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

Lecture - 18
Link Budget-8

Welcome back. We were discussing on the Link Budget and we have seen the C by N naught calculation in uplink and downlink and from that the total C by N naught which will be quality that is required by the user and this C by N naught calculation depends on the uplink power in terms of EIRP and downlink power from the satellite then the G by T of the satellite and the ground station and the path loss is or other loss is put together and Bull Men's concept this can be done in ratio or in dB that also we have seen and then we have seen since satellite operates in the satellites are non-linear here particular is the power amplify on the satellite is non-linear.

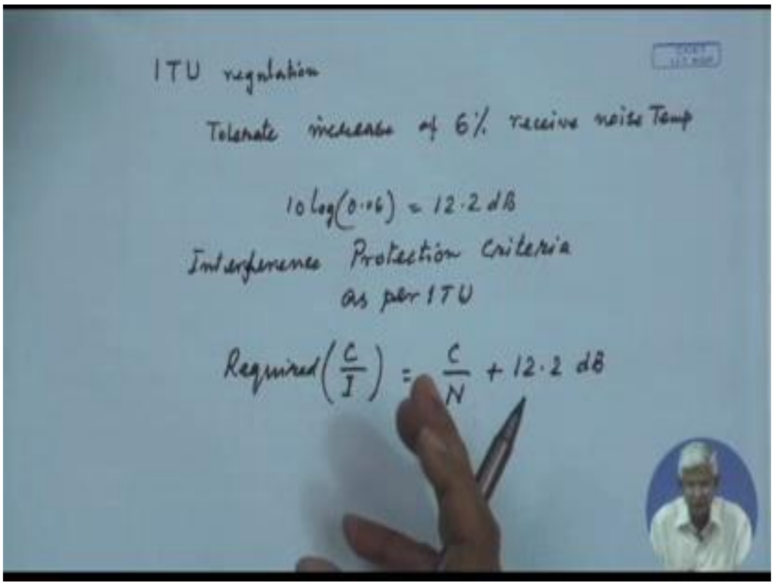
So, therefore, at some point of the input which is going to the satellite as input power we can call it a input power flux density as you go on increasing the output EIRP from satellite will linearly increased first and then saturated some point. These satellite manufacturers space craft manufacturers they specify at what power flux density and the output will be saturated. So, these input power flux density they call saturated power flux density or saturating power flux density s a t in short and correspondingly what should be the ERP maximum or saturated ERP from the satellite available these two specifications are given, but since that is in the saturation point and non-linear.

So, therefore, to operate in the linear region to avoid the spurious this will be harmful. We go back in the linear region from the saturation point. So, the input power flux density is reduced from saturated power flux density by few dBs which is called Input Back Off correspondingly there will be output back off from ERP maximum to the operating ERP point.

So, we have also seen how to calculate C by N naught uplink and C by N naught downlink using these two terms which is Saturation Power Flux Density and corresponding saturation ERP or ERP maximum and the for the operating point input back off and output back off also has to be known and in that process we have introduced a term which spreading which depends on the frequency of operation the spreading in the uplink and spreading in the downlink will be different, but we have seen a brief calculation with some small examples that what will be the corresponding numbers that will be appearing now in this a Geostationary mostly we are talking about Geostationary because you have seeing that uplink and downlink path loss is a quite large. So, Geostationary operation we are operating in the environment where other satellite operators also existing on the same coverage area is being covered by other satellites. So, there may be a possibility of interference and since it is a natural resource this interference has to be regulated properly.

So, the regulating body is International Telecommunication Union ITU and most of the agencies this space craft as well as the ground or satellite operators let us see the follow the guidelines which are given by ITU. So, today now will be discussing on this the interference and how much it can be tolerated. So, for that what can be done? That brief calculation, brief idea of that so interference coordination.

(Refer Slide Time: 04:24)



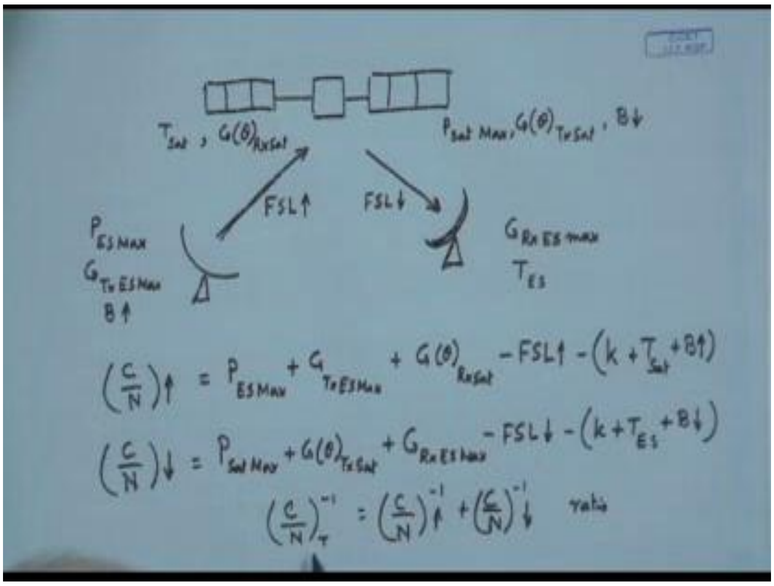
So, as per the ITU that is ITU regulation the person who is operating has to Tolerate increase of 6 percent receive noise Temperature, if it is operating on the same bandwidth.

That is the tolerance you have to live in a society. So, you have to tolerate some people there should be some toleration limits. So, this is the limit it given by ITU. So, single entry limit of interference can be should be tolerated (Refer Time: 05:22) everybody has to agree on that because they are sharing. So, there you know it is a radiation pattern of a antenna which may cannot be a straight rectangular, it cannot be just one single pin pointed focus to only satellite there will be some radiation which will be falling to the nearby angels with nearby satellite maybe there and if it is transmitted from the satellite a nearby ground station also will get some amount of power which will falling into them and if both are operating on the band width it is acting as a interference.

So, therefore, that interference is to be tolerated. You can see from this brief discussion it is the gain of the antenna is coming into picture is very very important. So, at which direction your a station is from the satellite or which direction a station is pointing to satellite and what is the game pattern that really affects the interference we will see into more detail of that, but let first let us see this six percent thing. This is percent if you convert into logarithmic 10 log of the 6 percent which is 0.06 becomes 12.2dB, Interference Protection Criteria.

As per ITU, is the required C by Interference now I call, it is carry a power to interference is the C by N plus 12.2 dB. So, the C by I should be more than C by N by 12.2 dB. So, that should be your required C by I, but when you are actually operating in the available C by I will be may be more than this or may be less than this, if it is more obviously, your available C by I is more than required. So, you are in the positive margin you are not interfering if is equal then also its tolerable up to 6 percent, but if the available C by I is a lower than the required C by I your interfering.

(Refer Slide Time: 08:15)



So, let us do how do this calculation. Will do it in dB and we draw simple picture. So, that you will get idea, let us see the uplink part let us see how we calculate the C by N first. So, let us draw a satellite, brief picture of satellite with the solar panels it is antenna and let us see there is a station which is up linking and there is a station which is getting the downlink there is a one way is going on now the characteristics of these we are assuming here one thing, that since it is earth station it is on the earth you can perfectly point it towards the satellite. So, your antenna gain maximum is towards the satellite. So, its gain maximum is towards the satellite. Similarly the earth station which is receiving you can properly point it and leave it is a fixed station. So, its gain towards the satellite is in both sides.

So, it is properly aligned, but the satellite antenna whether it is transmit or received is pointing to the center of the service area and from the center of the service area these transmitting and receive earth station may be a few degrees away looking from the satellite. So, the gain of the satellite antenna towards the uplink station is reduced from the maximum gain and by the angle theta of course, and similar thing is towards the towards the transmission station that is in the downlink. So, those things we will bring it to picture. So, let us term it.

So, the power from this uplink station we call it Power of the Earth Station maximum power and when I say maximum power it is a power amplifier of plus feeder minus feeder loss etcetera which is appearing at the satellite. This gain of the transmit earth station will take maximum it is pointed towards the satellite and the bandwidth is uplink bandwidth and at the satellite which is receiving from the uplink station and the gain of the antenna is reduced by theta that is received satellite and there is a of course, the temperature system noise temperature of the satellite that is the at the receiver of the satellite from the transmit side of the satellite it is maximum power that is transmitted P SAT maximum I mean feeder loss is everything is included into this, but the gain of this satellite antenna towards the receiving station is from the both side it may be different. I put this same angle theta these two thetas may not be same for the easy calculation you put same angles.

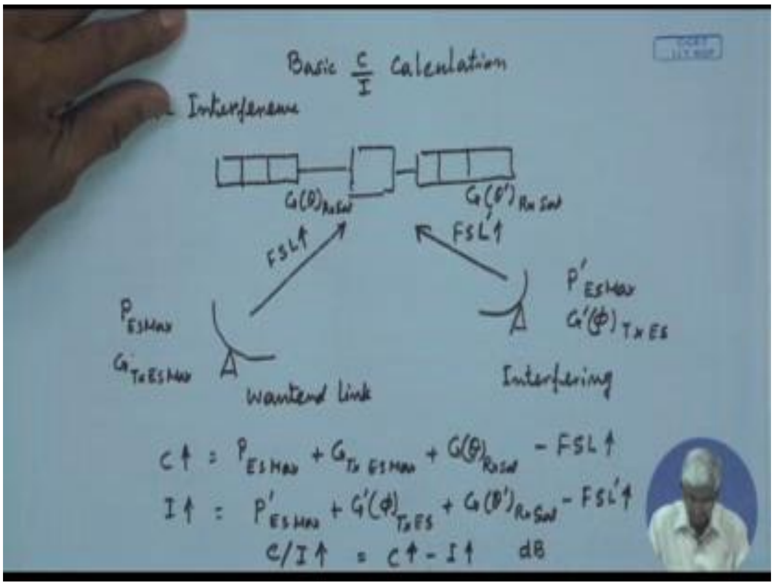
So, that transmitting form the satellite and of course the bandwidth of the downlink. The station which is receiving he has a receive antenna gain which is of the station which is pointed as a said since is on the ground and the temperature of the receiver a station T Es. So, in dB if I write it C by N instead of up I am putting upward arrow instead of down we put downward arrow and of course, there are two more things we skipped let us write the loss which is all these days we where write in path loss. Here I am introducing this new because in many books it is written other form to get yourself familiar I am writing free space loss which means the same thing this the path loss in the uplink in some of the books it is written free space you will be wonder in what is this free space. So, it is a free space loss same as path loss. So, free space loss uplink and free space loss downlink these two are different because the frequency there different. So, C by N you can call it C by N naught or C by N if here C by N bandwidth has to be taken care.

So, C by N uplink is the power of earth station max maximum power which transmitted from the station then the gain of the transmit earth station maximum, which is pointed properly and the gain of the satellite antenna receive with angle theta G theta it is receiving minus the free space loss which is path loss the uplink and minus the (Refer Time: 13:42) constant the temperature that is the system noise temperature of the satellite and of course, the bandwidth because we are taken C by N. So, this is all are in dB that is why you are seeing plus and minus.

So, similarly C by N downlink will be from the satellite. So, P satellite maximum plus G theta transmit from satellite plus G receive a station max this G is are gain of the antenna minus the free space loss in the downlink which is nothing but downlink path loss minus k the earth station noise temperature and the bandwidth fine. So, therefore, the C by N total or simply C by N if you can call is we know is expression this is in the uplink and this C by N in the downlink and this you remember that is in ratio we calculated these are all in dB here will be increasing and then you remember this C by N total what you calculated is 12.2 dB if you add then you get the required C by I.

So, this calculation we should do to find out what is the required C by I, but then you have to find out what is the available C by I. Let us do let us do that calculation here. Yes pictorially it is much easier is not it when you do it pictorially in dB.

(Refer Slide Time: 15:59)



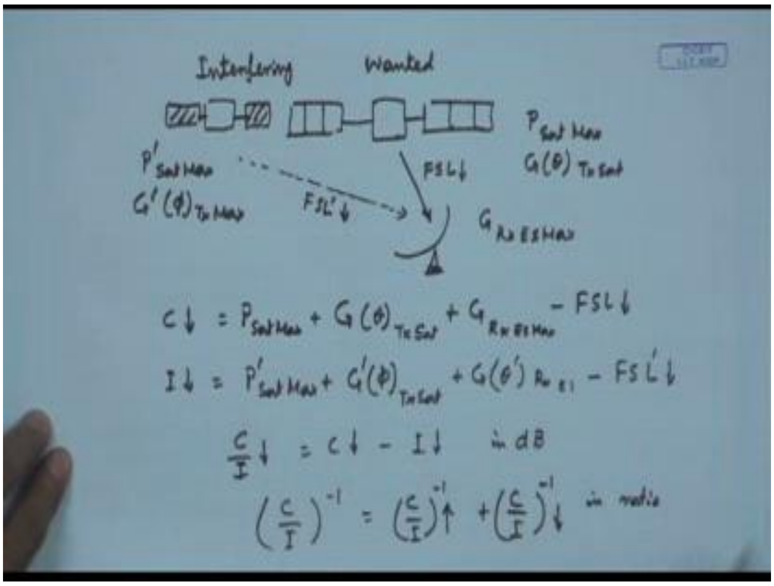
So, let us do some basics C by I calculation. So, for the uplink interference let us draw satellite again, now there is a station which is up linking towards the satellite pointed the antenna towards the satellite free space loss uplink. So, it has a power of station which is maximum and gain of the transmit antenna which is a station maximum this is the wanted and there is another station which is interfering, this is interfering station.

So, it has the same frequency of operation same bandwidth it is interfering. So, free space loss will be more or less same, but depending on the range it will vary, interfering station that is called by prime, FSL prime uplink. So, this power prime of the station maximum and G now since it may not co located it may be slightly away it is actually working with another station wanted station another satellite which is wanted satellite for this station now some of the gain is interfering. So, it is pointing to its own satellite of operation which may be nearby a G phi of that gain at the angle phi it is appearing as interference.

So, we will call G phi G dash because it is interfering at angle phi is transmit at station. So, that is interfering and at the satellite when it is looking since satellite might be pointing both sides at the pointing satellite antenna might be pointing at both sides which is theta degree away from the wanted station. So, will call G theta Receive Satellite and here call G theta dash receive satellite it may be slightly different angle.

So, the carrier power in the uplink is from the wanted station that Es max plus GTx earth station max plus the satellite G theta receive satellite minus the free space loss in the uplink this in dBw. And what is the interference in the uplink I is from this side, that is P dash earth station max plus G dash phi transmitter station plus G theta dash receive satellite minus FSL prime uplink this in dB w. So, your C by I uplink will be C uplink minus I uplink these in dB. So, C separately calculate is power and gain and receive antenna gain form satellite minus the free space loss or path loss and interfering station power you calculate which is interfering power. So, it is P dash G dash and G theta dash from satellite and free space losses dash satellite issue of that or in dB subtraction.

(Refer Slide Time: 20:50)

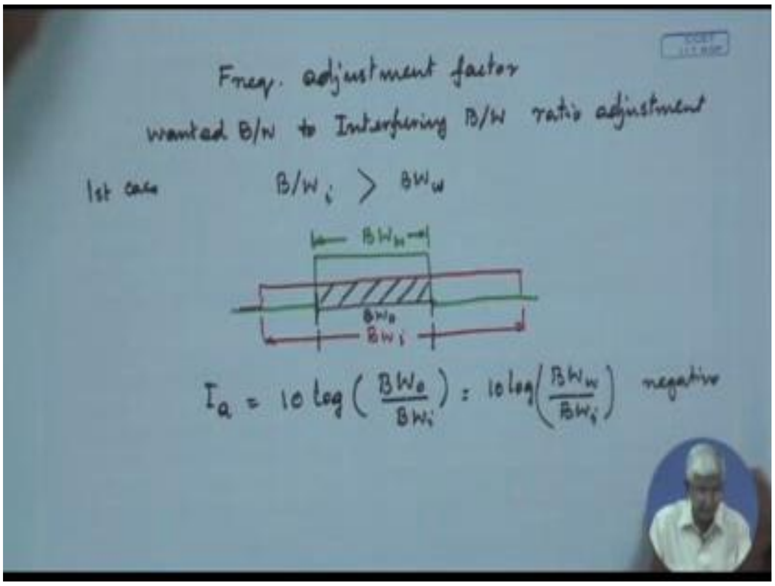


Similarly, downlink interference can be calculated. So, downlink interference from the may be from a nearby satellite. So, there is a nearby satellite. So, we have a station here this is the downlink free space loss and this is the G receive earth station max because this is wanted station and wanted link. So, it is properly pointed, but it is from this satellite you have P satellite max and G theta transmit satellite.

It may theta angle away from the interfering station the interfering link which is coming, it has a free space loss prime downlink. So, it is P dash satellite max P dash because it is interfering with the downlink and it is G dash phi transmit max from the satellite it is interfering satellite this is wanted satellite this is the interfering satellite, so wanted link interfering link. So, C downlink is P satellite max plus g theta transmit from the satellite plus g receive a station max pointed minus FSL downlink and interfering power I is equal to P dash satellite max plus G dash phi transmit satellite plus G theta dash receive a station minus FSL prime.

So, C by I downlink is C downlink minus I downlink in dB. So, C by I total is C by I uplink inverse and C by I downlink inverse this is in ratio and then you can convert back to dB . So, this is the basic calculation of the C by I what you have done what is really amount of power which is interfering in the uplink and downlink total C by I, but then there is some bandwidth interference, how much bandwidth is really over lapping interfering bandwidth is really over lapping on the wanted bandwidth that also has to be considered. So, let us see that we do a bandwidth adjustment factor.

(Refer Slide Time: 24:23)

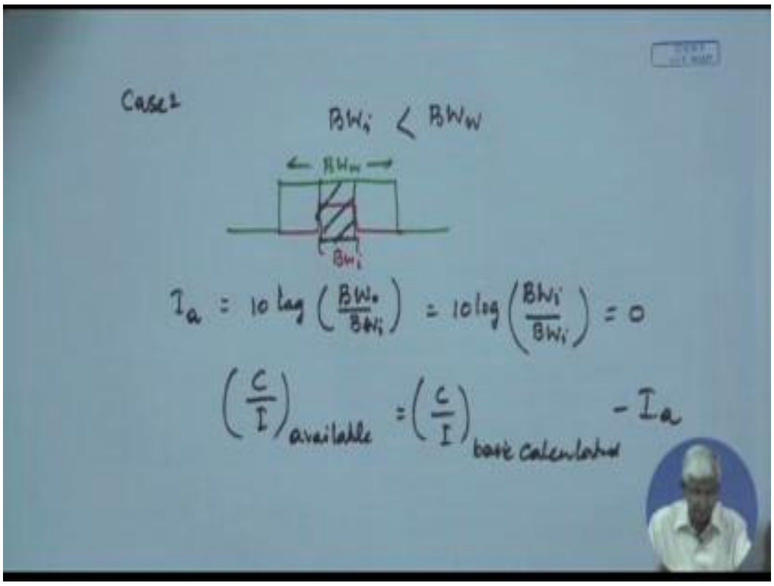


So, that is done like that is called Frequency or Bandwidth adjustment factor. That is nothing but that Wanted Bandwidth to Interfering Bandwidth is a ratio adjustment.

So, let us take a case, first case where that bandwidth which is interfering is larger than the bandwidth which is wanted is W stands for wanted I interference. So, this is larger and it may fully over lap on that lets write. Let us say this is my wanted bandwidth. So, this is bandwidth wanted and the interfering bandwidth is coming over this and which is larger. So, this is bandwidth interfering. Now you see in this what is happening that the whole thing of my wanted bandwidth is getting interfered.

So, it is all bandwidth overlap. So, interfere bandwidth is fully over lapping on that. In that type of case that is where the bandwidth wanted is less than bandwidth interfere, in bandwidth interfere is fully overlapping, the overlapping part has to be seen is fully overlapping then these interfering ratio adjustment which is termed as Ia is 10 log of bandwidth overlap by bandwidth interfere. How much is overlap, that is fully interfered bandwidth is fully overlapping on that. So, BW is also equal to I mean these two are only overlapping. You can take both of them are same sorry it cannot change, they are bandwidth interfered is more than that it is overlapping wanted bandwidth is fully overlapped with interfere bandwidth. So, in that case it is the 10 log of bandwidth wanted by bandwidth interfered which is bandwidth interfered is large. So, this is a fraction less than 1. So, this will be a log is a negative quantity.

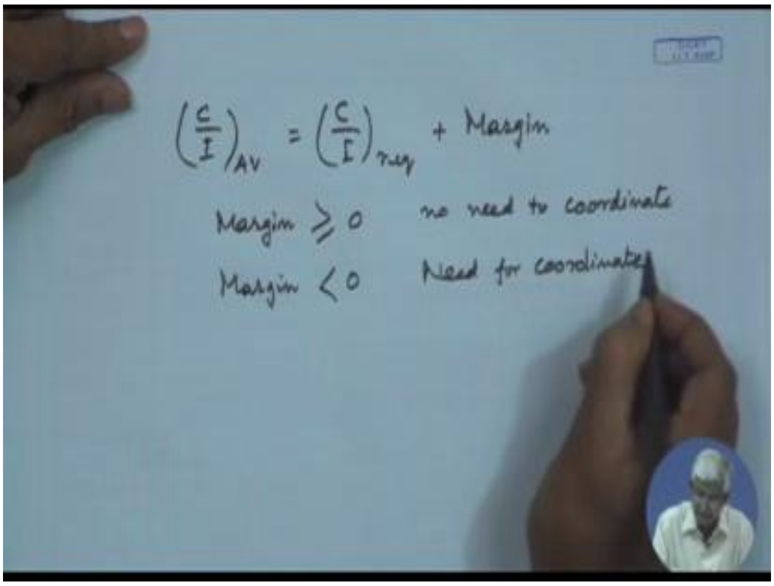
(Refer Slide Time: 27:53)



There can be another case where it is partially overlapped case 2, where bandwidth interfered is less than bandwidth wanted. Let us draw it, this is the bandwidth wanted and this is the bandwidth interfered.

So, in that case that frequency adjustment factor is 10 log of Bandwidth overlap by Bandwidth interfered; overlapping is only in this region. So, it is 10 log of bandwidth interfered by bandwidth whatever bandwidth interfering is the same as bandwidth overlap. So, bandwidth interfere, which is equal to 1 which is equal to 0. So, C by I available is C by I basic calculated minus interference adjustment factor in dB.

(Refer Slide Time: 29:21)



So, C by I available is equal to C by I required plus margin if this margin is greater than or equal to 0 no need to coordinate with the operator which is interfering, but if margin is less than 0 then there is a need for coordination, and in this game that is first come first out who have lunched the satellite first he has the more right and some new satellite operators is coming to operate nearby region or overlapping on that. So, that satellite operator has to coordinate with the original existing satellite operator and find out what is the C by Is getting from them and how much it is interfering them and. So, that 6 percent is only tolerable and therefore, he may have to adjust his gain in the satellite the antenna pattern gain of the earth station and antenna pattern or he may have to readjust the frequency band. So, that overlapping is much less. So, actually it is power flux density which is which are adjusted.

So, with this let us conclude the Link Budget I try to give you varieties of information and very quick calculation how it can done how the interference are calculated and what is to be done with interference like that is the coordination in the GSO scenario the similar thing in other satellite scenario also can be done.

Thank you very much and next period will talk about the medium that is through which the satellite signal is passing through impairment and mitigation technique for that.

Thank you very much.