Microwave Integrated Circuits.
Professor Jayanta Mukherhee.
Department of Electrical Engineering.
Indian Institute of Technology Bombay.
Lecture -15.
1 and 2 port passive components.

Hello, welcome to week 4 of this course microwave integrated circuits. in the previous modules in the previous weeks, we had covered the basics of microwave engineering, the various parameters associated with characterising a circuit like S parameters and also the methods for analysing. In this module, we shall be seen actual microwave components that are used. So, the way we will be going about discussing these components is based on the number of oats each component has. So, we shall be starting with one port microwave devices 1st and then we will proceed to 2 port microwave devices, then to 3 port microwave devices and so on.

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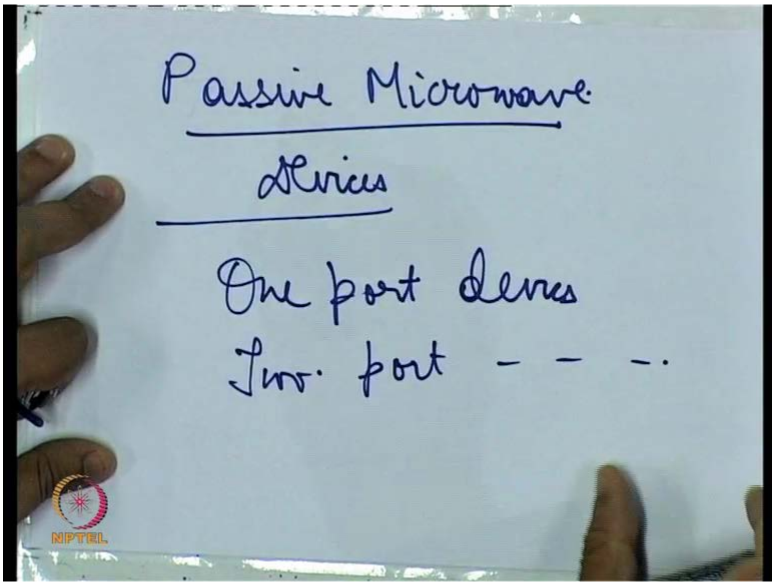

So, let us start with one port microwave devices. Now, this module deals only with passive components, we are not discussing the active components which we shall do it later models. So, and as I said we shall 1st be discussing one port devices, then we shall be moving onto 2 port devices and so on. So, let us 1st, start with 1 port devices.

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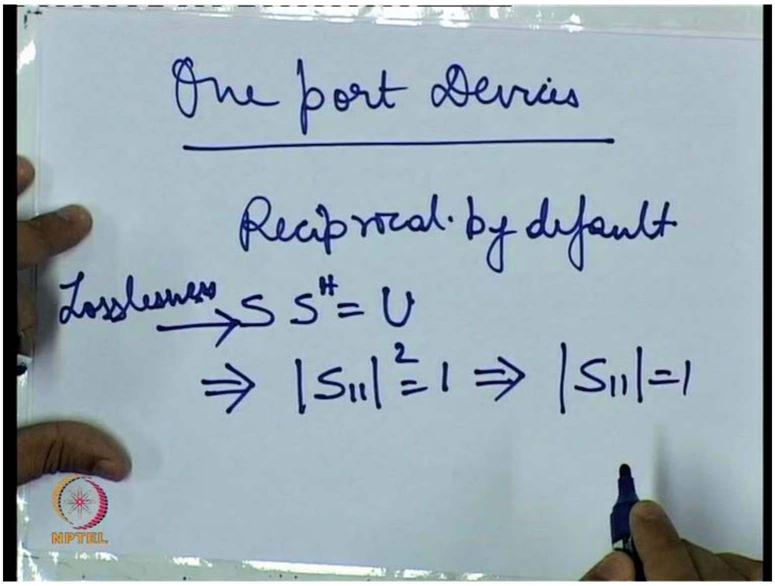

Now, a 1 port device has only one port, therefore it is reciprocal by default. And if it is lost less, then the unitary condition, that is S SH Hermitian is equal to U, this simply translates into S 11 square equal to1 which in turn…, so this is the lossless ness that will lead to this condition and from here we can derive that S11 will be equal to 1.

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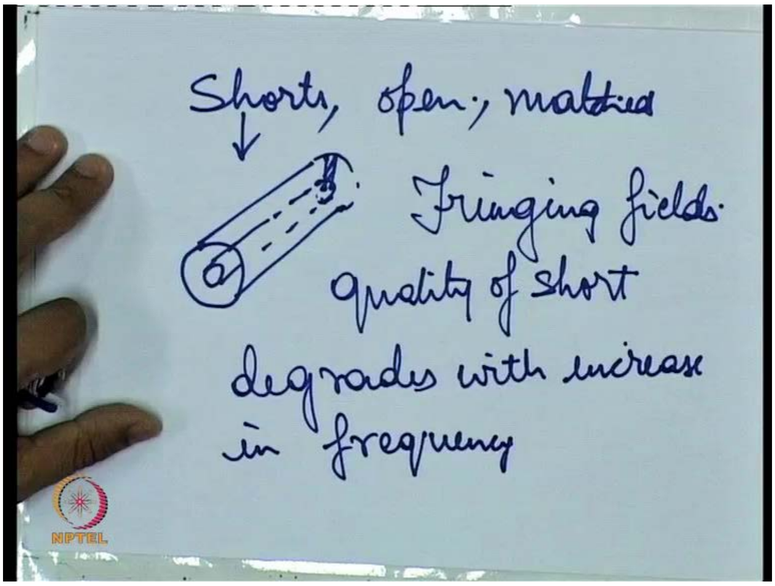

Some examples of such one port devices are shorts sometimes we need a shorted load or open load or a matched load. However, when you are actually making these devices, we have to take into account some aspects, for example, let us see a shorted termination. Shorted termination or short. A shorted termination by definition is just that, it is a short circuit. But how do we build such a thing?

Now suppose this is a short, simple way of implementing a short could be you know, to shot, this is a coaxial cable with an inner conductor and outer conductor, a simple way to implement the short would be to directly connect the inner conductor with the outer conductor. But the problem with such a simple connection is fringing fields. Lot of fringing field will be produced and the quality of the short degrades as frequency increases.

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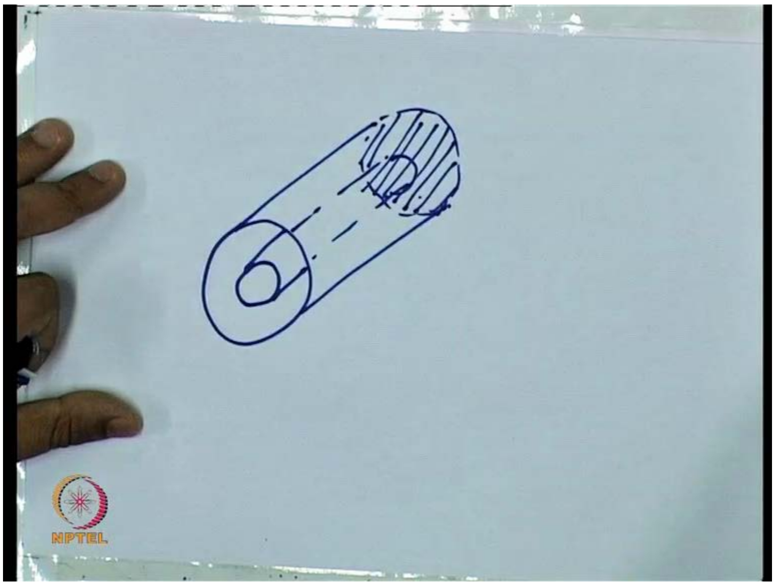

So, a better way of implementing the same short would be that instead of having one single connection between the inner and the outer conductor, we might actually have a throughout connection, what I mean is, say this is my inner conductor and this is my outer conductor and say this is the other end which is shorted. So, I kind of use a disk rather than single piece of wire connecting the short, use the entire bottom or the inner base of this inner conductor is connected to the base of the outer conductor. So, this is a better way of implementing a short.

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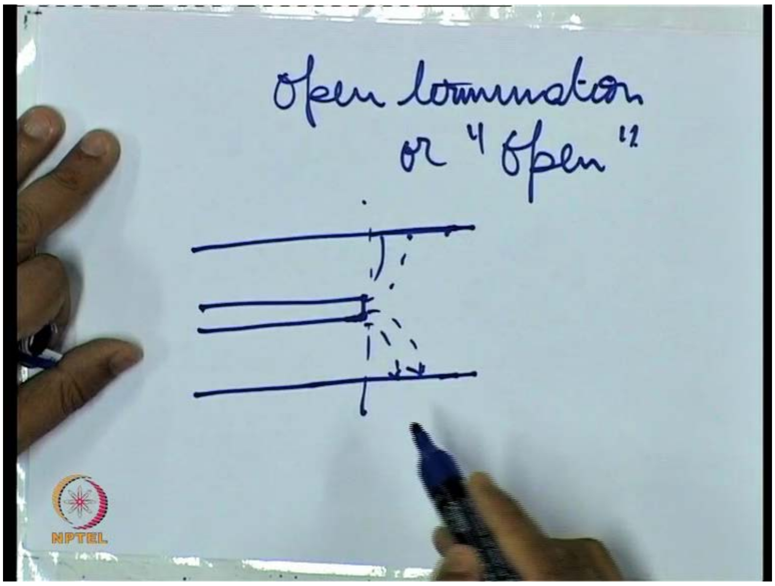

Similarly say if I want to implement an open termination, an open termination or simply an open. So, again suppose it take a cross-sectional view of my coaxial cable and say if I have have my outer conductor just at this level, this point, then there will be a lot of fringing fields and this will cause the quality of the open termination to degrade. So, that is why the outer conductor, to properly implement an open, of course, I might add here that open terminal is very difficult to implement in practice because the presence of parasitics cannot be totally eliminate.

But if you increase the length of the outer conductor with respect to the inner conductor, then the fringing capacitance or the fringing field problem can be reduced to some extent.

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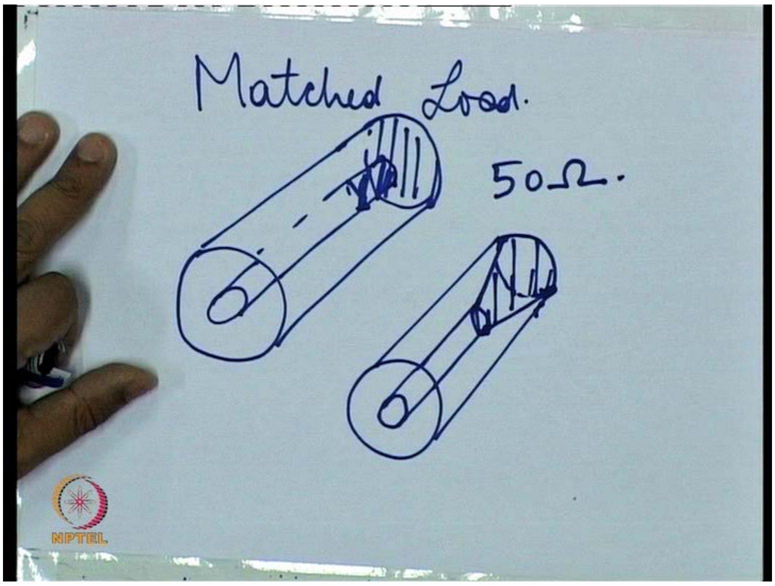

How to implement a matched load? A matched load, one way to implement is similar way to the shorted load that we saw, when we have a disk, we have our inner conductor and then instead of shortening it, we end our inner conductor with some other material.

And this way what happens is that the different conductivity or the resistivity of the material introduces high impedance as compared to the short and that is how you get this, get that matched load. Say, if matching required is 50 ohms, then there are 2 kinds of conductors, this part is just a metal and this part is a material of higher resistivity and when both can combine, there will be a matched load.

But then the problem with this kind of implementation that the boundary or the junction between the 2, that is at the junction of this disc and that of the inner conductor, since there is a sharp transition, the impedance matching will not be perfect and there may be reflections introduce at this boundary, at the boundary between the**,** inner conductor and the outer and this disc at the base. So, to avoid that, what could be done is we have our same thing, same outer conductor with the inner conductor instead of instead of being of the uniform width as shown here, the width can slowly change like this.

This is like a tapered implementation and because of this taper, the impedance matching is more perfect as compared to just this case where the impedance is 50 ohms but because of the geometry of this structure, because of the sharp transition at this end, there might be multiple reflections.

In a waveguide or in a… So, these are, these are the examples that I showed for 2 conductor waveguide. In single conductor waveguides, the way implementation is made is,

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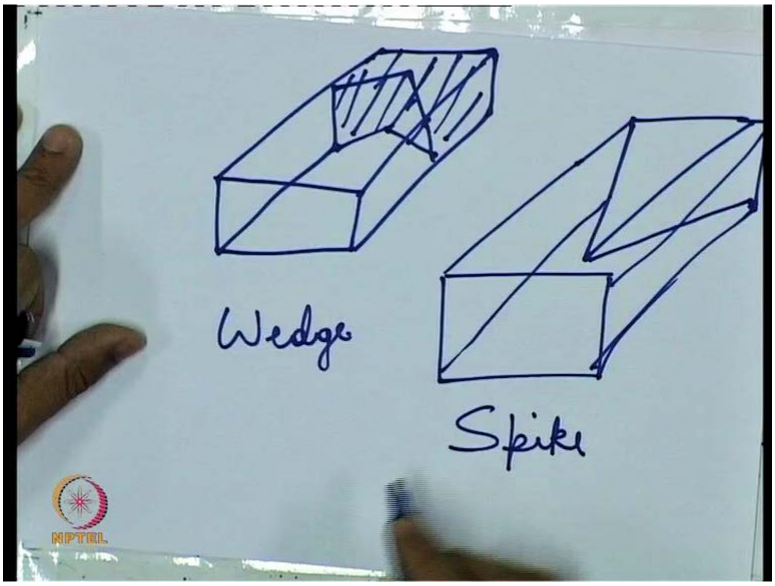

say this is our waveguide, then to introduce, to avoid having abrupt transitions, we can have implementations like this. So, here, this is a wedge shift structure and instead of having a very abrupt transition from one media to another, you have a wedged structure which gradually changes shape and it follows the principle of the taper and thereby avoids multiple reflections.

Or the opposite geometry, for the type of geometry also can be implemented. That is called the spike implementation, in the spike, by opposite I mean instead of this going this way, it can come this way. So, it will be something like this. So, here, we have a pointed spike like structure and that provides the required impedance matching. So, this is a spike and this is a wedge. So, those are some of the one port devices that are commonly used. Let us go to some 2 port devices.

So, 2 port devices, for 2 port devices, we have already discussed the properties of the S parameters earlier just go through them once again.

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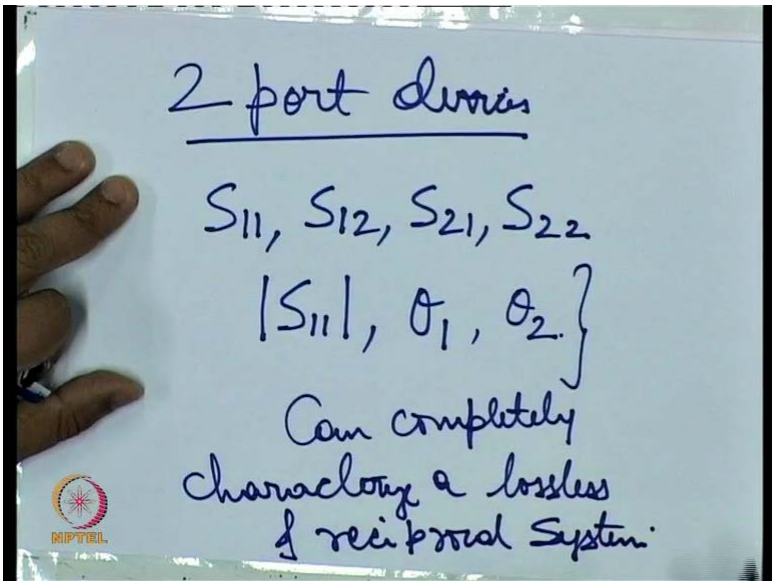

So, we saw that of the 4 S parameters associated with the 2 port network, if we just get information about S 11 magnitude, the phasor or the argument of S11 and argument of S22 which I call theta 2 and the argument of S11, I am calling theta 1. Then that can completely characterise a lossless and reciprocal system.

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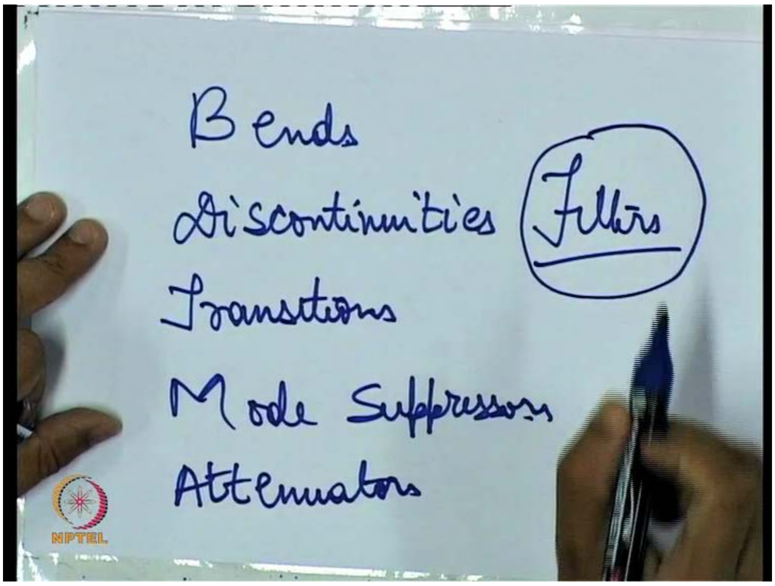

Now, some of the examples of 2 port devices are bends, discontinuities, transitions, mode suppresses, attenuators and filters. Now filters are 2 port devices but then since they are so extensively, there is so much variety of these filters, we shall be devoting the discussion of filters to a separate module. But right now, let us discuss the other 2 port devices that are used commonly.

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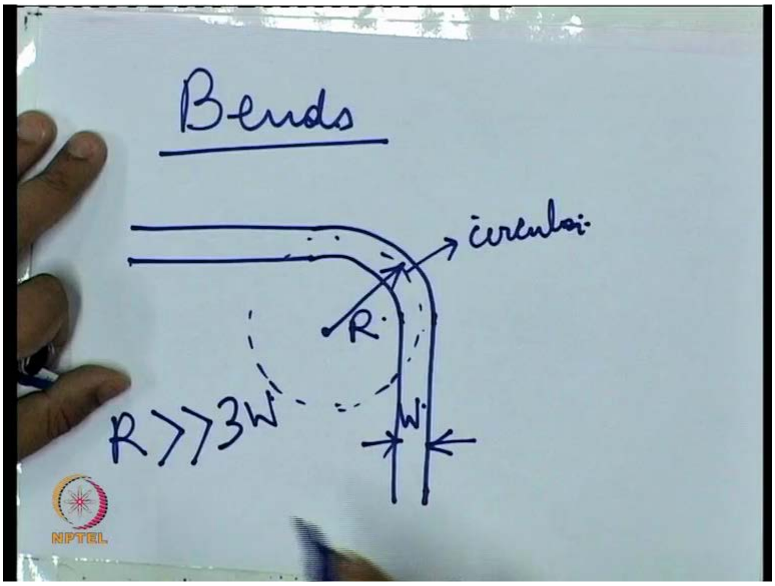

So, bends are like, you have a transmission line travelling in this direction and another transmission line travelling in this direction, then the connection between the 2 is called the bend. It is bend because it sort of bends the direction of the transmission line. So, 2 popular designs for these bends are common, one is what is known as the radial implementation. So, radial implementation, the outline of the bend follows a circle circular shape. And suppose R is that radius of that circle and W is the width of the transmission line, then the rule of thumb is R should be greater than three-times W.

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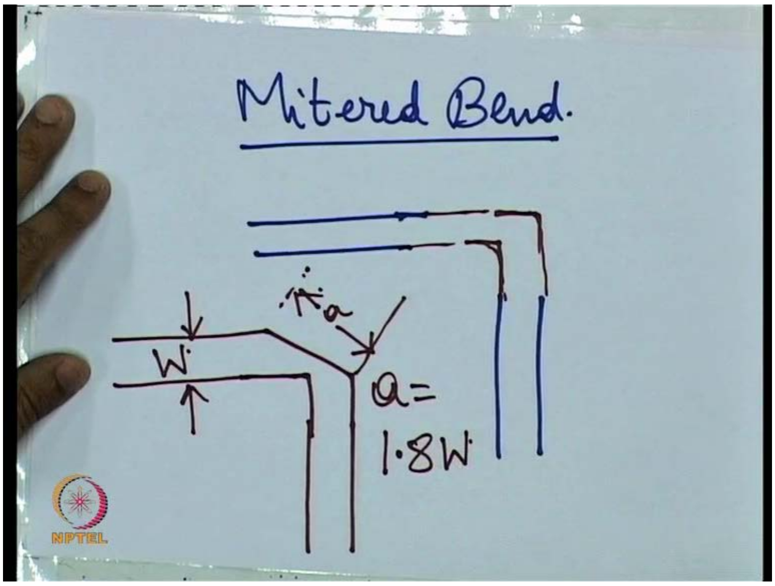

Another implementation of the bend is what is called as the mitred bend. So, simple way of you know, having a bend could have been this, just to next a rectangular connection like this. The problem with this is because of the sharp transitions here and here, there is a possibility of multiple reflections. So, that is why he mitred bend a similar to this rectangular bend except that the outer surface is chamfered like this. And again the rule of thumb is supposed W is the width of the transmission line and A is the length of this section then A should be equal to 1.8 W.

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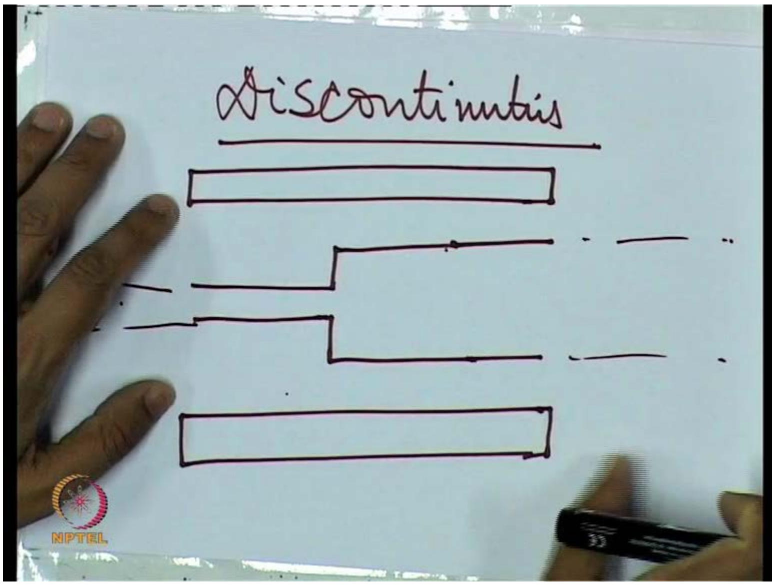

The next type of 2 port device that I was mentioning was a discontinuity. So, a discontinuity is similar to the bend in the sense that bend connects 2 different transmission lines, discontinuity connects 2 different types of, 2 transmission lines of different widths, different characteristic impedances. For example, say you have 1 transmission line of this width and another of this width and suppose this is the outer conductor, so say you have 2 coaxial lines which are of different thickness where the inner conductor is of different thickness and therefore of different characteristic impedances.

So, this structure that kind of connects a coaxial cable of this width to a coaxial cable of this inner width, this is that discontinuity. So, one way of implementing it is just this, direct connection between the 2.

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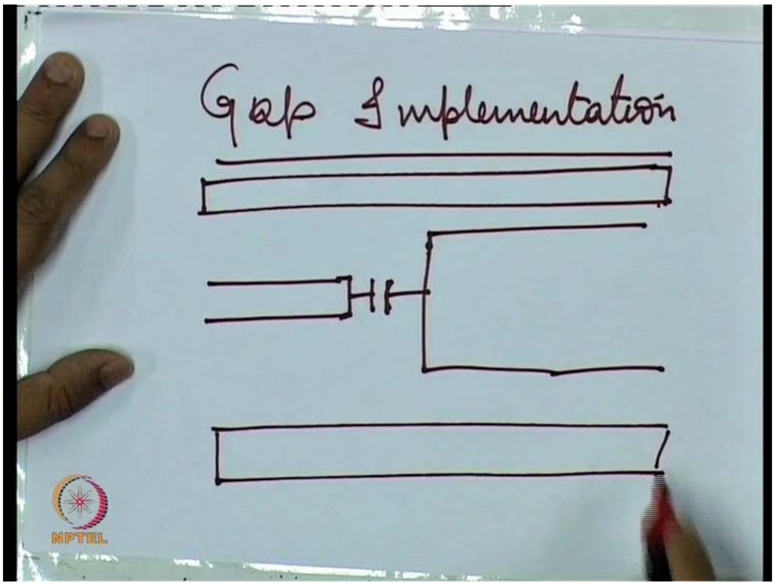

Another way of implementing is what is known as gap implementation. So, in a gap implementation you do not connect them, instead leave a gap between. And Inter capacitance, the inter-transmission line capacitance is the way in which the is the media through which the power is delivered from one waveguide to another.

So, this is a gap implementation, this capacitance does not actually exist, this is just I have shown as a symbol, this is a capacitance between the 2. There is no connection between this conductor, this inner conductor of a different width with this inner conductor of a different width.

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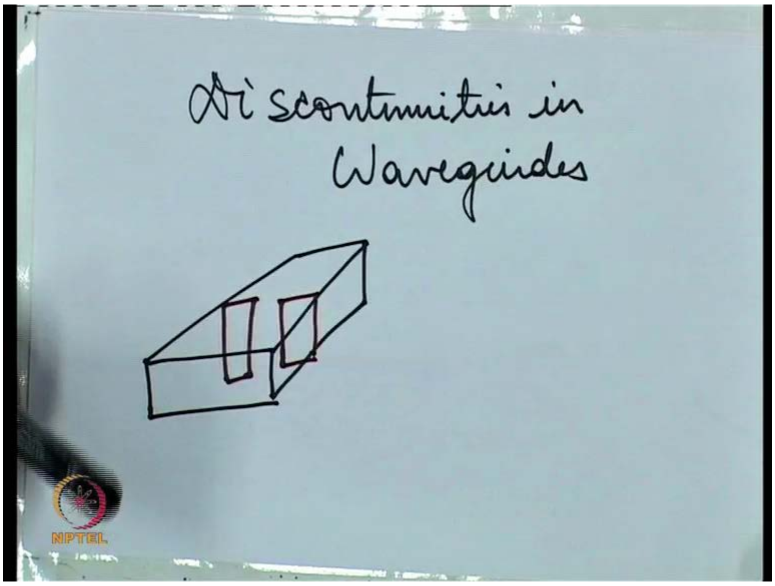

Sometimes, you know, we want to introduce an inductive parameter within a waveguide. So suppose you have a waveguide like this and you add 2 metallic strips which connects the surfaces which have greater widths.

So, in this waveguide there are let me draw it in a different, might not be clear from the previous video.

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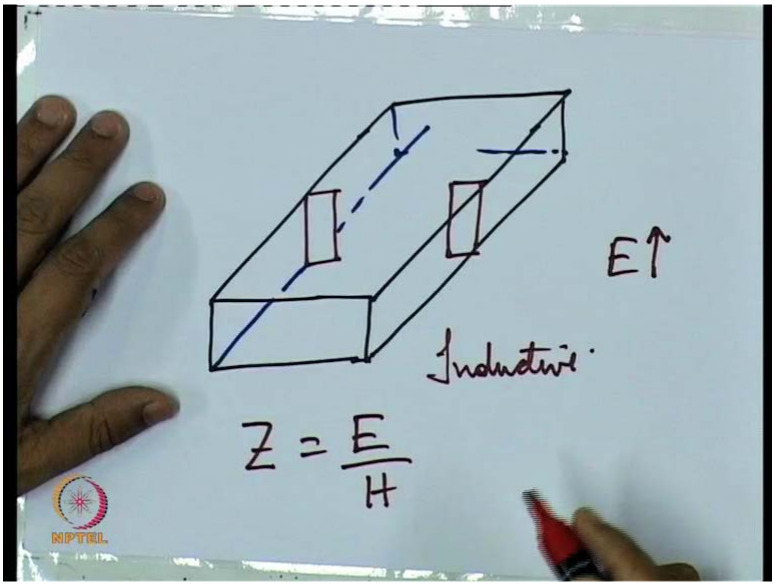

So, we have waveguide… So, if we have these strips connecting the surfaces which have the greater width of the 2 surfaces, then this produces an inductive effect. Now, in single conductor waveguides, you might ask me what is an inductive effect. It simply means that the electric field is made, the phase of the electric field after passing through this is ahead of ahead of the phase of the magnetic field. So, that is the inductive effect. Recall we had defined impotence also as the ratio of E and H fields.

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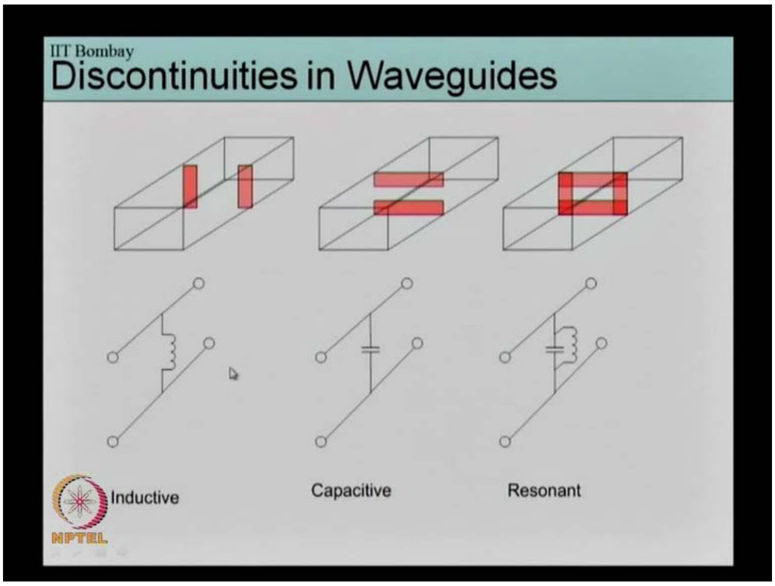

Now if we can go back to this slide monitor slide for a moment here we can see that more clearly, so if we have this metal strips connecting the surfaces which have greater width, then this produces an inductive effect and if we have these metal strips connecting the services which have lesser width as shown here, than this produces a capacitive effect. And if both are present, then it basically results in a inductive combined inductive and capacitive effect which basically is that of a resonator.

So, if we can come back to our written slide, so some of the others, so this is like that the previous this discussion was for introducing inductive and capacitive effects in waveguide. What if we have the same problem as that of the coaxial discontinuity? That is we have one coaxial cable of a particular inner conductive wave and we want to connect it to another coaxial cable of are different inner conductive wave. So, let us see that case.

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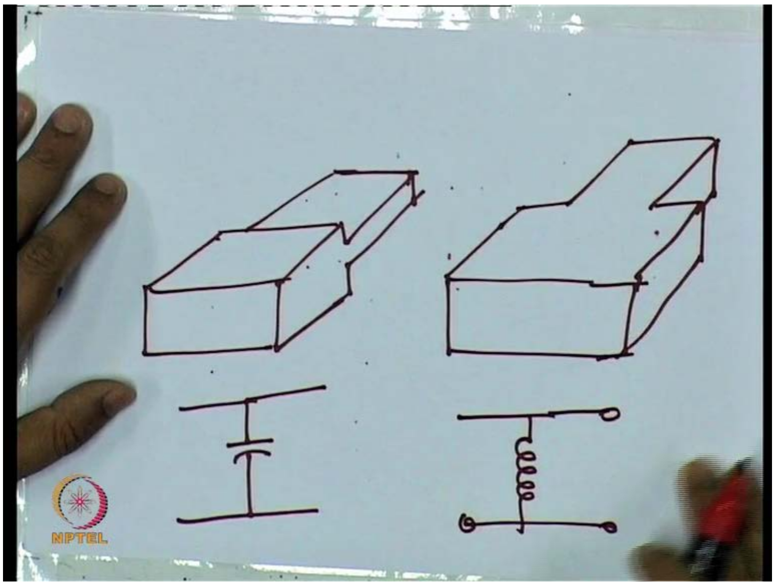

So, suppose we have one waveguide like this and connected to another waveguide like this and this is actually a capacitance. This actually produces a capacitive effect, it can be modelled by shunt capacitance. On the other hand, here the discontinuity is along the edge, along the edge which is the lesser width of the 2. So, this is one edge and this is another edge.

This edge has a lesser width and this continuity is along that edge, the other edge that length or width of the other of the broader edge remains the same. If we do it in the other way, that is if the discontinuity is a longer broader edge, rather than the thinner edge, then it will look something like this. And that will actually be an inductive effect. That can be modelled by this shunt inductor. Then there is another class of 2 port devices that are known as transitions.

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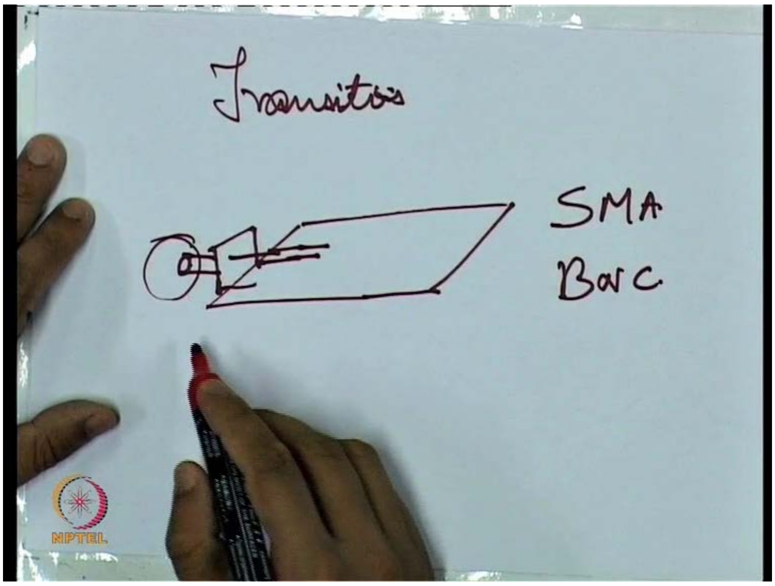

Now, when you connect your PCB board to the to some device or source or some measurement device like spectrum analyser, the way it is usually done is that suppose this is a piece of transmission line on a PCB board, then something called a launcher is connected like this. And that launcher leads to a output point which is, here then you connect, your external cable is connected to this output point. So, there are several type of launchers, some of them are called SMA, BNC like this.

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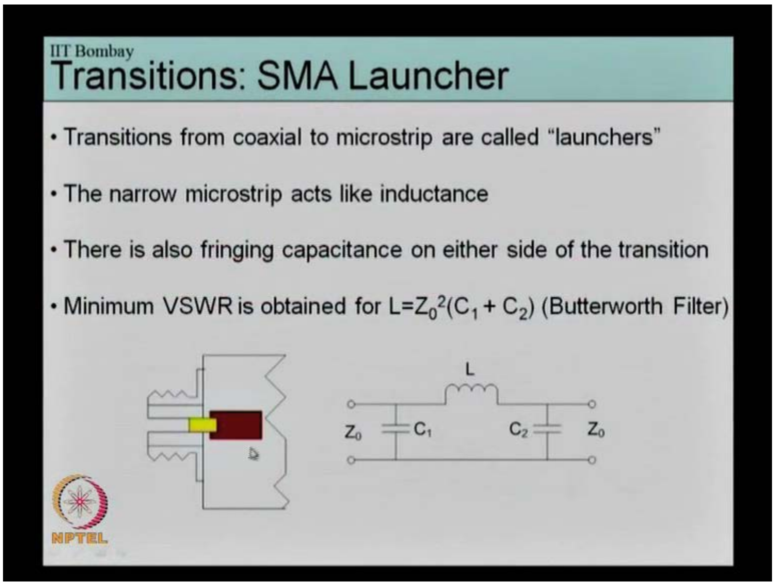

And for example, an SMA transition, the SMA launcher is shaped like this and its equivalent circuit is like a lowpass filter, pie implement of a lowpass filter. This is one end of this launcher, say this and and this is the other end, both are matched to Z0 characteristic impedance and the the inner circuit or the central conductor provides an inductive effect whereas the metal stack one over another produces a capacitive effect. So, that is how it is done.

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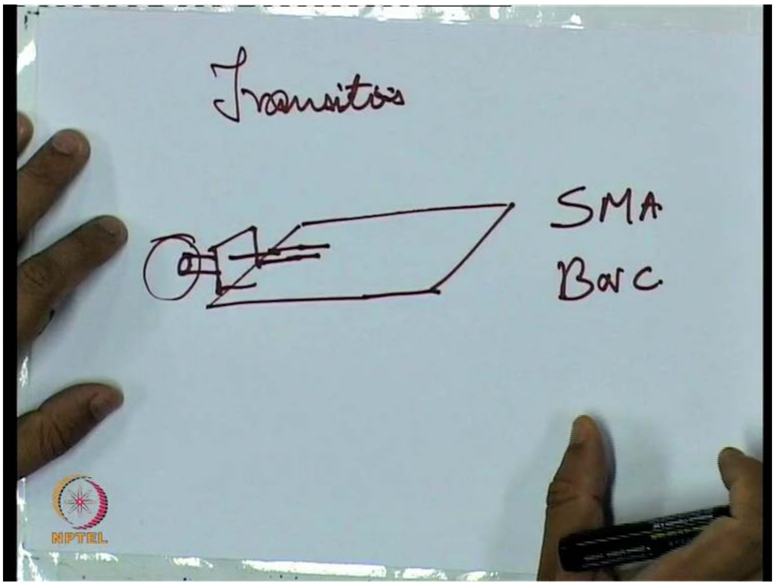

So, if we could come back to our written slides. And one another type of launcher or transition that is frequently used, especially when you are going from 2 conductor waveguide to a single conductor waveguide.

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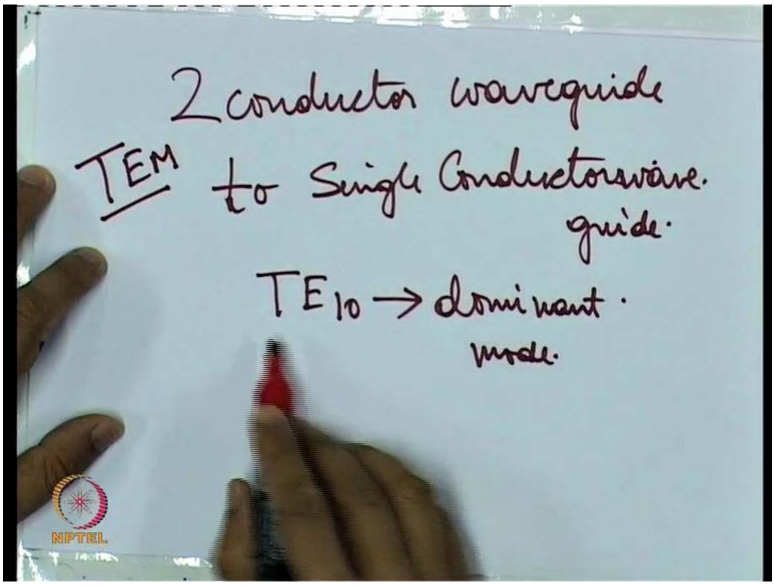

If you want to have a 2 conductor waveguide, as I said, 2 conductor waveguides conduct via TEM mode to a single conductor. And single conductor waveguides cannot transmit TEM mode, they have to classmate to either TE or TM mode. Now, for a cable or for a rectangular waveguide TE10 is the dominant mode. Dominant mode is that mode which has the lowest cut-off frequency.

So, in a 2 conductor waveguide, the power transmission is through the TEM mode and in a rectangular waveguide, TE 10 is the dominant mode. So, we have to have a converter which goes from which converts a TEM wave to a TE 10 wave. Let us see how it is done.

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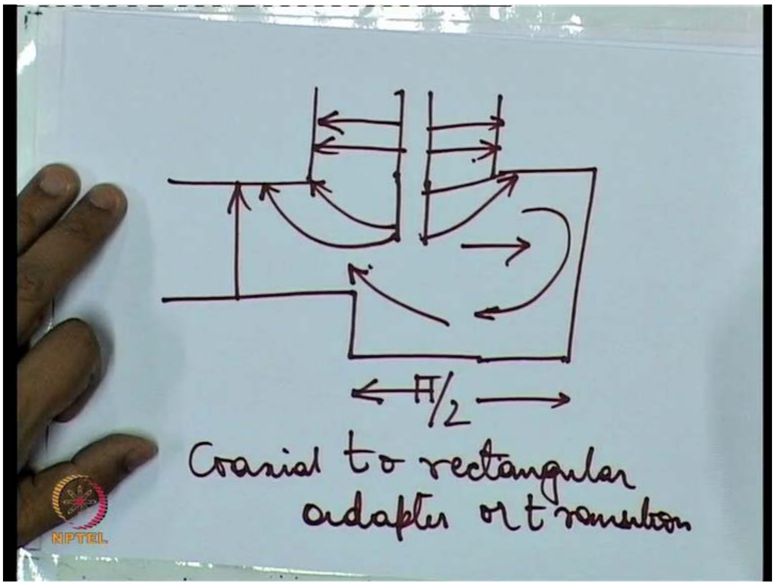

So, the construction of that is like this. This is your coaxial cable and this is your waveguide. In a coaxial cable, the node is TEM and therefore the electric field lines are radial on the central conductor. And as the fields, electric power reaches the inner surface of the waveguide, the field pattern or the electric field lines change like this.

And on this side, there is a pie by 2 length of the waveguide given, what it does is that any wave that flows along this direction will be reflected back and added constructively to this wave that is proceeding along this direction. So, this is how, this is a coaxial to rectangular adapter or transition. Then we have attenuators, now attenuators are well-known, and resistive network can provide attenuation, however in addition to providing power loss, attenuators should also provide impedance matching and to do that, say you have a simple rectangular waveguide.

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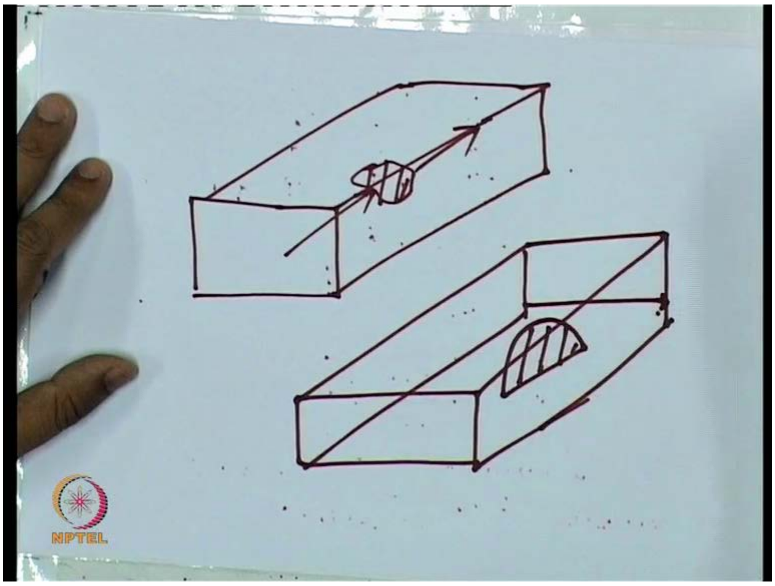

You can make an attenuator by keeping some material of high resistivity within that waveguide, that will cause some of the power to be lost in this high resistivity material and the and the remaining power to be transferred. A better way of implementing this is instead of having any arbitrary shaped structure inside, if we have a structure or a card inside this waveguide that a sinusoidal shaped, then the electric field lines at some point of time will be oriented nicely along the sinusoidal shape.

And since the electric field itself is sinusoidal, the attenuation will be more perfect, there will be less deflections because of the absence of because of the shape of the electric field is perfectly matched with this attenuator and those spurious reflections will not happen.

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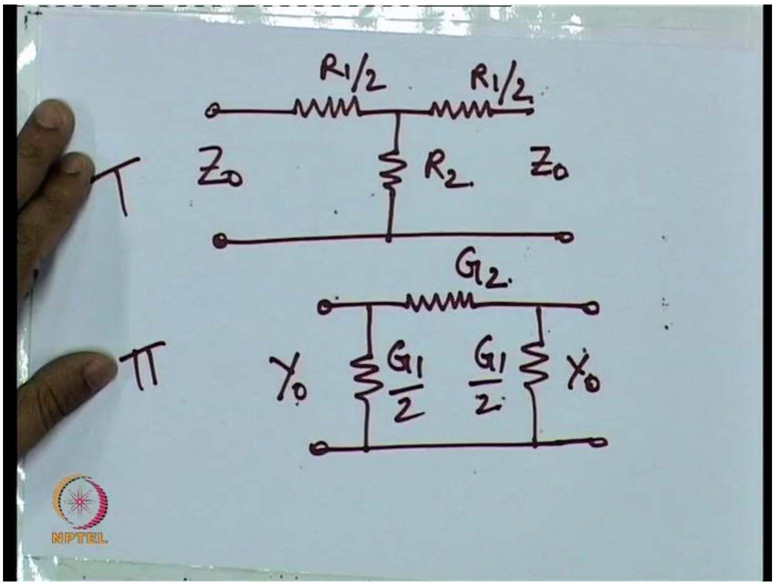

As far as resistive networks are concerned, we can make an attenuator simply using a T or pie network. Say we have as I said an attenuator is very simple to visualize because it has to provide power loss, attenuation is nothing but power loss.

So, these 2 shapes, these 2 structures immediately come to mind when we talk about attenuator. This is a T implementation, this is a pie implementation.

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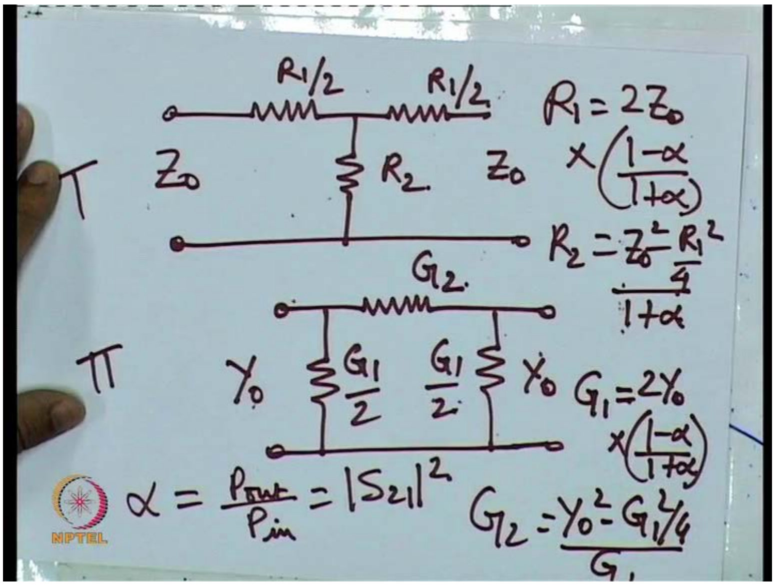

Now, in the book by Pozart, solution for this implementation is given. Suppose you need alpha attenuation, attenuation of alpha that is P out over P in, that is given by S21 square provided the inputs are matched and the design equations are that R1 should be equal to 2 Z0 into 1 - alpha upon 1 + alpha. R2 should be equal to Z0 Square - R1 square by 4 upon one + alpha and for this implementation, this pie implementation, G 1 should be equal to 2Y0 into 1 - alpha over 1 + alpha and G2 should be equal to Y0 square - G1 square by 4. So, the equations are basically the dual of each other.

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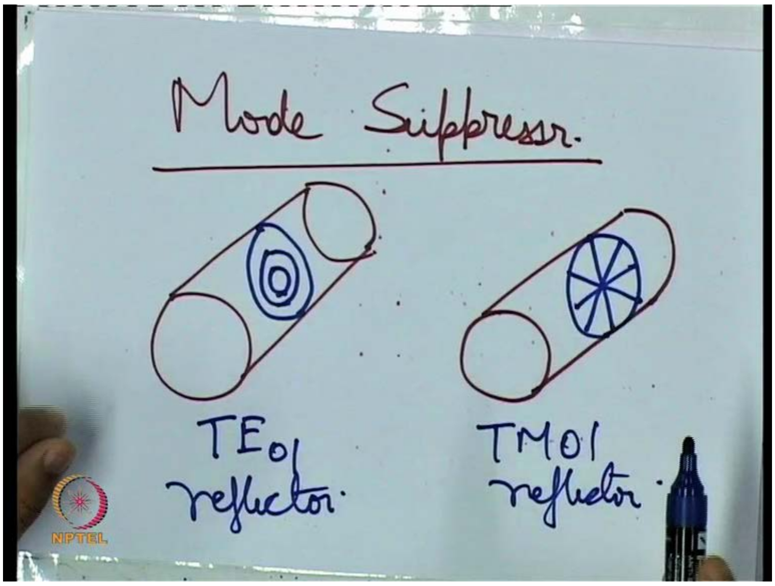

Now, one final 2 port device that I would like to discuss is what is known as mode suppressor. So, a mode suppressor is a device is a circuit which allows certain modes to pass through and does not allow other modes to pass through. Let us see this particular circuit, this is a cylindrical waveguide with some concentric metal structures present here and this is another structure which has instead of having concentric metal wires, we have radial metal wires.

It can be shown that this is what is known as TE 01 reflector and this is a TM 01 reflector. And you can prove this that this will not allow TE 01 to pass through and this will not allow TM 01 to pass through. The solution for TE and TM waves is given in for cylindrical waveguide is given in the book by Pozart. Just a hint to this proof is since that since these are concentric metal wires,

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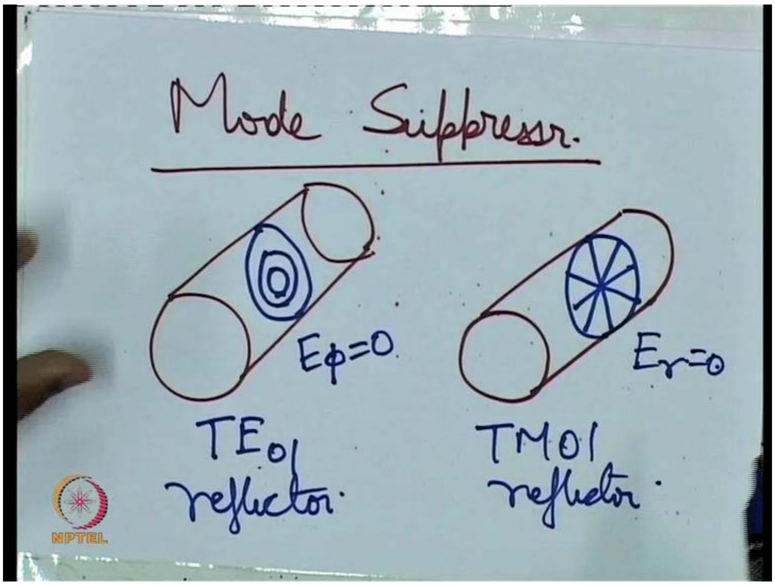

so here the E theta is in polar coordinate, I beg your pardon T Phi component will be 0 because these are concentric metal line wires and so they will nullify the radial, the tangential component of the electric field and these will nullify the radial component of the electric field.

So, now it can be shown that if the radial component the tangential component of the electric field is nullified, then the TE 01 mode will cease to exist and similarly if the radial component of the electric field is nullified, then TM 01 component will cease to exist. So, these are some of the 2 port devices that are commonly used, of course as I said, filters are also examples of 2 port devices but we shall cover them in a separate module. In the next module we shall cover 3 port devices, thank you.