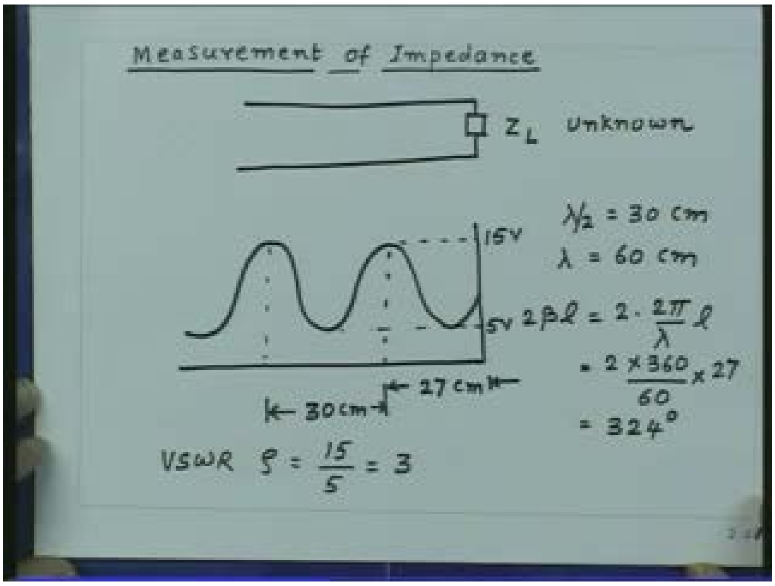
Transmission Lines & E M. Waves
Prof. R. K. Shevgaonkar
Department of Electrical Engineering
Indian Institute of Technology, Bombay

Lecture – 15

In this lecture, we solve few more problems of transmission lines but this time we are going to make use of the switch chart to solve this transmission line problems. Let us take a problem of impedance measurement using the transmission line.

(Refer Slide Time 01:37)



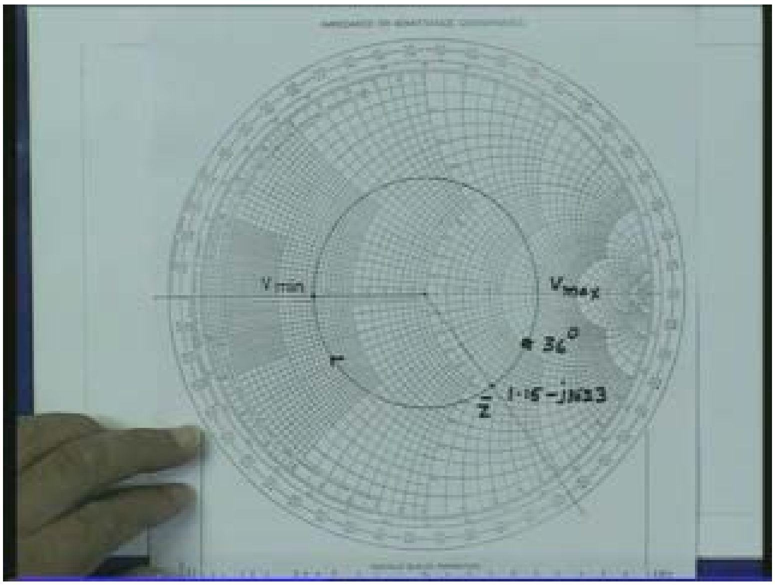
As we have seen earlier, the measurement of complex impedance is very tedious at higher frequencies because the measurement of phase is unreliable. So the measurement of unknown impedance at higher frequencies is carried out by measuring the standing wave ratio and the location of the standing wave pattern maximum or minimum, we calculate the unknown impedance. So here a setup we are having a transmission line to which the unknown impedance is connected and by using what is called a slotted transmission line to measure the standing wave pattern on the transmission line.

So this is a variation of the voltage as a function of length on the transmission line. So we measure the parameters let us say the maximum voltage which we see on the transmission line is 15 volts, the minimum voltage is which we see is 5 volts the location of the first maximum is 27 centimeters from the load end of the line and the distance between the 2 edges and maxima is 30 centimeter knowing this information now, we would like to find out what is the unknown impedance first thing since we know the distance between the 2 maxima of the standing wave pattern, these distance is lambda by 2 and that is the reason we have lambda by 2 equal to 30 centimeter. From here we can get the lambda which is 60 centimeter. Once we get the lambda then the phase corresponding to this distance of 27 centimeter, 2 beta l that is 2 into 2 phi by lambda into l which is 27 centimeter lambda is 60 centimeter.

So you get a phase 2 beta l which is 324 degrees, from the maximum and minima voltage on the line we can calculate the VSWR and that is 15 by 5 that is equal to 3. Once, we have this information then we can go for the switch chart to calculate the unknown impedance. So we take the switch chart and since we know the VSWR, first we draw the VSWR circle on the switch chart. So what we do we take the normalize R equal to 3 point on the horizontal axis on the right side of the center of the switch chart and draw a circle passing through this.

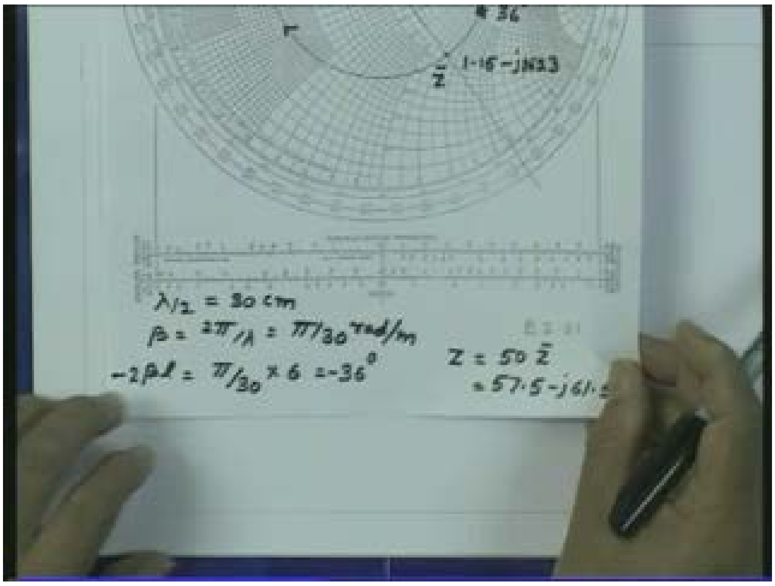
So this circle is VSWR 3 circle then the right most point here that represents the location of the voltage maximum and the left most point on the circle shows the location of the voltage minima. Since, we know the location of the voltage maximum in our problem we know this location on the transmission line and now, if I move from this voltage maximum points away from the generator by a distance of 27 centimeter that is 324 degrees then I must reach to the load point.

(Refer Slide Time 05:04)



So essentially from the maximum location if I move away from the generator that means in the anticlockwise direction by an angle of 324 degrees on this constant VSWR circle whatever point I reach to that point corresponds to the load impedance. If I make a moment like this by 324 degrees I reach to this point. Now a if I read of the value of the normalize resistance and reactance corresponding to this point I get a value “1.15” minus j “1.23”.

(Refer Slide Time 06:01)

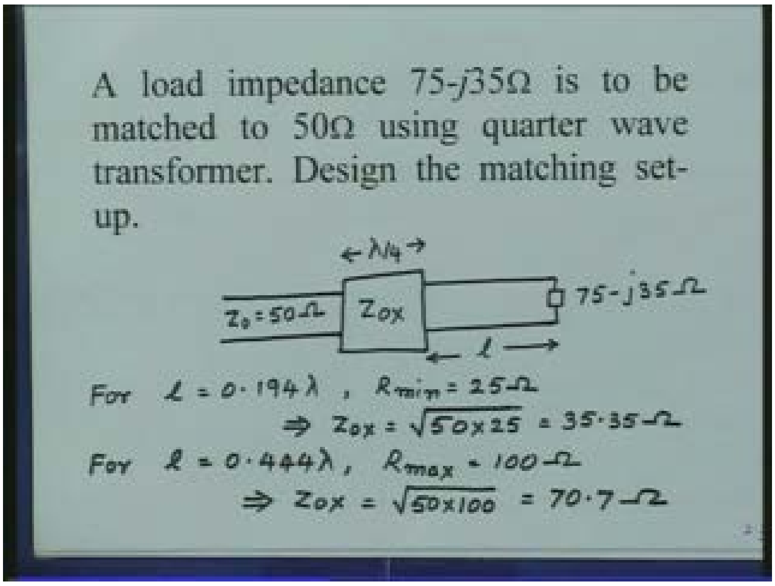


So the absolute impedance if I multiply this by the characteristic impedance of the line which is 50 ohms then I get this normalize impedance multiply by characteristic impedance, I get “57.5” minus j “61.5” ohms. So the unknown impedance can be measured very easily without doing much complex calculations by using the switch chart. Let us take now a problem for the quarter wave transformer again, we will consider a general problem here that the impedance to be matched by quarter wave transformer is not a real impedance, let us say a load impedance of 75 minus j 35 ohms is to be matched to 50 ohms using quarter wave transformer, design the matching set up.

Now if you recall the quarter wave transformer basically you can match 2 resistive impedances. Since our characteristic impedance is real any real impedance can be match to the characteristic impedance. However, the impedance which is given to us is a complex impedance which is 75 minus j 35 ohms, so by using a section of a transmission line first we must transforms the impedance to a real value, at that location we insert a quarter wave transformer and we get a match.

So the set up essentially would be that this is the unknown impedance which is 75 minus j 35 ohms, I introduce a section of a line of the same characteristic impedance. Let us say this is Z naught is 50 ohms, so this line also is of characteristic impedance 50 ohms then the impedance transform seen at this location should be real. So at this location I can introduce a quarter wave transformer I will get a match. So now 2 things have to be found out in this problem, first is what should be this length and what should be the characteristic impedance of this quarter wave transformer. The length of the quarter wave transformer is lambda by 4 for finding out the impedance at this location which will be real and the length we again make use of the switch chart.

(Refer Slide Time 08:32)

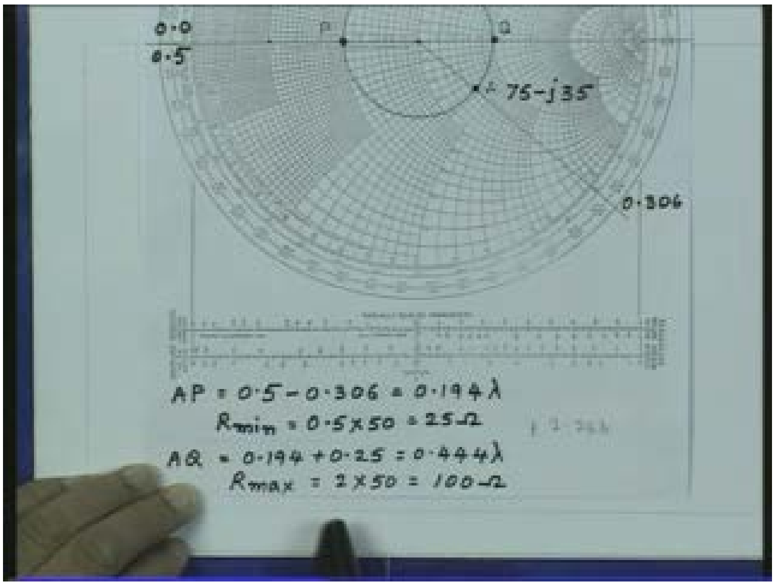


So first thing what we do, we take the switch chart, mark the unknown impedance which is to be matched to 50 ohms. So first we normalize this impedance of 75 minus j 35 ohms, mark this point on the switch chart, draw a constant VSWR circle passing through this impedance. So this circle is the constant VSWR circle corresponding to the load impedance 75 minus j 35. Now as we move on this constant VSWR circle towards the generator that may from the clockwise direction if I move by a distance corresponding to A P the impedance at this location seen will be real and it is the minimum resistance which we will see on the line, if I move by a distance corresponding to AQ in the clockwise direction then I will reach to a location of voltage maximum and then the resistance seen at that location will be R max.

So there are 2 possibilities either I insert a length of transmission line between the load and the quarter wave of transformer by this and then, the impedance to be matched will correspond to this value or I can take a distance corresponding to this and then, the impedance to be match will correspond to R max value. So there are 2 solutions to this problems, firstly if I move by a distance AP and how I measure a distance I take a radius vector, go to the circle here here the lengths are marked on the outer most circle of this switch chart its start from 0 it goes all the wave up to “0.25” and then goes up to “0.25”. So here the circumference is calibrated in terms of lambda.

So I can take a radius vector, read of this value this is “0.306” if I move up to a point P which corresponds to “0.5” lambda, difference of these 2 will tell me the length of the line which is to be introduce between the load and the quarter wavelength transform. So one possible solution is that if I take this length then that length will be “0.194” lambda and the impedance to be match will be R min and that will be the 50 ohms multiplied by the normalize value here which is “0.5”.

(Refer Slide Time 12:22)



So the now I get the impedance to be match will be 25 ohms if I insert a length of a line between the load and the transformer are “0.194” lambda. Other possibility, if I go from A to Q then the distance will be AQ will be “0.194” which is distance plus lambda by 4, “0.25” for that distance will be “0.444” lambda. So if I introduce a quarter wave transformer at a distance of “0.444” lambda from the load then the impedance to be match will be R max and they are to be 50 into normalize value 2 corresponding to this point Q.

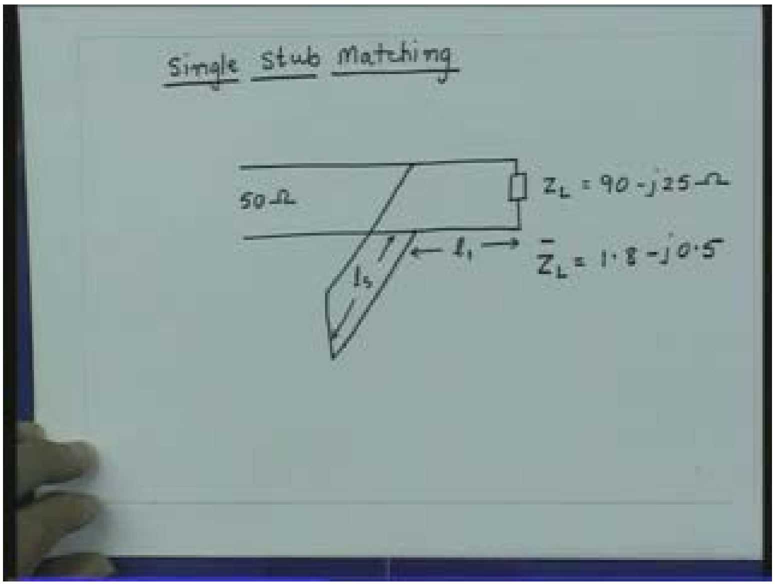
So if I take this as L in this case then the impedance to be match will be 25 ohms, so the characteristic impedance of the quarter wave transformer will be geometric mean of the characteristic impedance and the impedance to be match which is 25 ohms. So the characteristic impedance of the quarter wave transformer will be “35.35” ohms. On the other hand if I take L as “0.444” lambda then the resistance to be match will be 100 ohms and then the characteristic impedance of the quarter wave transformer would be geometry mean of 50 and 100 and that will be “70.7” ohms.

So in this problem, we see how to match a complex impedance to the characteristic impedance by using section of a transmission line and the quarter wave transformer. Let me remind you that initially the quarter wave transformer can match the impedances which are real, only thing is by using a section of a transmission line we have converted a complex impedance into real impedance and then we have use the concept of the quarter wave transformer. Let us take now one problem for the single stub matching let us say we are given an impedance of 90 minus j 25 ohms.

Now as we know that is the single stub matching the line which are use for the matching purpose is the main line and the stub they both have the same characteristic impedance 50 ohms. So the parameter which are to be now calculated or the length of the transmission line L 1 that gives the location where the stub is to be introduce on the main line and the length of the stub Ls. So these 2 quantities are unknown the impedance of the transformation line is same as the characteristic impedance of the line which is 50 ohms. So as we proceed first thing we do we normalize this impedance with the characteristic impedance.

So you get Z l normalize that is this ninety minus j 25 divide by 50 so this will be “1.8” minus j “0.5”. Remember, now that this is the impedance the stub is connected in parallel with the main transmission line. So as we have seen earlier whenever we have a parallel connection that dealing with admittances is more a propagate. So first our task would be to convert this impedance into admittance and then carry out the single step matching in terms of admittances. So now you proceed as follows firstly we consider switch chart as the impedance switch chart, since the impedance to be matched is “1.8” minus j “0.5” considering the chart as the impedance switch chart at mark this point Z l bar which is “1.8” minus j “0.5”.

(Refer Slide Time 15:35)



So this point here is the impedance to be matched, I draw a constant VSWR circle passing through this point, so this circle is the constant VSWR circle. Now since we want to do the further calculations in admittances. First we convert this impedance to admittance and as we have seen earlier if I take a diagonally opposite point of Z L bar on this constant VSWR circle then I get the normalize admittance at that location. So this point diagonally opposite point Q gives me a normalize admittance corresponding to this normalize impedance, let us say that normalize load admittance is g l plus j b l.

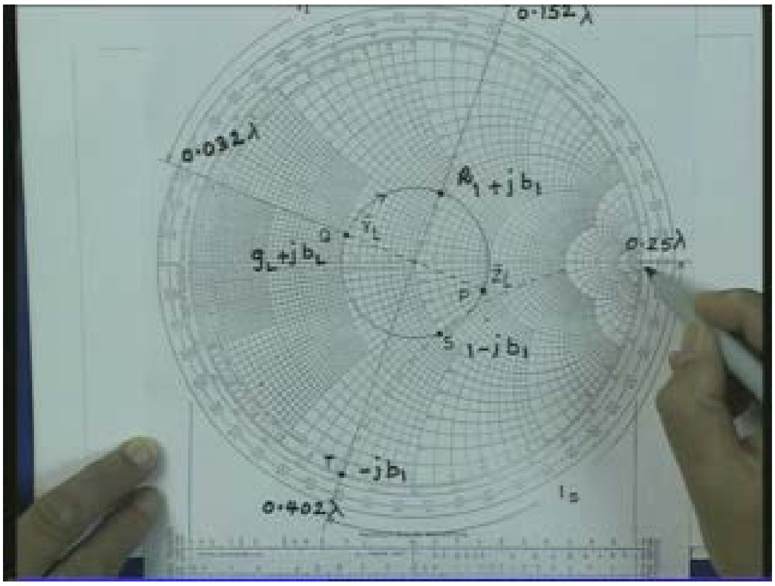
So essentially our single stub matching starts from here, this is the admittance which is to be match by using a single stub matching where stub is connected in parallel with main line.
As we have seen in the single stub matching the first is I move by a distance such that the resistive part of this admittance becomes unity that means the conductance g 1 that get transform to the unity at this location. So this point here if I see it should become from 1 plus

j b 1, so by moving along the main transmission line first we said the conductive part to unity whatever is the susceptance part that you cancel out by placing a stub in parallel with main transmission line.

So here first we move on this constant VSWR circle up to a point where this constant VSWR circle intersect g equal to 1 circle, constant conductance g equal to 1 circle. So this location here, this point now which is given as R, this point is R. The admittance corresponding to this point is 1 plus j b 1, how do I get the length are the location of this this point. I just draw the radius vectors passing through this 2 points that is the length which is L 1 on the main transmission line. So again I can read of the values which are marked on the switch chart. So this location corresponds to “0.032” lambda this is “ 0.152” lambda, I can get a length L 1 which is “0.152” minus “0.032” is equal to “0.12” lambda.

So the location of the stub is “0.12” lambda from the load, second thing you have to find out is the length of the stub and for which this j b 1 acceptance has to be cancel. So the stub has to introduce a acceptance of minus j b 1, as we do we take the mirror image of this point on the constant VSWR circle, find a constant acceptance circle passing through this point take the outer most point on this circle.

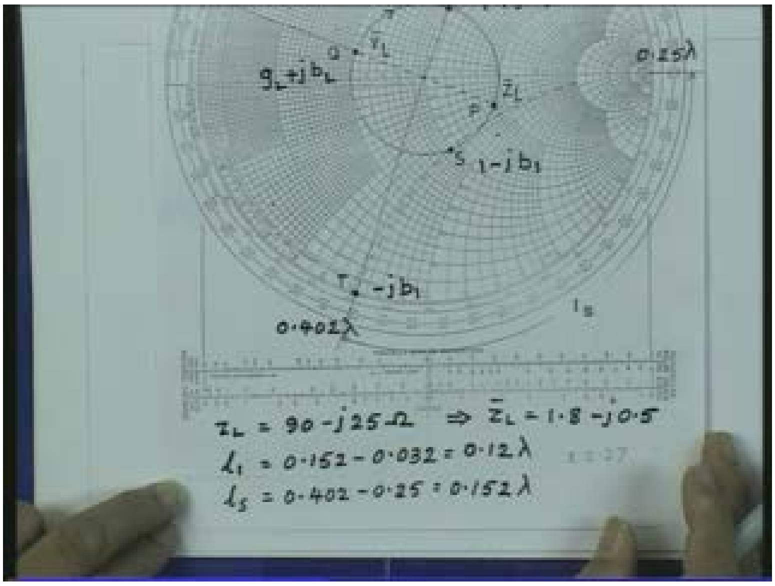
(Refer Slide Time 20:47)



So this point here T represents pure acceptance of a value minus j b 1. So now, if I want to have a acceptance seen here minus j b 1 from that acceptance if I go away from the generator, till I reach to the short circuit point then that gives me the length of the stub. So from here this is my acceptance which I want to add I have to move now away from the generator. So I have to go in the anticlockwise direction on this, till I reach to the short circuit point and since this chart is become now the admittance chart, the point corresponding the short circuit is the right most point, so this is short circuit. So I move on this in the anticlockwise direction till I reach to the right most point on the switch chart. So again I can read the length this points corresponds to “0.25” lambda this is “0.402” lambda.

So difference of these 2 that gives me the length of the stub and that is “0.402” minus “0.25” is equal to “0.152” lambda. So now we have got the length of the stub we have got the location of the stub so in a single stub matching if the impedance is given first and if the line is connected in parallel with stub then the first stub is to convert the impedance and admittance beyond that point we did the chart as the admittance chart, do the moment on the constant VSWR circle on the admittance chart while calculating the length of the stub remember, since the chart is become admittance chart so the short circuit point is right most point on the chart and the open circuit point is left most point on the chart.

(Refer Slide Time 21:20)



So move on the chart from the reactance value which you want to match up to the short circuit point and you will get the length of the stub. So these are some of the problems which can be solved very easily with the help of the switch chart, if I to do the same calculation by using analytical approach you will see finding the lengths and locations of the stubs on the transmission line is extremely tedious task. So these examples clearly demonstrate the use of the switch chart for solving complex transmission line problems. Having discuss on these problems, let me go to the final thing in the transmission line that is the characteristic impedances for the various structure which you see in practice. At the beginning of this discussion on transmission line, we are seen various kinds of transmission lines like a coaxial line, parallel wire transmission line micro strip structure and so on.

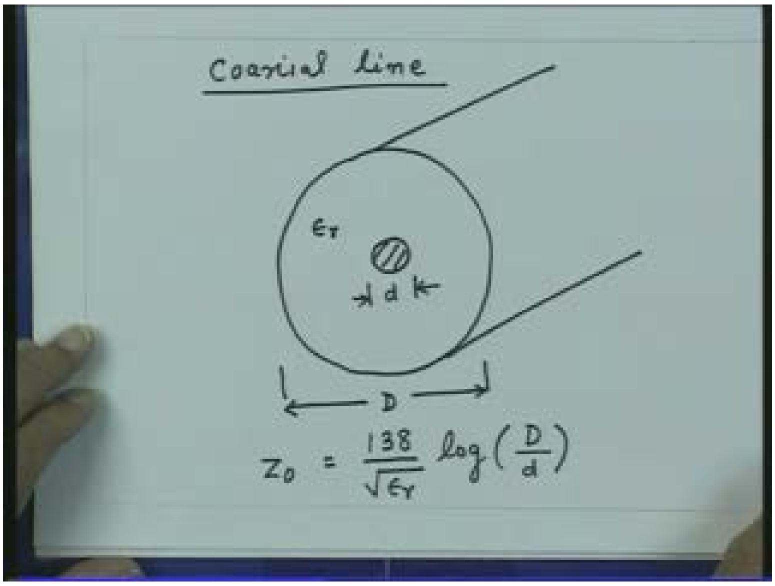
In practice then, one would need to calculate the characteristic impedances of these lines. So let us see here directly the formula which are use for the characteristic impedance of the various transmission lines. So the most commonly use transmission line is the coaxial line which is practically use for making connections between any electronic equipment. So this structure is coaxial line has a outer conductor which is cylindrical and inner conductor, these are conductance and you apply a voltage between the center conductor and the outer conductor.

Let us say the diameters of these 2 conductance are given by small d and capital D and let us say, the dielectric which is filling the medium between these 2 conductors is having a dielectric constant epsilon R for the relativity permittivity of the medium which is filling this cable is epsilon R. In practice, we use the material like perfect short a plan for filling these cables.

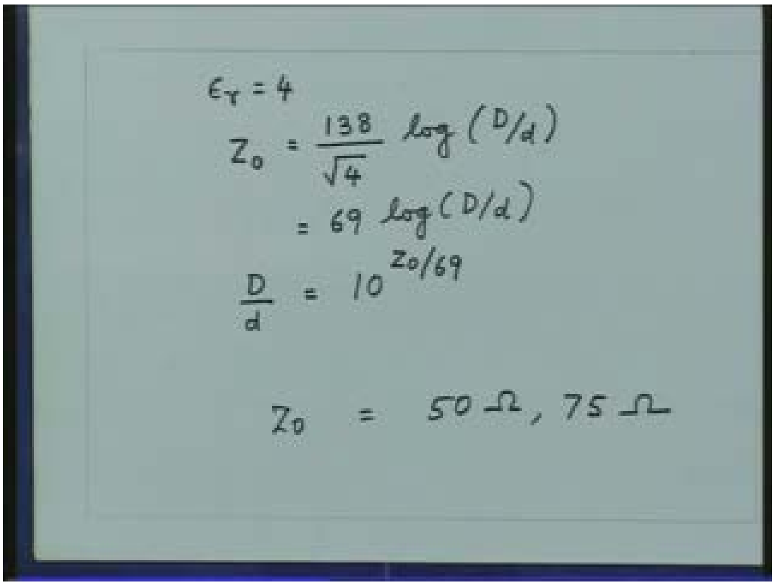
So the dielectric constant may lie typically in the range from 2 to 4. The characteristic impedance of the structure Z 0 is equal to 138 divided by square root of epsilon R log of D by d. So the characteristic impedance for a coaxial lines depends upon few things, the ratio of the inner and outer diameter of the conductance and the dielectric constant of the medium filling the coaxial cable. If I now take some typical value just to calculate the impedance of that just to get a field what kind of parameters are required to realize certain characteristic impedances, let me take just for simplicity the epsilon R is equal to 4.

So the Z 0 for this coaxial cable will be 138 upon square root of 4 log of D upon d. So that is 69 log of D upon d, so by inverting this relation I can get the ratio D upon d is equal to 10 to the power Z 0 upon 69, what you see from this relation is that the ratio of D by d increases very rapidly as the characteristic impedance increases, just when the Z 0 is equal to 69 ohm the ratio of the diameters of the outer and inner conductor will be 10, when the impedance becomes double of 69 the time the ration will become 100.

(Refer Slide Time 25:38)



(Refer Slide Time 28:34)



So the size of the outer conductor compare to the inner conductor increases very rapidly as the characteristic impedance of this line increases, what that means is that this structure, the coaxial structure is more suited for realizing low characteristic impedances and that is the reason typically is the lines which are use in practice, the coaxial lines their characteristic impedances are 50 ohms, 75 ohm something like that but if I say, I want to realize the characteristic impedance of 200 ohms or 300 ohms, it will have a structure whose size will be physically prohibited. We will not be able to realize the structure because the outer conductance size will become very large compare to the inner conductor.

So the coaxial structure intrinsically is more suited for realizing low characteristic impedances, so typically we get the characteristic impedance for these lines which we which will be of the order of 50 ohms, 75 ohms and so on. Generally, the cables are standardize for 50 ohms. However, whenever we go for the antenna applications we get a cable which is having characteristic impedance 75 ohms and the reason is that normally the antenna which is use in practice as will see little later that is half way of dipole and its input impedance is very close to 75 ohms.

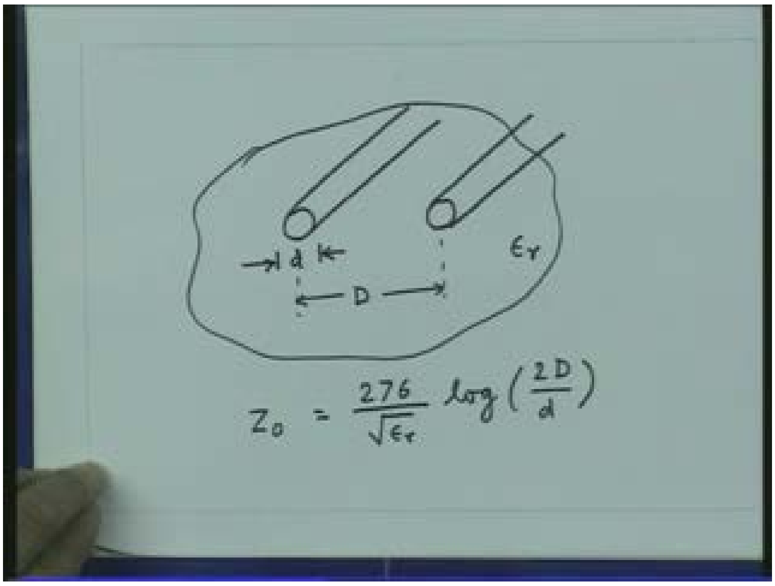
So just from the comparatability point of the impedances whenever we use the cable for the antennas we use the cable which is having a characteristic impedance 75 ohms. However most of other applications or higher frequency equipments, the impedance has been almost standardize to 50 ohms. Let us take the second line which is use very commonly in practice and that is the parallel via transmission line. As the name suggest, it has 2 conductors which are parallel, these are these are the conductors which are running parallel and let us say the separation between these conductors center to center is given by d and let us say, the diameter of each conductor is given by small d. Generally, these lines are use in air normally the open via transmission line you will see the parallel structure which are realize in air.

So the dielectric material which separate these conductor is generally air. However, there are certain application where these are encapsulated inside some dielectric material. You may go and see this structure either whenever we are having open wired like a power line or something just like you see this structure, you can also rewrite this structure whenever you use the flat ribbon cable for connecting a yagi antenna to TV. The flat ribbon cable which are runs from the yagi antenna to TV is essentially a parallel wire structure and in that case that is no air medium you are having a plastic encapsulation on that. So there may be some kind of a encapsulation which will be on that and then you will be this will be fill with a dielectric material with some dielectric constant epsilon R. For this structure with general dielectric constant epsilon R, the characteristic impedance Z 0 is 276 divided by square root of epsilon R, log of 2 D divided by d. As I mentions the dielectric separating this conductor normally is air because normally this structure is realize as a open structure.

So epsilon r is generally 1, if I take epsilon r equal to 1 then z 0 will be 276 log of 2 D upon d. One thing immediately one can notice is that the D I can match as small as D only, if I bring the 2 conductors to almost touch each other then, this quantity D will be equal to d. So the minimum impedance which I can see on this line if I use the dielectric as air will be 276 log of 2 because D become equal to d to conductors are almost touching each other.

So the minimum impedance which I can see for a open wire, parallel wire transmission line will be 276 log of 2. So which will be about ".3", so if I take epsilon R is equal to 1 then Z 0 will be 276 log of 2 D upon d. So for minimum D equal to d, we get Z 0 minimum that is 276 log of 2 ultimately "82.8" ohms just should take another value, if I take D by d equal to 5, I can substitute here D by d equal to 5, it is becomes 10, so log of 10 is equal to1.

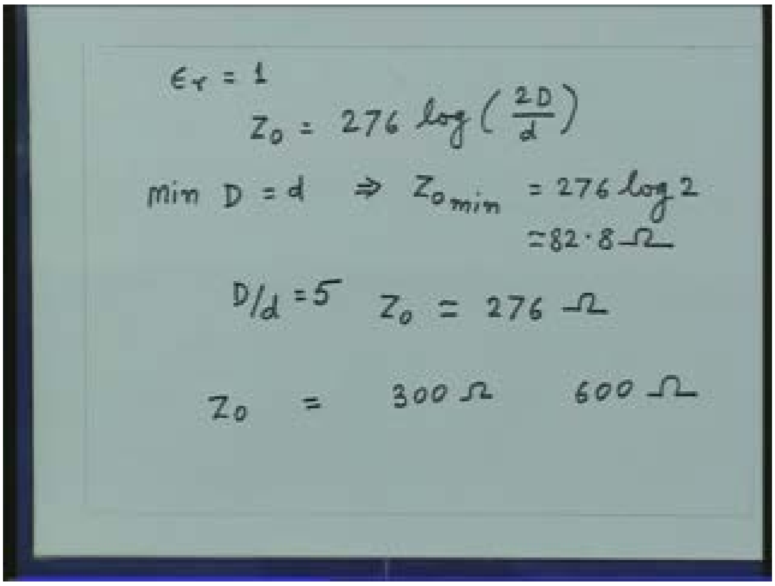
(Refer Slide Time 32:49)



So Z 0 for this is be 276 ohms, so as we can see for this structure realizing low impedance is more difficult. I cannot realize to impedance a lower than "82.8" ohms. However, I can realize the high impedances rather easily I can get just by putting a D by d ratio of 5, I can realize the impedance of 276 ohms and since I am talking about the 2 conductors which are parallel separating this, these 2 conductors by large amount is not that difficult. So these lines intrinsically are capable of giving you the high characteristic impedances, these lines are also use in telephone lines.

So all the telephone line which you see on the towers they are in the form of this parallel wire lines. So generally the parallel wire transmission lines are use in those applications where you would like to realize high impedances or if you use the parallel wire transmission line conversely, you have to deal with the high impedances. So the 2 structures, the coaxial cable structure and parallel wire structure, they are complimentary in terms of characteristic impedance. The coaxial cable structure can give you low impedances rather easily it difficult to get high impedances whereas if you go to the parallel wire line then it is rather easier to realize the high characteristic impedance then the low characteristic impedance.

(Refer Slide Time 35:50)

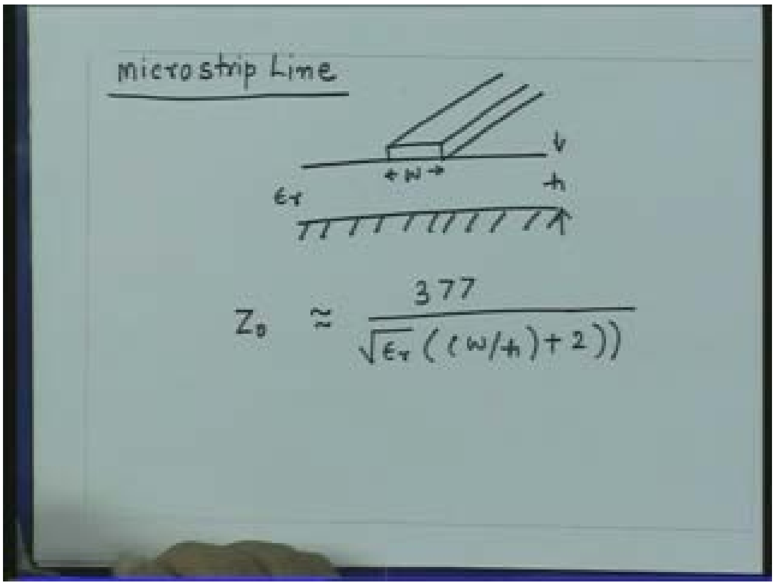


So typically for a parallel via transmission line the characteristic impedance would be like 300 ohms or 600 ohms. So the lines which are standardize for the parallel wire lines they have the characteristic impedance either 300 ohms or 600 ohms. The third structure which you see commonly in practice is what is called the microstrip line structure and this structure normally the realize at the microwave frequencies for making circuits also whenever we have a printed circuit board configurations, you have this kind of transmission lines.

So this structure is to have a dielectrics slab, dielectric constant is epsilon r which is plated with conductor on one side and there is a strip of metal on the other side. The height of this dielectric lab is let us say h and the width of this is W. The characteristic impedance of this structure depends upon the dielectric constant and the ratio of w by h. So the characteristic impedance for this line, what is called the microstrip line is approximately given as 377 divided by square root of epsilon r, again the dielectric which is use here can have a dielectric constant ranging from 2 to even 10 because when you go to micro frequencies, you can use the substrate which could be like alumina for with the dielectric constant is “9.8” or something.

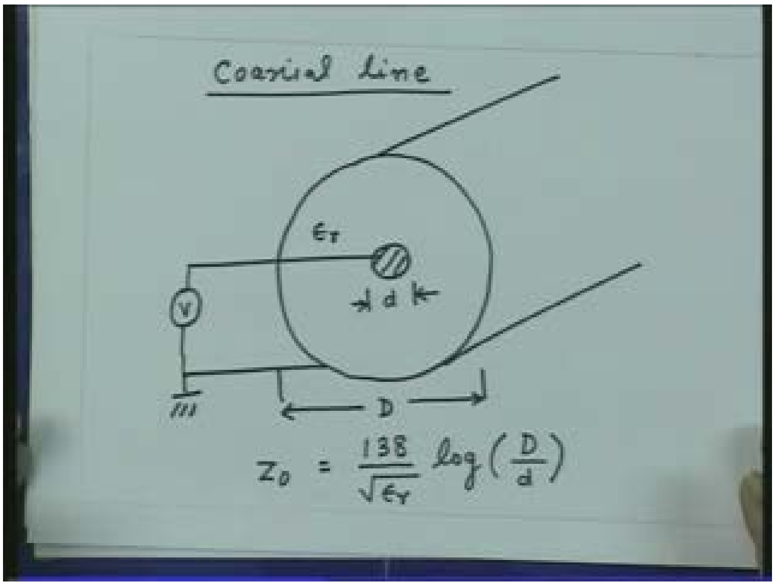
So in this configuration that dielectric constant values may have a very wide range and also the w by h can vary by a very wide range. So as we can see from here, you can realize a wide range of characteristic impedances because if I use a high dielectric constant I can realize the low characteristic impedance. However, if I take dielectric material who directly constant is small then the characteristic impedance can be increase, also by changing the ratio of w by h the impedance can be vary by a large amount.

(Refer Slide Time 38:58)



But when you go to high frequency its again we standardize the impedances either 250 ohms, if I am going to connect this structure to a coaxial cable or I can realize this structure with higher impedances, if I am going to um make the connection to the parallel wire structure that is the small difference however between these two connections and that is if I take a structure which is the coaxial cable structure then the voltage is connected between the center conductor and the outer conductor and the outer conductor is ground. So I can have a voltage source which is connected to this to in the center conductor and the outer conductor which is which is the ground conductor.

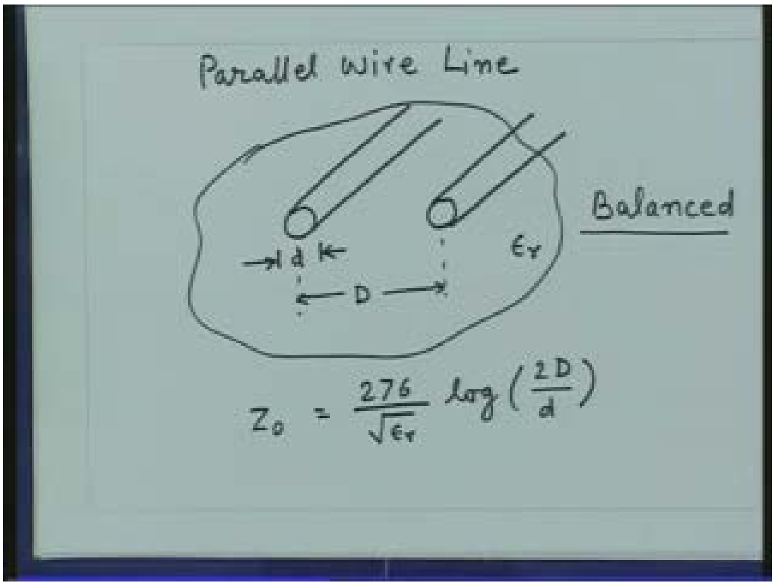
(Refer Slide Time 39:59)



So in a coaxial cable I have a center conductor to which the voltage is connected and the outer conductor is ground same is true for the micro strip line structure this plane is a ground. So I can connect the voltage between this and the ground plane I get the same way is did for the coaxial cable. So this is the voltage is connected between this and this and this point is ground. So in both the cases the ground is define and the voltage is applied with respect to ground, if I compare this structure however with the other structure which is the parallel wire transmission line structure. This structure is a completely floating structure there is no ground define for this structure.

So I can either say one of the conductor is a 0 potential and other one is that V or I can say there is a virtual ground find somewhere which is set to that ground, this voltage is v by 2 plus this voltage is v by 1 minus. So this structure is a floating structure for which the ground is not define whereas the other 2 structure if you take the ground is define and the voltage is applied between the ground and the conductor. The other 2 structure are called then the unbalanced structure and this structure is called the balanced structure.

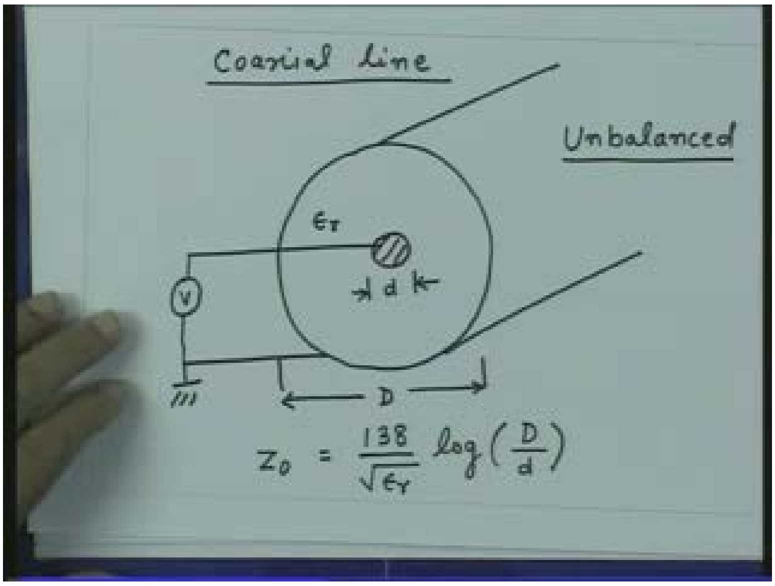
(Refer Slide Time 41:45)



So this structure which is the parallel wire line this structure is a balanced structure whereas if I take a line which is a coaxial line or the micro strip line then this structure is an unbalanced structure. So in practice you see both kind of lines, the balanced lines and unbalanced lines and whenever we make a connection between the balanced and unbalanced lines, 2 things are to be seen one is of course the impedance has to be match, so that there is no reflection from the junction.

Second thing is since we are making now a connection between the floating structure and a structure which is a symmetric or unbalanced, you require a some transformer in between which can connect appropriately the voltages from balanced structure to the unbalanced structure. This device is called balanced to unbalanced transformer or in short, it is called balanced. So a structure which matches the impedance as well as the nature of the cables is what is called balun which is balanced to unbalanced structure. So on this side essentially, we have a structure which is the coaxial cable structure. So I connect the outer conductance with this center conductance goes to that and in the other side, you have a balanced structure.

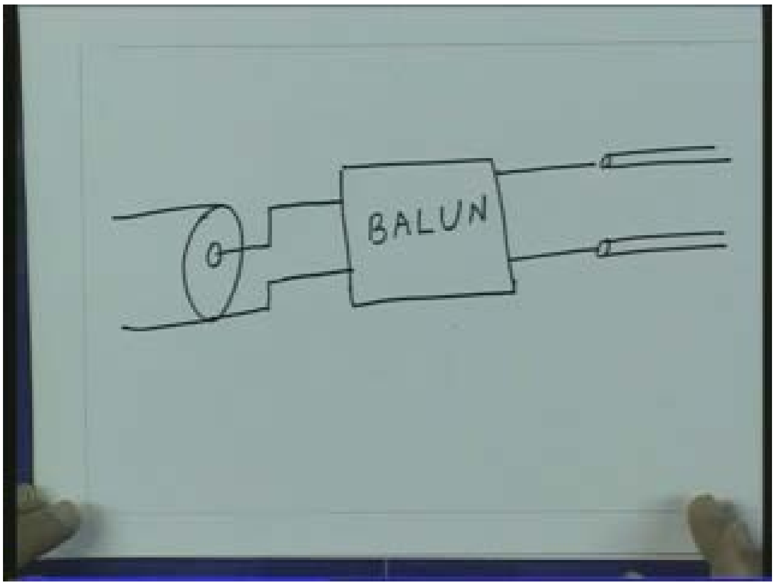
(Refer Slide Time 42:03)



So you have a parallel wire line connected to this and other side. You will see this balun whenever you make a connection between a yagi antenna and a TV that is the most practical application you can see around, of course there are many other high level technical applications where the balun is used but practically whenever you are using yagi antenna for reception and connecting it to a TV, you bring the signal from the antenna by using that flat ribbon cable which I mention that is the balanced structure then there is a small black box which is kept just at the input of the TV because the connector which you are having on TV is the coaxial connector.

So that connector is a unbalanced connector also the impedance which you see here is 50 ohms but the flat ribbon cable that impedance is might difference compare to the 50 ohms.
So normally we introduce a small box what is called a balun and which transform this impedance from the balanced structure to the unbalanced structure, if you do not do that many times we get the reflections from the junctions which appears in the form of the ghost in TV. So appropriate transformation of the impedances on the line and also connecting balanced and unbalanced structure properly with the help of balun improves the quality of the reception of any high frequency signal that essentially completes our discussion on the transmission line.

(Refer Slide Time 44:50)



Let me take a recap what we have done in this very important of that of higher frequency circuits, what is called transmission lines. We saw the limitation of the analysis of the alarm circuit and that is as we go to the higher frequencies, the size of the component becomes comparable to the wavelength and then the voltages and currents cannot be assume constant along any electronic component.

So we introduce the concept what is called the distributed element, we studied the effect what is called the transit time effect and from there essentially we derive the relationship between voltage and current for high frequencies circuits that means for the circuits over which a transit time effects cannot be neglected and we saw that relationship was in the form of differential equations when we solve the differential equations, we got a solution of voltage in current which we saw where in the form of waves.

So in general, we saw when we go to higher frequencies the voltages and currents exist in the form of waves on the electrical circuits then we studied the super position of this waves and we saw that in general there could be standing waves we also investigated under what condition you will have 2 wave which are travelling in opposite directions or you will have standing waves.

So we introduce the concept of what is called the reflection coefficient which is a measure of energy reflected from the load then we introduce the concept of what is called the matching which means if the load impedance is equal to the characteristic impedance, the energy is transformed from the generated to the load efficiently and there is no reflection on the line. Following this we studied the very important thing which is the impedance transformation characteristic of the transmission lines and that we want to many applications of transmission lines.

So we studied the application of transmission line as circuit element, we studied the use of transmission line as resonant circuit, we studied the use of transmission line as stopping of voltage and current transformers and then we studied the graphical approach to analyze a transmission line problems that was the switch chart. So we also solved certain problems and towards the end of this discussion on the transmission lines we called the expression for the characteristic impedances for various structures which are used a transmission lines at higher frequencies.

So we saw the coaxial cable which is very common structure which is give you that higher frequencies and we saw its characteristic impedance is rather low, it is difficult to realize high characteristic impedances by using the coaxial structure. On the contrary the parallel wire structure is more capable of giving you the high characteristic impedances, you also saw certain applications where the coaxial and the parallel wire structure will be used .The third structure which we saw for transmission line was the micro strip line structure which normally is seen at microwave frequencies of you eagers also whenever we are having the transmission line on printed circuit boards, this is the transmission lines.

So we had a comparative discussion of this structures and then, we also saw very briefly how this different structure can be connected by using a device, what is called balun? So this gives now a overall picture of the transmission lines. Today, when even the computer speeds are going into Giga hertz, the transmission line are going to play very important role in circuit design. So may be few decades back when the frequencies there not very high the electronic circuit design was quite simple because all these transmission line concepts are not in playing any role in the electrical circuit.

However, today when your chips are going to frequency the few Giga hertz, your computers are going to frequency of 2 gigahertz that reflections, the mismatching all those things which we discussed have become very vital in making the electronic circuits. So in today's electronic circuits, the concept of transmission line play a very very important role. So the subject of transmission line has become very important in this indices because of this high speed electronic circuits which are now becoming part of our routine life.