Surveying
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Module - 12
Lecture - 2

Global Processing System

Welcome to this video lecture on basic surveying. Now today we are in module 12, lecture number 2 and this is the module about the GPS. So basically in this module we are talking about how we can do surveying with GPS. Now this is our schedule.

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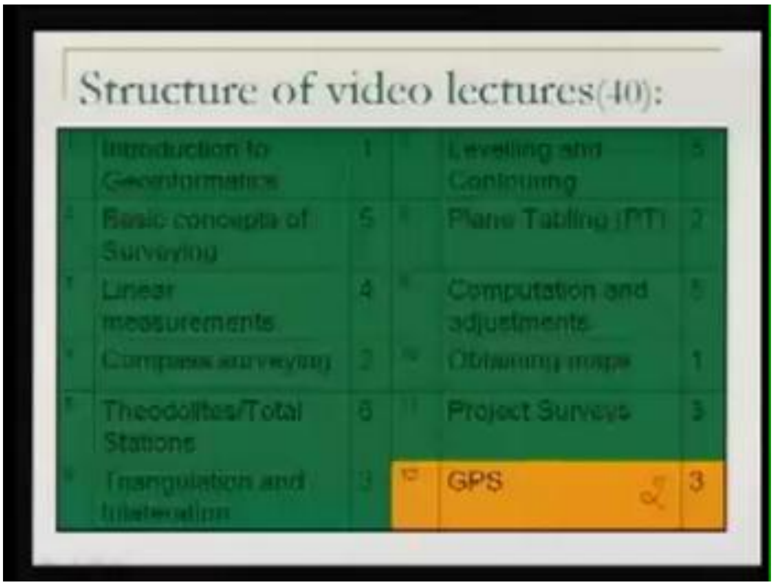

So we are doing lecture number two today.

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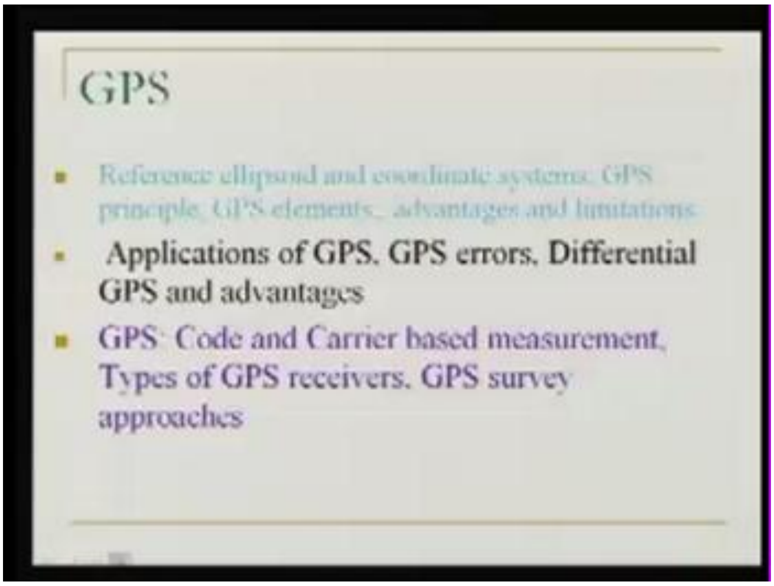

And what we have seen so far in our last lecture? We talked about the ellipsoid, the reference ellipsoid, because when we are talking about the GPS, GPS gives the coordinates on a certain system. The coordinate system. We need not to know we need to know what that coordinate system is because it's not a local coordinate system unlike the surveying or the land surveying or one small project rather it's a world coordinate system. So we saw last time the coordinate system, then also we saw the principle of GPS, advantages and limitations of the GPS. Now what we are doing today because we understand a bit about the GPS now? So what we will do today? We will first look at the applications of the GPS, what all areas where the GPS can be used. Of course the list of the application is very wide. We will only concentrate on a few applications. Then we will talk about the GPS errors, differential GPS. This is done to improve accuracy and its advantages. So to begin with, the applications of the GPS.

Now what is the GPS giving us? GPS gives us the coordinate of a point, wherever we are going with the receiver because receiver is the device which is receiving the signals from the satellites and we have seen the principles. Also that how by receiving these signals

The GPS can compute the coordinate of this particular point. So the basic thing that is being given by the GPS is the location where we are.

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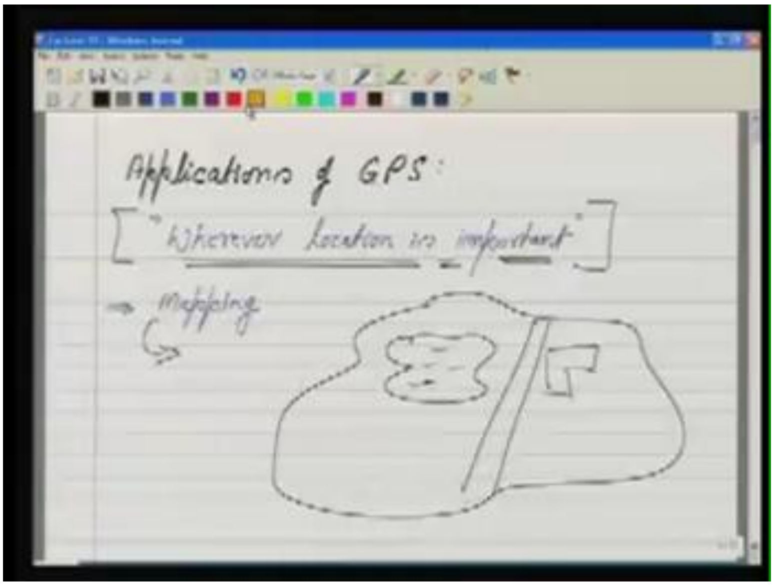

Now this location is very important and there are many applications where the location is very important. For example number one is mapping. Whatever we are doing, in case of surveying you know we are making the maps there. We can do the same job by the GPS also because in order to make a map. For example if we have a garden, in that garden we have some water bodies, then some little houses and a road and we want to make a map of this. So what we would like to do? We would like to occupy all these point by the GPS so that i have got their coordinates as well as i would like to occupy some points along the road also their the corners of the building. So once i am occupying these locations what am i getting? I am getting the coordinates and then later on i can go to any you know cad package or any plotting package or maybe you know simple drawing sheet and i can plot those coordinates, join them and give the proper symbols.

For the house we will give the symbol of the house, for the water the water body symbol and so on so the map is ready. So the mapping is the generic term here. The mapping could be for varieties of purposes you know. The application of the GPS you can say in agriculture mapping, in disaster mapping, in urban mapping. Okay? Or a mineral mapping. So depending our application area the GPS can be used in all those areas for the basic thing that is mapping.

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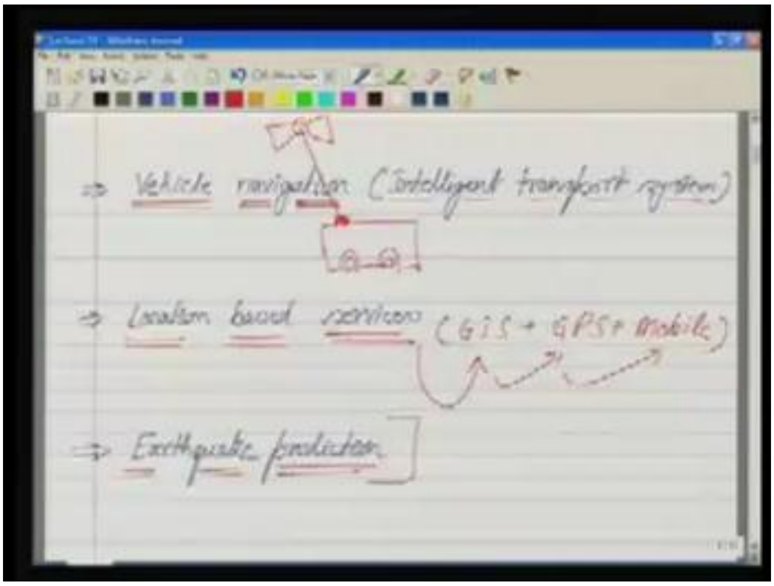

Then one second application, which is very interesting is the vehicle navigation or intelligent transport system. Now what is there in intelligent transport system? Basically on a vehicle the GPS is fitted somewhere. Now this GPS is communicating with the satellites. Now with this we are able to know where that particular vehicle is. Now this has many applications. For example if there is an owner of the transport company and he wants to see on his screen in the office the location of his various taxies or various trucks. So if the GPS are fitted in all those taxies or the trucks and through some telemetry process through some communicating device the location which is being recorded by the GPS there is being transmitted back to the office. So here in the computer screen these locations can be plotted. So the transport operator he knows where his vehicles are. So this is just one idea of this you know application of the GPS in the vehicle navigation.

Then many more applications where it can be used. For example in firing of the missile. If the missile is fired from one place and then it has to fire at other place the target is there. Now this target coordinate are fed in to the missile and then with the GPS and there is one more device which we say ins navigation system. With the combination of these two devices the missile knows where it is travelling, is it travelling towards the target or not. If it is not it can correct its course because wherever the missile is travelling it is also communicating with the satellites so it knows its position. Similarly in case of air traffic the GPS are fitted it is already being done and all the air crafts and using the GPS, the air craft knows their own position. Then next application we can say as location based services.

Location based services means they combine GIS, GPS and some mobile communication technology.GISat the moment we can consider it as though; in our very first class, in our very first lecture we talked about theGISa little bit, butGISwe can consider as set of data. Our terrain is in our computer in the form of maps or layers of the information. Now this information can be in a vehicle. For example if this information can also be in the mobile. Let us say in the my mobile I have got the map of the town. Also in my mobile I have got the GPS. So on that map with with the help of the GPS and that map I know where I am because GPS is giving me my present position and that position is being plotted on that map. Now there are many location based services, okay? You have a particular location what service can be provided to you. One interesting example is if you are looking for some restaurant. Then depending our present location depending on the data base which is there in the mobile or in your device you can query that. Okay. Where are the restaurant and the nearest restaurant can be shown to you and you can also query in order to go to that restaurant what is the best possible route that I should take.

SoGISgives you that particular route. Now GPS is helping you to negotiate that route because GPS will guide you. GPS will give you the coordinate. So GPS can guide you that you have to move hundred metre in front then take a left turn move fifty metre. Then again you take a right turn and go for another seventy-five metres and there is the restaurant. So various applications like this are possible now with the GPS mobile technology and theGISput together. One more application here this also interesting and very important is application of GPS in earth quake prediction. Now in this case as it is shown here in the diagram.

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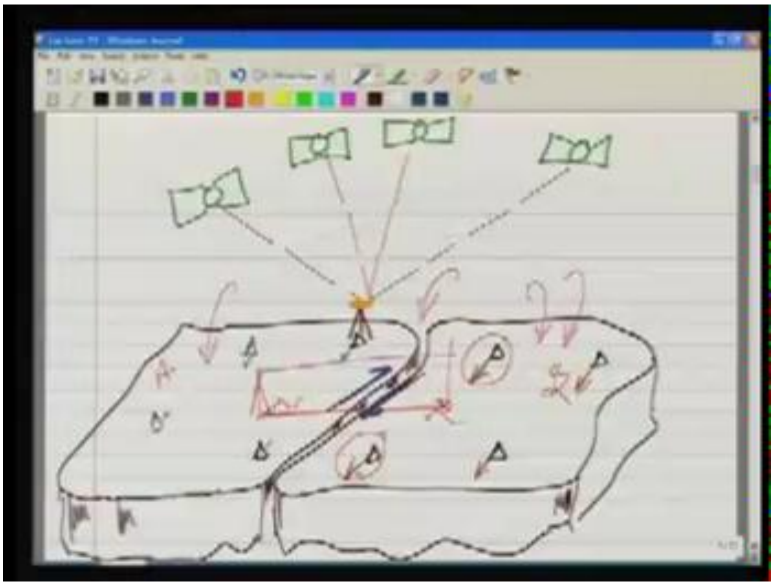

What I have tried to show in this hypothetic diagram there are two land masses, A and B for example which are moving. So this shows the sign of their movement. They are moving or rather there is a tendency to move. There is a fault between these two so what will happen because the land masses are crushing against each other. So the stress will develop there and when these land masses they fail they will move or they will slide. Now this stress which is being developed the strain which is developing there. We need to observe that , if you can observe it how the strain is developing there. Possibly it is it can be used for earth quake prediction and the same thing is being used in many countries. The entire country has been you know develop a network of the GPS. So there are various GPS stations and each and every GPS is finding it's present location and this location is being compared from the previous location

So for example here if there is relative movement we will be able to measure how this particular station has moved over time. So this green one here it shows the movement factor. So by knowing these movement factors it will be possible to know or to estimate how these stress are developing over this particular land mass and possibly it can be modelled that when this particular fault will rupture and there will be shaking of the land masses and the earth quake will be there. So this is one important application where GPS is being used here.The important thing is because our GPS system is totally independent of the earth mass

Our GPS satellites are up there and we are finding our locations with respect to those. If we use some ground based method for example if I use the total station I keep a total station here and I start measuring this way so I am measuring particular factor here. In this case this land mass as well as this land mass move. If the movement is same in same direction the between two points will not change but in the case of the GPS because each GPS point is being independently measured with respect to the satellites and satellites are not going to be affected by slight movements of the land masses. So this is very important technique and it is being used. Well having said that now we will go for errors in GPS survey.

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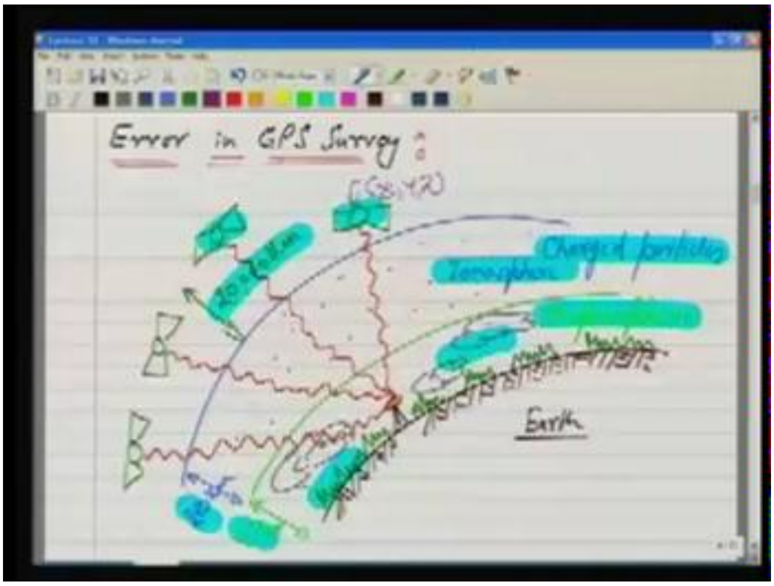

What are the various sources of the errors? For this what we would like to do? We would like to see how the GPS signals start where from it starts then how does it travel and finally where are the sources of errors. Well in this diagram i will keep highlighting over here are the satellites. I have shown you four satellites here then over here is the GPS antenna and the signal is being transmitted from all the satellites and using these signals the GPS antenna over here is able to locate its position. At the same time we have our troposphere here where we have got you know the biosphere then the clouds our atmosphere then on top of that we have the ionosphere where we the charged particles.

Now this is the height or the width of these spheres. At twenty thousand kilometre above that ionosphere we have our GPS satellites. Well let us follow the movement of signal or where are the sources of error because we are making use of these positions x, y, z means where the satellite is. We need to know this position correctly. If there is problem in knowing this position it will affect the coordinate which we are going to compute as well as as the signal is traversing through the ionosphere to the troposphere. What will happen to the signal? The signal will get delayed and because of the delay again there will be error in our GPS position then of course the antenna itself because this antenna itself is observing these signals so if there are problems with the antenna again there will be error. So these are the various sources of the error in the GPS. What we will do now? We will go one by one.

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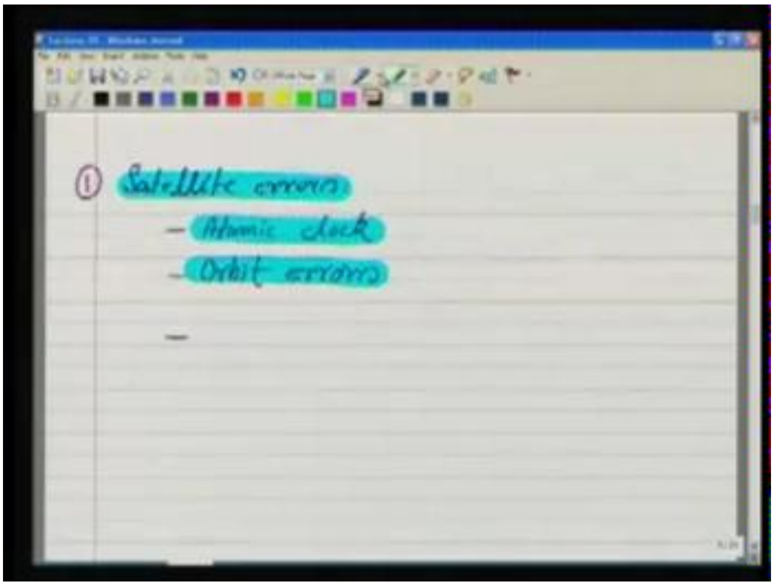

So first of all is the satellite errors. So there may be error in the satellite because of it's atomic clock, though it is very precise but still there may be some error in the atomic clock as well as there will be orbit errors. When we are predicting the orbit we know it is a stable orbit and we are predicting that but in the prediction there will be errors as well as as we discussed the ephemeries. Data is collected from the ground stations. These satellites are observed from the ground station and any change any perturbation in their orbit is being recorded so in that recording process also there are errors. So all these errors are finally going to be introduced or being propagated into our final coordinate.

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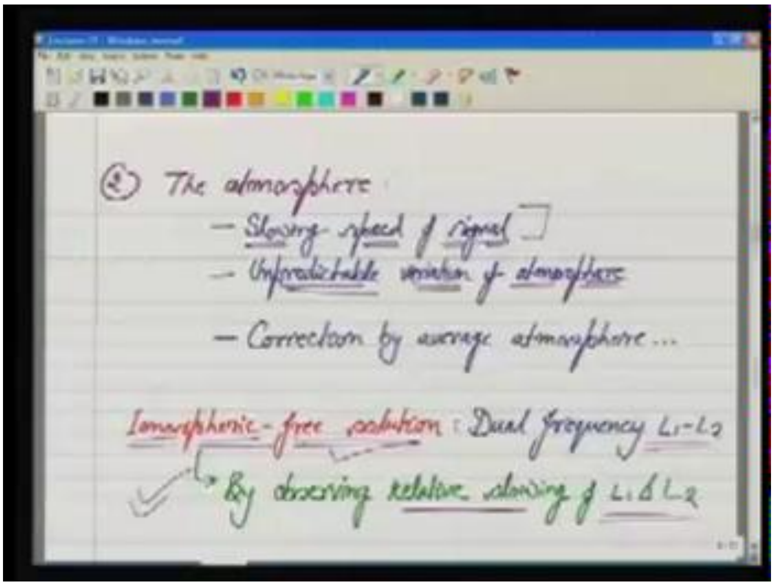

Regarding the atmosphere we discussed well there will be slowing of the signal of a speed as well as our atmosphere behaves in with unpredictable way. Now what is the meaning of this? From the satellite the signal is travelling towards the antenna. In between the atmosphere is there. Now in the atmosphere the speed of signal will alter. If we can model it how it is altering, we can apply the correction but in order to model it we need to know the characteristic of the atmosphere but the atmosphere is also changing rapidly. What we can do? We can go for some average kind of value but that average will be different from the actual changes which are occurring. How this signal is being delayed. So whatever the the case the atmosphere will always introduce some error in our position now there is one important way of getting away with this ionosphere delay which we say ionospheric free solution because we use dual frequency. If you recall in our GPS we have dual frequency.

Dual frequency means we are using L1 and L2. The L1 signal it also get delayed and L2 also it also gets delayed. Now these two L1 and L2 are two different frequencies.

Now the way L1 has got delayed and the way L2 has got delayed we have we can compare these two because both of these were transmitted {simu} (00:17:11) simultaneously from the satellite but the moment they arrive there at the antenna the times are different. So by knowing this relative delay in L1 and L2 it is possible that the total delay which is being caused by the ionosphere can be eliminated. So an ionospheric free solution can be achieved it is being realised by L1 and L2 by observing their relative slowing.

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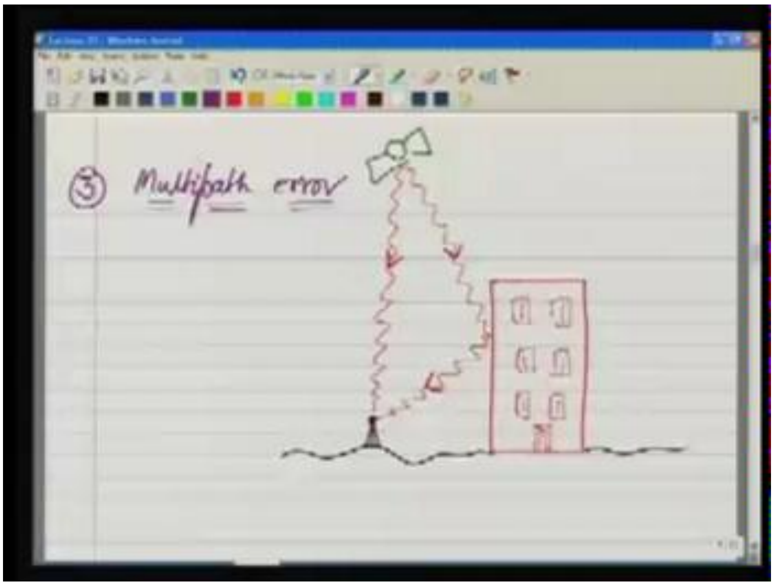

Well one more error from the satellite because the GPS signal is coming. Let us say our antenna is kept somewhere here. This is where my antenna is and I want to know the position of this point. So the signal from the satellite reaches my antenna as well as the reflected signal if there is a building here so from the building also the reflected signal will reach the antenna. So what it does it measures? In multi path because signal reaching antenna from different paths and because of this multiple path there will be confusions and that will lead to the error which is called multi path error.

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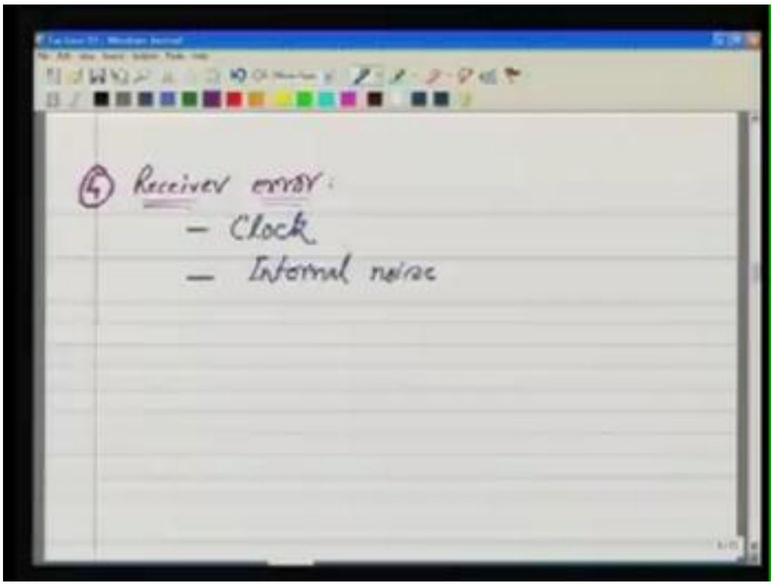

Then because we are using the receiver the receiver will also have some error in its clock as well as the noise which is being produced by the receiver.

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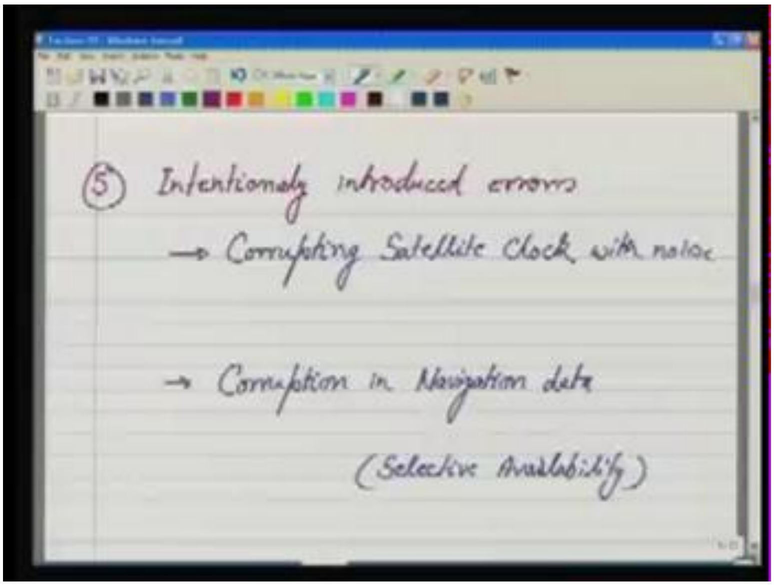

This is also important. Over here intentionally introduced errors, what is this because GPS is the department of defence system DOD and what they can do, they can corrupt the ephemeries which is being received by the satellite in navigation data. They can corrupt the signal or the clock information of the satellite they can corrupt that. So this possibility is there. So sometimes if they wish they can corrupt these signals now with the corrupted signal if you are locating our position our position will be wrong. So this is corruption of the satellite clock with noise and as well as corruption in the navigation data basically can be provided by DOD.

There was always an error being introduced earlier that was called selective availability. So sometime back though, it is not there now. But couple of years back always the GPS signal was corrupted. So if you are using a single receiver the position which will be given by single receiver will be in error by sixty metres or eighty metres because of the errors which are being introduced in the navigation data or in the clock. So that was called selective availability. Now in present GPS signal there is no selective availability but there are other kinds of errors: one more source of error here.

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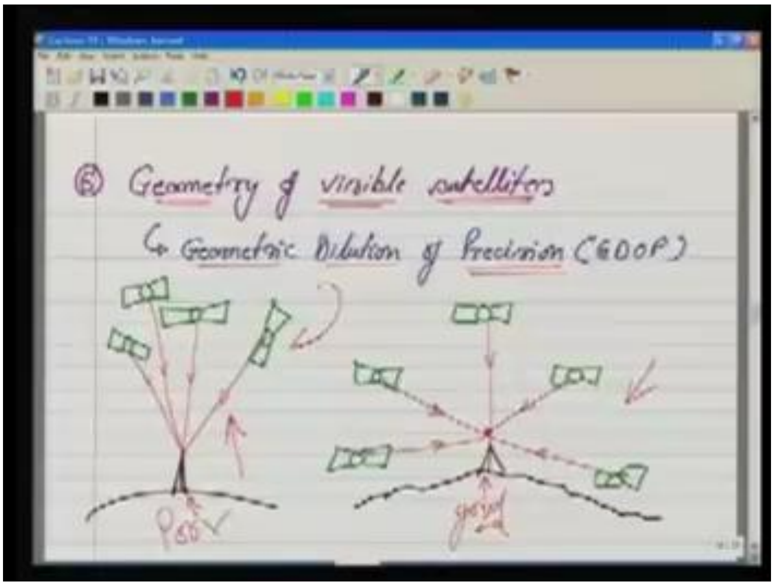

It is because of Geometry of visible satellites. Now what is the meaning of this? The receiver is here and the receiver is looking at the satellites. Now there are various possibilities. In one case all the satellites are hanging on top of the receiver and the angle which they form is a very small angle. This particular is very small. The other case possibly one satellite is here and one two three four so the angles which the satellites form or with the receiver is are very larger angles or ninety degree angle, we can say all. Now what is the effect of that because what is changing here it is the geometry as you can see here. The geometry is changing we say. This as poor geometry and this is as good geometry. This good geometry of the satellite will give us more accurate position if we compare it with the poor one and this entire process is called geometric dilution of precision because the precision is being diluted because of the geometry. Now why is it so? Well let us look look at here.

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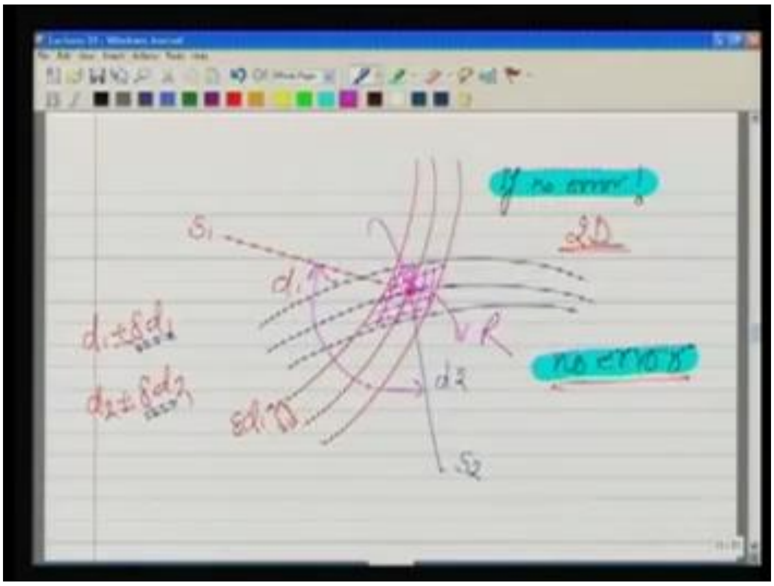

We are measuring the distance of a point. We have a point here and for this point we want to determine the coordinate. We have a satellite s1 and s2. I am giving you this as two d example. So please note it down that we are having a example in two d. Well s1 and s2 are two satellites. So what we are doing from the receiver? We are measuring the distance d1 and we are measuring the distance d2. If there is no error and in that case this position will be fixed as we can see here. We have taken the arc corresponding to this s1 at a distance of d1 and similarly this arc about this point s2 at a radius of d2. So this will intersect exactly at this point if there is no error, but if there is error what will happen? If there is error let us say the d1 is being measured by some error and d2 is also being measured by some error. So in that case if this error is there error is of course we can say plus minus then this particular point we have now an uncertainty here. This uncertainty is d1 here. That is the uncertainty. Similarly for the other satellite case also we have an envelope of uncertainty here.

So what is the meaning of this? The meaning is if we have errors in our ranges in our ranges which we are observing. Now where is our position where is our point if there was no error we could find the point was here but if there is error our point could be anywhere in between this area. So this is the total error or uncertainty involved in the location which we are computing. Now let us say about the geometry. How this is being affected by the geometry? Geometry means the angle between satellites where with respect to the receiver. How it is being affected for that?

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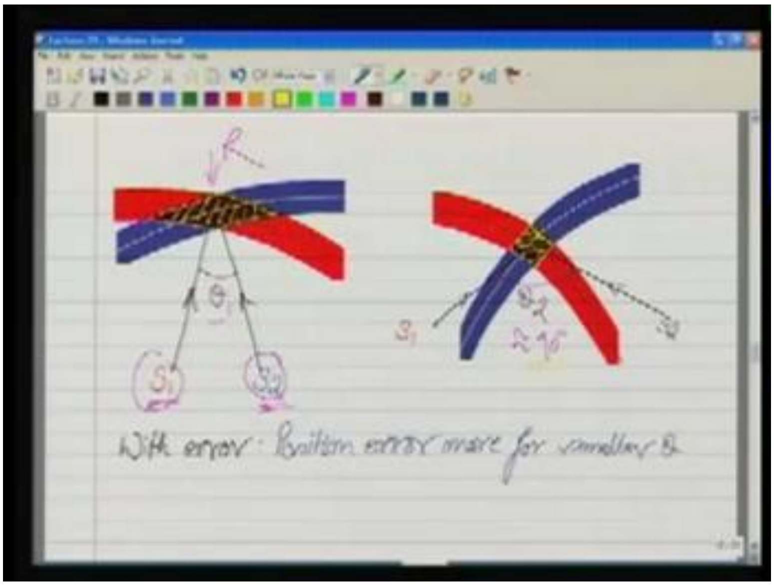

If the angle is very small between two satellites at the receiver, the receiver is kept here. So in that case this is the case the blue one is for satellite s2 and the red is the envelop of uncertainty for s1. Similarly here if the angle is around the ninety degree this is the case. What do you observe from here? The interesting observation that we can get is in case if the angle is a small the area of uncertainty we are showing it graphically the same thing can be shown in mathematically also that's the area of uncertainty and over here in this case this is the area of uncertainty. So when the angles are around the ninety degree the uncertainty is less so this is why we say the angles should be nearly equal to ninety degrees. So a good gdop or a good geometry could be one where one satellite is on top and four satellites on the horizon. So this is a good geometry. It will give very good geometric precision or the dilution of precision because of the geometry will be less, while if all the four or five satellites are hanging up there in that case the dilution of precision because of geometry will be large.

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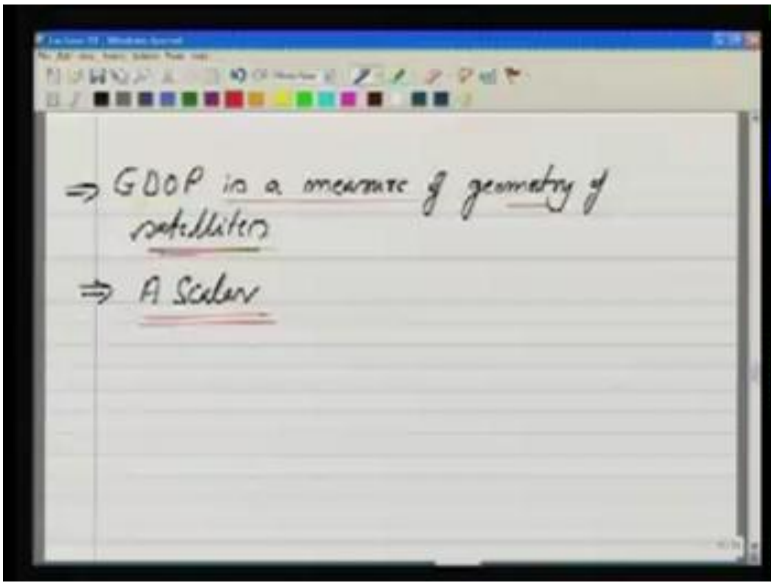

Okay this GDOP is a measure of geometry as we know now and it is a scalar value. The way it is computed is a scalar. Now what is its effect what does it do?

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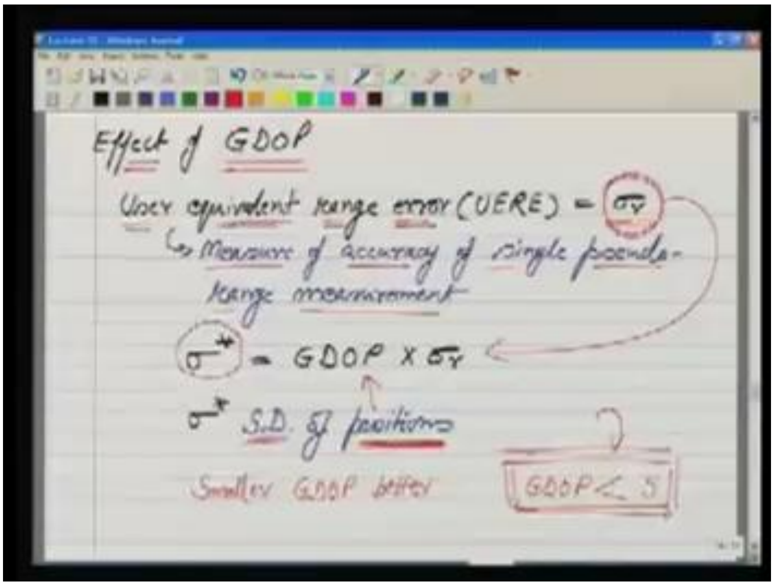

The effect of GDOP: if the user equivalent range error is sigma r, what is this? User equivalent range error it is basically we can take it as the measure of accuracy of single pseudo range measurement a single pseudo range is being measured. We know the pseudo range what is the meaning of pseudo range and why do we say pseudo because we are not measuring the actual one, it's a pseudo range. From the receiver to the satellite that's the pseudo range. So whatever is the error in the observation of this pseudo range that we are writing as sigma r, that is the pseudo range. Now this sigma r gets further modified and it is being multiplied by the GDOP in order to determine sigma star. So what is sigma star? Sigma star is the standard deviation of positions the final positions. So what we notice here? The positions which we are finally getting by the GPS, they are of course, they depend upon the accuracy of the rays, the pseudo ranges, how accurate these are as well as they also get multiplied or modified because of the GDOP.

So if the GDOP is very small we will have good accuracy for the positions, if the GDOP is very large we will have less accuracy. So generally the GDOP of less than five is considered to be good. Of course it is a very relative term, very subjected term. It depends upon your application, which area of what application you are working, but this is a kind of thumb rule. We can take a GDOP less than five is considered good. Now we will talk about some services which are given by the GPS. What is the meaning of these services? Services means how or what kind of signal we are using for our position and accordingly we name some services. So the services which I say as the GPS services.

Number one is SPS. SPS stands for standard positioning service. What is the meaning of this? A standard positioning service means it is based on single frequency number one as well as it may use the CA code. So if we are using this CA code and this single frequency we say this as SPS and this is available for Civilians, the Civilian user, while the PPS which is precise positioning service. It is precise because it is using dual frequency as well as it is using the P code. We know about the P code that if the frequency of the P code is very high in comparison to the CA code. So when we are using dual frequency naturally we are able to eliminate the effect of the ionosphere and as well as we are using a more precise code, because of this this is called precise positioning service and which is available to military, I mean the US military.

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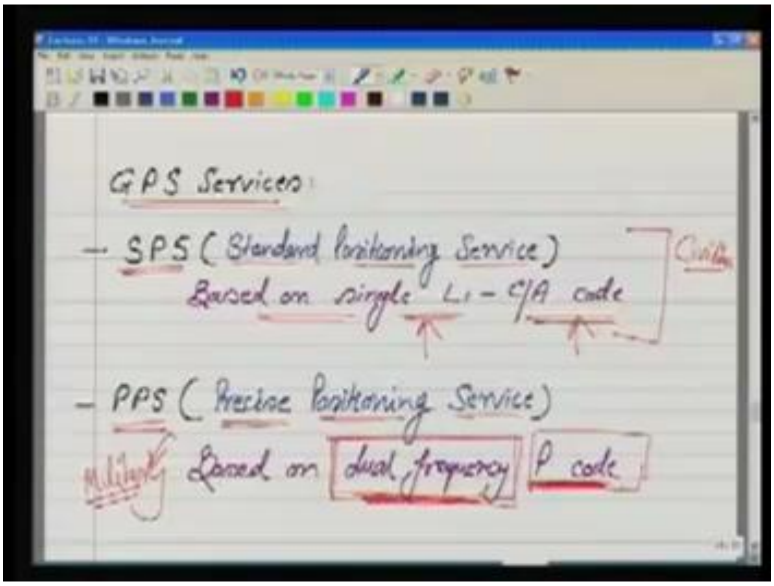

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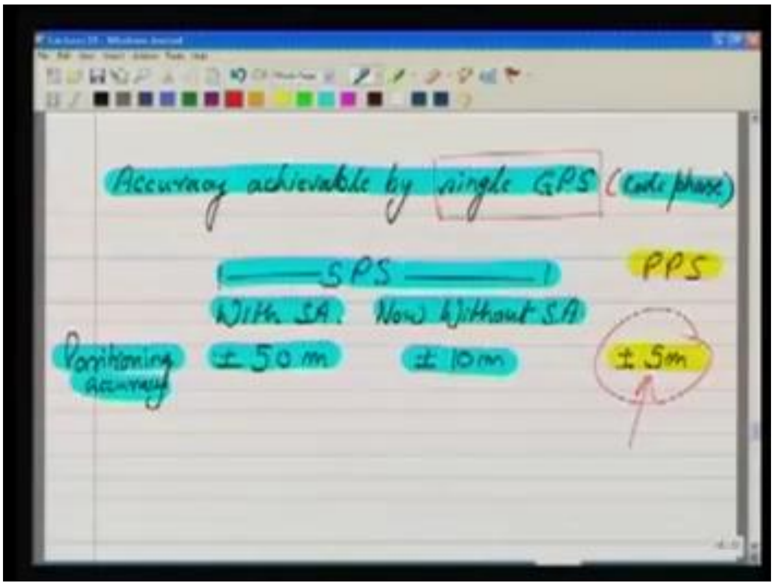

Another thing. What is the accuracy which is achievable by single GPS? So what we are saying here, we are using a single GPS in code phase mode. Code phase mode means we are using only the code signa, either the CA code or P code. We are not going for the carrier phase, we will talk about the carrier phase in our next lecture. So when we are using only the code phase and a single receiver in that case in SPS standard position service the positioning accuracy with SA; so this is not now but with selective availability it was approximately around fifty metre. Now because there is no sa or the selective availability so it is approximately around ten metre with PPS. With PPS means this is the precise position service. The accuracy is plus minus five metre. So obviously as we know that our PPS is more accurate and of course in this case please note it down that we are using a single GPS and in code phase, okay? Now we have seen the accuracies.

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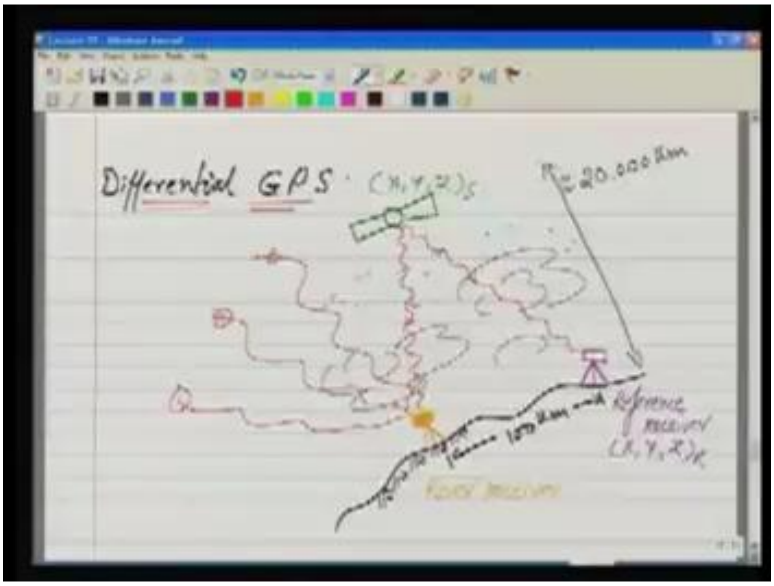

One thing here, once the selective availability was there, the meaning of selective availability is we work the navigation data as well as the satellite clock, they were being corrupted, is still the researchers of the people who were able to determine or to eliminate the effect of that and to determine the positions more accurately. What was being done? The differential GPS or the differential global positioning system was the technique which was being used for that case. So differential GPS is a technique which can eliminate several errors because of the satellite. Because of the satellite clock the navigation data the ionosphere, the troposphere, all these errors can be eliminated with this DGPS.

Now what is DGPS? In the DGPS, well our aim is, as we can see in this diagram, our aim is we want to determine an accurate position over here, so I will highlight this. We want to determine an accurate position here and we are making use of the satellites, this is our receiver. If I use only this single measurement our position single measurement means only this single pseudo range and similarly we will have the pseudo ranges also from four more satellites. So there are four more satellites. So if we are doing it that way our position here will be with error.

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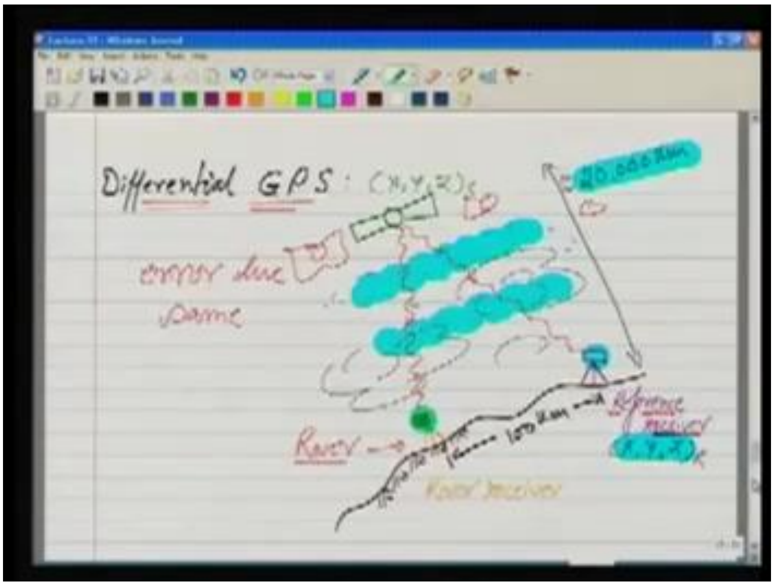

So in this case, what we do? Instead of this, we fix a reference receiver also. So this is the reference receiver. Now what is the meaning of reference receiver? Reference receiver means we know its position where it has been fixed. So we know the coordinates where the reference receiver is actually sitting. Now what is we are trying to achieve the distance between the receiver where we want to determine the coordinate. We say this is our as rover, so name of this receiver is rover because it is moving. So we are interested in the coordinate of this particular point and the reference receiver. If these are within certain limit you know hundred metre to two hundred kilometre that kind of distance they are in between or may be less than that twenty kilometre five kilometre, depending on the application.

In comparison to this distance the distance by which these two receivers are apart, the distance of this particular ground this entire ground here to the satellite is very less, so this distance is very very less in comparison to the distance of the satellite or altitude of the satellite which is of the order of twenty thousand kilometre. Now what is the meaning of this? The meaning is we can consider now the same ionosphere and troposphere which is affecting the signals, which are using this satellite or this receiver and this receiver. So we can also consider that the error error due to these ionosphere and troposphere are same. At the same time we can also consider that both the receivers are making use of same set of satellites. So if these satellites which are there, so the same number of same satellites are also being observed by this receiver. So whatever is the error because of the satellite clock and navigation data, that is also same at these two locations. These two locations means the location of the receiver and the location of the rover. So both of these are same.

Now how we make use of this? So far we know that the error which is occurring at rover and at receiver, all the errors due to satellites, due to atmosphere are same but the important thing here is we know where our reference receiver is. Well we do the computation now how?

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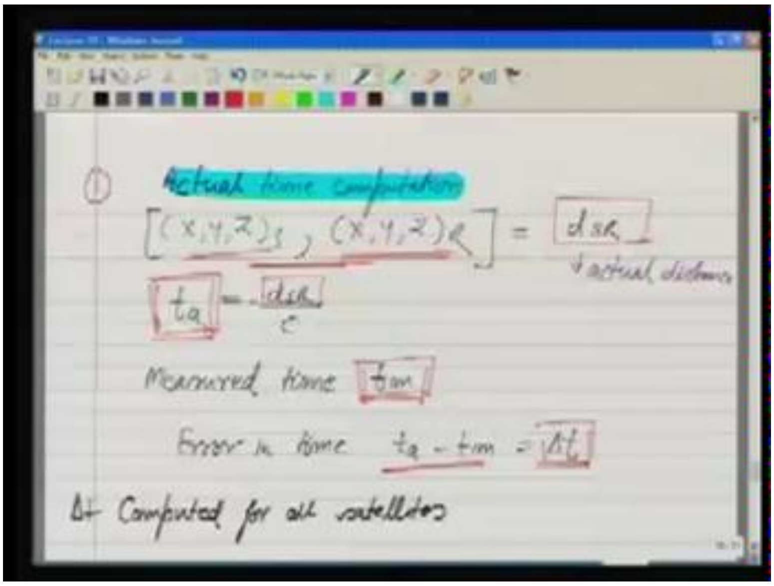

First of all we would like to compute the actual time. What is the meaning of this? The meaning is because we know the actual position or location of reference receiver. So for the reference receiver if we know the actual position what we can do? Using this actual position or the actual coordinates this receiver also knows where the satellite is so by this information we can compute the actual time of signal travel. So actual time of signal travel can be computed. Now if the actual time of signal can be computed this receiver reference receiver is actually also measuring this time it is also measuring . So the meaning of actual time of signal travel here is because we know where it is we know it. Its actual position is known to us and this receiver also knows where are the satellites because it is getting the navigation data. So from this information from its actual position and the actual position of the satellite we know now the distance between the satellite and the receiver. If this is the distance we can divided it by the speed of light and we can find the time of travel. How much time the signals should take actually to reach from satellite to the receiver but this receiver is also making observations. Observation means it is actually doing the pseudo ranging, it is actually measuring the time of travel.

So it knows the major time of travel is different than the actual time of travel. Now why it is so because of the errors? In case of measurement once it is measuring the time of travel the measured time of travel that is being affected by the various errors. But in the case of the actual time because we know the actual position of the reference receiver we know the position of the satellite so it is already known to us. So this is a kind of theoretical computation and by the computation we know the actual time. So these two will not be same. Now as we see over here. This is the position of the satellite and this is the position of the reference receiver which is known, so by using these two positions we can compute the actual distance and from this actual distance we can compute the time of travel or actual time which should had been there had there have been no errors, but the measured time because there are errors so the error in time is delta t.

So what we have done? We have computed this error in time for a particular satellite. Now this error in time can be also applied because the error in time delta t was computed over here because we are considering that the errors are same, that is the assumption here. So the same error or the same time error can be also applied to the rover. So what we do here?

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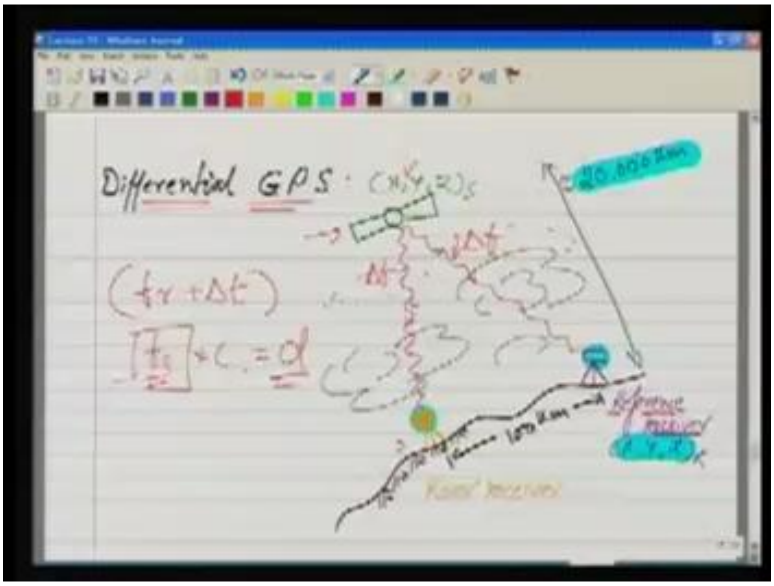

The same time error is applied to the time measurement by the Rover so if the time measured by Rover is tr, so we apply the time error to it and this gives us the actual time which is without the error and then using this we will get the actual pseudo range. So we are making use of a known position in this case by that we could compute the error in time and then we are applying it to the particular satellite. So what we will have to do because now in the positioning we are using four satellites, this error time error will be computed for all those four satellites and these four values of time error will be communicated to the Rover receiver where it applies those corrections and find it’s position correctly.so what we are able to do by that method? We are able to eliminate the errors which are occurring there because of the atmosphere because of the satellite.

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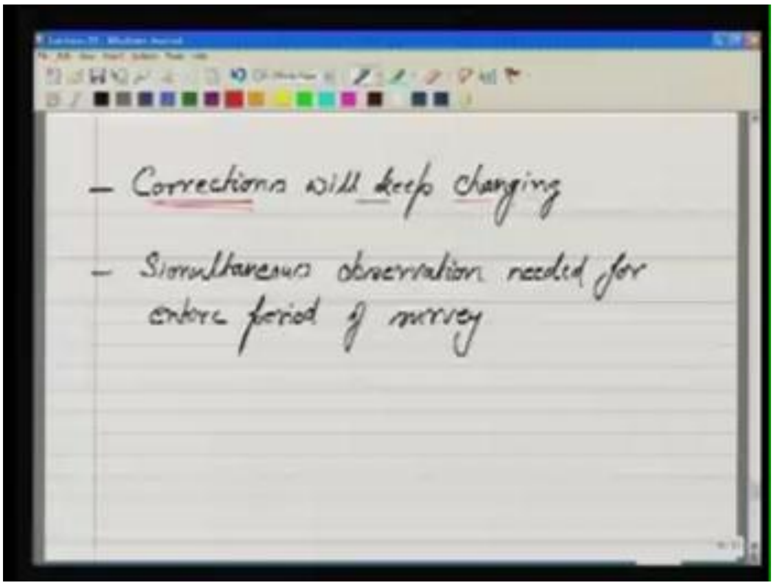

Now over here these corrections will keep changing. Why they will keep changing? Because if my reference receiver is here and the rover receiver is here, now the satellites are changing there position. We are taking this observation for half an hour. The satellites are changing their positions so because of the change in satellite position, because of the change in atmosphere, because of the perturbations in the satellite the corrections will change. So what we need to do? We need to transmit continuously the corrections to the rover in order to locate the rover position accurately.

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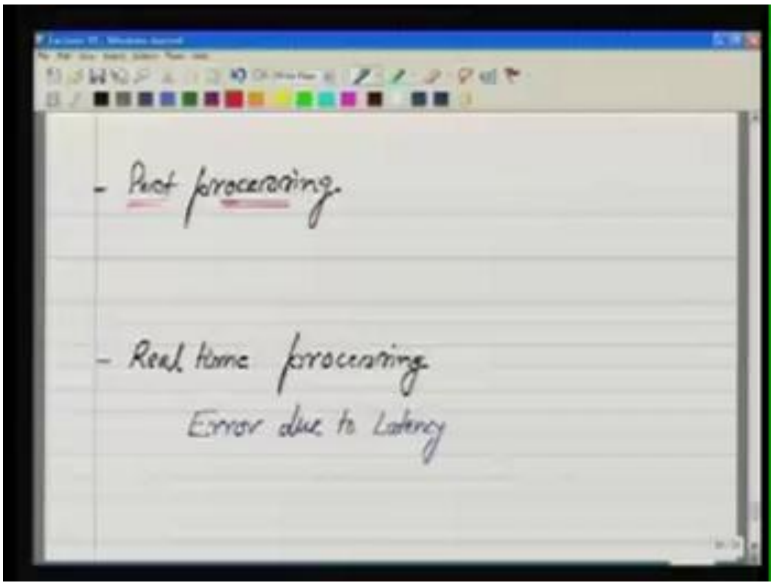

Now what we can do, we can go for two kinds of processing of data. One is post processing. Post processing means whatever the corrections are, these corrections are being determined after the survey. So the receiver is collecting all the data all the data means it is collecting the measured times and the rover is also collecting the data the measured time. There in the field if there is no communication between reference receiver and the rover receiver, but once we come back to the laboratory in the laboratory we find the corrections. So corrections are being computed in the laboratory then the corrections have got a relationship with the time because they are varying with the time.

We know at a particular time what was what was the value of the corrections. The rover data is also there in the laboratory and that data is also available with the time. So now the corrections can be applied after coming to the laboratory after computing them in the laboratory to the rover data as per the time sequence. So this is called post processing mode.

We can do the same exercise in real time also. In the case of the real time the moment the this reference receiver computes the correction it computes the correction there in the field itself. Then using some radio device communication device it is transferring them to the rover. So the rover is also computing its coordinates correctly there itself, it is applying the corrections there in the field itself. So this kind of processing we say the real time processing.

Of course in the real time processing, as you can observe the time which reference receiver is taking to compute the corrections as well as the time it takes to transmit the correction to the Rover and the time the Rover is taking in applying this correction, there is a gap between these. So this gap we say latency as we have written here. So there will be error due to latency here in the case of the real time processing.

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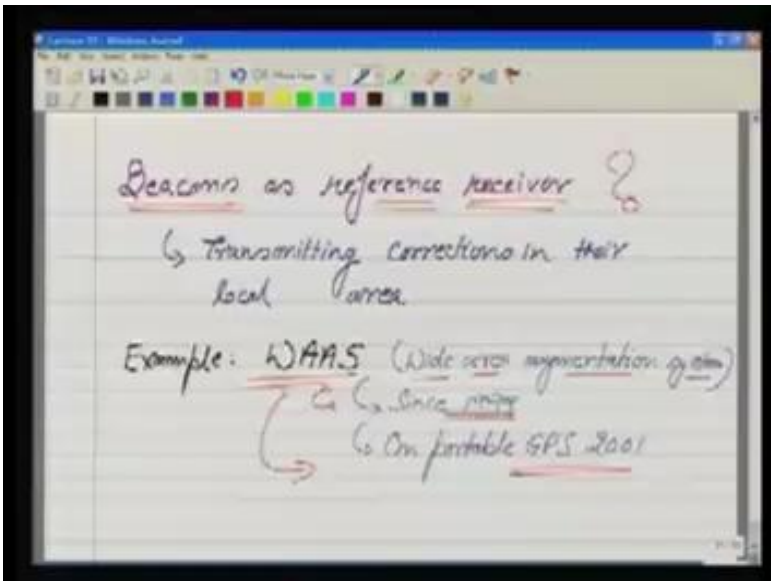

Now finally we can also use some Beacons as reference receiver. What is the meaning of this? These are the services, there is a augmentation device, the GPS survey can be augmented. Now with the means of some Beacons so for example in a town there are some permanent stations or references stations and these reference stations are collecting the data twenty-four hours all days in the year and for this reference station we know its position. So it is also observing it is finding the measured time. So this reference receiver keeps computing the corrections for all those satellites which are visible to it. Now if there is a receiver which is Rover receiver there in the ground and this receiver needs the time corrections, so what it will do? It will register to the service provided by this reference receiver and will get either in real time or in post processing mode the corrections. So there are several this kind of services which are now available. One example of this is WAAS which is wide area augmentation system. So this system was started in nineteen ninety-nine and now the portable GPS also since two thousand one can get the corrections from this WAAS.

So basically this is also the principle of differential global processing system. So your rover receiver could be now anywhere in the watch in mobile in the vehicle and it can get the corrections for the time from these augmentation services. So this is how the accuracy of GPS survey can be improved. So what we saw today in this lecture? We saw the applications of the GPS number one and the list which i gave you is a very small list. Then many more applications with the GPS are being used combined with gis, you know varieties of applications are there and many new applications are coming up. Then we saw how we can improve the accuracy because there are various sources of the errors we discussed about those sources of the errors. Then some of those errors can be eliminated by differential positioning.

One thing to note here the error because of the receiver or because of the multiple path cannot be eliminated by differential positioning because that is a local error, error due to the receiver error due to the local multi path. In the case of the differential only the errors which are because of the atmosphere and the satellite only those can be eliminated. Then finally we saw about some augmentation services like the waas which a user can make use of so a user need not to do differential positioning himself. He need not to buy two receivers rather he can register to the some surveys like waas and can get the corrections. Thank you