Satellite Communication Systems
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Lecture - 14
Link Budget – 4

Ok, welcome back, we were discussing about the noise figure and noise temperature and their relations. And we will see the relations how it is happening with a device, which is amplifying having some gain G or loss the G is negative in that case.

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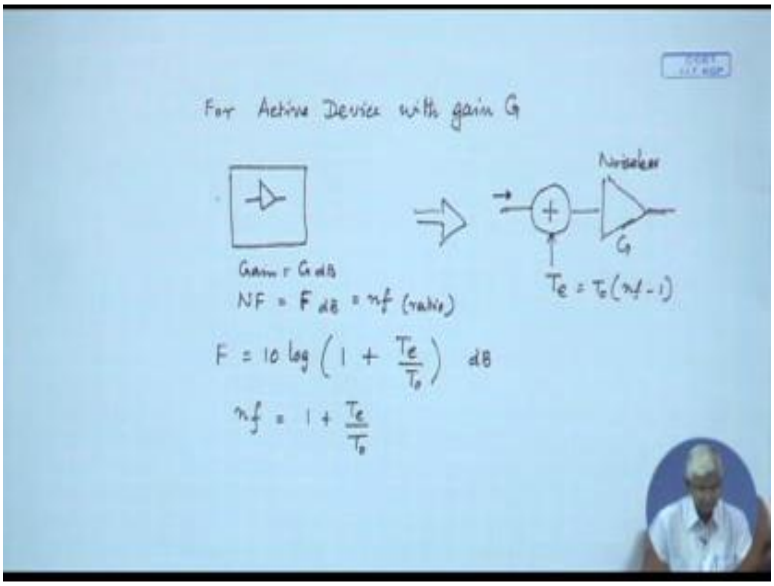

That is, let us write it that is for active device in this case I mean it has a gain, with gain of g. You can write in this way, that is a amplifier and gain is G in dB, a noise figure we write F in dB capital f. Earlier I was using capital F always just to distinguish. We will convert into small n f. I am writing noise figure this is in ratio, just differentiate and these are the nomenclature people use. So, capital F is normally in dB and denotes the noise figure when it is converted into ratio I am writing is as a small NF.

So, F is equal to ten log of 1 plus Te by T0. Since it is 10 log, this is in dB and noise figure in ratio will be simply 1 plus Te by is T0. Earlier we have said this 1 as capital F just to make sure that we do not make any mistake, is why we are calling it as n F that is ratio not in dB. Do not confuse when it is ratio a temperatures are simply a numbers in ratio. So, Te by T0, for it is in dB it has to be 10 log of that. So, this active device with gain G can be equivalently drawn as if there is a, I am drawing this same thing what we have discussed earlier that is there is a input with a noise temperature effect in noise temperature Te which is equal to T0 nf minus 1 in ratios and a noise less amplified which is a gain G this is noise less.

As if the noise is coming from the input and there could be sell input temperature that is coming in, and this is the output. Now let see that a how do you present the same thing for Lossy Device, which is a Lossy Device a ne2rk and let us normally we denote it by resistance and that is a power which is coming in and power which is going out. So, lossy are many times we say attenuation. So, that is why it is denoted by A it is in dB and at the same thing we will I write in ratio we call small l which is ratio. Now this can be equivalently drawn has the similar way and the input that is a Te which is equal to l minus 1 into T0 and there is I can call the amplifier with the gain which is equal to 1 by l as if the noise is denoted as the input part and this is noise less amplifier.

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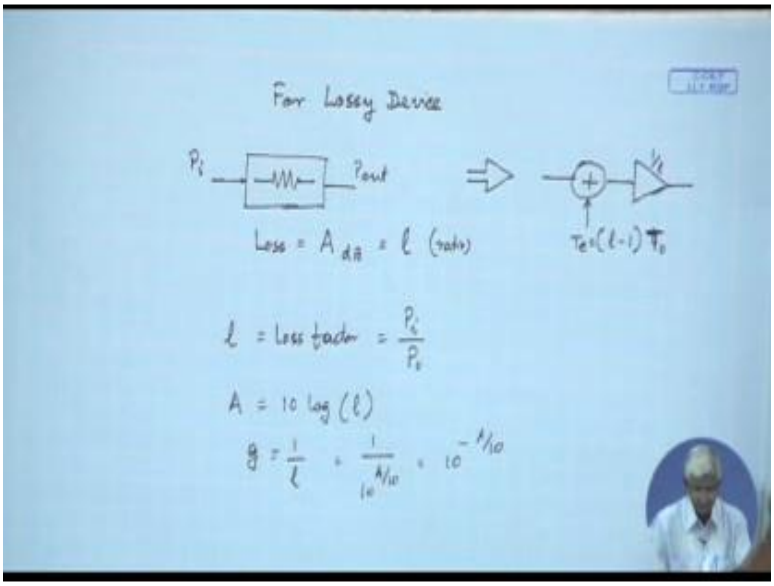

So, l small l is the (Refer time: 05:00) called loss factor which is Pi by Po, the A is the 10 log of l and; obviously, the gain also you can say gain in terms of ratio G is equal to 1 by l. I have it in small g for ratio, that is 1 by 10 to the power A by 10, 10 to the power minus (Refer Time: 05:30) various ways you can represent the whole thing. The issue what I am trying to point out is you should use when we go into the temperature we should use a number which is a ratio not in dB. So, attenuations are defined in terms of d b many times convert into number which is a ratio and then go in to the temperature noise temperature calculation, and it is same as the noise figure in case of the gain with the gain or the active device we have seen this is this was the noise figure, and it is a lossy device it is the loss in ratio. These you have to remember, because we have we will come across in many cases there may be loss or gain, but before that in our total system we have seen that a there will be various stages like we have seen that there is (Refer Time: 06:37) then there are down converter then there are there are amplifier. So, many systems are cascaded each of them they have different gain, different effective noise temperature and may be different bandwidth also.

So, let us see in a cascaded system totally what should be the system noise temperature that may that may arise.

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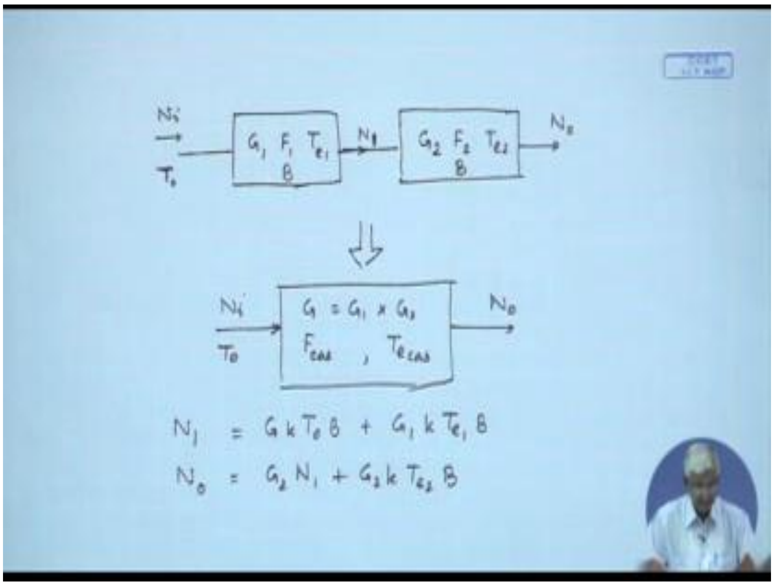

Let us look at 2 stage cascaded system say first stage we call let us say it is having a gain G1 it has noise figure F1 it is effective noise temperature Te1. And it is cascaded that is connected to and the system which has a gain G2, noise figure of F2, noise effective noise temperature Te2. These are two cascaded, where there is a noise power coming input in I with the temperature of normal temperature of T0 and this goes out as a noise power No. So, for the first stage the output noise power let us call N1 first stage is output is N1. That is a this whole thing in a equivalence, you can put as a one single unit which has a gain of G1 into G2 which has a noise figure which you call F cascade and which has a effective noise temperature Te cascade is equivalence of that which has a similar noise power has a input and effective and temperature T0 and the noise power as a output N 0.

So, we can write n1 which is intermediate stage from the first stage is G into k into T 0 b and then of course, each of them has a bandwidth b b both of them same band width plus G1 into k into Te1 b it is erective noise temperature it is whole temperature is added then n zero is G2 into N1 multiplied by G2 plus it is 1, that is G2 k Te2 b. So, this is the output of the first stage which is the input multiplied by G1 input noise multiplied by G1 and it is whole noise which is denoted based on the effective noise temperature and output of the second stage is input from the first stage multiplied by the gain of the second stage and it is own based on it is own noise temperature Te2 whatever noise power that is generated.

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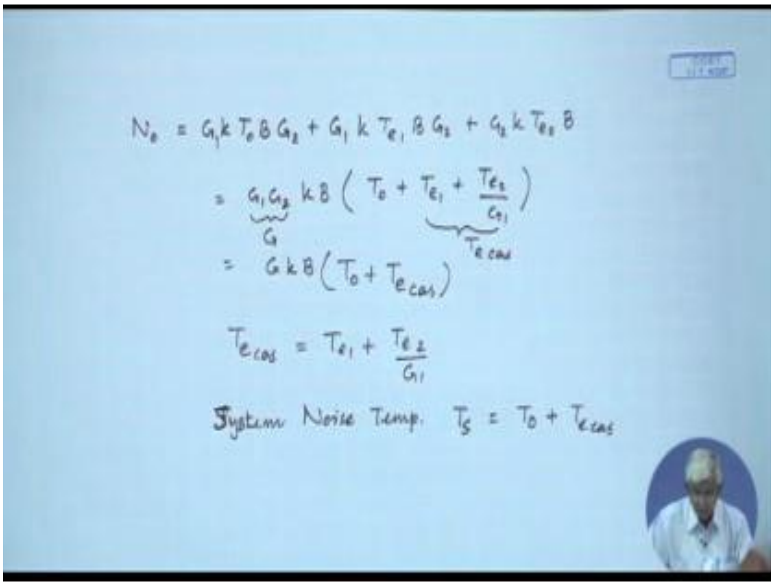

Now, if we expand these two the N 0 is G into k T0 B G2 plus G1 into k Te1 B into G2 that is on the first stage and then G2 k Te 2 into b. See if you take as a common G1 and G2, and then of course, k and B are there. So, only in temperature it will be T0 plus Te1 plus Te2 here G1 is not there, divided by G1. Now this 1 is the equivalence we have seen, said that total G. So, this is G into k into B and this 1 you can say Te cascaded. So, then it will be T0 plus Te cascaded; that means, Te cascaded is equal to Te1 plus Te2 by

G1 and if you look at the overall system, let us call it system noise temperature with term is a Ts which is that input temperature which is T0 we have assumed plus Te cascaded.

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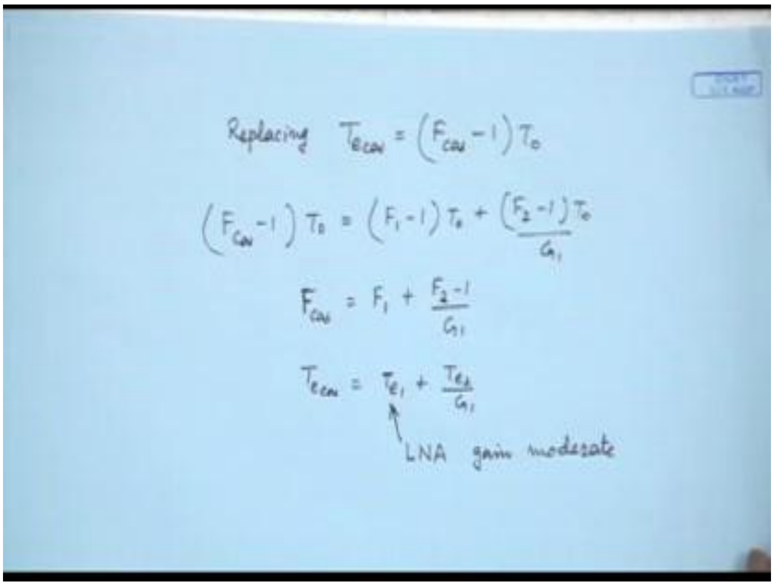

So, that is the system noise temperature. Now we can convert the whole thing from noise temperature to noise figure. So, replacing Te cascaded with F cascaded minus 1 into T0 we will get that F cascaded minus 0 into T0 is equal to that F1 minus 1 into T0 plus F2 minus 1 into T0 by G1. So, that gives F cascaded has F 1 plus F2 minus 1 by G1 and we have earlier seen that Te cascaded is Te1 plus Te2 by G1. So, this shows important thing that is, that first stage noise figure to reduced the total cascaded noise figure first stage noise figure should be slow and it can have a moderate gain.

So, that second stage noise figure will get reduced since it is divided by the gain. Same thing, the first stage noise temperature should be low and second stage noise temperature is not that critical because it is divided by the gain. So, the first stage gain can moderate to high. So, first stage noise temperature should be low, that says this should be low noise amplifier. And the low noise amplified gain should be moderate. If you remember in our space system we have said that LNA gain is roughly of the order of 20 dB it is kept and subsequently gain can be higher; that, particularly, LNA has to have low noise temperature or low noise figure.

Now, with this second important aspects that come out and that can be seen if you try to solve this particular example. I will give example. I will solve it here but I will try to put the problems in front of you. So, that you can solve and you can find out what is the different interesting part that comes out of it.

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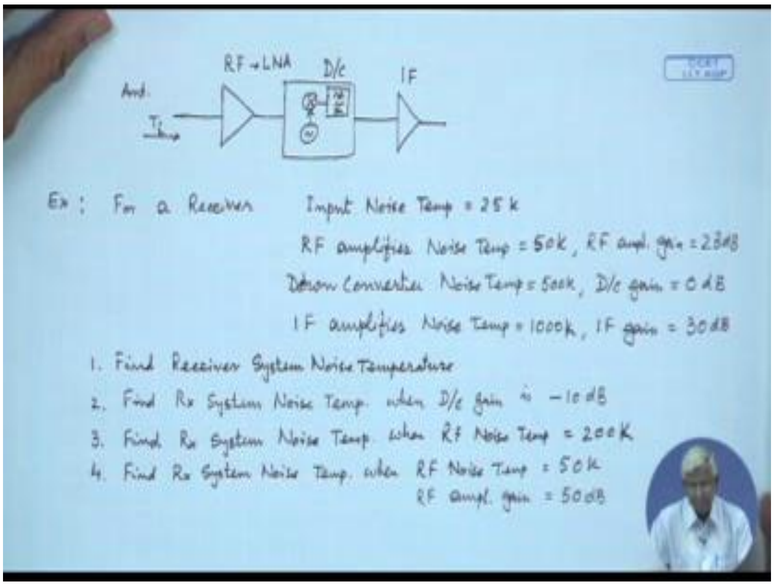

Let us say, that is a there is from the antenna I means let us exclude the filter for the timing and we have this is antenna. So, it is giving some temperature, let us say Ti is the input or Ta is coming from antenna and this is the RF stage which is nothing, but LNA we will see and then after that there is a stage which is nothing, but the mixer, then lo, then filter try to recollect our space segment diagram. So, this is called Down Converter. Then the Down Converter thing has to be amplified by amplifier which is IF.

Now, selection of the gain and noise temperature of each of them, assuming all of them operate with same bandwidth, is very important. Now I will try to impose a problem, a couple of problems with different numbers by changing their gain and temperature etcetera and you will find the effect of that how this coming. So, let us see, for this is a example, For a Receiver Input Noise Temperature is 25 k remember it is not T0. Then RF amplifier, noise temperature 50k no noise we can see and RF amplifier gain is 23dB, then down converter noise temperature when I say noise temperature is effective noise temperature is 500 k. You can see that no noise amplifier having lower the second stage I am having much higher noise temperature and Down Converter gain is 0 dB it does not provide any gain let us say and then IF amplifier noise temperature is let us make it very loose 1000 k and IF amplifier gain is more 30 dB.

Now, find first problem is Find Receiver System noise temperature. When I say system noise temperature you have to find out that equivalent noise temperature of this 3 subsistence, in cascade and add the input noise temperature also. So, that gives you system noise temperature. You will find you will get some number and if you look at these numbers it looks. So, quite practical that is initially noise temperature of LNA is low subsequently it will be higher for their higher initially moderate amplifier gain down converter is 0dB IF gain is much larger.

Now, what happens that if the down converter gain reduces actually it is a loss because the filter is there mixed is there that is a lossy. So, second stage you find receiver system noise temperature when down converter gain is minus ten dB and then what is the effect of this much more important is now this gain is reduced, but the effective noise temperature is mostly dependent on the gain of the first stage. Some effect of the second stage will appear. So, little change you find. You will find more changes if we change the RF value Receiver System Noise Temperature, when the RF Noise Temperature RF stage is equal to 200k, instead of 50k I am increase it is to 200k.

You will see the effective, as it is we know that if these noise temperature is high the effective noise temperature the total system will be high because this plus second stage divided by gain of the first stage plus third stage noise temperature divided by the gain of first stage and second stage like that it goes, but here you will find with numbers and then let us go back to that RF gain and RF noise temperature same, that is find receiver system noise temperature, when RF noise temperature is go back to the 50k value and RF amplifier gain is increased 50dB. Earlier it was 23dB I increase to be 50dB.

Then what is the effect, you will see; obviously, from here you can find out that the first stage the effective noise temperature maintain the same value as 50k this second stage was reduced by the gain value of 23dB initially as a first problem and in the last problem we said the first stage gain is increased. So, this noise temperature will be reduced by this much gain. Remember that these calculations when we do you are doing on the temperature. So, therefore, the values what you are going to use for gain which is given dB as to be converted into numbers, do it in numbers and then you will get finally, the temperature value in dB Kelvin again call it dBk later converting back to the back to the dB.

So, in case we need a briefly we have gone through the noise temperature and noise figure and let us try to recollect some of the important issues what we discussed till now that is initially we have said that the power is important aspect of our link budget. So, we transmitted the power from a isotropic radiator with pt and as the distance increases the power flux density reduces by the ratio of distance square and then instead of isotropic radiator because the distance is very large in our satellite communication.

The process a reduction of the power is much more. So, therefore, we focus with antenna having gain and then we have come across a term which is focused power which you called Effective Isotropic Radiated Power EIRP that is the transmit side characteristics and on the received side we have got the received antenna aperture which also determines the gain of the received antenna and because of the distances the losses are happen it is called Path Loss that was a very basic thing, but then subsequently we have seen the there may be many more losses if the transmitted received antenna are not properly aligned to their both side it will be de pointing losses from the transmit side as well as the received side antenna there between the power amplifier output to the antenna point there is a there are cables and other systems are there which we called feeder loss.

Similarly at the receive antenna to the receiver there will be certain feeder loss transmitted receive feeder losses are there. Then there are the paths losses which we have already see depends on the path which some people call it free space loss, but in addition to that there may be atmospheric losses details of that we will discuss later. There are some losses and then there are certain polarisation losses if there is a polarisation miss match between transmitted and receiver antenna. So, with all these losses we will get some power.

Then we discussed about the noise how in a any real practical device which is not at a temperature 0dB Kelvin generates noise, how it can modelled and then effectively said there is a physical temperature but then there could be effective noise temperature which is as if it is a resistance having a particular temperature generates that amount of noise which is equivalent to that particular circuit which may be amplifier or it maybe lossy device. So, you have got effective noise temperature for each of them and it is equated it to original constant the temperature and the bandwidth and there is certain assumption that is assumption box in the frequency range of micro wave and normal temperature.

And subsequently we have seen a another characterisation which we called noise figure relation between noise figure and noise temperature we have seen and then we have tried to cascade different systems and try to find out what is the total equivalent noise figure or equivalent noise temperature and one question always we have seen that when we try to do calculation it is better to do it in noise temperature range and you do it in ratio, all numbers which it gained and noise figure which we have given in d b convert them into ratio and then you calculate and try we have try to seen these.

The first stage is very important it is noise temperature it is gain is very important which effects the total system noise temperature or noise figure and there may be certain input noise temperature or if there is a noise figure assumption then better you do it as if the input is matched with a with temperature normal temperature T is 0 is to 90dB k and we have given you some examples and problems which you should work out yourself to get the numbers and understand what we have discussed till now.

Thank you very much till now and then we will continue our Link Budget discussion in more detail based on antenna the ratio of carrier to noise etcetera

Thank you very much.