Satellite Communication Systems

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

Lecture – 26
Multiple Access-1

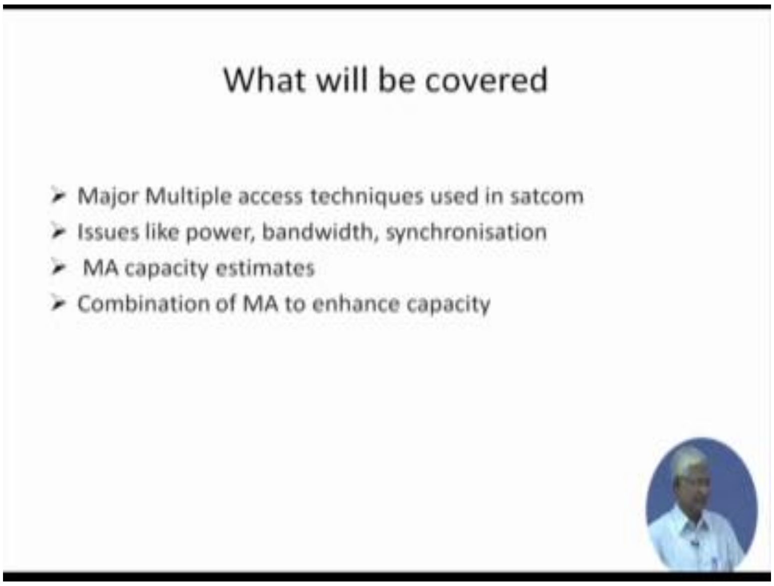
Welcome. We have covered the topics like orbit, then we went to space segment, and then we tried the budget for the link power and then we came down to ground segment. And in between we have studied propagation effect, and today will start with the multiple access technique. That is if you remember the satellite basic advantage of the satellite system is that it gives a large coverage area, and large coverage area means many users can use the satellite means the satellite resource, and since many users are trying to use a common resource, so multiple people are trying to access the common resource which is power and bandwidth of course. And since multiple people are trying to access it is called Multiple Access.

The other side of it is one agency or one person or one user is accessing the satellite and giving the information to many, one, two many that is broadcast. So think of reverse of broadcasting many users are trying to access the common resource of the satellite and then it is either communicating with a central station that we have calculated last time and showed that ground segment. If it is very small like very small aperture terminal, if they are trying to access from the link point of view from the power point of view it is more comfortable that if they communicate to the large station.

So, multiple access is sharing that the resource and going to a large station. And then it may come back to the small station so two small stations can communicate two VSAT can communicate, but this part of the link which is uplink from the small station to large station, uplink from the small part small stations to the satellite that is earth to space link this uplink is multiple access in this case. So, let us see.

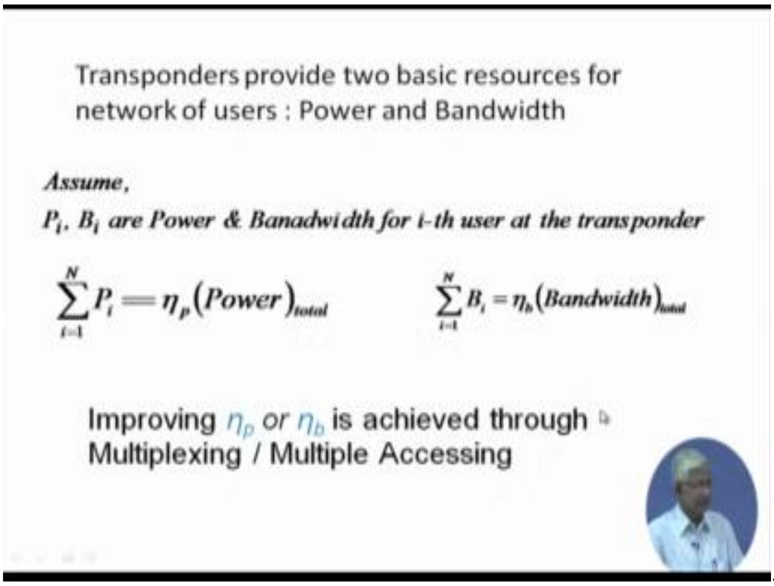
Multiple accesses, we will talk about the techniques.

(Refer Slide Time: 02:50)



What will be covered? We will cover major multiple access techniques, there are many many of them but major of them will try to cover. And then we will cover the issues like power, bandwidth that is a satellite resource and the synchronisation in case of time relative issues. Then what is the capacity for those couple of multiple access techniques. What we will talk about the; I can estimate the capacity with lots of assumptions of course we will take, and then combination of multiple access to enhance the capacity. Generally we will try to cover this.

(Refer Slide Time: 03:35)



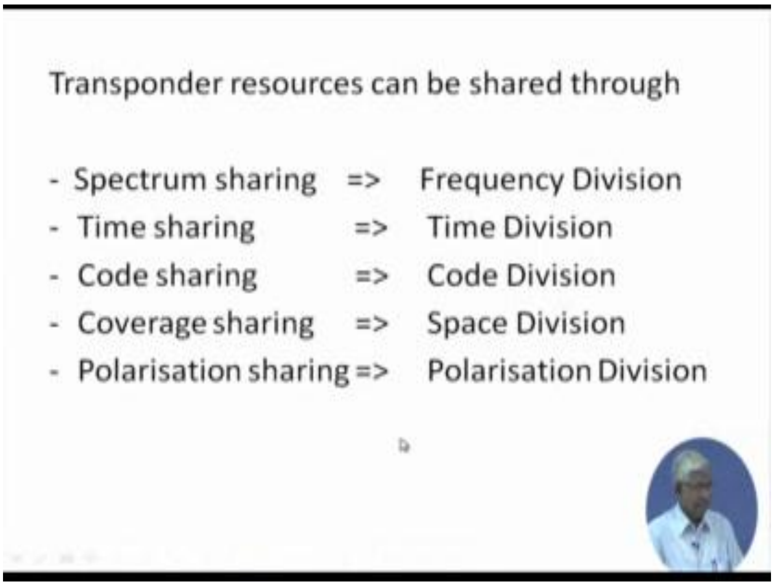
So, let us get into the business the transponders provide two basic resource for the network of users; the power and bandwidth. Let us assume that P i and B i are power and bandwidth for ith users at the transponder. Now transponder has some power that we have converted into EIRP if you remember that power coming out of amplifier of the transponder is then put to the antenna to focus to service area, so antenna gain multiplied to this is EIRP. So, here we can consider EIRP also.

Now, the Pi of the each users EIRP each user is trying to access some of the satellite power, so ith user is P i is taking out some EIRP that EIRP of the ith one and if I is going to 1 to n sum of all of them will equal to some power, but that total power what they will take that is total power available from the satellite there will be some losses and that is we are terming it as eta P that is efficiency or eta P some losses are there. So, full capacity of the transponder power may not be able to utilize.

Now our intention will be to make this eta P as near as 1, this maximum value is 1 so then all the powers each user is taking together will be the available power which is available from the satellite total power available from the satellite. Same thing can be put for the bandwidth. So, each individual users B i is the bandwidth of each individual user that bandwidth sum of all of them should be equal to the bandwidth available from the resource that is the transponder total bandwidth, but may not be able to fully utilize if eta B is equal to 1 then only it is possible.

So, our intention in this multiple access is to make this eta P in case of power and eta B in case of bandwidth we should make it as near to 1 as possible. Now, improving this eta P and eta B is achieved through multiple accessing and sometimes can be called multiplexing in some cases. So, that is the issue I have shown in terms of power and bandwidth it can be done in other parameters also.

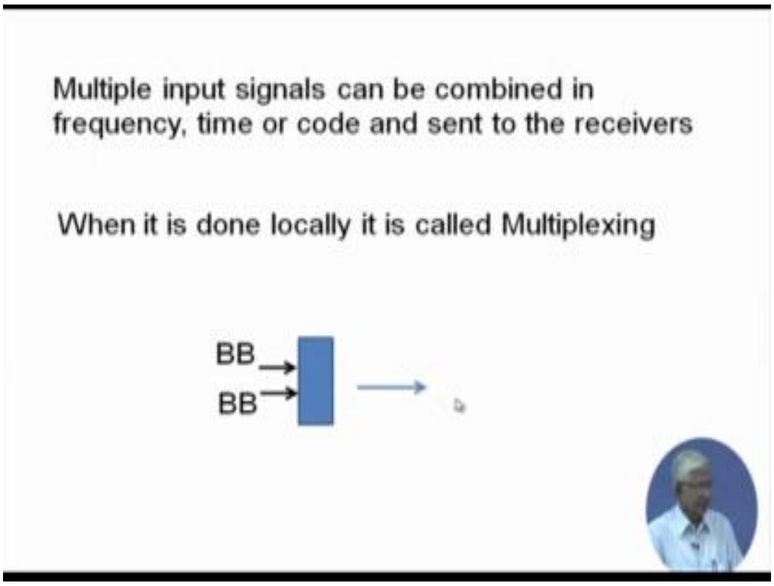
(Refer Slide Time: 06:26)



The transponder resources can be shared through many ways. If we share the spectrum that is bandwidth is called frequency division then if it multiplexing it is multiple accessing; frequency division multiple accessing. In terms of time if the user share the resource then it is called time division, and then multiple access or multiplexing. In terms of code if you share then it is called code division multiple accessing. Is there any other possibility? Yes, in terms of coverage area the satellite can generate some spot beams and that each spot beam will cover certain area, so if it is coverage area it is space actually; so it is called space division multiple accessing

In terms of polarisation if you do polarization; there are many possibilities. So, some of them we will try to cover here.

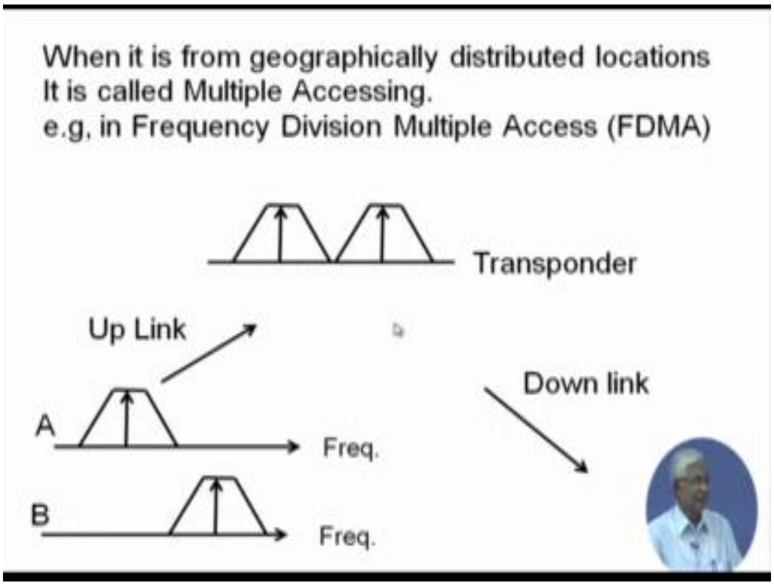
(Refer Slide Time: 07:31)



Multiple input signals can be combined in frequency time and code and sent to the receiver. That combination is happening at the satellite at the transponder, each individual is giving separately at the transponder combination is happening and then the combined thing is broadcast down to the earth and on the earth receivers are there, and based on the type of multiple accessing receivers will pick up their intended signal for that.

Now, if it is done this type of resources sharing is done locally it is I just try to give a definition. When it is done locally it is called multiplexing. Two base band signals are combined at one place and sent to the receiver so you can call it multiplexing.

(Refer Slide Time: 08:22)



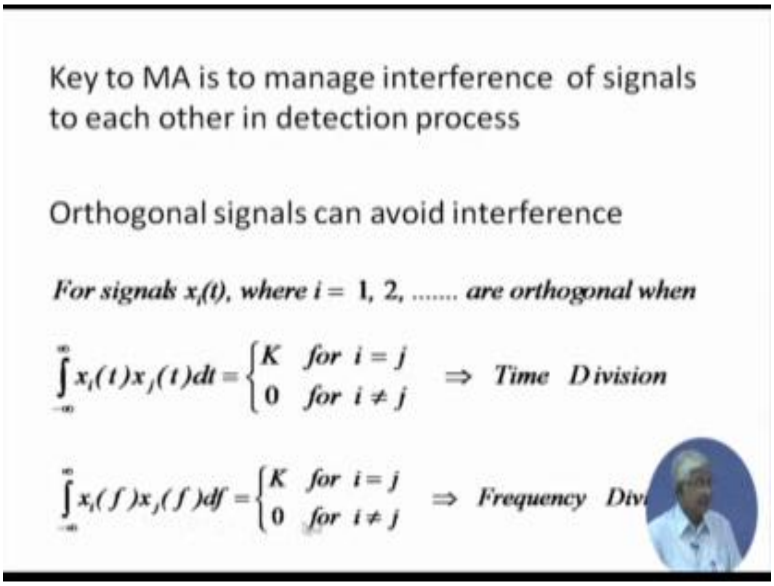
And when it is from geographically distributed locations it is called multiple accessing. One way of defining it, like frequency division multiple accessing in sort we call FDMA; frequency division multiple access. Similarly, DDMA will be there.

Now just let us take the example of FDMA, a part of the spectrum is this x axis is spectrum frequency is part of the spectrum or part of the bandwidth is taken by a station A and another part of the bandwidth is taken by station B with certain amplitude and each individually they are uplinked. So, it is going to the satellite and the satellite are at the transponder since their frequency wise band wise they are slightly separated, so at the transponder they are (Refer Time: 09:16) one after another that is in terms of x axis is frequency.

So say this is the total bandwidth available at the transponder, it is being shared by two users, so it is frequency division multiple accessing. But from the transponder to the receiver rate comes down that is in the downlink, now it is multiplex signal is coming down. So, the receiver has to have a to receive both have to have a wider filter individually they have to have a individual type of filter knowing where they have transmitted, how much bandwidth or which part of bandwidth is taken by which station. These are details, but this is the concept.

Initially they are transferring at different frequency when it reaches the transponder it is multiplex looks likes multiplex it is coming down in the multiplex form like (Refer Time: 10:13) in case of DDMA.

(Refer Slide Time: 10:17)

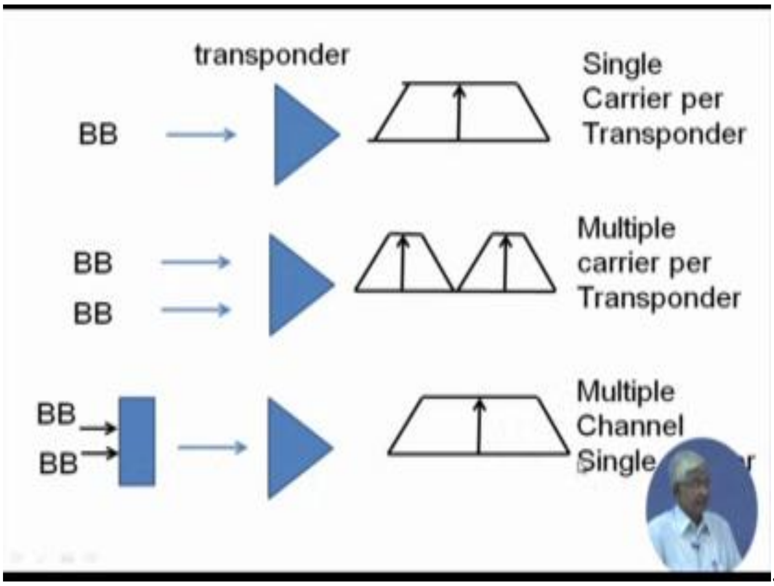


Key to the multiple accesses is to manage this interference of the signals from each other in the detection process. They could be interference as you can see here that if this band is overlapping over this band that means, if the filters are not proper then there will be interference in terms of power. So, some power of A will be interfered with some power of B or the other way. So, it is that filter that determines

Similarly, at the receiver also the filter will determine; the transmit side as well as the receive side that is important. The orthogonal signals can avoid interference. Mathematically if you put for signals x i t analog signals, where i could be 1, 2, 3 are orthogonal if they are. In orthogonal it is principle says that x i t multiplied by x j t and dt over integration over infinity when they are i and j when they are equal they will be k and when they are orthogonal unequal they will be 0 i not equal to j.

Now, since it is in terms of t we can call it time division, if it is in terms of f x i f, x j f then it is called frequency division mathematically you can represent it.

(Refer Slide Time: 11:53)



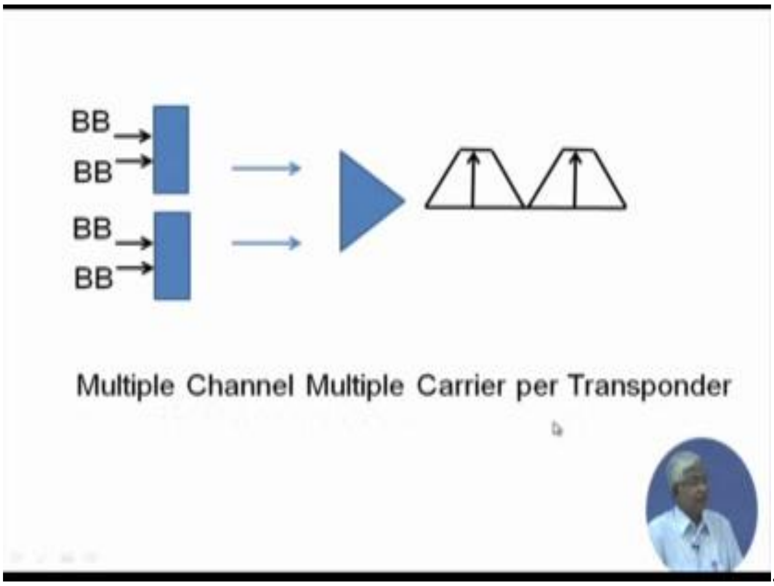
Now, let us get into some of the definition or some of the terms that is used. Let us say there is a transponder and the transponder in frequency domain it have this much bandwidth and one base band signal is occupying the full transponder. So, it is a single carrier being transmitted and received at the transponder and the switch will be pushed down to the downlink and so in one transponder there is a single carrier it is called a Single Carrier per Transponder.

If there could be multiple carriers. So, two carriers like our earlier examples are transmitted in slightly the different spectrum band so that they do not overlap. And then it will be called multiple carrier in one transponder; so Multiple Carrier per Transponder.

It could be a multiplexed signal in one carrier coming and that one carrier coming is occupying the whole transponder. So carrier is one but the channels are more, so it is Multiple Channel, but single carrier per transponder of course. This is a common example of our TV signal, the broadcast TV what we observed to our DTH or even though our cable in the satellite part where most of the operators they book the full transponder. So, they pay for the full transponder like let us say Tata sky or Doordarshan or Zee any anybody they take the full transponder, and in one full transponder which is 36 mega hertz they transmit multiplex signals.

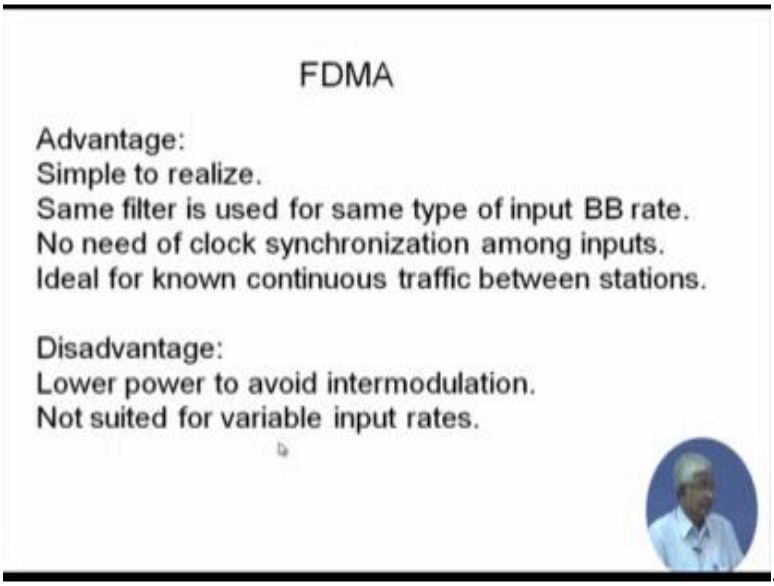
So, if your antenna is pointing to that particular satellite and that particular transponder if your receiver or set top box is receiving you will receive so many multiplex channels which are coming, so that that is how the broadcast representing is to be done; multiple channel in a single way.

(Refer Slide Time: 13:57)



It is possible that multiple channel in multiple carrier also there. So there could be two carriers two separate operators are sharing one transponder and each of them is transmitting multiplex signal could be TV or voice or sound or anything. In this case the transponder is carrying two carriers and both the carriers are multiplex so it is Multiple Channel Multiple Carrier per Transponder. It is some form of definitions.

(Refer Slide Time: 14:24)



So, let us go into the first multiple access most commonly used which is called FDMA; frequency division multiple access. It is advantageous people started with this because it is very simple to realize, you have to have some filters. And if the bit rate or bandwidth requirement for the each of the input is same from the each station then the same filter can be used for the same type of input bit rate. Take everybody is transmitting in some 10 mega hertz, so filter of 10 mega hertz that is required everywhere or at the transmit station and the receive station etcetera.

So, there is no need of time synchronization, it is continuously it is going so there is no need of clock synchronization, this complications of clock synchronization we will see when we will go in DDMA. This is one of the basic advantage people see about FDMA is over DDMA is no need of clock synchronization among the input and they can transmit any time.

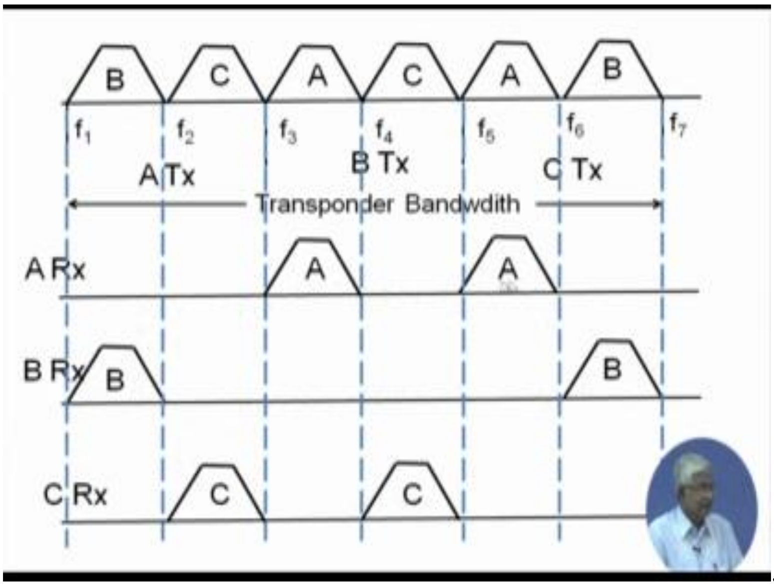
It is ideal obviously, they can transmit any time but ideal when it is a continuous traffic. If you do not have traffic in one of the channel that particular part of bandwidth is wasted. It is ideal for known continuous traffic it is unknown and non continuous for traffic it is a problem, so it is very simple when the trunk route between telephone exchanges or trunk routes of ISB they are using satellite. They have huge volume of traffic and it is continuous, therefore it is ideal for those cases.

But it has disadvantage obliviously in terms of the continuity of the traffic. Another problem is the lower power to avoid intermodulation. Intermodulation we will discuss in detail, but there is non-linearity in the satellite. We have talked about it transponders are non-linear. So, in the non-linear mode of operation if your operating point is at saturation or nearer saturation non-linear then there will be interference or intermodulation that will generate in (Refer Time: 16:41), we will discuss that one in much detail later.

But to avoid to this (Refer Time: 16:46) we have to go back to the linear region which is called back off, and so back off means you will be transmitting less power. So therefore, actually your EIRP will be lower than what is the capacity. That is to avoid this (Refer Time: 17:02). So, it will be lower EIRP operation, lower EIRP operation means you can understand your link equation the G by T of the received station has to be more. So, G by T of the registration mode means diameter of that received antenna will be more or the temperature has to be lower. So that is that is a one of the problem of FDMA operation. That is why in the transport it is used where larger stations are there only few of the larger stations, where you can increase the gain of the antenna by sizing the antenna to larger one and temperature also can be controlled.

And of course, it is not suited for variable input rates, because everywhere you have to put the filter at the transmit side and the received side and if your input varies so the filter bandwidth has to be changed and that has to be dynamic. So, it is not at all suited otherwise it will be a very complex dynamic filter as we design.

(Refer Slide Time: 18:04)



Let us give a quick example pictorially. It is easy, you can realize that let us say there are three stations and three stations are given at two frequency bands each a station A has f 1 f 2 and put a center frequency, but it is total bandwidth. Then B f 3 and f 4 center frequencies. And C f 5 and f 6 center frequencies and with certain bandwidth available here again it is shown that bandwidths are written that is at the transponder.

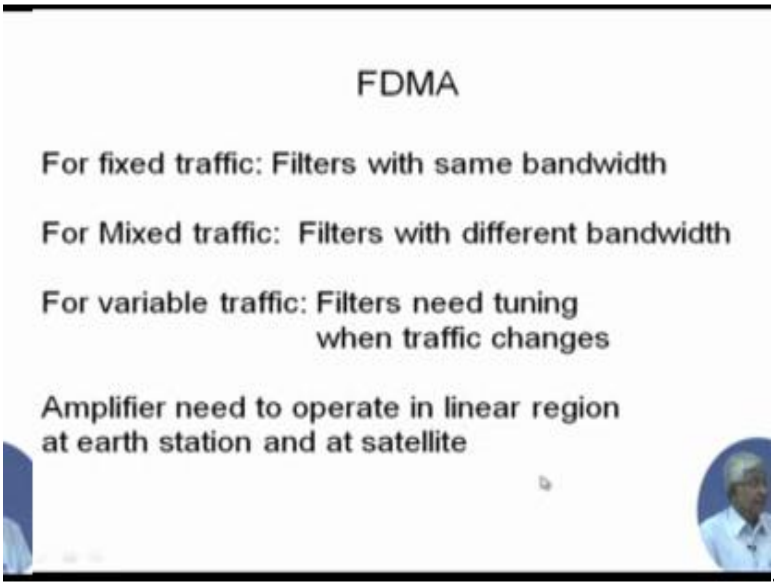
So, A is transmitting for B and C at the transponder it is occupying f 1 and f 2 center frequencies. Similarly, B is transmitting traffic for A and C obviously, B is not transmitting for himself it will be transmitting for others so it is f 3 and f 4. And C is transmitting f 5 and f 6 for A and B stations.

Now, at the received station A you will look for only there is C traffic the whole thing is now multiplex frequency multiplex and coming down in the downlink that is a transponder after reception it is pushing down the downlink at the downlink it will look like the way which is shown B C, A C, A B like that the stations meant for which this band is mainly for f 1, f 2, f 3, f 4. When the A station is receiving you will look for the f 3 which B is transmitting and you look for f 5 when C is transmit, so this filters will be at f 3 center frequency with bandwidth and f 5 center frequency with bandwidth. We need not have all the filters, because it is whatever traffic is meant for m he will receive whatever traffic meant for C he should not receive. So, he has to have filters at these points.

Similarly, B will receive f 1 and meant for B is f 6, so B filters will be at center frequency f 1 and center frequency f 6. Similarly, for C center frequency f 2 and center frequency f 4. So, you can see that at each station it is pre assigned filters are located and if the traffic is known; here it is shown as equal value if the traffic is known that A traffic from B is coming larger and A traffic from C is smaller so accordingly filter bandwidth can be adjusted. This is the allocation of the transponder which is pre assigned known. So, the receiver filters are properly designed and they are kept.

But if you change this dynamically then you can see that filter bandwidth has to change where that is the problem. So, for a fixed traffic filters are with same bandwidth.

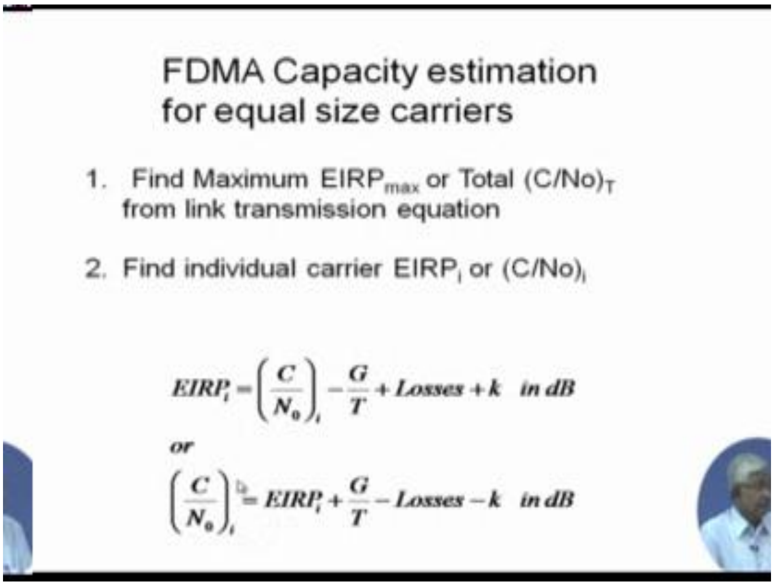
(Refer Slide Time: 21:59)



For mixed traffic also can be done. Different sizing of the filters with different bandwidth, but for variable traffic filters need tuning with when the traffic changes that is a dynamic adjustment and mix it much complex. I mean it is not that it is not possible, but it is difficult and costly. People do not use and then the other issue is that amplifier need to operate in the linear region at the earth station and at satellite. At the earth station also there are multiple carriers are going up for different stations here I have shown only three stations there may be given more number of stations, so multiple carrier going up.

So, earth station HPA has to operate in the linear region, otherwise (Refer Time: 21:51) will be generated similarly at the satellite. So, earth station uplink will have lower power so to maintain it is EIRPs is G and it again has to be increased since satellite antenna gain is fixed. Similarly, satellite here it will be lower because of linear operation and the earth station receive antenna gain has to be increased earth station antenna larger. This is the other part of problem, one is the filter problem another is the power problem and we have to operate in the linear region.

(Refer Slide Time: 22:24)



Now, let us try to see how we do some capacity estimates and we will have some assumptions of course lot of assumptions. One of them is equal size carriers in terms of power in terms of bandwidth both way all carriers are have been same power, all carriers are having same bandwidth How do we do it? So, first we find out the maximum EIRP possible in this transponder I have shown the whole transponders we have used for easy calculation. So, what is the maximum EIRP or the total C by N naught that is the link and support from the satellite?

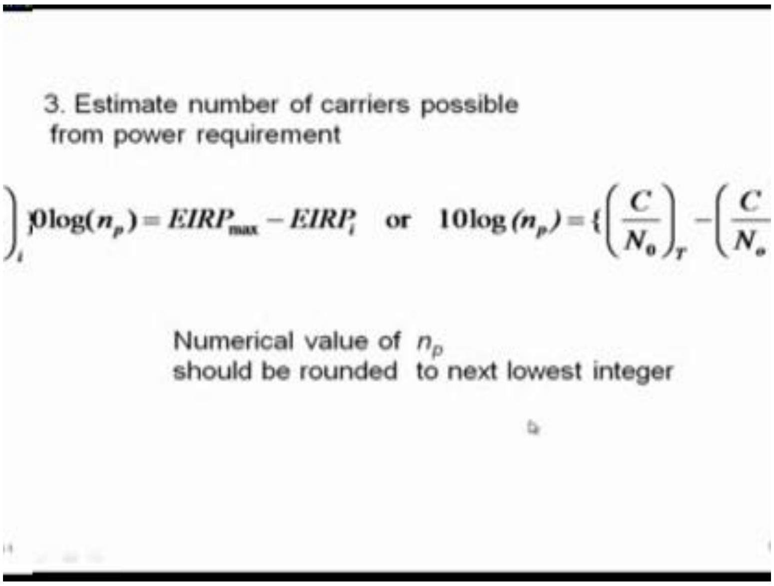
And then find the individual carrier EIRP from the earth station which is going up and the individual carrier EIRP which is coming out from the satellite. So, from the total EIRP you know from the satellite individual carrier EIRP from the satellite transponder, because individual stations are taking smaller bandwidth smaller power. So, their EIRP are lower.

If you remember the transmission equation that C by N naught is EIRP in dB C by N naught is EIRP plus G by T minus losses minus k, EIRP will be t in this case from the satellite we take so is it is EIRP downlink and G by T of the earth station. Just by changing the sign EIRP of individual carrier from the satellite is C by N naught of individual carrier minus G by T of the earth station plus whatever losses are coming and k, k is the (Refer Time: 24:00) if you remember.

Now, where is that efficiency coming in? It is the losses, as I told you that there are possibilities that if the filters are not designed properly or because of any intermodulation or interference some of the power will come into the wanted band and therefore it will increase the noise and that is where the losses will increase. So, our intention to improve the efficiency and reduce the interference losses or (Refer Time: 24:33) losses which is coming in.

So, let us go back to the calculation of the capacity estimate how much is the capacity is based on this expression. These two expressions are same and only such changes are there and only the losses will determine that how much. In this case losses are taken inside the calculation.

(Refer Slide Time: 24:54)

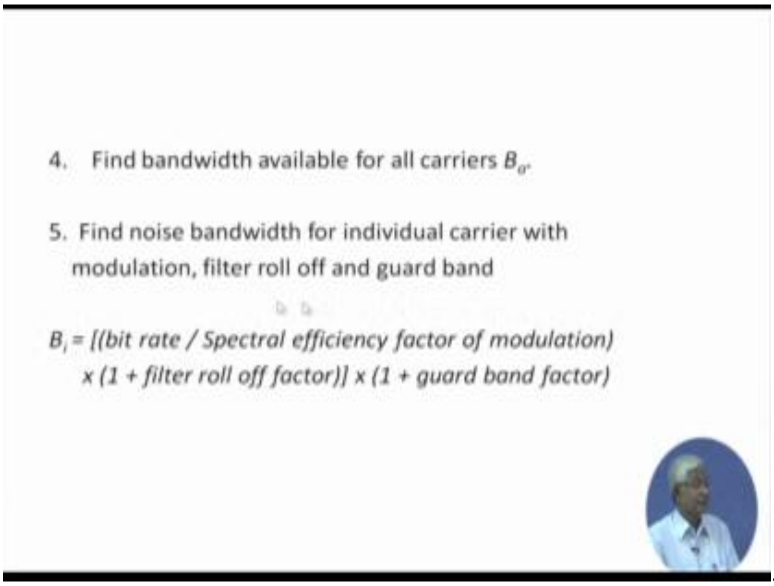


So, estimate the number of carriers possible from the power requirement point of view. It is very simple that the number is the dB subtraction log of the number is dB subtraction of the maximum EIRP satellite can support and individual carrier. And we have assume that all carriers are same, so it is just subtraction of that or in terms of C by N if you do C by N naught total minus C by N naught individual and that will be their log n p.

Now, this numerical value of n p it convert into numerical from the dB, it should be rounded to the next lowest integer that is that is important. Well, we do that many of the students they miss this point that is you do go on doing the calculation as per the formula or expression given to you get something some decimal points after decimal points some numbers and it put that one. Practically you look at as engineer that really I should give a fraction of a number as the how many carriers can go, a part of the carrier cannot go; n p is the number of carriers that can be supported.

C B is coming 31.56, 0.56 carrier cannot be uplink ideally up to 0.56 carrier can go. So, you will go to the next lower integer do not go to the next higher integer because up to 31.56 it can be supported. So, definitely 32 carriers it cannot be support, so it will support 31 carriers. So therefore, the n p would be the next lower integer that that is very important you remember.

(Refer Slide Time: 26:33)



And bandwidth wise that is power wise. Bandwidth wise is also easy find the bandwidth available for all carriers that is total bandwidth supported by the transponder in full transponder case. Then find the noise bandwidth of the individual carrier with the modulation, filter roll off guard band etcetera.

And that how do you calculate? That is the bit rate by what modulation you use it has a spectral efficiency, so bit rate by spectral efficiency factor of modulation and then whole thing is multiplied by role of factor of the filter 1 plus role of factor that much it will increase the bandwidth. And then between two carriers you put extra band of frequency and that in terms of percentage of the total it you can call as guard band factor so 1 plus guard band factor. That is the individual I can call it noise bandwidth of the total thing.

So, since time is almost up so we will stop here and continue in the next period.

Thank you very much.