Geographic Information Systems
Prof. Bharath H Aithal
Ranbir and Chitra Gupta School of Infrastructure Design and Management
Indian Institute of Technology - Kharagpur

Lecture – 27
GPS: Working and Signals

Hello Namaste, welcome back to the course on geographic information system, as I said in the previous class we would be looking at the entire module of geographic information system. So, in the previous class we have learnt about how the geographic information system has evolved over a period of time, we also looked at different segments when I say segments these have the different parts of a GPS system.

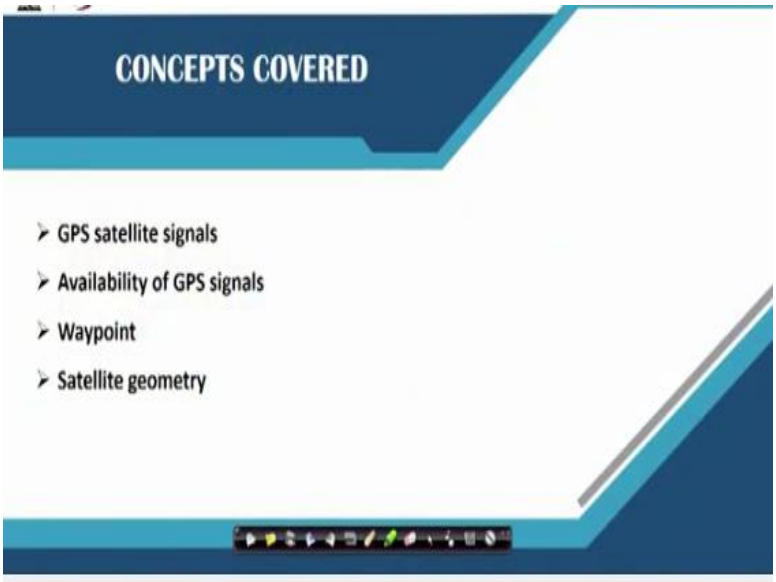
So, we looked at the master segment or the space segment where you have the space satellite vehicles which actually send in the signals to the control segment now, the control segment corrects those signals for various errors. So, this corrected values is sent back to the satellite vehicles which actually communicates it onto the ground. So, then the ground that receives the radio signals is in the form of the corrected radio signals which is a user segment.

So, this is where your applications happen, so this is the entire flow of different segments of GPS or it is the different parts of a GPS system. We also looked at how are you located on the Earth's surface now, yeah once you have understood that how the GPS locates your GPS receiver on the Earth's surface now, let us also understand that what types of frequency of signals that are there, what are different systems, positioning Systems that are there.

As I previously said there is selectivity also induced in this GPS system by the US Department of Defence and the next thing that we would also look at how for example, how does that Google maps can understand where you have to really go for example, if you are looking at a restaurants from your place, it gives you where the restaurants are located and it actually gives you the navigation route.

How does this particular Google with assistance of AGPS can tell you that exact route from one point to the other, other than if it does not; even does not have a database, then how does it actually help you in navigations? So, let us look at this aspects in this particular slide; particular class.

(Refer Slide Time: 02:35)



So, when we look at this particular class we would look at as I said satellite signals very importantly, the availability of GPS signals across the globe where we would also look at waypoints. What do you mean by a waypoint? Way point is extremely important for people who are actually navigating using a GPS receiver also, a waypoint is an extremely important aspect when you are validating your data set back does not have any ground truth that is being collected by using a GPS system.

Then, you have satellite geometry, this already I have spoken but I would really not get into this but this is, what are different concepts that I would be speaking in this particular class.

(Refer Slide Time: 03:20)

So, when we look at satellite signals; so normally any of those space vehicles which are in space can transmit 2 microwave carrier signals that is in L1 frequency which is 1575.42 megahertz, this is the frequency of that L1, it carries the navigation message and the SPS code signals. Next you have L2 frequency which is 1227.60 megahertz, this is used to measure the ionospheric delay by the PPS equipped receivers.

PPS is the precise positioning service, SPS is the standard positioning service, so these are the 2 different services that we have but very important component that you can see here is the ionospheric delay. Whenever there is issue with GPS signals, it is because of the ionospheric loss that is there that is either accounted, unaccounted by the GPS receivers.

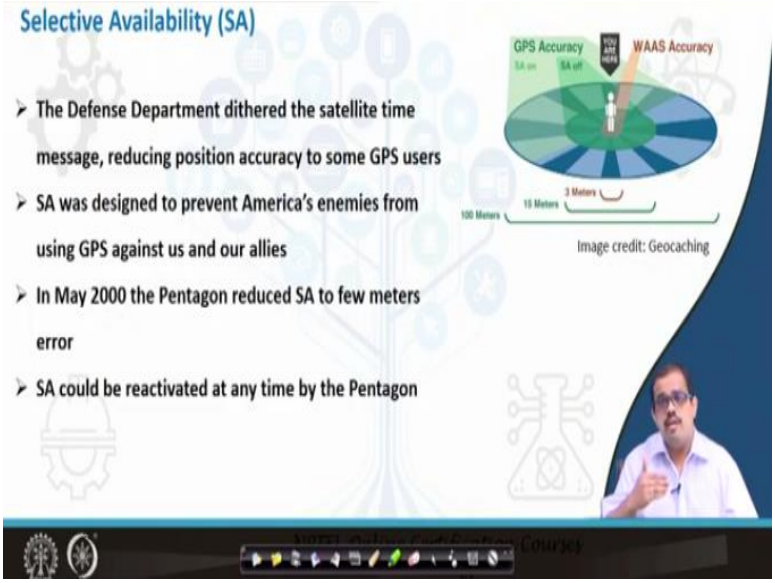
(Refer Slide Time: 04:24)

So, when you are looking at this, the first thing that application that you can see is; surveying, the carrier phase tracking. So, when you look at it a line of sight along the ground is not necessarily a precise positioning, okay. If you have any line of sight across your entire surface, then it may not be your precise positioning. Positions can be measured up to 30 kilometers from the reference point without intermediate points, please keep this in mind.

If you anywhere on the Earth's surface without having an intermediate point, I can look at the reference point with the measurement of the reference point, I can look at other points to be measured but you should know the reference point that is very important, okay. To know the reference point again, you need the GPS system which has with excise precise value on the ground.

Then carrier phase is tracked on both receivers and changes in the tracked phase are recorded over time in both the receivers which means, when I say receivers, it is on your; maybe on your car or on your mobile phone etc., okay.

(Refer Slide Time: 05:37)



So, the concept of the; here, there is a concept of selective availability, so when I say selective availability you can understand selective, it is selective to certain segments of users only or when you look at the Department of Defense, the satellite time, the message, the position accuracy was withheld for certain GPS users of certain countries. It is mainly the policy of Department of Defense.

So that in the countries which does not have the same talk as that of the US will not have the access to your precise positioning system whereas, it is only it will have a selective availability. When you look at this, it is basically in May 2000, the Pentagon which is the head of Department of Defense or headquarters of Department of Defense USA, reduce SA to few meters error.

Now, the when you look at SA, it has somewhere around 50 to 100 meters of error that you may get in terms of the selective availability. So, SA could be reactivated anytime by the Pentagon it can be increased now, it has been decreased to about 50 meters to 100 meters and when you look at this particular image here okay, so if we consider this as an entire system that is being tracked okay, let us say this is the entire system okay, this entire region.

So, now when you have this particular radio signal that is coming here if and let us say that SA is on okay or selective availability is on, as a user, if user is somewhere here, his point can be somewhere located in this location or in this location, okay. So, depending on if the signal is here, so it may be located in this particular region, when you look at this is the entire signal for when the SA is on.

So, you are located somewhere there which means, it is about 50 to 100 meters away from the point you are located but let us say that your selective availability is off so, it gives you an location which is as close as 5 meters to 10 meters, so this is where you may be located, okay. So, if you have something like was accuracy, I will explain what it means, it is even less than 3 meters of your positioning service which means, it can easily locate where you are at any point on the Earth's surface.

So, that is why WAAS is basically used for aircraft navigation and ship navigation, extremely useful in that term. So and when you look at selective availability, it is some of the very well-known enemies of United State of; I would not say if anyways, it was a (()) (08:54) force have selective availability, whereas some of very good nations which have good relations have precise positioning system, okay.

(Refer Slide Time: 09:01)

So, when we look at GPS positioning system, we have 2 types; one is the precise, another one is a standard and standard, when we look standard is for most of the countries which actually is a list of positioning system where the accuracy is very limited and when you look at

standard positioning system, most of the civil users worldwide use SPS without charge or restrictions.

So, most of the civilian of application is on a standard positioning service, so normally the accuracy of a standard positioning service is 100 meters horizontal accuracy which means the accuracy of your horizontally, where your distance is located may be somewhere around 100 meters okay, and 156 meter is a vertical accuracy. So, you can see it is quite imprecise in terms of accuracy measurements.

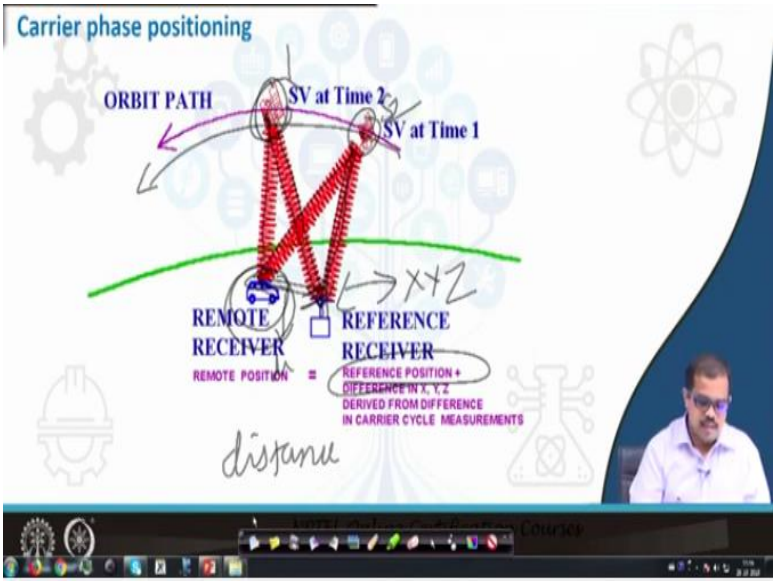
And 340 nanoseconds time accuracy, this you can have; you would have seen many times when you are actually locating a point on the Earth's surface, many of the users would have got this particular issue, when you are actually navigating and the other positioning service is called a precise positioning service, then authorized users with cryptographic equipment and keys and specially equipped receivers okay, that is extremely important.

Authorized users with cryptographic equipment so, these are specific equipments where, which is manufactured for receiving GPS signals and keys that is provided by the Department of Defense for specific purposes only and specially equipped receivers only then you will be able to have a precise positioning service which is not on your mobile phones, not on your normal GPS devices that you get for 10,000, 6000, 8000 rupees, not on all those mobile phones, not on all those GPS receivers.

So, it has about 22 meter horizontal accuracy, 27.7 meter vertical accuracy which is quite better compared to your standard positioning service and most importantly, 200 nano second time accuracy which is very important in terms of measurements on the Earth's surface or you are looking at the positioning service. So, these 2 positioning service are normally available but standard positioning service that is available for everyone.

But precise positioning service is available only for select people with select the instruments or equipments that are used to receive this particular signal.

(Refer Slide Time: 11:37)



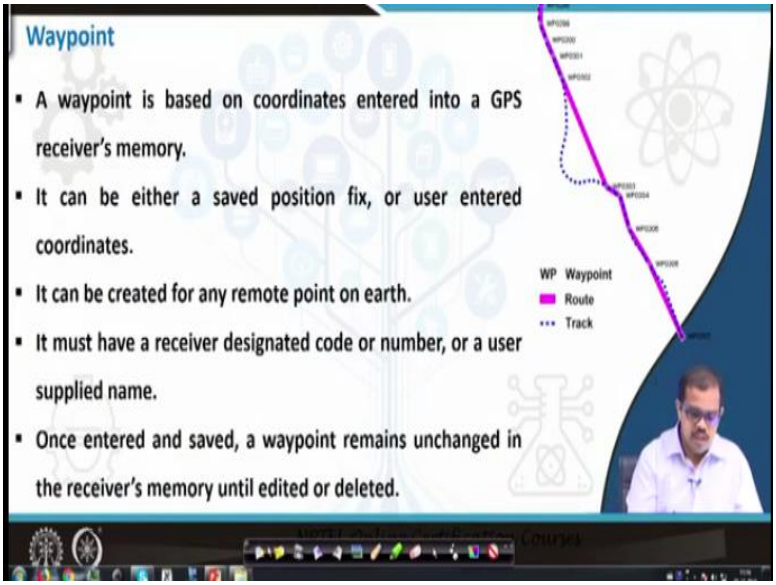
And when you look at the carrier phase tracking, using a I mean a non-precise or the standard positioning service, if you look at it let us say you have a car that is moving, you are moving in a car, you are moving from a point A to the point B okay, now the satellite orbital path is something like this let me draw it to you, this is a satellite orbital path which is going like this, this is a satellite 1, this is a satellite 2, let us say.

Similarly, you may have another 2 satellites now, reference receiver receives this particular position of let us say, this is a satellite, it is now giving the position of this particular receiver, okay. Now, this will be the difference in X, Y and Z okay. Now, when the; when you want the carrier which is the remote receiver, if you want to understand the carrier cycle measurement, you will understand it with the difference in this particular distance that is given by your orbital time.

When you look at this, this particular signal is then sent back to the satellites okay, corrected signal, this is communicated to the receiver which is in the remote position and this receiver is the difference at this particular point of time, this is a distance that is calculated. So, I did say that how you mean is how you derive the distance okay, using speed and time, okay the time of it reaching that particular point.

So, looking at this, the carrier phase positioning is normally done that is how you can position yourself on the ground.

(Refer Slide Time: 13:24)



Then you have waypoints, I said this is extremely important in terms of how you track your route for example, when you are looking at this, if you are traveling from this is your let us say point A and you are going to point B okay. So, now if your; see a satellite has to know this path, the first thing is this path is in your database, if you are looking at the GS, so this entire database is fed, this database has selected now has a huge number of points, okay.

So, with this also you have these points are connected through a line segment so, it says if it is a line segment it is a road okay. So, now what GPS basically does is with these points, it tries to map your location to this end point okay, so that is through these points are called as waypoints okay, this is how your way, if your point is somewhere here your GPS has to move something like this, okay.

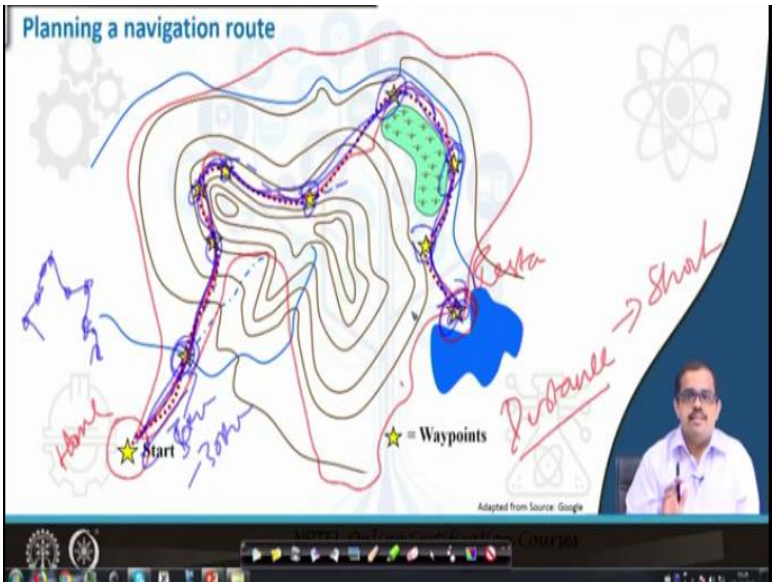
So, you have number of points that is connected here, so your GPS tracks this through the waypoints so, a waypoint is basically, a waypoint is based on the coordinates entered into a GPS receiver. So, what I am speaking here in let us say in terms of what coordinates we feed into the GPS in order to move to a particular point okay, it can be either a saved position fixed or an user entered coordinates.

So, it can be created by any remote point on the Earth's surface, it must have a receiver designated code or number or a user supplied name, so with this what happens is that the entire waypoint that is whatever you has located, it will when you reach that particular location, it beeps and tells you that you have reached that particular location. So, once you

have entered and saved it, a waypoint remains unchanged in the receivers memory until it is edited or deleted okay.

So, once we have understood the waypoints, let us understand very interesting point of it for example, how you reach a particular restaurant from your house okay.

(Refer Slide Time: 15:47)



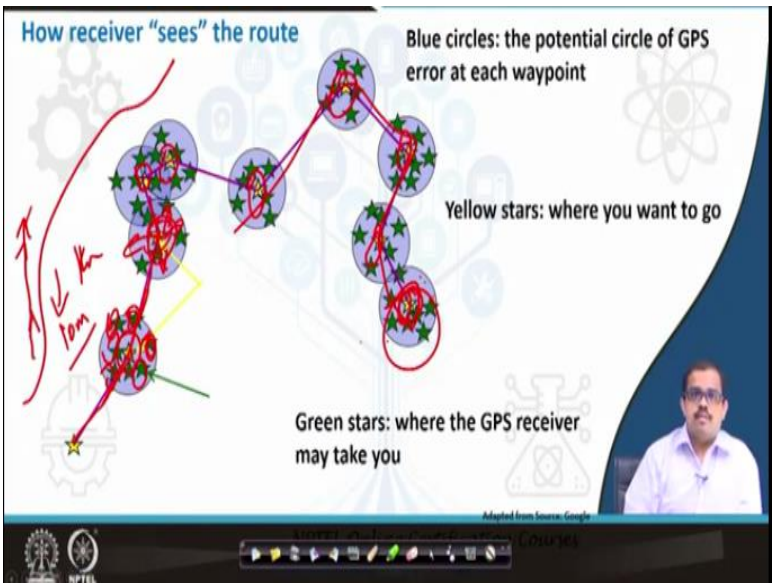
So, let us look at it, let us say you are going to some maybe let us say a lakeside restaurant okay and your home is somewhere here so, this is your home and you are going to a restaurant here. Now, with the database that is built in the GPS system, sorry, GS system, GPS knows that this is your point, this is the path that is taken to reach this one, it also knows that this is another path that may be taken in order to reach this.

It also knows that there is one more path through which this particular thing can be reached so now, you have 3 different paths. The first thing it calculates is the distance between each path okay, so once it has looked at distance between each path, it will determine, what is the shortest distance, okay. So, the shortest distance is given through this, let me take a different colour, so shortest distance is sorry; the shortest distance is through this, okay.

So, now this is my shortest distance now, it starts looking at these points that are connecting to form the line segments otherwise called as a waypoint. With this way points, it makes at least at every 10 kilometre to 30 kilometre range depending on how big is your route okay, it starts looking at a main waypoint okay, so where normally a turn is there, it can be even 5 kilometre many a times, so you can see these are the points where there is actually a curve.

So, it locates all of these main waypoint okay, or points of known location where exactly the GPS has to tell the user that there is a turn or any of those aspects. In a small city road which maybe something like this, you have every point here as a star, okay these are the main way points. So, including this, so when you look at this; these entire regions, then you have main way, with this it starts navigating to the root as you drive and reaches this point.

(Refer Slide Time: 18:38)



That is how a GPS plants your navigation route fine so, if you have understood this, the next thing that you that may be that is very interesting is how GPS receiver sees the route okay, it is not as simple as the previous one but when you look at the GPS receiver as I said these are the main way points, okay but due to your positioning service that you have, GPS receiver can look at all of these green stars can be the positions that a GPS receiver may take you, that is why you can see when you are actually navigating in this road.

It would sometimes the receiver would be something like this, next to the road or it may be saying that there is an error of 10 meters, 20 meters 1 kilometre, okay that is the adjustment error that you have to make in your entire, the way you are navigating. It looks at all of these points okay now, with this it is actually locating where you want; where exactly you have to go, so that is the error that is induced by your system either through the positioning service or through the ionospheric delay.

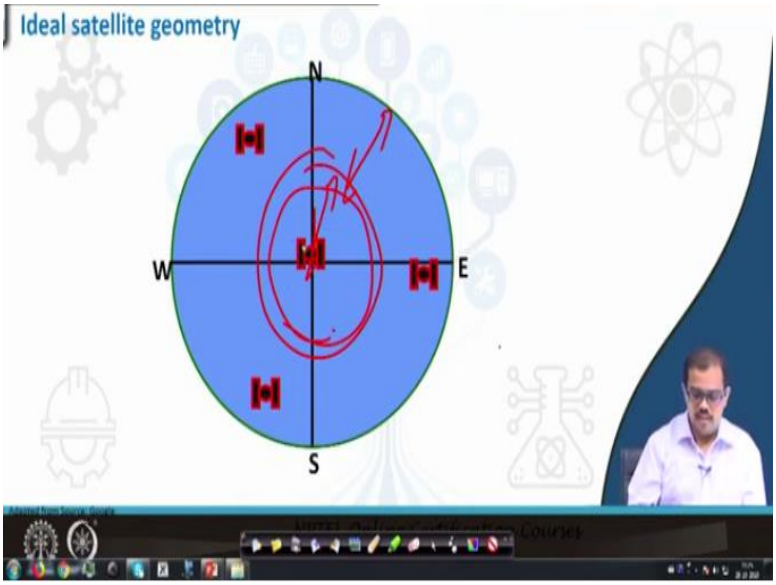
So with that the movement of your navigation; navigation of your vehicle starts and when it is hitting at every point here the distance is actually calculated at every location and now, you

can find out approximate delay in this particular distances that is what it gives, 10 meter delay, it may be that your navigation is 10 seconds delay or 15 seconds delay, so that you know that instead of reaching that particular location at 45 seconds, you will reach at 40 seconds, okay.

Similarly, it goes on until it reaches the last point where it is actually, the end point of your entire travel route, okay. So, when you look at this; if you have a very precise positioning system where you have an error of 3 meter or less, then it means to say that it is instead of having these many circles, you may be somewhere here itself okay, if let us say you have a this is what for a standard positioning service.

But if you are looking at a precise positioning service, this particular thing may hardly have any effect in terms of reaching that point okay.

(Refer Slide Time: 21:10)

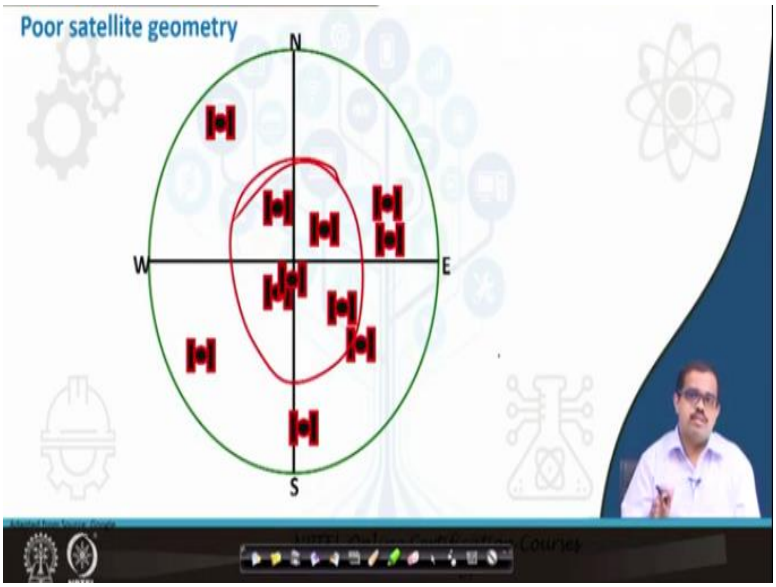


So, when you look at your satellite geometry basically, it also matters a lot because just by a bad geometry your entire signals, the strength of your signal may get worsen, so when people say about ideal job satellite geometry, these satellites should be in place in such a way that normally, you have something called as an inner circle at from the; at a certain distance from the equator and there is an outer circle.

So, at least some satellites in the inner circle and many satellites in the outer circle is extremely necessary and most of the satellite signals should not crisscross each other that is

another very important point when you are looking at the ideal satellite geometry. So, if you look at this particular system okay, if this is the thing that is ideal.

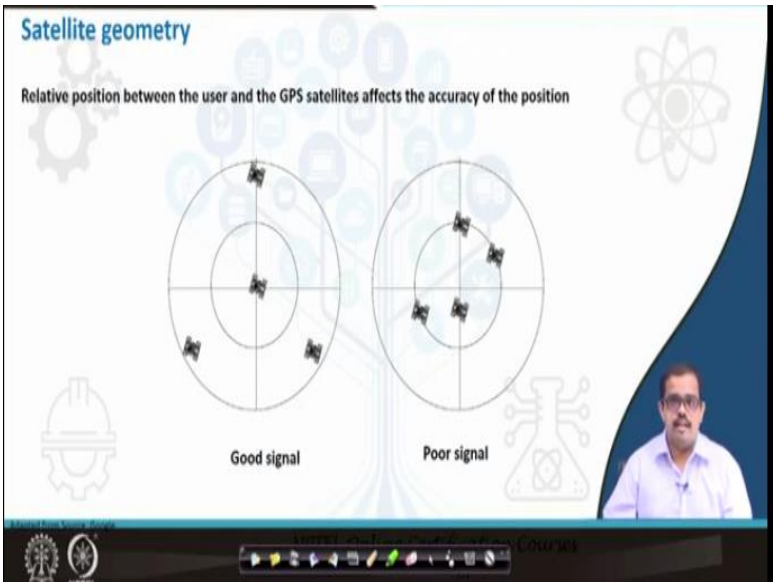
(Refer Slide Time: 22:11)



But when you look at many of your systems, most of your systems are something like this, it has a very poor satellite geometry where many; if you look at the entire signal, there will be many satellites that is in the inner circle and outer circle will have many more satellites and most of here, if you look at the entire geometry that has spin the satellites have so, these have a crisscross crossing signals which means that it is actually inducing error by itself.

And also, the measurement error, the distance error; creep in at every point on that surface. So, if you have something like this, then it shows a poor satellite geometry okay.

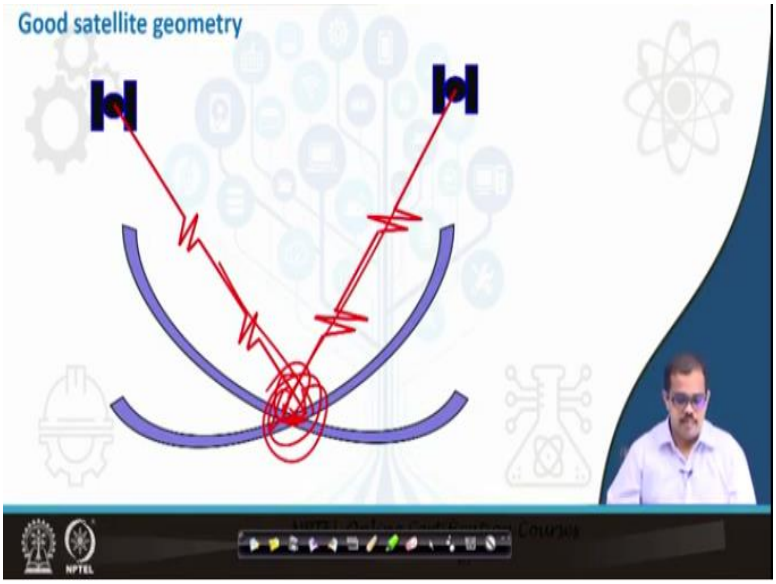
(Refer Slide Time: 22:52)



So, when we are looking at this, there is also a concept of how you are relative positioning between the user and GPS satellites are also affected for example, if you have something like this, there is no crisscrossing, so you have a best signal that comes and your measurements is quite precise based on the positioning service you have but if you have something like this, even with a precise positioning service, you may have certain errors induced because of the satellite signals.

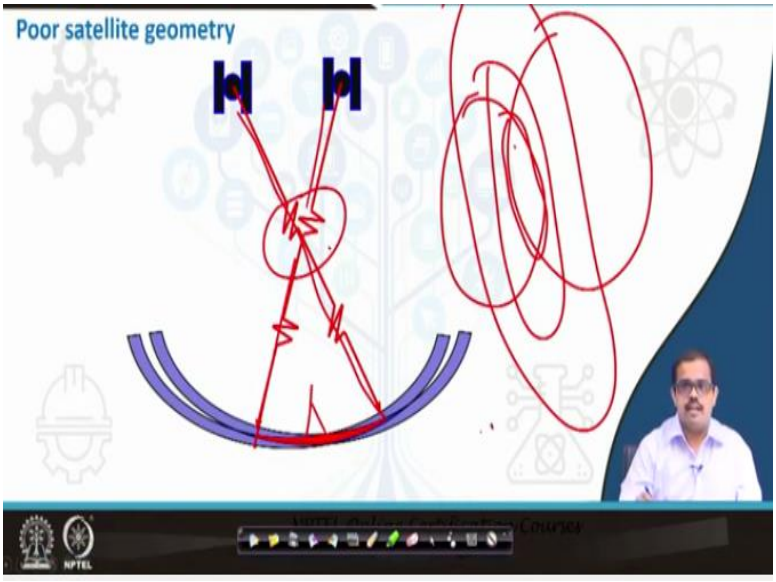
So, Department of Defense has taken care of these issues and at least 99.99% of the chance these issues are always I mean, it does not occur in most of the phenomena but there are chances that certain places it really occurs and the error is too high.

(Refer Slide Time: 23:40)



To give an example of signal error, so this is; this is what it means so, you have a satellite signal that is reaching and this is a satellite and that was crisscrossing each other because of which the error is actually induced into the system, okay.

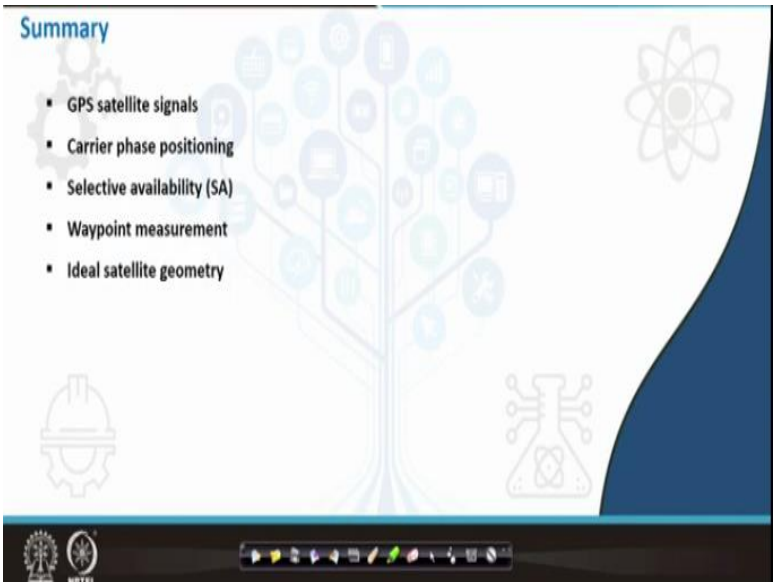
(Refer Slide Time: 23:57)



So, you have a poor satellite geometry even in terms of something like this, whether it is joining at a particular position or it is having, so now what happens when it is actually measuring a point, the 2 satellites measure this particular location right. So, now with the previous; the way the previous 2 signals were adding it, it would have given the location somewhere in this region.

Now, it is giving a location somewhere here, so that is how your locational information distortion increases in terms of positioning service, so that is one in case you have a poor satellite geometry this is what may actually happen you know for your analysis, okay especially that is not good for when you are trying to look at your; the way you have some validation data that you are connecting and how your validation data is there.

(Refer Slide Time: 24:44)



So, to summarize this entire presentation, we looked at GPS satellite signals so, when we looked at GPS satellite signals I did say we have 2 types of frequency; the microwave frequency that is L1 frequency, other one is the L2 frequency. Now, I would suggest that in case you have some interest in understanding the L1 and L2 frequency, I would request you to go back look at its electronics, it is actually fascinating in terms of understanding the electronics.

And most importantly, the bigger research that is happening today as in terms of the GPS is in terms of this particular signal receiving. So, please look at the satellite signals how they are received and if in case, you have enough time otherwise, why I have specifically introduced as GPS system here is people should understand how GPS system works. So, if someone gives you a GPS tomorrow to do a validation, so if you understand some basics point, this particular thing does not cover the entire aspects of the GPS.

But it is selectively giving you some important information about the GPS system so, if you are able to understand this, it may be useful when you are trying to go in the field with the GPS system you can exploit the very good or thing of the GPS system and get better results. So, then we looked at carrier phase positioning, which is extremely useful in terms of positioning yourself on the ground.

And the next point that we looked at is selective availability, so I did say that selective availability gives you a huge error up to 100 meters, so when if the selective availability is not there, if the error can go up to 15 meters and if you have a WAAS system, then it has 3 meters, so this selective availability is given to only certain countries which are not in good terms with the United States of America or Department of Defense, United State of America.

And the selective availability is actually degrading the entire system of how the measurement is done okay, so though the 100 meter error that was introduced has been reduced to almost closer to 50 to; in the range of 5 to 100 but though you have 50 meter error that is induced today also in certain regions, so that makes every application erroneous okay. So, that is what we learnt, then we looked at the positioning services that is the precise positioning service and your standard positioning services.

When we look at precise positioning service, we have a good accuracy measurement in terms of horizontal and vertical accuracy measurement, precise positioning service can only be received by certain specialized equipments and specialized designated receivers only and where a standard positioning services for all civilian applications, so we also looked at various applications that we can have.

Then we looked at what is a waypoint, how does waypoint matter, how does a satellite actually easily locates you or a GPS receiver locates you through a waypoint; number of waypoints, then we looked at how a waypoint is marked when you have defined positioning; different positioning system, the waypoints can be either side, so how do you actually the; with this waypoints what are the errors that are induced.

And normally, you would have seen such errors in your may be when you are actually navigating and then we looked at what is the ideal geometry of a satellite, we looked at what are the; how the satellites has to be located and what are the different ways that particular satellite receives it signals or the signal is sent okay. If there is a criss-crossing signal, then error is induced.

If the error is induced, then your distance measurement is actually provides it with an error, so we have; with this we learned that what is the best kind of geometry that we may have or an ideal geometry that we have with the satellites which are taken care of normally by the Department of Defense. With this, we would end this particular class, so I hope everyone has understood the basics of the GPS part.

Then now, let us in the next class we would look at more precise positioning systems which include the DGPS and also looking at the WAAS system, how these are extremely helpful in either for navigation or for example, the WAAS system is used for aircraft and naval systems. So, how that is those particular applications are very different in terms of how the receiver receives or perceives the signals.

Let us look at all of these okay, as of now I hope, I tried to convince how the GPS works, so this is how the normally, a GPS system works, when you have not handled receiver, you receive only a radio signal. So, with this let me end this particular class, thank you; let us meet in the next class with more details on more important issues, thank you.