Satellite Communication Systems

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Lecture - 35
Synchronization-II

Welcome back, we are discussing about the synchronization and we have covered the frame synchronization particularly unique (Refer Time: 00:29) detection part of it in the burst and then we just started on network synchronization. In the network synchronization we talked about open loop synchronization, and then we were starting the loop synchronization in terms of time and frequency.

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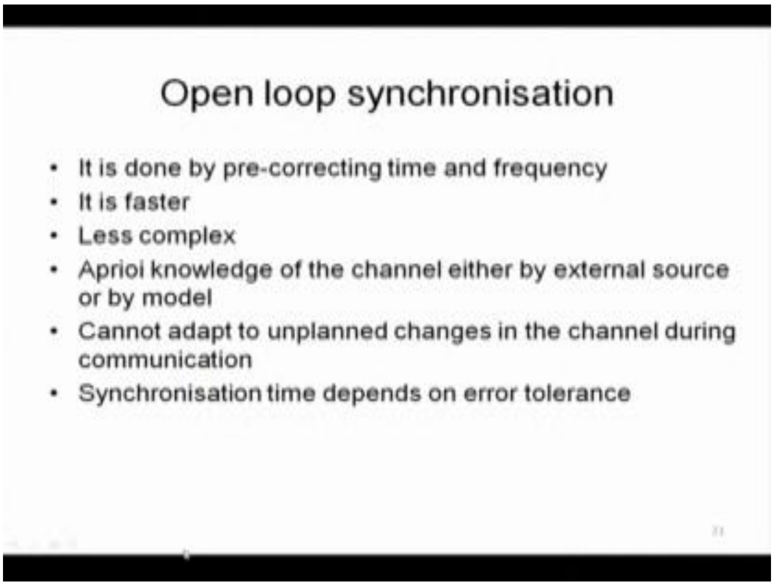

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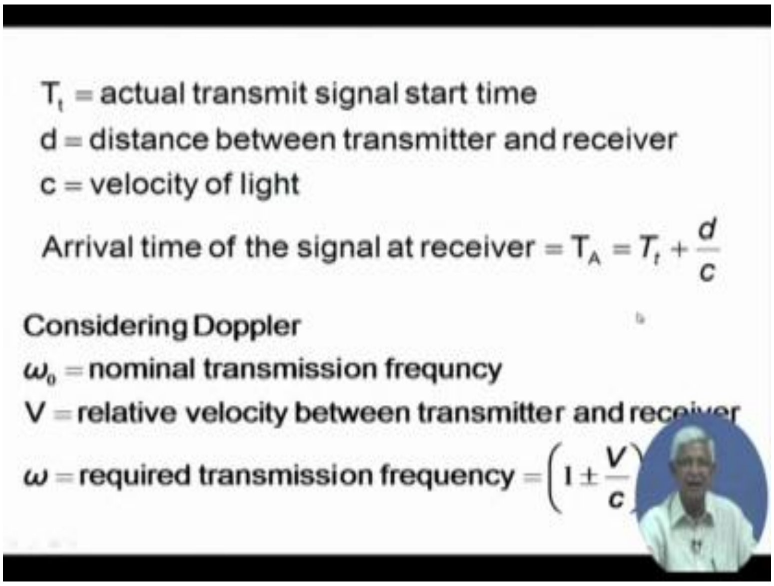

So, when the transmitters have to pre correct it should know that after how long time the burst has reached the receiver. So, the actual transmit time at time t t it has transmitted that is the started the transmission and the delay that is the distance between transmitted and receiver divided by velocity of light assuming the it is a constant propagation time. So, with this we estimate what is the time of arrival at the receiver. So, the whole thing is depending on that is d the delay as of course, the transmit time now similarly in the frequency domain the considering there is a Doppler, since the receiver might me moving or the transmitter might be moving. So, omega 0 is a nominal transmission frequency and v is the relative velocity between transmitter and receiver in that case the transmission frequency what should be corrected is pre corrected is one plus minus v by c, plus minus stands for the velocity towards the transmitter or the away from the transmitter, v by c that is the Doppler into omega naught.

Now, these the time source or the frequency source whatever it is. In fact, time source is derived by frequency source this will have certain error or your measurement, might have some mirror therefore, this pre correction as to be corrected for the error also.

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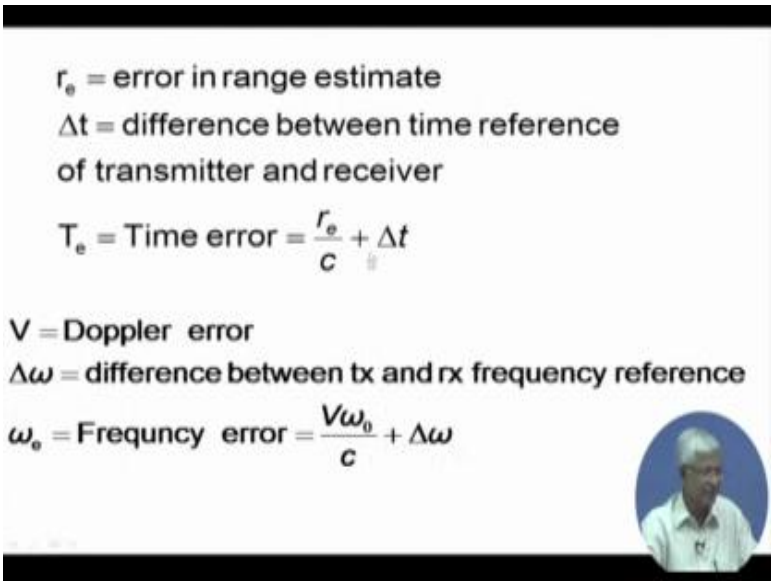

So, let us say the r e is the range error in the range estimate and delta t is the difference between the time reference, it is the transmitter as the time reference receiver as the time reference. They have they have a certain reference difference because there accuracy stability all this things are not same, since they are not same; physically they are separate. So, they may have a time mark a time you poke at different may be as different time transmitter and receiver. So, that is the difference between time reference, there is a time error t e is r e by c that is range error plus delta t is the difference similarly it can be done for the frequency.

So, v is the Doppler error and delta omega is the difference between transmit and received frequency reference the each, each of the as I said that in case of time there is a frequency reference which may have some difference and the omega e that is the frequency error is the Doppler v omega naught by c, plus delta omega the plus is it could b plus minus depending on which direction is going.

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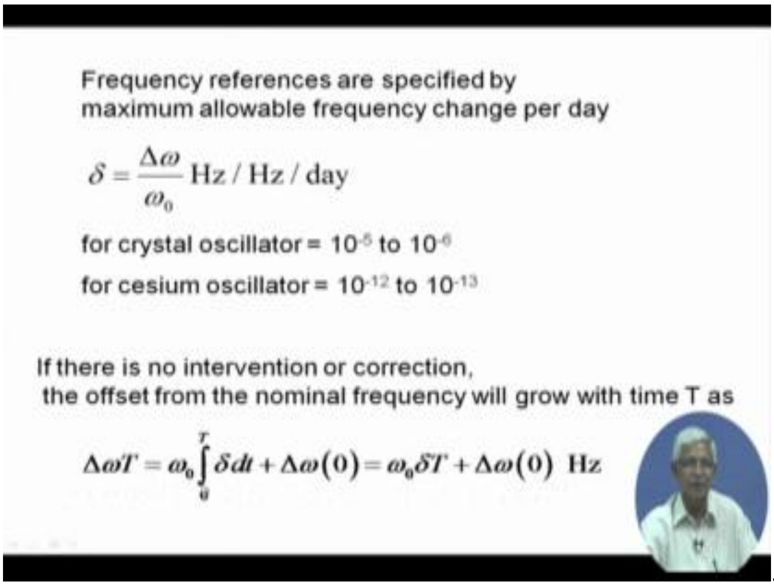

Now, the frequency references are specified by the, there is a way of specifying by the maximum allowed frequency change per day with respect to number of frequency. So, in this called a small delta, small delta is a delta omega by omega naught that is the allowable change of frequency with respect to nominal frequency and the and it is change per day. So, it is hertz per day, this is delta omega hertz omega naught is hertz and per day. So, it is specified as hertz per hertz per day, giving some examples cesium is very stable oscillator cesium oscillator in GPS satellite cesium oscillator time reference is the cesium oscillator. So, that is 10 to the power minus 12 to the 10 to the power 13 this is the order where as ordinary crystal oscillator crystal (Refer Time: 05:03) is 10 to the power to the power 5 to 10 to the power 6 depending on oven control ordinary it may be slightly poor than that this range of the change is that that is seen in frequency references.

Now, if there is no intervention or correction one thing should be noted this offset of the nominal frequency will grow with time. So, if time grows, correction will be applied after some time that after some time, as the time elapsed this error or off set will grow. So, this can be presented in a mathematical found that is over time capital T, delta omega t is omega naught, 0 to t delta dt this delta is that frequency change per day and over t will grow and the initial frequency whatever, initial frequency difference what was there initial frequency was difference what was there. So, it is omega naught delta into capital T plus omega delta at 0 that is initial time going to start. So, these is without intervention over the time capital T and then let us see the time scale and the time when you do actually the time is counted with number of cycles from the same reference.

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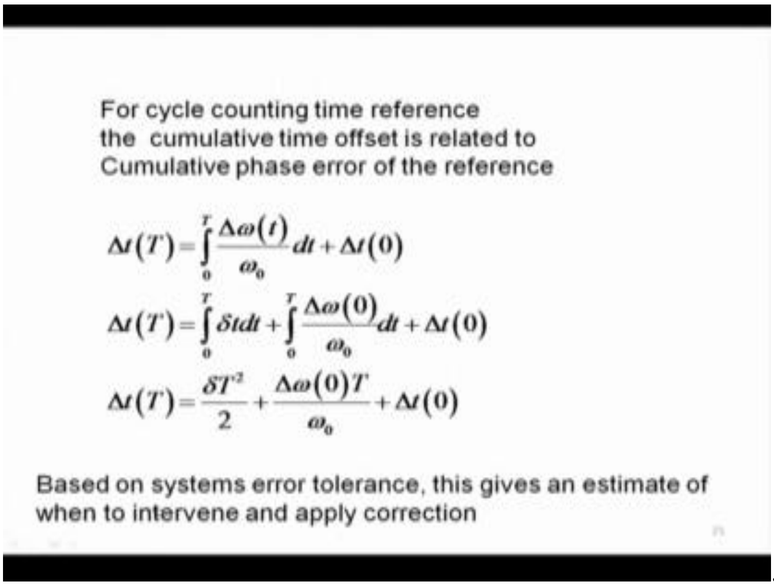

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So, cycle counting is the time reference, and the cumulative time offset is related to cumulative phase error of the reference. So, the cumulative time offset over capital T time is delta omega t by omega naught dt is the phase error plus the initial time offset. Whatever 0 time starting transmission that what is delta t, if I replace that delta omega t from the previous equation, then it become 0 to capital T delta t dt delta t omega 0 by omega 0 dt over again integrate over time dt and delta T0.

So, this gives us that delta into t square by 2, and because this multi is there delta t square by 2 delta omega 0 into t by omega 0 plus delta t at 0 position. So, this is that cumulative error. So, a designer, operator as to know how long this will go a cumulative, how much error it can tolerate after that he will apply correction, that is how long he will wait for applying the correction that is that is what is the delta t.

So, based on system error tolerance this gives an estimate of when to intervene, that is what I said when to intervene and apply correction should not be very frequently that is that the cost of that.

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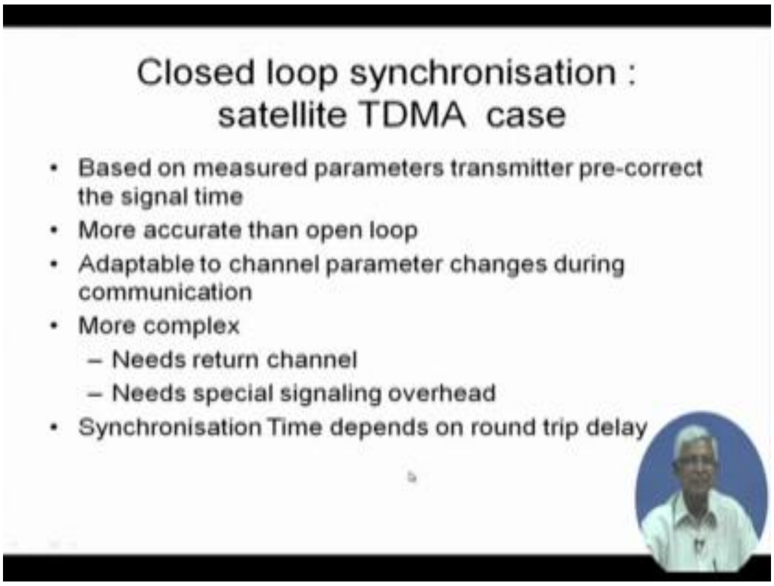

Now that is about open loop synchronization let us go to a closed loop synchronization let us take a case of TDMA. TDMA is a best example for the will go little bit more deeper into whatever earlier we discussed about TDMA synchronization let us see now it Is based on measured parameter or the transmitter and then pre correct the transmit time pre correct the signal time for a transmitter the it; obviously, more accurate the open loop, Because it is doing the real time measurement there itself.

So, that if there is a drastic change or if there is the change during the operation which the open loop system assumes that this is a model after some time it will either available data or model data will use copy correction here it is more accurate. So, it would not allow to error into grow large; obviously, adaptable to channel parameter changes during the communication that is what that is why more accurate and, but it is more complex because you need a return channel; that means, you need a receiver. So, it needs a return channel and it needs a special signaling overhead let will see synchronization as a synchronization time depends on the round trip delay that is in case of satellite it is the one half delay. So, round trip delay is that of quarter of second. So, that that is also another constraint.

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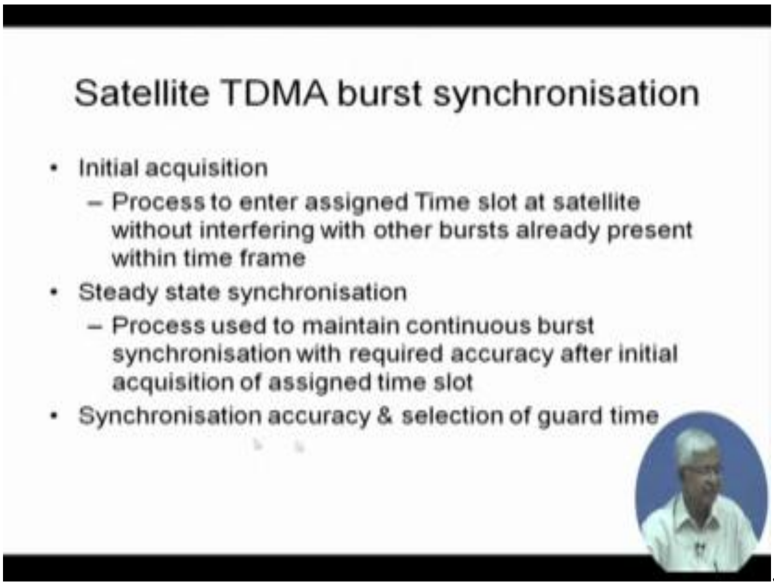

Now, this TDMA satellite TDMA burst synchronization as can be divided into two parts one is the initial part which is initial acquisition another is the steady state synchronization and from this two we will discuss this 2 from this 2, we will try to see what is the synchronization accuracy and how do you select what is the guard time of that.

Now, initial acquisition is a process to enter the assigned time slot at the satellite without interfering the other burst which are already present within the time frame you can imagine that let us say 10 stations operating all TDMA mode each of them, given some specific time slots for transmission of their burst and the station number 7, was not on and it is joining the network. So, all line stations are working with their slots allotted and there are transmitting and station number nine is joining as a number 7 is joining.

So, therefore, it as to it as to enter the network such a way that it should not disturb the none of the other burst particularly the adjacent burst number 6 and number 8 should not get disturbed it should not overlap, Its transmit over there their burst. So, that is the initial acquisition and steady state synchronization is the once you acquire the your slot properly you know when, to transmit then the process used to maintain continuously the synchronization the burst synchronization with the required accuracy is a steady state synchronization and from this two. Try to derive that the synchronization accuracy and selection of guard time the.

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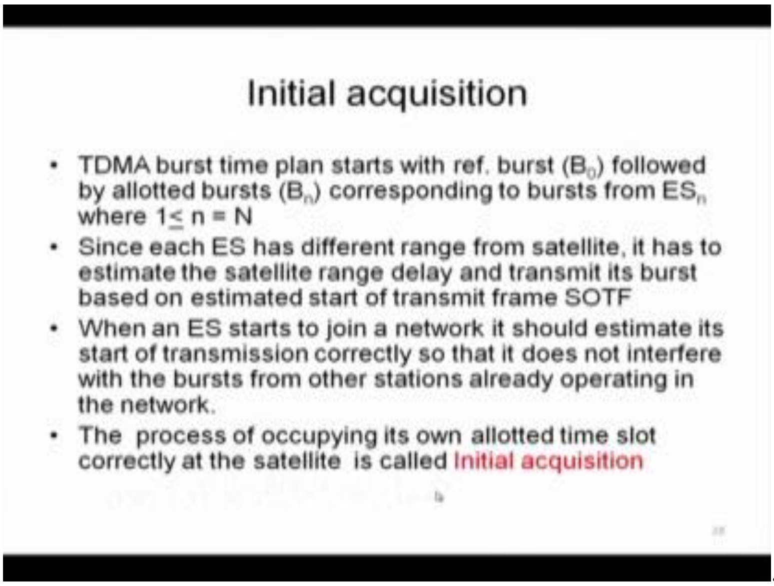

Let us say t d ma burst time plan will show you the plan let us normal, let us define with reference burst will call B0 burst b and 0 is the reference burst followed by allotted burst n number of stations b n the corresponding to bursts from station n our n is one to n since the each earth station has different range from the satellite, it as different delay. So, it as estimate the satellite range delay and transmit it burst based on the estimated start of the transmit frame start of transmit frame SOFT short we will see will come across this, but SOFT you do remember start of transmit frame which each station as to estimate when an earth station starts to join a network.

It should estimate it start of transmission correctly. So, that it does not interfere with the burst from the other station which are already operating in the network this I have explained in terms of number 7 transmitting should not interfere with a number 6 and 8 etcetera this process of occupying its own allotted time slot correctly at the satellite is called initial acquisition very clear.

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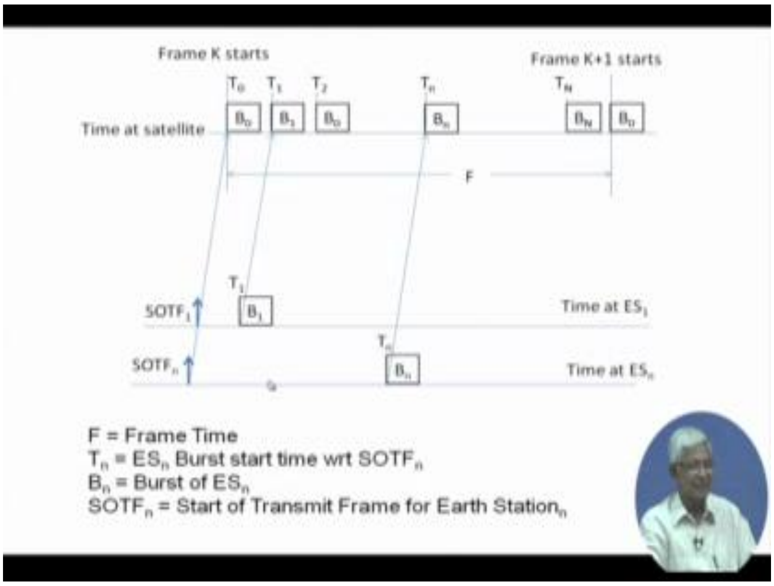

Let see pictorially let us say this is the frame f you can call it in terms of bits or in terms of time the frame number k, starts from here and lets frame that is k plus one frame starts from here. So, first is the reference burst. So, B0 is the beginning of the frame and it repeats after the f bits or f time and the allotted burst for station number 1 B1 which is from T0 it is away. So, it is given time T1 similarly b this should be b 2 is allotted time T2 it could be another reference burst also as we have discussed, that there could be semi point failure.

So, there would be at leasT2 reference earth stations. So, those is why it could be 0 also, but let us take that this taken take this T2 and may nth is b n where, capital n number. So, lasT1 is b capital n. So, this start time at T1 T0 T1 T2 with respect to T0 T1 T2 TN.

So, f is the frame time t n is the earth station n burst start time with respect to start of transmit frame is that of transmit frame b n is the burst of station n. So, the earth station one whose position in the time frame is b 1 e as to estimate is this is, if he himself is the reference burst though he should have transmitted start of transmission transmit frame he should transmitted at some point from there which is T0 from there T1 time away he will transmit its burst. So, it will reach similarly station 2 or station n will estimate SOFT n for this position and the n th position with respect to that n th position delay. So, as if he replicating, what is happening at the satellite that is with respect to reference, but the point is he is imaging as if he is transmitting the reference burst how you know at when is SOFT should be there that is that is the question.

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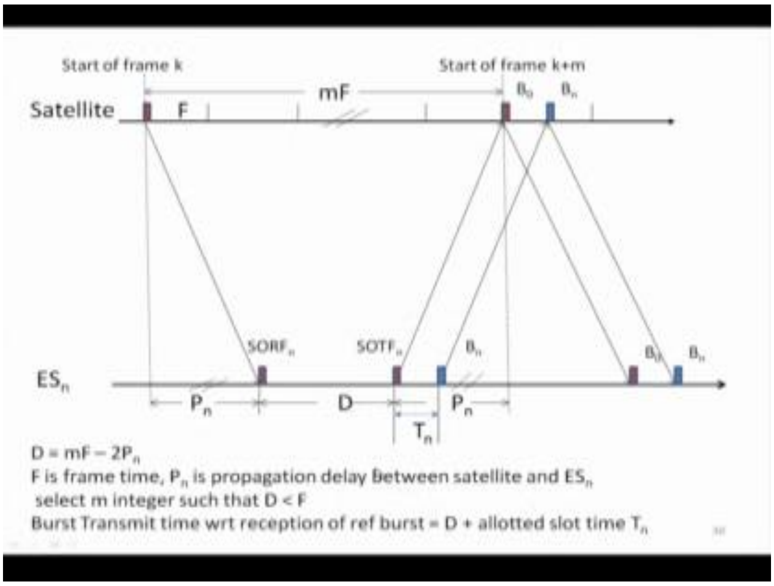

So, this diagram unrelated some discussion we had earlier, I repeat that - that is at the satellite in way of presented that is the reference burst is shown in color here f and ACPT B0 is here bn is here. Let us say station n he receives the reference burst which is called start of reference frame. So, he receives the burst and he transmits at this position with respect to start of transmit frame now this is an imaginary he does not know. So, this delay he calls capital d he has measured this start of reference frame and if he knows this d then after t n time he transmits his burst. If we do which in the correct position and he can verify he received that reference best which is received like this here and the delay t n he will receive at the t n. So, he know the correctly he as transmitted the point is how he will know this d which is which is not known him how you will estimate.

But this can be estimate very simply pictorially you can see that when it is happening at the satellite here the reference burst B0 and after m frames m into f f is the frame time number of bit whatever you can calculate. So, after m frame this whole thing is happening now at receive, at the same time at the received station are this this particular earth station it is at start of reference comes after a propagation delay and transmits is imaging he is transmitting the reference burst. So, after a propagation delay it will reach the satellite. So, this is to times the propagation delay of the n th station p n is n th station propagation delay to the satellite and plus d. So, two times p n plus d gives you m f.

So, it is a simple equation d is m f minus 2 times p n m is a integer number which is integer number of frame as passed combined to this frame durations are very small that of 4 millisecond, 2 millisecond where as propagation delay is 125 millisecond.

So, therefore, it is m time f and then that the f is a frame time p n is a propagation delay between the satellite and the earth station n. So, you have to select this integer m such that d is less than f this condition you can easily find out. So, burst transmit time with respect to reception of the reference burst will be d plus t n d plus allotted slot time t n. So, this up to this we have seen the earlier, but while initial acquisition he actually as to more careful of transmitting exactly here because just guard time away the other burst is waiting. So, if you are propagation delay calculation is wrong you will fall into that.

So, therefore, he should not transmit at beginning of the burst they should transmit somewhere in middle in the burst with a very small patterns that is what initial acquisition.

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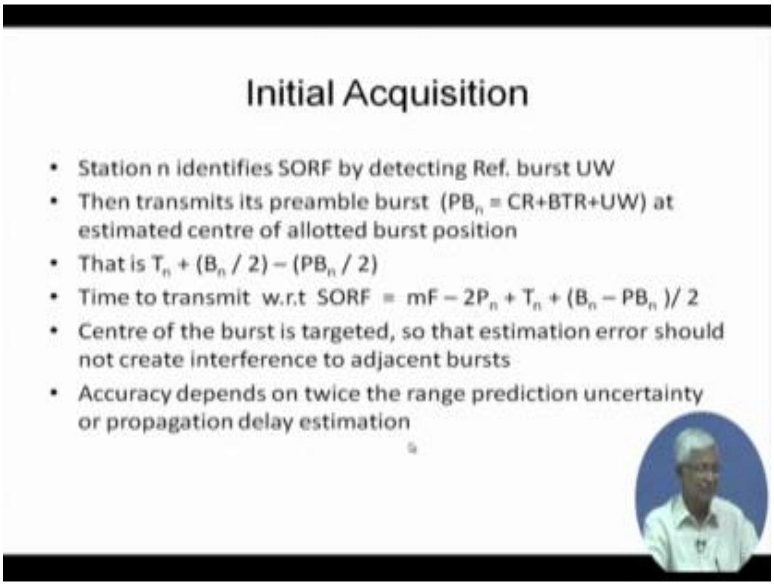

So, initial acquisition the station n identifies SORF by detecting the reference burst in unique word then it transmits a small few bits which is preamble burst that PB, PB the n th station of PB n which consists of the carrier and bit time recovery and the unique word because this denominator as to detect the particular burst. So, c r necessary and unique word is frame separation.

So, this preamble he transmits its much smaller than that capital n that is burst time the estimated center of the allotted burst position. So, therefore, the transmission is t n delayed that center of the burst position is b n by 2 and the preamble by 2 subtract the preamble by 2. So, then you will get the start of the preamble, but the whole preamble sit at the center of the burst. So, the transmit time with respect to SORF will be m f minus two p n that is the f d plus the t n plus you are moving to the center. So, b n minus PB n by 2 that is how it calculated and transmitted. So, center of the burst is targeted.

So, that estimated error should not create if there is estimation error should not create interference to adjacent burst and accuracy depends on the twice of the range predication uncertainty that is 2 p n. So, whatever predication you have done that uncertainty or propagation delay estimation there is some estimation or information available based on that whatever error is there this case shown in a pictorial like this a burst consists PB n and the rest of things are data.

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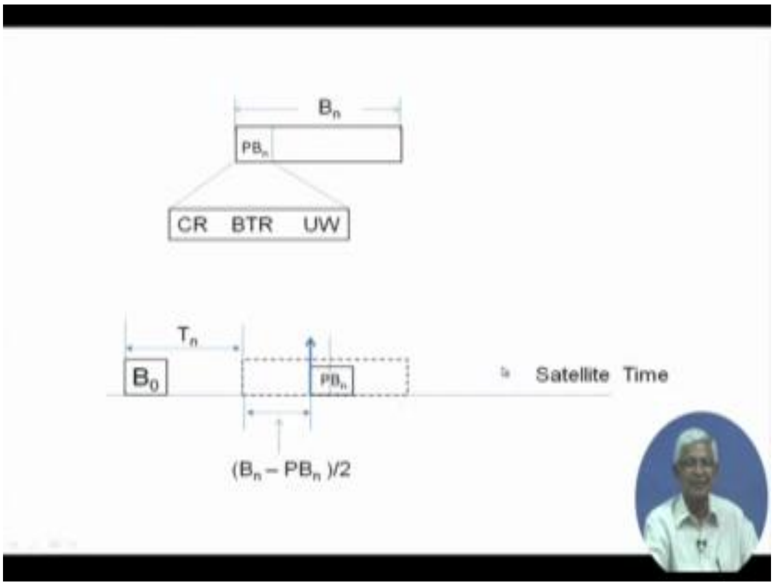

So, this whole thing is b n now this is B0 and the b n as to start after t n it should start here the dotted line the center position is b n by two is here that PB n is the pre nominal of the n th station. So, PB n is placed exactly at the center. So, that is why start of PB n will be b n minus PB n by two that that is where we should starts transmission let us say the satellite time.

Now, received preamble burst at a time with respect to the received reference burst time of the same frame is then compared with that is the that as I said at the at the u transmit and then received and you find this difference of time, is an compared with allotted time the time correction is then applied in subsequent.

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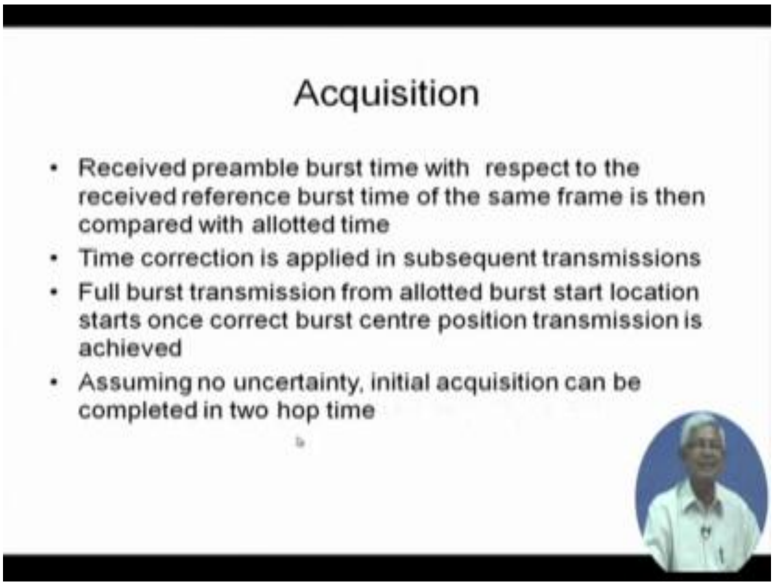

If there is a error then time correction is applied in the subsequent transmissions a full doss a full burst transmission with the actual data from the allotted burst, start location starts once a correct burst center position transmission is achieved and it can be achieved very fast assuming no uncertainty initial acquisition can be done 2 hop time you know where the acquisition that is the initial acquisition.

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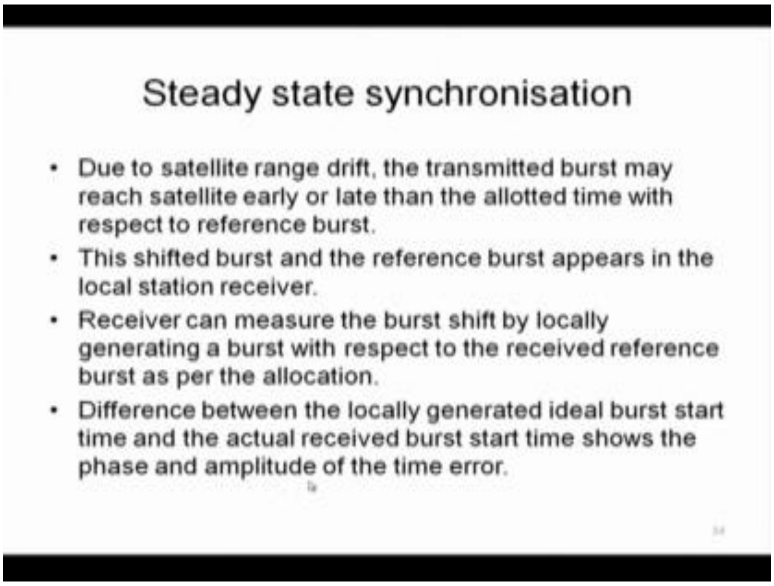

Now how the steady state synchronization due to satellite range drift the transmitted burst may reach satellite early or late than the allotted time with respect to the reference burst because this is when you are acquired after that also satellite is drifting. So, you have acquired any fix the clock such that it will transmit exactly that you are based on your calculation d, but then satellite itself is drifting. So, there will be more delays either more or less delays.

So, they as continuous synchronization as to be required that is steady state synchronization. So, for that they shifted burst and the reference burst appears in the local receiver, but what is coming down from, the satellite and that as to compare locally generated a locally generated burst with respect to the received reference as per the allocation this they difference between the locally generated ideal burst start time and actual time start time shows the phase and amplitude of the time error pictorially.

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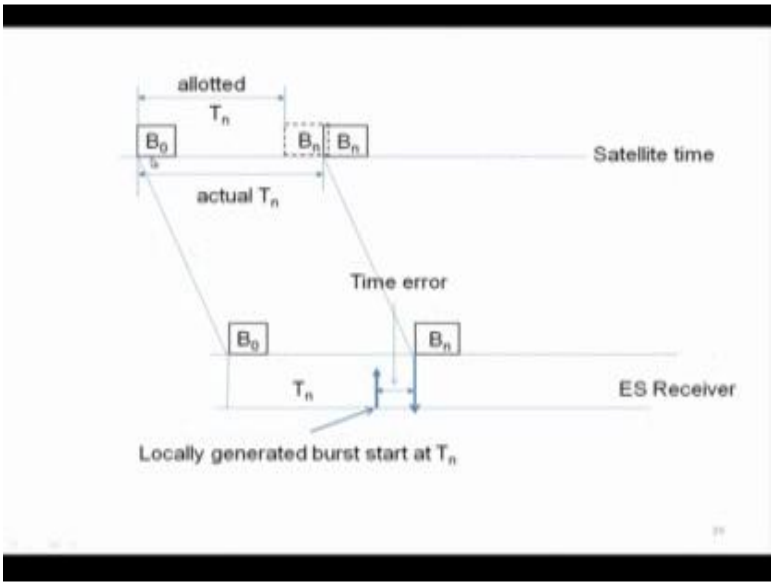

It can shown like this that is I repeat your reference difference between the locally generated ideal burst start time and the actual received burst start time shows the phase and amplitude of the time error.

So, you receive the B0 and you receive the b n which might have shifted this is the allotted time, but because the satellite as drifted. So, b n is reached here it actual t n is actually what satellite has received it will be transmit down. So, you will receive it slightly away now locally you can generate with respect to the b n and after t n which is allotted time you generate local reference this is supposed to come where as you have got this. So, there is a time error. So, locally generated burst time and the received burst time beginning will give you the time error. So, this time error as to be corrected every frame slowly.

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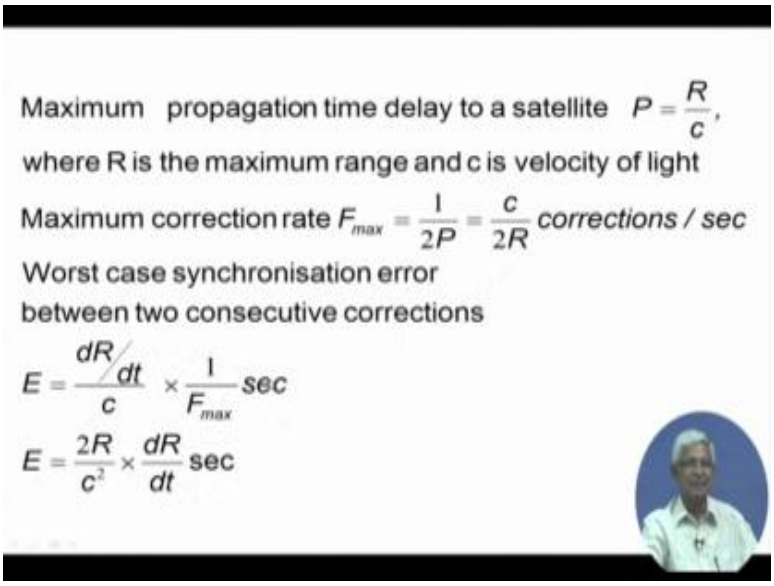

Now let us see the actually see part of it before that lets try to understand what is the error. So, maximum propagation time delay to a satellite p is the range by cc is the velocity right r is the maximum range. So, the maximum correction rate is one by two p is after one half you are able to correct.

So, it is a c by 2 r that is corrections per second that is the correction rate, many corrections per second, So, what is the worst case synchronization error between 2 consecutive corrections between 2 consecutive what is the synchronization error that is e is equal to d r dt by c and 1 by f max f max we know c by 2 r. So, that makes e is equal to 2 r by c square into DRDT seconds. So, that is the total error.

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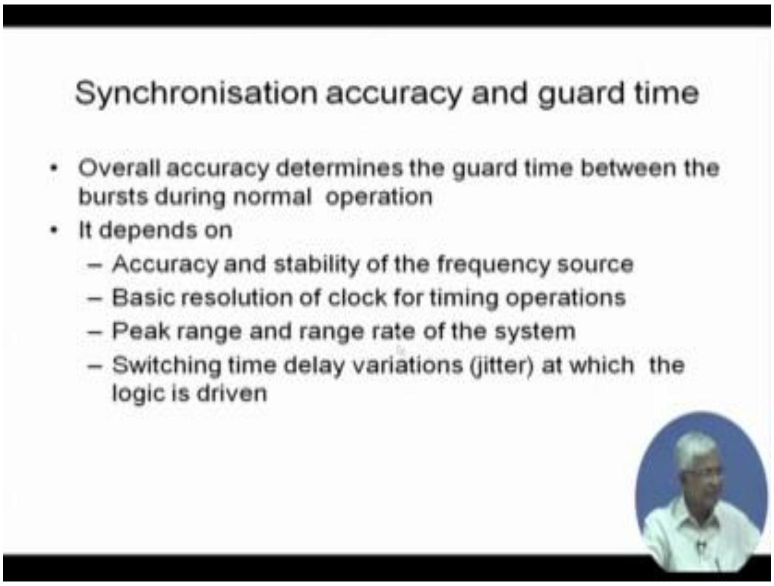

Now, synchronization accuracy and guard time we have to design the guard time accuracy and over all accuracy determines the guard time between the burst, between 2 adjacent bursts during normal operation it depends on accuracy and stability of the frequency source what is the stability and accuracy of the frequency source and then basic resolution of the clock of the timing operation resolution of the clock, also come into the picture and then range and range rate of the system maximum of that and then the circuit jitter clock jitter. If there is a switching time delay variations at which the logic is driven is a very high speed logics.

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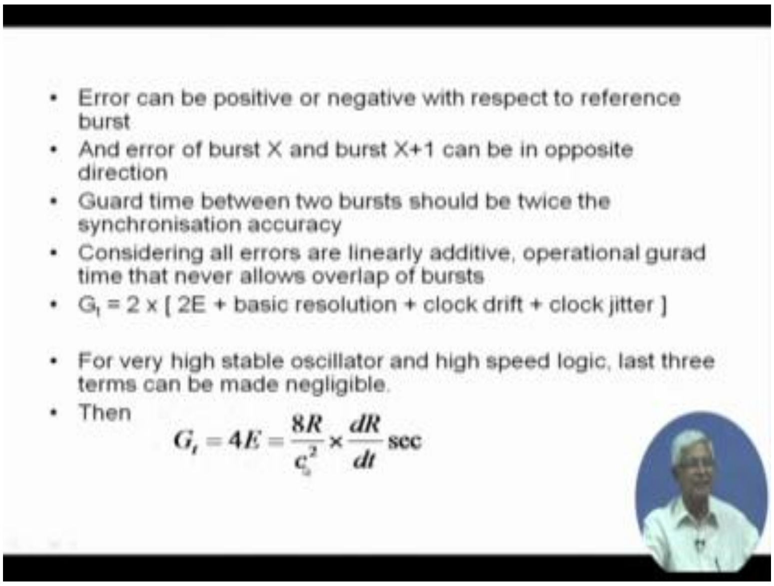

So, all this contributes to the error, the error can be positive or negative with respect to the reference burst. So, the error burst x and x1 between these two burst could be in opposite direction. So, the guard time should be two times guard times between two bursts should be twice the synchronization accuracy considering all errors it becomes g t is 2 times 2 e basic resolution clock drift clock jitter together now this last 3 points are small highly stable oscillator. So, therefore, g t is 2 times 2 e that is 4 e which is 8 r by c square DRDT seconds.

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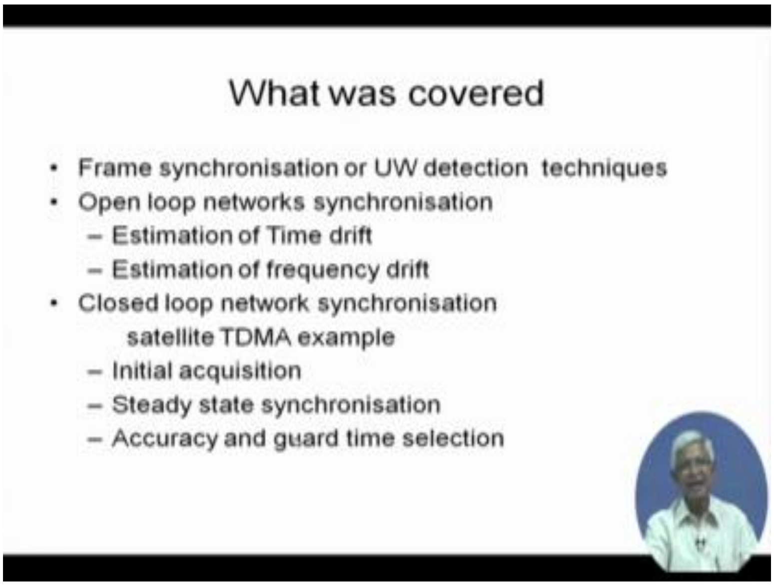

So, with this what we have covered is frame synchronization and unique word detection techniques open loop network synchronization estimation of the time drift and the frequency drift and the open loop closed loop network synchronization TDMA, example and initial acquisition steady state synchronization and the accuracy and the guard time selection.

Thank you very much.