Geographic Information Systems
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Lecture – 28
GPS errors and DGPS

Hello namaste, so let us welcome all of you back to the geography information system class. Now as I said in the this is the next class we would also continue with geographic positioning system but here in this particular class we would look at the different advanced systems where and we can make more accurate measurements using the GPS signals and also we would look at certain errors that are there in the entire GPS system.

And how it is actually induced as an error in your GPS system. So let us look at these topics in detail and we will also at the end of this class probably have more clear idea about what are different errors, different systems and finally how we will make use of each systems for our different analysis okay.

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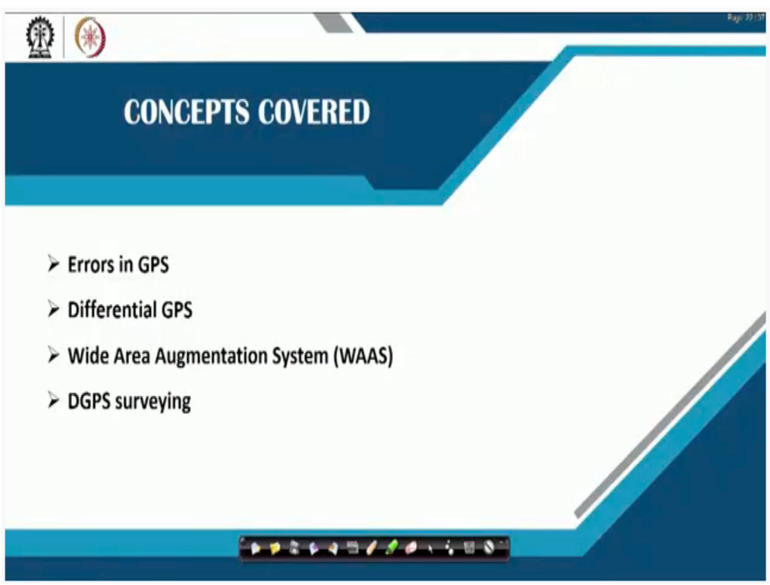

So when we look at the different concepts that has been covered. We would look at errors in the GPS entire system. We would look at what do you mean by a differential GPS you would look at wide area augmented system this is a kind of GPS system. Then we would look at surveying how do we do a DGPS surveying okay. So we would look at all of these aspects in this class.

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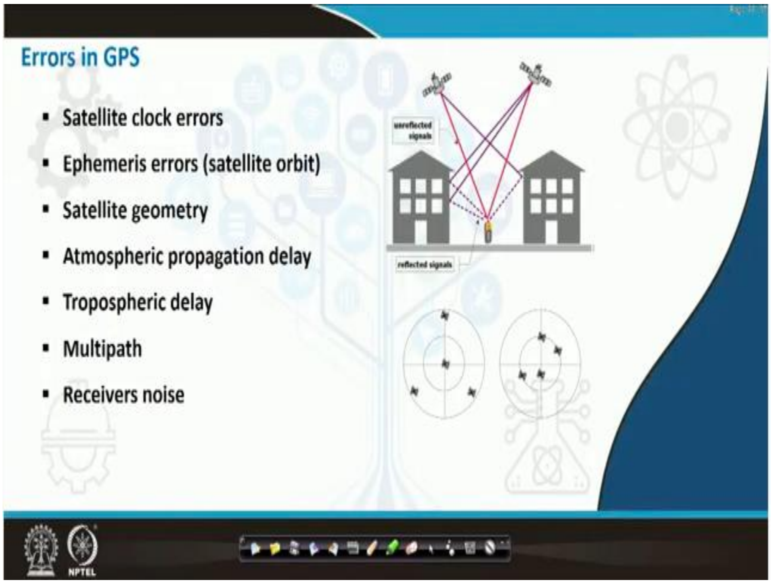

So when we look at errors in a GPS. So GPS errors are normally induced through various means I have looked at in my previous class we have somewhere or the other looked at certain errors that may be induced. The first error that may be induced is the satellite clock error. That is where your control stations is extremely important in terms of correcting this particular satellite clock. So though the correction is made there are certain errors associated with the satellite clock.

There are satellite orbital errors which is also called as ephemeris errors. So if there are errors due to how the satellite movement is across the Earths surface okay. Then the geometry of the satellite we discussed this in the previous class normally satellite has to be in the ideal geometry. If this is there you get the best signals and the errors in the GPS either through the delay or through the time shift or through the distance measurements is absolutely not there.

But when you look at the real systems most of the satellites have a bad geometry and because of this bad geometry you can see that there are errors that creep into the GPS and the next thing is the atmospheric propagation delay. I spoke about the ionosphere issues. So when you look at the ionosphere it interferes into the GPS signal or let us say that there is interference due to the composition of the ionosphere through the GPS signals and because of which we lose a lot of signals in terms of it being propagated to the ionosphere.

That is exactly why we have an atmospheric propagation delay. Then we have a tropospheric delay. So that is another cause so when you are looking at the troposphere there is a certain amount of delay that is integrated. Normally it is somewhere that is shown that this delay can be handled also can be corrected in better way when we are receiving these particular signals. Then other one is the multipath which you can see here.

So you have a multipath signals that may be because of the entities on the Earths surface when you have different entities on the Earths surface and your signal is somewhere here which means that your signal reach maybe from some of this if there are 4 satellite signals that is available to you but of which 2 satellite signals are actually directly being received by the radio signals are received by your receiver.

But other 2 signals are actually taking a multipath or number of it has certain errors that is induced through these reflections and then comes into this particular receiver. So that is nothing but a multipath error that is induced into your GPS. Then finally it is the receivers noise. So there are noise that are induced due to the receiver that may also be an error in this particular GPS system.

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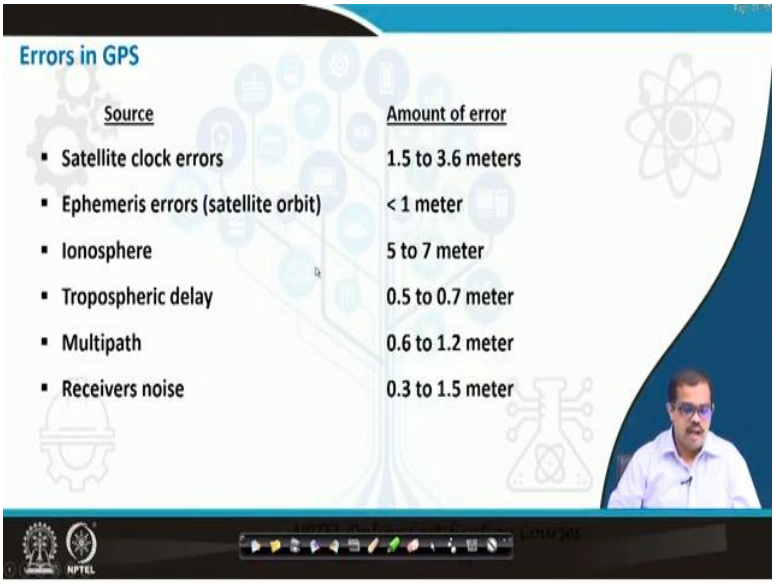

And when you look at different errors amount of error okay satellite clock errors is about 1.5 meters to 3.6 meters whereas ephemeris or the satellite orbital error is less than a meter. So when you are looking at each of these please look at in terms of how relatively the errors can displace you on the ground okay. The ionosphere is 5 to 7 meters okay. Then you have a troposphere which is 0.5 to 0.7 meters.

Then you have a multipath which is 0.6 to 1.2 meters. Then the receiver noise is about 0.3 to 1.5 meters. So on an average if we consider all of these okay so we may have somewhere around 6 to 7 meters or even sometimes 10,12 meters of errors that may creep in without even after it being corrected at the control stations. So these are certain errors that may that GPS may have.

Other than these errors are the errors due to the human himself or herself when he or she is on the field in case you are collecting our validating data okay. So if you are collecting a data or you are looking at the data acquisition through the GPS signals onto your receiver so there are errors that may that your receiver has certain precision certain way and certain errors that are reduced okay. Second thing is the way you are collecting the data.

Third thing is the way the receiver perceives that particular data and whenever you are going to the field first look at what is the error in the measurement. Switch on the receiver look at a known point on the Earths surface where you are close to. So once you have known the known point you know if you look at the GPS point so you know what is the error that is induced into the system either correct that error where some of the systems gives you will help you to input the + or - errors.

So if that is there you do it otherwise once you take the measurements come back to once you come back to your lab then + or - that many units will actually give you the least error okay. So this is how the error is induced and certain errors can be corrected in terms of your whatever the measurements are done okay.

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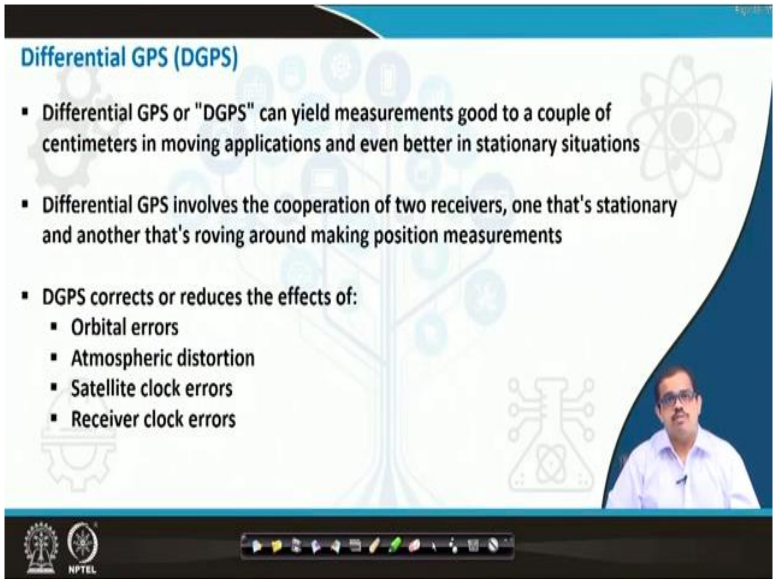

So when we look at this particular happening the very important point where your errors are actually minimized using a DGPS or very well known as differential GPS. It can yield measurements good in terms of couple of centimeters not even meters couple of centimeters we can say our data is accurate to 10 centimeter or 20 centimeter. In moving applications and even better in terms of stationary applications we can go up to 1 centimeter or even less than 1 centimeter error in terms of differential GPS.

Differential GPS involves the cooperation of 2 receivers okay. One that is stationary another that is roving around making positional measurements so which means that always you have a stationary receiver which actually knows exact point on the Earths surface. There is a rover which is actually collecting other points on the Earths surface. So when you have such system the first thing that the error that is reduced is the orbital error that the satellite induces okay.

That error is reduced then the atmospheric distortion because when you have a receiver that is already fixed and the rover that is moving. Now the contact is between the receiver and a rover. So now there is no atmosphere in between this okay. So that actually brings down the error minimizes the error to a very large extent atmospheric destruction is minimized or made 0 okay. Then you have a satellite clock error.

So this this error will not be there because both are on the earth surface. Then you have receivers clock error which again have not because both have the same mapped units on board. So that is why DGPS is extremely good in terms of measurements of your ground control points or understanding the distance on the ground surface.

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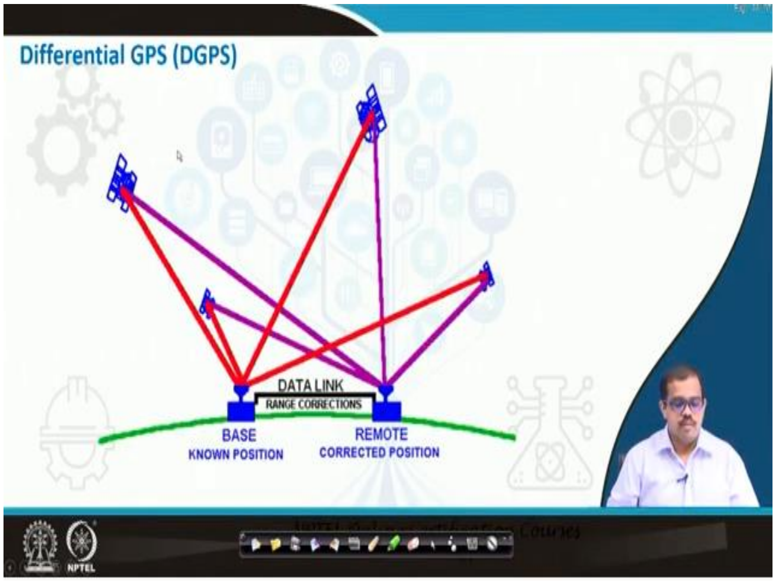

So when you look at the entire DGPS system this also from our Canadian remote sensing link which actually tells you the entire way of how a DGPS system works. For example when we look at it normally I did tell you that we need at least 4 satellites. This is satellite 1, satellite 2, satellite 3 and satellite 4. These are the 4 satellites that are required normally for you to locate yourself on the Earths surface almost closer to the precise units okay.

So when we look depending on the positioning system let us have all those riders okay. So when we look at this now we would fix a base station. That is let us say if we are trying to map the entire city maybe our rover may not get the signal from the satellites base station for the entire city. So we will have to shift the base station then fix the base station, correct the errors around the base station then make the rover move around that particular location.

So now I have fixed my base station. Now all of these satellite starts communicating to the base station okay. Now I have the rover which is actually moving around let us say this is a remote station let me not take this. Let us say that this is a rover here. So this rover will give me the measurements based on the base stations. Now I know what is the error that this particular rover is with the help of this rover I find out the error that is being propagated through the satellite.

Because satellite is actually giving this particular location through the base station as we have discussed before. So now with the rover **we** know what is a distance measurement and with the satellite what is the distance measurement at the clock measurement? And based on that this error is corrected.

That error can be propagated to the satellite then to your remote control positions or directly to the rover where it is noted down at a particular point or this is again communicated back to the base stations if there is another receiver. So that receiver actually gives you the exact point on the Earths surface for this rover okay. That is sorry for this base station. That is how we see a differential GPS working in terms of measurements okay.

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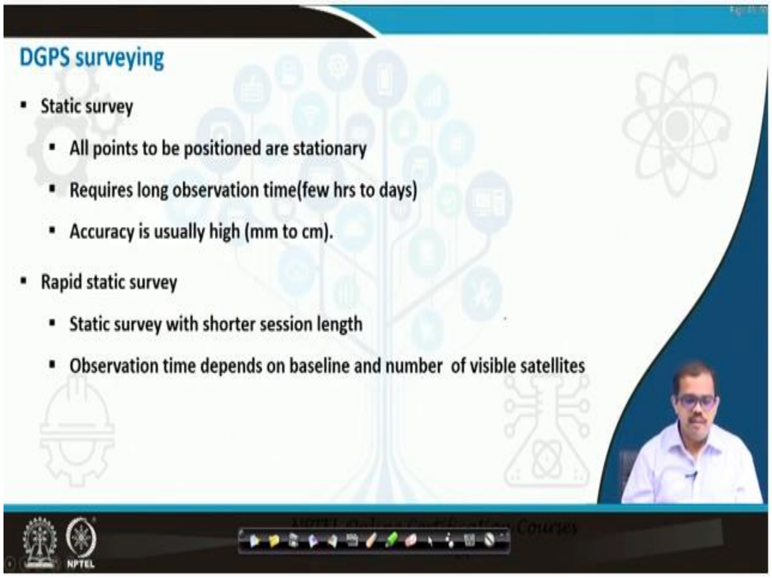

So when we look at the DGPS surveying there is 2 basic kinds of surveys. One is a static survey and another one is a rapid static survey. When I say a static survey all points to be positioned are stationary always stationary okay. So this requires long observation time few hours to few days and this accuracy is very high. So normally when we look at a static surveys most of them have an accuracy of millimeters to centimeters normally less than a centimeter okay.

It depends on what application you are trying to look at but normally it has millimeter to centimeter it can be somewhere around 2 centimeters to 8 centimeters to 10 centimeter or even 10 millimeter, 15 millimeter etc. So the accuracy dependent on how you actually measure and how close is your rover to the unit. The signal that is transmitting between the rover and the unit should not have multipaths again or should not have certain different incidence angle.

So with that the static survey is extremely good. But there is another survey which is called as a rapid static survey where static survey with shorter session length. This actually induces certain errors into your system and because of this, this is not extremely accurate in terms of accuracy that is needed though but the observation time depends on the baseline and number of visible satellites that are there in this station.

So now the visible satellites is extremely important in terms of a rapid static survey whereas in a static survey that may not create much of an issue okay. Normally when you have a rapid static survey we say at least 4 satellite signal must be there in for measurements okay.

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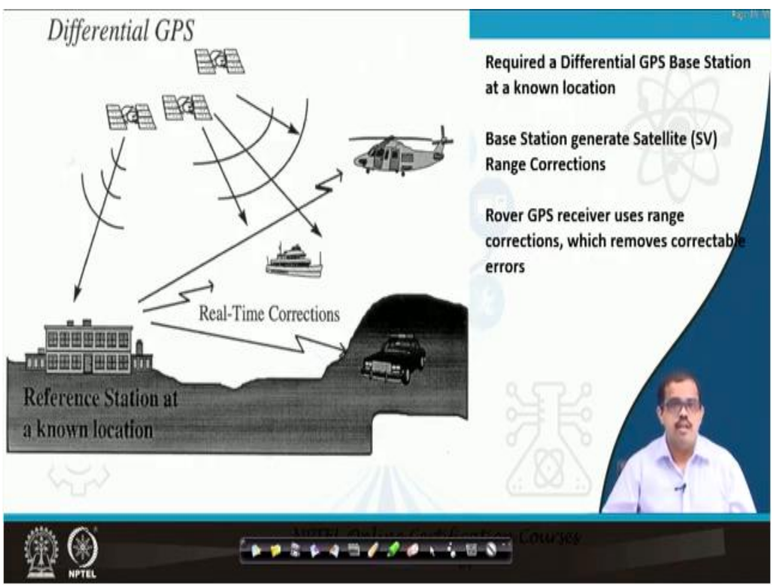

So to give you an another example of how this DGPS works you have satellites different satellites here the satellites sends signal to the reference stations at a known location. Now you know the location the signal is corrected. Then this signal is then communicated to various application along with the satellite signal. So now you know this is the corrected signal because of which you will be able to navigate in a much better way.

That is what is called a differential GPS okay. So what it basically needs is a well-known reference station okay. So known location that is nothing called reference station. So when you look at the reference station it basically does a range correction okay. Then rover GPS uses this range corrections which removes the correctable errors from your GPS signals. Once it removes the correctable errors this is then communicated back into your navigation system wherever you are trying to apply okay yeah.

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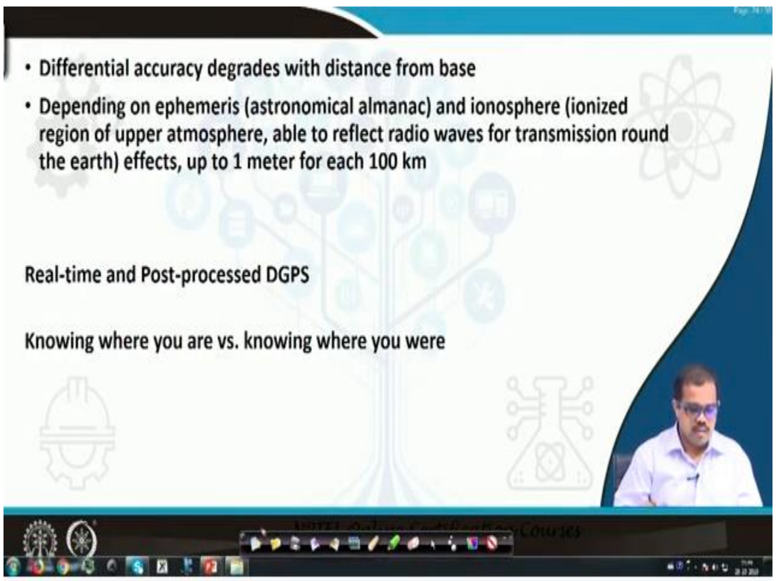

Now so when you look at differential accuracy it degrades from the distance from the base that is what I said as the closer from the base as there is no different incidences between different entities or it does not have a multipath. The differential GPS works extremely well when you have the distance from the base increases as you move around then your DGPS also can have certain errors that is induced.

But it is not error as the kind that normal GPS system have these are very small or very least errors that are actually induced into the system. Depending on your ephemeris and the ionosphere region of the upper atmosphere it may be this particular differential GPS or this base station can able to reflect the radio waves for transmission around effects up to 1 meter for each 100 kilometer.

So every 100 kilometers the amount of signal that is sent from the differential GPS can have distortion of up to 1 meter which is extremely small okay compared to other discussions where we have up to 8 to 12 meters in the minimum and can go up to 50, 60, 100 meters. But when you look at the differential GPS it is 1 meter for every 100 kilometers which means every 100 kilometers without any issues in terms of radio communications or if you no issues with your entities that are actually crossing these signals then you need every 100 kilometers.

If you have a differential GPS your navigation can be extremely precise. But in the real scenario when you look at cities etc it may not be possible to really have differential GPS at every point on the Earths surface and most importantly you have to understand whether it is real time differential GPS signals are important or a post process differential GPS.

Because when you look at the real time differential GPS it gives you the real time information about where you are actually moving. When you look at the post processed information which has the corrected signals that is actually sent. So these corrected signals after processing may be that is kept in certain stations is then communicated to you when you are moving through your satellite geometry.

So that will actually help you in navigating in a better thing. But differential GPS had a very good this one at the real time will give you exact position okay. So when you have to differentiate between the real time versus a post processed DGPS it is actually the differentiation that you make from knowing where you are versus knowing where you were okay.

That is a difference. When you are looking at the differential GPS. Now once we have understood with what do we mean by a differential GPS. Let us also understand how the WAAS system also works in terms of movement okay.

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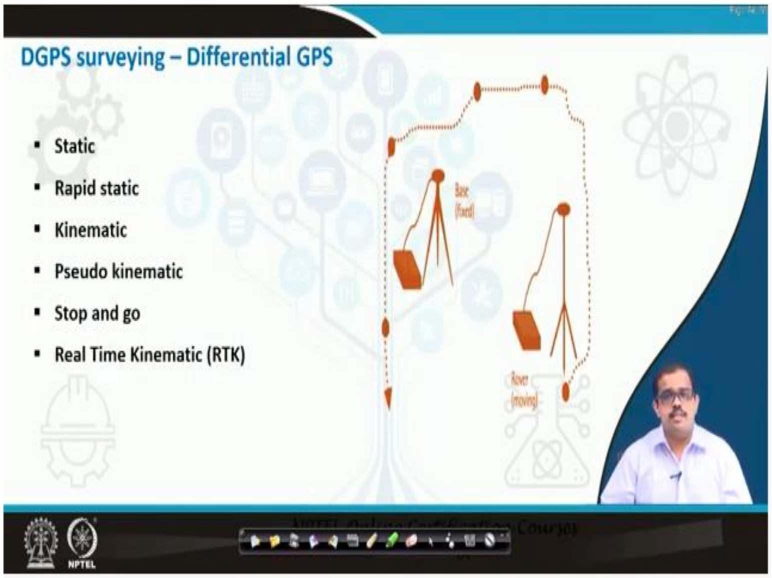

Sorry for that when you look at DGPS surveying systems this differential GPS has different kinds of surveying system. From the static, rapidly static, then kinematic, pseudo kinematic, stop and go, real time kinematic. We have looked at static and rapid static we will look at kinematic, pseudo kinematic, stop-and-go and real time kinematic also. These are different kinds of DGPS systems. So all of these are useful for certain applications. So looking at what applications your DGPS service can be done.

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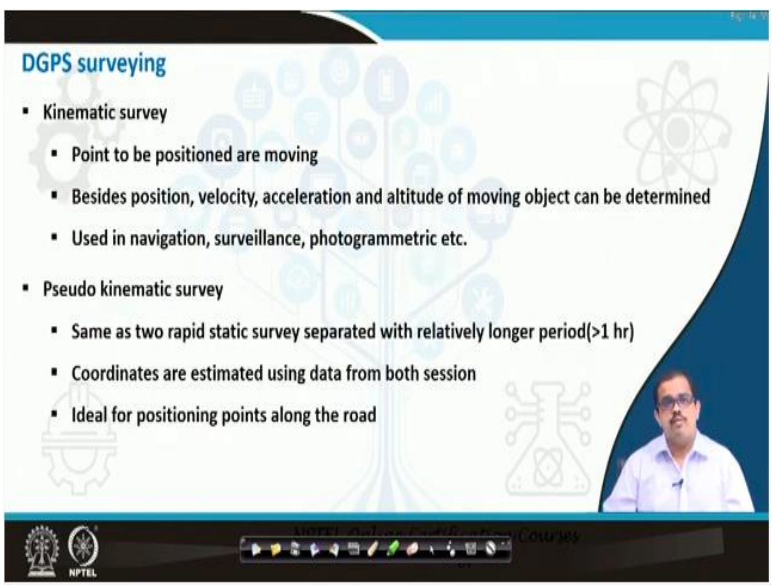

So when you look at kinematic survey. These are the point to be positioned are moving okay. It is not static the point is moving okay. Besides position, velocity, acceleration and altitude of a moving object can be easily determined in terms of kinematic survey and basically these kinds of

DGPS surveying the signals that is sent out are used for navigation, surveillance, a photogrammetric applications.

But when you look at pseudo kinematic service these are for 2 rapid static service separated with relatively longer period. So these are coordinates are estimated using the data from both the sessions. Ideal for positioning points along the road. So normally these are for road positionings or for the navigation route positionings. So normally these are between 2 static surveys that are separated have a relatively longer period.

When you are looking at a longer period it is greater than 1 hour in terms of surveys. So this is pseudo kinematic so we have looked at static then we have looked at a pseudo kinematic okay kinematic and pseudo kinematic.

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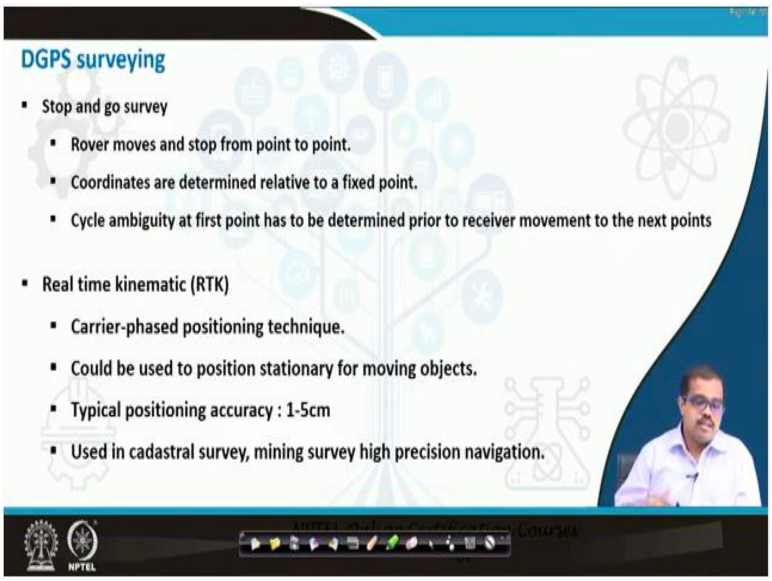

And there is another kind of DGPS surveying which is also called as stop and go. So rover moves and stops from a point to point okay. You have 1 survey station base station which you know okay rover moves around stops at a particular point from point to point. So this gives an input that is nothing but your stop and go survey. So coordinates are determined relative to the fixed point that is what is the biggest advantage or sometimes a disadvantage.

Cycle ambiguity of the first point has to be determined prior to the receiver movement to the next point that if that ambiguity is not determined then probably you are actually missing out the entire error that may be induced in this particular system okay. Error maybe up to maybe even less than a meter so but the error is inducing if in case you are not looking at the what is ambiguity in that particular point when you are actually starting this particular survey.

Then you have real time kinematic RT which is also called as RTK very well-known way of looking at DGPS survey. So it is normally a carrier phase positioning service it is for positioning stationary. It is used for to position stationary for a moving object okay. It is actually a stationary survey. If there is a moving object then it is acting as a stationary point. Now typical positioning accuracy is 1 to 5 centimeter.

Normally 1 centimeter is the positioning accuracy that you can see here. But in certain terrain you can find out that it may move up to 5 centimeter and not beyond that. So basically this kind of surveys are used in cadastral survey, mining survey where you need high precision navigations etc.

Real time RTK surveys are normally used okay. So and these surveys are a bit pricey in terms of looking at the survey measurements and number of working hours of the survey instruments that you may need and also the person you may need. So that is by this RTK surveys are done only where you need extreme precised surveys okay.

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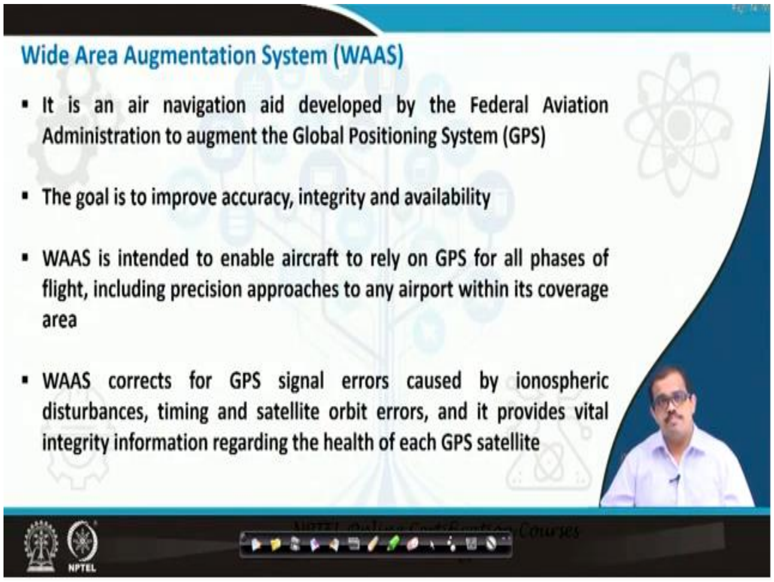

So this about the DGPS different survey systems of the DGPS system then we would look at the another system which is also called as wide area augmentation system. Why this is extremely important is that this was used by the federal introduced by the developed and introduced by Federal Aviation Administration for to augment as a part of a global positioning system.

So the most important part here is the point that people have to understand here is this was integrated or augmented as a part of global positioning system. This what does it do? Is basically it is improving the accuracy, improving the integrity and improving the availability of the system. So WAAS is basically intended to enable any of the aircrafts to relay on the GPS for all phases of the flights okay.

So most of the information that you see here is that the signals are sent into the systems which are automated basically and the GPS navigation system tracks it all along so that the automation has absolutely no error that is done through the WAAS system. WAAS is intended basically for all phases of the flight including precision approach to any Airport within its coverage area.

So which means to say that every airport has its own WAAS system which means to say rather than saying that own WAAS system has a WAAS system which is integrated across through other WAAS system so that you have a precise landing precise take off time and availability for wide area augmentation. Then WAAS corrects for a GPS signal errors that is caused due to ionospheric disturbances, timing and satellite orbit errors.

And it provides a vital integrity information regarding the health of each GPS satellites. So that is extremely important when you are looking at the satellite signals also the health of a GPS satellite is important and that input is provided by the WAAS system.

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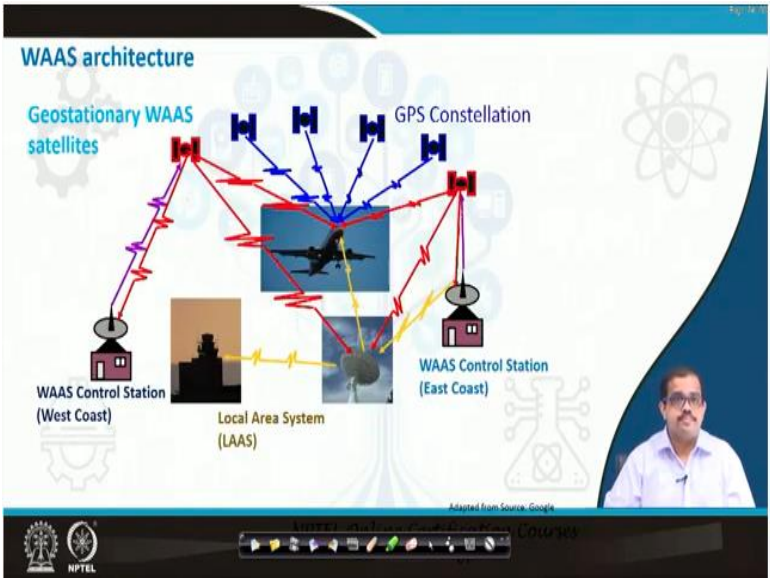

And when you look at the entire architecture of WAAS you have let us say we have geostationary WAAS satellites here okay. If you look at these are the 2 WAAS satellites that are represented here and when you look at it we have 2 WAAS station one on the west coast other one on the east coast. So when you look at this there are signals that are sent from these geostationary satellite into these WAAS control stations.

These signals are corrected okay. Once these signals are corrected this is sent back to all of these satellites okay. This particular geostationary satellite then transmit it back into the local area systems okay. Local area systems can be your receiving stations on the Earths surface or it may be your naval systems like your ships etc or it may be your aircraft. So along with this corrected signals from the geostationary satellite you have your GPS satellite that are providing the signals.

Which means this is a corrected signal that is actually tracking all throughout the globe okay because when you say that GPS satellite it covers as a when you say a geostationary satellite it covers a large majority of the Earths surface almost when you look at a geostationary satellite it has a capability of covering 45 percent to 60 percent of the Earths surface because it is located at a very high its very away from the Earths surface almost closer to 35-36,000 kilometers.

And because of which it can cover a large part of the Earths surface. And because it is covering the large part of the Earths surface it will be able to track any of those systems that are actually going from one place to the other and because of this health then you have your GPS constellations which are providing an input to this particular navigation system along with this can be you able to track the entire process of going from one place to the other at any point on the Earths surface or throughout the globe okay.

This is how a WAAS architecture works or a WAAS system works and is extremely helpful in terms of aerial and naval navigations okay.

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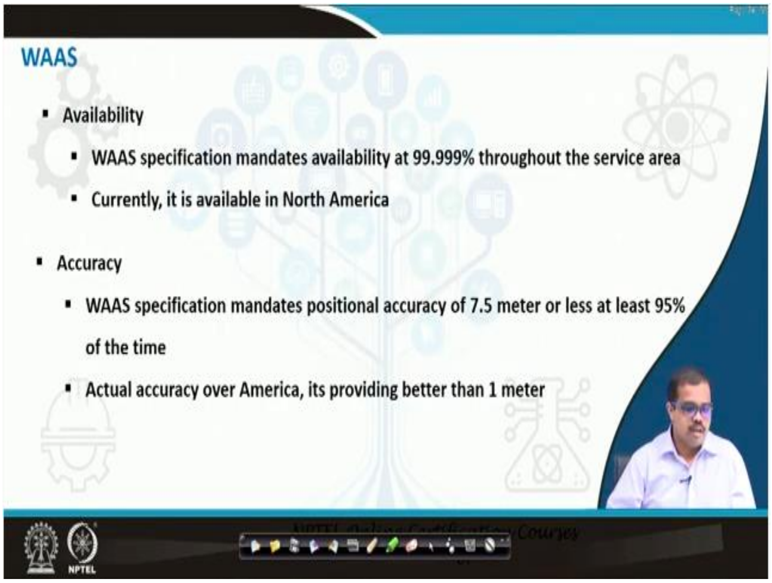

So when we look at the WAAS system the availability is extremely important as it mandates 99.999% service throughout the region or throughout the service area and currently it is available in the northern part of America. But slowly being spread into different parts we can see some of the WAAS system even traveling across the coast of America and now reaching some part of the Middle Eastern nations and also Southeast Asian regions.

But it is not yet fully functional in terms of how it is measured. There is also terms of accuracy that has to be maintained quite normally mandates that the positional accuracy of this WAAS system should be 7.5 meters okay. Extremely precise or less than 90% of the time 95% of the time which means very nanoseconds of the time it is actually has an accuracy.

Actual accuracy over America is very high. Its providing better than a meter of accuracy sometimes even less than 50 to 60 centimeters. So that is how the accuracy is really good in terms of a WAAS system okay.

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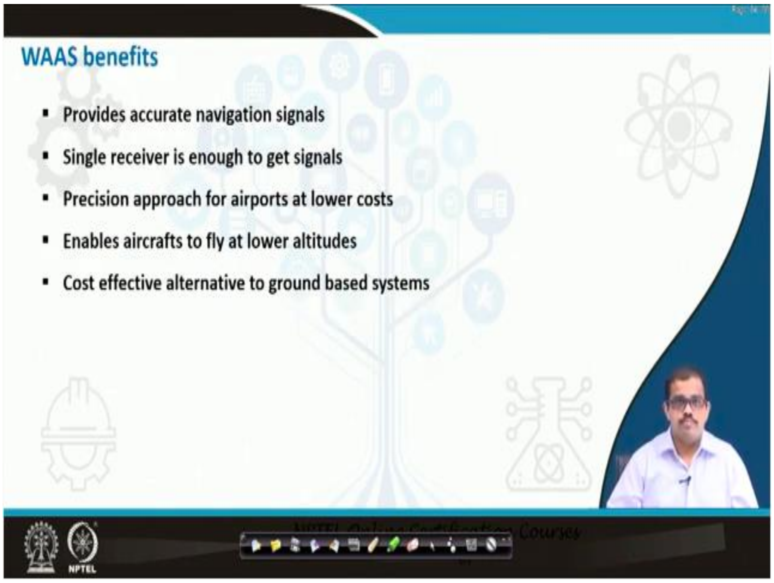

So that has provided a large number of benefits. Now it has been migrated to various other places and when you look at WAAS benefits it provides accurate navigation signals we have seen how it actually helps in navigation. Single receiver is enough to get signals we do not need multi receiver.

Precision approach for airports at lower cost very low cost in fact when you look at the maintenance and when you look at the reception and when you look at the quality of signals it is at a very low cost. Enables aircrafts to fly at lower altitudes so that it can be tracked easily also it helps in tracking at even at the lower altitudes and a very cost effective alternative to ground based systems.

So ground based systems always have this issues of corrections and errors. But when you look at this it is very cost based effect cost effective solutions in terms you do not need to have a ground base stations. So that the error is minimized also the cost is minimized.

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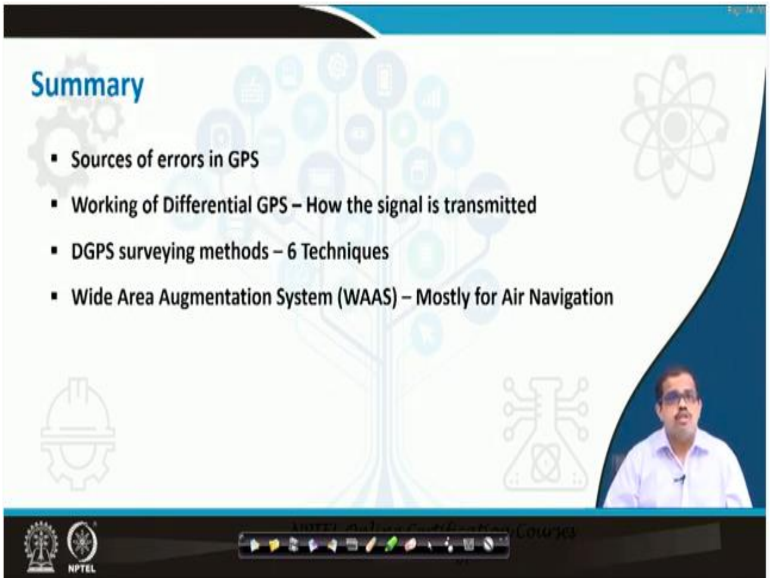

So when we look at this entire class we looked at what are the different sources and errors in the GPS? When we look at an average source of error it can be somewhere around 8 meters to 12 meters of error that is induced in a GPS system. But that can go up based on the positioning surveys, based on availability the selective availability if it is there or not. So all of these add to an errors in the GPS system.

So the basic errors are those errors that I have already explained whether it is from ionosphere whether it is from the signal receiver noise the multipath all of these issues. Then we looked at differential GPS how differential GPS is extremely useful to us. We can set up the differential GPS anywhere as necessary and absolutely remove. The atmospheric issues that may interfere into this or any other issues that is actually for example the operational clock errors.

That are there with the satellite signals and then we looked at DGPS surveying methods. We looked at 6 static kinematic methods, pseudo kinematic methods also we looked at it and stop and go method also we looked at it. So all of these different methods are used but normally it is RTK method which is well known in terms of usage of our accuracy is used worldwide. And we also looked at wide area augmentation system or WAAS system which is normally used for air navigation and the naval navigations.

So this we looked at the entire architecture of this particular system. So with this I would look at more aspects of how the GPS may work and how the application is there in my next class. As of now I would stop with this. Thank you very much. Let us meet in the next class.