Global Navigation Satellite Systems and Applications
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Lecture – 11
Differential Global Navigation Satellite System (DGNSS)

Hello everyone and welcome to 11th lecture of this course which is Global Navigation Satellite Systems and Applications. And today we are going to discuss one of the very important techniques with these navigation systems which is Differential Global Navigation Satellite Systems. Earlier, we used to say differential GPS but now we are having many other navigation systems. So, now we are calling as differential GNSS. Let’s understand first about the basics of this one.

Basically in differential GPS or GNSS, what we are doing; we are recording not only the signals which are being received by receiver but also at the same time at a permanent station or base station, we are recording errors as well. And assuming that the roaming station which is in the field and the permanent station data, they are accessing the same sets of satellites.

So, if this is the situation then from one location which is stationary, we can have the error information and that error, we can subtract from the location which we are getting through rover GPS or GNSS receiver and then we can improve the accuracy.

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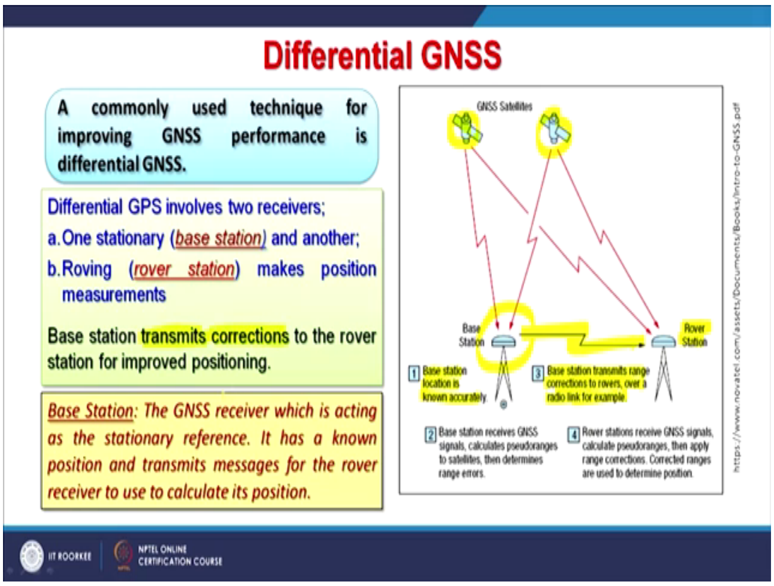

So, the main purpose of differential GNSS is to improve the accuracy so that we can get much more accuracy than using a single stand alone GPS. So, it is basically differential technique to improve the performance and differential GPS involves as just mentioned two receivers as you can see; one is the base station and another one is the rover station.

And these two receivers, they will have some distance. So, the baseline is there and this is the baseline basically. And rover receiver can be taken at different locations whereas base station is permanently located and these two receivers will receive signals from the same set of satellite. As you can see here; the example given is only of two satellites but normally you require 4 or 6 satellites to get good location.

So, whereas the base station location is known accurately. How it is known accurately? That if you want to develop a permanent station or base station, you keep recording the data and take average location value. So, suppose recording has been done for 24 hours or 7 days or a few months then we assume that the average location of that place where this permanent receiver station has been kept that is more accurate information and this location can be used as sources of errors, later on when the rover’s data is available and then these errors can be subtracted from rovers location. So, this is how this functions.

So, base station location is known accurately; we assume that it is giving accurate information and base station then transmits range corrections to rovers over a radio link. Now, this is optional. It is not necessary that you need to have a link between base station and rover station as shown here. Later on, through post processing also, these corrections can be done; errors can be removed and therefore the position can be improved.

So, this is optional part that whether in real time, the location information from base station or error information from base station is transmitted to the rover. It can be done later on also because some time it is not easy to transmit the data when the baseline; the distance between these two receivers is large than sometime it is not possible. So, later on, through post processing, differential GNSS can work and differential position or accurate position can be achieved.

So, as already discussed that one is the stationary station or we also called as base station; in this GNSS receiver which is acting as a stationary reference, it has a known position and transmit message for rover receiver to calculate its position. So, known position means if I have to do some survey in an area where I do not get any benchmark or known position so this base station if I run for few days or months or hours; I can make that location as a known position and that known position can be used for getting errors information for the rover station.

And rover station basically will do the measurements in the field; base station will remain stationary in the area. So, base station transmits as I have already mentioned not necessarily all the time; it can record also and later on, it can be used to improve the position. So, let us discuss further on this aspect that how these things works.

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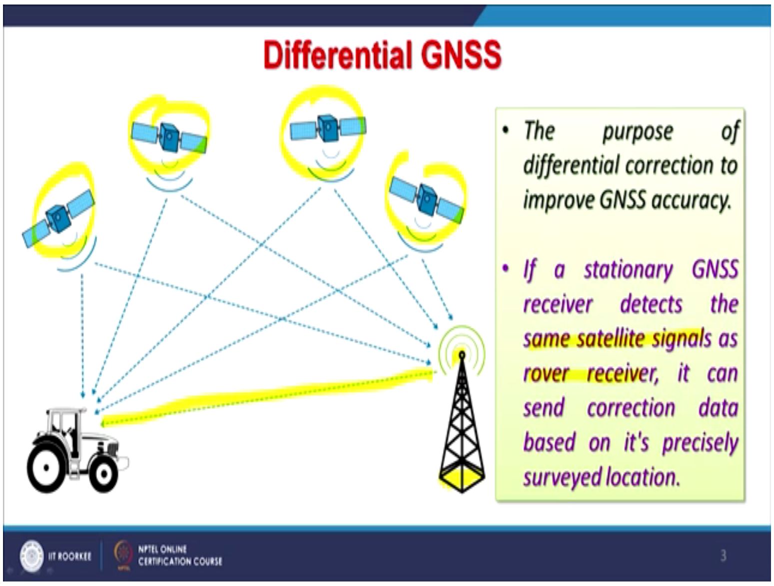

Basically as we are discussing that the purpose of differential correction to improve the GNSS position accuracy; like one example is there that all these four satellites you know, their signals are being received by base station as well as a roving receiver which is here; it is shown through a vehicle is there.

So, if all these four satellites are giving signals to these receivers then the task becomes much easier and we can achieve much better accuracy. So, if a stationery GNSS receiver detects the same satellite signals you know, as rover receiver as in this figure, it is shown. It can send correction data based on its precisely surveyed location. So, this tower which is shown as a base station, it can transmit the data as shown here as a green line. In a real time also, the position of this vehicle in which the rover receiver is installed can be achieved.

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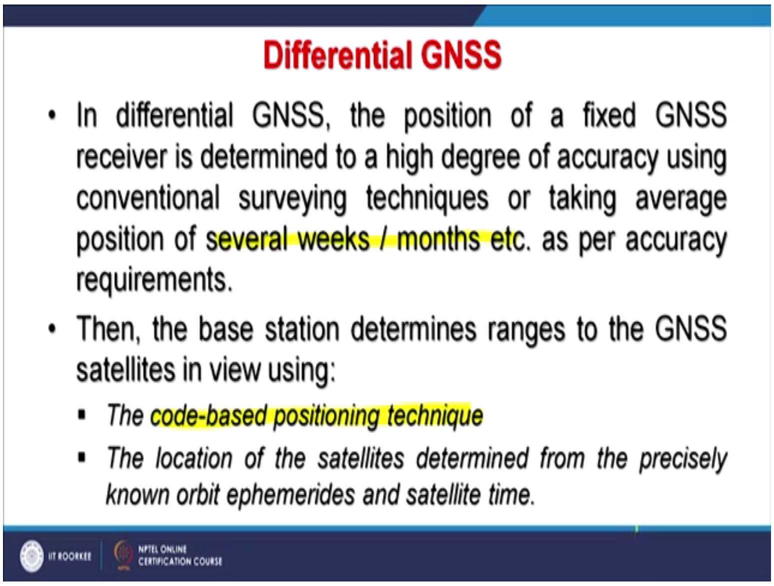

So, in differential GNSS; the position of a fix GNSS receiver is determined to a high degree of accuracy using conventional surveying techniques or taking average position of several weeks or months or it depending on how much accuracy do you want; in 24 hours sometimes it is also done. But more the data you are having, better the average would be and errors which you can use for the roving station would be much better and your accuracy requirements will also be fulfilled.

And then the base station basically determines the rangers to the GNSS satellite in a view using the code-based positioning technique. This one has to remember. This is important thing here that in differential GNSS, we are using code-based positioning technique. There is another technique which is called RTK; Real Time Kinematics in which we use carrier-based positioning techniques. So, we will be discussing in next lecture about that topic but here in differential GNSS, we use the code-based positioning technique.

And in this, the location of satellite determined from precisely known orbit and ephemeris and the satellite time.

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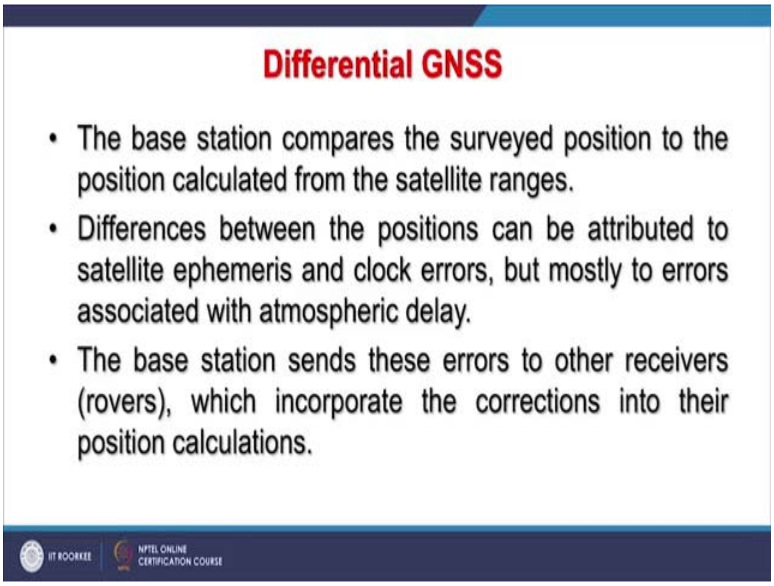

And the base station compares the surveyed position to the position calculated from the satellite ranges. And differences between the positions can be attributed to satellite ephemeris and clock errors but mostly two errors associated with atmospheric delays. And the base station sends these errors to other receivers, there may be more than one rover receivers, which incorporates the corrections into their position calculations. If a real time differential position is required, then the signal can be send from a permanent station or base station to the rover station.

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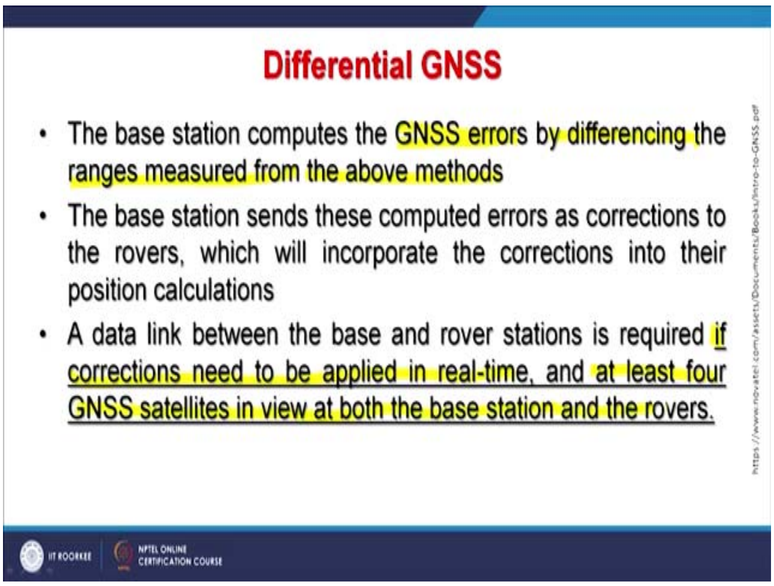

And the base station basically computes the GNSS errors as I have been mention earlier also by differencing the ranges measured from the above methods. This is important that these errors are used assuming that if I am having in average position and I get the current position. Then I can compare with the average position and that average position minus current position, I get the error and that error is transmitted to rover station or through post processing, I can improve my position accuracy of roving receivers.

So, base station sends these computed errors as correction to rovers which will incorporate the corrections into their position calculations. A data link between the base and rover stations is required if corrections need to be applied in real time. Sometimes it is not required at all. So later on, it can be done and at least four GNSS satellites in view at both stations and rovers.

So, that is why sometimes the baseline or the distance between this stationary base station and the roving station is kept in a manner that they are not very far apart and therefore these will have access to the same set of satellites. And if this scenario is happens then we get better accuracy but if the base station and the roving stations are accessing different sets of satellites then our position accuracy through this differential technique may not be at desired level.

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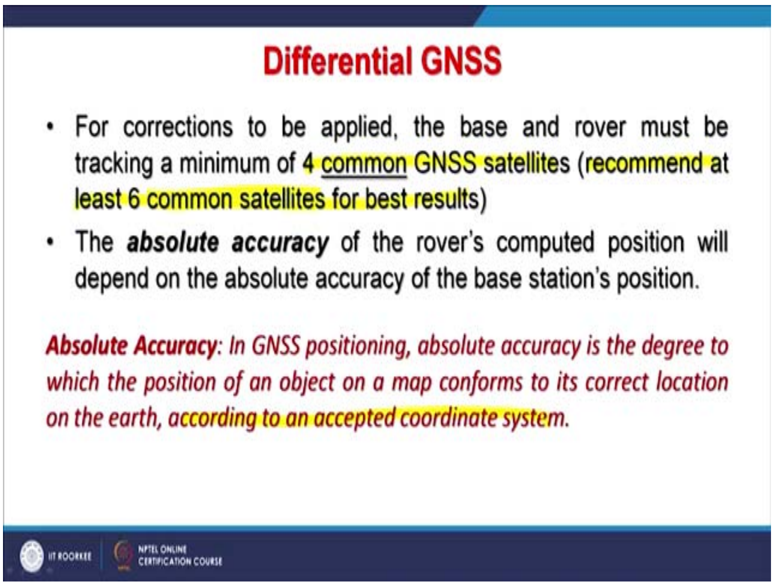

So, for corrections to be applied to roving stations data; the base and rover must be tracking a minimum of 4 common GNSS satellites. However, it is always expected that more number of satellites if are there and common satellites; this is important common satellites that same set of satellites that rover and base are accessing.

And there is a term which we used in GNSS parlance that is the absolute accuracy of rovers computed position which will depend on the absolute accuracy of the base station position. And what is absolute accuracy in this domain that is in GNSS positioning, the absolute accuracy is the degree to which the position of an object on a map conforms its correct location on the earth and according to accepted coordinate system. Because if I determine position of a location even from DGNSS then how to confirm or you know, how to mention that this is accurate position because I have to have some comparison with that.

So, that is why it is written here that according to an accepted coordinate system that whatever the coordinate system which I am using if my accuracy estimates are as per my requirements then I may call as absolute accuracy. So, in GNSS positioning we will relook this statement that the absolute accuracy is the degree to which the position of an object on a map conforms to its correct location on the earth and that too according to an accepted coordinate system. So, if this happens then we can call as absolute accuracy.

Normally, using a single receiver without differential technique, we do not get as accurate position as in case of differential. So, if I give some values then in single handled receivers or even through smart mobile receiver, the maximum accuracy generally we get of 3 metre. But if we bring the differential technique or RTK which we are going to discuss next then our accuracy can be improved 2 centimetres even sometimes 2 millimetres. So, that is the major difference between a normal GPS or GNSS operation and differential GNSS operation.

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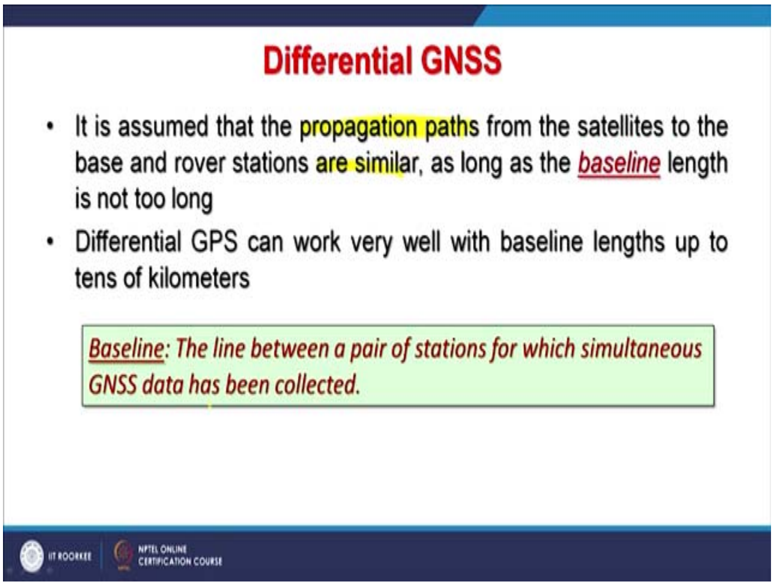

Now, in differential GNSS; it is assumed that the propagation paths from the satellite to base and rover stations are similar. As we have been discussing that both receivers; base and rover should receive signals from the same set of satellites. However, further assumed that the propagation path that means the signal which is coming from these set of satellites to these two receivers; base and rover, the signals is going through the same propagation path. If this is different than it will affect our accuracy estimation or location estimation.

So, it is assumed that the propagation paths from satellite to the rover and base stations are similar as long as the baseline length is not too long because as also I mentioned earlier that if the distance between base station and rover station is too large then it is highly likely that we may not be accessing signals from the same set of satellites. And therefore, this propagation path for these two receivers from these satellites is also going to be different and if it is the scenario then we will have less accuracy.

So, if we would like to define here that the baseline; the line between a pair of stations maybe base and rovers for which simultaneous GNSS data has been collected. So, differential GPS or GNSS can work very well with baseline length up to a tens of kilometres but it is not that in few metres only but if they are far apart of 10 kilometre, 20 kilometre is still we can work and use this technique that is differential GNSS.

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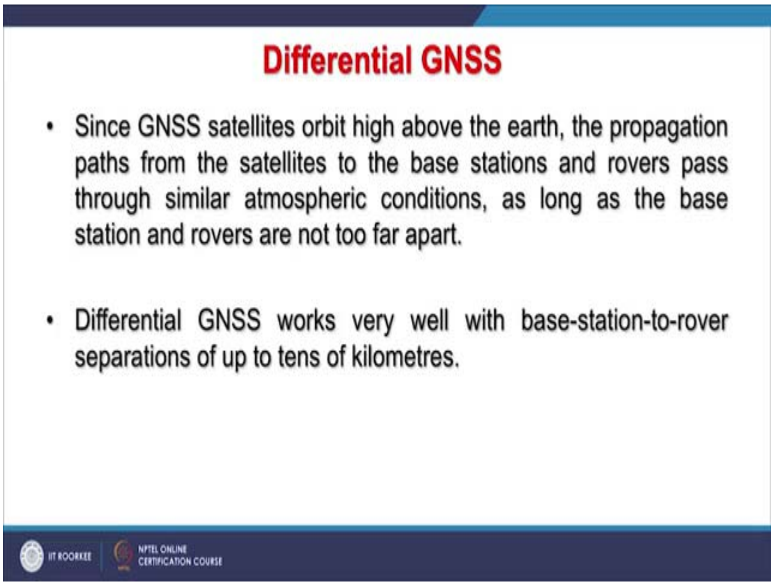

And GNSS satellites orbit high above the earth as we know the propagation path from the satellite to the base stations and rovers pass through similar atmospheric conditions as long as the base stations and rovers are not too far apart.

And differential GNSS works very well with base stations to rover separations of up to tens of kilometres. So, if we go for 200 kilometre baseline then definitely we might be introducing some problem about propagation path and not accessing the signals from the same set of satellite and then problems will come. But if baseline distance is 20, 30, 40 kilometres hopefully, one should not get any such problem.

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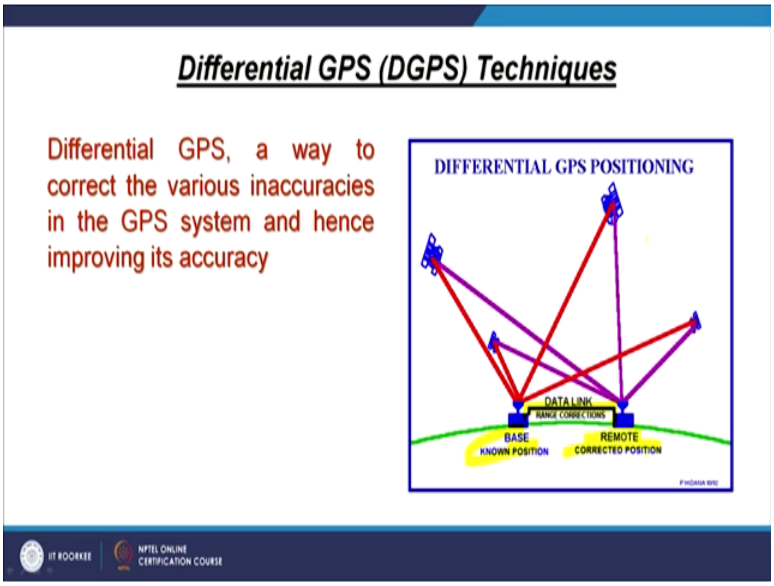

For example; in differential GPS, a way to correct various inaccuracies in GPS system and hence improving the accuracy is as here shown also that this is the base station, this is the remote or roving stations. You are having a direct data link transmission and receiver here and same data from same sets of satellite is being accessed. And if this is the scenario, it works very well.

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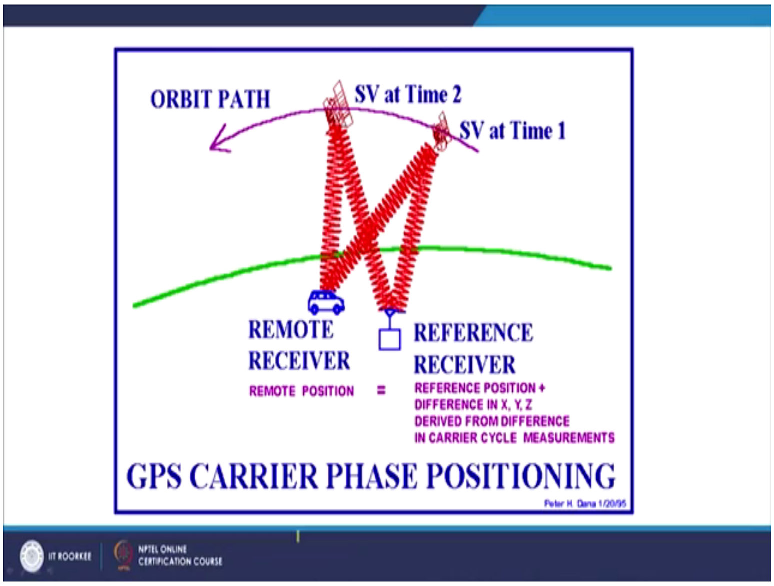

Now, because there are two ways of accessing signals or calculating the position; one is the code-based, another one is the career-based. So, we will be also looking in detail about the carrier-based system that is RTK; a Real Time Kinematics later in.

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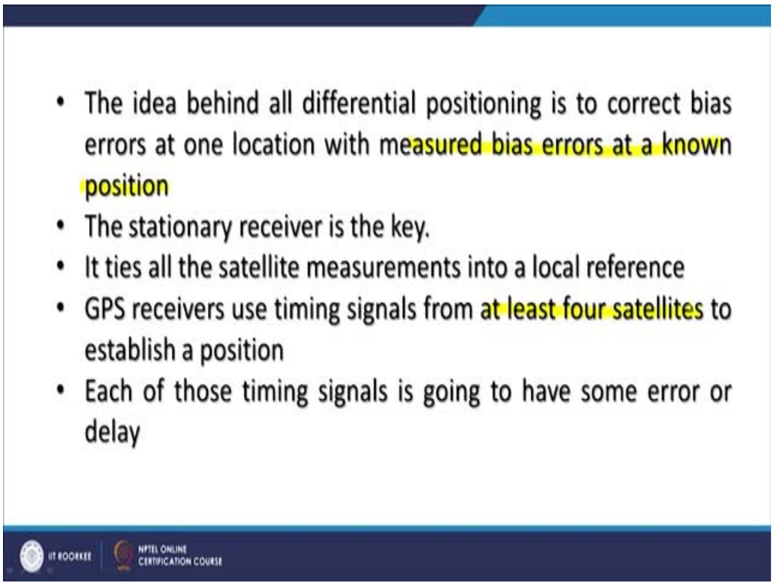

So, the idea behind all differential position is to correct bias errors at one location with measured bias errors at a known position. So, measured bias errors; what we are doing is measured errors from the base station and the errors at one location that is rover station.

And the stationary receiver is the key. If we do not have that benchmark base station then of course, the error information will not be available to us and then differential GPS or GNSS technique will not work.

So, the key is to have a base station or a stationery receiver because it ties all the satellite measurement into a local reference and then GPS or GNSS receivers use timing signals from at least four satellites to establish a position and each of those timing signal is going to have some errors or delays.

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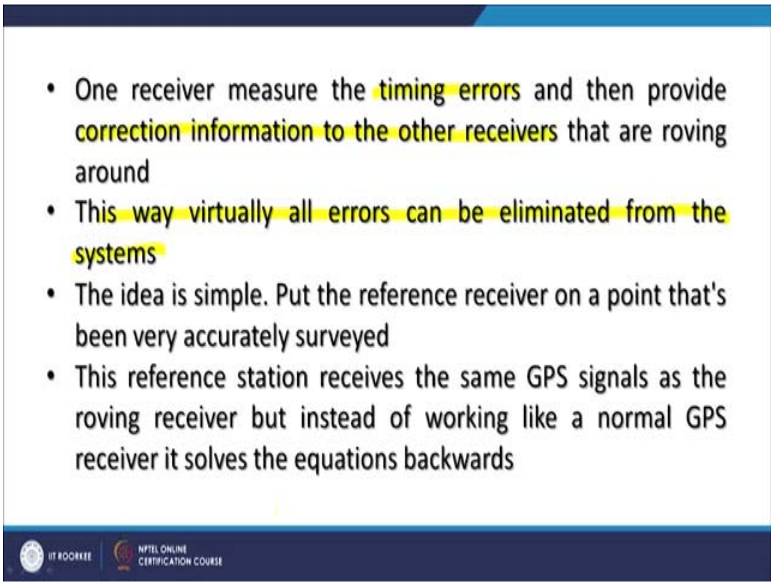

And the one receiver measures the timing errors and then provides correction information to the other. So, the timing error is being measured or recorded by the base station and whereas, then it provides the correction information to the other receiver that is roving in the field. And this way virtually, all errors can be eliminated from the systems. Assuming, again I am repeating assuming that both base station receiver and the rover receives; they are accessing signals from the same set of satellites one and the propagation path is also same. If this is the thing then this way virtually all errors can be eliminated and we may get accuracy of few millimetre range.

So, this idea is very simple but put the reference receiver on a point that is been very accurately surveyed or it can be developed. A base station location can be developed after recording for a week or month. And this reference station receives the same GPS signals as roving but instead of working like a normal GPS receiver, it solves the equation backwards. So, likewise we get the accurate position through differential.

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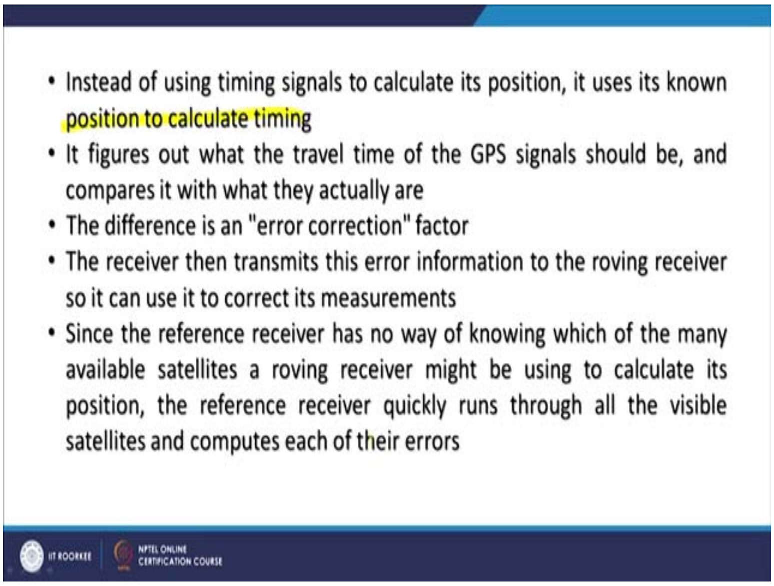

So, instead of using timing signals to calculate this position, it uses its known position to calculate timing and that is why it is mentioned that is a reverse process. So, it calculates the position to calculate to timing and this way, we collect the error information; those errors being received by our rover receiver. And once these errors information is available, we can subtract these errors from rover's position and can get accurate position.

So, it figures out that what travel time of GPS signals or GNSS signals should be and compares it with what they are actually and the difference is an error correction factor. And this receiver then transmits this error information or may record for post processing to the roving receiver so that it can use to correct its measurements.

Since the reference receiver has no way of knowing which of the many available satellites, a roving receiver might be using to calculate its position, the reference receiver quickly runs through all the visible satellites and computer each for their errors. So, sometimes how to assume: How to assess that the both receivers are receiving signals from same set of satellite. So, instead base station or stationery receivers go through that signals or errors data or this backward calculation of timing for all visible satellites to the base station. So that you are having data from various satellites, your roving receiver may not be having signals from the same set of satellites.

But if I am having signals from base station from ten satellites and there I am having from five satellites; at least it is expected that those five satellites are must be common among these ten and that way things can be improved further.

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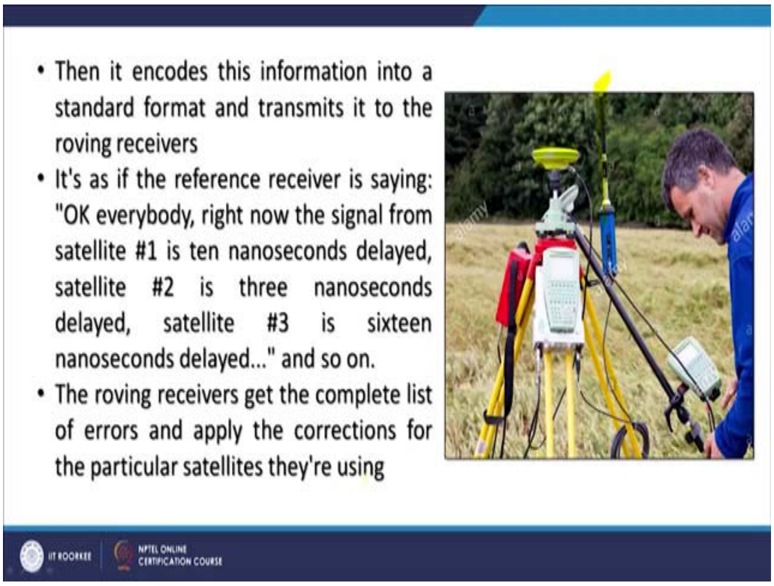

And once this information is there then it encodes this information into a standard format and transmits to the roving receiver in real time. And this is shown here complete setup of a differential GPS station and you can also see a transmitter is shown here, this is the receiver and these all controls are there.

Once as if the reference receiver is saying that for example; Ok everybody, right now the signal from satellite number 1 is ten nanoseconds delayed, satellite 2 is three nanosecond delayed, satellite 3 is sixteen nanosecond delayed and so on so forth. So, this information is going to the roving receivers and roving receivers then correct its position. So, you get very accurate position.

So, roving receivers get the complete list of errors and apply the corrections for the particular satellites they are using. As mentioned earlier that the base station might be giving this information of ten satellites but the roving receiver is getting access to only five satellites but these are the common five satellites and that way, it can improve the accuracy. So, it brings to end of this discussion on differential GNSS.

As discussed in this topic that you require basically two receivers. Sometime people use the identical receivers from the same company, same brand, same setup so that any other problem will not come during such investigations or surveys or recordings. Base station ultimately records the errors and your roving stations collect the data which is having errors. So, these errors which base station has recorded can be subtracted from roving stations and better accuracy of positions or better position accuracy can be achieved using this differential GNSS technique.

Thank you very much.