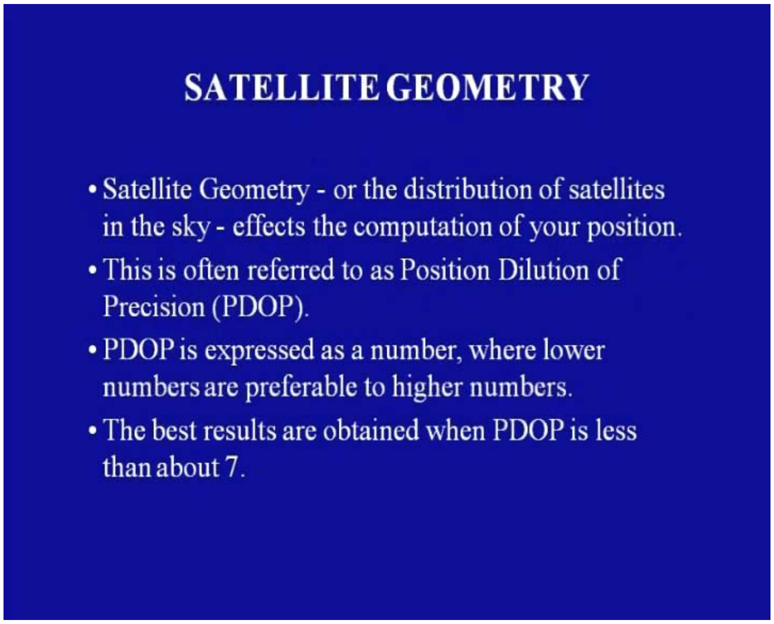

Then is satellite geometry; satellite geometry or the distribution of satellites in the sky effects the computation of your position. This is often referred to as position dilution of precision or in short, PDOP. PDOP is expressed as a number where lower numbers are preferable to higher numbers. The best results are obtained when PDOP is less than about 7.

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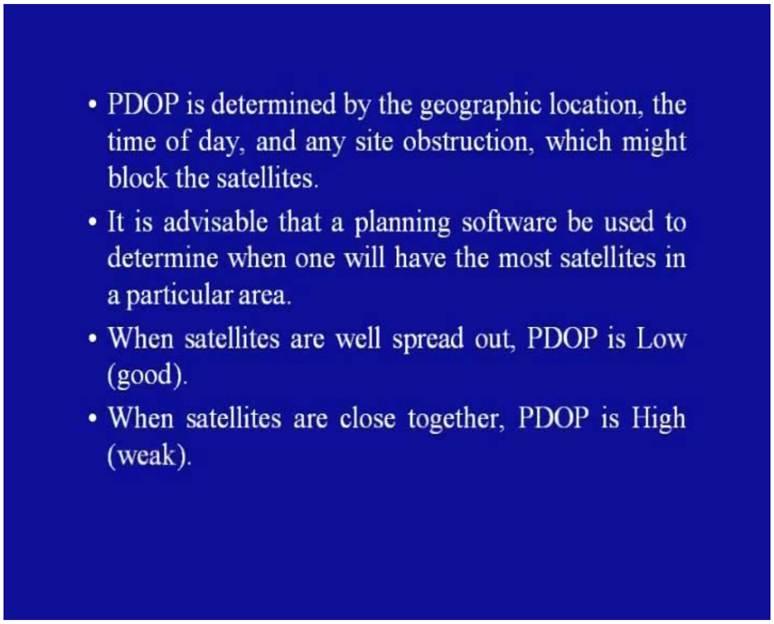

PDOP is determined by the geographic location; the time of the day and any site obstruction which might block the satellites. It is advisable that planning software to be used to determine

when one will have the most satellites in a particular area. When the satellites are well spread out, PDOP is low or we can say the satellite geometry is good.
When the satellites are close together PDOP value is high or we can say that the configuration of the set or the satellite geometry is weak.

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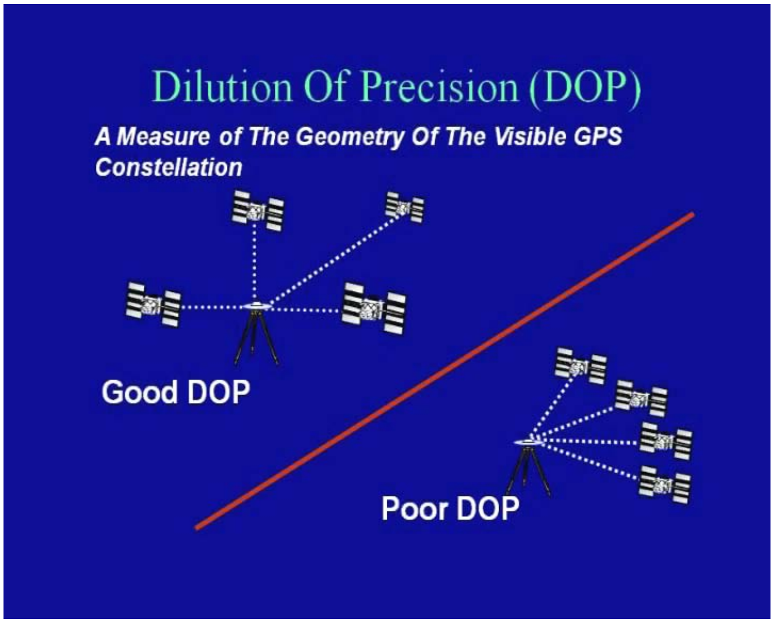

This particular slide provides a schematic representation of good DOP and poor DOP. In a good DOP, we find that the geometry of the visible satellite communicating with the GPS receiver are well spread over the sky; while in a poor DOP, we find that the satellites are concentrated and located close to each other, may be on one side.

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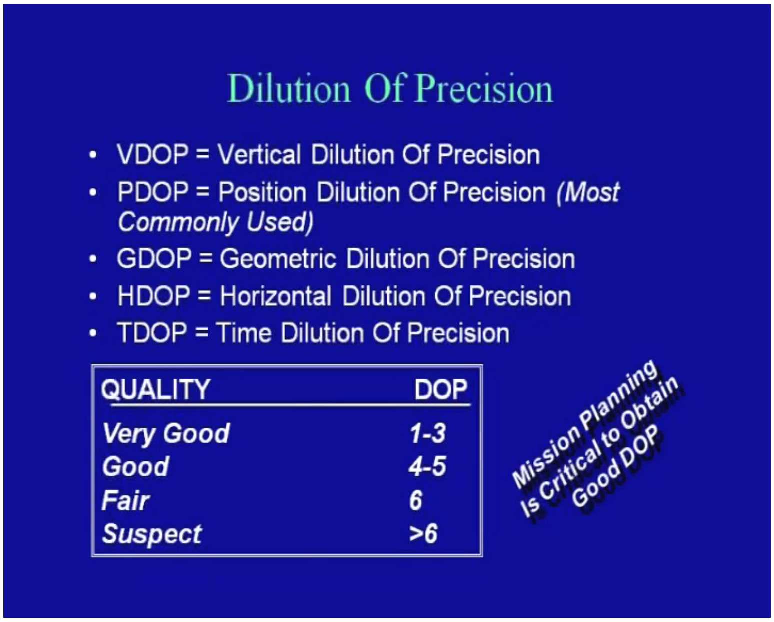

Well, when we talk about the dilution of precision, it may be observed that there are many components which contribute to this. For example; VDOP which is the vertical dilution of precision, PDOP which is the position dilution of precision and this is the most commonly used factor for expressing the satellite geometry. Then we have GDOP which is the geometric dilution of precision, HDOP which is the horizontal dilution precision and TDOP which is the time dilution of precision.

Well, in order to have a good satellite geometry; if the value of DOP is between 1 to 3, it is considered to be a very good configuration, between 4 to 5, it is a good configuration, if the value of DOP is 6, it is fair and greater than 6, it is considered to be suspect. That is the satellite geometry may is not a good one.

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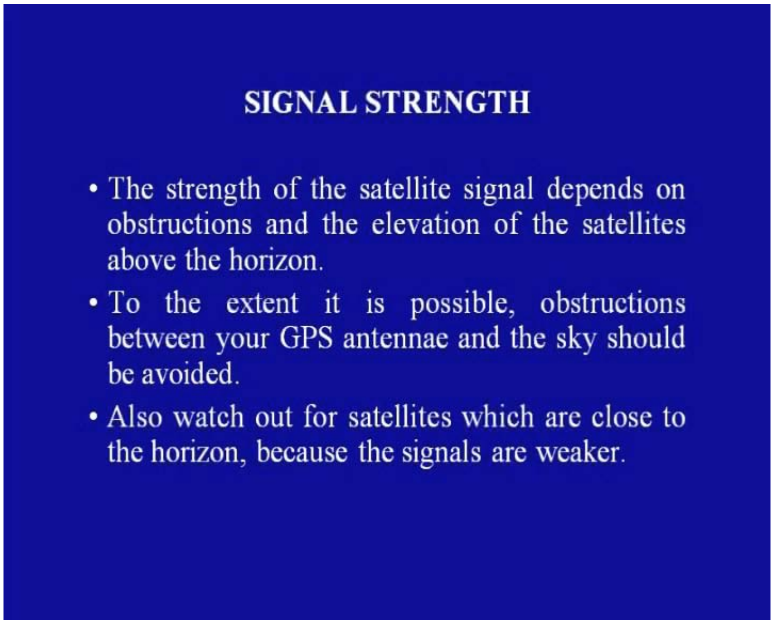

Then is signal strength. The strength of the satellite signal depends on the obstructions and the elevation of the satellites above the horizon. To the extent it is possible, obstructions between your GPS antennae and the sky should be avoided. Also, watch out for satellites which are close to the horizon because signals are weaker.

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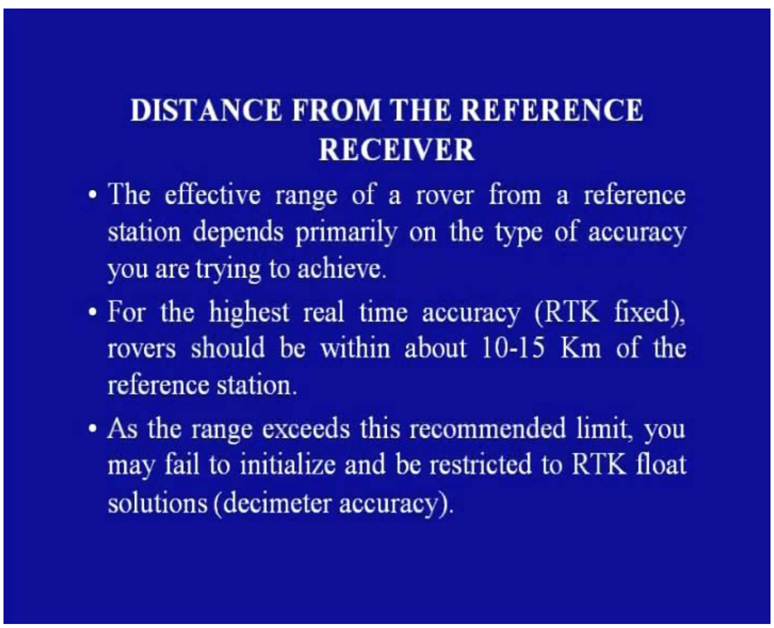

The next factor which may effect the GPS observations is the distance from the reference receiver. The effective range of a rover from a reference station depends primarily on the type of accuracy you are trying to achieve. For the highest real time accuracy, that is RTK fixed, rover should be within 10 to 15 kilometers of the reference station. As the range exceeds, this recommended limit, you may fail to initialize and be restricted to RTK float solutions. That is at the decimeter level accuracy.

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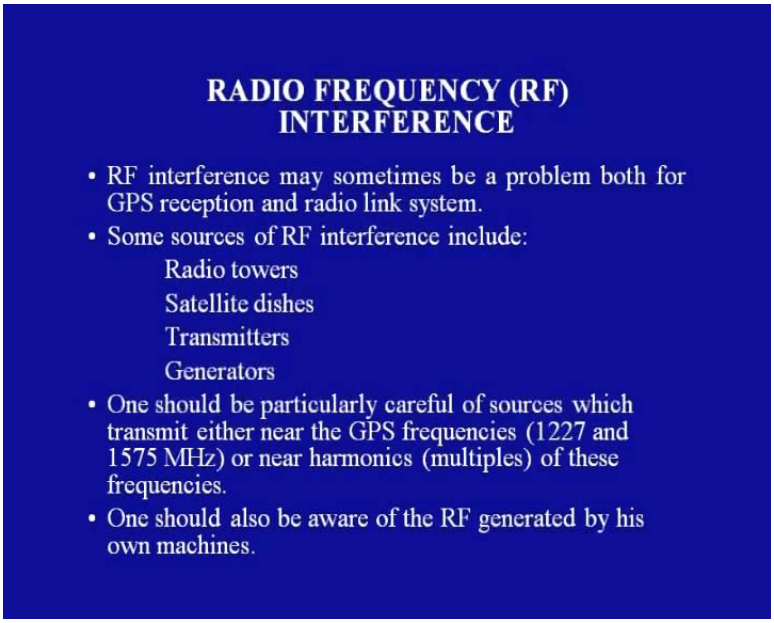

The next error is radio frequency interference or in short known as RF interference. RF interference may sometimes be a problem both for GPS reception and radio link systems. Some sources of RF interference include radio towers, satellite dishes, transmitters, generators. One should be particularly careful of this sources which transmit either or near the GPS frequencies of 1237 and 1575 mega hertz or near harmonics that is the multiple of these frequencies. One should also be aware of the RF generated by his own machines also.

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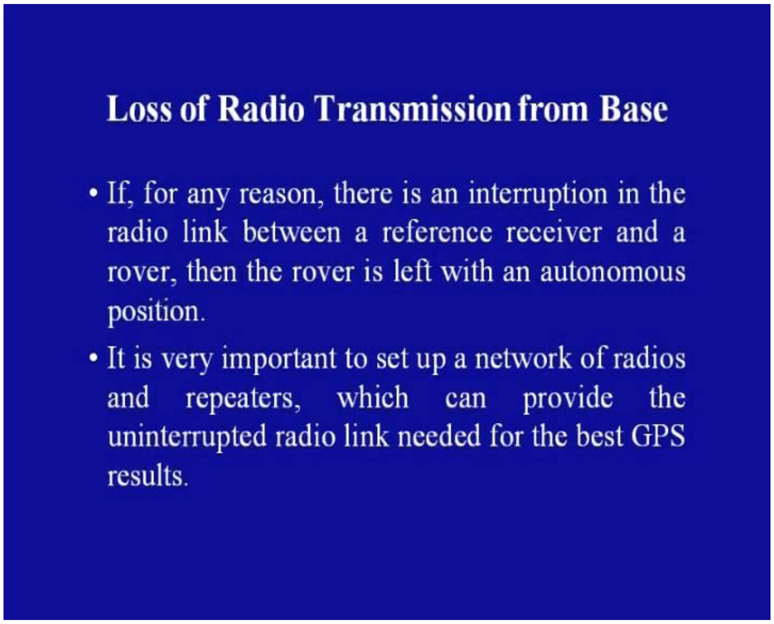

Then loss of radio transmission from base; if for any reason there is an interruption in the radio link between a reference receiver and a rover, then the rover is left with an enormous autonomous position. It is very important to set up a framework of radios and repeaters which can provide the uninterrupted radio link needed for the best GPS results.

In my next session, I would discuss the various applications of GPS.

Thank you.