GPS Surveying

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Lecture – 10
Errors in GPS Observables (Systematic Errors)

Welcome friends today is the 10th class on GPS surveying, in this class I am going to discuss on errors, errors in GPS observable the systematic variety of error in GPS observable will be discussed.

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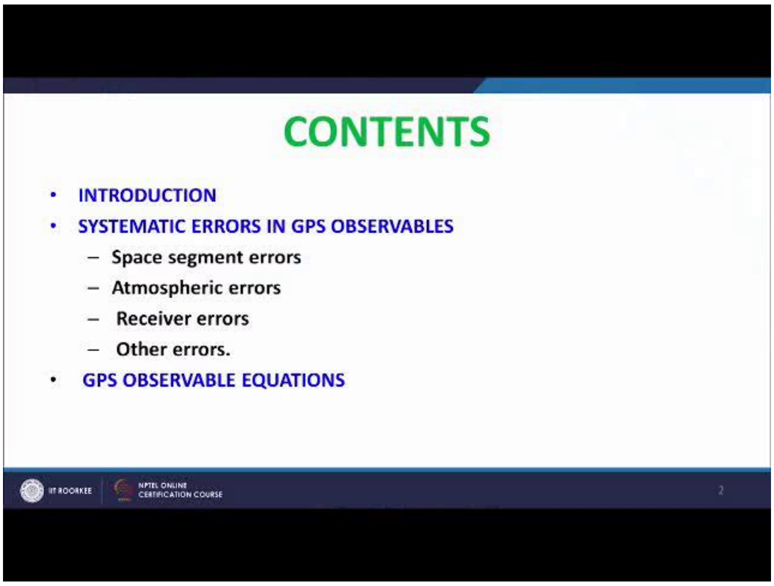

Now, the content of this class will be like introduction then followed by different types of systematic errors in GPS observable. There are four basic types space segment error, atmospheric error, receiver error and other errors followed by the GPS observable equations which already I had discussed in the last class.

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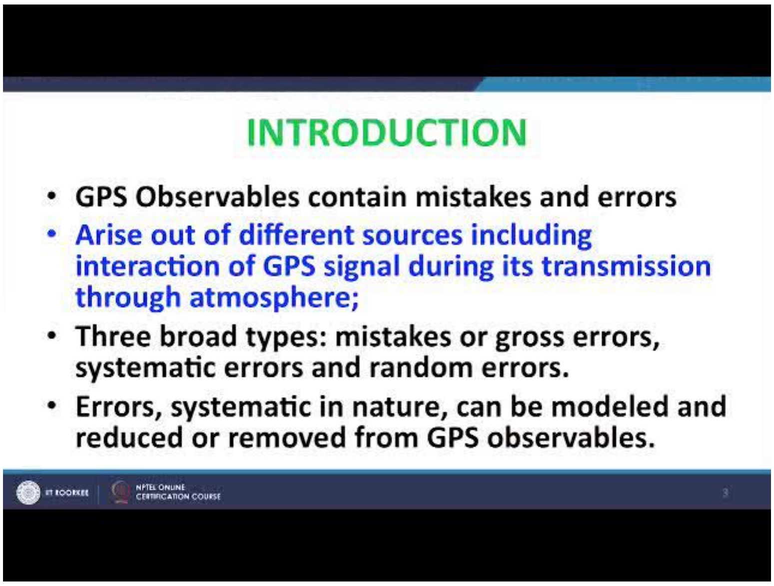

Today I will just repeat it, now as you know that GPS observables are endowed with errors, different types of errors are present there due to different sources of generation of those errors and the errors are for fundamentally divided into three types like gross errors, systematic error and random error. Of these errors the systematic error is other errors, which really follows some physical laws so it is called systematic and on the basis of the laws, this may be model which further can be removed from the GPS observables. So, actually these errors have very big deteriorating effects on the GPS positioning so we need to know thoroughly about the different types of systematic errors and how they can be minimized or removed from GPS observables. Now form thus on the basis of the source, the GPS observable contains four types of systematic errors.

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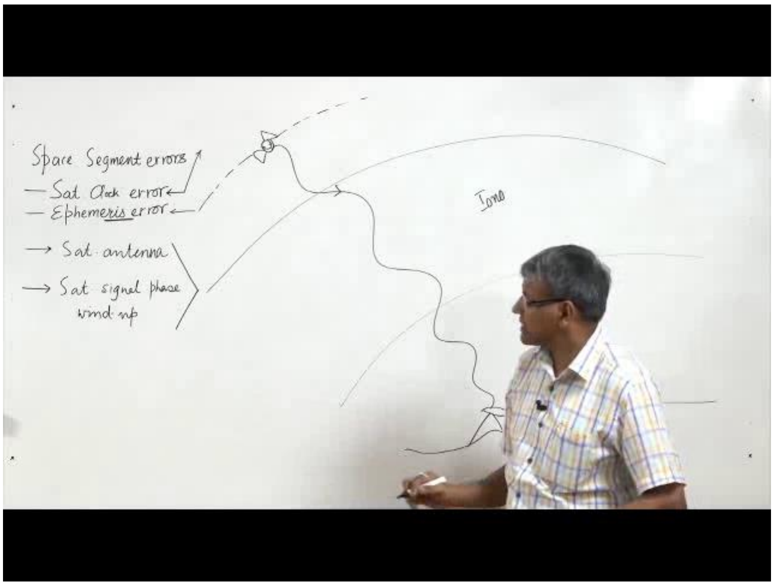

Now if we assume that the GPS signal is coming from satellites to a receiver, now while these signal is coming from the satellite to the receiver, it will pass through atmosphere. So, now there may be errors in this signal which may be generated out of the space segment; that means, related to satellites they are related to orbit. Now as it travels through the atmosphere, there are different types of interactions of this signal with the atmosphere.

So, depending upon the type of interaction there are two types of atmospheric errors, one is in the ionosphere and another is the troposphere. Apart from that, when it is coming to the receiver there will be some errors due to; around this receiver. So, and apart from that there may be some other errors, so we can discuss like your space segment errors. There are four types these are satellite clock error, then your ephemeris error, satellite clock error as the name itself understood that it is the error related with the clock of the satellite. Actually the any satellite, any GPS satellite makes use of some automatic standard and there may be lack in synchronization of the automatic standard with the GPS system time and that is what is called satellite clock error and this error may be removed or reduced by making use of some parameters which are available with the navigational message.

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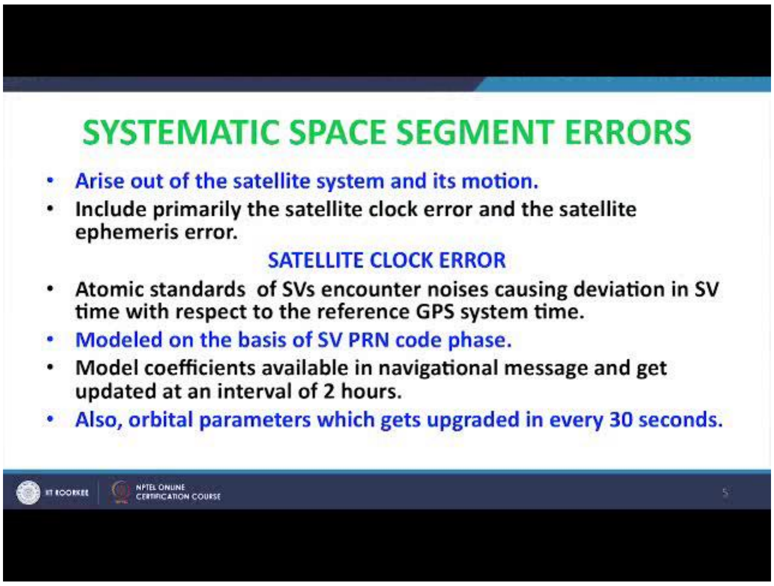

So, actually as it is systematic error; there is a standard model of its behavior and that model is based on some parameters as well as some orbital parameters, as well as some model parameters and those values of those parameters are available in the navigational message. Now the ephemeris error, from the name itself we can understand that it is related to the orbital motion of the satellite. As we know that the satellites are designed to (Refer Time: 06:08) along certain orbital path and those parameters are available in the navigational message and that is called broadcast ephemeris data, but due to the extra gravitational forces like our sun, pressure there may be drift in solar drift and so many other things so these satellites do not or incapable of moving along the predefined orbit.

So, there will be a difference between the actual position or actual orbital parameter and the navigational orbital parameter. So, that discrepancy arises and that is called ephemeris error and due to this error, the position we do get from the broadcast ephemeris data will end up with some error in position. So, to avoid that thing we should go for relative positioning if the baseline length is small, small means less than 20 kilometer because in that case it is assumed that most of the ephemeris error or error due to ephemeris may be equal for the both station and that may be cancel each other or for long baseline we should go for precise ephemeris.

Now, the next type of space segment error is; satellite antenna error, now what is this actually satellite is considered to be moved along the orbital path with respect to its center of mass, but the signals are coming and the range is being computed with respect to the antenna face center of the satellite. So, there is a discrepancy between what we are computing and what actually it is, so the difference between the antenna face center of the satellite and the center of mass of satellite, there is a some certain values and that may be taken into account while computing for very precise estimation of position and the values are available in the i g s site, this one the available. So, this may be used to compute the errors as well as to remove the errors from GPS positioning.

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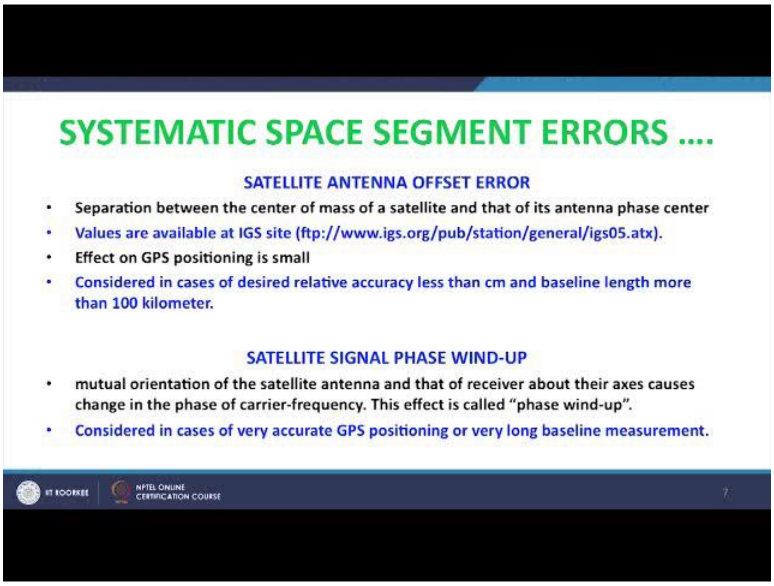

And the last one among the space segment error is that; satellite, signal, phase, wind up error. Now this is the error, error is out of the axis of the antenna of the sat GPS satellite and axis of the antenna of the GPS receiver should be identical to otherwise there will be some error in the phase measurement of the signal. So, this is also these two errors are very minute and specifically for very precise estimation of position these errors should be taken into account, so this is all about the space segment error.

Now, after the as the signals are coming from the satellite through the atmosphere during the propagation of the signals through the atmosphere, the velocity of the signal as well as the nature of the signal will be disturbed.

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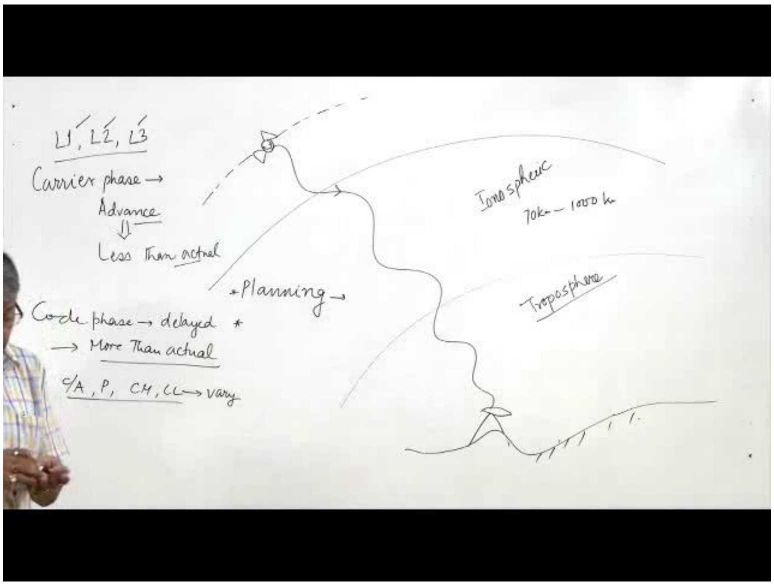

Specifically velocity will be reduced and the signal will get dispersed in the ionosphere and it will physically obstruct or deviated in the troposphere. So, all these thing will make or provide some error in GPS observable and causing the error in GPS positioning. So, these errors need to be addressed, has to be computed and then has to be removed from the GPS observable. Now depending on the type of the interaction that the GPS signal we will be undergone as we will propagate through the signal, there are two types of error we do say one is called ionospheric error or ionosphere say ionospheric error and the other is called tropospheric error.

Now, for GPS ionosphere is that part of the atmosphere which has significant amount of ions which will affect the propagation of the signal because GPS signal is electromagnetic in nature and there is a layer of atmosphere varying from 70 kilometer to 1000 kilometer from the surface of the earth which is having significant amount of electrons, which cause dispersion in the propagation of the GPS signal. So, as it causes dispersion in the ionospheric GPS signal, the velocity of propagation of the GPS signal will vary. Now there is a peculiar thing in this case, the ionosphere splits up the carrier phase, so the velocity of the carrier phase; carrier phase gets advanced; that means, it increases due to dispersion phenomena velocity of carrier phase gets increased. So, as a result of which, the carrier phase range measurement will be of less than actual because velocity is increased means time of transmission will be less so the distance measurement or the end measurement will be less than the actual.

Whereas the code phase of the signal will be delayed or and the phase measurement will be more than actual. So, the effect of ionosphere on the carrier part of the signal is different from its code part. Not only the nature but also for different types of codes, the amount of ionospheric error will be different for different types of signals, a carrier phase that L 1 carrier phase, L 2 carrier phase, L 3 carrier phase, the effect of ionosphere will be different for each of this.

Similarly for C A code, for P code, for C M code or C L code this effect of ionosphere will vary. So, and the effect of ionosphere on GPS signal is the worst kind of error that is available in GPS observable, so it is very important to know the amount of errors due to ionosphere and in fact we should rather than finding out the errors we should try to plan our observation in such a way so that the ionospheric activity is least because ionospheric activity is maximum when it will depend upon the position of the sun, time of a day and the latitude of the place observation, as well as ionospheric activity is in the upper atmosphere, ionospheric activity chart is also available in the internet. So, we should plan well, we should carry out well before how when to take our observation, so that ionospheric action is less.

Now, one that is one way how we can minimize the ionospheric error in GPS observable; first one is that planning proper planning and observation schedule and then because in spite of all our best effort, there will be ionospheric error in the GPS observable. Now next way to minimize the ionospheric error is to model it, now some models are already available in GPS signal, GPS navigational data we can make use of those model and those model, by using those model about 50 percent of the ionospheric error maybe minimized. Still there will be some error, so for small baseline length we may go for relative positioning that will also provide some; it will also minimize some error then we may go for some pre-processing operation in the next class, we will be discussing on those and those pre-processing operations also minimize the amount of ionospheric error in the GPS observable.

So, in that way under different categories means different categories of operation as well as observation planning observation then pre-processing all those steps will minimize the ionospheric errors in GPS observables. The next variety of atmospheric error is the tropospheric error, in case of GPS observation the layer of the atmosphere where the signal gets physically obstructed; that part is known as troposphere and it is about you can say 40 kilometer, up to 40 kilometer from the surface of the earth and the tropospheric error are caused due to the temperature pressure humidity and their variations, so apart from particulates.

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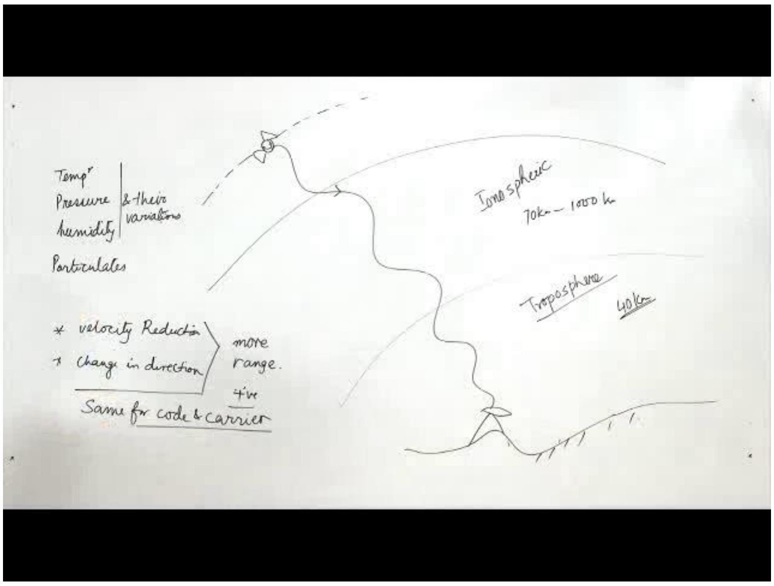

So, temperature pressure humidity and other particulates, their presence and their variations will; may cause the physical obstruction of the transmission or propagation of the GPS signal through the troposphere and also it will deviates. So, there are two types of effect; one is change in velocity or we can say reduction in velocity and change in direction, change in direction means (Refer Time: 19:25) so the tropospheric error is will cause always delay in propagation. So, it is always it will provide more range than actual, so it is additive in nature; always additive and moreover it is same for same for code and carrier part of the signal. So, the code part and carrier part of the signals (Refer Time: 20:04) will be having same tropospheric error different types of code, different types of carrier will be having same types of, same amount of tropospheric error and these are positive in nature.

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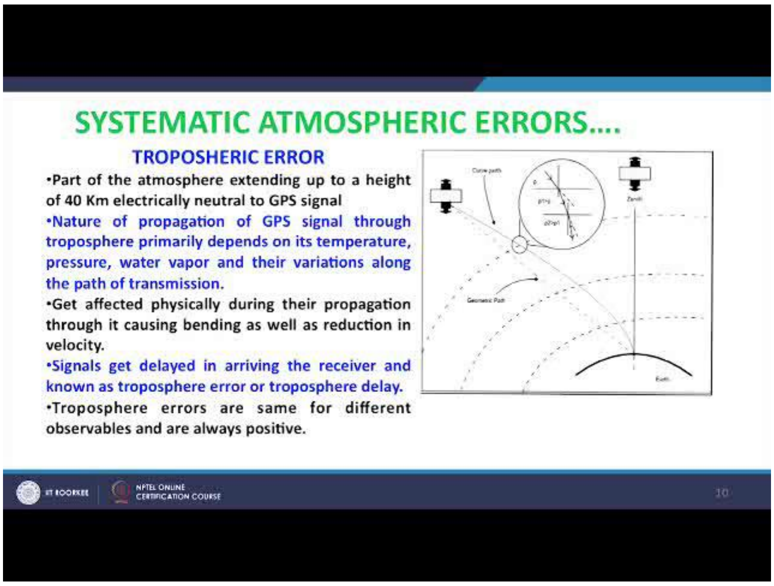

Now, in this diagram you can see it is shown; if we the signal is coming from the satellite to the receiver instead of coming along the line of path, that is the optical path; this is a geometrical path, they will take something like this due to obstruction as well as due to and this is what is called refraction of signal and also the velocity will be changing depending upon the density of the atmosphere. So, as the velocity is decreased as well as the path is increased, the time of transmission will be more and the computed range will be more than actual so the error is more, so correction has to be taken out, so this is what about the tropospheric error.

Now because of these, now tropospheric error also can be modeled. Now some of the whatever precaution during planning that we have taken in, we should be taken in during planning, some relative positioning can be done for removing some error some pre-processing techniques can be applied to reduce or minimize the error. Over and above the tropospheric error may be minimized or removed by developing some models and now one thing is important in case of troposphere, that the troposphere is very much slightly specific, so to deal with tropospheric error; it would be wiser to have a slightly specific tropospheric model.

Now, with this I can go to the next step of errors that is error that is around a receiver; GPS receiver.

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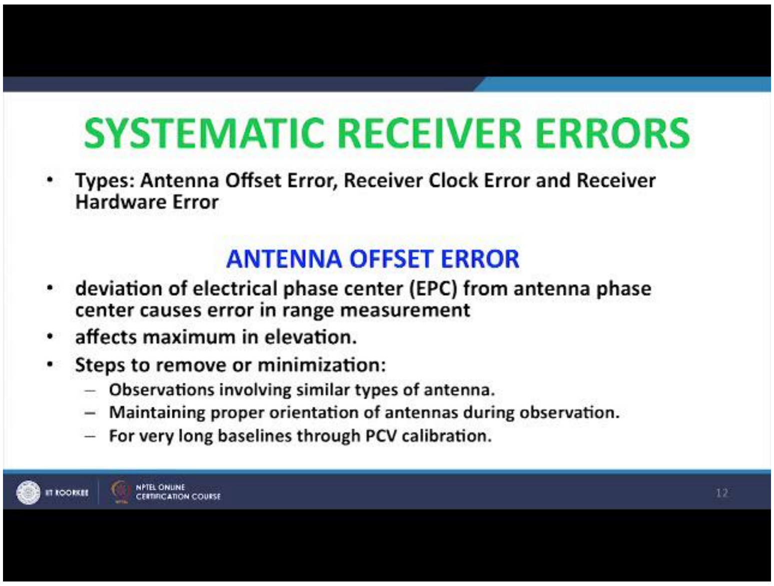

Now let me discuss about the third category of the systematic error; that is the systematic receiver errors, under this there are three types of errors we will be discussing.

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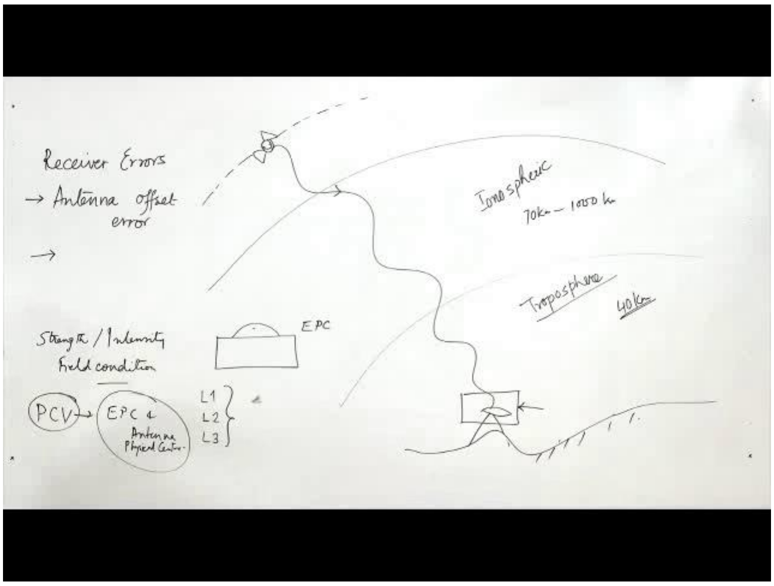

The first one is called antenna offset error, now what is this actually the antenna of the receiver there is a point called electrical phase center and this electrical phase center is different frequency of the signal as well as for; now these theoretically there is one point, but practically these point will vary, depending upon the signal, strength, intensity, field condition etcetera. So, as a result the parameter called PCB that is the difference between EPC and physical antenna, physical center.

This is the parameter which is used to compute the height of the instrument, so if there is a variation in this; that means, there will be errors in measurement in this for each observation, for each number of observations and that will come into the height of the instrument; that means, in the height measurement of the GPS position. So, antenna offset error is a important parameter to be considered, while specifically we go for height measurement and that can also be reduced by relative positioning or by making use of same type of instrument in all observation; that means, in comparing other if we have two, three receiver we want to use for each receiver, we need to use same type of antenna and the orientation of the antenna has to be maintained same.

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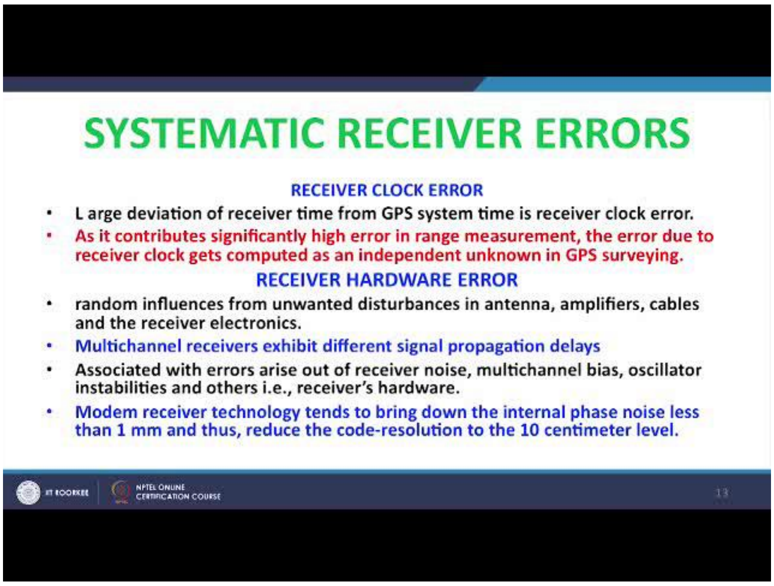

Next one which is the most important of all errors, that is the receiver clock error.

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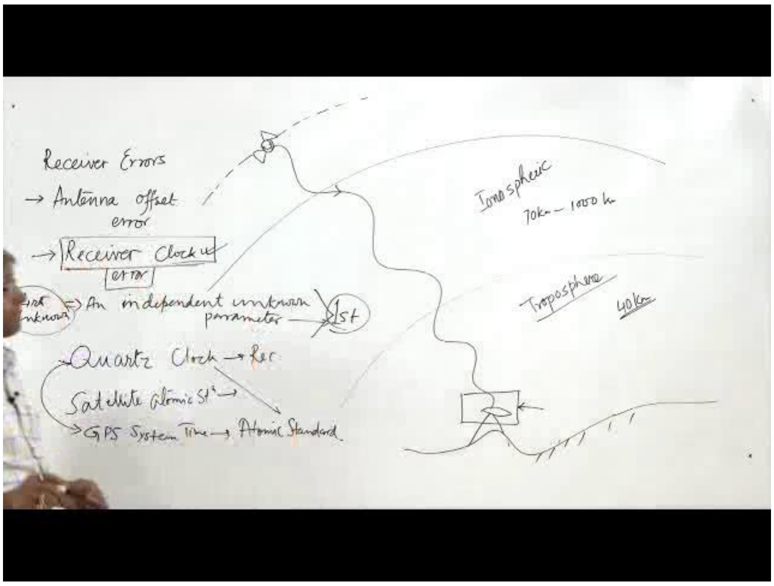

As we know that the receiver, GPS receiver make use of quartz clock whereas, satellite use atomic standard and also our GPS system time, also GPS system time is also based on atomic standard. So, there is a large discrepancy between the quartz clock of the receiver and the GPS system time. As a result, there will be a huge error that will be introduced in GPS positioning due to the receiver clock and the error is such a great, that whole of GPS positioning will be spoiled if we do not take care it in the beginning itself.

So, the error due to GPS receiver clock is to be considered as an independent unknown parameter which we go for computation during positioning and it is considered as the fourth unknown during GPS positioning, but though it is termed as the fourth unknown in the GPS positioning computation, but this is the parameter which has to be computed first. So, if we get signal from only one satellite, we will go for; we would go for measurement or computation of this error and this is the most important unknown which has to be computed of all in the beginning.

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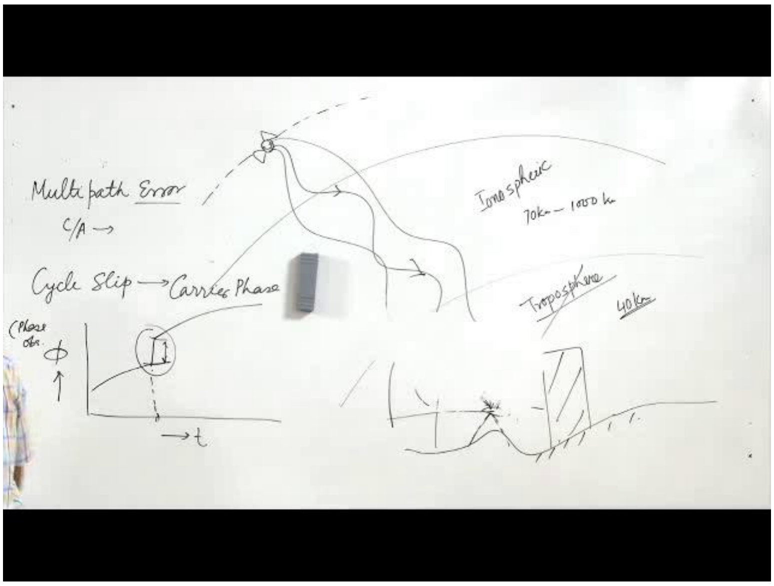

And the another variety of error which is important that is called receiver hardware error, receiver hardware error, so these are the errors which are associated with the malfunctioning of the hardware and by taking a good variety of hardware, we can take care of this. Other than that there are two important errors which is to be taken into account that is one is called multipath error, actually multipath error is caused due to presence of some trees or building; building or trees along the GPS observation. So, what will happen? Signals will first come to the tree and then, it will be reflected to or signal will come from the building and then it will be reflected.

So, along with the direct signal also some reflected signal will come to the antenna and that is called and the error caused due to these reflected signal is called multipath error and the amount of multipath error will vary from carrier part and code part, where it will be different for both carrier and code and the worst affected is the c a code and because c a code positioning is the first positioning we have to determine, after which we go for very precise measurement, so if there is error in c equal c a code positioning then there will be end up with the very bad solution.

So, we should take care of multipath error and the best way to take care of multipath error is to plan properly, so that our receiver is not placed in a crowded area or if there is a crowd then we should take the cutoff angle beyond that crowd so; that means, cutoff angle should be taken more may be (Refer Time: 29:50) 25 degree, sometime may be 30 degree and also we should make use of antenna which is and it will take care the multipath, so that is called multipath resistant antenna or we should go for some receiver which is embedded with multipath mitigation technology or we should go for some signal processing techniques which is also take care of multipath error.

Another error which is important that is called cycle slip, these error will come if there is some obstruction in the signal or there is interference in the signal then what will happen, the number of cycles of; that means, if we plot the integer ambiguity then we will see that with time, this if we plot the phase observable then we will get a scene like this; that means, at this point the signal got lost and then again it start after some time. So, we need to identify this time and we have to find out what is the amount of jump in number of phase cycles and that has to be identified, removed, rectified as the pre-processing.

And these can be taken care of by (Refer Time: 31:56) pre-processing and our many commercial software provides us the flexibility to process these data and remove the cycle slip. Incidentally the cycle slip occurs only for carrier phase measurement.

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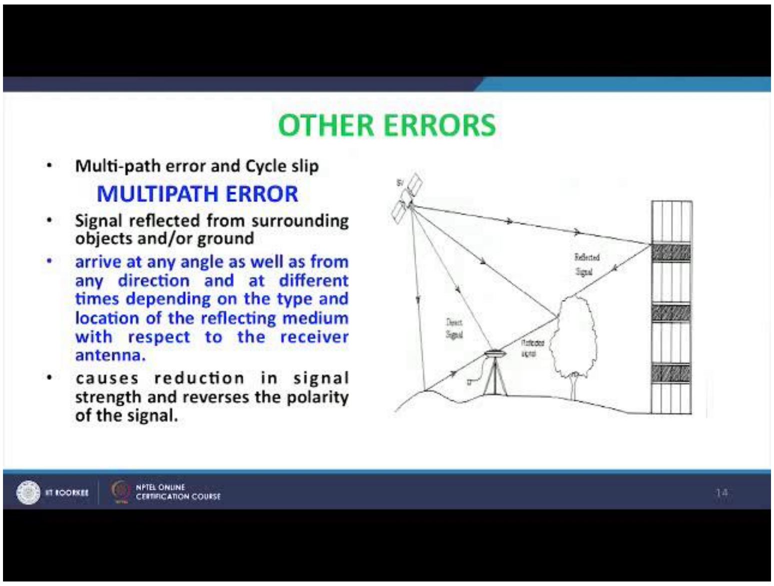

So this is what we can show about the cycle slip and so with these different types of errors we have discussed.

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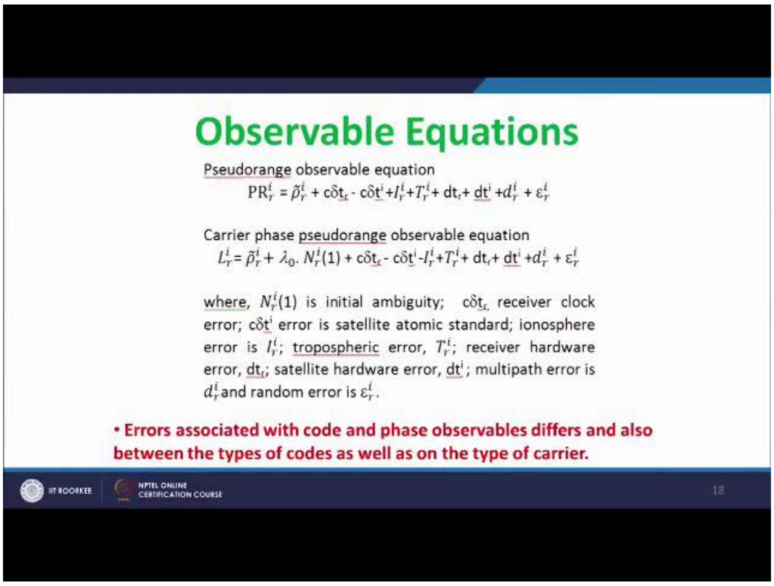

So, finally all these will be taken into account, can be taken into account under GPS observable equations which already I had discussed in the last class that the pseudorange observable is equal to geometric range, this is the error due to receiver clock, this is the error due to satellite clock, ionospheric error, tropospheric error, this is the error due to receiver hardware, this is the error due to satellite and this is the multipath error and this is the random error.

So in that way pseudo range, which we will be getting from GPS observation, actually it will consider so many errors and this is the actual thing; that means, this is the geometric range which we want to find out. Similarly for carrier phase observable, this is the geometric range, this is the integer ambiguity, this is the receiver clock error, this is the satellite clock error, and this is the ionospheric error, tropospheric error, receiver hardware error, satellite hardware error, multipath error, random error; however, though the symbols are same the amount of errors will be different.

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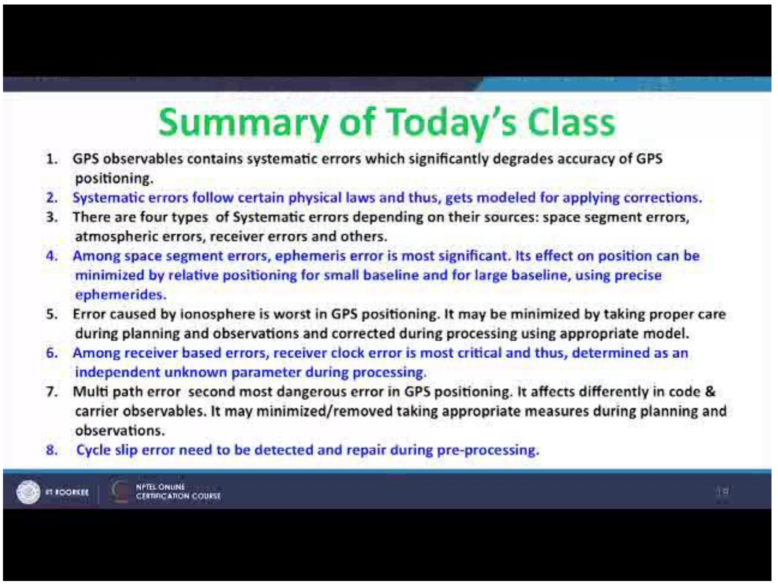

So, with these I want to conclude today's class and the summary of today's class may be like this, that GPS observable contains many systematic errors. Of these the most significant and important error is that our receiver clock error which we take as the unknown parameter while computing the GPS positioning, that is to be done in the beginning itself, next worst variety is that ionospheric error which varies from signal to signal (Refer Time: 34:10) to different components of signal and it can be minimized through proper planning and modeling and the next variety is the multipath error, which has to be removed or to minimized. Thank you very much; see you again in the next class, in the next class I am going to talk on GPS data pre-processing.

Thank you very much.