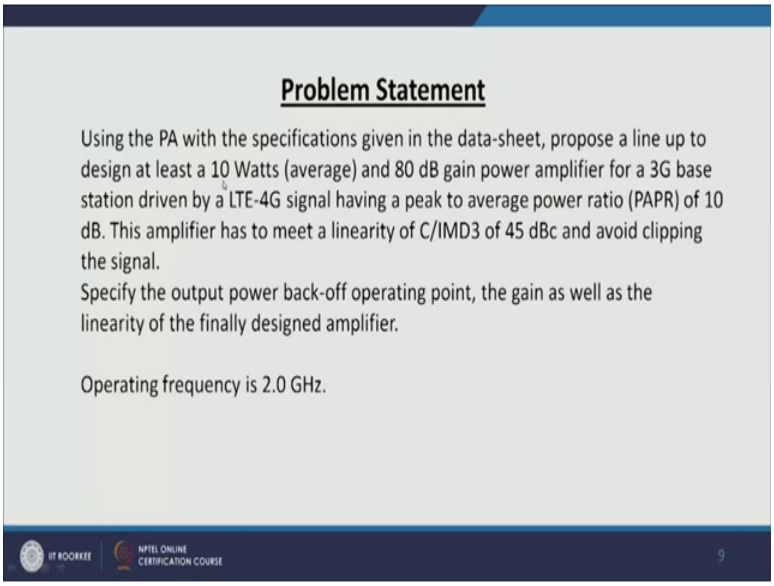
Basics of software-defined radios & practical applications
Dr. Meenakshi Rawat
Department of Electronics & Communication Engineering
Indian Institute of Technology, Roorkee

Lecture - 14
Case study-II: Power amplifier Line-up for linearity & power requirement: Need for linearization techniques

So, in the series of basics of software defined radios and practical applications, we were discussing power amplifiers, how to select the power amplifiers? And today we will discuss the power amplifier lineup, for linearity and power requirement calculations. So, yesterday we have studied, this problem statement we had to design a PA system, p assembly.

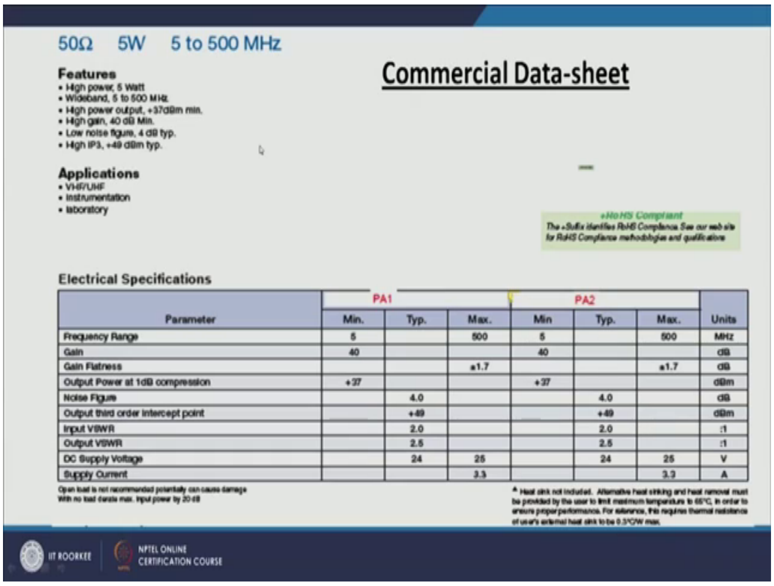
(Refer Slide Time: 00:43)



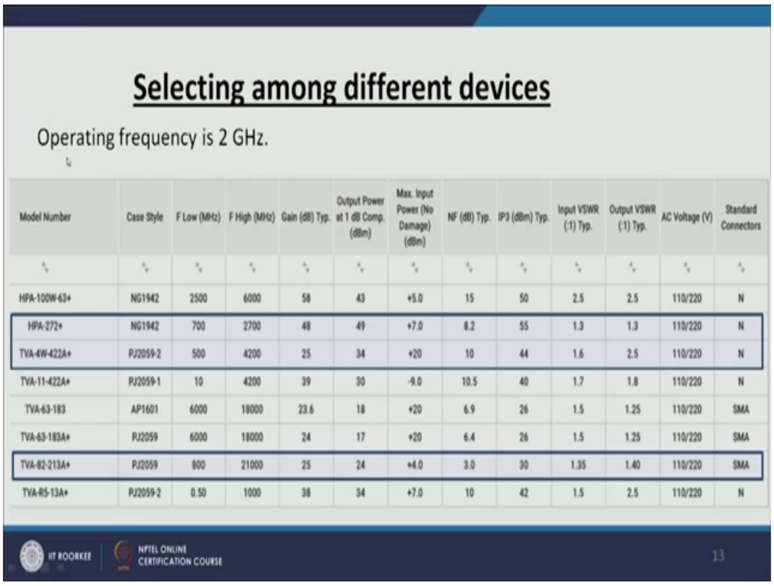
So, that we can achieve at least 10-watt average and 80 dB gain at the output of the this, assembly and the PAPR of the signal, which was a LTE signal was 10 dB, and we have to meet the linearity criteria of C by IMD 3 of 45 dBC and we should be able to avoid the clipping.

Now, after that we were supposed specify the output power back off operating point gain, as well as linearity of the finally, designed amplifier assembly. Yesterday we had done this exercised, by using the power amplifier, with the particular given a particularly given specification and these were this specification, now today we will discuss, how we can select among different power amplifiers. So, in the previous lecture, we didn't have any choice, we were just given 1 amplifier and we had to design based on that.

(Refer Slide Time: 01:31)

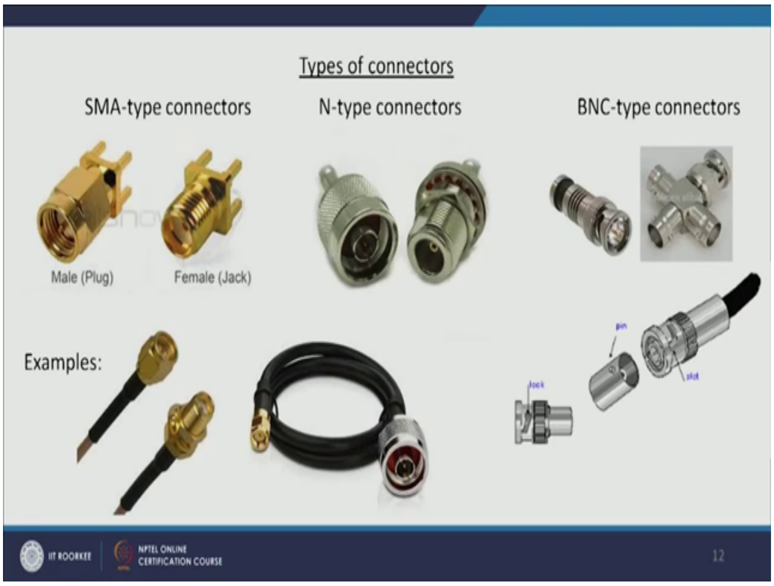


(Refer Slide Time: 01:35)



Now, today we have number of devices, among which we can select, I have taken this sheet again from the mini circuits and as you can, see we can see the model number then we can see the frequency range gain P1 dB maximum input power without damaging it, IP3 value and because, we are given the P1 dB, from IP3 value we can actually see that, which one is the most linear among this, apart from that we are also given the voltage and current values and based on those values, we can have some idea about the DC power consumption.

(Refer Slide Time: 02:23)

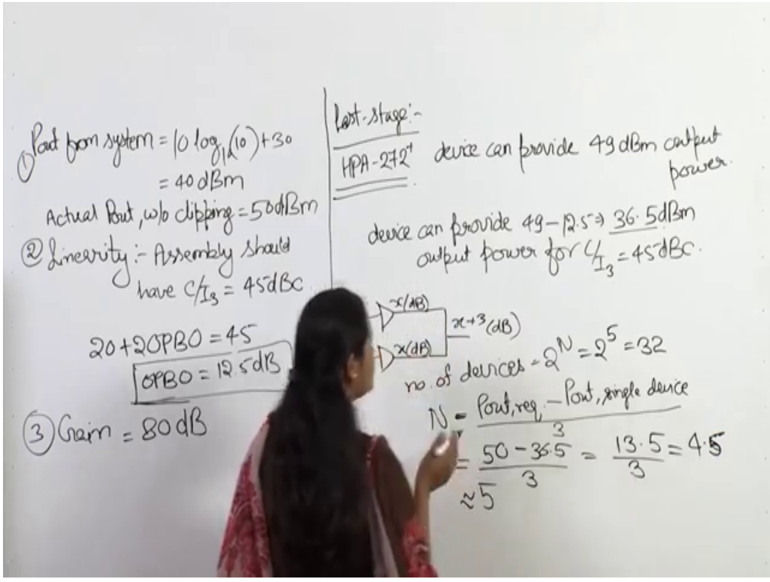


Now, in this sheet you can also see that there showing connectors, N N N N SMA and N. So, let us quickly go through the different types of connectors. These are different type of connectors SMA type connectors, these kind of connectors and they are known as male or plug, and female or jack type of connector. Another type of connector which can support high power are N type connectors, this is the picture of N type connector and these are BNC type connectors, this kind of connectors, they have a slot where you can actually put the pin, and then you can turn it around and it will be locked into this small slot.

So, this BNC type connectors can be used to, actually divide signal into different paths or combined signal. So, for example, into this kind of BNC type connector you can add 3 of this connectors and, if you break the signal which is coming from this path into these 3 paths. Now, these kind of connectors can be soldered, at any equipment or they can be soldered, at the end of particular cable and based on whatever is required you can select this connectors. So, if you go back and look at this, we can see here that initial 4 hour using N type connectors.

So, in that case you should have cable, with a N type connector handy. So, that you can actually attach, those power amplifiers with your system. Similarly, 3 of the devices they are using SMA kind of connectors, which are these kind of connectors. So, your cable end should be like this, to receive or to sand data to this kind of devices. So, these are different kind of devices and their values are given, now we will again go through our original problem and which was designing a power amplifier.

(Refer Slide Time: 04:18)



So, let us note down our key ideas. So, first of all Pout from system. So, yesterday we have calculated that 10 watt, should be equal to 40 dBm and because we are using a signal with 10 dB PAPR; so we should be able to provide the signal without clipping it. So, if this is the average power then to (Refer Slide Time: 04:51) out the peak of 10 dB the actual Pout, without clipping would be 50 dBm. So, this is the output power requirement.

So, first requirement is this, second linearity requirement, at the output assembly should have C by IMD 3 ratio of at least 45 dBC and how this criteria was affective there? Because this was the C by I ratio we have to maintain. So, we have to work at a particular power back off, for our small sorry for our solid-state power amplifier. So, what was the formula, 20 plus 2 times OPBO was equal to this C by IMD 3 ratio.

Now, this particular formula which is applicable to all SSPA, it gives us them idea how we can take our output back off according to this, our OPBO was coming out to be 12.5 dB. So, whatever is the output power we can get from any device, our device has to work 12.5 dB lesser power than, what we can get from the device actually. So, this was the linearity requirement and third requirement was gain. So, we should be able to get 80 dB gain from the system.

Now, if you look here, today we have added one statement operating frequencies 2 gigahertz. So, let us starts choosing our component based on that, first of all our operating frequencies 2 gigahertz. So, it should our frequency range should be able to cover that frequency, based on that among all these devices, we have selected these 3 devices, because other devices are from 2.5 gigahertz to 6 gigahertz, which is beyond this again this, 3 can be the part of this one from 6 to 18 is away and again this is lower then, what we have require. So, this, this, this and this actually 4 devices are there which are full filling the criteria which we require.

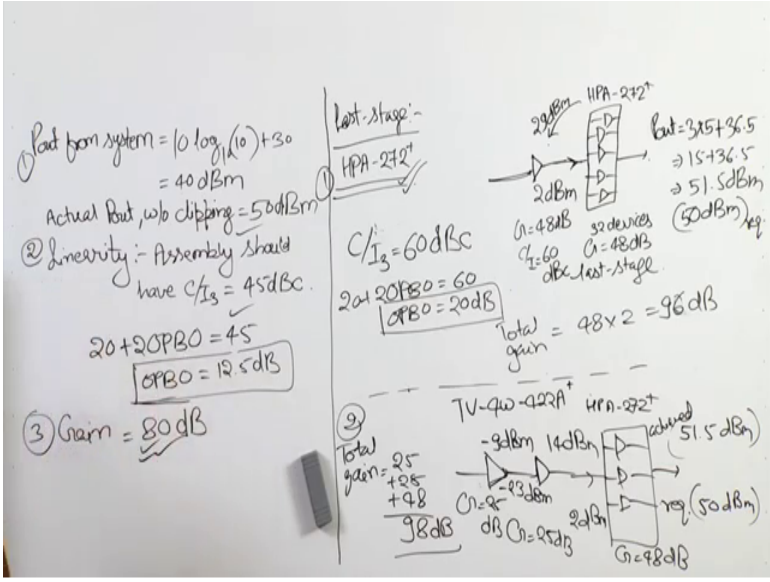
So, keeping this in mind, now these are the 4 devices which we can play with. So now, let us start our calculation, and how do we start? First of all, we have to maintain this output power back off, but at the same time we need total output power, to be 50 dBm. So, that we can avoid clipping. So, because you want this power, which is a very high power. So, we have to choose device which has very high P1 dB. So, if we look here this device HPA272 plus, it is having highest P1 dB with respect to the other available components. So, let us choose HPA272 plus for the last stage.

So, design of the last stage, HPA272 plus has been chosen now P1 dB point here in this cases 49 dBm. So, device can provide output power at 1 dB saturation, this is the definition of P1 dB point, but because we have to drive our signal at 12.5 dB back off. So, that you know we can avoid the clipping, device can provide 49 minus 12.5 which is 36.5dBm output power, for C by I 3 ratio of 45 dBC which is required.

So, this is the power we can get, from one device, in the last lecture we also discuss that when we have some of the these devices, how we can do the calculation of number of parallel stages. And we have discuss then when we add 2 devices together, and they have x dB power value then, there combination gives you x plus 3 dB power. So, based on that we have calculated formula, that number of devices should be 2 to the power N, where N is given as output required, minus power output from single device, divided by 3.

So, we will use this formula here, we need 50 dBm here and our single device can provide us 36.5only. So, N is coming out to be 4.5, now N cannot be fraction. So, we will take it to be equal to 5. So, the total number of devices will be 2 to the power 5 or 32. So, for the second stage basically, we have to put all this power amplifiers 32 power amplifiers in parallel and then we will get our Pout, which is more than 50 dBm.

(Refer Slide Time: 12:23)



Now, if you see here we have then one approximation from 4.5 to we have taken it, to be equal to 5. So, because of that our output power will be something different so, but the last stage, which is combination of many parallel devices. What will be the Pout, which it can take the formula again take from here, Pout from the single device, we bring it here plus 3 times N and N is coming out to be 5.

So, it will be actual Pout, which we can get from this is; so 3 into 5 plus the input power which is 36.5. So, our requirement was, that our device should be able to sustain 50 dBm and with our calculation, we have arrange our assembly which able to give us 51.5 dBm output power. So, it is allowing us more than 50. In fact, so, it is the last stage. So, we have use 32 devices here, now if you look at the gain of this particular device the gain of this particular device here is 48 dB. So, gain is 48 dB and based on that, how much power do we require here, at the input of this one that will be actually 50 dBm which was required minus 48.

So, 2 dBm; so please note that it was the required and with respect to required, we are doing all the calculation what we actually got, we are not calculating with respect to that, because it is margin, which we have living here. So, 2 dBm, we want here if you calculate with respect to 51.5 we will get, I think 3.5 dBm, but it is possible that in some of the scenario, it will load some of this power amplifier. So, we will keep our calculation of with respect to 50 with that it will keep working on back off, now last stage is define decided, now we are talking about the previous stage to that one.

Similar to last lecture, if 45 dBC both our requirement for the last stage, it is previous stage should have much relax requirement, as compared to 45 dBC. So, this stage C by I 3 ratio we always assume to be very high. So, let us say it is 60 dBC, and we have why we are taking this much high linearity requirement, because the assembly which we have going to connect before they should be linear, otherwise it will load that assembly also this why I have discussed in the last lecture to.

So, we have selected this much. So, according to that, what should be the OPBO again let us do the same calculation and OPBO should be equal to 20 dB here, now whichever power amplifier we choose, and whatever power that amplifier can give, we have to work 20 dB back off from that. So, let us select our next power amplifier and that amplifier, should be able to give us 2 dBm or more than 2 dBm. So, that whenever we apply, our power amplifier does not burn it is able to provide this power.

So, if you look here, now this requirement is quite low, if we choose HPA272 which has 49 dBm Pout at 1 dB compression, we can use this one also we can use this one also, because if I put minus 20 here, it will give us give you 40, I can never choose this one it will give me 4 dBm. So, any of those can work now. So, let us choose the first one, if I choose the first one then, again using the same device it was HPA272 plus and it we were use 32 devices here, and now I use single same device here, the gain is again 48 dB and it is providing 49 minus 20; so 29 dBm here although we required 2 dBm.

So, here well beyond our boundaries. So, it is good to have this here. So, it is 2 stage amplifier basically, with only this single device. So, for this one, what will be our total gain total gain will be summation of these 2 gains it will be 48 into 2. Total gain 96 dB, our C by I ratio is maintained easily, because we have done the calculation at the output for that. So, C by I ratio is actually 45 dBC and C by I ratio for this stage will be 60 dBC, and OPBO for this stage was 12.5 and for this stage it is 20 dB.

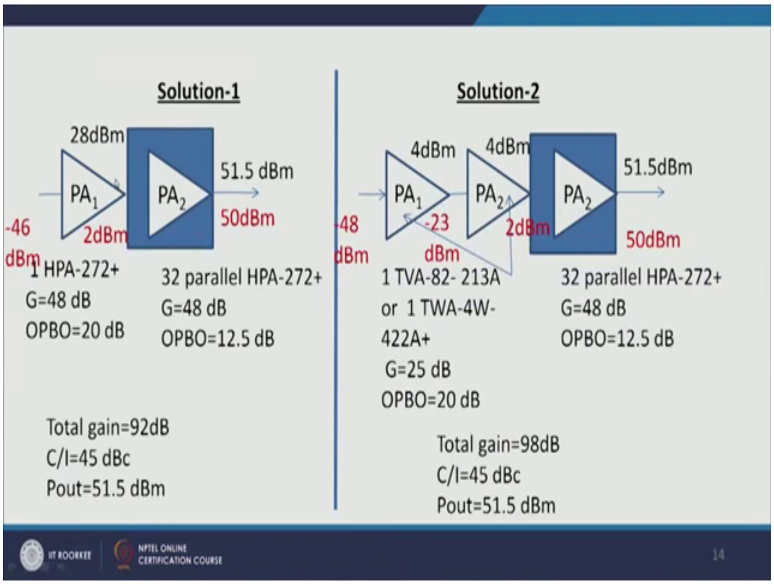
So, this is how we design by using this stage, now we can do we can use another device also for example, I choose TWT 4W 422 A plus in that case 34 minus 20 which is 14. Now, solution one second solution can be same assembly here, for the last stage which is calculated for both the solution HPA272 plus , we are talking about solution 2 here and we are getting we want 50 dBm and we are getting 51.5 dBm, which is better than this. So, it is good. So, it is required one and it is achieved.

Now, here we required 2 dBm, because of it is gain which was 48 dB, now the selected device here, we can use single of that device also which is TV 4W 422 A plus, now this one has a gain of 25 dB and we need 2 dBm, but we are getting 14 dBm which is above this. So, it can stand this much easily. So, it is good to have it here, now in this case if we do the summation of these 2 stages, 48 plus 25, we are getting 73 dB gain, but we require at least 80 dB gain. So, this alone is not sufficient.

We have to put one more, stage before this. So, that we can at least qualify our gain criteria there. So, let us put the same device here or we can put another one it has 25 dB gain. So, if I do the subtraction between this 2, it will be minus 9 dBm according to this one and from here, it will be minus 23 dBm, this one will again have gain of 25 dB. So, total gain will become 25, plus 25 plus 48. So, 98 dB will be total gain in this solution.

So, as you see by selecting different devices, you will have different, different solution. So, first requirement is 2 qualify your criteria of Pout, of linearity and gain and once it is done, then you can select your device based on the cost of each of these devices. So, the cost is not reflected here, but in actual life, when you are dealing with your making a setup you can select you this device is based, on your cost value also. So, this was the example when you can use different devices and this is where, we are showing some calculation, for this kind of solution.

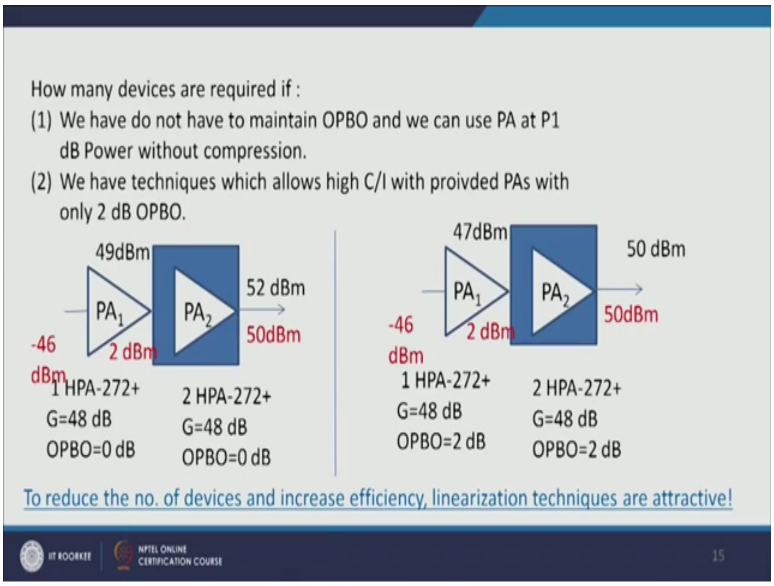
(Refer Slide Time: 21:48)



So, one is when we are using the both HP of 272 plus in the most stages and the second one, when we can use any of the other 2 solution either this device or this device both of them has 25 dB gain.

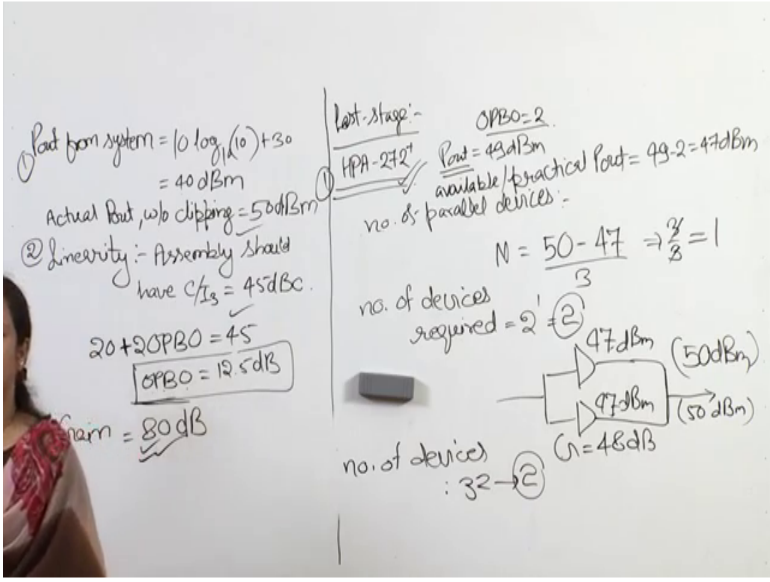
But they have different P1 dB powers here. So, based on this we could have done this. Now, this not the only solution you can mix and match and get other solution, only for though output stage, you see we always have to select highest P1 dB point, otherwise number of device will increase, like we have a discuss with the last lecture.

(Refer Slide Time: 22:40)



Now, once we have seen the assembly of all this. So, based on this. Let us reflect on 2 cases what will happen and how many devices will we require, if we do not have to maintain output back, power back off and if we can use PA at P1 dB power, without compression, what does it mean actually these are the requirements we want. So, 50 dBm we required and initially, because we have to take the power output power back off of 12.5 dB our HPA272 plus, which was able to give us the Pout of 49 dBm.

(Refer Slide Time: 23:08)



We were only using 49 minus 12.5 dB for the calculation, because you have to maintain this C by I 3 ratio, but now we are told that, we do not have to maintain output power back off. So, what does it mean? It means when that calculating number of parallel devices, in output assembly N can be calculated as 50 minus output of the device itself, which is 49 dBm divided by 3, it will be 1 by 3 and it will be approximated to 1, to make it a integer now number of devices required, will be 2 to the power 1, which is only 2.

Now, if you look at this and we compare this, with our previous case, we were requiring 32 of such devices, when we required that output power back off of 12.5 dB. Now when we do not require any output power back off, we can use all the P1 dB range, we actually required only 2 of these power amplifiers in parallel. So, with only 2 power amplifiers in parallel, which are giving us 49 49 dBm, we are actually getting 52 dBm output power this by you by using 2 amplifiers.

Now, it is what we are achieving and what we require is 50 dBm, now based on that we can do our next calculations again, we require 2 dBm power here and our device which can provide 49 dB power actually only one of that is sufficient here. So, basically from 32 devices, to we come to only 2 devices at the output stage. Now, what will happen if we say we want to have some small output power back off, to drive our power amplifier at a linear range, but we want that back off to be very small.

So, let us take OPBO equal to 2. So, what will happen that case, OPBO equal to 2 is given in our condition. So, based on that, let us do our calculation based on this output power back off. So, Pout from the devices 49 dBm, but available or useful or practical we can say Pout from the device, which we can take is actually 49 minus 2 which is 47 dBm. So, we have 47 dBm instead of 49 dBm because we are driving at output power back up off 2 dB and it is given condition in the question here.

So, what will be number of parallel devices in that case, instead of 49 now available power is 47 and if you do the calculation according to this, we are getting exactly 1 and number of devices will be then 2 to the power which is equal to 2. So, we will be easy both of the devices here, like in the previous case where we were having no output power back off, but now we can have some small back off of 2 dB and a still we reach 2 devices and we will get exactly 50 dBm at the output.

So, with a same structure in same calculation, we are able to get better linearity condition right 2 dB output power back off. So, what is the usefulness of such tactic, we have seen if we are able to have the output power at P1 dB without compression then we can reduce our number of devices, from attitude of 2 only and within this 2 also, if we do our calculation properly, we can drive our power amplifier it little bit back off of 2 dB and we can maintain all the conditions.

So, what is the motivation here, the motivation is there, that if they are some linearization techniques, we can apply then we can reduce the number of supply significantly and because of that, because each of these devices they consume some power here, they have some voltage value and they have some current, all of them are taken from DC power. So, number of devices when they go down, then this power consumption goes down and eventually, it is a efficient way of transporting your signal without any distortion. So, in the next lecture we are going to discuss the linearization techniques. So, that we can actually do the transmission without distortion, but in a efficient way.

Thank you.