INDIAN INSTITUTE OF TECHNOLOGY KANPUR

NPTEL

NPTEL PROGRAMME ON
TECHNOLOGY ENHANCED LEARNING

Course Title
Electromagnetic Waves in Guided and Wireless

Lecture - 08
Additional Applications of Smith Chart

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Hello and welcome to NPTEL MOOC on Electromagnetic Guided Waves, the Electromagnetic Waves in Guided and Wireless Media, this is our module 8, so in this module we are going to look at additional applications of Smith Chart, I'll mostly be giving you again a high level version of this mid charting, so you will have to have your mid charts, pencil, compass, scale and other things to verify my calculations, and doing so couple of problems will give you a good handle on how to use Smith charts, okay.

So we will look at two applications of Smith chart, one we have already seen the application but we did not mention it until the end of the problem. Shunt stub matching, we are familiar with the basic idea you have this main transmission line which is terminated with some unknown load ZL, and this transmission line has to be matched to the characteristic impedance of the main transmission line, we are going to assume that the lines are lossless to simplify our calculations,
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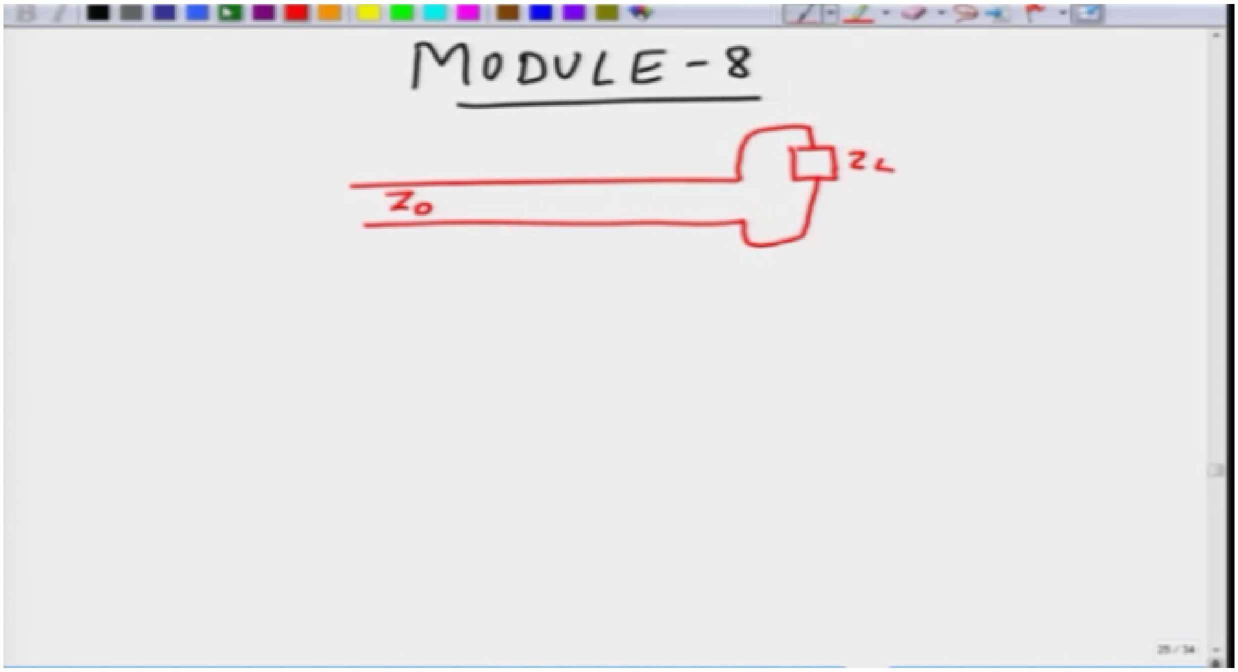

and the procedure also you know, you need to connect a stub of appropriate termination whether it would be an open circuit termination or it could be a short circuited termination, both will actually work but then depending on which termination you have chosen the length of that stub will change, so we will denote the length by D2 and the position at which you are going to place this stub as D1, okay.

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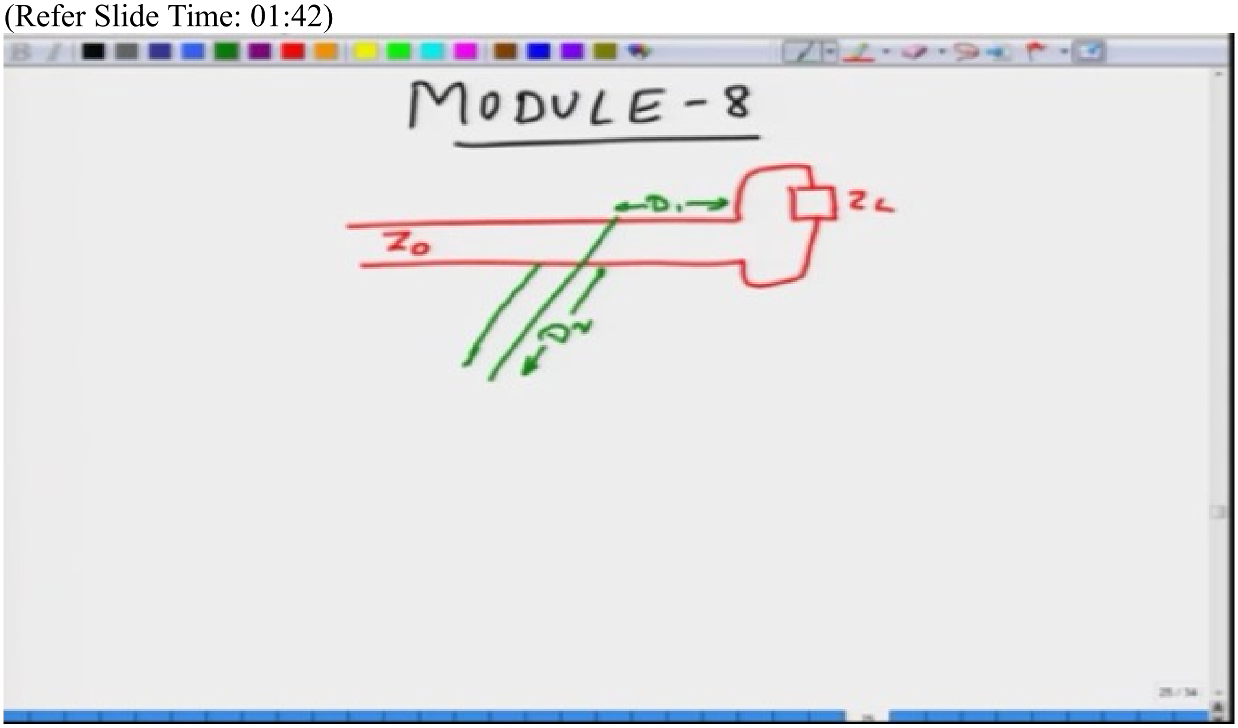

In the previous problem you were given D1, given D2, you are given Z naught and ZL and you are asked to find out what is the input impedance at this particular plane or rather we found that it is easier to deal with admittances and therefore we were asked to find out what is the normalized input admittance at this plane and we found that this was actually equal to 1, okay, and it was equal to 1 because two things happened, one we start off with ZL and then you convert it first ZL to ZL bar, from ZL bar you convert it that into YL bar, right, so that was actually the admittance that you would see right at the load point itself.

And then by moving YL bar you know from starting from the point YL bar and moving on to the WTG scale that is clockwise from the WTG scale, what you did was to file the intersection or rather it turned out that way that now you are going to do this one, so what you found was the new point which we called as say YL bar was actually equal to 1 + some JB, where B was the reactance that you form, B could be positive or negative doesn't matter, I'm just writing it as 1 + JB, it could equally be 1+ or 1- JB you know when B is negative.
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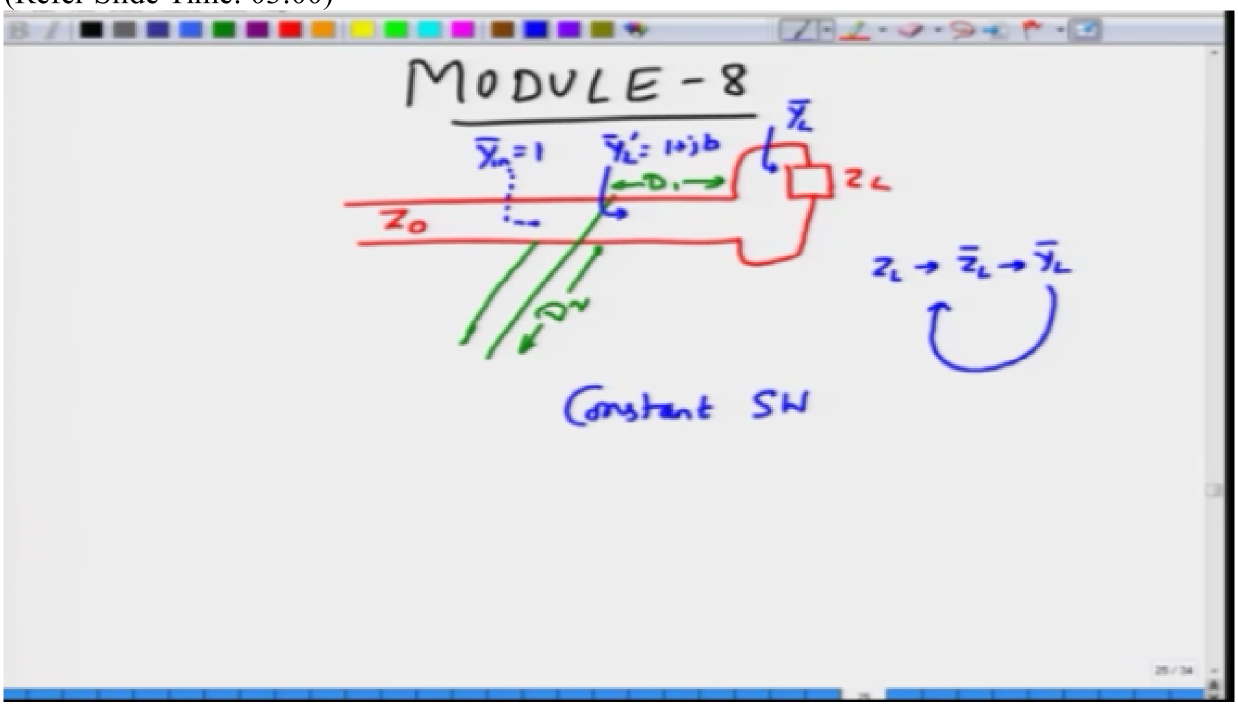

So what you found was starting from YL right to mu YL bar, YL bar was actually the position where the constant SWR corresponding to ZL intersected with unity or unit circle on the Smith chart, unit circle on the Smith chart was given by R = 1 this is a special circle and the point where the constant SWR circle and the R = 1 circle, this is R = 1 circle sorry this is R = 1 circle, this is constant SWR circle somewhere, okay, and when these two intersected you obtained the impedance or the admittance YL bar as some form 1 + JB.
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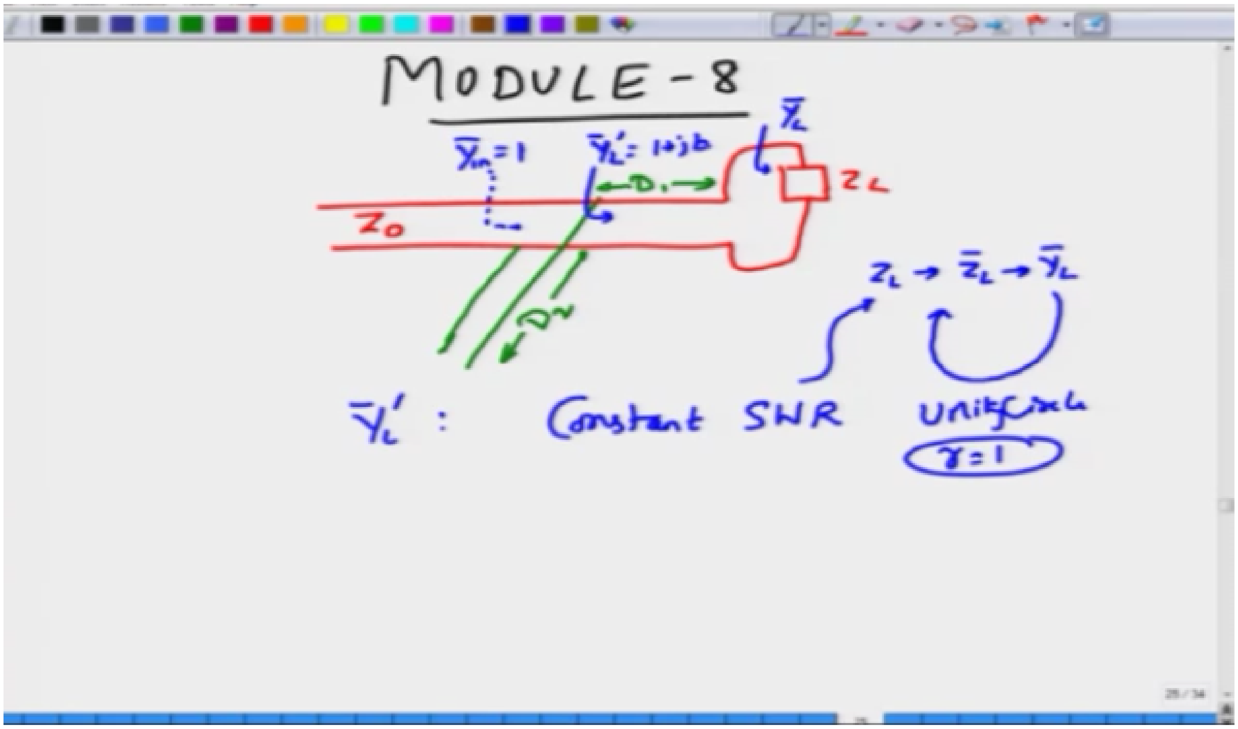

And what this stub actually did was to cancel off this B that is the reactive part by starting with either a open circuit or a short circuit in such a way that this YS prime which was the stub admittance was exactly equal to –JB, okay, so if for example YL prime was 1+J2 then the stub B supposed to give you –J2 if the YL bar admittance is 1-J2, then the stub is going to give you +J2, right,

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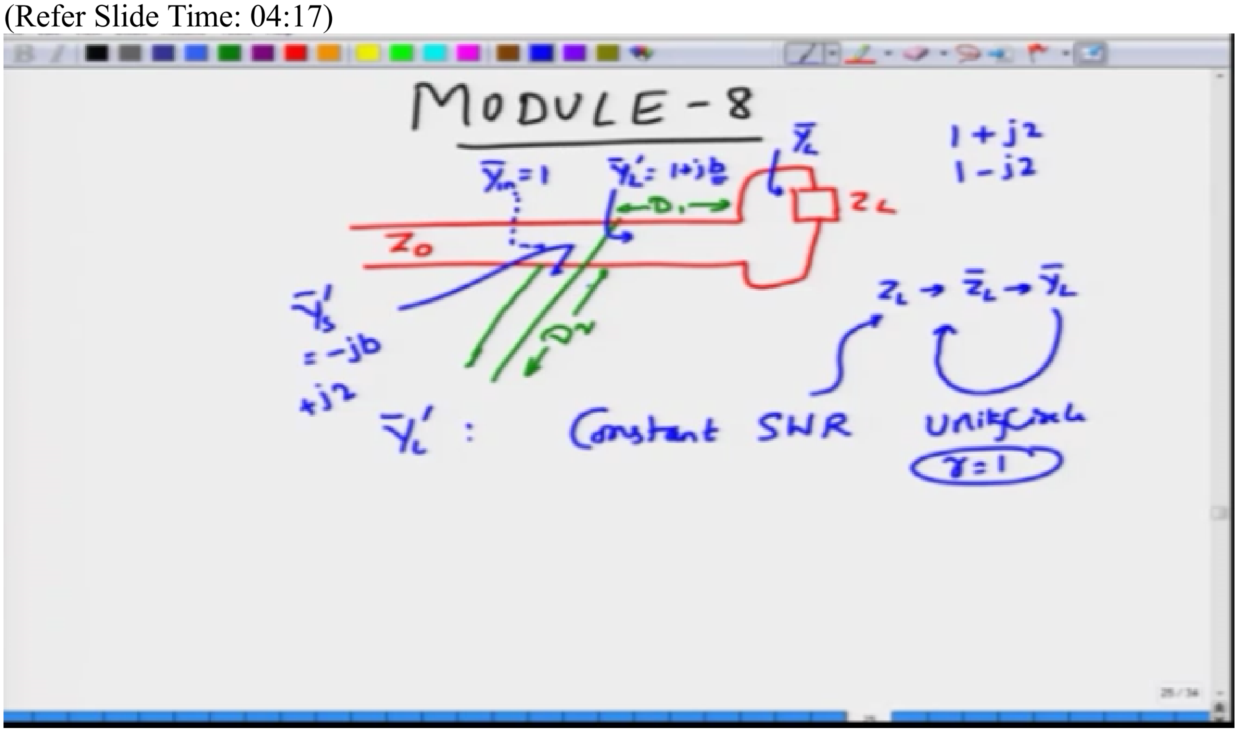

so this is the basic idea and the distance D2 in order to give you that admittance can be found again by Smith chart, okay, so hopefully this process is very clear, we are going to solve a simple problem, right, and then we will see how to obtain this D1 and D2, okay.

Let’s assume that someone has already calculated what is the normalized load impedance which is ZL bar, and this is given by 1+ J2, okay, if we are already given what is 1+J2, then we really need not do anything else, you simply have to design D2, okay, of course here the problem is that you need to place the stub right at the load itself, okay, this problem of placing that load right at the load itself does not in any way make it impractical, because these are connections done in the parallel manner, if it was series, yes then you have to make some space for this you know line to be placed in series and that would have created a little bit of a problem, but because you are going to connect in parallel you can simply connect right at the source itself that is make D1 = 0 and simply choose the length D2 appropriately to convert either an open circuit at line we will take that in this problem into -J2, so all that you are trying to do is to obtained the length of the line such that you get –J2.
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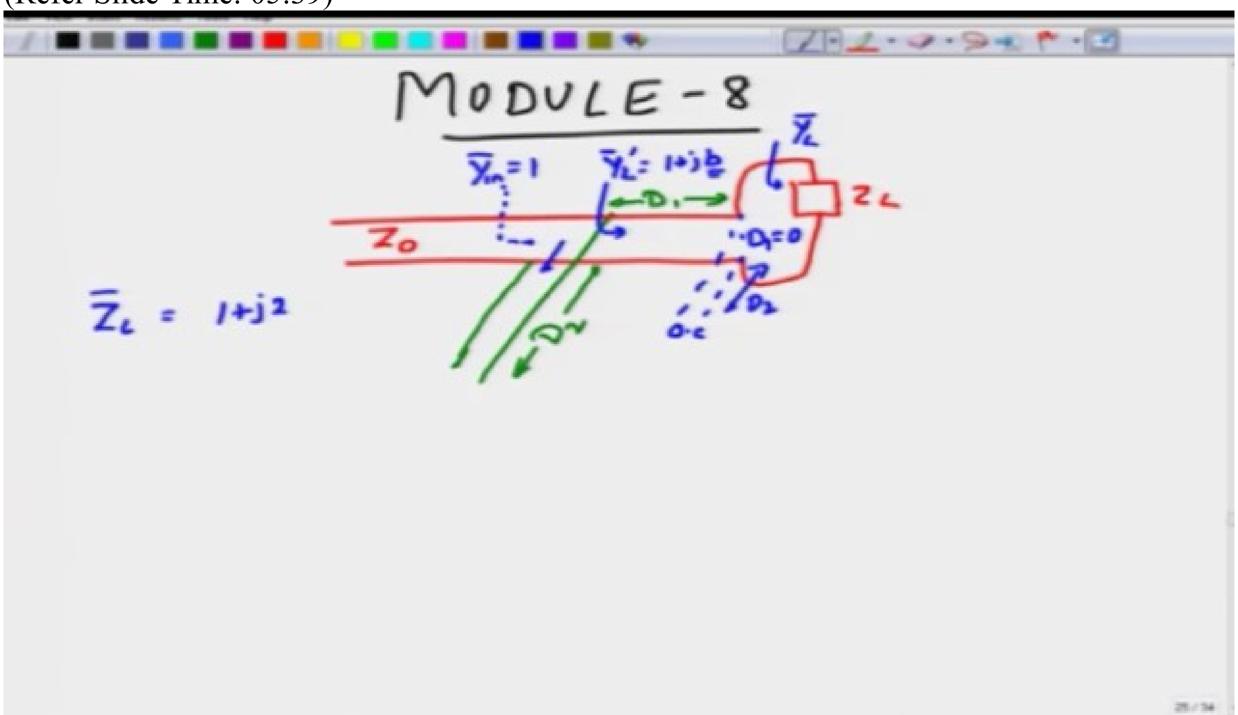

And how do you do that? Well we know that you are going to be moving on the outer circle because an open circuited impedance will be located here but then after transformically to the admittance you are going to start at these point which we called as B, this was point A,
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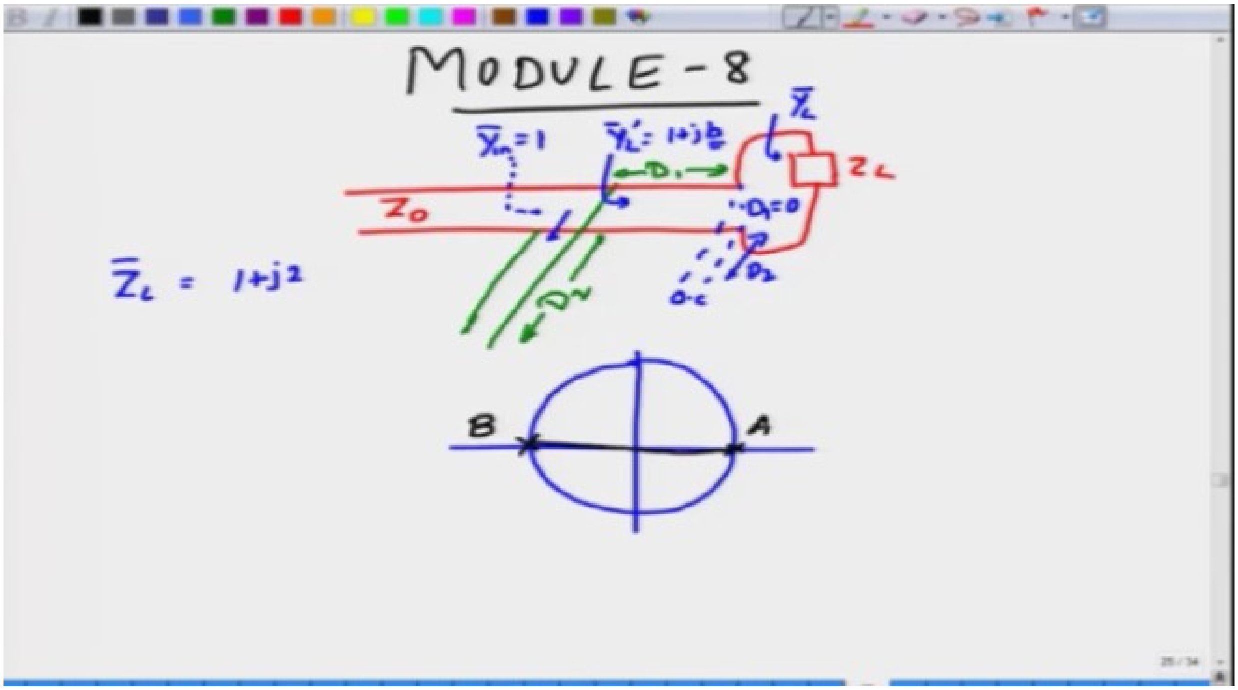

right, A corresponding to the open circuit, impedance B corresponding to the open circuit admittance, okay, so the open circuit admittance is located at B, and then this outer circle you are going to move clockwise, okay over a length D2, right such that you get or you land up at – J2, right.

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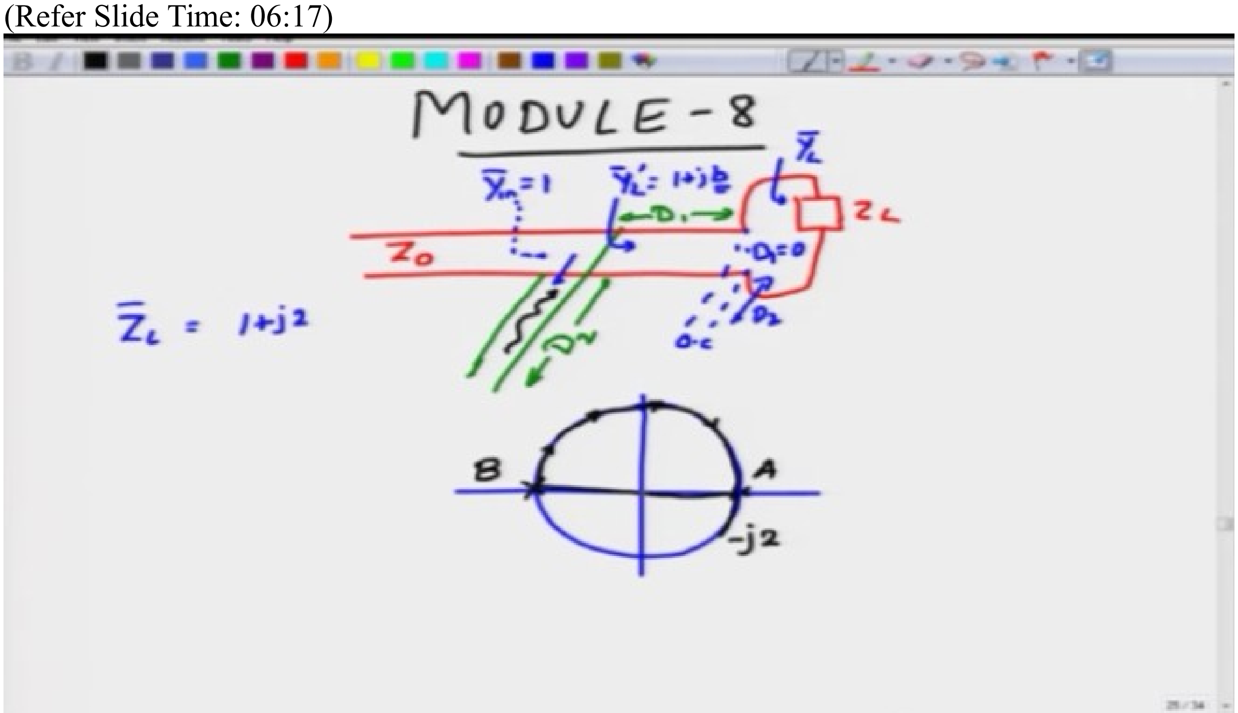

And then you find out how much you have moved, you probably have moved all the way 0.25 anyway to land up to a negative value of J, and then you would have moved some additional distance, okay, so you have moved this distance and what you get is whatever the value, so this is about you can find this, so whatever the length that you have found, so 0.25 + I think this is about 0.11, so there is a total distance of 0.36 lambda that you have moved, please verify the calculation I may be wrong in one of these numbers, but I do know that B to A distance is 0.25 and then you have to move an additional distance to reach this point which is C which gives you YS bar = -J2, okay.

Now if this problem seem very simple to you, let's alter the problem here by making the real part to be different then Z naught, so let us say take the real part to be say 0.5 and then I'll still keep this as +J2 the load, normalized load impedance there, so that I can find out what would be the distance D1 and D2.

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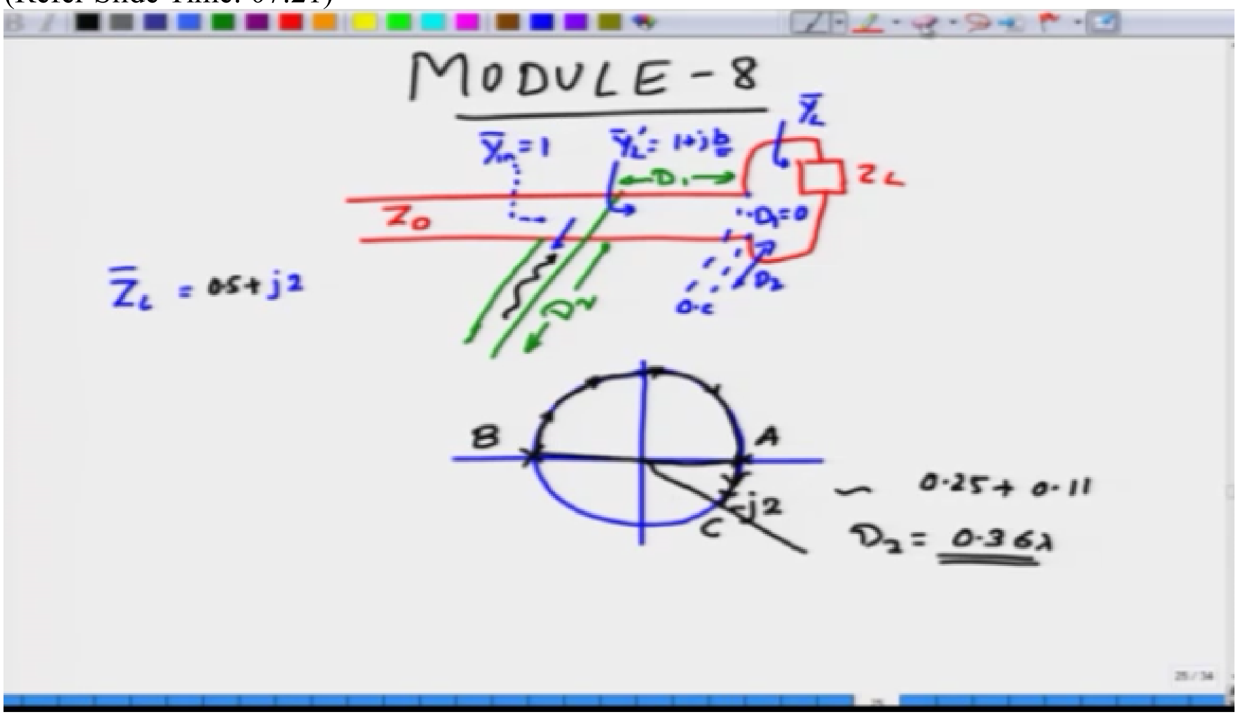

Now of course I can't place it right on the load point itself that is clearly not possible because the real part is not equal to 1, so I have to keep the stub at a distance D1 in such a way that after transforming the real part 0.5 would become 1, and then you have whatever the left over for the susceptance that you need to cancel, okay, so we'll do that again by going back to the Smith chart, but this time our objective is to determine both D1 as well as D2, again this is my skeleton of the Smith chart, this is my unit circle,

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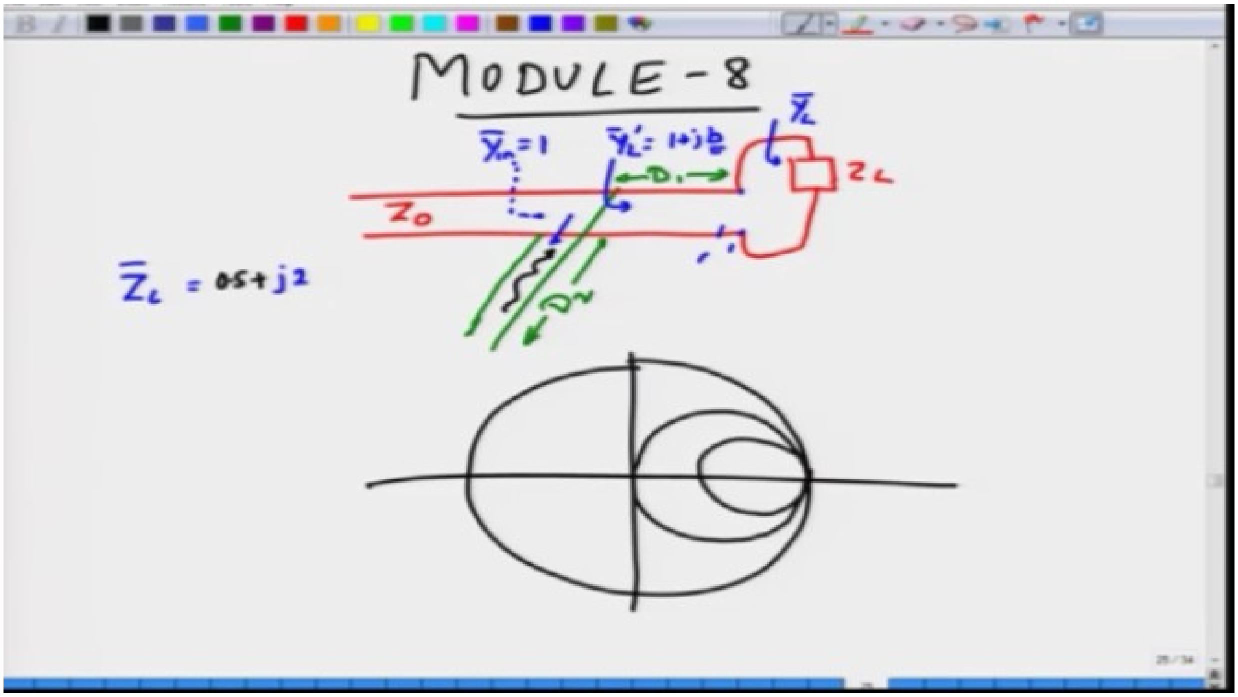

okay, and then I have this other thing, then I have this 0.5 circle, okay.

And then I need J2 so let me draw one additional arc, so this 0.5 + J2 ZL
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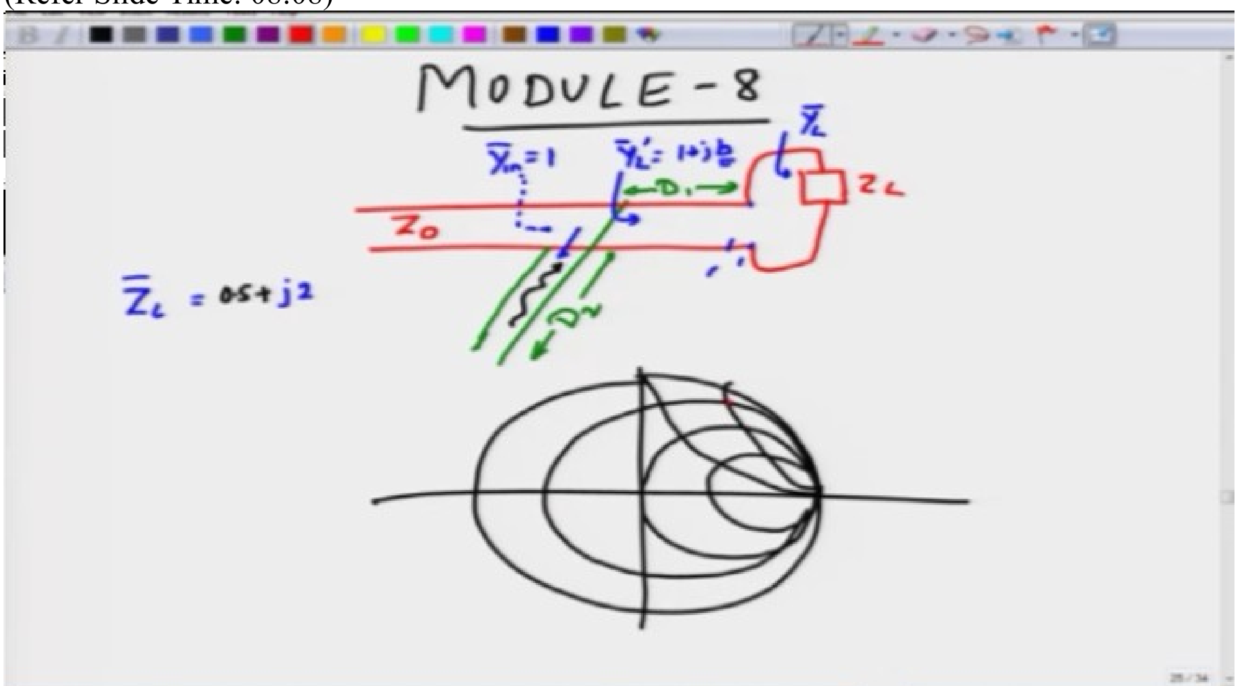

bar will be located somewhere over here, we will call this as A, but then I'm not really working with impedances I need to work with admittance, so I will first draw the constant SWR circle, okay, so this green line is my constant SWR circle, and then I moved to the opposite point here to land at point B,
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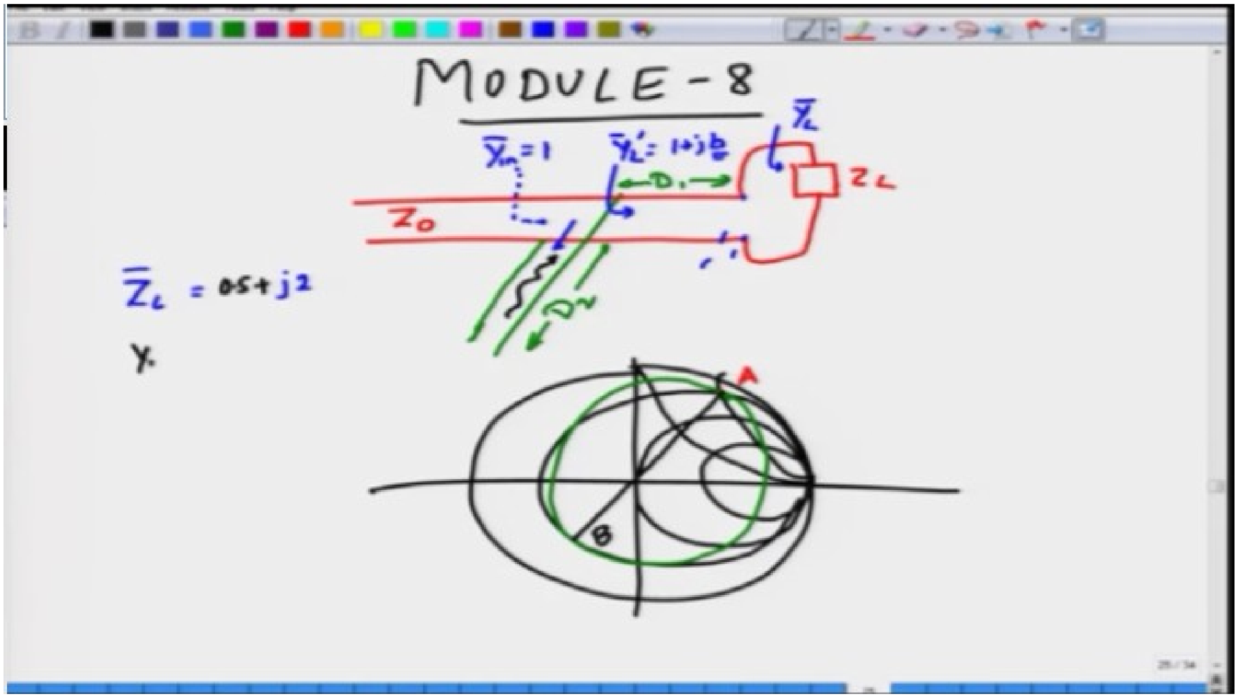

and point B would give me the equivalent admittance YL bar, okay, so point B is where you actually looking at YL bar.

And now on this constant SWR circle you have to move until you reach or you reach the point C where you are actually landing between the intersection of this R = 1 circle, and the SWR circle, if look at this blue circle which is R = 1, and this circle which is green circle which is point C, and at point C you have something like 1+J may be this is 3 or something, no I’m not obtained the correct answers here, may be it is J or 2.2 something you can find out what exactly is the value here after you have drawn the constant SWR circle, okay.

So point C would correspond to YL bar, okay, ZL will correspond to point A, YL will correspond to point B and after transforming YL through a length D1 you get YL bar, so what length did we transform? We moved a distance on the WTG scale from B prime right all the way up to C prime,

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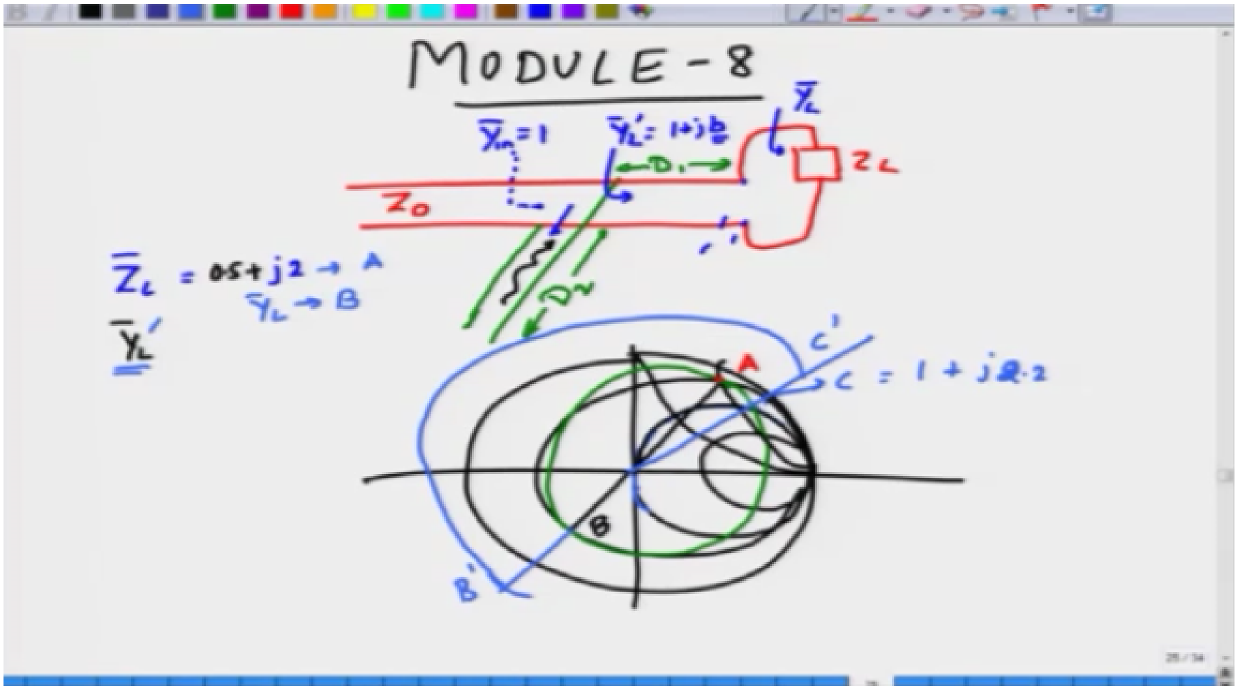

right, so this point was C prime and the intersection of these two points was the point C that we have found out, okay, so this length from B prime to C prime arc length will be given by D1.

Now you could observe an interesting thing as you keep moving along this green line, right, you'll actually land up at one additional cross-section or additional intersection which we can call it as say D, and then D prime the arc length B prime, D prime you know is also another solution which we will call ad D1 prime for the stub position, so you could choose either to place the stub at the arc at B prime, C prime,

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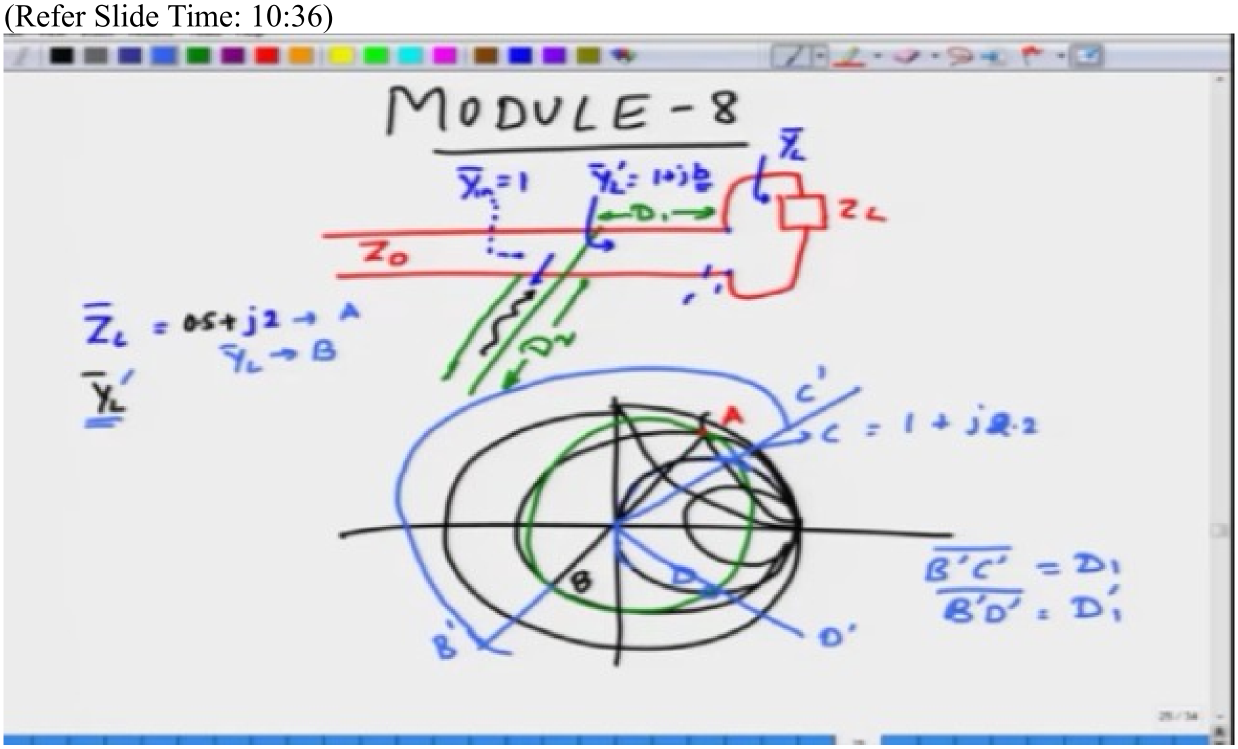

okay where the impedance is of the nature 1 + J, some position value of B or you could place the stub at a length D1 prime where this admittance YL prime is actually of the form 1 – J something, okay, so both are actually possible and you can pick one of the solutions, so let's arbitrarily pick the solution to be D1, you want to place the stub as close as possible to the load that is there, okay, so you don't want to place it too far from the load, because the lines are usually not lossless, they are actually lossy so, the longer the line that you use the distance that you make D1, then the chances are there that there is excessive loss accumulated there, so you keep D1 you know short, and then after you have placed D1 and noted down what is the value of the impedance which in this case or admittance which in this case is roughly say 1+J 2.2, you can again depending on whether you have a open circuit at stub or a short circuited stub you can start from this point which corresponds to open circuit admittance or this point which corresponds to short circuit admittance and move a certain length such that you make or you get –J B in this case is 2.2 let's say, so you need to simply move on the outer circle and then move appropriately, okay.

And we can also notice that if you started off with a short circuit and you want a negative value of B that is you know admittance to B susceptance to be negative you will be covering a shorter distance then you start with an open circuited stub, okay.

And in fact in most printed circuit boards it is kind of easier to short circuited stubs rather than open circuited stub simply because open circuited means there is a chance for radiation also happening, okay, so this completes our shunt stub matching network, we have seen two cases where the real part is already equal to 1 in which case the stub is located right at the lower itself, but the length is chosen in such a way that the susceptance offered is minus of whatever the real imaginary part of the load ZL is or the load admittance YL is, and if the admittance does not have a real part equal to 1 to begin with, then you have to move the stub length such that you get that real part equal to 1.

And you try and you know use a combination such that you have D1 and D2 to be as small as possible by it turns out that you can't simultaneously satisfy both of them and it also you know happens that this kind of a matching is not really broadband, meaning that this match is very, very good for a given frequency but as you move away from that frequency of operation,
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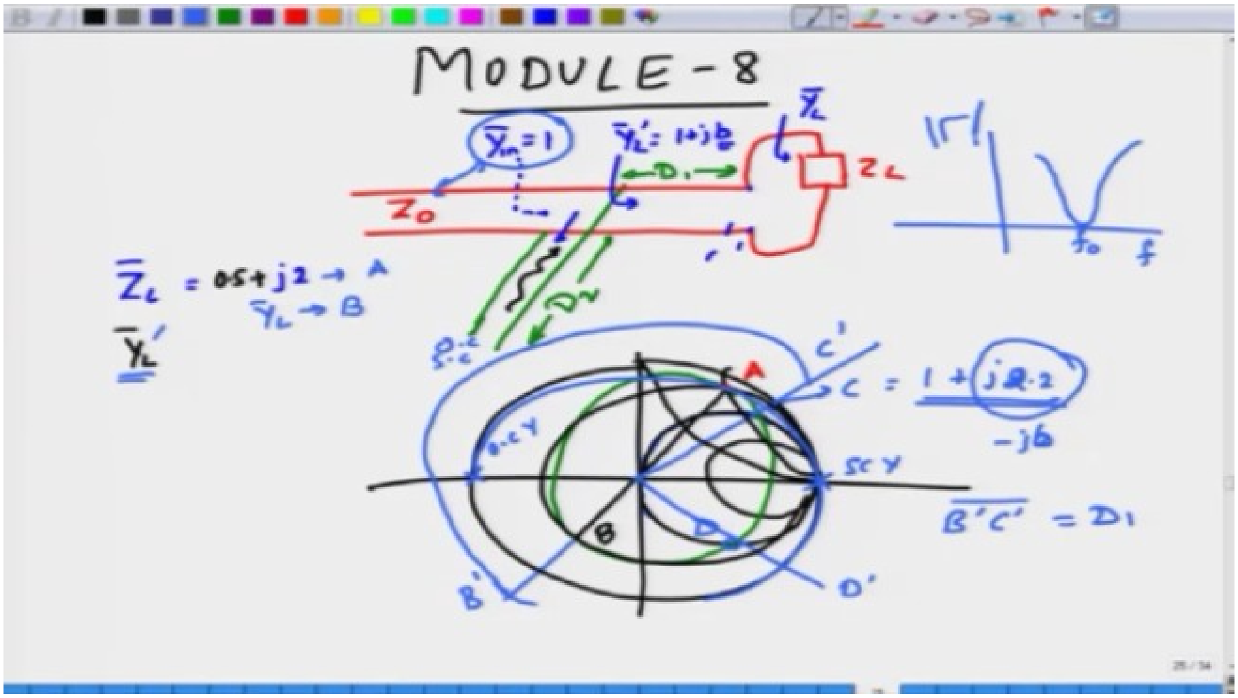

for example when a pulse is traveling, the pulse spectrum is usually you know non-zero around that frequency where you have designed, right, then in that case what would happen is different frequency components will be slightly seen different values of the you know in equivalent input impedance Y in, meaning that the reflection coefficient will not be zero over a small band, okay, in fact if you plot the magnitude of reflection coefficient between Y in and Z naught for different frequencies we'll see that it will be equal to 0 exactly at the design frequency F naught, but then as we move away magnitude of gamma quickly becomes larger, okay.

There are many techniques to make this broadband, okay, there are many techniques to make it even broadband as possible, but that could involve you know having more design parameters and those design parameters means we are going to have more than one stub, so in fact you can actually have another stub place at a distance, sometimes you can also have a third stub placed and so on and so forth, okay,

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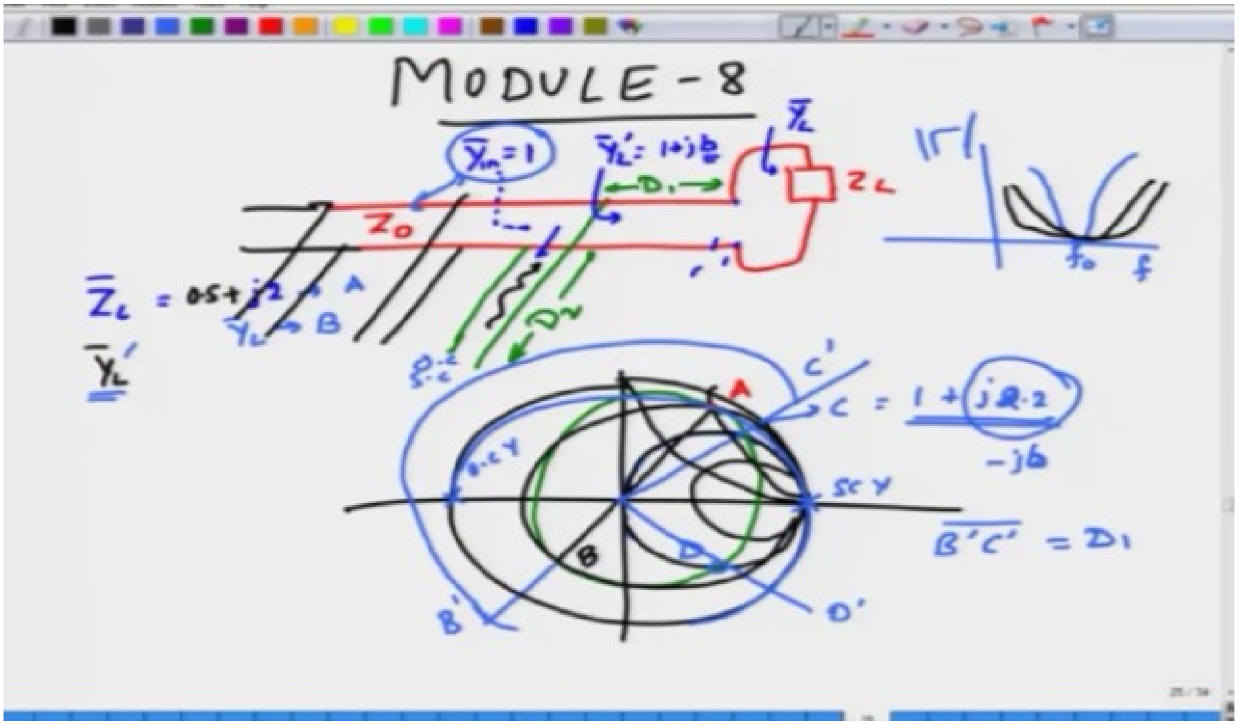

so we are completely not done with impedance matching, we will take up this subject later on when we look at plane waves and you know interaction of plane waves between 2 media, many of the concepts that we have discussed so far will be applied again there as well and those are also very interesting cases where interestingly even for the wave cases we can actually use this Smith chart, you can convert all those problems of uniform plane waves into equivalent transmission line problems and then work with even Smith charts and that is what we are going to do later on. Thank you very much.

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