Basic Tools of Microwave engineering
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Lecture - 04
Application of Smith Chart for finding unknown impedance in laboratory

Welcome to the 4th lecture, that now we will try to see that the same thing which we have found the unknown impedance by hand calculations.

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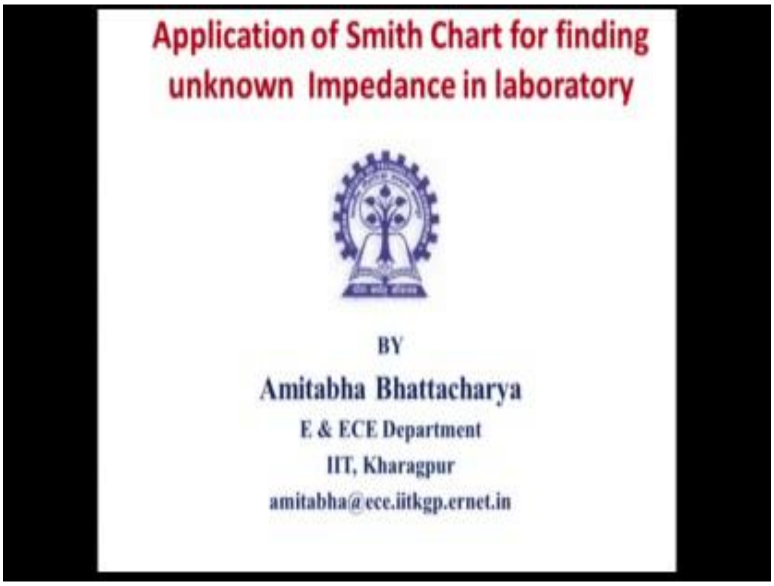

Now, the same thing we will attempt to because we have learnt Smith Chart. Now; obviously, the calculation for this particular measurement is not so extensive that always you need to do it by Smith Chart, but we encourage always to use Smith Chart because, later you will find that many times in analysis and design things that the network is not. So, simple and in laboratory we are creating much more control things, but in actual microwave applications, the things may be complicated and that time if you do not use this tool you will be, at a loss.

Like calculator you can always find out 10 into or 5 into 4 by calculator also we know, but you know that if I ask you to make a 4 digit number multiply with another 2 or 3 digit number you will be at a loss. The similar thing, if you do not know, how to use this Smith Chart, you will be later at a problem particularly we will see that, when will do impedance matching by that time if you do not use Smith Chart you will be at problem. That is why we encourage that the same thing let us see, how we can do by Smith Chart.

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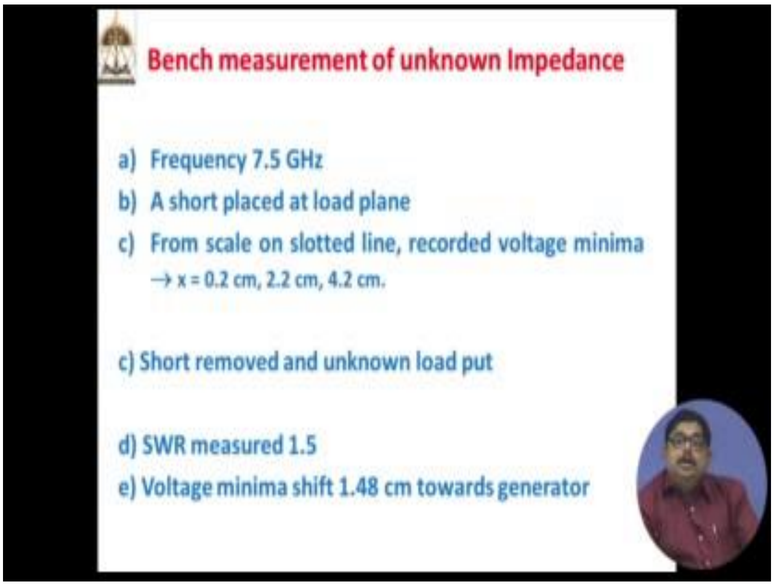

So, again the same problem that we have that 7 point unknown impedance measurement, frequency is 7.5 Giga hertz. A short placed at load plane just I am repeating because that was in the earlier lecture. So, you have noted that voltage minima's are at this points, then short removed and unknown load put then, as I described how to measure VSWR by VSWM meter you have measured the VSWR to be 1.5 and also from that you have found that voltage minima shift due to this change over from short to an unknown load is 1.48 centimetre towards generator. So, now, instead of manual calculations we will do it by Smith Chart.

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So, this is the first point. So, we are saying that we have measured VSWR to be 1.5. So, the first step we are asking you that locate the point where, constant resistance of 1 point circle cuts real axis of Smith Chart. Now obvious question when I first was instructed this was why? I have measured VSWR why I will do it by constant resistance circle of 1.5? The many times we see that instructors of microwave laboratory they also are not clear about these. So, they say and students sometimes believe, but later; obviously, if you just without understanding do something later you forget.

So, please understand this is a very actually this whole lecture this is a only new thing, which is very important. So, we will explain now again going back to the basics of transmission line that why this is? So, VSWR we have measured to be 1.5, we are trying to locate that where the point where r bar is equal to 1.5 circle; that means, constant resistance of 1.5 circle cuts real axis of the Smith Chart.

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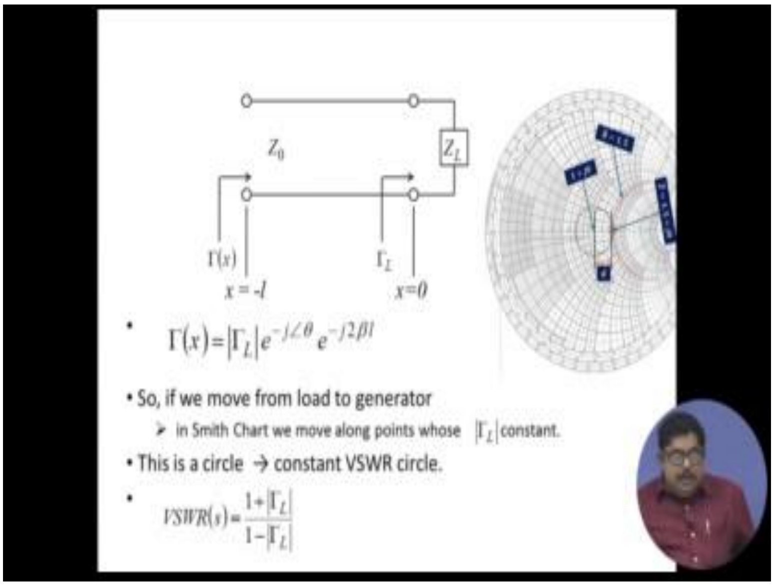

So, you see that that line reflection coefficient gamma x, I have already said that you have connected a transmission line of characteristic impedance to a load of Z l. So, there is a reflection coefficient at the load, but that is called gamma l. If you move across the transmission line your reflection coefficient value changes; that means, the ratio of voltage wave reflected wave by incident wave that changes, this is called line reflection coefficient gamma x is a line reflection coefficient.

Now gamma l is a complex quantity. So, that is why we are breaking it into the magnitude part and the phase part gamma l bar e to the power minus j theta, and then due to the movement by a distance of l I am acquiring that phase e to the power minus j to beta l the simple transmission line thing.

So, you move from generator, you move from load to generator in the transmission line what is the equivalence in Smith Chart? You see that gamma x the line reflection coefficient its magnitude its magnitude is not changing, what is changing is its phase. So, line impedance its magnitude is always equal to gamma l bar; that means, loads reflection coefficients magnitude and line impedance a line reflection coefficients magnitude they are always same.

So, if I move along the transmission line, where I am moving basically I am moving along the points whose gamma l magnitude; that means, l magnitude part of load reflection coefficient is constant. So, what is that? Now think of that Smith Chart as a transmission line. So, I have some reflection coefficient picture that there is any arbitrary reflection coefficient magnitude, and you are changing it, but the radius; that means, that radius vector is remaining change. So, changing means what you are moving in a circle. We say that this is a circle and what is that circle you see that what is VSWR? We have already in previous cases discussed VSWR that VSWR is how it is related to the reflection coefficient 1 plus gamma bar by 1 minus gamma bar. So, if gamma bar remains constant, VSWR is also constant.

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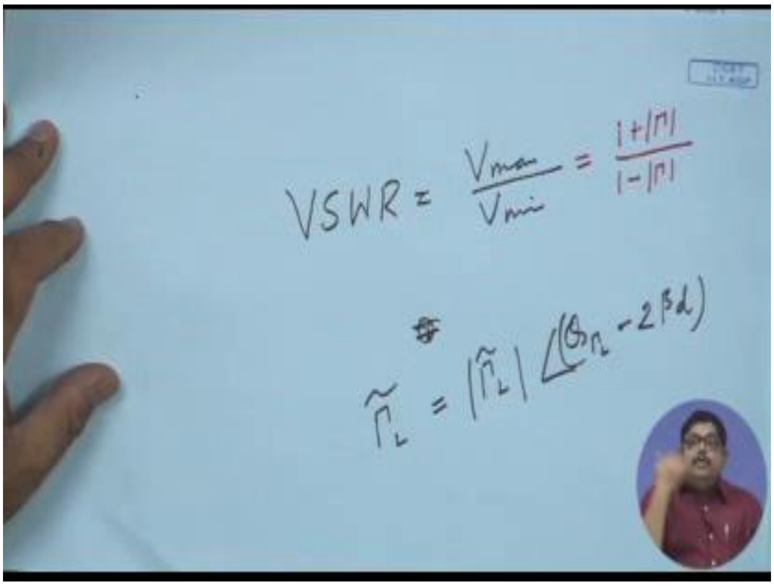

That means, when I am moving the line reflection coefficient is changing, but basically I am moving on a circle and that circle represents a constant VSWR. I say that if I move along transmission line VSWR does not change, it depends on only the load impedance and the characteristic impedance of the line.

So, basically moving along transmission line means; now come back to the slide that moving along the transmission line means, in the Smith Chart we move along points move along a constant VSWR circle.

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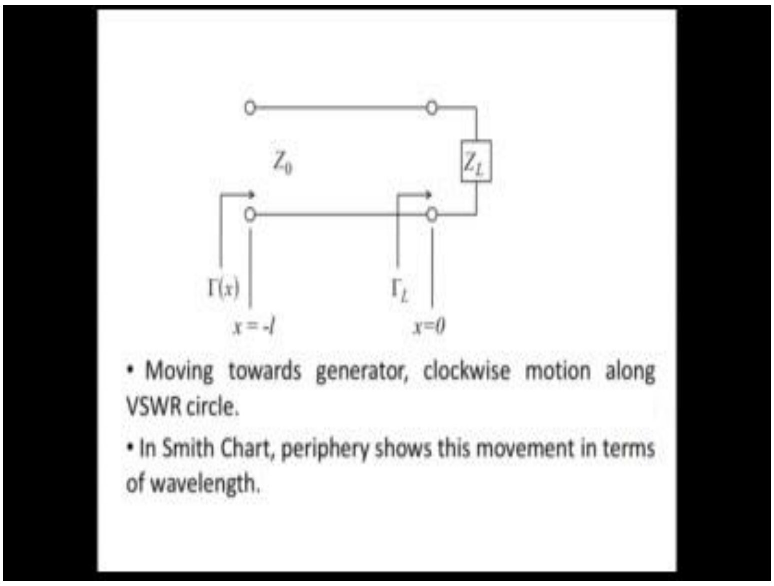

So, we know that in a transmission line if we move towards generator in VSWR circle that will be clockwise motion along VSWR circle, why because you see the phase of the first equation gamma x is equal to something you have that what is changing is e to the power minus j 2 beta l. So, a negative angle; that means, I am moving along clockwise direction, moving towards generators clockwise motion along VSWR circle.

Now in the Smith Chart periphery I said that this movement you can convert to a wavelength if I move in the transmission line by so and so. Distance I can always tell that in terms of wavelength suppose I am moving a 4.5 centimetre and if my frequency is says that lambda wavelength is 3 centimetre then, I can say instead of 4.5 centimetre I have move a distance of 4.5 by 3 that is 1.5 lambda.

So, like that. So, in the Smith Chart periphery you can find out what is 1.5 Z lambda. Actually in the Smith Chart they do not give more than 0.5 because, we have seen that after every 0.5 lambda g the whole thing repeats. So, that is why Smith Chart will give you up to 0.5. So, if you have 1.5 you make 3 rotations that will be 1.5. So, these VSWR circle when it cuts real axis let us see what happens because that was part of the instruction.

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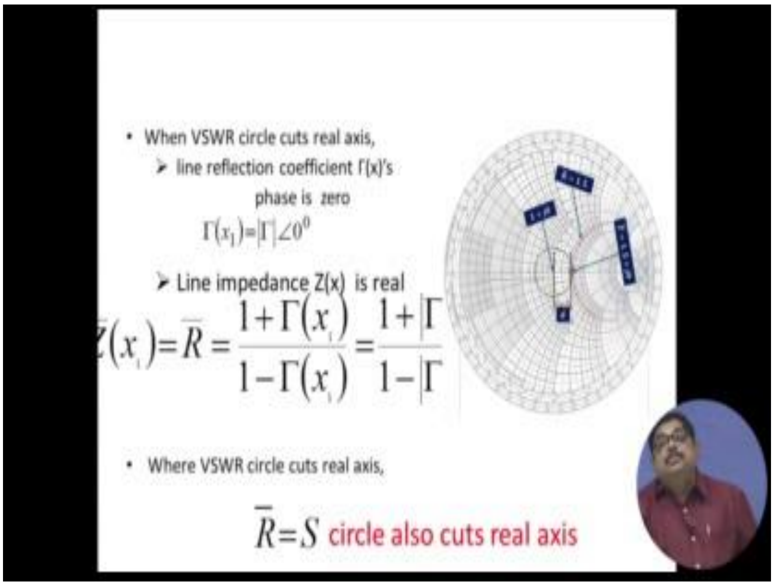

So, when VSWR cuts, circle cuts real axis as you see this VSWR circle is cutting this real axis this, VSWR circle is cutting the real axis here, where my cursor is showing. So, there now think, that Smith Chart I have said that always you can in your mental thing think that it is purely a reflection coefficient plane. So, in terms of reflection coefficient, what is the reflection coefficient at this point where it is cutting the real axis this point? Can I not say that reflection coefficient there is a pure real quantity its phase is 0. So, that is what I said that line reflection coefficient gamma x phase is 0 that point I am calling x 1 point.

So, I am calling that gamma x 1 is some magnitude 0 degree. So, now, I know that Smith Chart is anytime transformation from reflection coefficient plane to impedance plane. So, what will be the corresponding line impedance? To do those calculations we know Z x that will be what? So, that you see 1 plus gamma bar gamma magnitude by 1 minus gamma magnitude gamma magnitude is a real quantity. So, 1 plus some real quantity by 1 minus real quantity, that is also real quantity.

What do mean by this that impedance which is a complex quantity is a real quantity; that means, it is simply the resistance r. So, that is why at the point where VSWR circle cuts this real axis both the line reflection coefficient and line impedance they are real quantity and now look at their value line impedance is r bar, but its value is 1 plus gamma by 1 minus gamma again see our this slide always this is a condition VSWR is 1 plus gamma by 1 minus gamma.

Now, go back. So, you see r, r bar that is actually nothing, but s the value of VSWR. So, at the point where the circle is cut this constant, VSWR cuts the real axis basically that VSWR value equals to the resistance value. So, if I read the resistance value because in Smith Chart VSWR value is not explicitly same, but impedance; that means, r and x values are same r bar and x values are same. So, I will find out that r bar value that will give me 1 point of that VSWR circle.

In a circle if I can find out 1 point and if I know the centre I can draw the circle. So, that is the idea and that is why we made that step 1 the instruction was locate the point where r bar is equal to 1.5 circle cuts real axis of Smith Chart because I know that at that point that r bar is equal to VSWR.

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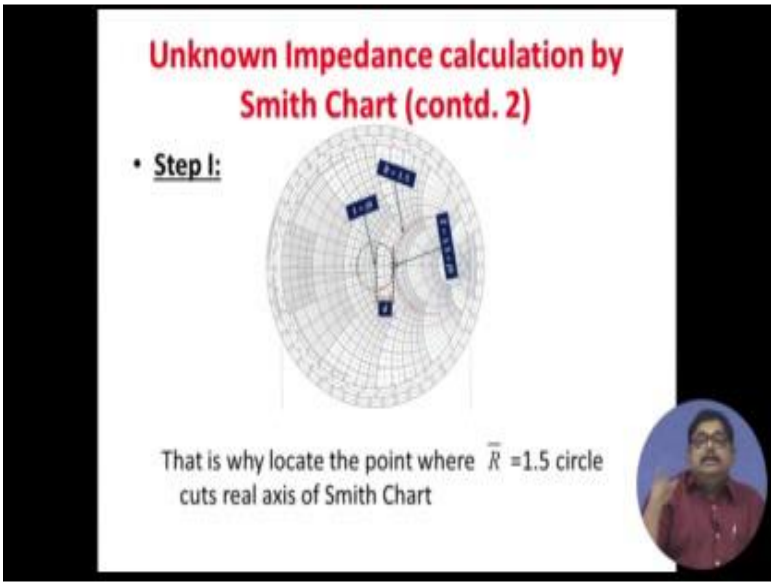

So, since I have measured VSWR to be 1.5 I am locating that point by which I am locating 1 point of the VSWR circle and I know all VSWR circles, their centre is the origin of the Smith Chart.

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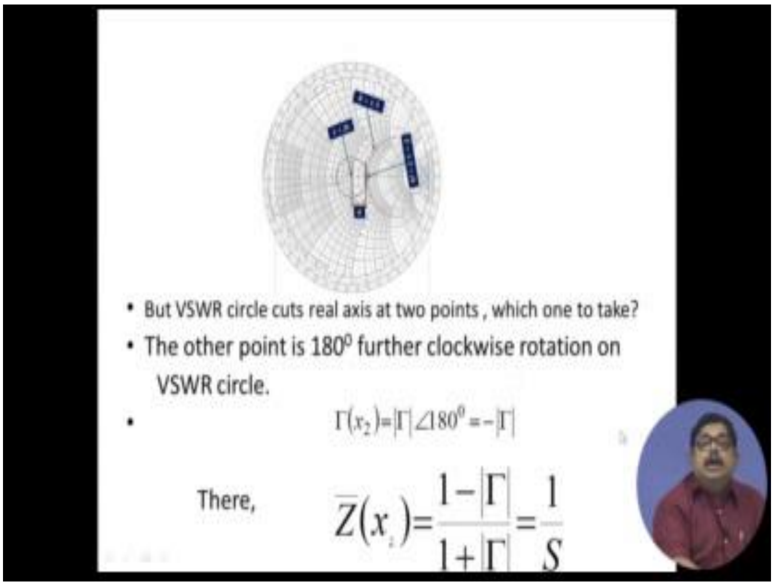

Now, again another point this is again another point you can say that VSWR circle points cuts real axis as 2 point. So, which one to take for drawing the circle it does not matter, but for taking the values because it will be confusion. So, let us see what is the other point. So, if I have this point the other point where the same circle cuts is another point here you see where I am pointing. So, what is these 2 points? I can say that from this point I need to go a rotation or I need to take a rotation of 180 degree clockwise; to do this point we know clockwise; that means, towards the generator I am going now put it. So, I knew gamma x 1 gamma x 1 previously I knew.

You see that gamma x 1 is that gamma wave the first expression of this slide. So, from that if I take a 180 degree rotation we have earlier seen how to do 1 eighty degree rotation. So, you had a phase of 180 degree you are learning with minus gamma, then that, what is the corresponding line impedance that will be Z bar x 2 and there it will be 1 minus gamma by 1 plus gamma. So, that is 1 by s 1 by VSWR now we have seen whatever may be the load VSWR fluctuates from 1 to infinity 1 for match load infinity for short or open circle.

So, that is the clue to resolve this ambiguity that which point to take. So, the VSWR circle will cut the real axis at 2 points. So, you can get 2 values of r from that. Because in the Smith Chart graduation there will be 2 such circles at those points' constant r circles, but 1 of them will be having value more than 1, another of them will be having value less than 1 because VSWR or s is always greater than one. So, which one we will take it is your judgement.

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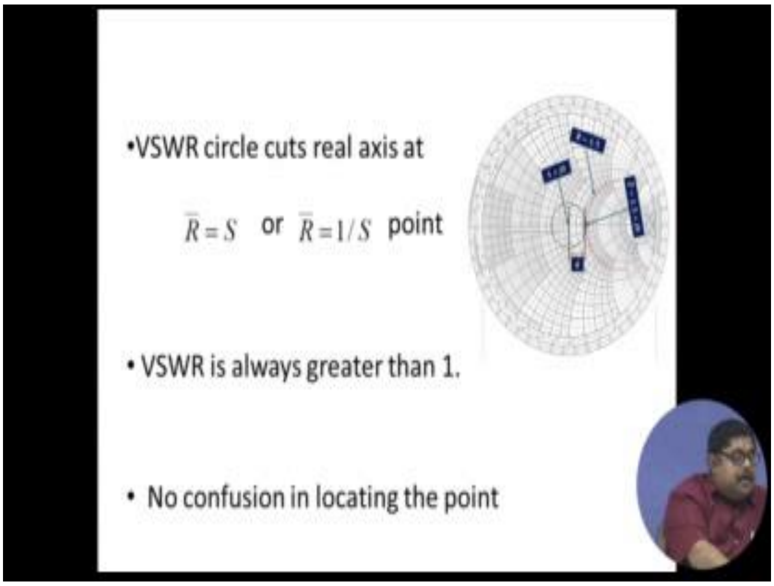

So, VSWR circle cuts real axis at r is equal to s or r bar is equal to 1 by s point VSWR is always greater than 1. So, no confusion in locating the point if you just read those 2 values of r you will understand which 1 to take. The one with higher the 1 with r value r bar value greater than 1 that will have to take the other will be always less than 1 guaranteed.

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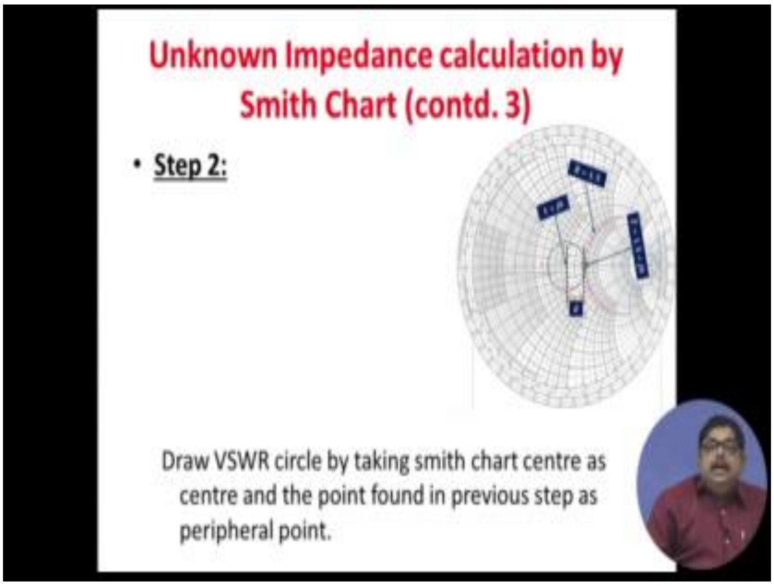

So, let us come back that we have done the first step we have located, now I know the centre I have located this point I can draw this circle this is the constant VSWR circle. So, the second step is draw VSWR circle by taking Smith Chart centre as centre, and the point found in previous step as the peripheral point. So, you can draw a circle. So, that circle is drawn then next step you see now.

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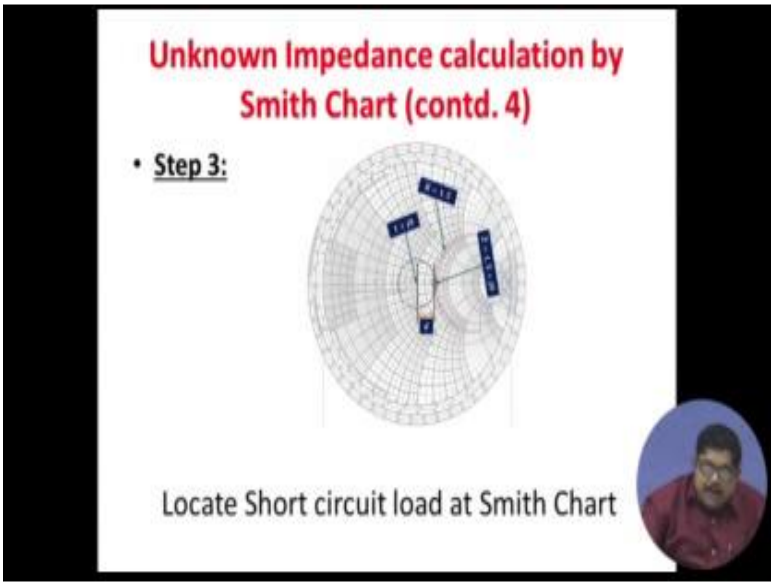

So, we have done the VSWR we have measured. Now VSWR circle we have plotted on the Smith Chart. So, we have done half of our measurement part or calculation part. Now step 3 now we will have to utilize the other information what was the 2 information that I said that can if I help you to detect the unknown impedance? One is VSWR another is l min; that means, shift in minima when load is change from short circuit to any unknown impedance.

So, step 3 demands now you locate short circuit at Smith Chart. What is short circuit? What is the short circuit short circuit means, they are my load reflection coefficient is 1, 180 degree or minus 1.

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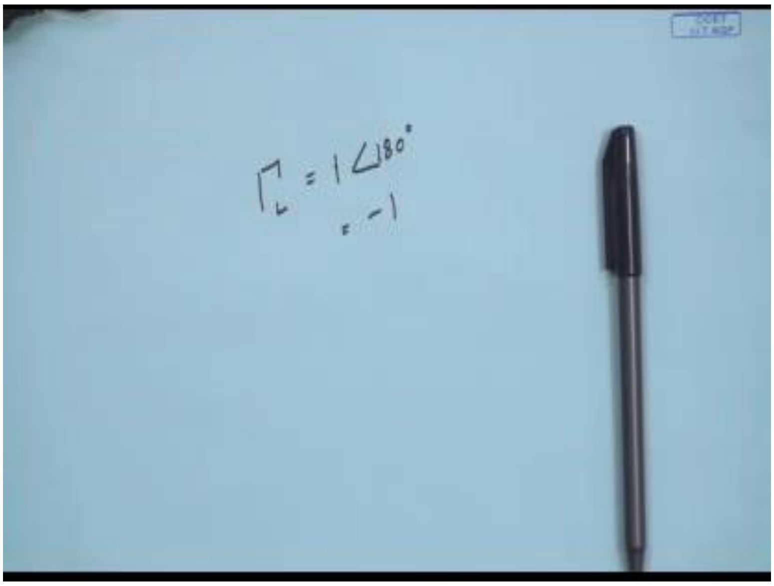

Open circuit means load reflection coefficient plus 1. So, where is this point? Gamma l is equal to 1, 180 degree. So, think now Smith Chart as a reflection coefficient chart. So, 1 you see that is why while introducing Smith Chart I said that, your radius of the outer boundary that outer circle which corresponds to r bar is equal to 0 circle that radius we consider as 1. So, I have 1, 180 degree; that means, it is which end that is why I always I ask this confusion to student is the short circuit load at 1 0 or minus 1 0.

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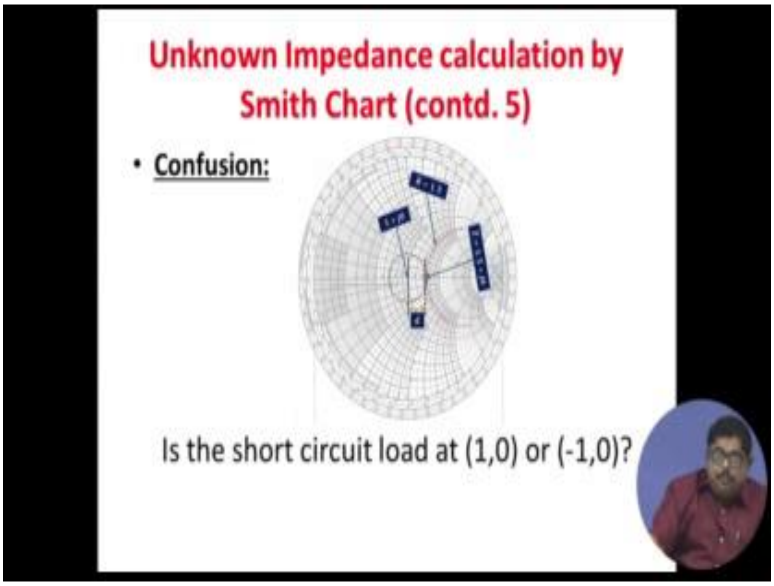

So, you should know if you look at gamma l is equal to 1, 180 degree there is no confusion it is at the left end of the impedance Smith Chart.

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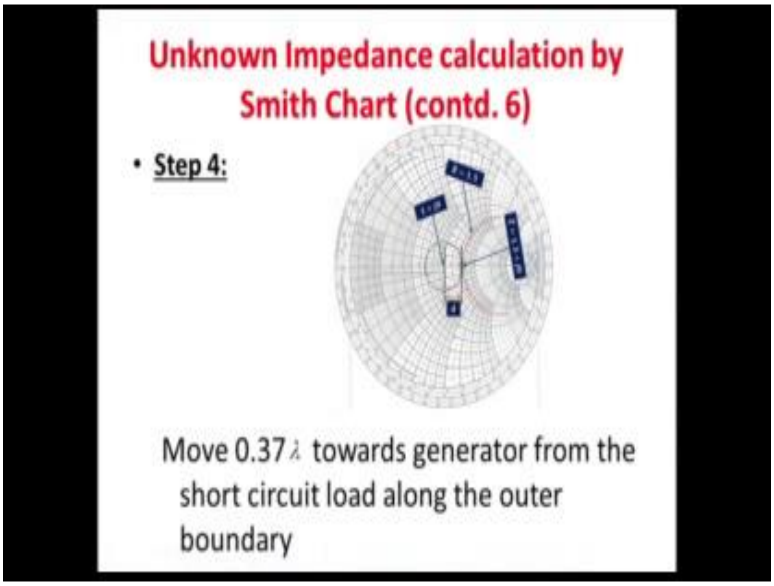

So, where it will be deliberately it is not shown because this you will be confident enough to plot it. So, it is at the left end you plot the Smith Chart then plot the short circuit then we have seen that we will have to move 1.48 centimetres which happens to be at seven 0.5 Giga hertz.

So, lambda will be 30 by 7.5 centimetre. So, if you do that that is 0.37 lambda towards generator from the short circuit loads. So, you move towards generator, now in the Smith Chart in your Smith Chart you will see which way to move for going towards generator. Since we have noted that minima shifts by 0.37 lambda towards generator. So, we will have to move along that. So, that. So, you find that point and join this outer boundary peripheral point to origin. That next step the point where VSWR circle is the cut is the desired impedance; by that you can find out that these will be the values you are getting because once you have found out the point of unknown impedance.

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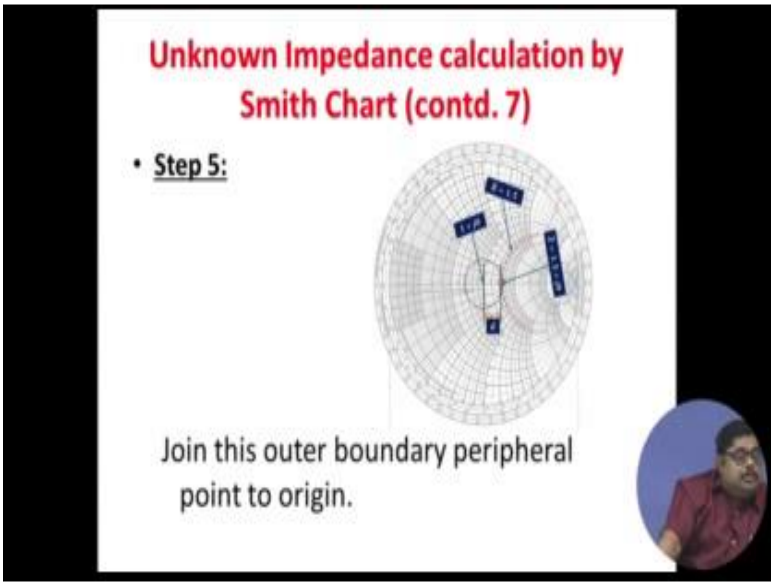

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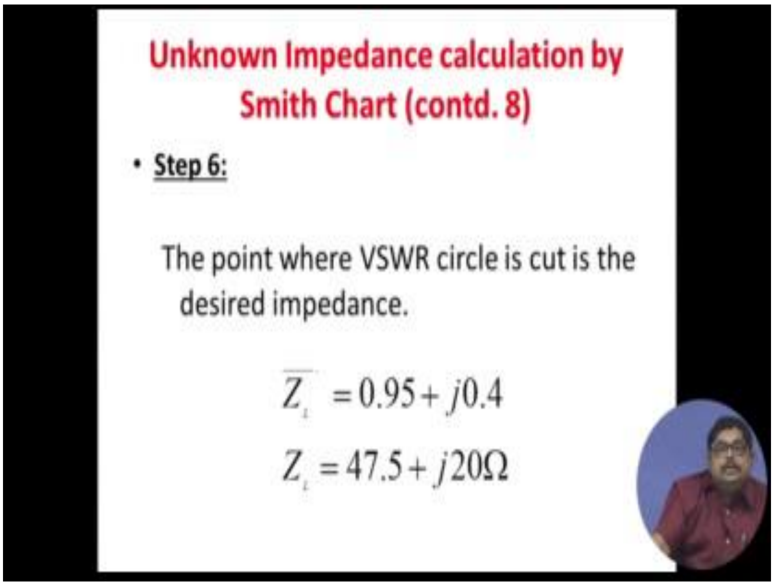

So, I am writing for you do it that this is the Smith Chart, you have located already you have drawn the VSWR circle let that be let.

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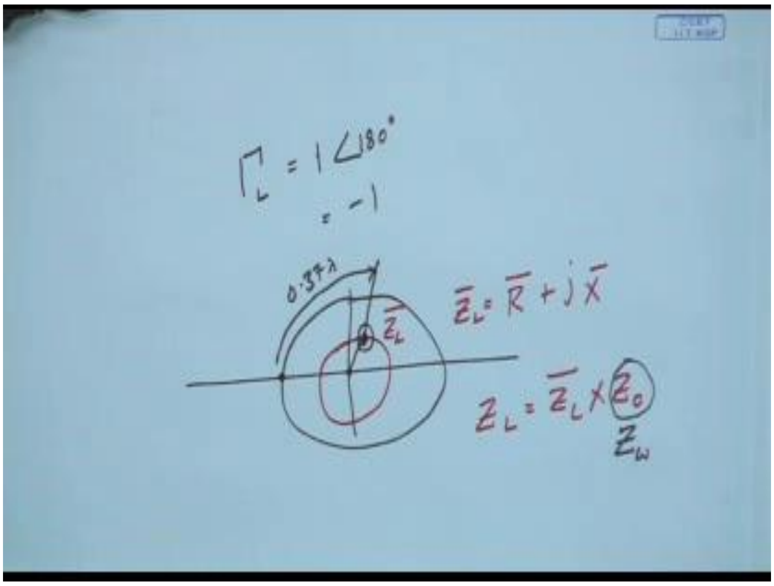

So, VSWR circle we have described how to do. So, this is the VSWR circle now you have located your short circuit this point 0.37 lambda. You have move towards generator let us say this is your 0.37 lambda this chart is given on the Smith Chart. So, you have come here now you find out connect this with the centre. So, at this point it is touching or cutting the VSWR not touching cutting the VSWR circle, this is your required Z l dash point, now, unknown Z l dash.

So, this will be again in the Smith Chart the intersection point of 1 constant resistant circle and 1 constant reactant circle. So, find out the value of this point for r bar. What is the r bar value what is the arc thing x bar value. So, you know now, r plus j x bar is the Z l bar now depending on the characteristic impedance given you can do. Suppose if you do it with the waveguide in that case characteristic impedance is what generally in laboratory we work with a waveguide r g 90. So, that 1 is the x band waveguide generally we do because of the size etcetera also these are radar band.

So, that has only permits t 1 0 mode to the waveguide. Now you will have to calculate the wave impedance for t e 1 0 mode in a rectangular waveguide, which is quite a good amount of value depending on frequency that you will have to put multiply with this, so that you can get. So, this is Z l into Z naught in case of your waveguide this Z naught is not simple 50 ohm or something here, this will be the wave impedance which is again a may be a complex quantity, but you take the magnitude part of that and multiply it. So, that you get the total thing as we have shown this. So, this completes your impedance thing that how to do it in the laboratory to Smith Chart.

Now, you know at least completely that how to find unknown impedance in the laboratory. With this knowledge we will proceed to the later modules for finding the first job of an Arab engineer that he should know how to measure impedance also he should know how to measure 2 other things frequency and power. So, that he can knows what is the source at any point of the circuit how much he is getting, and then he can start designing various things, that this he can transfer the power. So, impedance measurement he can do.

So, by this we conclude the 4th lecture.