Satellite Communication Systems
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Lecture - 17
Link Budget-7

Welcome. We are continuing our discussion on Link Budget. And we have seen that for a bent pipe transponder that C by N in the uplink that is from ground to space that is earth to space, uplink C by N N naught in a noise power density or C by N if you take only noise power. And the downlink C by N naught or C by N they can be put together to get the total C by N or C by N naught. And those relations have been found out this is true for bent pipe transponder.

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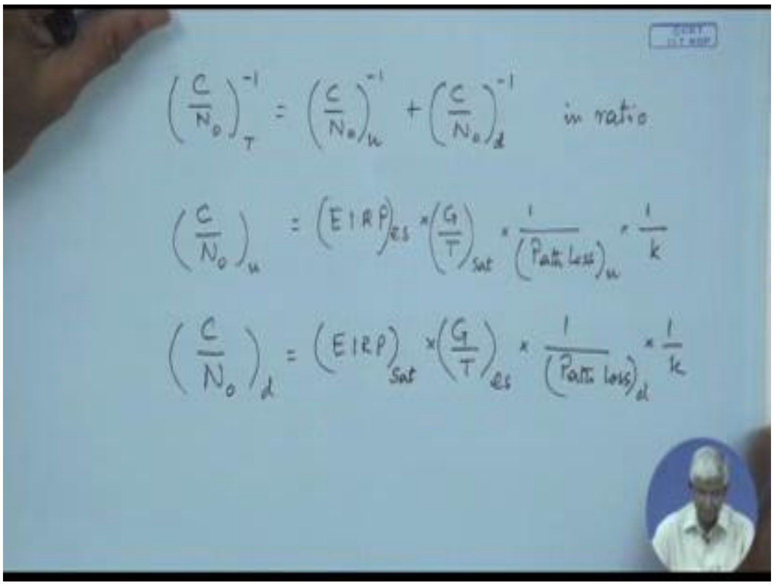

Let us look at it slightly deeper, because we just recollect first that is we have seen that C by; let us call N or N naught both are same let put it as C by N not because seen till now N naught inverse of that of total is C by N naught of uplink and C by N naught of downlink. Remember that for these calculations how it was derived, and when it was derived numbers were not taken in dB they were in ratio.

So, though many times I go on writing this form in also in another form, it will not where it was dB and where it should be ratio. So this calculation if C by N not is given hard convert in to C by N not in ratio, so let is write this is in ratio. And C by N not of uplink was issue try to recollect it is EIRP, since it is uplinks so EIRP from the earth station multiplied by G by T of; let us put it this way then it will easier to remember of satellite and then 1 by path loss or all other loss put together, many times I will simply say loss or loss P gets loss path since path loss was dominating.

But since it is dependent on the frequency so there has to be being this case path loss in the uplink and the (Refer Time: 03:10) constant this is in ratio. When we put in dB then the log version of these this multiplication will become plus and inverse will become minus just remember that. Since I am writing in ratio show in this form let us look at it.

So, C by N naught of downlink similarly EIRP of satellite in this case because it is in downlink and G by T of the earth station it is receiving 1 by path loss this time it is downlink and of course 1 by k. And they by getting this C by N naught uplink and C by N not downlink you can calculate the total C by N naught. But we have to see some more things into a detail; this is a straight forward calculation.

But since the things are power limited we have seen that distance path loss is quite large. So therefore, to manage the C by Naught to get a positive number in that and could get equal good quality of service we have to pushing maximum power is possible so EIRP have to be quite high.

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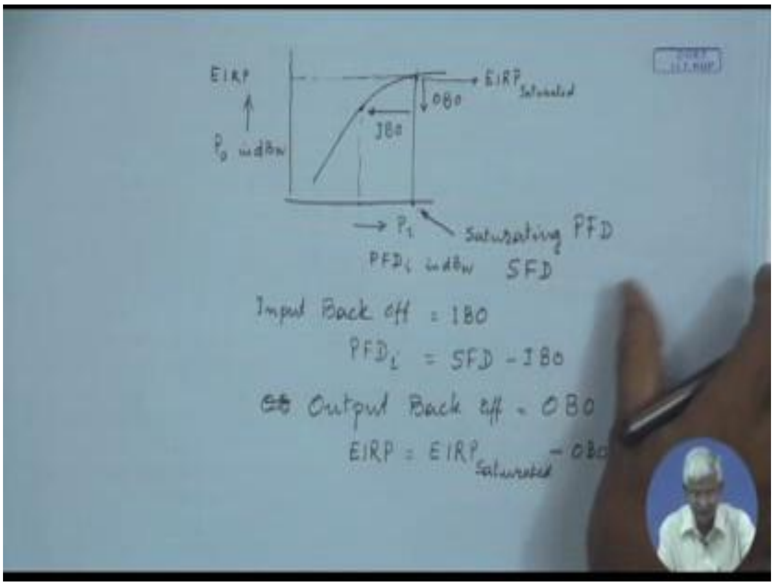

Now satellites are generally nonlinear and if this side is input that is called power input and if this side is power output. For low to high as input goes to the satellite this (Refer Time: 05:05) of the any nonlinear power amplifier, but this is the characters of the total satellite, where the power amplifier is dominating.

Now, we can see that at some point of the input the output power is getting saturated it is given giving constant value so more increase in the input power the output power does not increase. That means, if you go on increasing the uplink power which is received by the satellite as a input the output power will not increase linearly it is getting slowly saturated. So, there could be a specification that at this point somewhere if gets saturated so that is the maximum power part the satellite output can give, we can we can correlate this thing since output power from satellite we have put along with the satellite transmitter antenna gain so we can call it equivalent to EIRP, and this is the input power which is coming which is the we can equivalent to we can put power flux density which is coming as a input to the satellite similar curve will remain.

So, input power flux density this PFD you are familiar earlier started with this. So, power flux density input coming to the satellite antenna as we go on increasing the output EIRP of the satellite will go on linearly first and then it will some point. So, this point we can call it EIRP saturation or saturated EIRP. And this point correspondingly the input which saturating we can call as a saturating PFD or in short SFD; saturating power flux density.

That means the amount of the power flux density which is coming at input of the satellite corresponding output of the satellite is maximum EIRP or saturated EIRP. Now, the spacecraft manufacturers when they give this specification they give like this they said for saturation power flux density SFD you get EIRP saturated value is like this. These two values are specified there is an input point and that is the output point.

Now, we do not like to operate in nonlinear region we have seen simple nonlinearity that it generates lots of spurious signals. So therefore, we must operate in the linear region, so the input maximum has to be reduced has to reduced that is from back off from SFD. So, let us say this is the linear region will be operating. So, corresponding input that is PFD input it is backed off from the saturating PFD which is SFD, so it is called input back off or IBO input back off from the SFD. So, the corresponding PFD input is SFD minus input back off. When I say minus these are all in dB so this is in dBw and this is also in dBw.

But you can see based on the sloop of the curve you can see that input back off correspondingly saturated EIRP reduced by this amount. So, this is output it is happening this is called output back off. So, there is output; I write it this way output back off or OBO. So, the operating EIRP at which at the operating point it is EIRP saturated or maximum EIRP other way you termite as maximum EIRP minus output back off is in dB. So these are all dB values. So, you find out the operating point.

Now, let us try to correlate this uplink EIRP and downlink EIRP or uplink C by N naught or downlink C by N naught in terms of saturated EIRP and in terms of the saturated power flux density, and that will be correlated to the operating point so we have to use input back off and output back off. So, let us try to do (Refer Time: 10:57) on the calculation. I hope you have understood input back off and output back off condition.

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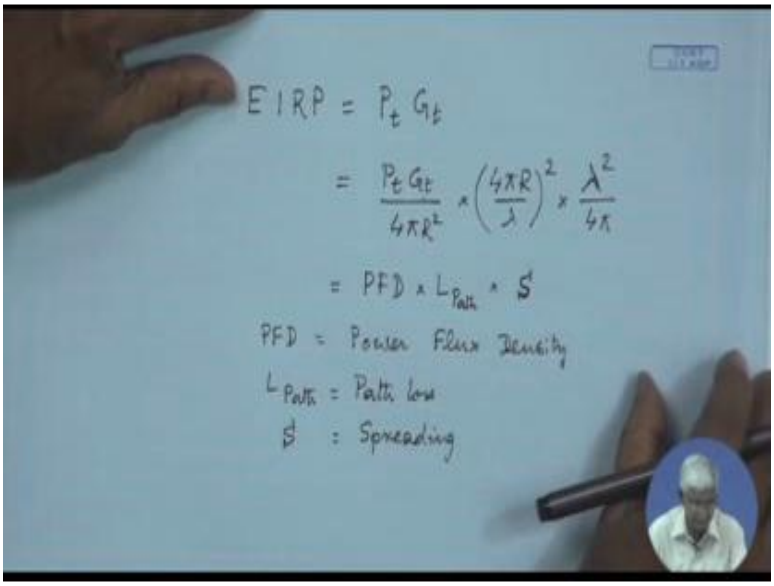

Let us do some (Refer Time: 11:06) of parameters that is let us see EIRP was P t into G t in ratio. Now I try to put is in terms power flux density that will be by 4 pi R square and also I want to putting in terms of path loss that is that is 4 pi R by lambda whole square. So simply this P t G t can be written in this form; P t G t divided by 4 pi R square I have introduced 4 pi R square so I will try to cancel it 4 pi R by lambda whole square and brought in lambda so cancel it lambda square by 4 pi. You can see that that R square is canceled out 4 pi one of the canceled out here one is remaining that will canceled by this 4 pi this lambda square get in canceled with lambda square. So, this terms what I additionally introduced and value equal to 1; so P t G t remains.

But then we try to interpret this term, this one is our power flux density P t G t by 4 pi R square and this term is our path loss that is loss path loss by 4 pi R by lambda whole square, and this is something new term. And let us see what is this term this is related to the lambda or the frequency of operation and it is spreading divided by 4 pi. So, term a new introducing new terms is called S is something like spreading we can call it as spreading loss which is slightly different then path loss; so it is it is spreading.

So, let us write it down PFD stands for power flux density is known, L path is path loss, and this is we simply called spreading for a particular frequency. Now this is in the ratio. Let us try to dB term.

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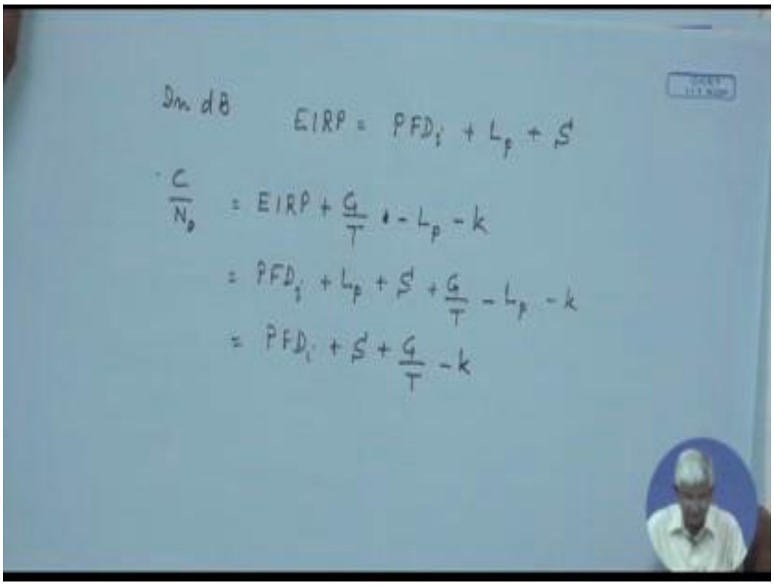

Then in dB terms it will be EIRP is equal to PFD input in dB plus path loss in dB plus the spreading in dB. So, C by N not with the up or downlink is equal to if I remembered in dB term EIRP plus G by T minus path loss minus k. This EIRP I replace by the additional term as PFD input power flux density input coming and then path loss plus the spreading plus the rest of the term is G by T minus path loss minus k.

Now, this path loss and this path loss in this equation getting canceled because plus minus so remaining term is PFD input plus S plus G by T minus k. These are all in dB, I started this in dB. Remember that we have changed it now this C by N not could be in the uplink side or could be downlink side. Now, let us try to introduce our nonlinearity again that is in terms of saturation power flux density and in terms of saturation EIRP let us try to express this. Let us recollect.

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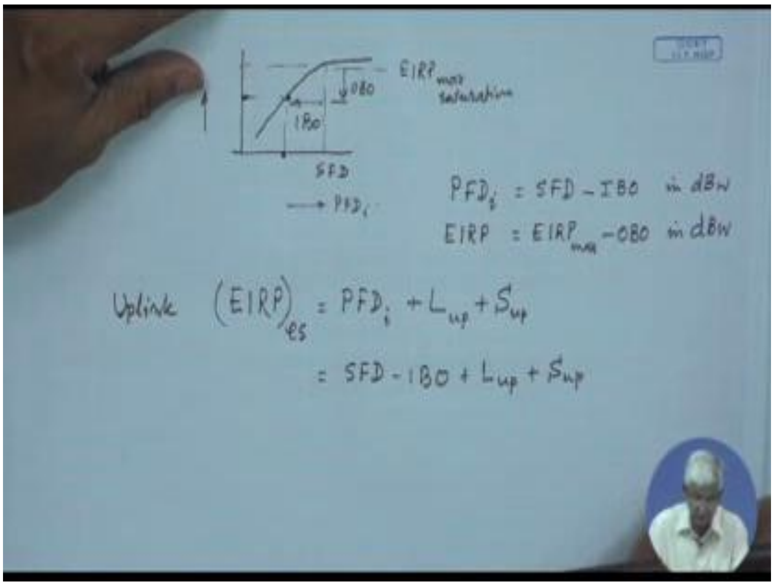

This was our transponder characteristic and this was our SFD saturation power density, this is power flux density and this side we take it EIRP and this is EIRP max or EIRP saturation. And if this is my operating point, this much is input back off and this much output back off. And you recollect this is PFD i operating point as a input is SFD saturation power flux density minus input back off in dB and, sorry this will be in dBw I output input back off is in dB and then EIRP this is the operating point is equal to EIRP max or EIRP saturation minus output back off in dB since it is EIRP it is dBw.

So if you write for the uplink, the uplink EIRP is EIRP from earth station is PFD input to the satellite the loss in the uplink that is mostly path loss and other losses added; that spreading in the uplink because it is depended on lambda the uplink lambda. So therefore, it is equal to I can write PFD i is equal to SFD minus input back off so saturation flux density minus input back off plus L up plus S up. So, correspondingly we can use this EIRP expression in terms of C by N naught uplink.

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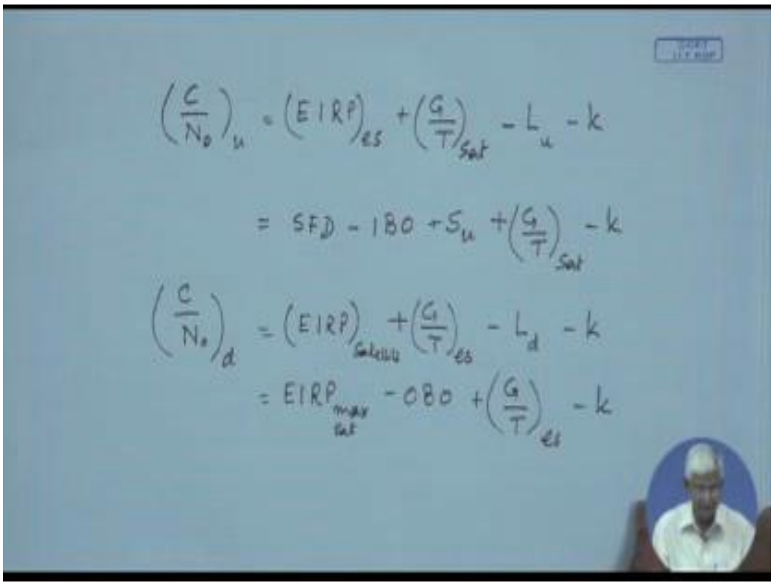

So, let us write C by N naught of up is in dB EIRP of earth station plus G by T of satellite minus the loss in the uplink minus k. This EIRP will replace by EIRP of earth station is SFD saturation flux density of the satellite input minus input back off of the satellite that is operating point L uplink and S uplink addition. So, then it becomes SFD minus input back off then that L uplink is positive here in the C by N naught equation L uplink negative here so they get canceled.

Then S uplink then plus G by T of satellite and minus k these are all in dB. So, the whole thing is C by N naught uplink is dB hertz. Correspondingly I we can write C by N naught of downlink is EIRP of satellite that is operating point of the satellite then plus G by T of earth station it is downlink minus L of downlink minus k. This EIRP of the satellite which is operating point is EIRP maximum minus output back off, EIRP maximum minus output back off.

So, we write here EIRP maximum of course from satellite then minus output back off is the actual operating EIRP of this is satellite and this is outer satellite do not think of saturation that is why I change the word to max. So, output back off plus G by T of earth station minus k. So, now this uplink is defined in terms of the instead of earth station

EIRP if defining in terms of satellite saturation power flux density minus input back off that is operating point defined.

So, if we know from the specification of the spacecraft forty saturation power flux density what is the maximum power flux density that can be given to the satellite so that you have clearly corresponding maximum EIRP these two specification SFD and EIRP max and the satellite if it is known from the specification. And if you can decide a operating point which is the linear region which is input back off and output back off, then using this two expressions you can find uplink C by N naught and downlink C by N naught and correspondingly we can find the total C by N naught.

Let us use this thing to do some quick calculation using some examples space one small examples I will give, although I will try to give certain results also that you can you should do your own calculation. Find out if there is any mistake you should correct that.

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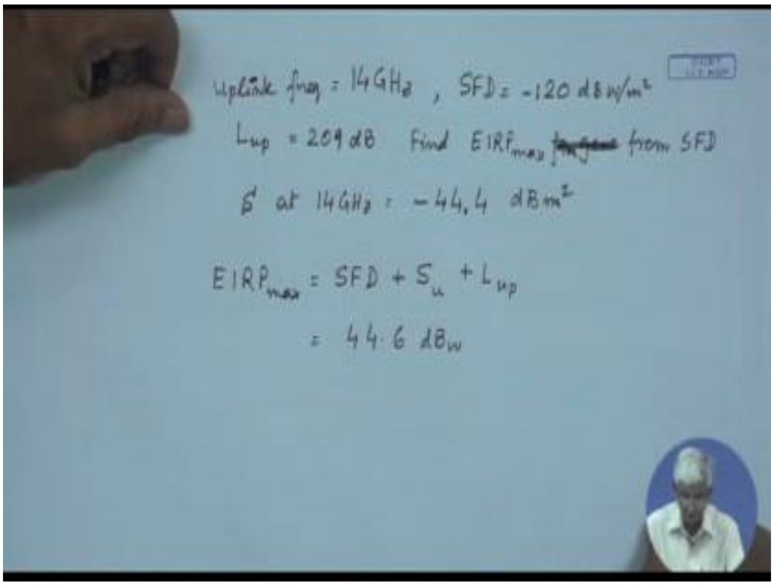

So, let us take one example, simple small examples to get you familiar with this type of expression is called uplink frequency is 14 gigahertz SFD of the satellite is minus 120 dBw per meter square saturation flux density for the satellite. The uplink loss is already walked out a given as 209 dB. Find EIRP maximum to generate get maximum from SFD given; this SFD given what should be the EIRP maximum.

So, in this we have to find out that S that is spreading at 14 gigahertz you can calculate which was lambda square by 4 pi and lambda you should know for 14 gigahertz. So, from that we can find out a number it will be like minus 14.4 dB meter square it was lambda square so dB in meter square now it is converted into dB. So, EIRP maximum will be the SFD plus S in the up plus L up; L up is already given, S we have calculated up and SFD is already given. So therefore, we just put this numbers and you will get something like 44.6 dBw can you verify the number.

So, this is how if SFD is given and frequency is given you can find out the lambda and loss is given path loss. So, you can find out EIRP maximum from SFD; SFD to EIRP maximum can be found out.

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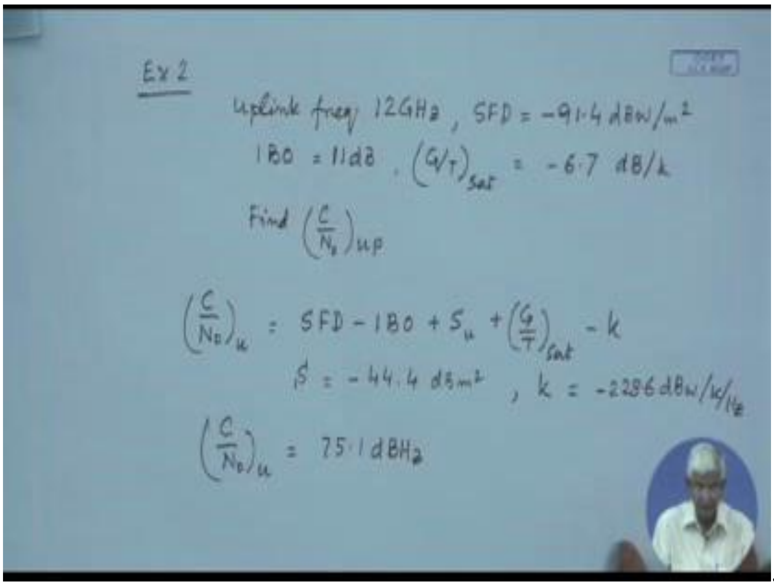

Let see one more example is a small one; can also let us take uplink frequency as 12 gigahertz SFD is like change in SFD 91.4 dBw per meter square. Now we are introducing IBO input back off as 11 dB that means, your operating point is 11 dB lower than the saturation flux density. And the G by T of the satellite is minus 6.7 dB per k. Then find C by N naught of up.

So, let us rewrite the C by N naught of uplink will be the saturation flux density minus the input back off and plus S in the up plus G by T of the satellite minus k. So, S value will be same as the previous problem. So, minus 44.4 dB meter square and this k value (Refer Time: 27:15) constant, we have seen this as a number if you convert dB into will become minus 228.6 dBw per k per hertz. Remember this number minus 228.6 dBw this k is coming in all the C by N naught calculation. So, when you are operating in dB, when you are calculating in dB you have to remember this number very clearly. So, C by N naught up you can put all this numbers S is known rests of the things are given. So, we will get something like 75.1 dB hertz.

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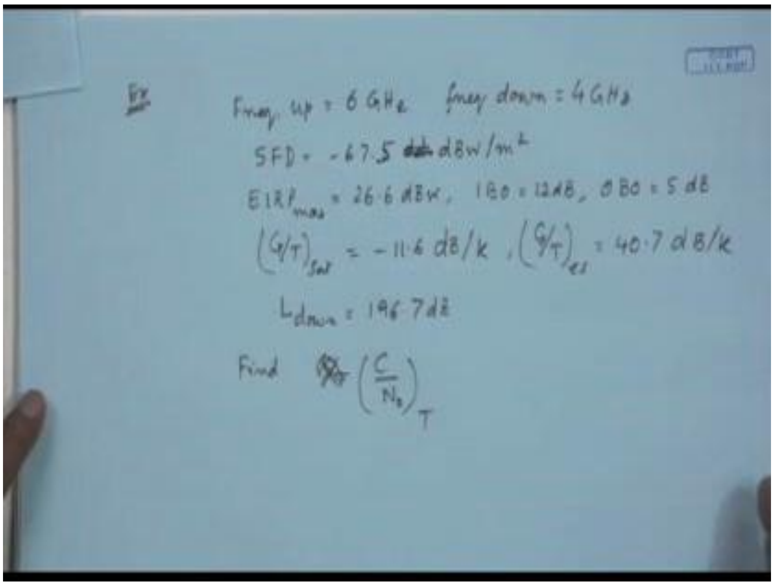

I will give one more example quickly, I just write it down. That frequency of uplink is 6 gigahertz, frequency downlink is 4 gigahertz, SFD is minus 67.5 dBw per meter square, EIRP maximum from satellite is 26.6 dBw, input back off is 12 dB, output back off is 5 dB, G by T of satellite is minus 11.6 dB per k, G by T of earth station is 40.7 dB per k, and loss in the downlink is 196.7 dB. Find C by N naught total.

Since the uplink C by N naught and downlink C by N naught both has to be calculated you get the all the numbers. One thing will be surprised that L uplink is not given and in our equation for C by N naught uplink with the modified equation in terms of SFD and IBO L uplink is not appearing, so that not required, G by T for both satellite and earth stations are given, SFD and EIRP max is given input back off output back off is given, frequencies are given so that you can find out an S and S SFD is already given.

So, it is easy to calculate the C by N naught total. You can do it in dB it is much easier, but when you go from C by N naught up to C by N naught down to total C by N naught calculation then its better what you get in C by N naught up in dB convert into ratio C by N naught down convert into ratio and then do the calculation for C by N naught total convert back into dB hertz in the total. Thank you very much we will continue discussion in the period.

Thank you.