Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Applied Electromagnetics for Engineers

Module – 17
Impedance matching techniques: Part 3

by

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Hello and welcome to the mook on electromagnetics, applied electromagnetics for engineers. In this module we will first briefly complete the discussion of lumped parameter impedance matching that we were discussing since last couple of modules. And then we will start looking at the time domain analysis of transmission line circuits. So let us begin by looking at this lumped parameter or lumped circuit impedance matching.

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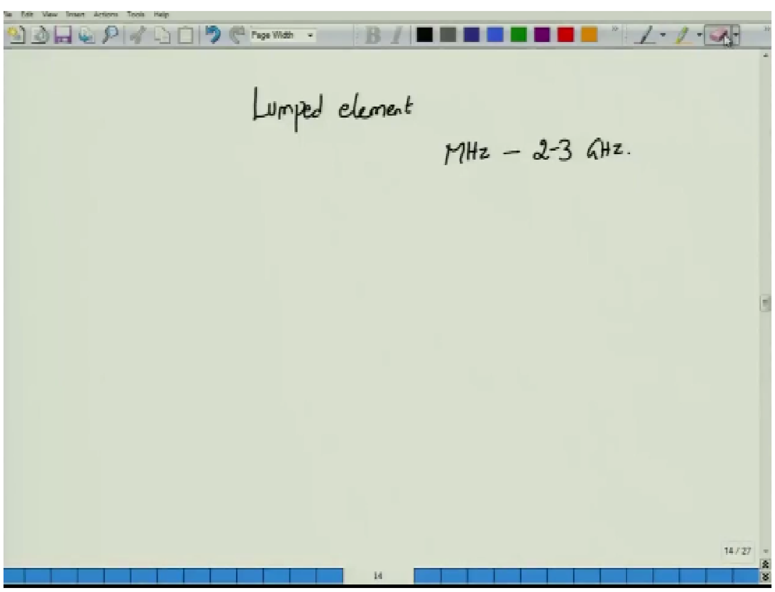

We said that lumped circuit impedance matching or lumped element circuit impedance matching is normally taken care at lower frequencies, that is in the range of few 10s to 100s of mega hertz range, or with some luck and with some fabrication expensive the fabrication you can push this one up to 2 to 3 gigahertz. Beyond this if you try lumped element circuits for matching problems, then the problem of fabricating the corresponding inductances and capacitances become very expensive, not that it cannot be done, but it become prohibitarily expensive.

In that case you simply go over to the transmission line matching or the distributed circuit matching okay. How about, if you want to perform matching for AM or FM broadcasting elements lumped element would probably be much more easier, and it is in fact why it is preferred and it also gives you lot of flexibility, solutions are inexpensive, but they do again and suffer from the problem of either a narrow band matching or the broadband matching.

Most cases will be narrow band, however you can use multiple such lumped elements matching network or matching sections in order to improve the bandwidth of your matching network okay.

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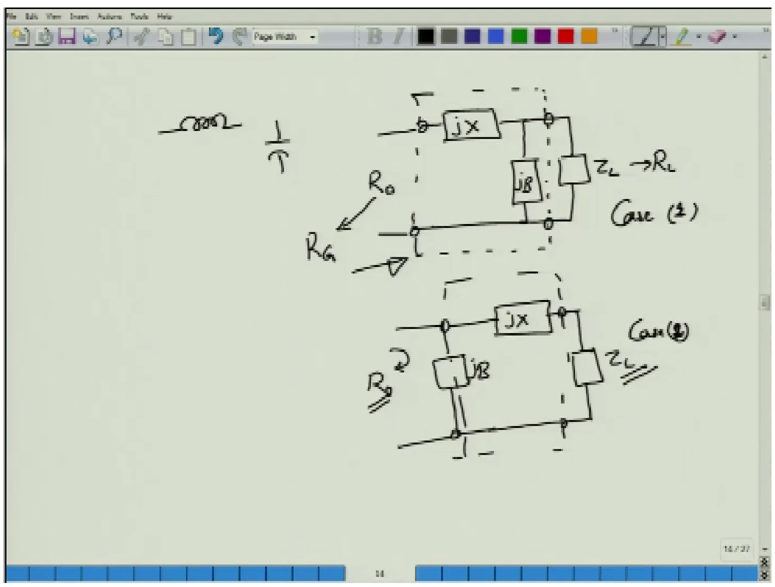

What is the lumped element matching network, it is of course made out of lossless inductances and capacitors okay, you can connect this lossless inductors and capacitors in various forms. We will look at only this particular matching network which is called as the L section matching network. So in the L section matching network we distinguish two cases, one there is a susceptance immediately before the load okay, or immediately after the load I should say.

So this is how the matching network would look. So let me just dimidiate this matching network in terms of dashed lines okay. So this is where the network is going and let us say this is some R0 or the reference load that you are trying to match okay. And ZL is of course the load, in many cases this ZL would be real at lower frequency, so if you are looking at then it would be RL and this would be R0 in many cases this R0 is actually equal to the resistance or internal resistance of the generator RT itself.

So this a null section in which the admittance part comes first and then you have a series reactance so you have a susceptance here and the series reactance there is another case in which the matching network would have reactive part okay connected to the load there would be a reactive part and then there would be the susceptance connected in parallel, so this case of matching networks is usually encounter.

So this is again the marching network that we have been designing the goal of matching network of course is to be able to match this Z_L and R_0 so that there are no reflections or there would be maximum power transfer and of course that will be maximum power transfer so we can refer to these two cases as say case 2 and case 1, or rather case 1 and case 2 we will only consider the 1 here as in the case two as exercise for you to follow up okay.

So let us look at y case 2 and how to calculate the corresponding values of x and b in case 2 problem we will solve this problem using smith chat therefore you can feel how the impedances go or transform as we add elements in series and elements in parallel remember that we want to add elements in parallel you need to convert the impedance smith chart into an admittance smith chart okay.

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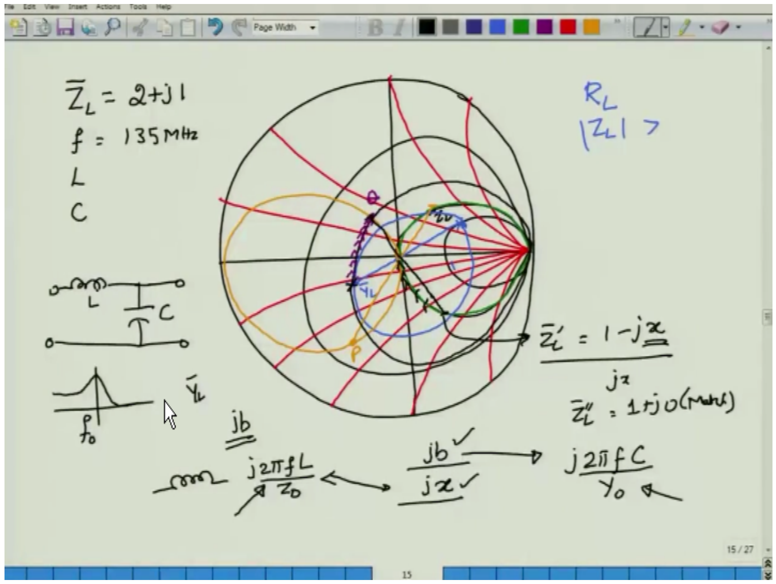

So let us draw your rudimentary smith chart over here okay so this is the smith chart I hope you have your smith chart with you so that you can look at the correct values okay and practice along with this so I have the impedance and the reactance circles as I said this is just a very rudimentary very elementary type of a smith chart that I am drawing you should have your copy of the smith chart is felicitated I understand this problem I mean understand how to solve this problems.

Case 1 is applicable when the load resistance R_L which is what usually happens or may be the magnitude of Z_L would be greater than Z_0 or R_0, Z0 is essentially the same as R_0 right so it would be either greater than Z_0 or in the real case of R_0 in terms of smith chart it is simply implies that the corresponding load will be within the unit circles so the one that I am drawing with this green wound be the unit circle and the load would lie inside here.

So let us arbitrarily locate the load to lying at the point where which is at the point where I have marked across okay now you realize that this is luckily also happens to be so this black circle on which this blue point is present or blue cross is present also happens to be the constant resistance circle. Now the goal of any impedance matching network is to be transforming from the point x to the point at the origin okay, you cannot do that if you keep moving on this constant R circle remember you are only going to add reactants so suppose you start with this load okay, let us call this as the load point Z_L or the normalized load Z_L okay, so if you start adding series reactants to it you would not go anywhere.

Because you are only going along this black circle and black circle will not touch the 1+jz circle or the unit circle so that you are able to cancel of the remaining reactants, so here you should not start with the series resistance or the series reactants first we should convert the load into an admittance add a required amount of susceptance so that you bringing the total admittance or rather you bring in a total impedance in the form of 1+jz and then add a series reactants such that of value –jz so that –jz will cancel out the +jz. So let us go back to the circuit that we have drawn.

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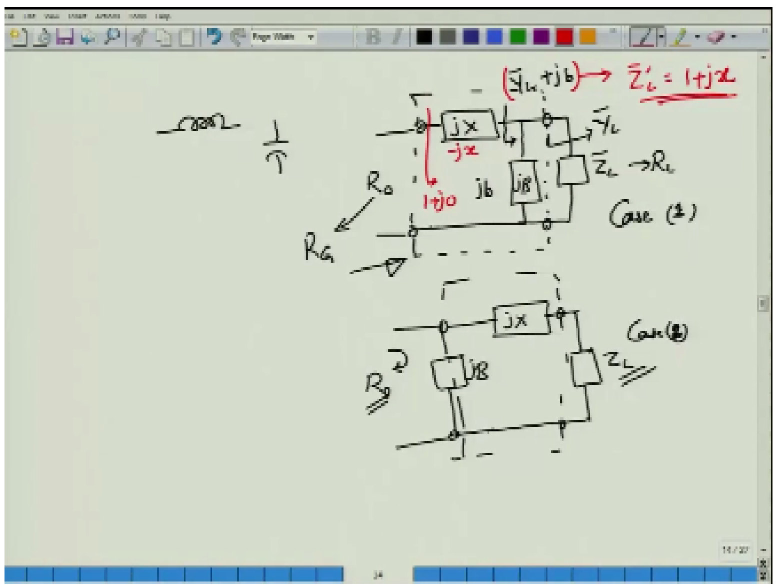

So let me just go back to the circuit here so if you see the circuit, so if this is the load Z_L you first convert the load Z_L into the admittance Y_L you can also consider in normalized loads as we will and once you add the susceptance of jB which will again be normalized so B/R_0 will give you a normalized susceptance magnitude value, so once I go over to jB the total admittance would have been $\bar{Y}_L$+jB right, so the corresponding impedance if I look at so it is not the admittance if I look at the corresponding impedance now so this is the admittance that I have.

If I transform this impedance I should then have a transformed impedance of so let us call this as some Z'_L to be of the form 1+jx where x is the normalized reactants. Now when I add +jz or –jx in this particular case so if I add a –jx again x denoting the normalization the impedance seem looking here will be 1+j0 and that is this is the normalized impedance and therefore we have achieved the match, okay.

So there are two things, first I need to determine how much normalized susceptance I need to add in parallel to Y_L which is the admittance at the load and how do I move from there on to the unit circle impedance 1+jx so that I can then add the remaining amount of –jx. So we do this two step procedure by first converting the load point into an admittance point.

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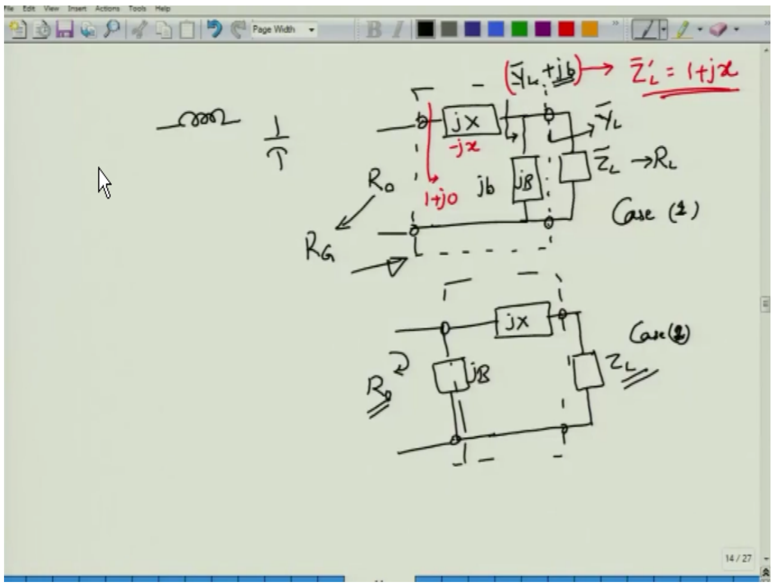

In order to do that I need to draw the constant SWR circle as I have explained to you earlier so this is not a very nice circle please forgive me, but once you draw the constant at SWR circle and then obtain a point which we would call as $\bar{Y}_L$ that would be the admittance corresponding to this setup. So it could be located diametrically opposite here, now from here we need to move in order to obtain this impedance.

So first you have to obtain you have to add an amount of Jd such that once you obtain the admittance and then turns from to the impedance you should lie on 1 + jx for the way do that +jx, for that way do that. Well remember that any point on the split chart can be rotated by λ / 4 rights if you rotate this impedance or rotate the unit circle by λ/4 we will land up with the rotated admittance circle or the admittance circle which is now we are going to look like this okay.

Each point on the rotated unit circle which corresponds to the admittance will have a corresponding point as the impedance okay, any point here when you take the impedance corresponding to this points so let us call this point as P, I will write a the impedance corresponding to the point P you would actually land up on the lower point okay. Or you land up on the unit circle.

So because of that what we do is, we know this and till so we move on the constant or circle so this would have a certain constant or circle let me draw that one okay it is again not a very nice drawing but there would be a constant or circle here and if I now and if I now I am obtain the admittance now I will start moving oaky. So I move in such a way that I am move I can move either in this way in which case I am adding positive substance or can move downwards of the counter clockwise in which case I would be adding negative susceptance okay.

So let me chose to add positive susceptance, so that I keep moving and I reach the point over here let us call this point as some point K. what is the nature of the point Q? And please note how we have move we have not moved on the SWR circle we have actually moved on the constant or circle corresponding to the point y L bar, so after moving reach Q I know that point Q must corresponds to a point on the unit circle okay.

So I can go and find out what would that point be by and the line fast through from Q origin and landing on the unit circle so which is the unit circle over here. Now this corresponds to zl bar' and you notice that zl bar' in this case happens to be of the form 1-jx because it is non-lying in the lower hemisphere the imagine part would be negative here.

Now from this side we should start move on by adding the certain amount of reactance which is the amount of x that you want to add you would reach the center of the chart and then you would have obtain matching how much susceptance you are added you can first note down what is the coordinates of yl bar or other coordinates of yl okay and then you have moved along the constant or circle by this amount okay subtract the reactives at this point and subtract the reactives at yn and bar and you would have obtain what is the amount of susceptances you have added in this case please note that the susceptances to be added is positive the reactives to be added is also positive.

This is zn bar but if you add to this +jx then you will get z and double bar which is equal to 1+jo which corresponds to the match conditions okay so you need to add positive susceptances and positive value of the reactives consider the inductor what is the reactives of this inductor is j2πfL is the actual reactives but then need to divide the actual reactives by the corresponding value of impedance right.

In order to normalize this jωL is the reactives of an inductor and then divide by z^0 will give me the corresponding normalized value so if you equate this two and solve for L will be easily find out will be able to easily find out what is the required value of inductances which gives a corresponding reactives of +jx .

Similarly for positive susceptances we know that the capacity of positive susceptances so jb would correspond to j2πfC right again solving these two by equating this two sorry this is just j2πfC but this has to normalize with respect to the admittance please note that inductive reactives of the normalized by Z^0 capacity susceptances or normalized by the admittance y^0 okay.

So now equate this two find out the expressions for C or find out the values for C okay if you want to get some practice with this you can start by this example assume that the normalize load that you are trying to match is 2+j1 okay and assume f of the equals of about 135MHz by following this procedure determine the L and C values and of course determine what is the structure of matching network.

In this case please remember B turn out to be positive X turn out to be positive, positive reactives means inductor so matching network would have a capacitor of the values C that you have found out and it would have an inductor whose value we would find out from equating this two expressions okay so jx and $j2\pi fL/z^0$ so this clear that matching network unfortunately this matching network that we can obtain is not broad band because you known if you start looking at this frequency response at the desired frequency they would have some value.

They would be the peaking they would peak at the desired value but the happens when the frequency is very large then this inductor will have a reactives which would be very large the capacity reactives short out becomes this open circuit and the response actually drops downs to 0 okay. So on the other side it will not dropped out 0 it would be slightly because at very low frequencies the inductor will act like short circuit and the capacity will act like a open circuit so this is the frequencies response of this particular matching network okay so this completes our discussion on matching networks thank you.

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