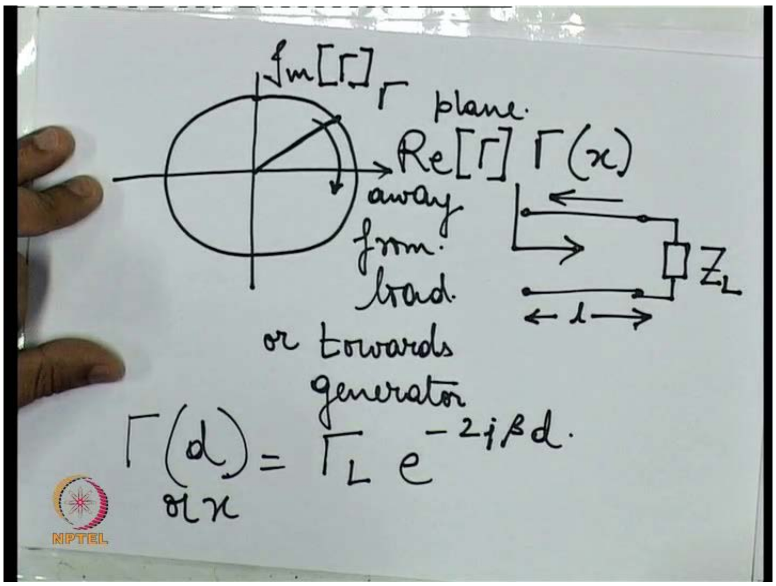
Microwave Integrated Circuits
Prof. Jayanta Mukherjee
Department of Electrical Engineering
Indian Institute of Technology, Bombay
Mod 01, Lec 05
Applications of the Smith Chart

Welcome to another session of this NPTEL mock scores on Microwave Integrated Circuits. In the previous module we had talked about this Smith Chart and how the Smith Chart is formed. In this module, we will continue our discussion on the Smith Chart and also see some applications of the Smith Chart in impedance matching.

[Refer Slide Time: 00:55]

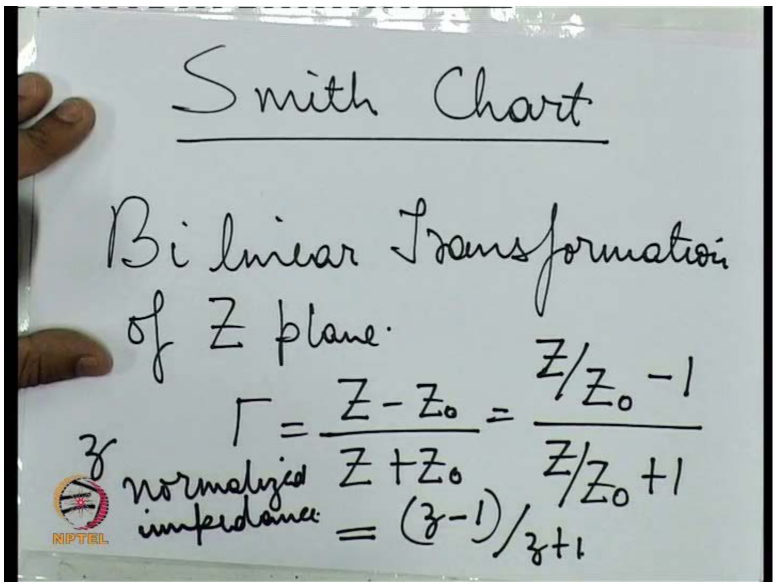


So as you know, as we discussed in the previous class, the Smith Chart originates from the concept of the reflection coefficient. If I can just redraw that figure…so this is the gamma plane and as we go away…so if this is the representation of a transmission line with a load ZL connected then, and say this is a transmission line of some length L, then as we are going away from the load, our phase angle decreases and that's why we are going in a clockwise direction.

So we can write this as away from load or towards generator. And the other thing is, the other thing that I mentioned is the magnitude of this gamma. So this is the gamma X or D, gamma X or D. The magnitude of this gamma X keeps constant, whether we are moving away or towards the load towards the load. So this is the imaginary gamma and this is the real gamma.

Now this is the concept we had this concept of this increasing or going towards the load, away from the load, going clockwise, anticlockwise this follows from this equation that we had earlier discussed about, the gamma D or X, whether its gamma D or X is equal to gamma L E raise to minus 2 J beta D. This is the equation from which this concept of clockwise or anticlockwise movement follows. So this is the basic concept as I said on which the Smith Chart, concept of Smith Chart arises.

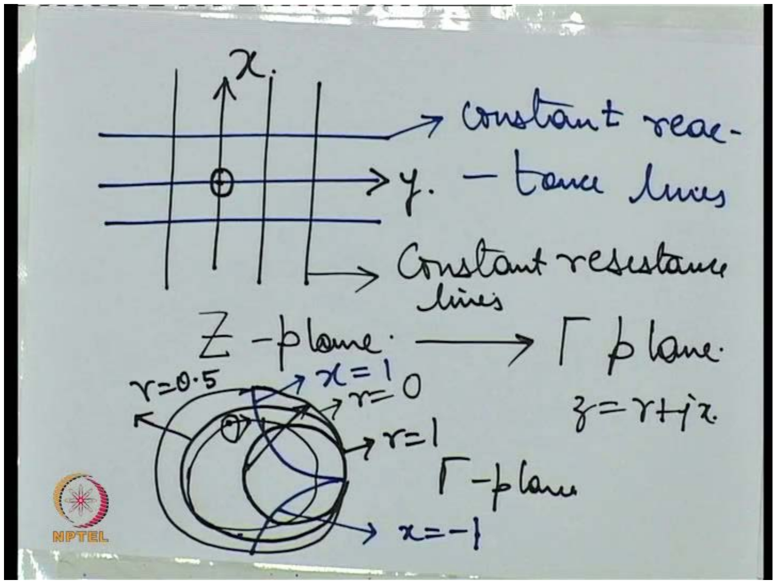
[Refer Slide Time: 04:05]



Now if we further analyze the Smith Chart, this is basically how we had gone in the previous class. I had mentioned that Smith Chart is nothing but a bilinear transformation, bilinear transformation of Z plane.

So in terms, mathematically what this means is this relation. Where this small z, as I as we discussed, is called the normalized impedance. Fine? So then if this is the formula that we discussed so how does it actually translate graphically? So let us see how it translates graphically. So if I draw some straight lines on the Z plane, I'll use a different color for different types of lines.

[Refer Slide Time: 05:36]



Say these black lines are representing constant resistance circles and so this is our X our X axis and Y axis on the…So this is X and say this is Y, this is the origin. Now these blue lines, I hope it's visible, these blue lines represent a constant reactants or constant values of the imaginary component of Z. Now this whole plane is the Z plane. As I said this bilinear transformation will convert from the Z plane to the gamma plane. So these are the constant reactants lines and these are the constant resistance lines. Fine?

Now when you apply this transformation, what happens is, these constant resistance lines i.e. these black lines are they are converted to constant resistance circles. I hope this circle is pretty enough. So say this is the R equal to 0 circle where R refers to, if I write the normalized impedance as R plus JX, and this is the normalized resistance and X is the normalized reactants. So then this R that corresponds this R this circle corresponds to the R equal to 0 straight line. From the origin of the, now we are in the gamma plane, ok?

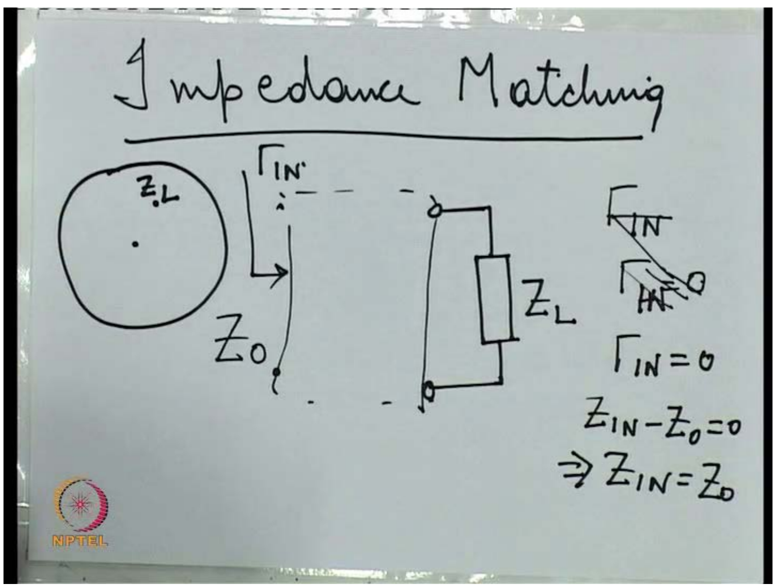
Now from the origin, this circle has a radius of 1. As the value of small R goes on increasing, we will get a number of circles. For example, this is the R equal to 1 circle and so on. so between say R equal to 1 and R equal to .5, R equal to 1 and R equal to 0, we will get other constant E resistance circles like this.

So say this is the R equal to .5 circle and these constant reactant (cir) lines, these constant reactants lines, they also get converted to circles like this. For example, this is the X equal to 1 circle and this is the X equal to -1 circle. As the resistance or reactants value goes on increasing, the radius of these circles keep on decreasing.

Now falling the discussion on this constant reflection coefficient that we had seen in the previous line, suppose we take S any point on the Smith Chart, we take a compass and draw a circle concentric circle which has a center at the origin then if we move along the surface of that circle then basically we are moving along a transmission line because now we are on gamma plane and I said that along a transmission line, the magnitude of the reflection coefficient is constant.

So then if we move along the surface of the along the edge of this circle which has the center at origin then we are moving along a transmission line. If we are going in a clockwise direction then we are moving away from a load, say this load. If we are moving in an anticlockwise direction then we are moving towards the load, ok?

[Refer Slide Time: 10:20]



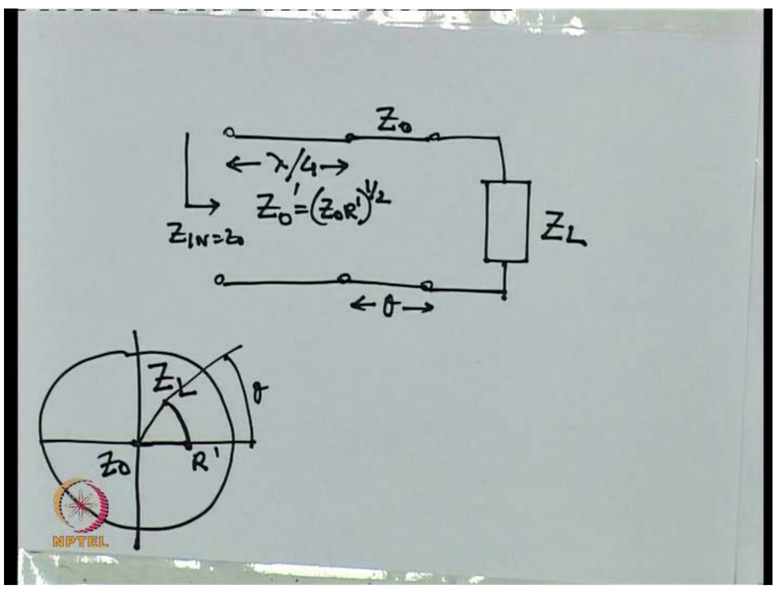
So with this concept, h with this concept with this concept actually we can further you know analyze some situations like what we call impedance matching. Consider a simple case. Suppose we have load ZL and say on a Smith Chart this ZL is represented, say this is the origin, say ZL is represented by this point.

So impedance matching refers to the case when the total reflection coefficients seen at the input is 0. That is gamma in is equal to 0. Now if we have a load ZL for achieving gamma in and suppose our input is somewhere here then for achieving this we have to have something in between this load and the input which will create the gamma in equal to 0.

Now gamma in equal to 0 means Z in minus Z 0 equal to 0 implies Z in should be equal to Z 0. So we have to transform this ZL so that Z in becomes equal to Z 0 where Z 0 is the characteristic impedance. Now how do we do that? There are various ways of doing it. Will discuss a few of the common ways to do this.

1 is the first point will be based on a quarter wave transformer. For quarter wave transformer as we have know is a is a circuit where we can convert where we can kind of reverse the output impedance by putting a quarter wavelength of transmission line.

[Refer Slide Time: 12:50]



So if go back to our circuit once again we have ZL. Now on the Smith Chart as I said this point is represented by this point ZL. So the various ways for going from this you know we can go from this point to the origin in various ways.

One could be you know we simply add a piece of transmission line so that we are transformed from this point to the X axis and then from transforming to this point to this the origin we use a quarter wave transformer. So the circuit would look something like this. We have a piece of transmission line and then a quarter wavelength.

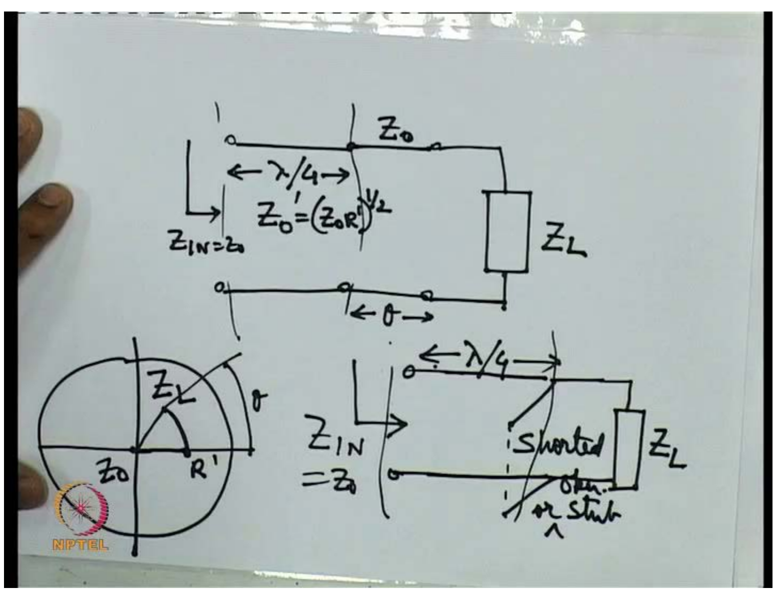
So this is lambda by 4 but here the…suppose this point is R dash then this will can say we have to see an input Z in equal to Z 0, this point so then the characteristic impedance of this quarter wavelength will be…so this is what the circuit would look like. Ok?

As I said what we are doing is we are transforming this ZL to this origin because origin is always equal to corresponds the characteristic impedance Z0. We can there are various parts we can travel from ZL to Z0. After all impedance matching you have to understand is finding the path from this impedance to the origin.

We could have found many paths and we will discuss some more, few of more those paths. But whichever path we choose, it should be feasible. It should actually you know we should actually be able to realize that path. So while you there are infinitely (no) infinite number of paths possible from the load to the origin.

But we have to (choo) it should be actually physically possible. And also it should have the minimum number of components that makes us convenient also and from a noise perspective also where we have to choose the path which involves the minimum number of components.

[Refer Slide Time: 15:59]



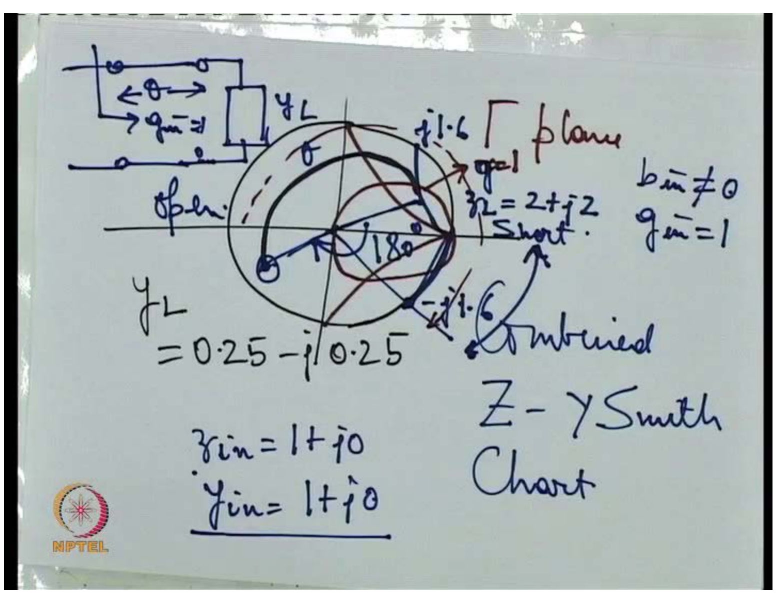
So this is one way to do the impedance matching. Yet another way of doing it could be we (s) start with a load and we simply cancel its imaginary part by either adding a shorted or open. So shorted or open stub is connected directly at the Z L. So one the purpose of connecting the shorted or open stub is to cancel the imaginary component of ZL and then once we (ha) have cancelled it, we simply add another quarter wave we add a quarter wavelength of transmission line to bring the input impedance equal to Z0.

So instead of rotating it along the (trans) along and keeping the reflection coefficient magnitude constant we directly cancel the imaginary component of ZL using a shorted or open stub and then do and then do the transformation using a quarter wave transformer. So this part here is same as this part here. Only this part is different from this part. This is this is a standard way to realize this impedance matching using a quarter wave transformer. There are other ways also I'll show one of them.

Now the problem with quarter wave transformer is that it is it is it has a different characteristic impedance compared with others either shorted stub or the piece of transmission line that we are using. And that makes it sometimes inconvenient because we would prefer to have uniform aa characteristic impedance and also uniform with.

As you know uniform characteristic (mea) impedance corresponds to uniform with along (th) for all transmission lines. So if you want to keep the a characteristic impedance for all the stubs and all the transmission lines constant then we can employ this technique that is that that I am going to describe now.

[Refer Slide Time: 18:15]



Now suppose again we have our Smith Chart if I use a different color for this Smith Chart…so this is my Smith Chart and say I have an impedance say I'll write the value also. Say small ZL is the normalized impedance that is… Now in this method we will be using a combined ZY Smith Chart.

Equal how to convert from the Z Smith Chart to so now we are in the gamma plane corresponding to the Z Smith Chart. If I want to convert it to the Y Smith Chart the process as you know, we shift this by 180 degree. Once you shift it you get this point YL corresponding to… Now even now once you are getting Y L that means you are in the Admittan Smith Chart.

So the origin corresponds to the matching for both the Admittance Smith Chart as well as the Impedance Smith Chart. So we have to again bring this point to the origin. How can we do that? Now one way we can do that is again you know you take a compass with the origin of the gamma plane as the center and draw an arc till you are crossing the R equal to 1 circle.

So let me draw this properly. So you are crossing the R equal to 1 circle here. Now see once you cross the R equal to 1 circle because for impedance matching you have to have Z in is equal to 1 plus J 0. So you have already or I can write in terms of Y in you have to achieve 1 plus J 0.

So now see you have actually this is the G equal to 1 circle. Just I want to make this small correction. This is G equal to 1 circle since we are on the Y Smith chart. So as I said for impedance matching you have to obtain the input admittance as 1 plus J 0 (clears throat) and you have already achieved the G equal to 1 point. So the G condition is satisfied.

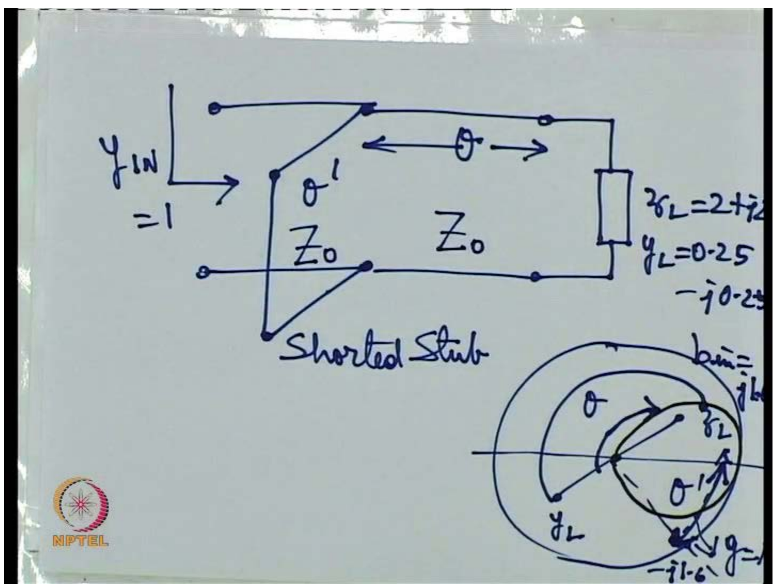
But now this point necessarily doesn't correspond to 0 succeptance that is b in may not be equal to 0 but G in is equal to 1. How can I make B in equal to 0? So now on the circuit what this corresponds is 2 is I had my YL, I added a piece of transmission line whose length is theta and at this point I have my G in equal to 1. But my I have to still cancel my B in.

How can I do that? To cancel B in, I can just put a shorted or open stub so if I have to cancel it that means I have to have the corresponding negative value of the succeptance here. So that succeptance value I have to connect here and the length that I would need for cancelling that, this length of the shorted or open stub that I would need for cancelling would…

First of all, see this is, say in this case this is J 1.6 the B in value and this is minus J 1.6. If I am using a shorted stub then I would have to calculate the distance from this point because this point corresponds to short on the gamma plane and this point corresponds to open on the gamma plane.

So this is the length of the shorted stub that I would need to achieve minus J 1.6 succeptance. If I am using an open stub then I would need a length of starting from the open end so then I would need this distance. As you can sees the since the open length of the shorted stub is lesser than the length of the open stub hence I choose the shorted stub.

[Refer Slide Time: 23:50]



So just to summarize the whole process, I have a ZL. This corresponds to YL equal to .25 minus J .25. First I connect a length of transmission line corresponding to theta. Then I add a shorted stub of length theta length and I get Y in equal to 1. On a Smith Chart this would look like this.

I started with ZL, I converted it to YL then I drew one arc corresponding to the G equal to 1 circle. Then I found out that here the B in is equal to J 1.6. Then I chose a point minus J 1.6 and I calculated the total length of the shorted stub theta length. So this is theta and this length is theta length.

So this is how we can do the impedance matching (throat sound). The advantage as I said here is that the characteristic impedance of all the segments are the same. Now I have shown 2 methods of doing this, one using quarter wave transformer quarter wave transformer and the other using normal transmission lines along with shorted stubs.

The method that you choose is up to you but keep in mind the realizeability of the method and also it should whichever method you use should contain the minimum number of segments. Thank you.