**Satellite Communication Systems**
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**Lecture - 32**
**Nonlinearity II**

Welcome back, we were talking about the non-linear devices and when we give multiple inputs to the non-linear devices, what is the effect of that we have taken 2 inputs; omega1 and omega 2 with the same amplitude v.

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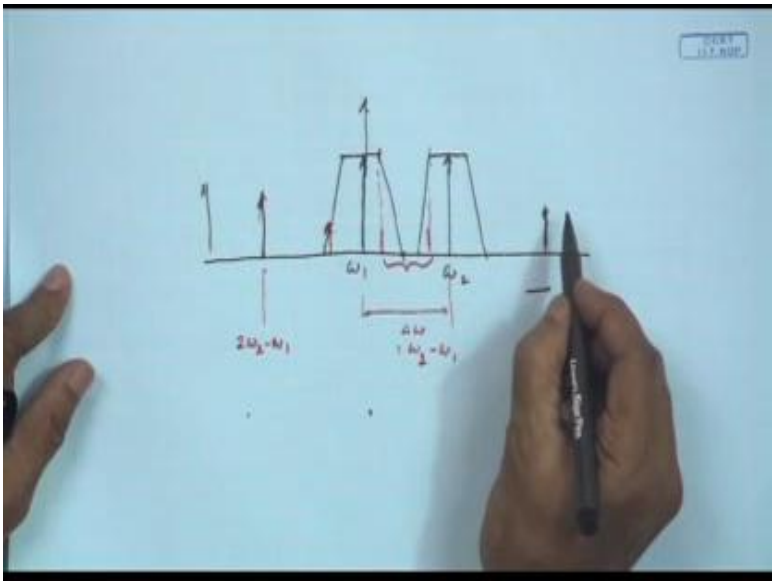

And then, we have tried to plot that this is omega1 with some modulation and this is omega 2 with some modulation this is frequency, and this is amplitude of course, and then what really happens I was trying to explain that the difference between omega1 and omega 2 is this that is delta omega. So, your omega2 omega2 minus omega1 will fall somewhere here, depending on the transport bandwidth it may fall within the transport band width that is one problem. When they are modulated there are other frequency components coming let us assume that this frequency compliant and this frequency compliant. So, they are smaller than delta omega whatever we are taking which is omega1 omega2 minus omega1 they are smaller than this. So, their product will be much closer it is possible that it may fall here this and this product may fall within the filter band width of one of the fundamentals, then it is a problem right.

So, therefore, this inter modulation products can create a problem and inter modulation product comes because of the nonlinearity, and the let us see there are some more definition of the that nonlinearity.

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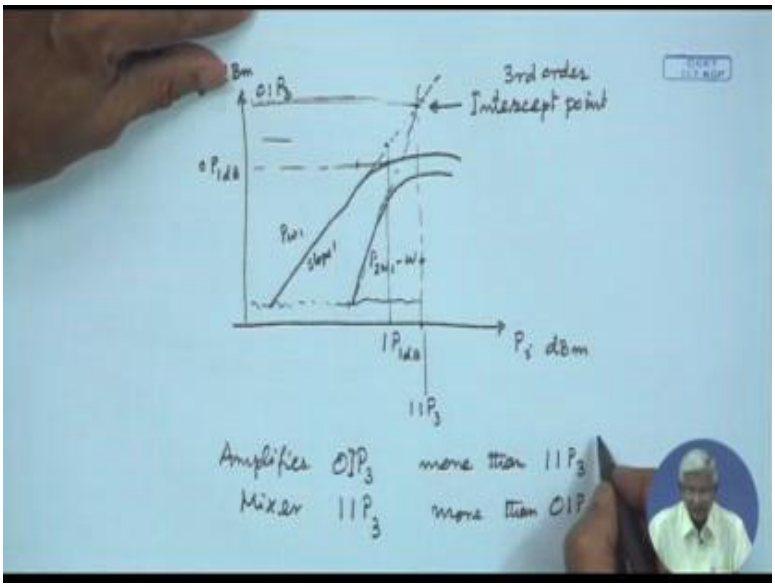


Let us say let us I try to plot this again, that amplifier characteristics which is p input in dB m and the out in dB m. Now initially the fundamental goes linearly and then it deviates from linearity. So, there is a1 dB comprehension point that is extreme this linearity this is, that let us say one of the comprehend that is p omega1 it is slope is 1 in dB the third order inter mod, one of the third order let us say, let us define that 1 dB compression point. So, this was supposed to be our IP 1 dB and this is OP 1 Db. Now the third order term since it is a cube term it is a slope of 3. So, it is minute start comes out of the noise basic noise level, it comes out it goes up within much higher slope.

So, I am extending the linear part of that which is let us say 2 omega1 minus omega 2 curve, power curve which is actually meeting at some point with that fundamental term where these point is defined as intercept point. And this is since it is taken from the third order so, it is called third order intercept point, from the input side you can define this as input intercept point third order and this side we can define as output intercept point third order three-forth third order this input and output we are defining because the output in some cases like in amplifier that output intercept point third order is more than, input intercept point in mixer; that input intercept point third order is more than output

intercept point. So, based on whichever is higher the device manufacture they specify that intercept point. It just referred that which side and then then output is always the gain times the inputs it is a on the linear p omega1 axis.

So, this is another definition that we have talked about two definitions that is 1 dB compression point in refer to input and all output. Similarly third order intercept point refers to input or output. So, like defining the 1 dB compression point and third order intercept point and the gain of the amplifier device manufactures they more or less say that this is the type of nonlinearity of the interface they always may not give you the full card, but from these two we can derive many things. So, let us see that how it can be utilized.

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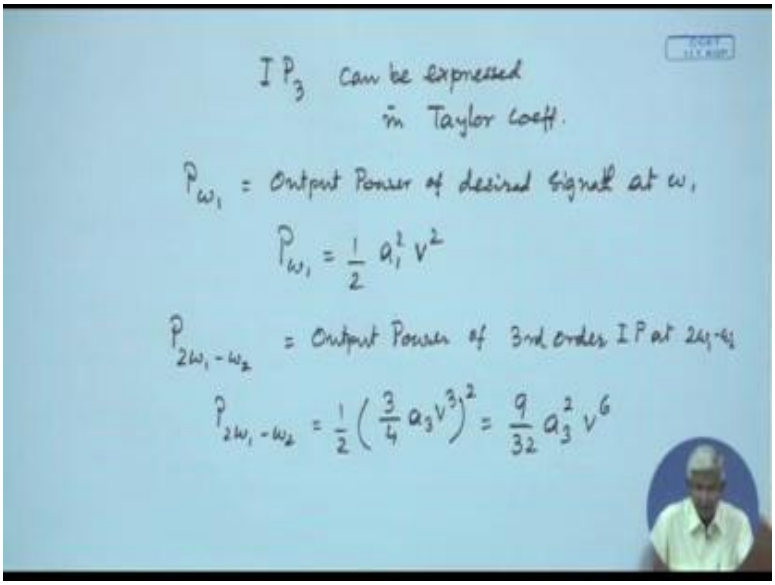


Let us try to see that how it can be expressed in terms of Taylor coefficient. So, IP 3 that input that is intercept 0.3, it may output or input whichever you can take can be expressed like in Taylor coefficient that is a p omega1 is the output power of desired signal at omega1. So, p omega1 is half of a 1 square v square is power.

So, a1 square v square similarly P2 omega1 minus omega 2 is the output power of third order intercept point at frequency 2 omega1 minus omega 2. So, P2 omega1 minus omega 2 can be expressed in the third order term three-fourth a3 b cube square which is 9 by 32 a3 square v to the power 6. So, it is now is coming in terms of in terms of Taylor series coefficient. Now we have seen in this is the intercept point where that p omega1

continuation of that, and P2 omega1 minus omega 2 continuation of that meets. So, if I take this extension of this, this is the point we can equate these 2 and find out the relation of that.

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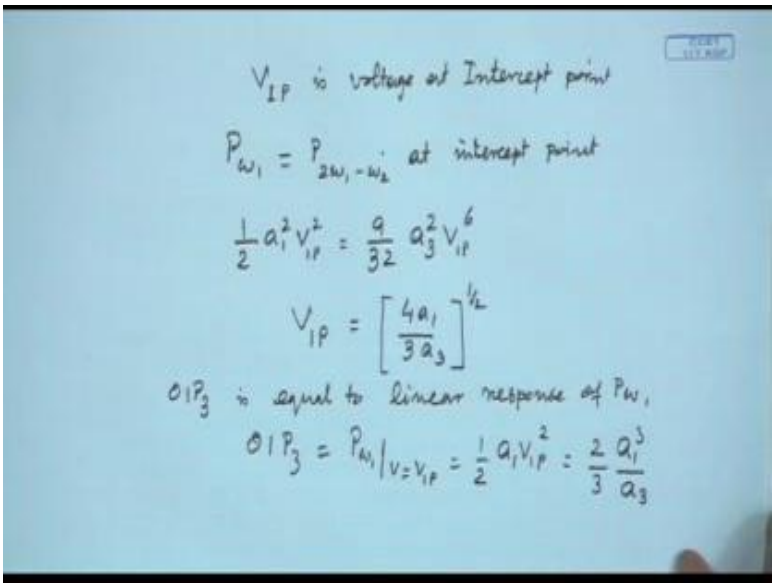


So, that if you define that V IP is voltage at intercept point, then p omega1 minus equal to P2 omega1 minus omega 2 hat intercept point can be expressed as half of a1 square V IP square is equal to 9 by 32 of a3 square V IP to the power 6 because individually we have seen in terms of Taylor coefficient.

So, from that you can express V IP as 4 a1 by 3 a3 square root of that to the power half this V IP can be I mean found out from this expression. Now since O IP 3 is equal to linear extension, linear response of p omega1 we can put O IP 3, we can define p omega1 at v is equal to V IP that would be equal to half of a1 V IP square and this V IP value if you should put here then you will get 2 by 3 a1 cube by a3. Now, O IP 3 can be expressed in terms of Taylor coefficient a1 and a3, O IP 3 is equal to 2 by 3 a1 cube by a 3.

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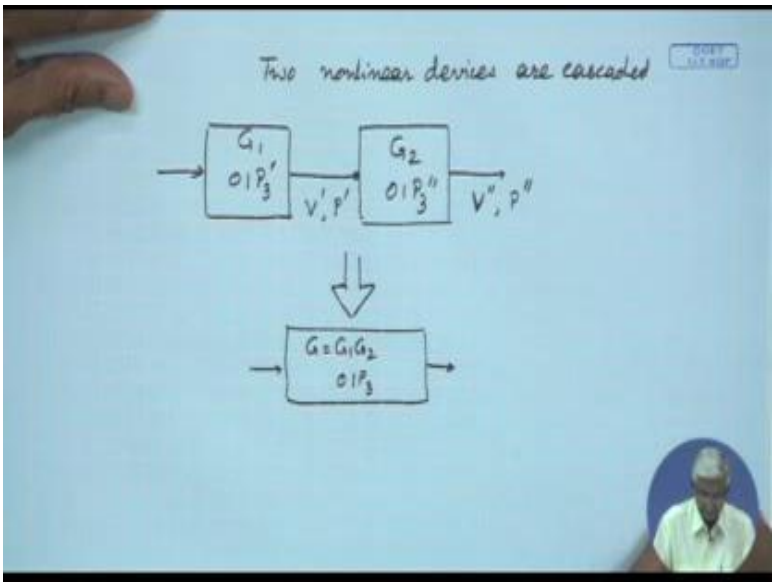


Let us look at it that when 2 non linear devices are cascaded you put one after another then what happens to our this O IP 3 and what should the equivalent of the third order intercept point?

So, let us take two devices instead of stating right now whether it is a amplifier mixer or what device simply we will put some gain. So, the first device gain G1 and it is O IP 3 since is the first way. So, I put one prime of that, and there is a input to this this output will have second voltage will call v prime, will have some power p prime and this is going to be the second stage which has a gain G2 and G1 and G2 are power gains O IP 3 double prime. I put for the second stage. So, output of that will be v double prime in terms of power it will be p double prime. Now this whole thing could be say it in terms of one single block which is the cascaded effect where G1 and G2 multiplied that is the gain g and it as a O IP 3.

So, this O IP 3 in terms of the individual O IP 3 of the individual stages and their gains will try to express that.

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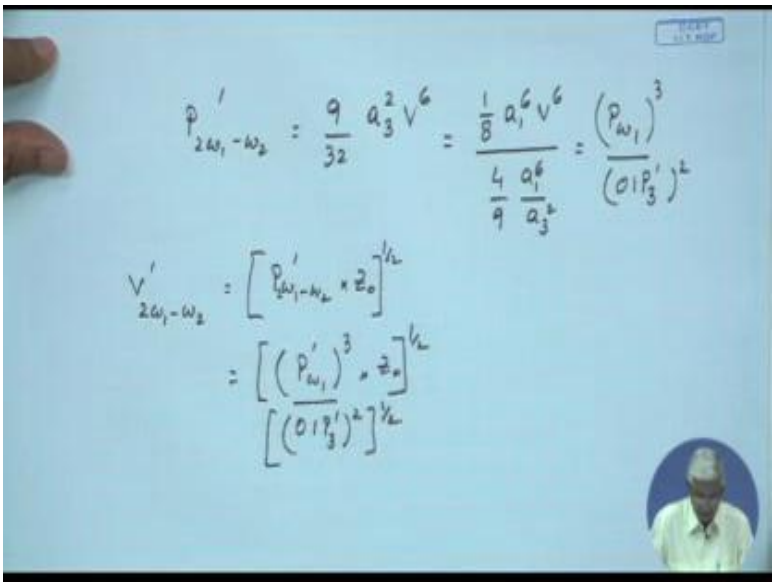


So, we can write that P2 omega1 minus omega 2 prime is 9 by 32; we have come across this a3 cube to the power v 6. Now this whole thing can be re written. So, that we get a relation between P2 omega1 minus omega 2 in terms of p omega1 and O IP 3, I will write that relation if I write it this way one-eighth a1 to the power 6, v1 to the power 6 by 4 by 9 a1 to the power 6 a3 square, now you can see you can cross check this and get back to 9 by 32, 9 by 9 goes up 8 into 4; 32. Similarly a6, a1 to the power 6 gets canceled when a3 square v6 v to the power 6 remains, but these means is p omega1 cube by O IP 3 prime square.

So, I have relation P2 omega1 minus omega 2 prime is p omega and cube and O IP 3 prime as square. So, the first stage output I can write in terms of voltage, if you write that that is v prime for the inter mod relation product that component the voltage of the distortion that is distortion voltage is the power P2 omega1 minus omega 2 prime into z naught to the power half. It is voltage and if I assume that z naught is the impedance for that. So, this is equal to p omega1 prime 3 into z naught by O IP 3 prime square to the power half and this again to the power half, P2 omega1 minus omega 2 I replaced by this damages from here.

Now, if we try to solve this, this is now the v prime of that particular third order distortion voltage. Now if we go to the second stage output, this voltage will be multiplied by the gain and this is of course, power gain. So, it will be you too aware of

that and the distortion up, distortion add it by this second device the distortion voltage that is added by the second device.

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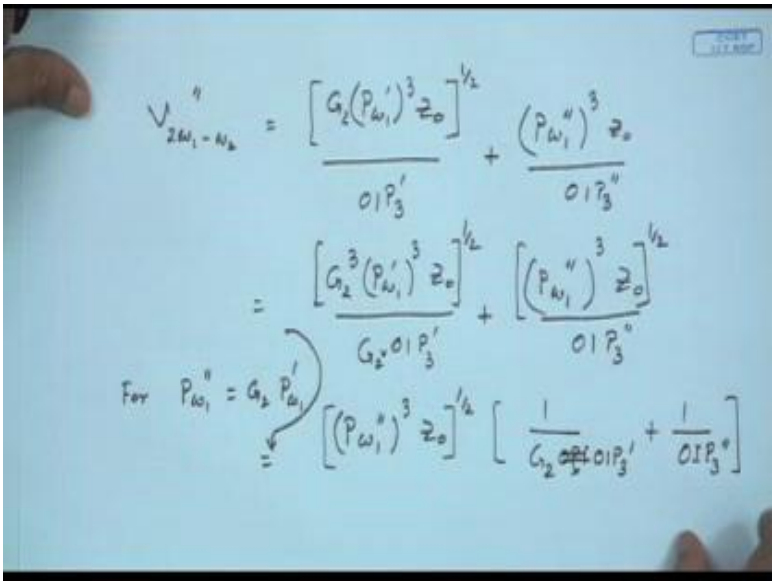


So, you can write the whole thing like this that is v2 omega1 minus 1 omega 2 double prime is equal to that gain times p omega1 cube z naught and since the whole thing is the power gain. So, gain has gone inside and this is to the power half and that half has reduced O IP 3 prime square was there, that root over get this canceled this is first stage gets amplified and the second stage distortion is p omega1 double prime whole cube in to z naught by O IP 3 double prime.

So, the first stage output is multiplied with gain of the second stage and the second stage distortion is added to this voltage. Now when we go from this voltage you can do some sort of a re adjustment that v because it is a cube here to make this and this term equal, if I make this G2 in terms of cube from g in to p omega1 prime is equal to p omega1 double prime. So, to make that I multiplied by G2 numerator and denominator, since it is the inside root over. So, it becomes G2 cube p omega1 prime cube then z naught divide by this is to the power half and G2 in to O IP 3 prime plus p omega1 double prime whole cube in to z naught O IP 3 double prime and this is the square root of that.

Now, for have p omega1 double prime is G2 in p omega1 prime. So, this part is replaced and this one comes out be or I can write the whole thing it is comes out to be p omega1 double prime whole cube in to z naught to the power half multiplied by since g

numerator is taken out. So, it will be 1 by G2 O IP 3 sorry O IP 3 prime plus 1 by O IP 3 double prime. So, this is the voltage part is coming, now if I try to convert in to power.

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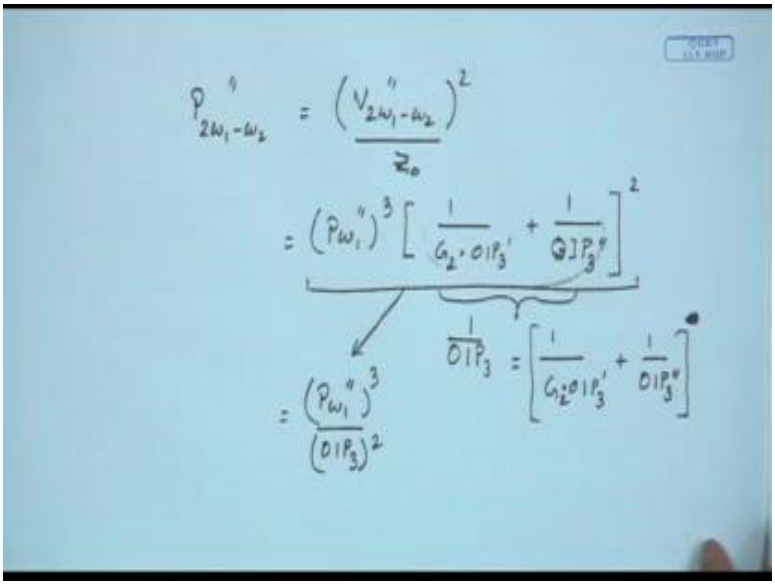


So, it is P2 omega1 minus omega 2 double prime is the voltage 2 omega1 minus omega 2 double prime square by z naught, by replacing this voltage v 2 omega minus omega 2 as this term here and square of that then it comes out to be p omega1 double prime cube in to 1 by G2 into O IP 3 prime plus 1 by O IP 3 double prime to the power square of that and that z naught gets canceled, there was a z naught there in that z naught gets canceled.

Now, if we define that this one is only inside this part is our equal to our O IP 3 which is the total that intercept point of the cascaded system then I can write O IP 3 is equal to 1 by G2 O IP 3 prime plus 1 by O IP 3 double prime minus 1 then, if I write this then this term the whole thing comes out to be p omega1 double prime cube by O IP 3 square is the square times. This is I can write it this way the 1 by this is equal to this that also. Now, I have the relation p two omega1 minus omega 2 is equal to p omega1 double prime cube that is the second stage omega1 that whole thing cube and O IP 3 the whole thing which is nothing, but one by O IP 3 cascaded system is one by G2 there is gain of the second stage O IP 3 of the first stage plus 1 by O IP 3 of the second stage or you can put it in first if this is put as a numerator.

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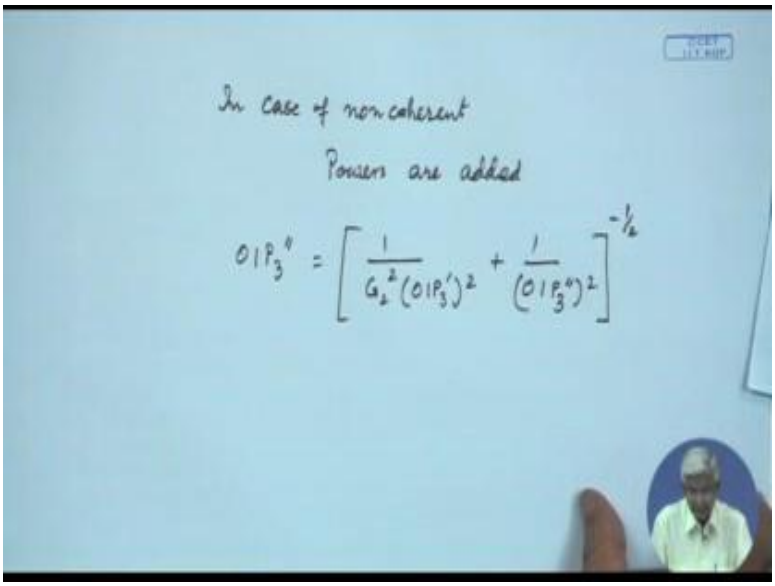


Now, in case of coherent and in case of non coherent it can be calculated it is a power addition because if the 2 carriers are slightly away then their inter modes will be further away and the due to random less there are many correlation. Therefore, it can be random and only powers can be added then in that case O IP 3 double prime will become 1 by G2 square O IP 3 prime square plus 1 by O IP 3 double prime square and to the power that is like this 1 by this is go to root over of there. So, this is the expression you can derive yourself.

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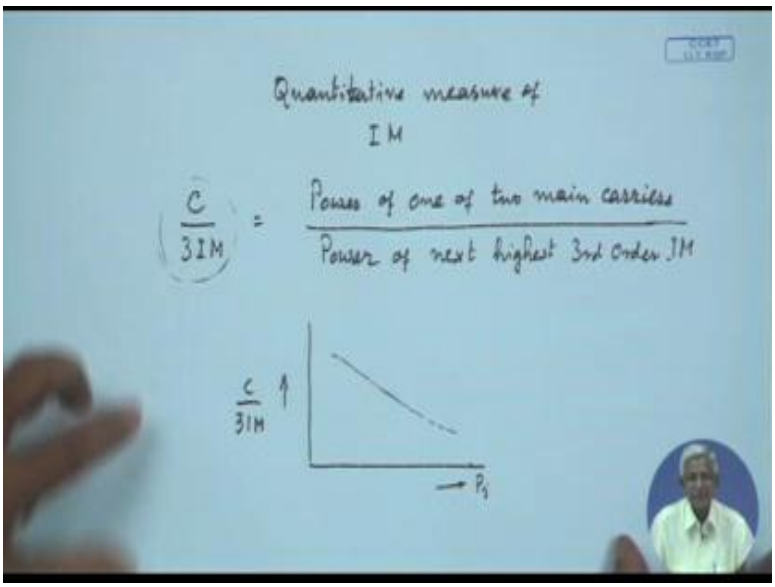

Now, with this I can give you some more information that is that the manufactures how do they quantitatively measure and then specify? This is quantitative measurement inter mod product that that term which is the use carrier to third order inter mod it is defined as power of 1 of 2 main carriers divided by power of next highest third order inter mod. I instance for inter mod, I have used the term next highest that is we were showing till now both are equal amplitude, but it is possible that the carriers are non equal amplitude. If this carriers are non equal amplitude say one carrier is larger than other, the inter mod products both side may not be of the same size, they will be higher one of them will be higher than the other.

So, the ratio what is defined is the next higher order third order, inter highest size of the third order this is the definition. So, this is a term which tells us about the two carriers in inter mod noise what it comes and it is a carrier two-third order inter mod ratio. So, you can plot it c by 3 IM as we increase the input power it will decrease. So, at the low input power, inter mod product is very low. So, this value will be high where as at high input the inter mod will grow and then this will start falling. So, this is one way of the presentation. Since time is up we will go for the next period have for the timing.

Thank you very much.