Basic Building Blocks of Microwave Engineering

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Lecture - 12
Port Microwave Power Divider/Combiner Part – II

So, we continue our discussion power divider and combiner. This is the part 2 this lecture 12th lecture.

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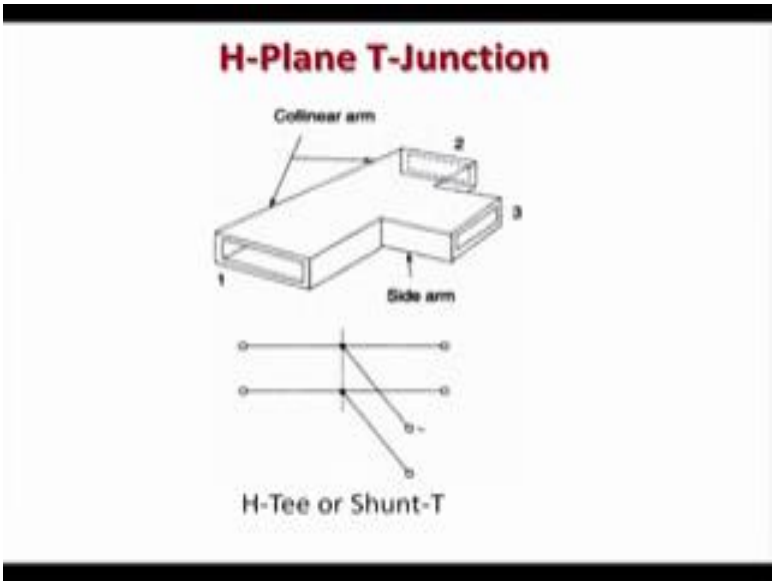

So, another way we can make a junction as you see, that this12 collinear arms. The web guide is going. Now we know that it is h field is in this x z plane; that means, we have yesterday seen that this, this is circular lines with the gap of lambda g by 2. Now, that in that plane if I cut the junction; if the junction is there then it is called a h plane t junction; that means, in h plane I am having a, hearing that line is taken out. So, the side arm or collinear arm that is in the h plane. That is called the h plane t junction. You see here. So, junction we take and we take it.

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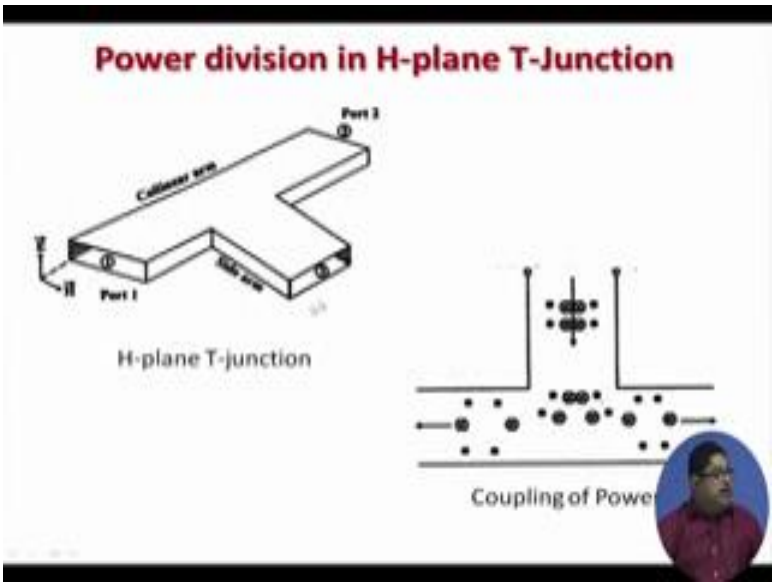

Now, in that that is why h plain t junction. Sometimes this t also people pronounce as t double e, but we probably to call it, t because it looks like English t. Now power division in h plane here also; you see the power is if you want to divide power, you give the power to port three. So, this power will be divided into these 2. If you see the field structure, that you see this is the power is coming here, that this powers the field lines magnetic field lines. So, they are in circles. So, you see that this cross means, it is going inside the plane. It is going inside this white paper. And here it is coming out of the white paper. The magnetic field will be going and coming out from there. So, this structure if you give here. So, here you see that it starts bending and finally, it is going after some time it becomes stabilized.

So, you see both the field structures, here after sometime must similar. So, from this I can guess physically that the signals, that are going into ports 1 and 2, there will be same case.

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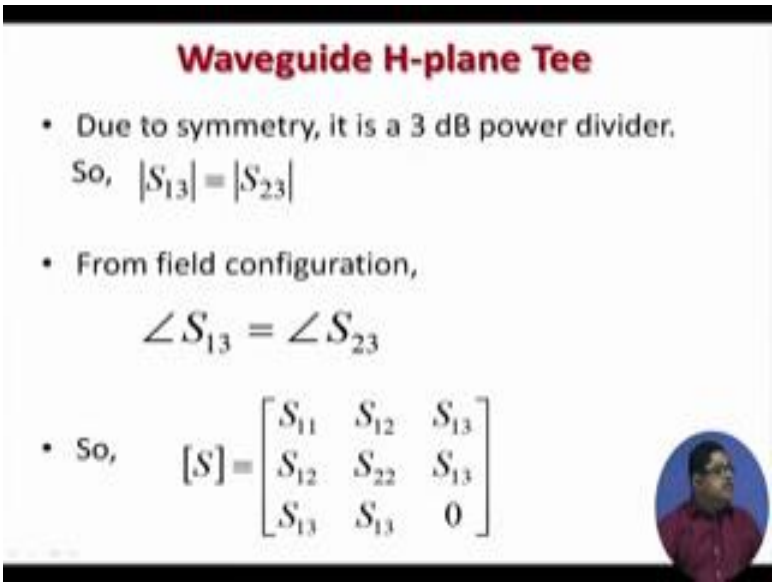

That will show here also -that due to symmetry again, I say that it is a 3 dB power divider. So, S 13 magnitude and S 23 magnitudes are same and from field configuration we can say that their phase is same. Now we write previous time it was minus now it is same. Other things are there. The third port is match. There are mismatch in the port 1 and port 2. So, S 11 and S 22 exists reciprocal device that is a web guide h pane tee.

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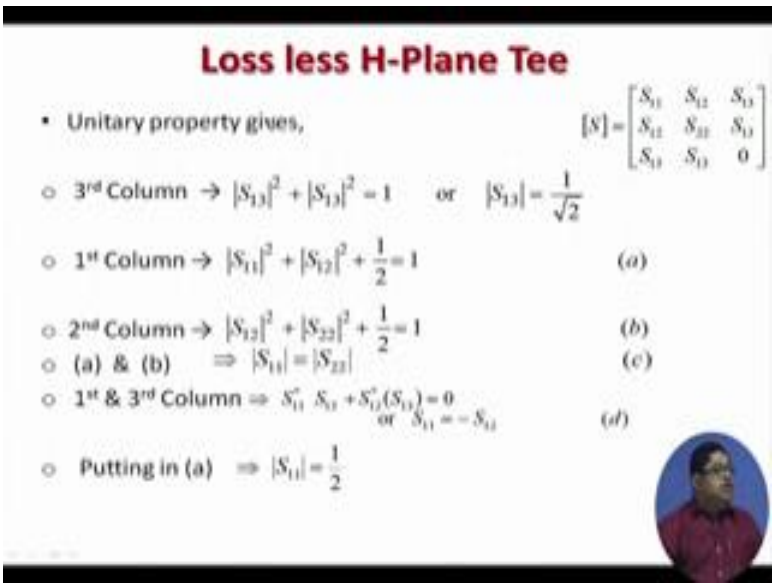

Now, you put the loss less condition that is unitary property. So, by that to proved that really half power is going and. So, and one the mismatching the 2 ports 1 and 2 their

magnitude of the reflection coefficients are also same, but you see that from here we prove that S 11 is minus S 12. So, the scattering parameters a port 1 and 2 they are having opposite phase; that means, voltage the opposite putting in 1 you get this.

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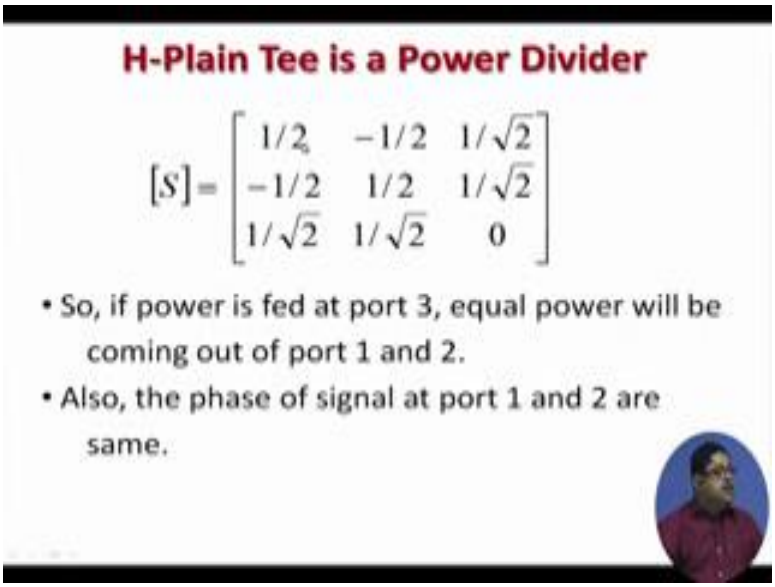

So, this is the power divider S matrix. So, here if you look, that if you give power to port 3, here you see that power going in port 1, is half power going in port 1 half. So, it is also a 3 d b power divider, but from the expressions you see that, the 2 signals they are of equal phase. So, phase half signal and port 1 and 2 are same.

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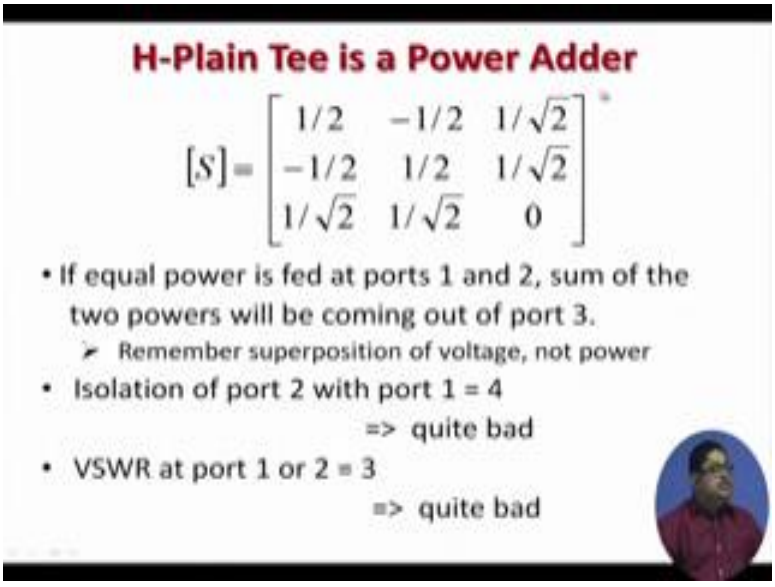

Now, what happens to it is combining activity. So, they are the e plain tee was the subtracted. Here it will be an adder, you see that if I get power here so; that means, that port 1. How much is going to port 3. Port 3 is getting 1 by root 2. Then, if I give power equal power at port 2; then that is getting 1 by root 2. So, total voltage is 1 by root 2 plus 1 by root that is 2 by root 2 that is equal to root 2. So, power will be 2 sum of the 2 powers will be coming out of port 3, I have given power 1 here, I have given power 1 here. So, power at the port 3 that is coming out as 3. So, it is an adder. So, it is a combiner so; that means, in in h plane tee if give port 1 and port 2, some power p1 and p2, p3 will be p1 plus p2. Again remember asking you that remember superposition of voltage not power.

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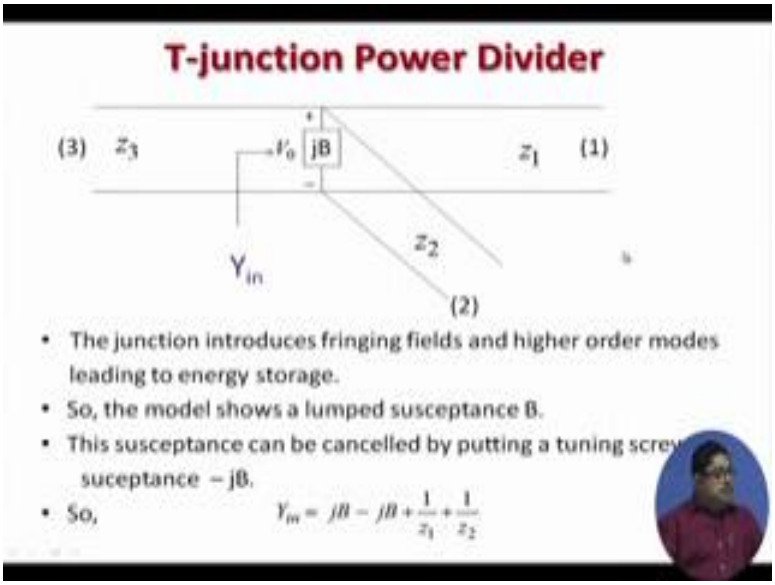

Now, what is the isolation of port 1 with port, port 2 with port 1 so; that means, if I give power to port 2, how much is coming into port 1. Minus of; that means, power wise this is voltage, power wise voltage ratio power wise this is 1 by 4. So, again isolation is 4 quite bad. So, h plain tee also has a bad isolation, VSWR you see half and half. So, both port 1 and port 2, they are S para, S 11 or S 22 is half. So, what will be the when all other ports are matched. This is their reflection coefficient. Now reflection coefficients magnitude is half. So, VSWR is 1 plus reflection coefficient magnitude by 1 minus reflection coefficient magnitude, if we calculate that will be 3. 3 is a quite bad value. That is 25 percent or you are losing in mismatch.

Now, t junction power divider. The earlier t junction power divider that we have done, you see deliberately from the while your designed we have taken that 2 ports these 2 ports they are same structured. By this we have made the impedance values of this line and this line. These were guideline these were guide line they are same. So, that is why we got equal power structure, but always we do not want equal power division sometimes I may need some forty percent power should go to one arm and another sixty percent should go to another arm. So, what we have to do, I will have to play with impedances that we will show now, that unequal power divider.

So, this is the general structure. You see that suppose I am giving power at port 3. I want the power should be divided into 1 and 2 has before, but we have taken the characteristics impedances, equivalent characteristic impedance, or you can say wave impedance, that I will play with the impedance of the ports, in ports you can define characteristic impedance, in an equivalent way, with either axial or my transmission line ort web guide.

Let us say that these are the characteristic impedance. So, this line; that means, the feeding line generally we call it port 3 for t, junctions. That characteristic impedance we are taking z3 this is z1 this is z2 now; obviously, due to junction there will be as I explained earlier there will be a susceptance we are calling it jb, but we can also put a matching screw. So, that this can be cancelled; that means, we can easily make here a minus j b. We know by another transmission line we can use. So, that is why you are telling this susceptance can be cancelled by putting a tuning screw susceptance minus j b.

So, let us see what is the input admittance? because these 2 are in parallel. These line 1 and line 2 are in parallel. So, let us reach about 2 admittance. What is the input admittance in from here, j b minus j b for that tuning screw then this one will show a characteristic impedance z1. So, admittance will be 1 by z1. So, this is 1 by z1 since these 2 are in parallel it will be 1 by z1 plus 1 z2.

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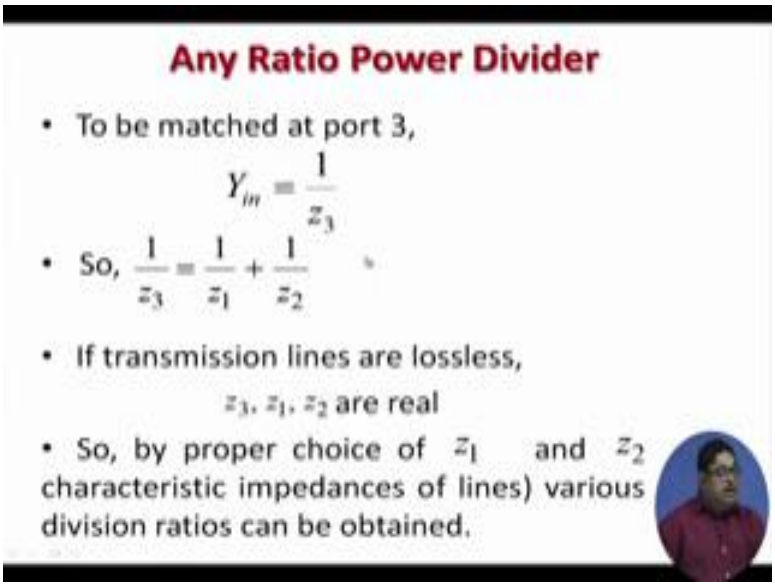

Now, to be matched at port 3, what I demand matching means, 1 by z3 is equal to y in then only it will be matched that is what I have detailed.

So, my condition is this now if transmission lines are lossless, transmission lines or web guides their lossless. We know that for a lossless any in second module of this lecture since we had seen that if you have a lossless line, then it is impedances is their real quantities or propagating modes etcetera. They are real inside if there are more modes then only their having some reactive power. Now while you choose your z1 and z2, and by that you can get the power ratios, you can choose any value to get a power ratio over here.

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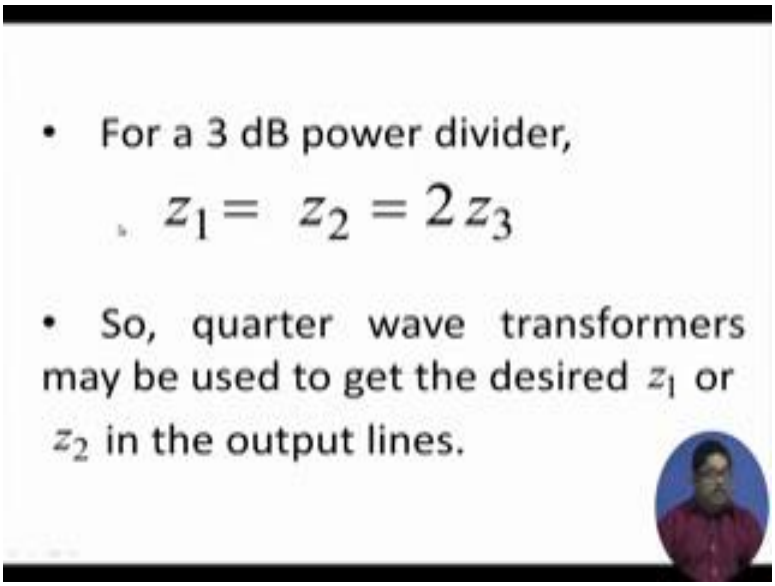

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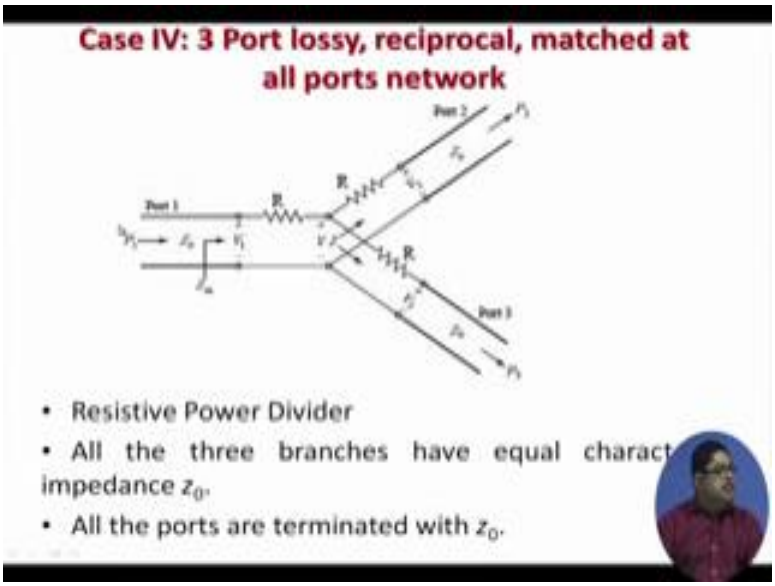

For a 3 d b, suppose I want 3 d b power divider. So, for a 3 d b power divider, I will choose like this that will give me 3 d b power. If you were to choose any other values you see that only remember that the power that will be the impedance always determines how much is the power.

So, quarter wave transformers may be used to get the desired z1 z2 in the output lines. So, we will see in tutorial as etcetera will how you a that 3 is to power 5 some, ratio we will take and there. We will show that by choosing proper impedances you can design

now characteristic impedance of the lines or characteristic impedance of the wave guide etcetera they depend on their dimensions. So, far required lines you will have to choose a by b by a ratio correctly. So, that you get some impedance. Any impedance you can fabricate, but practically there are some may be some mechanical or fabrication difficulty etcetera, but theoretically you know how to make impedances. So, you can choose proper impedances that will give you the power divider.

Now, there is another case left for that relaxed condition. That we have not tried this is a 3 port lossy reciprocal matched at all ports. Because always we have assumed that lossy lossless structure, but there can be 3 port lossy. I have 3 port the whole structure is lossy. Reciprocal matched at all ports network. So, that is also another possibility and that is also a power divider. This one we are showing as a very symmetric thing, how to make loss lossy structure. Basically in the line you give resistance, either in it is equivalent circuit there is a resistance or you if it is a lossless line you add equal lumped resistances. You have that been shown that symmetrically you add in the 2 ports 3 resistances of equal value.

Now, what is the value of this that will depend on these? So, here you have as shown in the symmetrical structure now various varieties are available you need not have these varieties together for various power division ratios that we have already seen, but let us assume for our analysis that this is z naught and z naught. So, all are of equal characteristic impedance z naught then we are adding equal resistances in 3 ports this is called a resistive power divider and also we assumed matched at all ports; that means, since the lines all have equal characteristic impedance the ports also should be terminated with load impedances of the value z naught, then only there will be a match so; that means, this port is terminated by z naught, this port is z naught this port is also z naught.

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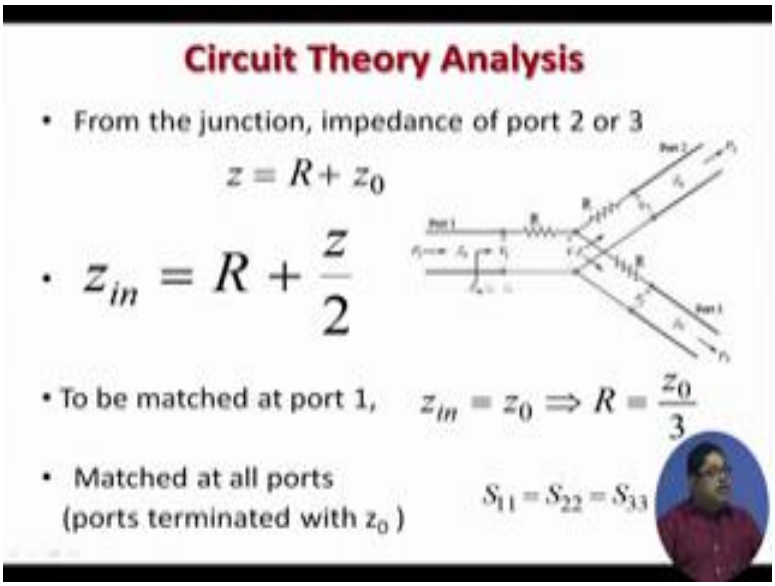

So, now what is from the junction? That means, junction then this is the junction. That voltage we are calling v; obviously, that j b is also cancelled by a tuning screw. Now we want to see from port 1, this is our port 1, this is port 2, this is port 3. Now from port 1 how much I am seeing the impedance, I will match that with z naught, that will be the matching because this is a matched 1. So, how much z in I am stressing to know that first let us see that from the junction if I look at port 2 and port 3 anyone suppose port 2 I am looking what I am saying r when the transmission line or characteristic impedance z naught terminated by impedance z naught.

So, from here I will if I look at; obviously, the definition of characteristic impedance says that, from here look I will see z naught so, but from here from the junction if I look at this port 2, I will say that I will look at an impedance of r plus z naught. That is what I call small z is r plus z naught. Now from this junction you see I have a; that means if port 2 is showing as r plus z naught port 3, is also showing as r plus z naught. These 2 are in parallel. So, the z in that, I will from the junction. I will how much, I will see r plus z naught by 2 equal resistances in parallel up, so r plus z r plus z naught by 2 that is z. So, I will see from the junction z by 2, but from this port z in how much, I a r plus this small z by 2.

Now, to be matched I put now the condition z in should be equal to z naught. If you solve you get that the value of r should be z naught by 3. So, the impedances, resistances,

lumped resistances that will have to put that will equal to z naught by 3. So, this is matched at all ports. So, you can put that it is S 11 S 22 and S 33 all are 0.

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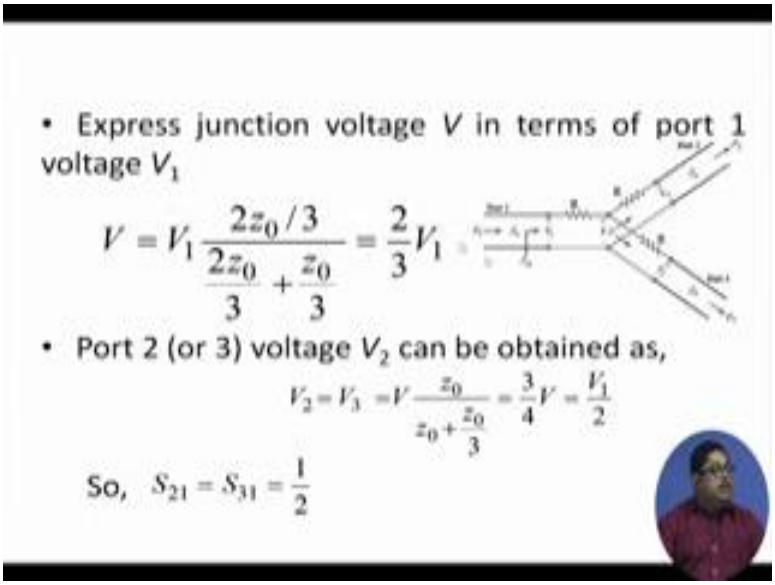

Now, this junction voltage in terms of port 1 voltage you can easily write. If this is V 1 this will be r plus this, 1 is small z by 2. So, if you do that you can easily relate V and V 1 that we have done here. So, V is equal to two-third V 1.

Similarly, if you call this voltage as V 2 and this voltage as V 3, obviously, from symmetry V 2 and V 3 will be same and that value we can say that this will be V 1 by 2. So, once you have these we can easily write what is S 21; that means, if I give some signal here how much will go there, if you do that already you have shown that V 2 will be V 1 since impedance is same. So, S 21 we can say as this will be half this will be half.

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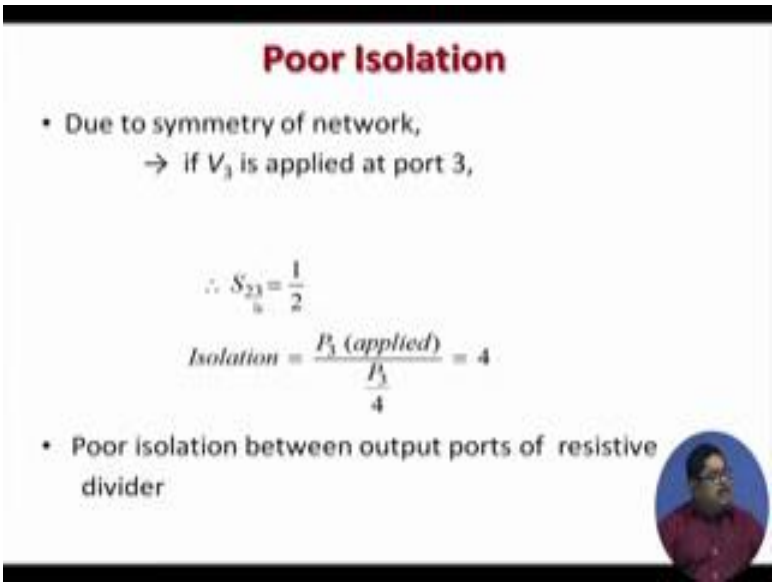

Now, due to symmetry of network V 3 is applied then S 23 also half. So, isolation of this device is again same as port that the poor isolation between outputs, ports of resistive divider. So, this is also possible.

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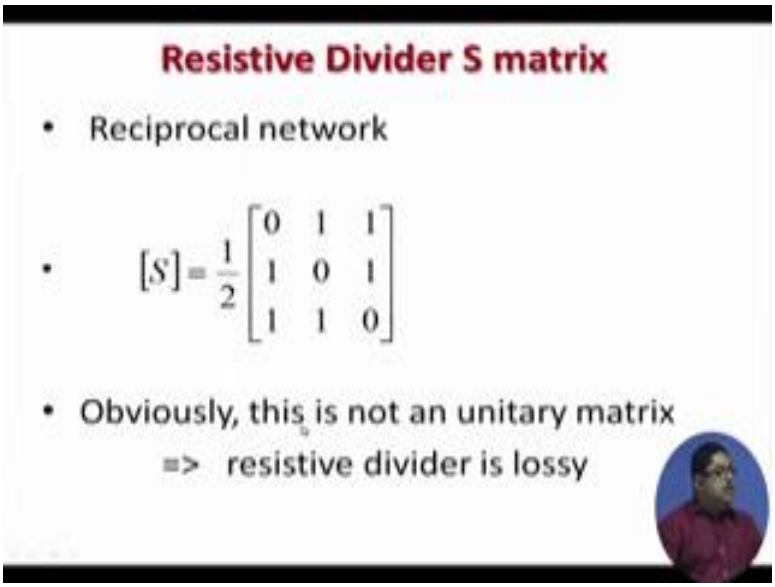

And here you see that, there will be resistive divider S matrix now we can write like this. From all those knowledge; obviously, this is a lossy device; that means, power will be lossed inside of the resistive divider also. So, this is the thing and; obviously, this is not a unitary matrix because this is a lossy device. So, we dont have resource to do not try to

find unitary property here; 1 square plus 1 square that is 2. Not equal to 1 or you can put 1 into 1 is not 0; 1 into 1 star that will be 1 into 1. So, since it is not a satisfying unitary property.

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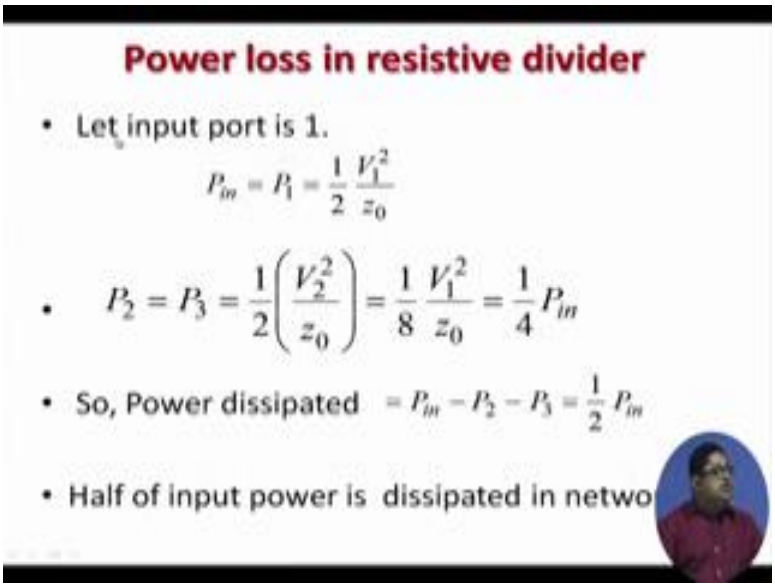

So, resistive divider is once as example. It is isolation is poor. It has loss. Now how much power is lost in the resistive one for that we have made this calculation power dissipated is half. So, you see whatever power I am giving half of the power is getting dissipated in the device. In case of non matched if there are e plain tee junctions or h plain tee junctions; we are getting that in mismatch there is one-fourth power going. Here that is absent, but in loss half of the power is going. So, half of the power is dissipated in the network. If you are ready to suffer that you can use resistive divider.

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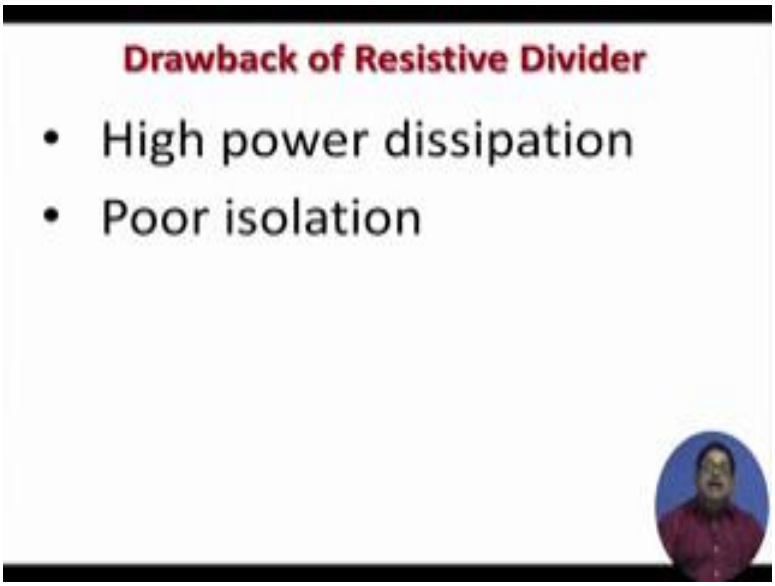

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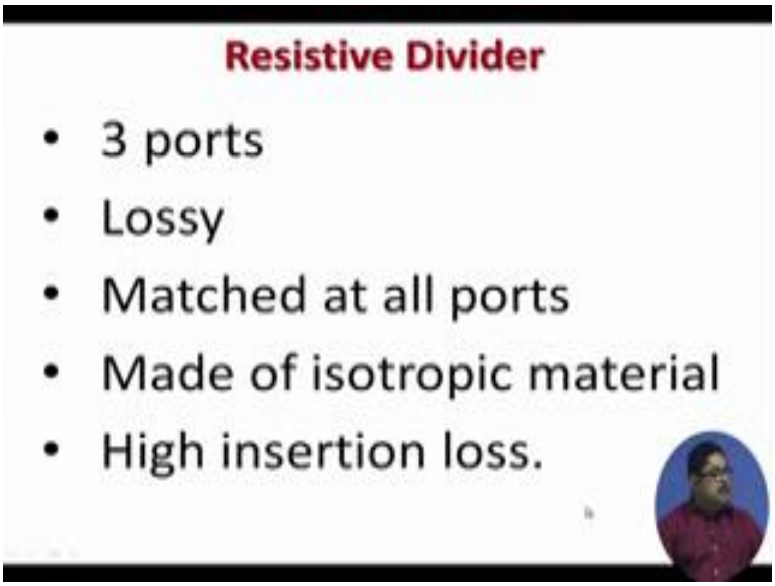

So, drawback of resistive divider is this. Now there is a design by Wilkinson. At the resistive divider, is you see again the summary 3 ports lossy matched at all ports, made of isotropic material. High insertion loss because this inside there is half of the power is lossed. So, insertion loss is quite high.

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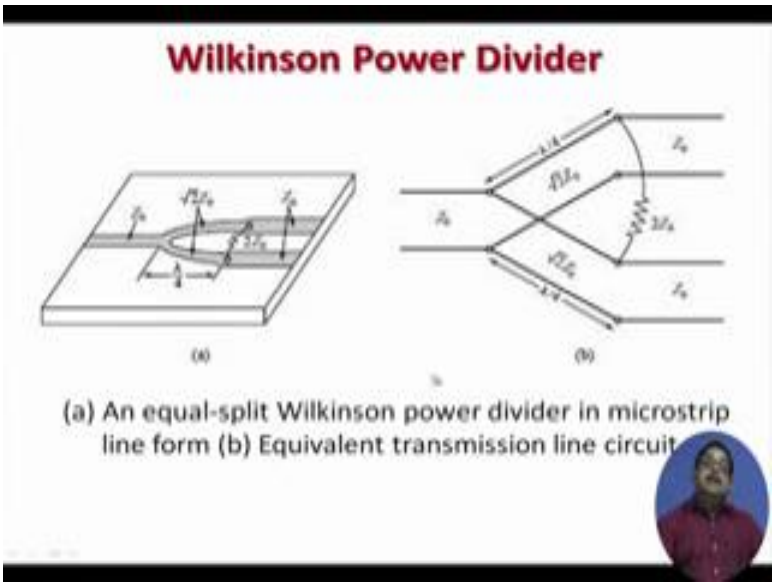

Now, there is another design, that semi structure that all 3 lines z naught z naught, but instead of lumped elements you have 2 other transmission lines in port 2 from the junction of lambda by 4 length, and root to z naught test to impedance and also there is a from that line. Here is a lumped resistance of value 2 z naught if you add these then you can correct 1 of the that isolation problem of power divider that is called Wilkinson power divider is very popular that very simply by you can make these.

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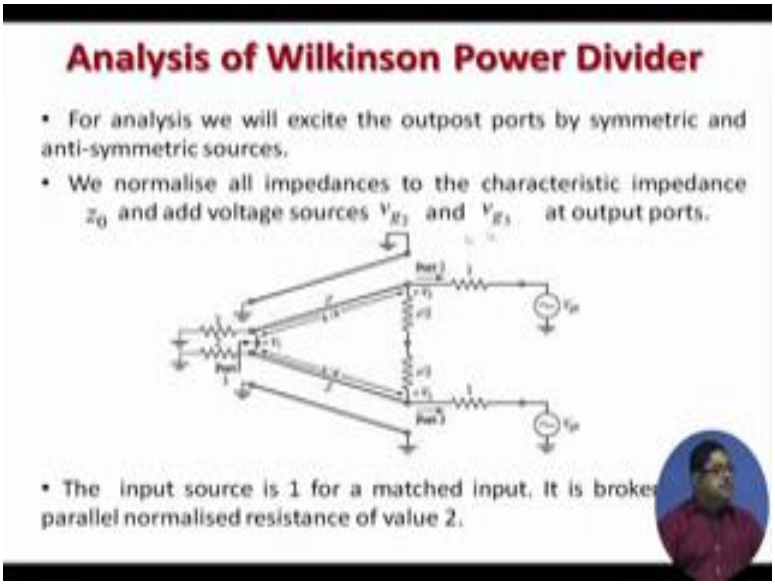

So, the analysis part we have given actually here, you see because of the presence of these actually there is a coupling between 2 and 3.

So; that means, the 2 ports where the power is getting divided, they are coupled by this resistance. So, anything 2 things going and they are coupled mutually coupled that analysis is difficult, but 1 of the way by which we tackle that difficulty is called that we break it into, some Eigen mode things you know that even mode is by proper excitation we can make. So, that that coupling is reduced. Those are called Eigen mode excitations. So, sometimes that is the even modes are called in terms of even and odd mode of it is excitation.

Generally they called that, but basically conceptually it is Eigen mode. So, that sums you utilize some properties. So, that that coupling part is absent. So, that does not make the analysis simpler. So, that we do here.

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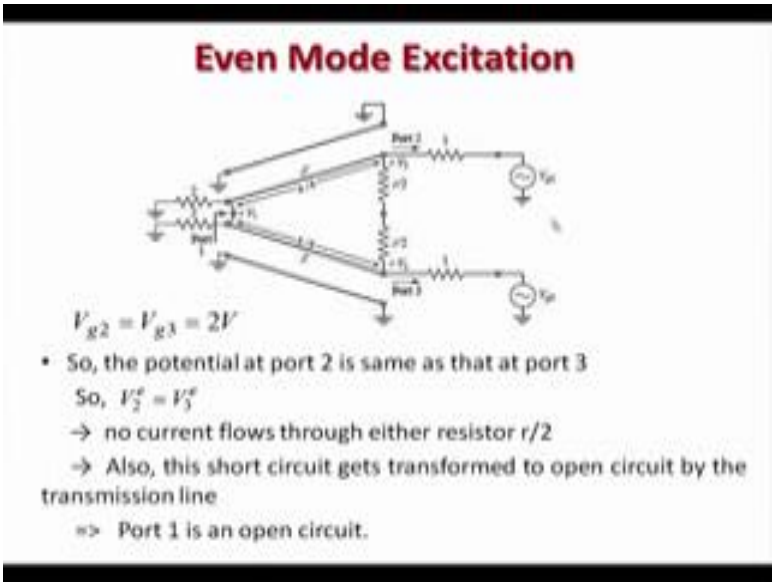

So, for that you see this even mode excitation is that 2 and 3, both the ports we will give equal value excitations.

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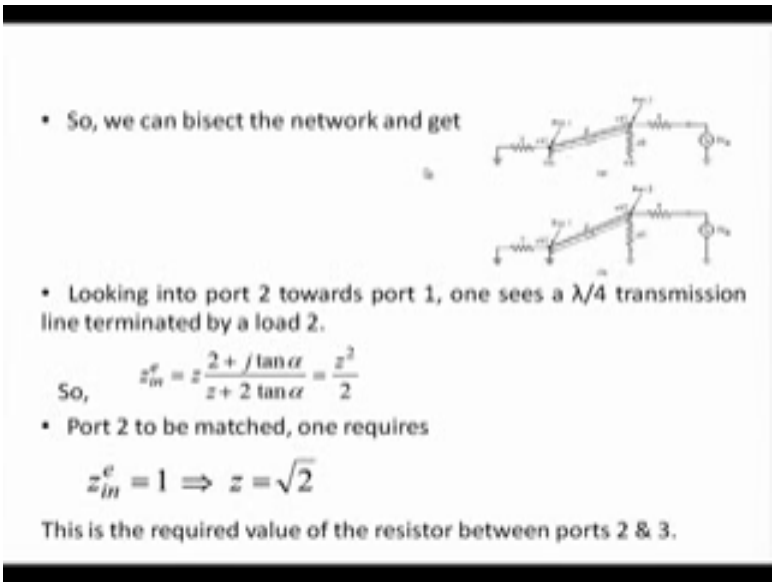

So, the whole structure is such that it breaks down the network and it breaks down through this simple thing, by that you find out and find out that input impedance of that is this one for even mode.

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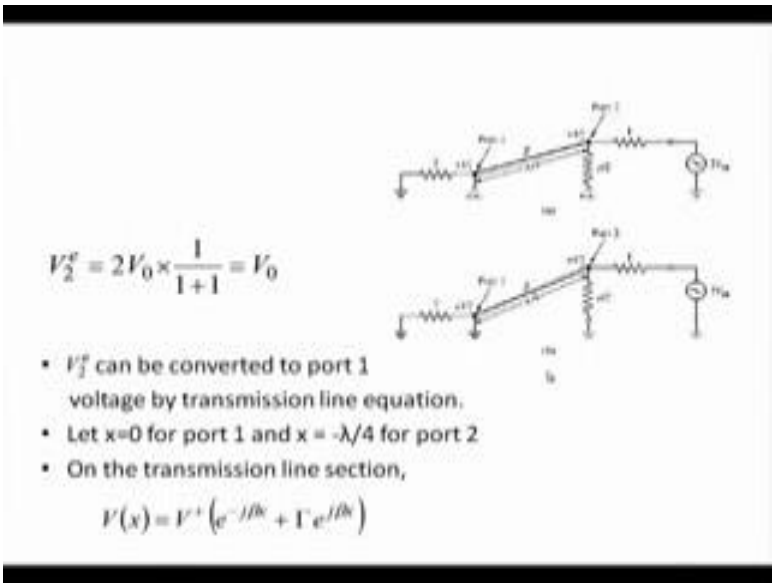

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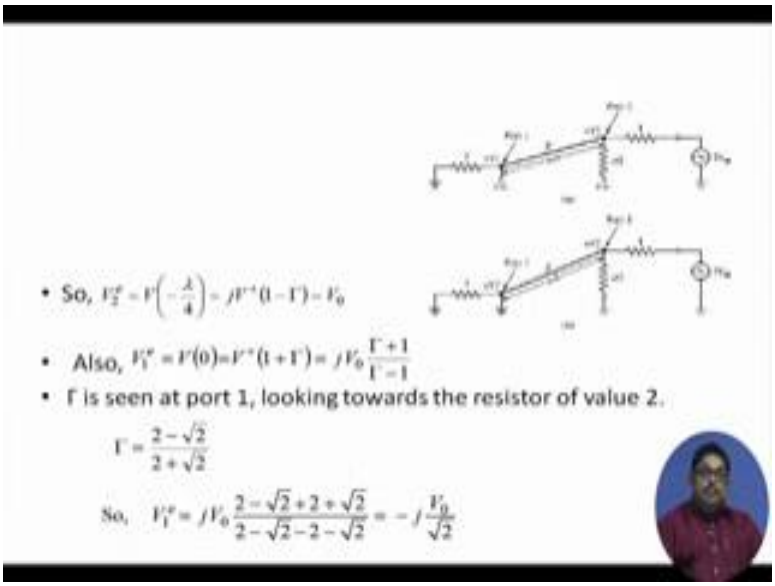

Now,. So, other things you can all explain if you have understand that thing. Transmission line concept you can find out this. So, we have shown odd mode excitation even mode excitation.

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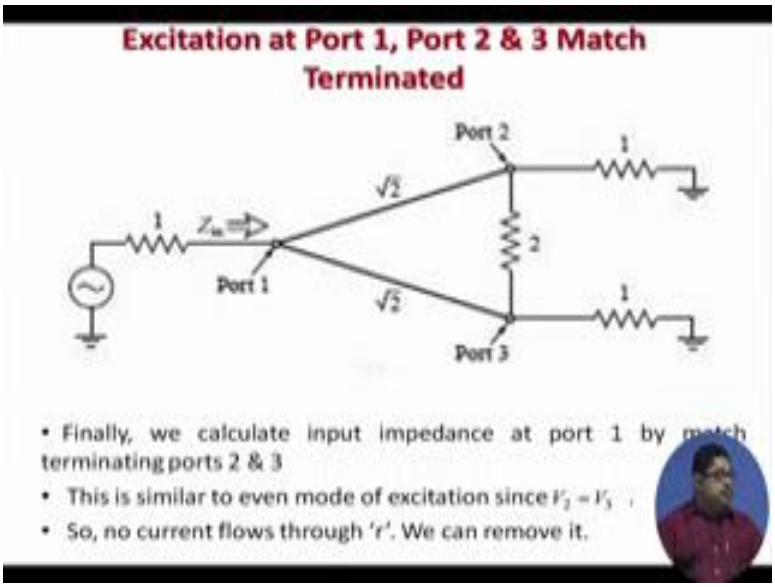

Now, excitation these 2 about the even mode and odd mode analysis, from that the final thing will be you see 1.

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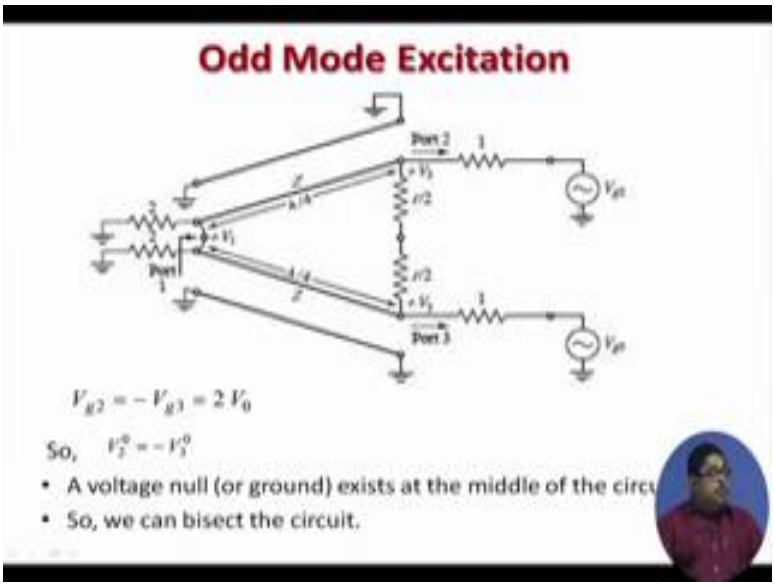

That one I can say that odd mode excitation is V z2 and V z3 they are opposite voltages. So, basically what we are doing when we will sum even and odd mode excitation, the port 2 excitations in previous case it was same as this. So, twice of that and this will be 0. So, basically sum of this is the actual excitation; that means, what we are finding is when I am exciting port 2 what is happening to port 1 what is happening to port three.

Now, due to symmetry I can say the same thing I can do for port three. So, this part is over only 1 part is remaining. That if I excite port 1 what happens. That we are is doing here excitation at port 1 port 2 and 3 match terminated. If we do that then it boils down to that there is a gain due to symmetry, I can say that the voltage here and voltage here will be same. So, there is no current through this resistor and that is why we can take it out of the circuit, and this is actually going to the similar to the even mode of excitation. So, no current again flows to that.

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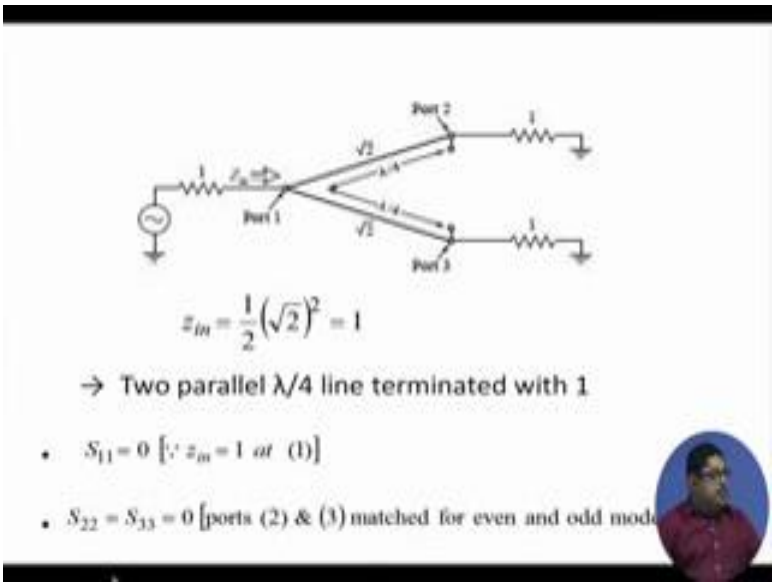

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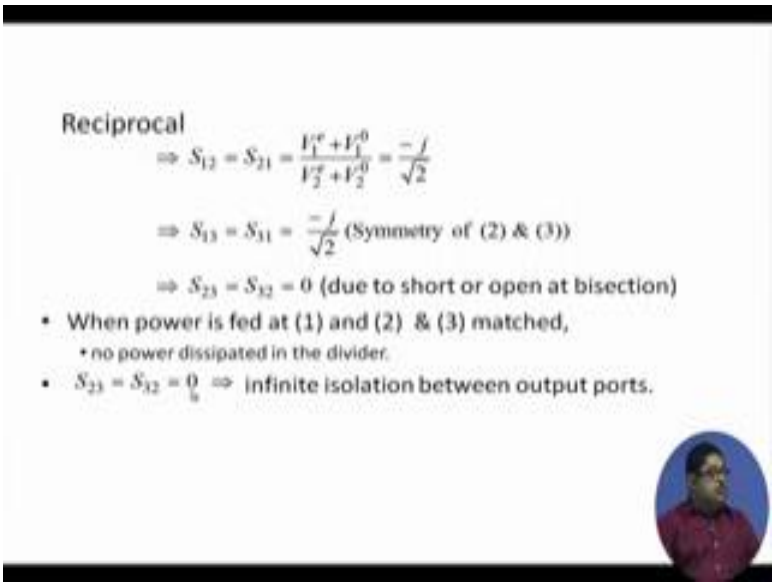

And then we calculate some values then what are the S parameter value. So, we got this thing, that it is a reciprocal when power is fed at port 2, so infinite. So, we calculated this S 23 and S 32 they turned out to be 0.

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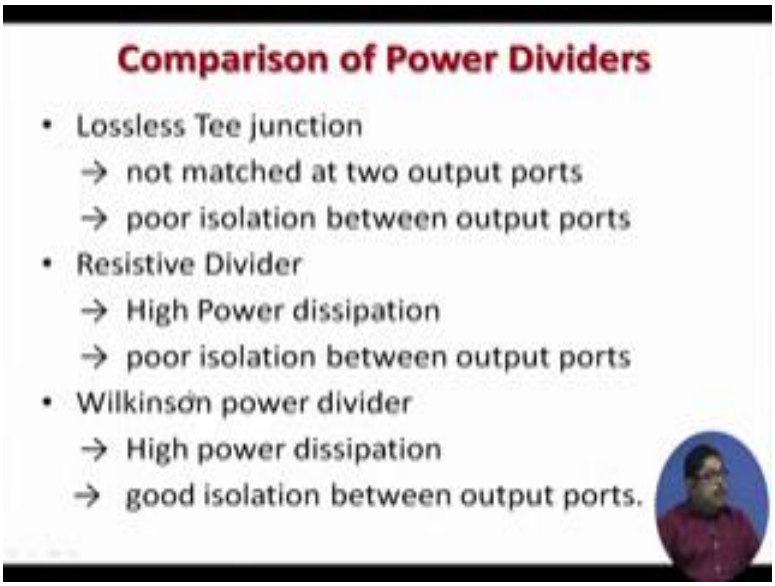

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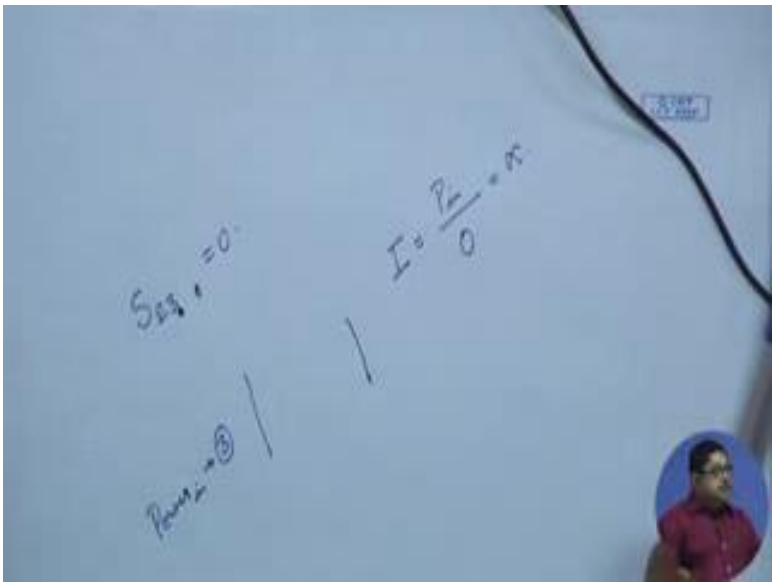

So, if you see that we have finally, proved that s23 and s23 0. What is s23, that means, I have the power is ampediant port 3 I am getting at port 2 there is nothing. So, what we will do isolation. Isolation is power given p in and the power suppose I am giving the power to port 3. Power a p in power at port 3. So, p in at port 3 and power going to port 0 is, if s23 is 0 power is also going to be 0.

So, isolation is infinity. So, this is ideal similarly. So, 2 and 3 both the ports they are isolated ports. That means this is the beauty of infinite isolation output port. So, let us go

back to the our original figure of Wilkinson power divider, this is analysis this Wilkinson power divider by putting this resistor, of this much value this values we have derived that how to find out what are the values of this resistor, that will be 2 z naught, characteristic impedance here is this root 2 z naught, if you do like this then the you can put between this port and this port they are isolated.

Now, isolation we required, because why we require isolation because actually we are trying to give that this port we are giving power, power should be divided between these 2. Now if there is by chance because load is in not in my hand. The loading of 2 or loading on 3 is different from their characteristic impedance. Here in analysis time we are assuming their match terminated, but in reality there can be some load. So, there can be some power that gets reflected.

Problem is if this port - 2 ports are not isolated, what about the reflected power that will again through this junction that will come here. It will unnecessarily disturb the 3 port. So, due to the mismatch in port 2 port 3 will suffer. If the isolation is poor, but if the isolation is high then even if there is some reflected power here, that will not disturb the others. So, do not disturb your neighbours you may have some fight in your house, but do not that fight should not be skill; to some junction it will go to your neighbours power, that is why we require isolation by this Wilkinson power divider that gives that isolation, that is why it is a popular. Though it has internal losses because this structure you have some losses here.

So, it is not a lossless structure but. So, now, let us see various power dividers their comparison, we have made a table for that. So, we have seen lossless tee junctions. Their good because internally they are not having power, but not matched at 2 output port also they have poor isolation between ports, resistive divider it has high power dissipation towards isolation between output ports. Wilkinson power divider again it is a high power dissipation, but it has input on one thing that good isolation between output ports. So, you choose that which one you want to take. Now you can see that all this power dividers they have some disadvantage. So, I cannot have the isolation and dissipation or matching; that means, loss I cannot, total loss I cannot make 0. Here now that limitation is because we have confined ourselves with 3 port device. Now if I go to 4 port device all this problem will be solved. That we will see in our next lecture.

Thank you.