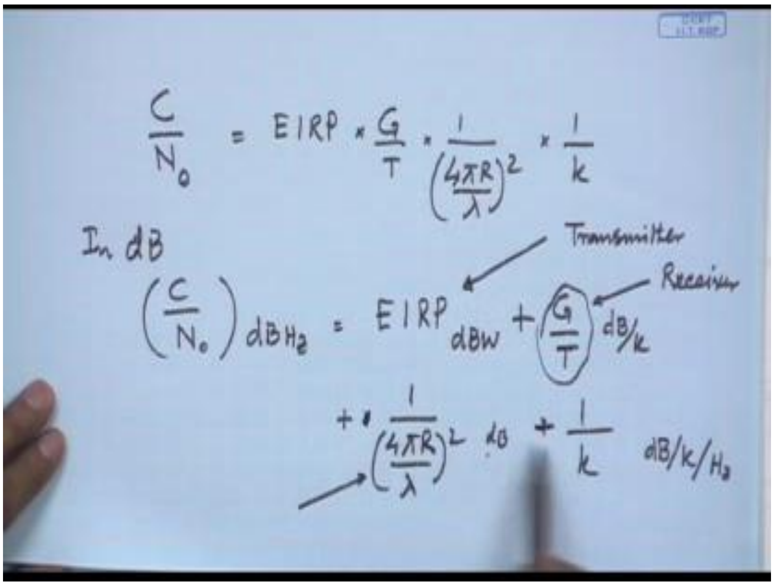
Satellite Communication Systems
Prof. Kalyan Kumar Bandyopadhyay
Department of Electronics and Electrical Communication Engineering
Indian Institute of Technology, Kharagpur

Lecture – 16
Link Budget – 6

Welcome. So, we will continue our discussion on link budget. Till now we have seen that how we can collect the link signal power at the received point and at receiver point and the noise which is generated by the receiver. Also, it is whether it is coming out from any external source and then we try to see the service in terms of signal utilization. We generally call here as carrier to noise ratio that is carrier power to noise ratio and we will try to derive how in terms of transmit power received power transit antenna gain the different type of the losses, etcetera let us go to our expression.

(Refer Slide Time: 01:10)



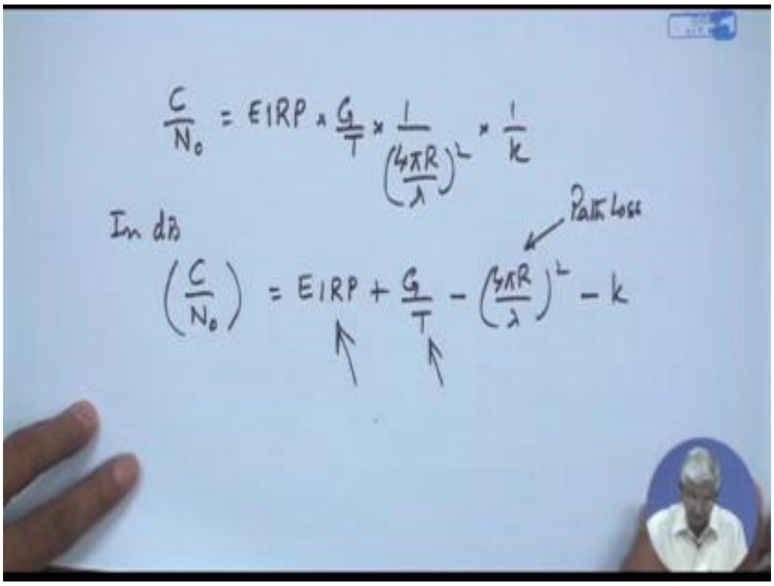
Our expression last time if you recollect it was like this that in dB terms C by N naught since we have made it noise power density. So, the unit will be dB hertz not simply d b. So, it is not simply ratio of two powers it is dB hertz now that is expressed in dB as in EIRP which is dB W G by T it is dB by k and then one by path loss which is four pi r by lambda whole square which is in dB and of course, the remains constant k that is 1 by k dB per k per hertz.

Now, in this there are couple of things are important things are coming out the characteristics that is one characteristic is this one which is EIRP; EIRP if you remember it is multiplication of transmitted power and the transmit antenna gain and of course, the related losses like mispointing and feeder loss at the power amplifier to antenna etcetera all these things appear in the EIRP this is the characteristic characteristics of the transmitter side. Now, there is a term G by T which is coming which if you remember this G is the received antenna gain and this T is actually the system noise temperature of the receiver.

So, this G by T characteristics the receiver and there is a path which is coming based on the path distance and the lambda that is based on the frequency of transmission. So, this is the path related loss remember though I am calling it loss it is not attenuated loss it is the spreading effect that is coming that is being seen here. So, this is not a d T b type of loss this is not attenuated type of loss this is the spreading loss though we are using the term loss because it is reducing the power it is 1 by therefore, it is reducing the power.

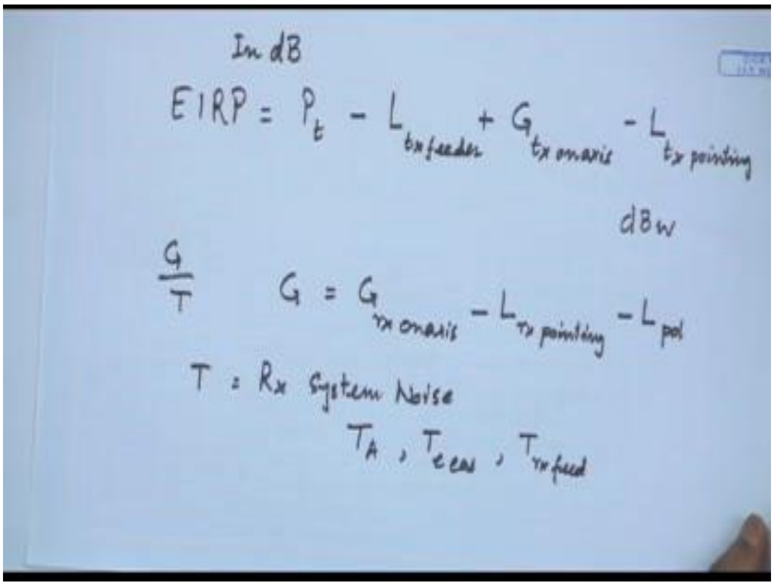
Here I made a mistake, did you see the mistake I was using ratios here and then dB I made it multiplication term which is not correct this should be this should be plus or I can put it as a minus value if I put up and this is plus. So, I should rewrite correctly you see the type of mistake generally people make I also made that mistake. So, let us correct it of course, I corrected it in dB it is like this. So, I will rewrite the whole two expressions properly.

(Refer Slide Time: 04:06)



One is when you write in ratio it will be C by N naught is EIRP multiplied by G by T multiplied by 1 by let us call it path loss or let us write the same thing four pi r by lambda square into 1 by k which is in ratio and in dB it will be C by N naught is equal to EIRP plus G by T minus four pi r by lambda whole square which is path loss minus k. So, this is it is in dB term and unit is dB hertz because it is N naught hertz have just gone up.

(Refer Slide Time: 05:14)



Now, let us let us see that importance of EIRP and G by T what is there content in the EIRP in EIRP people tend the P t, I write in dB P t minus the loss at the transmit feeder with actual power which is appearing at the antenna point P t is that power amplifier out and there is the feeder loss. So, the actual power will be reduced from this and then the G that is transmit antenna on axis or both sides that is in the maximum direction on line and of course, it is reduced by the transmit pointing I should.

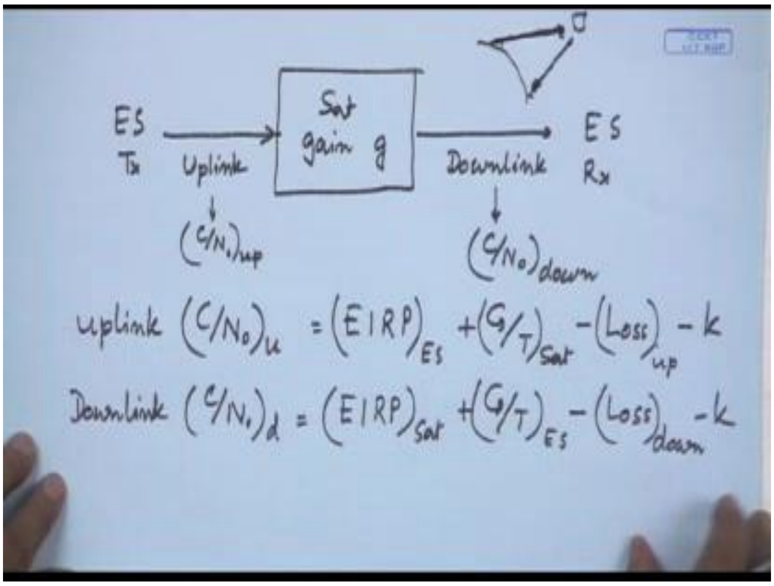
So, this unit is dB w that characteristic the transmit side and the G by T which is the receiver characteristic in this the G is the antenna gain of the receiver on axis then there is a loss the receiver by the pointing then there is a loss by the receiver polarization mismatch if you recollect. So, all these things will be put together and in the dB term it is the antenna gain path of that received at and there is a T which is the receiver system noise generated that includes the antenna noise what it is received the cascade that is the receiver cascaded sub system noise the noise temperature the effective noise temperature also the antenna point to the receiver that received feeder temperature which will be appearing as a loss.

So, the characteristic of the receiver is found out from the G by T and remember always this G is not always receiver gain or l m a gain it is the gain of the antenna of the receiver and T of course, the just the noise temperature and EIRP characterizes the transmit side which includes the transmit power amplifier and related losses the transmitter antenna gain and the related losses.

So, now we know that a link quality which is the signal to noise ratio in other case, we say it carry it to noise ratio carrier noise density ratio is now listed. Now, we have actually in the satellite two links uplink which is earth to space and downlink which is east to earth and till now mostly we are discussing about the satellite which simply bends the signal down of course, it translates because of it is isolation region translate the frequency, but the actual signal is going up getting amplified and coming down it is normal like a bent pipe.

So, the signal power is getting amplified and pushed down in the down ratio similarly noise power which is received by the satellite receiver also gets certain gain and comes down. So, at the receiver I see the quality in terms of signal to noise ratio or carrier to noise ratio or carrier to noise power density ratio or how it should be related to the uplink carry to noise ratio and downlink carry to noise ratio they are two separate things, let us try to see that how does it look like.

(Refer Slide Time: 09:29)



Let us say that this is the satellite unit which has a gain I call it small G because capital G we have used it for the antenna gains. So, this is the satellite gain there is the earth station which is transmit and going up to the satellite. So, it is called uplink that is earth to space similarly satellite is pushing down the link to the earth station which is receiver station and it is space to earth that is why it is called downlink always you remember there is uplink and downlink.

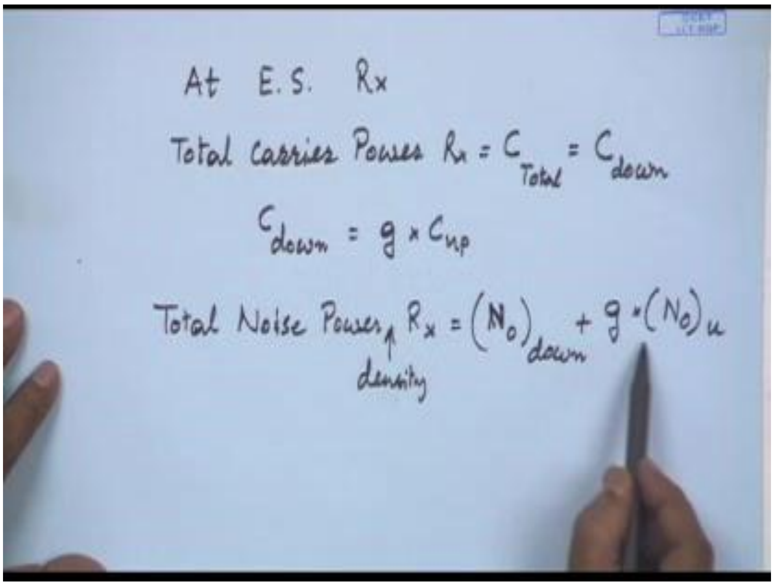
Since, there is a transmitter involved and the receiver involved in the satellite and there is a path in between. So, at the uplink we will get some C by N naught which we will call uplink C by N naught and at downlink also similarly satellite is transmitting it has a transmit antenna gain and a amplifier. So, it has EIRP and earth station receiving it has a G by T and there is a downlink path. So, it is also having a C by N naught which is downlink.

So, you can write separately that is for the uplink path C by N naught let us call only u instead of up is EIRP of the earth station plus G by T of the satellite minus loss path loss is dominant and other losses are there. So, I write simply write loss. So, that is in the in the uplink path this uplink path there is loss and minus the all are in dB there is plus minus plus minus here. Similarly, in the downlink path we have C by N naught downlink which is now EIRP from the satellite plus G by T now the earth station is receiving. So, it is the earth station minus the loss in the downlink minus k.

Now, if the same earth station 1 earth station is transmitting say this part of the earth there is there is a satellite here and from here somebody is transmitting and here somebody is receiving. So, the uplink distance and downlink distance maybe or may not be same and then uplink frequency is higher we have seen as per I T u regulation and downlink frequency is relatively lower from the uplink frequency. So, lambda is different. So, uplink path loss and downlink path loss because of the range difference their frequency difference they may not be same even if the earth stations are both located side by side located still there will be difference because the distance may be same, but frequencies of uplink and downlink if they are different the losses will be different remember.

Similarly, a station antenna diameter and power heat is transmitted is different than satellite transmit power and the antenna. So, EIRP earth station in EIRP satellite in the uplink path and downlink path will be different similarly the receiver characteristics of the satellite and the receiver characteristics of the earth station as well as the antennas they are different. So, G by T of satellite and G by T of earth station will be different. So, uplink C by N naught and downlink C by N naught are independent things they may have different value they may be adjusted to almost same value. So, let us try to see what really happen in totality what really happens in totality that is what we should look at it.

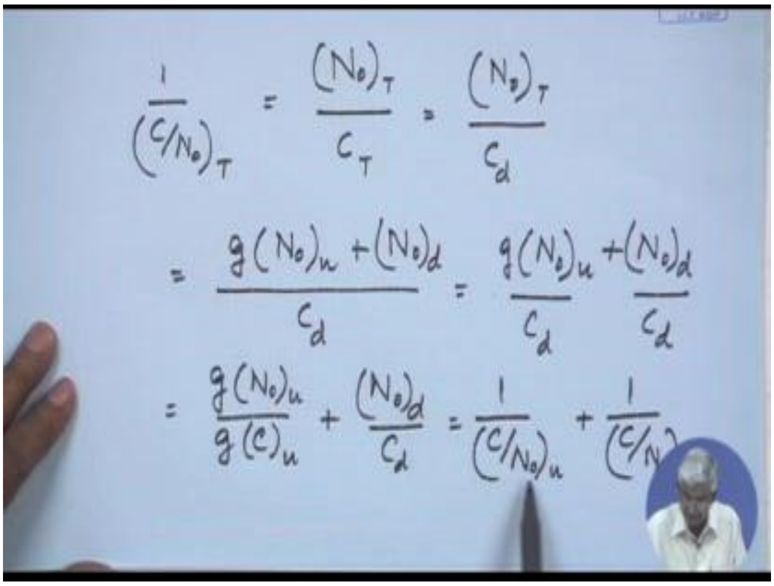
(Refer Slide Time: 14:19)



So, at quality of service we see at the receiver. So, at earth station receiver the total carrier power received is called C total is called C total what is received is downlink carrier. So, it is same as C down now this what is C down if you remember that we said that there is uplink carrier going up and there is a satellite gain that carrier power is amplified by this gain and the pushed in the downlink. So, the C downlink is C uplink multiplied by the satellite gain. So, C downlink is satellite gain multiplied C uplink

Similarly, the total noise power at receiver is noise power density. If we say noise power density N 0, N 0 of the downlink plus the satellite gain multiplied by the N 0 of uplink; that means, that uplink noise is amplified and coming down it is it is received noise is not only the downlink noise, the noise from the uplink is getting amplified and coming down though we are getting advantage of the carrier power is getting multiplied by the gain the noise power downlink noise power plus uplink noise power multiplied is coming down.

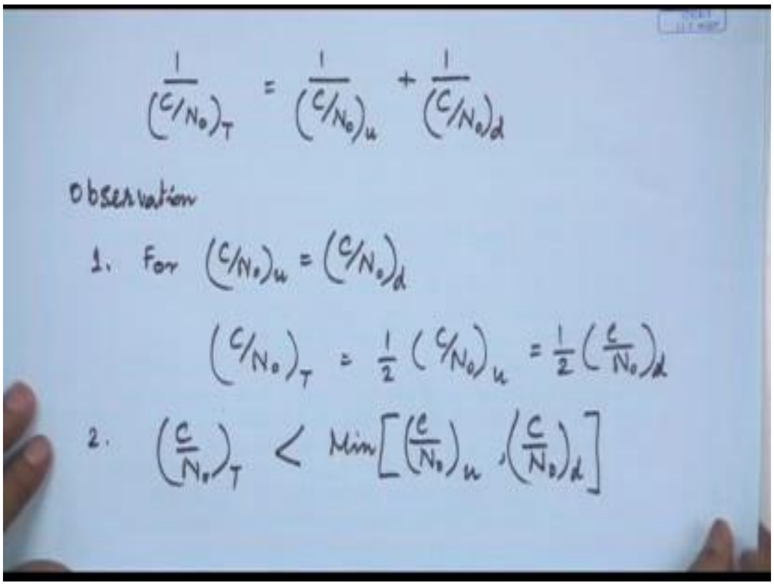
(Refer Slide Time: 16:38)



See let us see the resultant what really happens that is if we try to say 1 by b by N 0 total is I can write in different way N 0 total T for total by C total which is N 0 total by C downlink because what is downlink is seen is the total which is equal to G times N 0 of uplink plus N 0 of downlink that is N 0 total divided by C of downlink I can separate it out that is G of N 0 uplink plus N 0 downlink and this is separately divided by C downlink C downlink you can write it this way.

Now, what is this C downlink is G times C uplink. So, I can write it G times N 0 uplink by G times C uplink plus N 0 downlink by C, downlink G gets canceled. So, which is I can write reverse that is 1 by C by N 0 of uplink plus 1 by C by N 0 of downlink. So, 1 by C by N 0 total is equal to 1 by C by N 0 uplink 1 by C by N 0 downlink that what in transponder that we get.

(Refer Slide Time: 18:36)

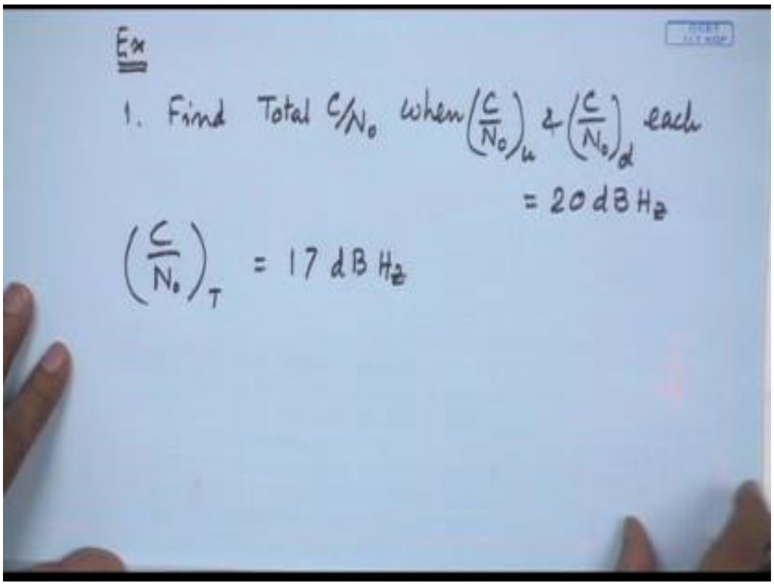


So, let us write it again for to see our observation 1 by C by N 0 total is equal to 1 by C by N 0 up and 1 by C by N 0 down remember when we do this type of calculations this is in ratio not in dB this is in ratio, but you should do this calculation in ratios.

Now, there is certain observations that is coming out of this 1 of the observation let us see what are the observations we can straight away see that if C by N 0 uplink and C by N 0 downlink if C by N 0 uplink and C by N 0 downlink are made same somehow we made both are same it is called balanced link if I make it a balanced link what is the effect you can see the effect that is for a condition where C by N 0 up is same as C by N 0 down then the C by N 0 total is half of either C by N 0 up or half of C by N 0 down.

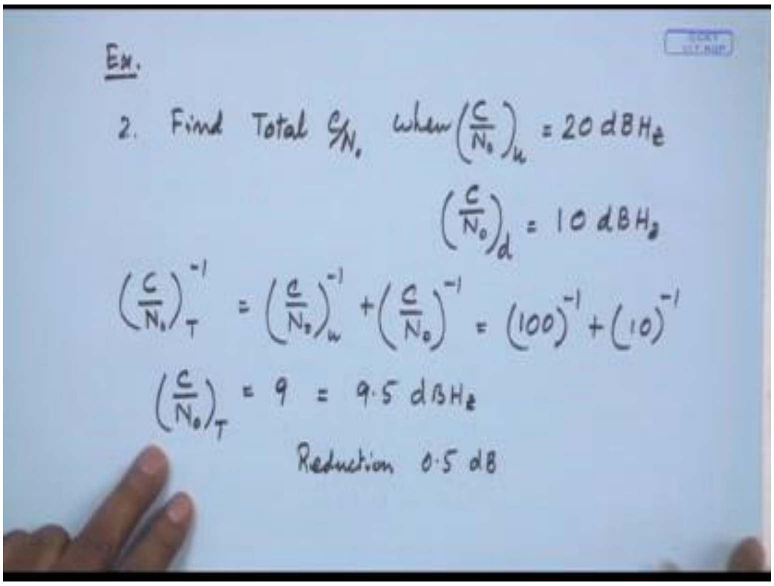
So, that is 1 of the observations. So, in dB terms you will see it is three dB now of since both of them are equal. So, dB round of that, it will be lower than which is half of that C by N 0 up and C by N 0 down whichever you take when both are equal another observation it is just like analog resistance and equivalent distance calculation. So, the other observation is similar that is if the C by N 0 total that is equivalent resistance would be lower than the minimum of the distance that is the observation number two is C by N 0 total would be less than minimum of C by N 0 half up and C by N 0 down should it be lower this will be lower than that. So, let us let us put some numbers then you will see the fun of it how much you know that is very important. So, let us look at some example, let us put some example.

(Refer Slide Time: 21:35)



Find total C by N 0 when C by N 0 up and C by N 0 down each equal to 20 dB hertz then what is the C by N 0 total that you can calculate actually it is calculated in ratio, but as it is we have seen it will be half of that and half of that is 3 dB. So, it will become 17 dB hertz when they are both same it will be 3 dB down, so 17 dB hertz.

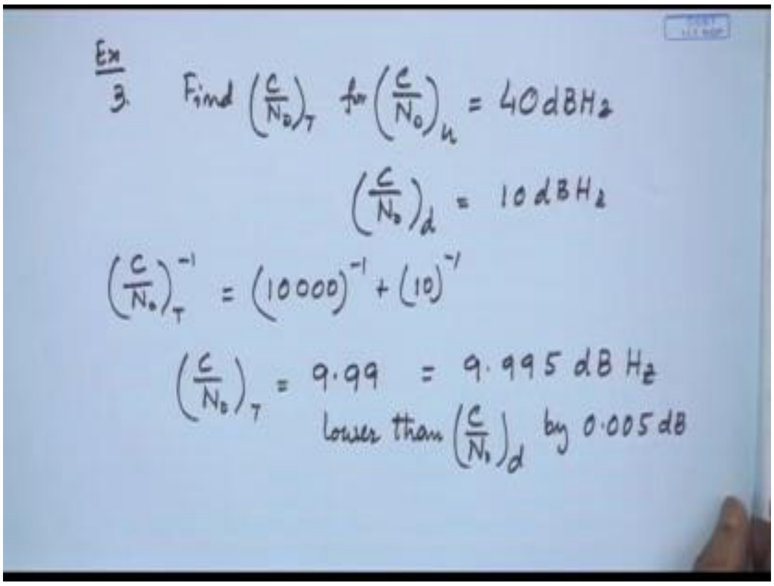
(Refer Slide Time: 22:42)



Let us see another example, example 2 find total C by N 0 when C by N 0 up is 20 dB hertz and C by N 0 down is 10 dB hertz when the downlink C by N 0 is 10 dB down that is 10 times slower than the uplink, downlink is now 10 times lower than the uplink just put 1 condition then let us see what is the effect on the C by N 0 totality

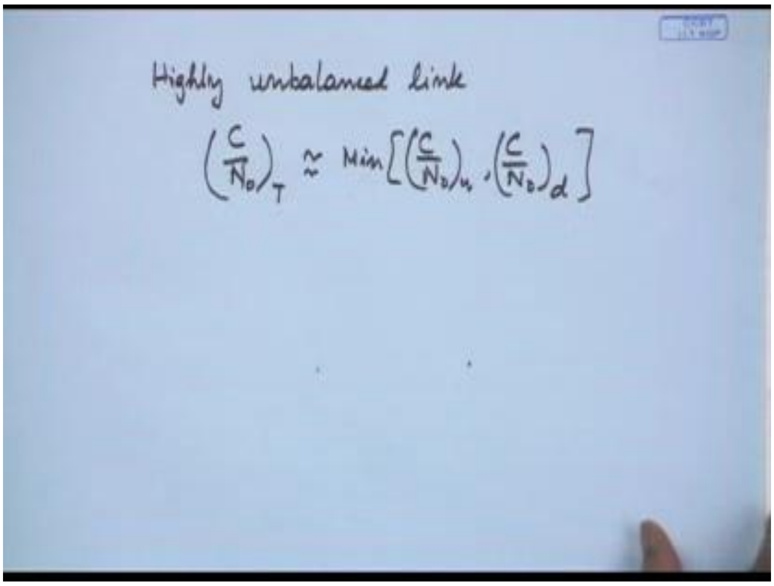
So, it will be C by N 0 total is equal to C by N 0 up inverse C by N 0 down inverse and we said calculation has to be done in ratio. So, we convert that 1. So, it is 20 dB means it is 100 inverse plus 10 dB is 10 inverse. So, result is roughly 9 and sorry if we inverse it again C by N 0 total result is 9, which is 9.5 dB hertz. Now you see it is lower than the downlink which is 10 dB hertz it has become 9.5 dB hertz. So, reduce this 1 10 times I reduction from the lowest 1 is about 0.5 dB let us say take another example which is more extreme.

(Refer Slide Time: 25:04)



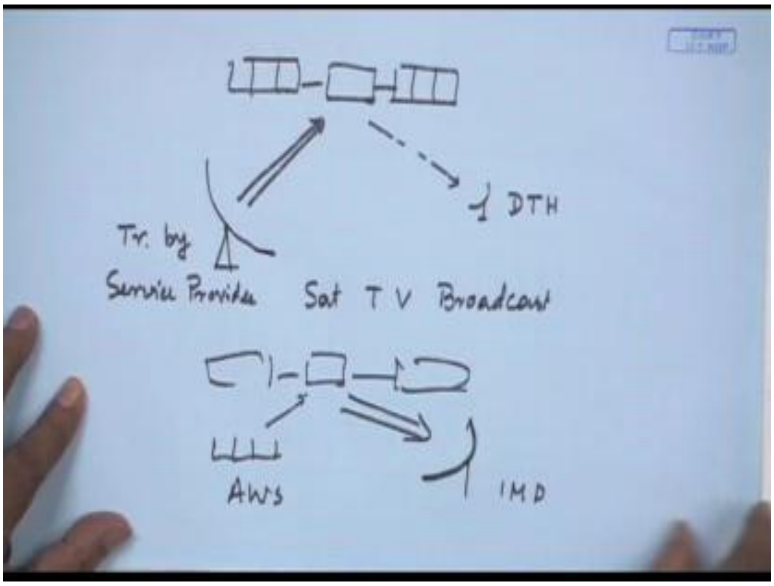
Let us say take example three find C by N 0 total for C by N 0 uplink as 40 dB hertz and C by N 0 downlink as 10 degree hertz. So, C by N 0 total inverse is now 10,000 inverse plus 10 inverse. So, C by N 0 total will become 9.99 approximately and that means, in dB it will be 9.995, let us say dB hertz in calculated in you will find some more decimal points.

(Refer Slide Time: 26:44)



So, now that is lower than C by N 0 down by 0.005 dB. So, that shows that in a in a highly imbalanced link or highly unbalanced link where uplink or downlink C by naught vary by 1000 times, 10,000 times or more than C by N naught total will be approximately equal to the minimum value of C by N 0 up and C by N 0 down out of that whichever is minimum it will be approximately there you can use always thumb rule to do this type of calculations that it really happens.

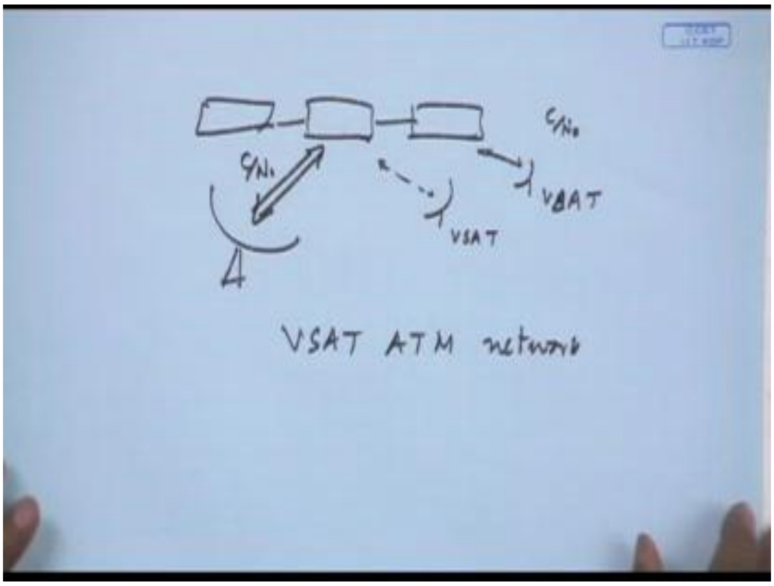
(Refer Slide Time: 27:35)



Let us see some of the practical examples where it really happens that is that is 1 of them let us put a satellite here this is the solar panel and bigger station and smaller station 1 of the example is satellite TV broadcast and this is your direct to home receiver and this is the this is the transmitter by service provider there are standard commercial service providers are there and government service providers are there like doordarshan like Tata Sky like many others like Zee, etc.

So, this link is fat link uplink and this link is a thinner link in terms of C by N naught. So, C by naught uplink is very high compared to C by N naught downlink 1 of the example the completely reverse could be there is a satellite and you have automatic weather station and you have large antenna by Indian meteorological department uplink is thin and downlink is fat.

(Refer Slide Time: 29:13)



There could be other examples where in VSAT ATM networks are there. So, that could be I just draw the picture we focus in this is satellite this is hub and they are VSAT very small aperture terminus which you have seen in bank ATM. So, it is a VSAT ATM network another example where it is two way communications. So, this is fat in uplink and downlink and this is thin in uplink and downlink in terms of C by N naught in terms of C by N naught.

So, with this for the time being we can close todays lecture and we will see what is the other effect that happens over the total C by N naught because of reasons like interference.

Thank you very much for listening we will continue this discussion in link budget.