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

Lecture – 09
Space Segment-4

Welcome back. So, we were discussing different subsystems in the satellite bus and we have covered AOCS TTC power. Briefly we will touch upon the other sub system. The propel sense system is already we are own going to detail of that because some part of the propel sense system is already mentioned during AOCS attitude and orbit control system. So, we will talk about the thermal.

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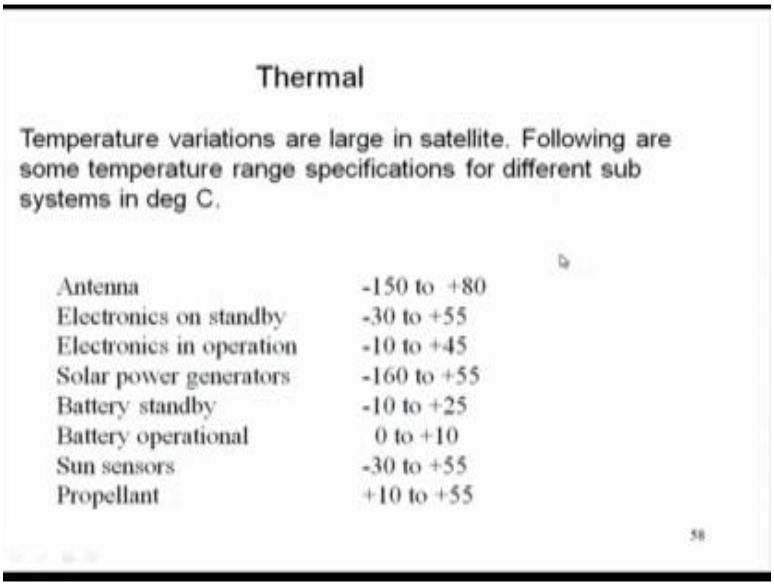

Now, temperature variations are large in satellite because one side the phase of the satellite which is phasing the sun is phasing large temperature, whereas the other side of the satellite which is phasing the cold sky has very low temperature. So, there is a large temperature gradient and there is some typical numbers I have listed here for different subsystem which phases this type of variations in satellite is also slightly tilting all around earth. Following are some temperature range specification for different sub system term typical numbers.

We can see the range antenna phase is maximum because it is outside electrics on the stand by the phase larger compared to which is in operation because when it is in operation, it generates its own hit. Then, the solar power generator that is also phasing larger variation that re-instant by a battery operational similar to the lecture 10 by Operation, there is a variation of that sun sensors and propellant in a typical numbers and all are in a degree certificate.

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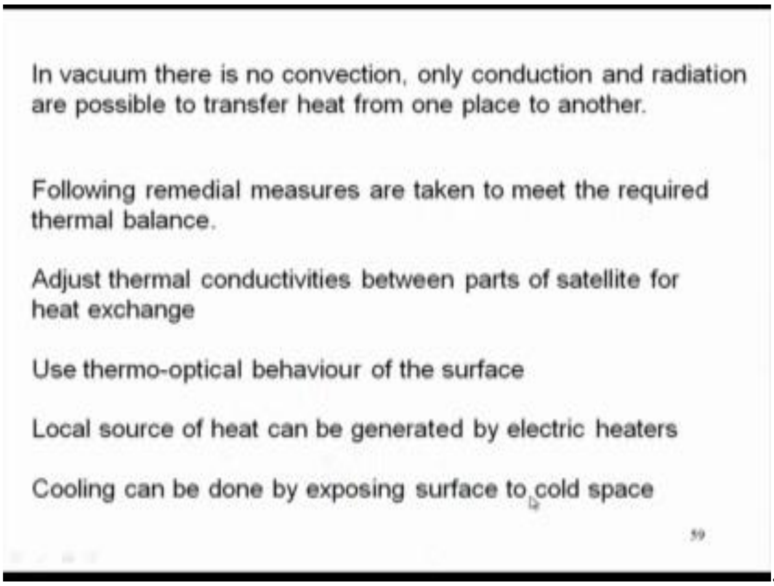

Now, through in vacuum it remembers that satellite is particularly geosynchronous. Satellites are in almost vacuum and no convection. There are three modes of dissipating heat that is conduction, convection and radiation. So, only conduction and radiations are possible and that to conduction is possible only where in metal pieces are there through that radiation is the main anything. So, when there is a thermal imbalance or thermal gradient, radiation is very large. Certain remedial measures are taken to take away the heat if hot spots are generated etcetera spaces. So, that can be done by doing certain heat exchangers that is you can use the thermo optical behavior of the surface to the surface has certain phasing that sun and that parts temperature is high and the other side is a cold sky that temperature is low. So, use that one.

So, local source of heat, it also can be generated by the electric heaters when it is very cold and it is going extreme cold, you can switch on certain local heaters and cooling can be done by exposing some part of the hot spots towards the cold space, so that radiation can take place and there can be heat pipes which is metal pipe which some fluid inside can be attached to the hot spot and that heat pipe can carry fluid which is inside the pipe in convection mode to the colder area. There are various techniques people uses and there is thermal modeling done as communication engineering is going to worry much about it. So, this is about thermal.

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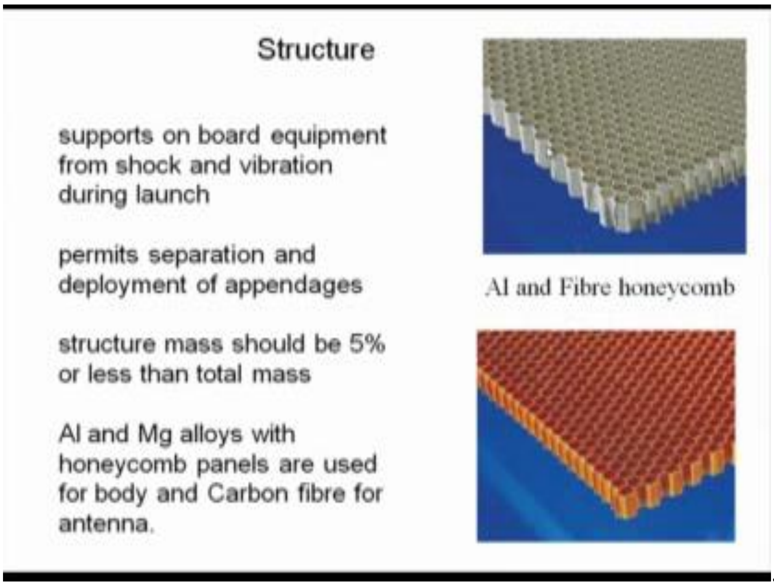

The last part is the structure which is holding the satellite which is supporting onward equipment from the shock and vibration during launch and during operation. It permits the separation and deployment of the appendages like solar panel, the antenna which has to be deployed and certain jerks and shocks and vibration that cannot occur. One thing is there that structure should not be heavy structured itself which is holding all the electronics and other systems should not behave generally has come to it taken as a five percentage or less than five percentage or less than five percentage of the total mass of the satellite.

So, therefore it is not a plain shit of metal. You can see in the right side that we have shown in pictures which is honeycomb type wholes are there and these are the metals, also the body. This gives strength as well as these can be made of aluminium or fiber, aluminium or magnesium alloy with honeycomb. Panels are used for the body or carbon fiber which is used for the antenna part. So, there structure here also it is only information we need for communication engineer much is required. So, with this very briefly we have gone through the different parts of the subsystem which continues the satellite bus.

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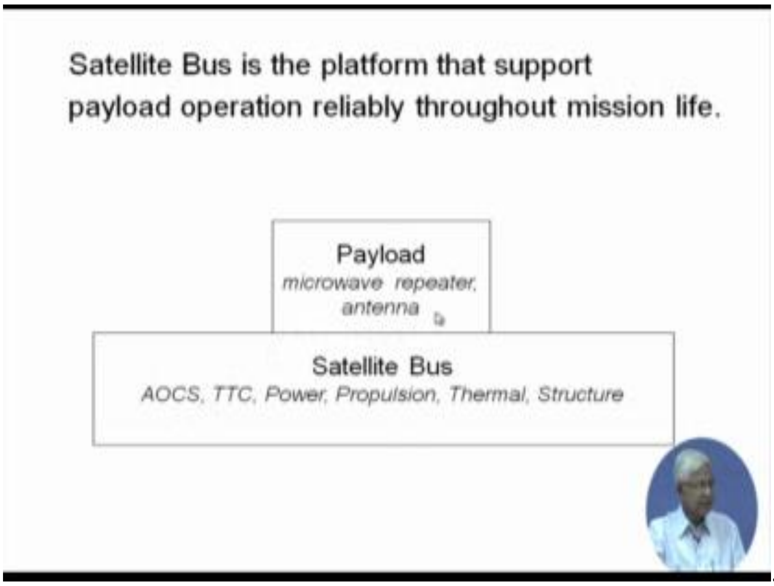

So, let us go back to that old diagram that is satellite bus is the platform that support payload operation reliably throughout the mission life and payload will be microwave repeater and the antenna and the satellite bus is AOCS, TTC, power, propulsion, thermal and structure. Briefly we have gone through each of them except the propulsion within much we have taken its part of AOCS.

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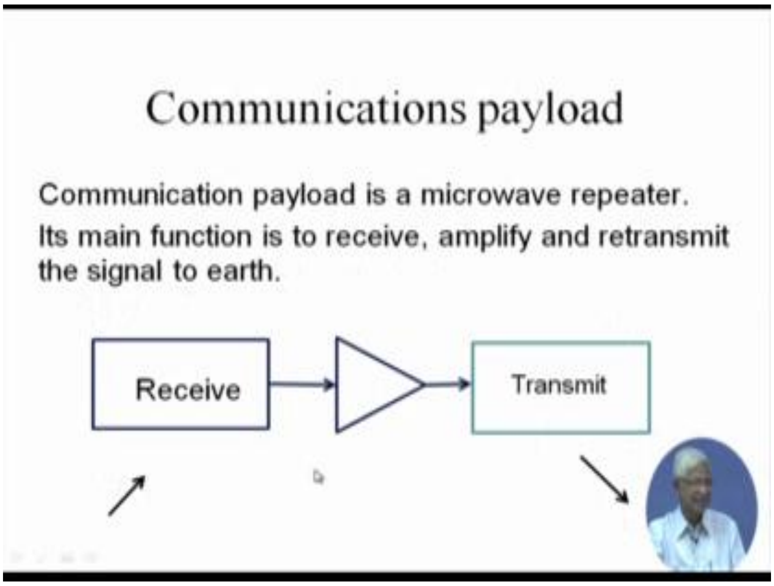

So, now let us concentrate to find out what is there in this payload. Communication payload, what is that? Communication payload we were using from the beginning. The term is a microwave repeater. Its main function then should be to receive, amplify and transmit the signal to the earth and earth was the service area. It receives the signal from the service area, amplify the signal and transmit that. That is what payload is.

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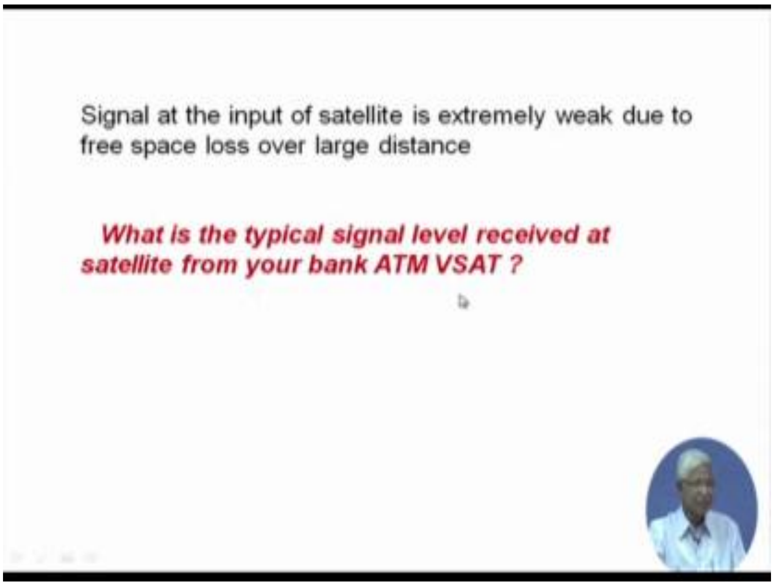

Let us see the complexity which lies inside signals are the input of the satellite, extremely weak due to the loss in the free space because of the long distance in the orbit from the ground. When the power is becoming very weak, let us do some rough calculation, very rough. It has a very correct pure calculation which has rough some numbers input. You have bank ATM and near the ATM, either roof top or somewhere near by you will find a small antenna which is looking towards some and that is called very small aperture term VSAT. We will try to learn about VSAT later when you talk about the ground system, right.

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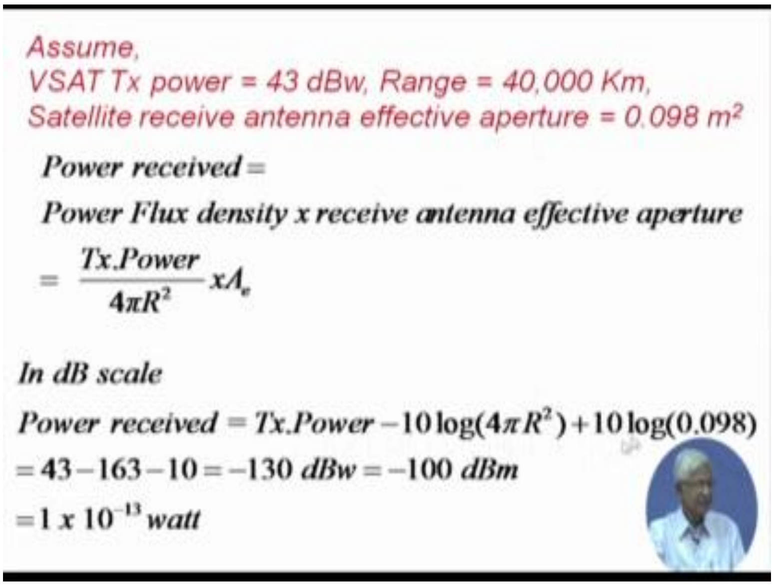

Now, let us see a typical signal level received at the satellite from your VSAT that bank ATM. Let us take some numbers. VSAT transmit power is 43 dBw and the range from the VSAT to the satellite is 40000 kilo meter and satellite receive antenna effective aperture to the size of the antenna diameters, so that it receives that aperture idea as 0.098 meter square, some typical numbers for calculation.

So, the receive power is the power flux density multiplied by receive antenna effective aperture that transmit power by 4 pi r square that will make it power flux density into the receive antenna aperture and if you put the numbers there in d b scale, the transmit power minus transmit power in d b minus 10 log 4 pi r square. R is the distance that is the range

40000 kilo meter plus 10 log 0.098 and it comes out to be minus 130 b w is 43 dBw as they address super in dBm minus 100 dBm. I mean in terms of what dBw is, if you put in terms of ratio, then it comes 1 into 10 to the power minus 13 watt. You just see 10 to the power minus 13 watt. If the level of signal even when we are transmitting 43 degree dBw, you can find out in ratio which is 43 dBw means in how many watts it is.

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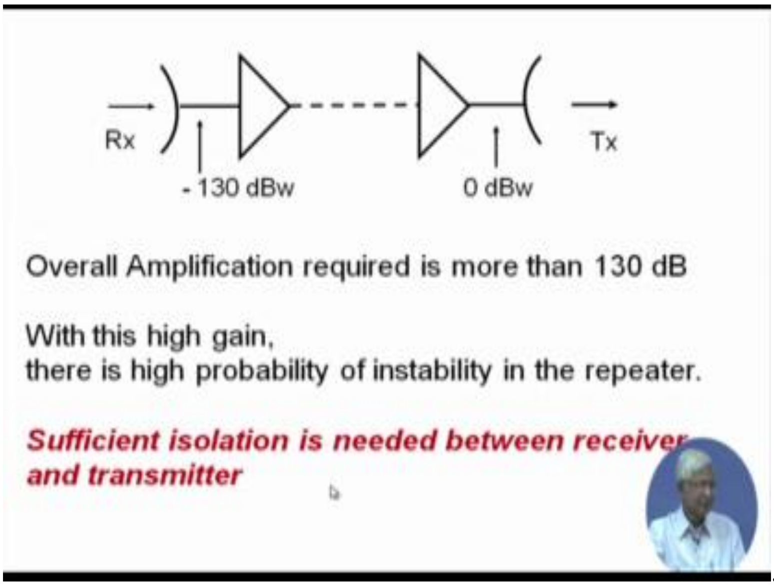

So, therefore it is a very small signal that is received. Let us go back to the diagram. So, there is a small amount of signal which is received. It is assumed that after the antenna has let us come that is minus 0.130 dBw and to make it zero dBw, its sequence to one word at put lot of amplifiers. So, instead of one amplifier put more blocks if amplifier, then there is transmit. So, overall amplification I want to give roughly about 130 dB quite large somewhere. So, there is a possibility if there is a main leakage, these amplifiers own system start with this high gain. There is a high possibility of the instability of the receiver. So, there has to be set isolation, sufficient isolation needed between the receiver and transmitter.

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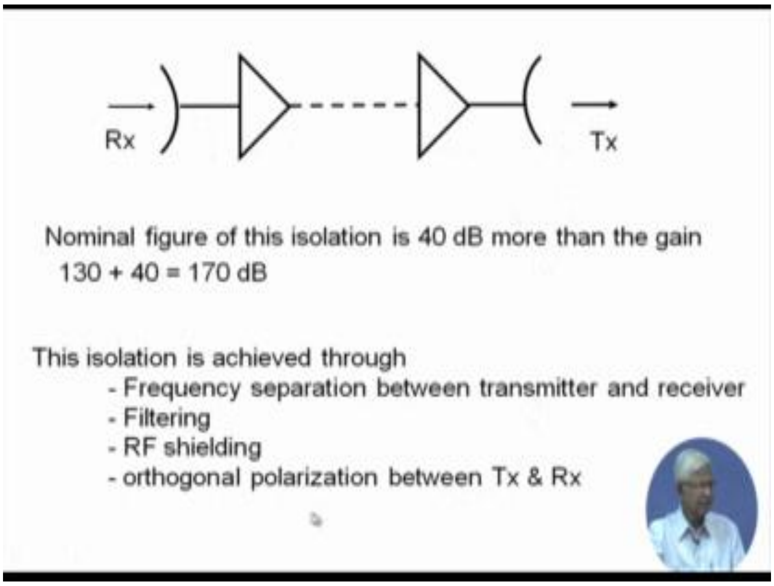

Now, this nominal figure of the isolation should be more than 40 db and over the gain. So, 130 plus 40 equals to 170 db is the total isolation requires. So, it is a very large number. So, various techniques are used. This isolation is achieved through the frequency separation between the transmitter and receiver. So, whatever transmitted frequency you are transmitting and whatever frequency you receiving, they are separated out. That means, it is not only amplifier we convert, the frequency to another frequency, then you do lot of filtering of course and then, you do RF shielding, so that transmitter power which is much higher compared to receiver input signal which is very low. So, lot of shielding is done. Also, sometimes we do the polarization, orthogonalization transmitter. Polarization part we will discuss during the antenna discussion.

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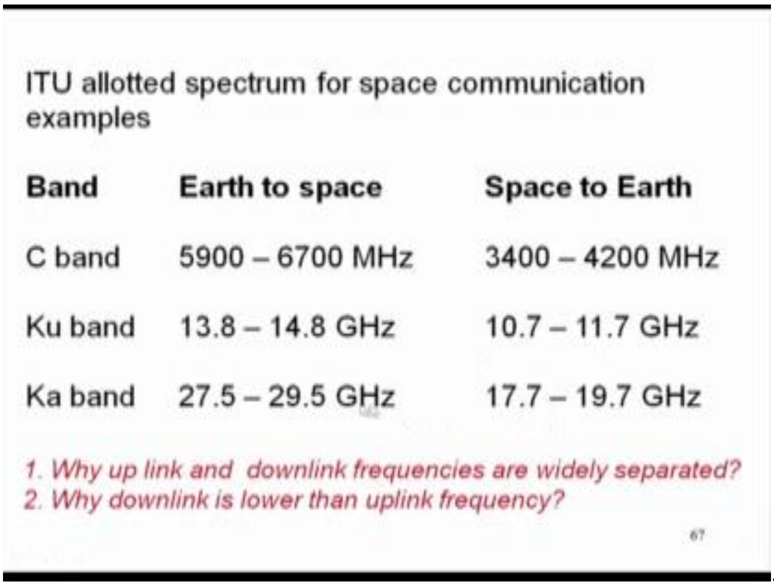

Now, let us look at the spectrum which is allotted by ITU. We have seen in earlier slides, I have roughly shown here as C band is almost 6 megahertz that is hope 5.9 gigahertz to 6.7 gigahertz is earth to space and space to earth is allotted 3.4 gigahertz to 4.2 gigahertz. In terms of megahertz, it is listed here. So, that is interaction telecommunication means they have specified and then also which is 13.8 gigahertz to 14.8 gigahertz in the uplink which is earth to space and 10.7 to 11.7 gigahertz in the down link which is space to earth at Ka band. Another trunk is 2.7 gigahertz to, sorry 27.5 gigahertz to 29.5 gigahertz and 17.7 gigahertz to 19.7 gigahertz. You can see that have C band, we have a band with much lower compared to Ku band. You have almost 1 gigahertz band with Ka band, you have almost 2 gigahertz and allotted is not a contiguous band. You can see there reflection in that, but this is the rough certain things from this table.

Look at it very carefully. Do you see that the uplink frequencies are always higher than down link frequency? So, why up link frequency and down link frequencies are widely separated only is that question and there is why the down link frequency is lower than the uplink frequency. You should find out the answer from the books please. It is very interesting.

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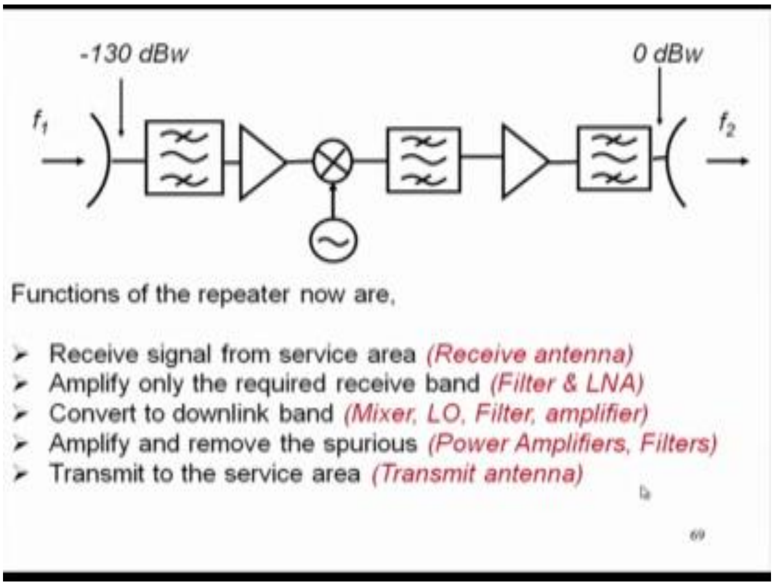

Let us go back to the payload. So, we have minus 130 dBw. Obviously, we have put lot of filters amplifiers and we have to change the frequencies. So, we have to have mixer and down link frequency is lower which is f2 is lower than f1. So, it is down converted again filter, again amplifier and you put and see lot of filter coming. So, each of them can be put into different sub systems.

The functions of the repeated now that is put definition and then, will go to the sub one is received the signal from the service area. So, you need a receive antenna and then, amplify only the required receive band by means in many things based on the antenna capacity, it is receiving many signals. Out of that only the required band has to it. So, there has to be certain filter and since the signal is very weak unit low noise amplifier, then convert that to a down link band. So, there has to be a mixture local oscillator and filters and amplifiers also and then, amplifier and remove the spurious that is power amplifier and filter and then transmit it to this service area that is the transmit f2 in through the transmit antenna. So, these are the basic functions.

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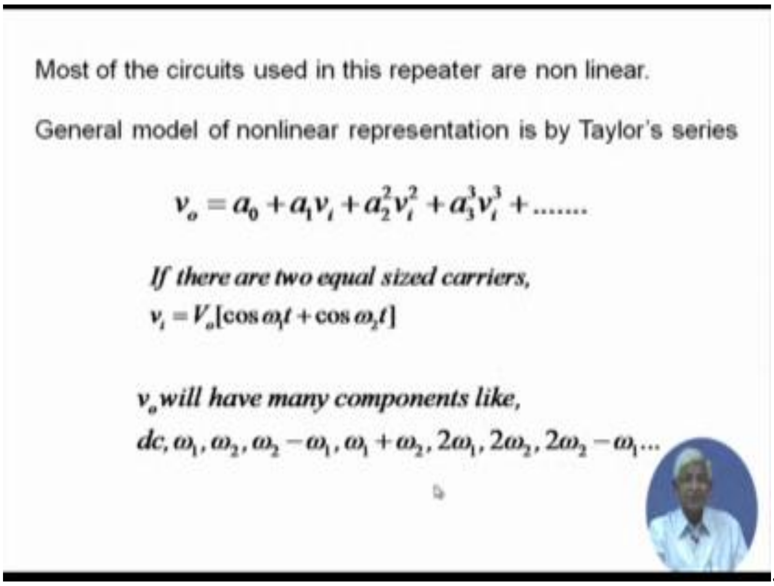

Let us see each of this. Most of the circuits are non-linear. One thing you have to see very carefully. The general model of a non-linearity can be seen by Taylor's series like v 0 is only non-linear. V zero is equal to 0 plus a1 v i a 2 square or a2 v i square or a2 square, a3 cube v i cube that is etcetera. So, if v0 is the output that is result in voltage depends on the input voltage, input voltage square, input voltage cube v i v i square v i cube and multiplied by certain coefficients. Now, if the inputs are two frequencies like v i is v0 cos omega 1t plus cos omega 2t possible because may be people are communicating with this satellites. So, at least minimum two should be there. So, two frequencies omega 1 and omega 2 communicating and then a is replaced in this Taylor's series. Wherever v i is there, v i v i square v i cube replaced into v 0 cos omega 1 t plus v 0 cos omega 2 t article. Both the signals are of same amplitude v zero and then may not be same for simplicity we have taken this.

Then, you will find that there are many frequency components that arise. One is of course the dc a is 0 part, then the omega 1, omega 2, two fundamental parts and then omega 2 minus omega 1 omega 1 minus omega 1 plus omega 2, 2 omega 1, 2 omega 2, 2 omega 2 minus omega 1, 2 omega 1 minus omega 2 like that will continue. So, many frequencies are generated to this non-linear. There are some advantages and disadvantages.

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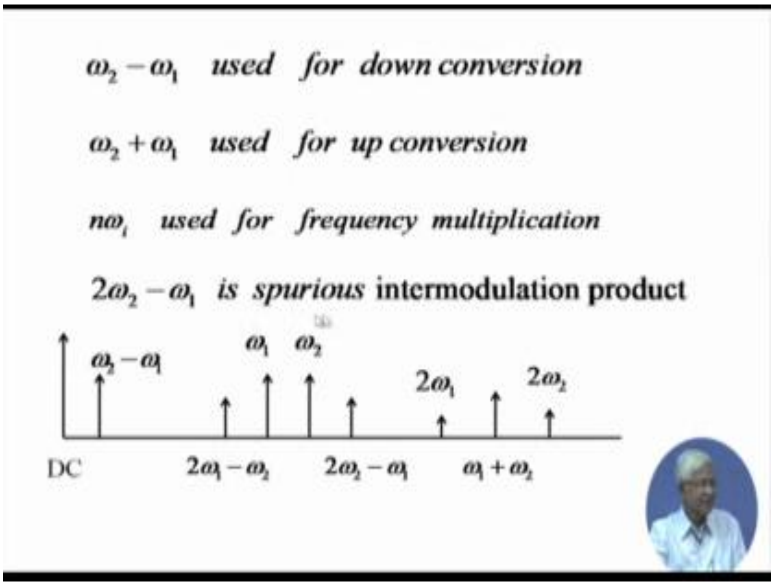

Let us see the advantages and try to find out. So, if there are two frequencies omega 1 and omega 2 in the frequency plot and if you are d c, something will be generated. Omega 2 minus omega 1 will be generated very near to d c and then, 2 omega 1 minus omega 2 and 2 omega 2 minus omega 1 generated near to omega 1 and omega 2. It is two fundamental, 2 omega 1 and 2 omega 2 will be generated far away and then, there will be true only omega 1 plus omega 2 another carrier one.

So, like that many I can see spurious signals generated. Omega 2 minus omega 1 can be used for down conversion input frequency and local accelerated frequency can be used. Omega 2 plus omega 1 can be used for up conversion n times omega i. Let us say omega 1 or omega 2 that is 2 omega 1 or 2 omega 2 or 3 omega 1, 3 omega 2, this kind be used for frequency multiplication. 2 omega 2 minus omega 1 is spurious inter modulation product which can be appeared very near to the fundamentals. There may be many other inter modulation products. So, like that each of them each of the frequency component has been used. We will try to use them.

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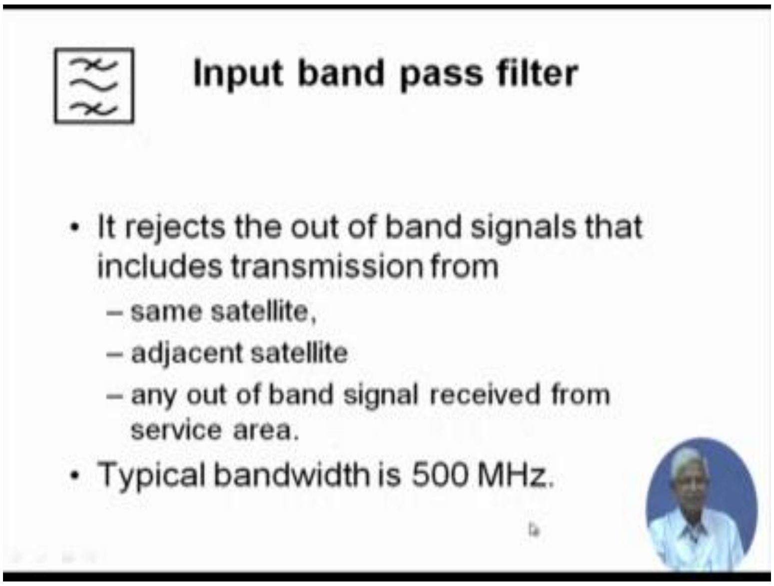

Let us go back. So, we have after then to input band pass filter, it rejects the out of band signals that includes the transmission from the same satellite and adjacent satellite and any out of band signal received from the service area, same from the same satellite, it can come because spurious are generated that can be feed from the transmitted receiver. Adjacent satellite might be using some of the signals which are out of band which is received by the antenna out of band signal from the service area. Somebody else is transferring which is coming as interference. All these things and we filter out which out of band and typical band width of c omega at c band is about 500 megahertz and mega based on the allotted. So, the input filters are of that size in Ku band Ka band.

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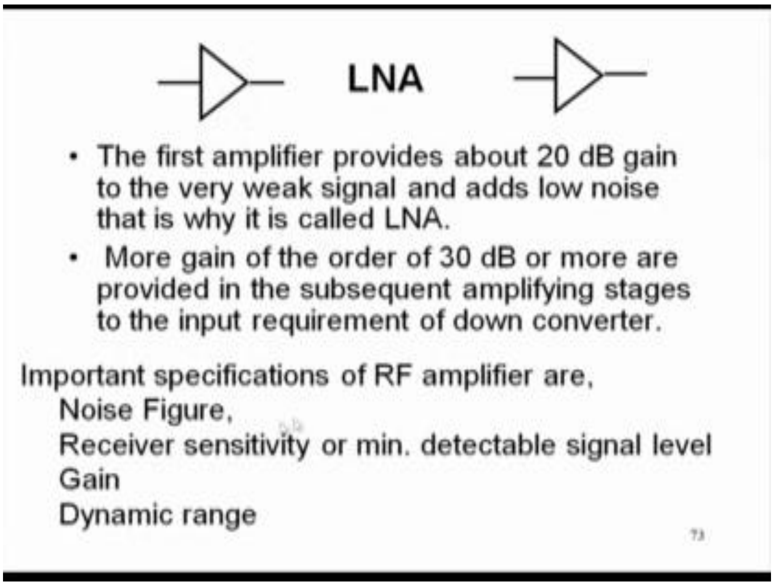

May be it has different man with them and there is an amplifier which is l n a same input signals is very small, very low, very week. So, the first amplifier generally about 100 times, k n is given that is 20 dB gain which is very signal and then, it should not add much of a noise. So, it is low noise will discuss about the noise much later. So, that is why it is called low noise amplifier. The first amplifier has to be no noise amplifier, but is giving smaller gain. So, we have to put additional gain that is more gain of the order of 30 dB or more are provided subsequently amplifying stages to the input requirement of the down converter even to down converter of to this.

So, input requirement of the down converter and each certain level, therefore output more amplifiers and typical specifications for these amplifiers are noise figure. We will discuss that one later. Receiver sensitivity that is minimum detectable signal level at the input, the gain and the dynamic range, there are many more specific and these are certain important specifications of this l n a and subsequent RF amplifiers.

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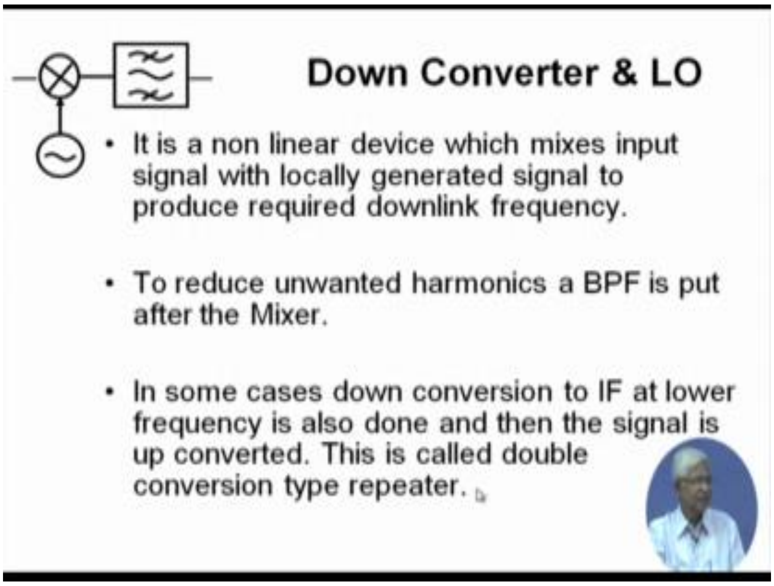

After that way there come across the down converter and local oscillator. It is the part of the down conversion local oscillator mix and filter. It is non-linear device which mixes the input signal with locally generated signal to produce required down link frequencies. You have seen omega 2 minus omega 1 and then, to reduce unwanted harmonics, a band pass filter we put after the mixer and in some cases down conversion is to another IF instead of directly to the transmitted frequency. Another IF at lower frequency is done and then signal is up converted is called double conversion type repeater. You are aware of this type of thing in your bit classes you have seen.

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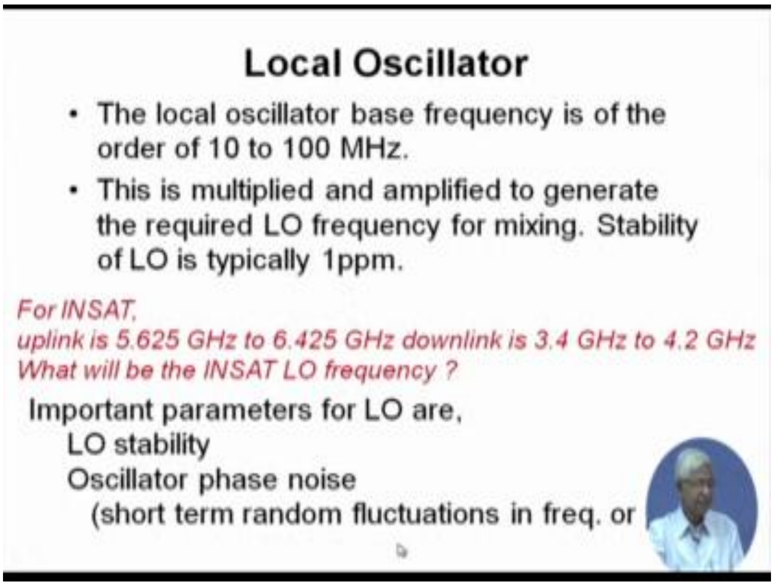

Local oscillator is generally its stable oscillator. So, it is at much lower frequency 10 to 100 megahertz and then, its multiplication that n omega 1 non-linearity is used. This is multiplied and amplified to generate the required LO frequency that is local oscillator frequency for mixing stability is important. It is roughly of the order of the one into the power 6 which is one part per million. Here I ask you question. There is a band for INSAT satellite. The uplink band is 5.625 gigahertz to 6.425 gigahertz done and down link band is there 0.4 gigahertz to 4.2 gigahertz. It is a band. What will be the INSAT LO frequency which converts the whole bunch of the input signal converted to the output signal which is down link? Now, this we have to solve the problem is to find out, it is very simple. Now, important parameters for the local oscillator are the stability.

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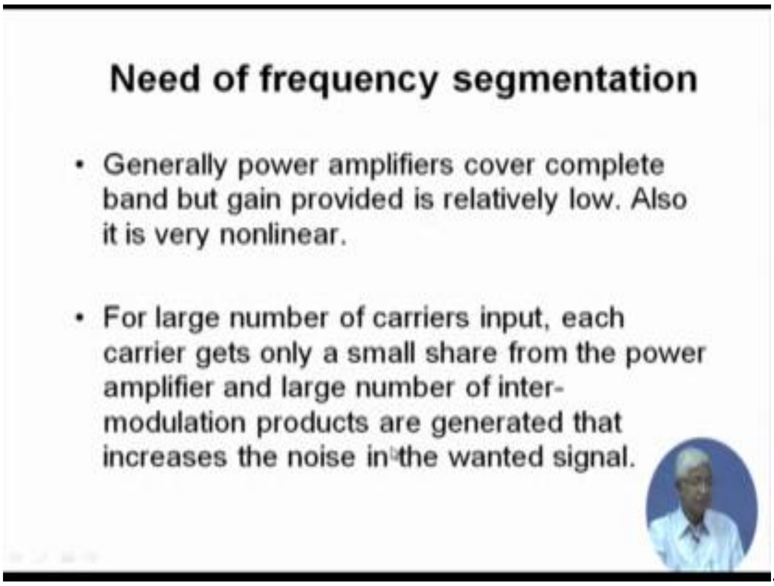

The oscillator phase noise which is nothing, but a short term random fluctuation in frequency or phase. Now, we have to see the total frequency band. We said 500 megahertz that needs to be segmented; it is a need for it. Generally the output amplifier, power amplifier covers the complete band. It is a white band amplifier, but the gain provides relatively low and of course you have to give maximum power. So, you have to drive it to the maximum saturation. So, it is non-linear. So, therefore many spurious will be generated. So, for large number of carriers as input carriers, input carriers means different users there sending signals. Each carrier get only small share of the total power given by the amplifier and the last number of inter modulation products also will be generated which will act as a noise.

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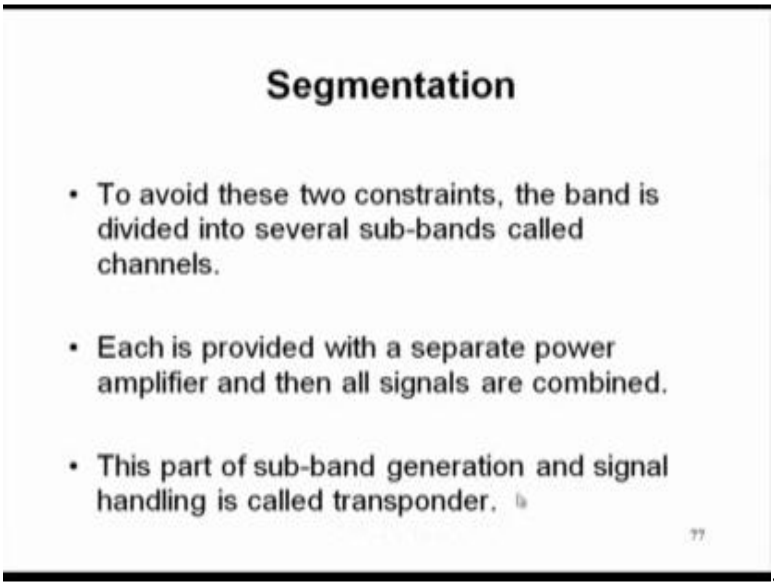

So, therefore these two problems of lowering getting individual carrier is lower power as well as getting node noise. If you take in each amplifiers, small number of carriers and then some them of later that could be one solution, in that case each carrier in each of the amplifier will be having much larger power. So, the band is then divided into several sun bands which you call channel. Each is provided with a separate power amplifier and then, all signals are combined. This part of the sub band generation and signal handling is called transponder. This is the terminology we are using from the beginning. So, here it is coming.

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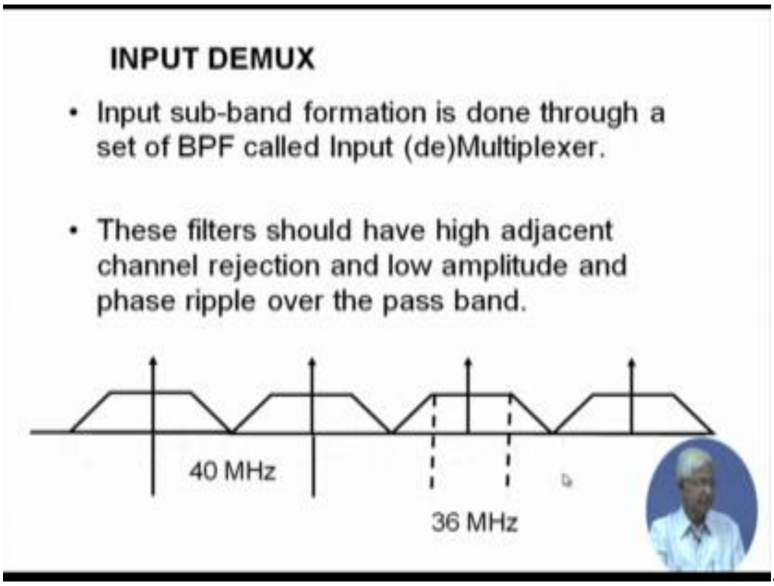

So, once you try to separate segment, you need separate filters. So, sub band formation is done by de multiplexer which is nothing, but band pass filter, bank of band pass filter. These filters should have high adjacent channel rejection because they are continuous. Low amplitude and phase ripple filter phase and amplitude ripple should be low over the pass band. So, the whole frequency band which is available is now here I have shown which is divided by 40 megahertz segment and since the filter characteristics are gradually increasing and then study and then decreasing. So, therefore the study part is taken roughly as 36 megahertz, the constant amplitude. So, there transponders are each of them at 36 megahertz wide roughly generally that is general I should not say sun rises generally is expected by industry.

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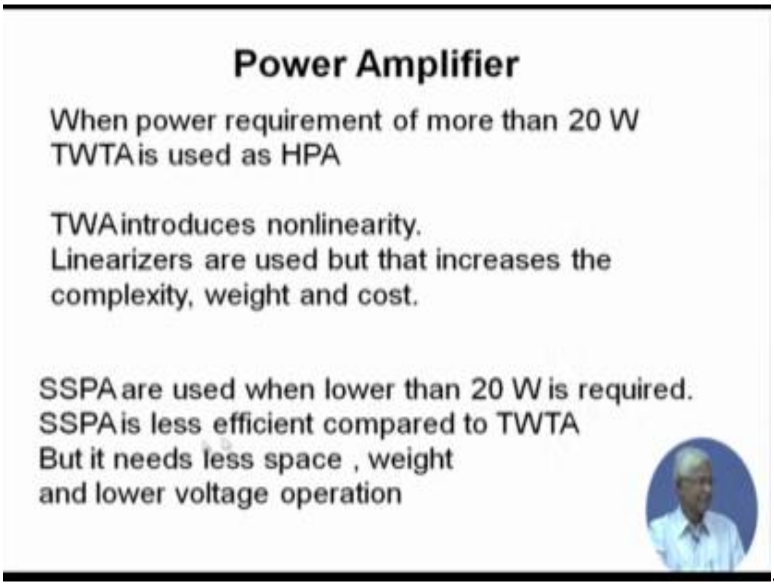

Then, the power amplifier when power requirement is more than 20 watt TWTA amplifiers at used as high power amplifier which base high power amplifier TWTA is have lot of non-linearity. So, there has to be linearizers that are used and we will discuss that one much later. What is non-linearity, their effect, but this linearizer increases the complexity weight and cost etcetera and solid set power amplifiers are used when the power is less than 20 watt. These are all typical numbers, may be 40 words are attempted available now a days.

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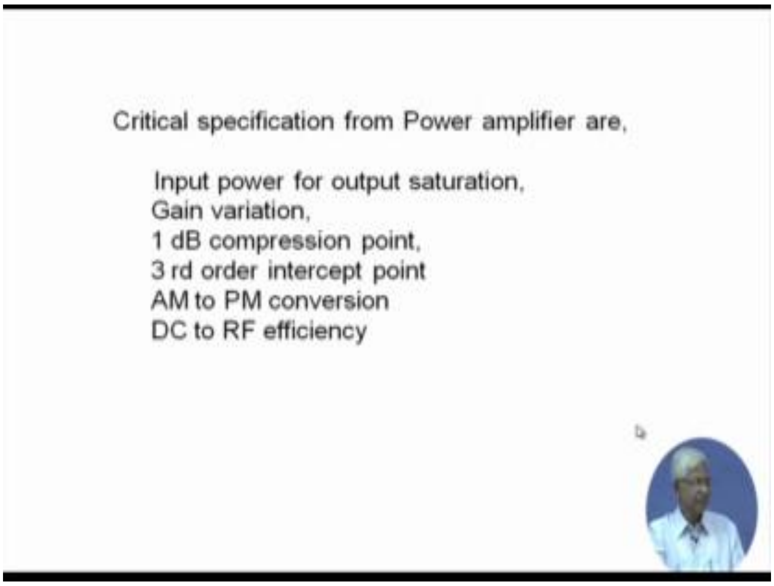

SSPA is less efficient compared to the TWTA that is conversion efficiency from DC to RF, but it means less base and rate and weight and lower voltage of operation. So, for lower product operation is SSPA preferred in this critical specification from the power amplifier is input power for output saturation. How much input power will give the output saturation that is we find in the non-linearity. Non-linearity or 1 dB compression gain variation compression point third order intercept point amplitude modulation to phase modulation AM to PM conversion. These are also part of non-linearity. We will discuss those things later DC to RF efficiency conversion efficiency.

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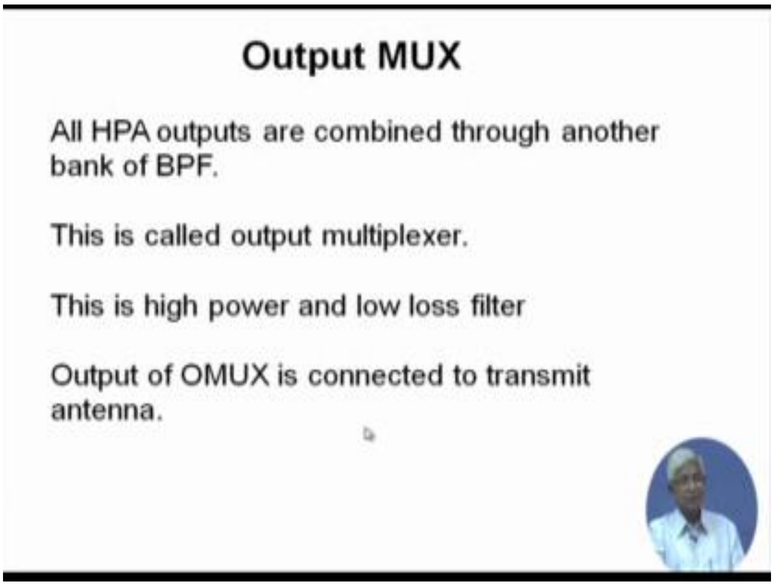

Then, each of these amplifiers output has to be combined again. So, we call another multiplexer which is output multiplexer or which outputs are combined through another band of band pass filter. This is called output multiplexer. These band pass filters are difficult to design because it has to handle high power. They have already power amplifier has been put, this is high power and low loss filter and output mux or OMUX is connected to the transmit antenna.

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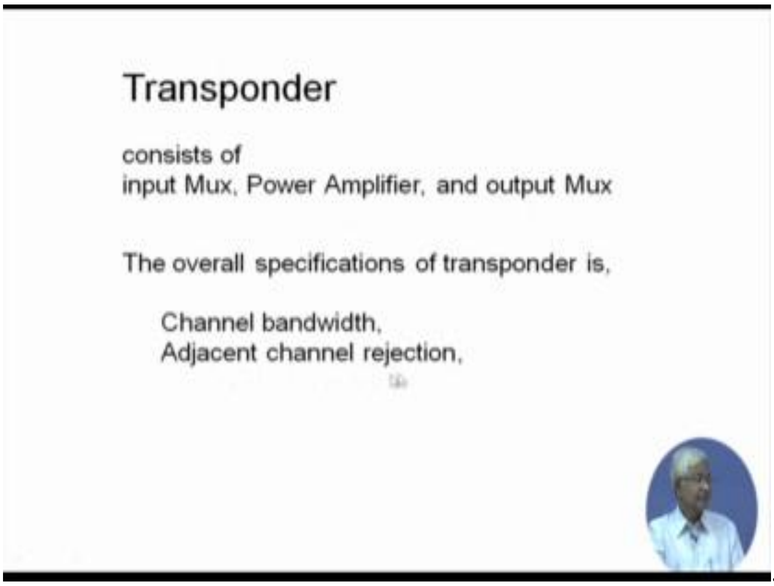

So, a transponder consists of input mux, the power amplifier and output mux and the overall specification of the transponder is channel band width adjacent channel rejection group delay.

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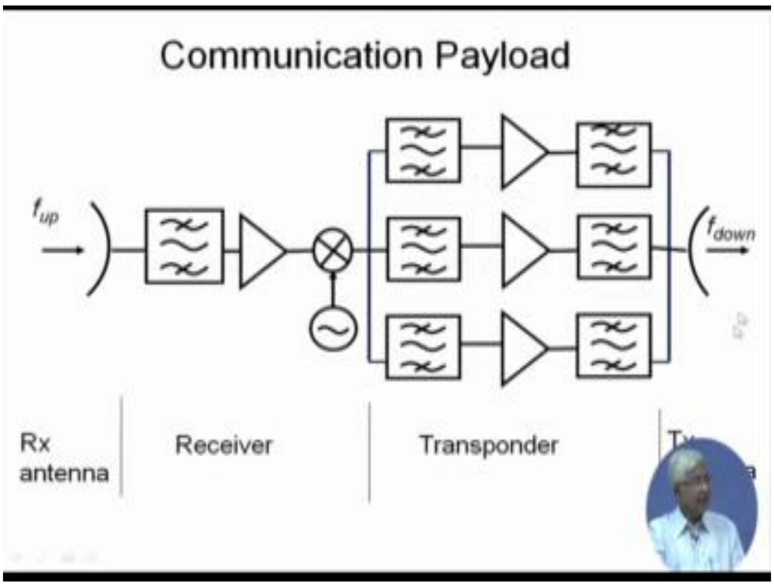

I can draw the picture. Now is the uplink frequency which is coming as it is see antenna and then the receiver is nothing, but the input filter and then, known has amplifier and then down converter. Of course, there is a filter here and after the down converter at that input mux which is de-muxing actually taking place and then amplifiers. I have shown one amplifier and then, output mux which is combined called transponder and then, the transmit antenna which is going as a down link.

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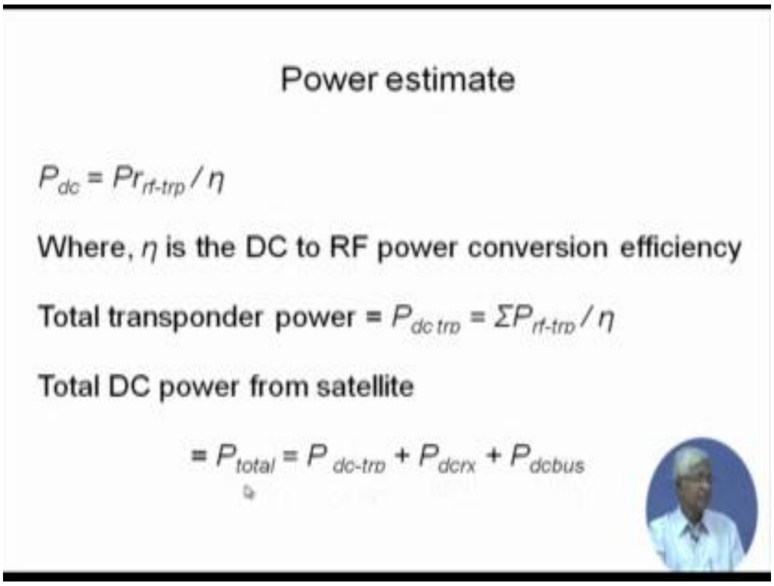

Now, you can do some quick power estimate DC power to RF power is by the efficiency. DC power multiplied by the efficiency or RF power divide by the efficiency is DC power. Now, from when there many transponders RFTRP, then it is some of RFTRP is the total DC power required by the transfer. This is where the higher part of the power which goes, but there are other devices or other circuits which are drawing the power that is receive the power by the receiver power by the bus system. So, all together it is a total power required by the satellite.

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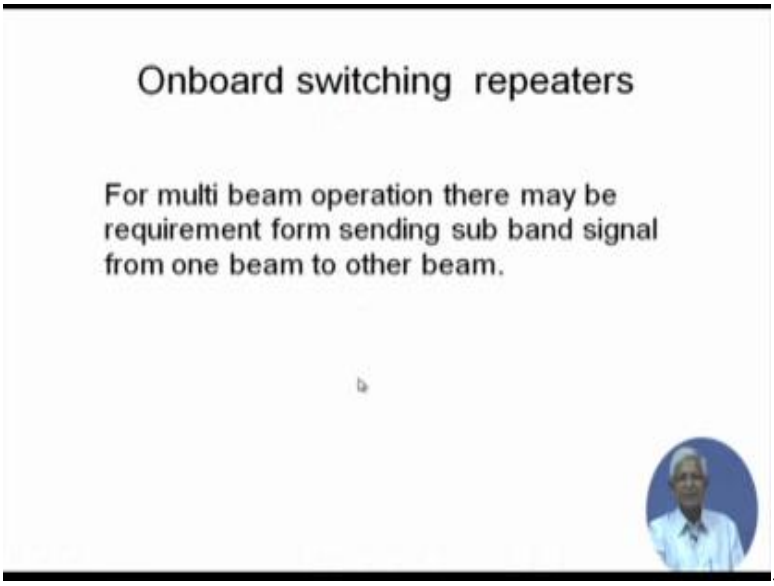

Now, this what you described as a simple conversion of the frequency is called bent pipe or transparent transponder, but in some cases move complex transponders I used which is having on board switching capacity. We will start discussion on this in the next class, right.

Thank you very much.