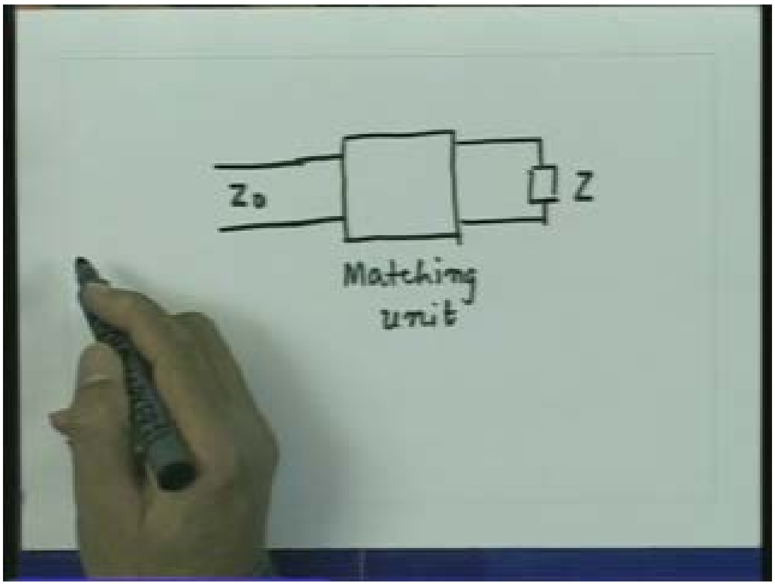
Transmission Lines & E M. Waves
Prof. R. K. Shevgaonkar
Department of Electrical Engineering
Indian Institute of Technology, Bombay

Lecture – 12

Now, we discuss one of the most important applications of transmission line and that is what is called the impedance matching. We have seen that is the impedance is equal to the characteristic impedance then there is no reflection on transmission line and there is a maximum power transfer. However, as we saw it is not always possible to behind the circuits which will have input or output impedance which is equal to the characteristic impedance, what we then require is a module which can convert this input, output impedance of a circuit to the characteristic impedance. This module is what is called the matching unit or a matching transformer.

So essentially, we want to introduce a some kind of a module in between what is called a impedance matching device or one side of which we want to see the impedance which is equal to the characteristic impedance z naught, other side to the impedance which is some impedance which is not equal to z naught through the impedance transformation unit when impedance is seen that should appear like z naught.

(Refer Slide Time 02:18)



So, we are suddenly using the impedance transformation characteristic of transmission line inside this unit, what is called the matching unit but once we come outside this matching unit then, the impedance always the pr equal to z naught. So beyond this point on the left if I see the impedance always will be equal to the characteristic impedance. Since, the matching unit is use only for transforming the impedances; ideally this unit should not consume any part. So we should see the impedance from the left side of this unit equal to the characteristic impedance, this unit should be completely lossless and the power should be finally deliver to the load which is not equal to the characteristic impedance.

So today, we discuss the various methods by which the impedances can be match to the characteristic impedances by using a lossless device in between. Let us take first a very simple problem and that is let us say, I want to match a real impedance to the real characteristic impedance. You will still follow that the transmission line which we are using is a low loss or a lossless transmission line. So the characteristic impedance of this line is almost real that means we want to match now an impedance to a real impedance which is the characteristic impedance.

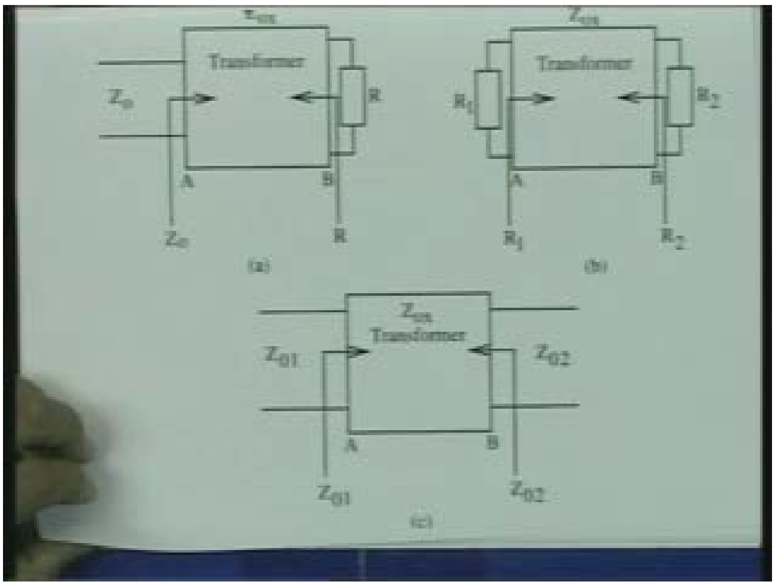
So let us say, you start with let me assume that I want to match a real impedance to the characteristic impedance which is also here. So I am looking for a device which can match a real impedance to a real impedance, what is the application of this, you will find there are many applications where this will be needed, one is the simple case. Suppose, I am having the module where the impedance is a resistive impedance these impedance when seeing through the transforming device, its should appear like its impedance which is equal to characteristic impedance, one possibility, other possibility I have 2 different resistances which are to be match by using some kind of a transforming deceive in between.

So let us say I have some electronics circuit on this side, some electronic circuits on this side and both of them do not have the same value and if you do not have the same value, if I directly connect them, there is a mismatch. So there is no maximum power transfer from this circuit to this circuit. So I can introduce some device in between which will transform R 2 to appear like R 1 when seen from this side and will appear R 1 to appear like R 2, when seen from the right side.

So both sides the circuit c as you they are match to the conjugate loads and there is a maximum power transfer. The third and important case would be the let us say suppose, I have 2 long transmission line which are to be connected, a joined has to be formed in this transmission lines, if the length of the transmission line is very large then, the input impedance of this will appear almost the characteristic impedance of this transmission line. If I have to make a join between these and if I just make a straight join, this cable or this transmission line will see as if it is connected to an impedance of Z 02 which is a characteristic impedance of this line. This line, we will see as if it is connected to an impedance of Z 0 1 which is characteristic impedance of this line and there will be a reflection on both sides of this junction, on these 2 transmission lines.

So what we want, we want to introduce a transforming device and between, so that this impedance Z 02 appears like Z 01, when seeing from this side and when it is from right side its Z 01 appears like Z 02. So from both sides you see as if the line is terminated in its characteristic impedance and then, there is no reflection on a either sides of the transmission line. So matching a resistive impedance to the characteristic impedance has many practical applications.

(Refer Slide Time 07:16)



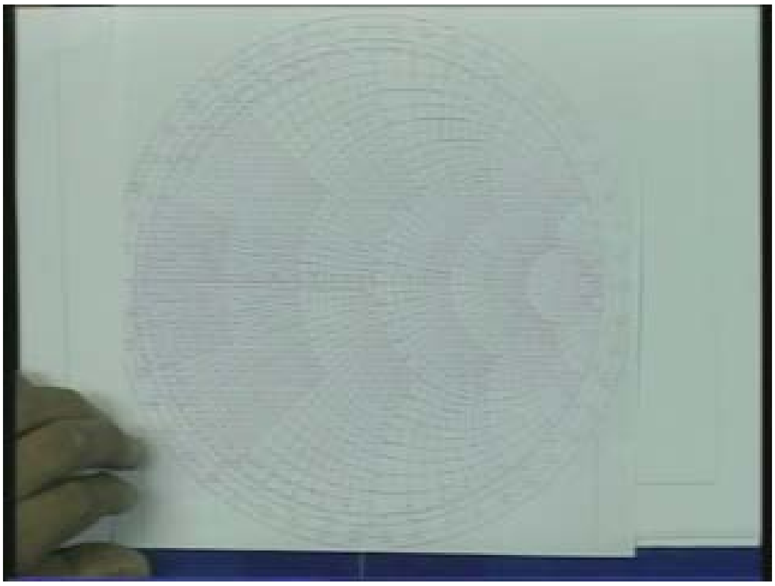
Let us see, how do we do that now. Firstly, you will note that if you are having a resistive impedance and its test to be match to the resistive impedance, the impedance seeing from the left side should be the resistance. Let us go to our switch chart and ask this question that if I had impedance which is a resistance then, how much should I go on a transmission line, so that the impedance always appears like resistance. So what are now saying is let us introduce another section of transmission line in between which we call as the impedance transformer and let us say, it has some characteristic impedance even by Z 0x, which is different than the characteristic impedance of this line to which the resistive impedance is to be matched.

So there are 2 parameters to be found out for the transformer, one is what should be the value of this characteristic impedance Z 0x and what should be the length of this transmission line which is introducing between the resistive load and the characteristic impedance. So, if I go to the switch chart and if I have an impedance which is resistive impedance. We know the resistive impedance law on the horizontal axis on the switch chart. So if I take any impedance which is greater than Z 0, it will lie on the right hand side of the center, if the impedance is less than Z 0 it will lie on the left side of the center but all purely resistive impedances will lie on the horizontal axis.

Now, if I move now on the transformer which is the another section of transmission line to see a resistance, I have to move on a constant VSW arc circle passing through a resistance. So that I reach again to the horizontal line because I want to see the transform impedance again the real impedance. So that is becomes equal to the characteristic impedance and Z naught, so there are 2 possibilities either I move a distance of lambda by 4 or I will move a distance of lambda by 2. So that I see the impedance again as resisting impedance.

So my original impedance is resistance by transforming by a distance of lambda by 4 or lambda by 2, I will again see an impedance which is the resistive impedance. However, we know that the impedance characteristic of transmission line repeatively lambda by 2 that means, if I move by a distance of lambda by 2, I will see the same impedance. So I do not continue advantage, whatever impedance I am seeing the impedance to be matched or the same impedance now appears after the distance of lambda by 2. So these possibilities are not any use because its transform the impedance itself. So only possibility that I see a resistive impedance after transforming to a resistive value is that I move by a distance of lambda by 4.

(Refer Slide Time 08:41)



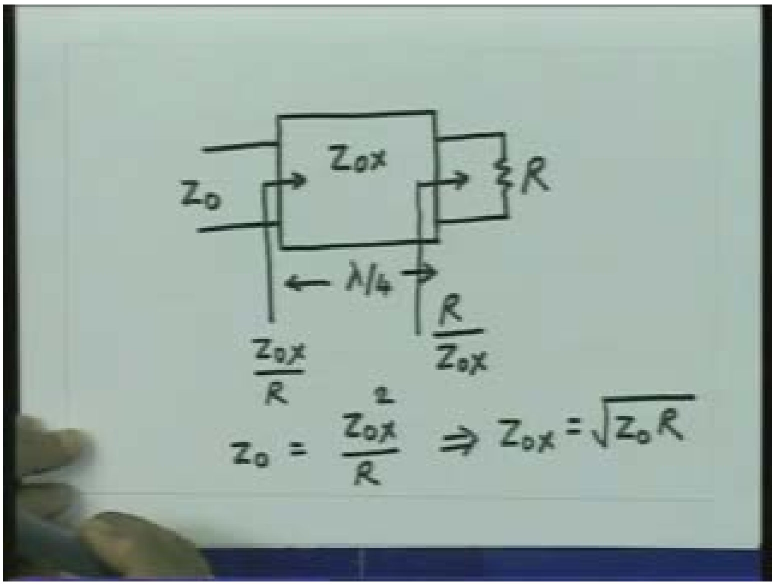
So, if I take the transforming device and move by a distance of lambda by 4 on this. So this is my transforming unit to this side of which is connected a resistance or which is to be matched to the characteristic impedance Z 0 which is also real and these distance now has to be lambda by 4 because then, only these impedance R will be transform to the another resistive value. We also know the property of transmission line then every distance of lambda by 4 the normalize impedance inverse itself. So the normalize impedance C at this point here that is R divided by Z 0x because the characteristic impedance of this transforming line is Z 0x.

So the impedance seen here is R divided by Z 0x, these normalize impedance which we see here. This normalize impedance inverse itself after a distance of lambda by 4. So if I see the impedance here, the normalize value of these impedance will be inverse of this. So it is Z 0x divided by R. So the absolute impedance which I am going to see here is multiplying these normalize impedance by a characteristic impedance of the transforming unit. So that is Z 0x multiplied by Z 0x divided by R that is absolute impedance I am going to see at this location. This impedance for matching should be equal to Z naught.

So now we have got a condition that for the transforming unit the Z 0 should be equal to Z 0x square divided by R or in other words, the Z 0x which is the characteristic impedance of the transform unit that is the geometry mean of the 2 resistances to be matched. So this is now in general true that if I have 2 resistances to be match R 1, R 2 are one of the resistance R and the characteristic impedance Z naught, all 2 cables which are arriving characteristic impedances Z 01 and Z 02, the transforming section must have a characteristic impedance which is the geometry mean of these 2 resistances and the length of this section should be quarter wavelength or lambda by 4.

So that means if I introduce a section of lambda by 4 length whose characteristic impedance is geometry mean of the 2 resistances which are to be match then from both sides, you will see a match the R will appear like z naught when seeing from this side I can verify just z 0, I can transform by this on the other side and that will appear like R.

(Refer Slide Time 12:33)

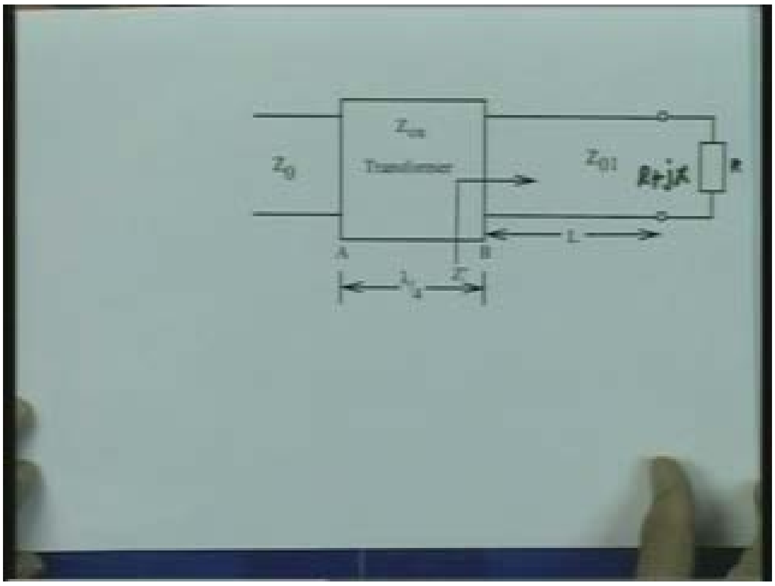


So on this side you see a match, this side you see a match and since we are introducing the section of a transmission line which is completely lossless, there is now a complete power transfer from the transmission line to the resistance R. So without losing any power now, we achieved the impedance seen on the left of these box equal to characteristic impedance and as we know once the impedance becomes equal to characteristic impedance every point on the left of this line will always be equal to characteristic impedance.

So this technique is what is called the quarter wavelength transformer technique. This is one of the very important devices which is used even in lump form to match the 2 resistive impedances. One can now wonder at this point, is this method only useful for matching to resistive impedances. In general, I may have an impedance which is complex and then I would like to match that complex impedance to the characteristic impedance which is real, is it possible to use the quarter wavelength transformer technique for matching a complex impedance to a real impedance, in first look for might say, it does not seem to be possible because what we got here is transforming real impedance to real, the whole argument was using the switch chart that the impedances are lying on the real axis and I want to transform them again back to the real axis.

So this is possible only for the real impedances. However, you think little carefully you will see that is not true because any complex impedance can be transform into a real impedance by moving along the length of a transmission line, whenever there is a voltage maximum or voltage minimum, you see the impedance to be purely real that means if you introduce some section of a transmission line, same transmission line with characteristic impedance Z naught then the impedance seen at the, this end of the transforming box that will be a real quantity, if the length transform the impedance in such a way that there is a voltage maximum or voltage minimum at this end.

(Refer Slide Time 15:37)

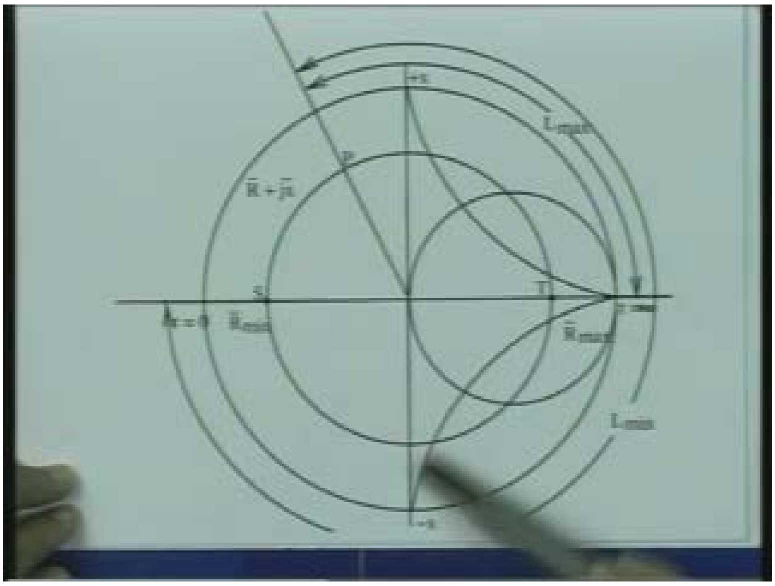


So it is possible to match a complex impedance R plus jx, so this impedance is R plus jx from here the principle is exactly same that if I get a impedance here which is real then, I can transform using quarter wavelength transformer, the impedance is to equal to Z naught.

However, to make the impedance real at this point I introduce a section of a transmission line which is having some characteristic impedance Z 01 it could be Z 0 and transform these impedance R plus jx to a value which is the real value. So that 2 things one is what should be the length of this line and what is the value of this impedance which is here this location. This we can do again very simply by using switch chart, so forcely we take the switch chart. Now here, I drawn the switch chart in very few cycles on that.

So this is the switch chart which is the outer most circuit, this is the unity circle and these are the x equal to 1 circles. Let us say my R plus jx in normalize form it denoted by this point P, as you are seen earlier the first type is should draw a constant VSWR circle through this, if I draw this circle which is the constant VSWR circle. So as I move on the transmission line of this characteristic impedance Z 01, I move on this constant VSWR circle, keep in mind since I am using the impedance for this line Z 01, the normalized impedance is with respect to this impedance Z 01.

(Refer Slide Time 15:52)



So normalization of this R plus jx is to be carried out with respect to this characteristic impedance. Once, I get this then as we move towards the generator, I move on the constant VSWR circle, if I reach to this point which is the right most point T on the constant VSWR circle then, the impedance here will be real and its value will be the VSWR. So the normalized impedance which is the resistive value is equal to the VSWR on this transmission line.

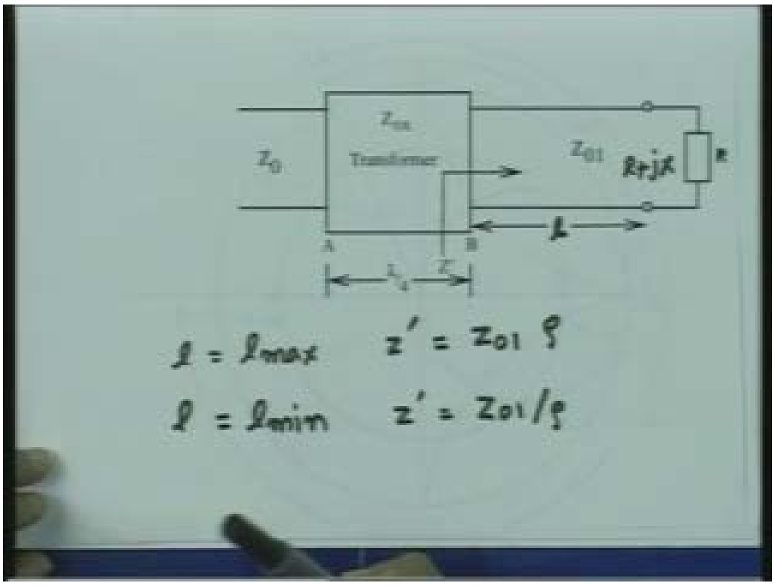
So if I know the VSWR from here then, the impedance seen at this point is known. So let us say the VSWR which is created on this is given by some row. So the value corresponding to this point T will be Z 01 which is the characteristic impedance of this line multiplied by the VSWR. So the impedance at this location which is R max that will be equal to the VSWR. Similarly, if I go to a point here S which use the minimum resistance that its value will be the R min and that will be equal to Z 01 divided by the VSWR. So if I move by a distance from here to here towards the generator since, I am moving clockwise, this distance will correspond to this length L and the value at this will be Z 01 into VSWR.

So if I take L equal to L max then the impedance which I am going to see which is denoted here by Z prime, this impedance will be equal to Z 01 into the VSWR rho on this line. On the other hand, if I take L as L min which is a length up to the minimum point which is this. So from here all the way clockwise up to this location if I take that length for L, this L, then the transform impedance Z prime will be Z 01 divided by the VSWR. Once, I know this impedance then the impedance of the transformer will be geometry mean of this impedance and the characteristic impedance Z naught.

So I have 2 solutions, if I take the transformed impedance here which is Z 01 and its rho then I gets some characteristic impedance value for a transformer. If I take this value I will get another characteristic impedance value for a transformer. So this problem has 2 solutions depending upon what length you choose for transforming this impedance to a real value. Any solution it acceptable depending upon whether you want a length shorter or larger and whether the transform impedance which you get can give you a realizable transforming line, one may choose one solution over the other but theoretically, there is no difference between the 2 solution and both the solutions are equally accepted. So this technique, the quarter wavelength transforming technique can match the impedances even from complex impedance to a real impedance.

So this technique is use in practice in many applications however, one could immediately note this technique has a biggest drawback and that is you require a unique characteristic impedance for this transforming device. Later on, we will see that the characteristic impedance of a transmission line it depends upon the physical dimensions of the transmission line that means for every impedance matching, we require a unique physical structure created for transmission line.

(Refer Slide Time 20:08)



So that I get precise value of this characteristic impedance, this is not a very desirable feature because in practice, we do not get the transmission lines whose characteristic impedance can be varied very easily, in normally we get the cables are the transmission line which has standard characteristic impedances. For example, if I take coaxial cables the characteristic impedances are 50 ohms or 75 ohms, if I take parallel wire transmission lines their characteristic impedances could be 300 ohms, 600 ohm or something like that.

So realizing any arbitrary value of characteristic impedance is not very easy. So though principally any complex impedance can be match to the characteristic impedance by using quarter wavelength transformer. In practice, it finds difficulty because you will not be able to realize a transmission line or it will be difficult to get a separate transmission line for each impedance matching which is to be carried out in the circle. So the next option which we now look for it, can I use the standard transmission line which are available and making use of those transmission lines, can I match a complex impedance to the real impedance and this approach is what is called the stub matching technique.

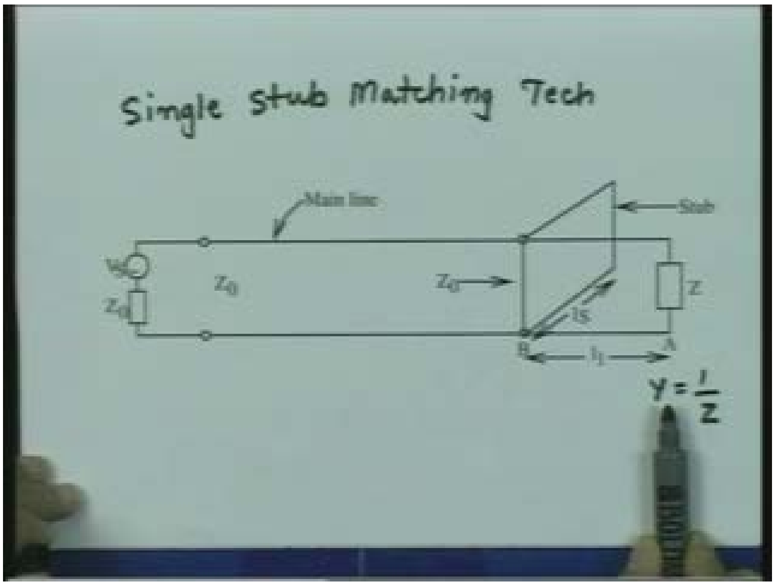
So this is what is called stub matching technique. Now stub is a section of a transmission line which is short circuited or open circuited connected to the main transmission line either in series or parallel. So, if the main transmission line, if I make a connection of another similar transmission line which is either open circuited or close circuited at the other end, then this appended line to the main line is what is called the stub and by using now, the sections of the stub at proper location on the main transmission line, it is possible to match a complex impedance to the characteristic impedance of the line. Note here, what you are realize in this is, we do not require a unique characteristic impedance for each matching.

The transmission line characteristic impedance is same only we want to change now the location and the length of this appended line to the main line. There are 2 possibilities for doing matching by using these technique, I can use only one appended line to the main line and then that technique we called as the single step matching technique if I have 2 appended lines to the main line then the technique is called double stub matching technique. So let us see first the single step matching technique and I have the name suggest, we have the problem has solve now. This is my main line which has the characteristic impedance z naught, this line is connected to a impedance Z which finally is to be match to the characteristic impedance Z naught.

Let us say we connect the line in parallel to this line which is what is called the stub and let us say, the stub is short circuited. So in this case we have connected the stub in parallel with the main transmission line whose length is ls and whose characteristic impedance is same at Z 0 and this stub is connected to the main line at a distance l 1 from the impedance to be matched. So now idea is that in this section here you have the standing ways because the reflection from Z, the impedance is transform from this point to this point.

So you get a reflected signal which come from here. So the reflected signal is going to come from here also because these short circuited. So let us see the further problem how the energy will start flowing, the voltage wave comes here its 2 parts, one towards this stub, one towards the load, the voltage you are reaches to the load part of the energy gets reflected from here. So you have a reflected waveform here the voltage wave which is gone towards the short circuit of stub is fully reflected and when the 2 reflected wave reach at this point, if we make sure that these 2 ways or equally in amplitude and opposite in face, they will cancel each other at this location.

(Refer Slide Time 28:42)



So the reflected way of coming from the stub and coming from the load, if they can cancel each other, there is no net reflection beyond this reflection or in other words, if there is no reflection on this, this point this part of the line, the impedance is always equal to the characteristic impedance, same thing we can say in different words from impedance point of view. If I take this impedance and transform the impedance at this point in general, it will have a resistive and reactive point. The stub which is short circuited will always have a reactive part, if I make sure that the parallel combination of the impedances which is see here. The reactive part cancel you see the impedance seen from here is purely resistive and if the resistive part is equal to characteristic impedance, I achieved the matches.

So the problem for now as follows find this length L 1 such that when the impedance is transformed here, its resistive part becomes equal to the characteristic impedance and it has some reactive part, choose the length of the stub in such a way that the reactive part cancels this reactive part. So the resistive part is equal to round the characteristic impedance beyond this point, doing this exercise analytically is rather tedious. However, if you switch chart for caring out this operation than this exercise terms out to be extremely simple. So this technique since, we are using only 1 stub for matching the impedance to the characteristic impedance, we call this technique is the single stub matching technique.

So since, we are doing here the operation of parallel connection of these 2 lines, let us say the problem now is defined in terms of admittance because the handling parallel connection will be easy, in terms of the parallel connection. So let us say, I write down the impedance in terms of the admittance. So I take 1 over Z, I let us say that quantity is given by y which is equal to 1 upon Z. So I have with the admittance at this location and I find out the characteristic admittance, I find out the normalize admittance at this location. So every operation which I am doing now is in terms of the admittances.

Let us see, how do we solve these problems by using switch chart. The problem is stated forward, let us say we are having some point which is the impedance which is to be matched, let us say this point is given by P, this P. So this location here is the normalize admittance and let me denote this normalize and admittance, y bar is g plus jb. So g is the normalize conductance, b is the normalize acceptance for this impedance which is to be matched. So since, I am now doing the calculation for admittances, I am using the switch chart as the admittance switch chart.

So here the switch chart is admittance, I mark this point g plus jb which is the impedance to be matched. So this point P is g plus jb, the first let us we do, we draw the constant VSWR circle passing through point. So this circle is the constant VSWR circle. Now we can note that when we move on the circle that means when we move on the transmission line towards the generator, my first task is to make the real part of the admittance equal to the characteristic admittance or the normalized real part should be equal to 1. So when I move on the circle, I find that whenever this circle intersect this g equal to 1 circle, conductive pattern become equal to 1.

So at this location B, I have the conductance g normalize as become equal to 1. Similarly, if I take a point D is normalize conductance as become equal to 1. So by moving a distance corresponding to this or a moving the distance corresponding to this, I can find out now what would be the reactive part it is location because the resistive part or the conductive part of this has become equal to 1, okay. Now let us do this exercise, so let me let me take this switch chart and do that.

So this is my switch chart, let us say we saw this point marked as P which is g plus jb, I draw a constant conductance circle asking through this point on this. This is the unity circle, so this point here or this point here at this location, the conductive part of the admittance has become equal to 1. So either I can move by a distance corresponding to this. So that it is conductive part is become equal to 1 or I move by a distance which is equal to from here to this, so there its conductive part become equal to 1. Any of the solutions are acceptable, let us say I take a solution that I move by a distance on the switch chart which is this then, this length is nothing but L 1 in this figure. So I moved by a distance L 1, so that here now the conductive part become equal to 1. Now so at this location the value of the admittance is 1 plus let us say some j b prime.

So if I just without a stub, if I move on this line and if I see towards the load, I will see now here an admittance which will be 1 plus jb prime. So if I see here just here it should be 1 plus jb prime, if I have to cancel now this admittance reactive part, jb prime, the stub which I have connected in parallel must have an acceptance which is minus jb prime. So if I if I take looking this way just acceptance must give me a value of minus jb prime. So when the 2 are connected in parallel 1 plus jb prime added with minus jb prime, the b, jb prime cancels and I will see beyond this point and normalize admittance which will be equal to 1 plus j 0.

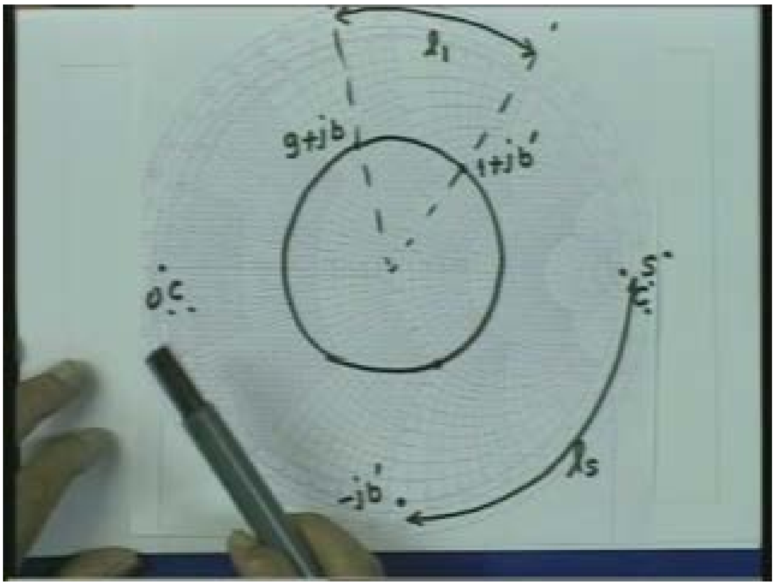
Now corresponding to this jb prime, now I want to find out what is the point which is minus jb prime, if I have to realize that reactance on the by using the section of transmission line that is easy if I take a mirror image of that and pass to the reactance circle which is passing through this point that is the point which is outer most point on the switch chart, this point that corresponds to minus jb prime.

So note what you have done, this location is 1 plus jb prime I take a mirror image of that on the constant VSWR circle, find the constant reactance circle or constant acceptance circle passing through this, go to the outer most point which represents minus jb prime. Now to realize this acceptance from the section of a transmission line as you have seen earlier, this acceptance can be realize by a length such that if I move from this point away from the generator, I must reach to a short circuit part. Remember now, we are using the switch chart at the admittance switch chart.

So this point is the short circuit point and this, this point is open circuit point. So to realize this reactance if I move from this point away from the generator till I reach to the short circuit point that give you with the length of the stub which is to be connected in parallel. So this length from here to here that is nothing but your the length ls which is the length of the stub. So you see the finding the length of the stub and the location, if you use the switch chart is extremely simple, with mark the unknown admittance which is to be matched move on the constant VSWR circle up to a point, when its intersects the g equal to 1 circle at that location, the value of the admittance is 1 plus jb prime, take the mirror image of this point on the constant VSWR circle, find the constant acceptance circle passing through that point, go to the outer most point on the switch chart on that circle, find the length of the stub from that acceptance to the short circuit point which is the right most point on the switch chart.

So by doing this simple exercise, we can find the location and the length of this term. The similar exercise can be done if you are having impedances and if the stub is connected in series which use the switch chart as the impedance and beyond that point exercise exactly identical. In this case, we have taken the 1 plus jb prime point which is this point, you have taken this point also in that case we have to move a distance L 1 which is corresponds to from this point up to this vector, this length and the value here will be 1 minus jb prime. So you will require a stub reactance should be plus jb prime which will corresponds to the point which is mirror image of this.

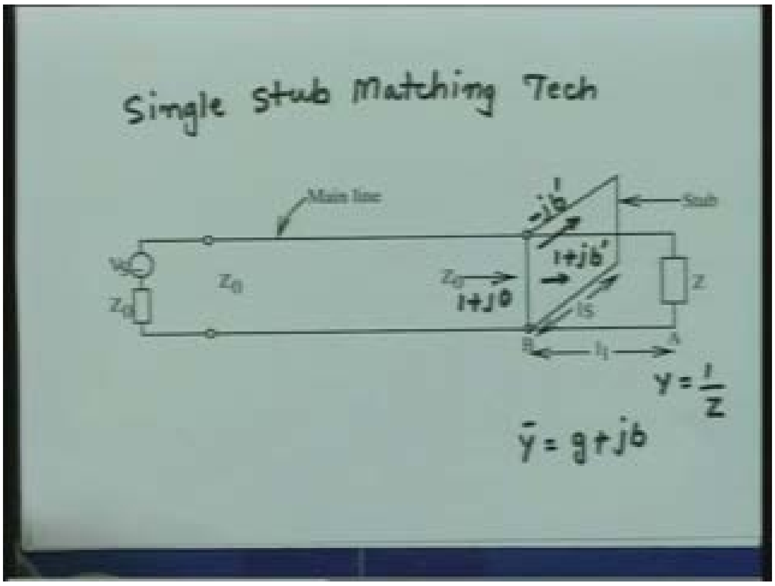
(Refer Slide Time 38:15)



So the length of the stub would be corresponding to all the way from here to here. So again the problem has to solutions depending upon what value of 1 plus jb prime you choose, if you choose this I get the length of the stub which is this and the location of the stub which is given by that if I choose this point all the way from here to here, location of the stub and the length of the stub could correspond to mirror image of this point measure all the way of this short circuit point. So single stub matching technique is an extremely useful technique in matching any impedance to the characteristic impedance of the line.

So note here now that as in the previous case of quarter wave transformer, we are matching here any unknown impedance to the characteristic impedance but we do not require any special transmission line now. The same transmission line sections are used. So without requiring any special type of transmission line, we can achieve the impedance matching between any complex impedance with the characteristic impedance. This technic however have the small drawback and that is the location of this stub depends upon the impedance to be matched, many time it is possible that you can connect the stub to the line, it is easy to the where is the length of the stub but it is not always possible to really change the location of the stub because once the stub is connected to the line, it is not easy to move the location of that stub, take a simple case.

(Refer Slide Time 39:42)



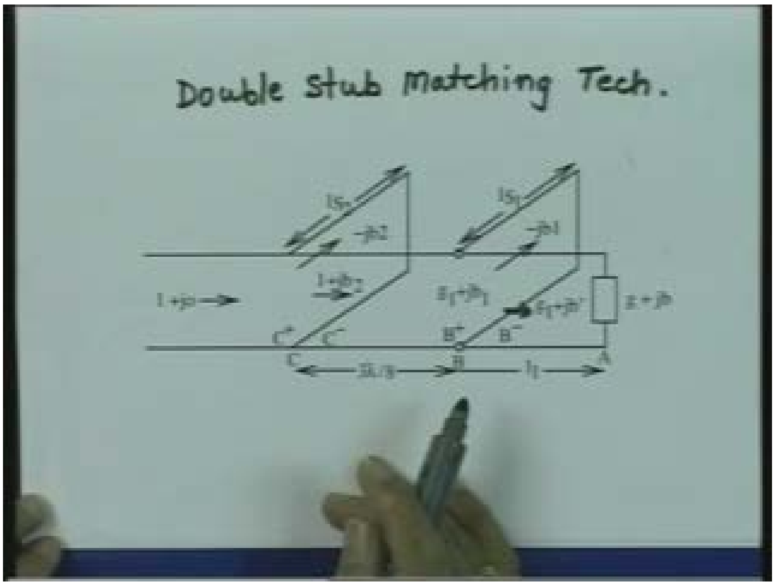
Suppose, I am having a coaxial cable this kind of structure for connecting the stub to the coaxial cable, I have to drill the hole in the outer conductor of the cable, make joined with the center conductor and outer conductor. Once the joined is made then, by having some kind of a shorting plenture inside the coaxial structure, I can change the length of the stub easily. But for changing the location of the stub, I have to deshoulder or remove the join again drill the hole somewhere else in the coaxial cable again make a join which is the extremely tedious process.

So though the single stub matching technique can match all possible loads, it has this drawback therefore every load to be match the location of the stub has to be change which every time may not be that easy. So we go to the second technique, what is called the double step matching technique where the matching between the loads is realize by changing only the lengths of the stub but the location of the stub remains fixed. So the second technique which is what is called the double stub matching technique is a technique which can match a load to the characteristic impedance without changing the location of the stub.

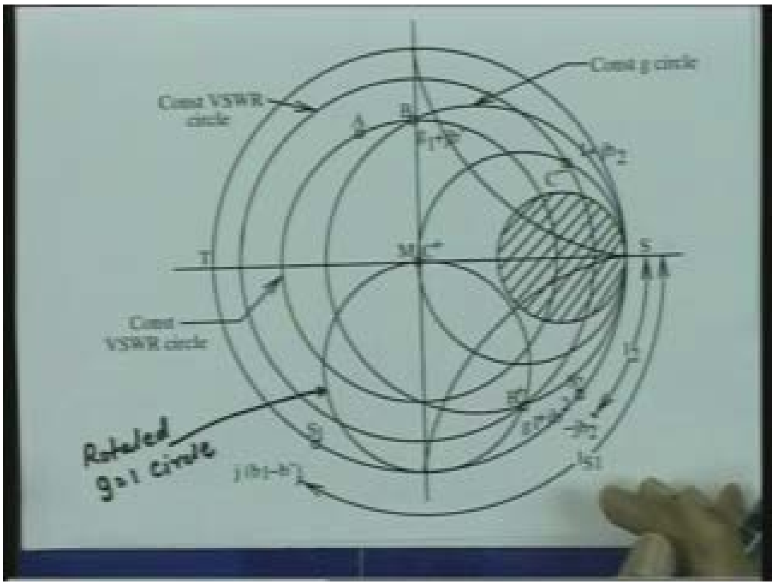
So the location of the first stub l 1 is fixed, the separation between these 2 stubs is fixed and by changing just the lengths of these 2 ls 1 and ls 2, we do the matching of the load to the characteristic impedance. Let us see how do we do that, so first let us work out how the they impedance variation would take place. So this point here we get impedance which is 1 plus j 0, which is the match would be done which is nothing but a combination of the impedance which you see here 1 plus jb 2 minus jb 2 come from this stub. So you see the impedance which is equal to 1 plus j 0.

So the whole matching requires that at this locations C, the impedance seen just beyond this point C should be 1 plus jb 2 that means the impedance which is seen here at this location should be such that when we move at distance of this from B to C, the impedance should fall on the g equal to 1 circle. This transformation now is the one which has to be worked out on the switch chart, if you do analytically again the problem is extremely tedious, with the help of switch chart. this transformation can be done very easily and then, one can work out the lengths of and the locations of the stubs. The separation between the stub is generally taken as 3 lambda by 8, why do we choose 3 lambda by 8, we will see little later. But at the moment let us say that the separation between the stubs was fixed which was 3 lambda by 8 and the location of the first stub also was 6 that was l 1. So the impedance seen at this location here just before this which is g 1 plus jb prime.

(Refer Slide Time 44:22)



(Refer Slide Time 45:08)



So the original admittance was g plus jb after transformation by a distance of l 1, the admittance seen is g 1 plus jb prime which, when is combined with acceptance minus jb 1 you get a admittance here which is g 1 plus jb 1, which is when transform appears like a admittance 1 plus jb 2 which is when cancels with the subsection of this step minus jb 2, you see a admittance which is 1 plus j 0. So how do we do this transformation by using switch chart, firstly if this point has to be 1 plus jb 2 the point has to this point has to lie on a circle which is the rotated version of g equal to 1 circle by C lambda by a distance which corresponds to 270 degrees away from the generator.

So first thing what we do in this double step matching figure has may circles, this is the g equal to 1 circle, in this switch chart. If I rotate the entire circle by 270 degrees which is 3 lambda by 8, away from the generator that must in the anticlockwise direction, I get a rotated g equal to 1 circle which is this circle. So this circle here is rotated g equal to 1 circle, so if this location B, if I can bring this admittance to lie on this circle somehow then, by a moving along the transmission lines that means along the constant VSWR circle after a distance of C lambda by 8 the point will come on g equal to 1 circle and once the point comes on g equal to 1 circle then, I know how to match because that is exactly same as what we have done in the single step matching technique.

So now the idea is just follows I have a admittance here which is g plus jb which is denoted by this point A, this is the length L 1 to which the admittance is transform that is denoted by this point B is g 1 plus jb prime. Now at this location, we are adding a stub that means we are changing only the reactive path of the admittance that means from here, I must move on a constant conductance circle because the conductance value is not change by this term. So I move on the constant conductance circle passing through B till I reach to a location on the rotated g equal to 1 circle.

So this is minus constant conductance circle, this is the point which is your B plus point so just beyond the stub this admittance, what you see that is this admittance so from point B, I move on the constant conductance circle, till I come to the rotated g equal to 1 side beyond this point then I moving on the transmission line. So I must move on constant VSWR circle, so I pass draw a constant VSWR circle passing through this B plus point and I move on this by C lambda by 8 or 278 degrees towards the generator that means in clockwise direction. Obviously, this point will fall on g equal to 1 circle which is this point that point is 1 plus jb 2 point which is in this location. Once, I get this I have to cancel jb 2, I take mirror image of this jb 2 and find out which is the mirror image of this point passing through this point and find out what should be the length of this stub. So that it will give me a acceptance of minus jb 2 which is same as what we have done in the single stub matches.

So let me again repeat what how do we do that, first mark the normalize admittance on the on the chart move I distance l 1 on a constant VSWR circle passing through A to come to a point B then, move on a constant conductance circle till you reach to the rotated g equal to 1 circle draw a constant VSWR circle passing through this point V, move on the constant VSWR circle in the clockwise direction, till you come to g equal to 1 circle, find the reactive component plus jb 2 mark minus jb 2 point on this switch chart, as you have done in single step matching, find the length of the second stub moving from that minus jb 2 point to the short circuit point in the anticlockwise direction, how do we find out the length of the full stub that length should give me a acceptance which brings the point from this to this.

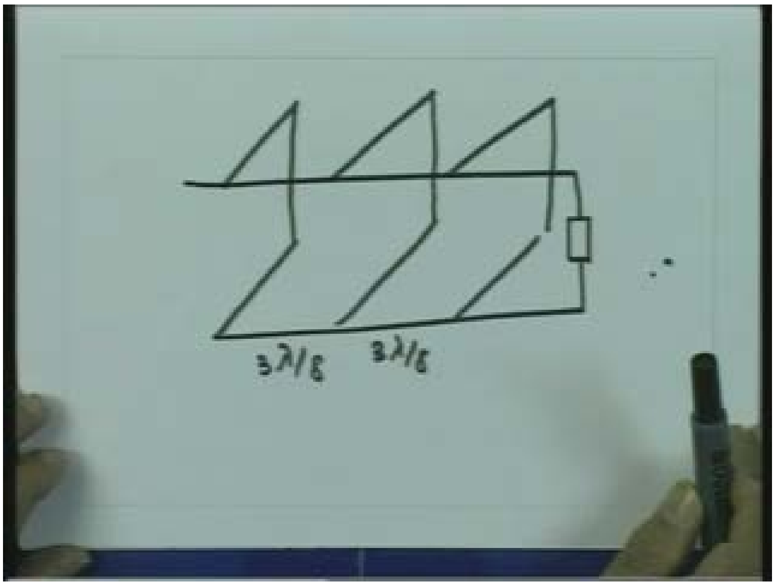
So if I know the acceptance at this point, if I know the acceptance at this point the difference of these 2 this minus this because the conductance is same at this 2 points, difference of these 2 acceptances are to be provided by a stub 1. I can take this difference mark on the switch chart outer most value, again measure anticlockwise direction that should be the length, we should give me a acceptance equal to the difference of the acceptances at this 2 points. So the different is this and if I move from this point away from the generator up to the short circuit point, I get a length which is the length of the 4 step.

So now by doing this, I can get the length of this stub and the length of this stub location of the stub is fixed down. So when the load impedance or admittance varies just by changing the length of these stubs, I can achieve the matches. So this techniques takes away the limitation of the single stub matching which has taken away the limitation of the quarter wave transformer. So for variable impedance or admittance environments that double stub matching technique is a extremely useful technique. However, this is a small problem and that is the whole process of matching is possible provided by moving a constant conductance circle, I can come on the unit g equal to 1 circle, if by this moment on constant conductance circle, I cannot reach on rotated g equal to 1 circle, the matching is not possible and if you know the nature of constant g circle they are one within another.

So this is the g equal to some circle, the higher value of g equal to some circle may be inside this, inside this, inside this so on. So it is possible that if the point, admittance point B at this location this one, if it lies here inside this region, then my moving along the constant conductance circle I will never be able to come on rotated g equal to 1 circle and if I cannot come here then the impedance after transforming cannot come on the g equal to 1 circle here and the matching is not possible.

So what that means is if this impedance g 1 plus jb prime, if it lies in this region what is called the forbidden region than the impedance matching is not possible. The grace however lies in the fact, this is not the load impedance it is this impedance which should not lie in the forbidden region. So impedance which you want to match can lie in the forbidden region but this impedance transform impedance after distance l 1 that should be out of forbidden region. So by choosing proper value of l 1 need not be very precisely just take a step, there is a possibility that this point can be taken out of the forbidden region. So as such the double step matching technique has a small limitation that it cannot match those impedances whose transform value after l 1 lies in this forbidden region.

(Refer Slide Time 53:34)



However, this thing has been taken away by introducing the concept simple which is the 3 step matching and that is, if I take this load, what we can do instead of using 2 stubs that we use 3 stubs, the distance between the all of them is 3 lambda by 8, this is 3 lambda by 8 and this is some value l 1, what I can do is if because of these 2 stubs, the matching is again double stub but if the matching is done with these 2 stubs, I can make this open circuit by checking this length equal to quarter wavelength. If I find that by choosing these 2 stub, the transforming impedance lies in the forbidden region, I can disconnect this stub and make use of these 2 stubs.

So depending upon whether the transform impedance lying in the forbidden region or not, either I can make use of this 2 stub of these 2 stubs. So the final solution in the impedance matching is the 3 stub technique that by using this now, all possible impedances can be matched without moving the location of the stubs on transmission line. So that completes the discussion of the impedance matching of unknown impedance to the characteristic impedance of transmission line.