Antennas
Prof. Girish Kumar
Department of Electrical Engineering
Indian Institute of Technology, Bombay

Module – 05
Lecture – 21
MSA Parametric Analysis – I

Hello and welcome. So, in the last lecture we looked into rectangular micro strip antenna and how to design a rectangular micro strip antenna by using some very simple equation and we also saw that that those simple design equations are fairly accurate we get an accuracy of roughly about one percent or so. And then we started looking into the effect of the parameters on the performance of the antenna. So, let us continue.

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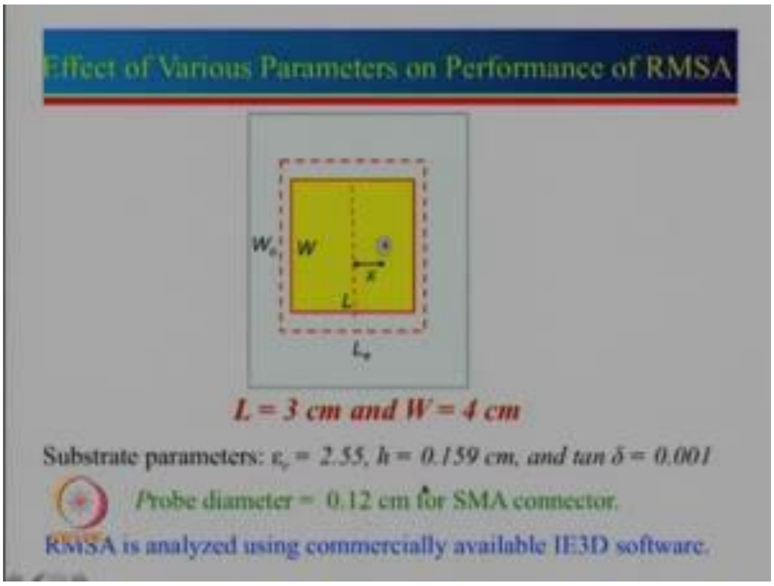

So, in the last lecture we started with the rectangular patch with the 3 centimeter length and 4 centimeters as a width, and we these were the subset parameters switch to and probe diameter was taken as a starting point, and then we looked at or what is the effect of the feed point and we actually notice that as x increases what happens input impedance plot shifts right towards higher impedance.

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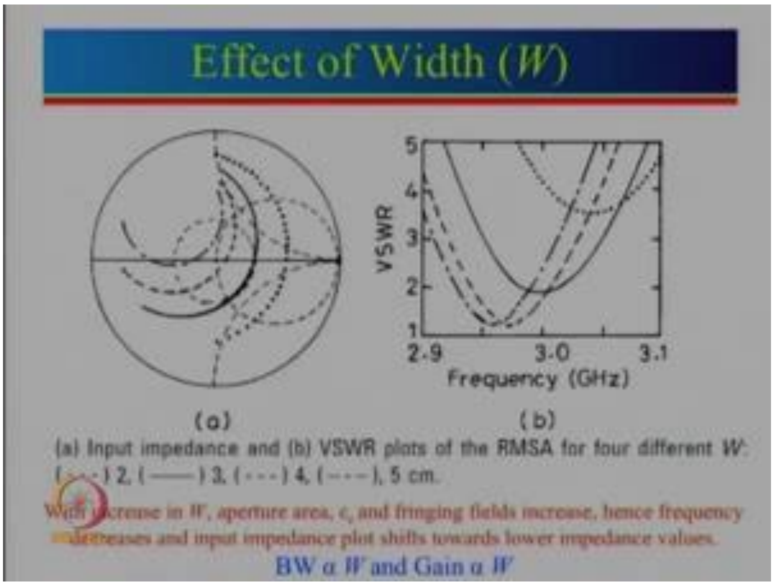

So, this is x 0.55, 0.6, 0.65. Then we looked into what is the effect of the W and it has a lot of effect on the impact impedance. So, you can see that this is for W equal to 2 then W equal to 3 W equal to 4 W equal to 5. So, we can see that as width increases input impedance is decreasing and whole curve shift towards lower impedance value. We also noticed that as W increases resonance frequency slightly decreases and the reason for that is as W increases epsilon effective increases, which reduce the resonance frequency.

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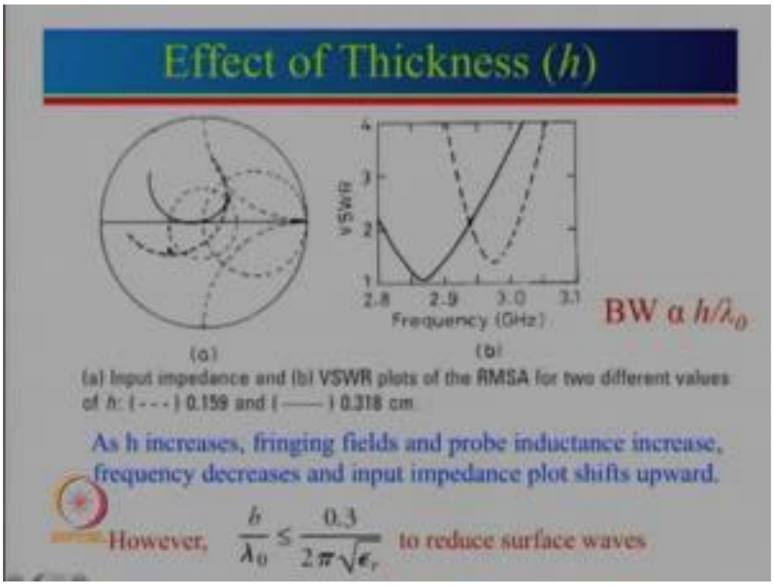

Now, let just look at the effect of the other parameter. So, if we increase the effect of the thickness; that means, if we increase the thickness of the substrate. So, what happens if we increase the substrate thickness? Now there are several things which happened. First thing is that if you increase the substrate thickness fringing fields will increase. And if the fringing fields increase; that means, the total length will increase because L E is equal to L plus 2 delta. So, the total length increases resonance frequency decreases.

So, that is effect one. There is a second effect that when we increase the thickness of the substrate. What happens? Then the probe which is feeding from the ground plane to the stop patch, the length of the probe increases and the probe induction is nothing, but proportional to the diameter. So, if the diameter is more probe induction will be less and if the height of the probe is more; that means, it is inductance will increase. So, that is why we can see here that this is for h equal to 0.159 and here the thickness is doubled. So, we can see that when it is doubled one can actually see that the whole curve is shifted towards inductance.

Now, if we look from the bandwidth point of view if you draw a line along VSWR equal to 2 here, if you see here this one has a relatively less bandwidth compared to this one here which has a larger bandwidth. So, in general we can say bandwidth is proportional to h by lambda 0. So, why I have added lambda 0 because h is not the absolute value everything is related to the wavelength. So, it is not that if we just take h equal to 0.1599, 0.1218, but if you look at a different frequency it is a normalizing effect which comes into picture. So, we know that if you keep on increasing h, we can the bandwidth or for the same h if we change the frequency; that means, if we keep on increasing the frequency lambda 0 will reduce bandwidth will increase, but there is a limit we cannot keep on increasing the value of h forever. So, there is a limit that h by lambda 0 should be less than this expression, and that is to reduce surface wave. How is this surface wave coming into picture?

So, think about a gain, we have a patch and below the patch we have a ground plane. So, there will be fringing field from the edges. Now this is the dielectric substrate. So, this fringing field from the ground plane it will reflect. Now this reflection part of that will go in the free space part of that will get partly reflected. And there will be an angle where there can be a total internal reflection. So, what happens then this radiation is towards the surface. And that is not the desired direction, because we are designing antenna right now for broad side and here the propagation is towards the surface wave so that means, energy is getting wasted. Also think about if we are going to discuss about think we start doing it about arrays. So, we have a one patch here we have another patch here. So, what happens? The surface wave from here, will go hit this particular patch surface wave from, patch will go to this one here. So, that will also create impedance miss matches also.

So, it is better to follow this particular criterion which will reduce surface wave. And what this criterion really tells us. So, let just see typically suppose if epsilon r is equal to 1 what is this number 0.3 divided by let us say approximately 2 into 3. So, that will be about 0.05, and if epsilon r is say 2 or 3 then this value should be smaller than that. So, this puts the restriction to reduce the surface wave we need to reduce the height h; however, to increase bandwidth we need to increase height. So, somewhere there is a conflict and that is why we always say bandwidth of micro strip antenna is limited, to 1 to 5 percent. We will see several techniques in the next few lectures how to increase the bandwidth.

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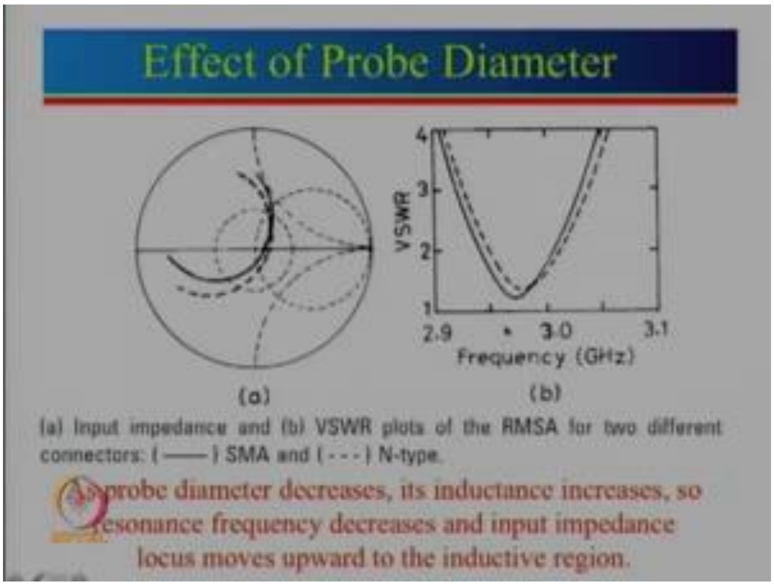

But now let just look at some other parameter also. So, here this is an effect of probe diameter. What we have done here is we have 2 standard probe connectors one is a SMA and another one is type connector the difference between the 2 connectors that this SMA probe has diameter of 0.12 centimeter n type has a diameter of 0.3 centimeter. So, here we can see the 2 plot. This is for n type plot and this is for SMA plot. So, we can see that this curve is shifted up, basically why? Because for n type diameter is more for SMA diameter is less. So, less diameter will have more inductance. So, more inductance means that the whole curve is shifted up; you can see that there is an inductive shift to this particular curve here. Also there is a small change in the resonance frequency why? Because if inductance is increased then the resonance frequency will decrease slightly again, why because omega 0 is given by 1 by square root L c, so if L increases; that means, resonance frequency will decrease.

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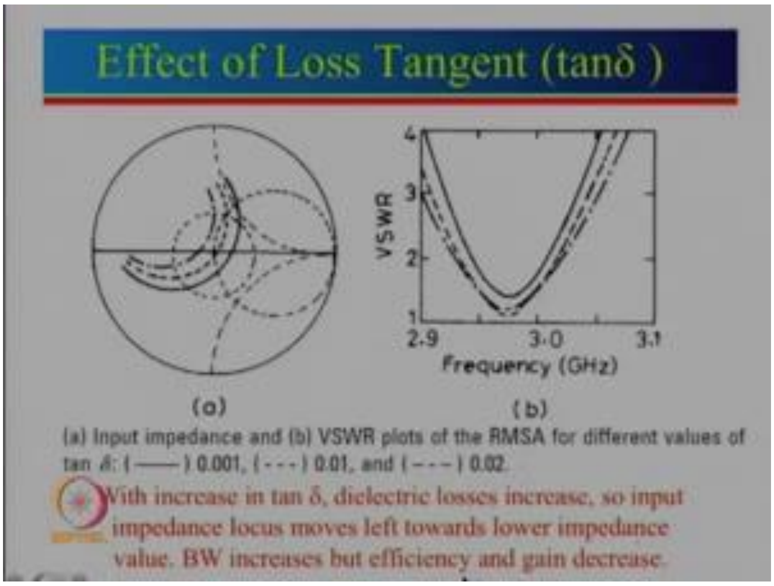

Let just see now the effect of the loss tangent. We have taken 3 different cases of loss tangent one is 0.001.

Now, this is the case for very good quality substrate. And that is the plot shown over here. And then there is a substrate which has a slightly more loss compared to this and then this is the lossy substrate a typically f r 4 substrate or glass epoxy substrate has a tan delta 0.02. So, if we now see the 3 curves here. So, this is for 0.001 then this for 0.01 and this is for 0.02. So, what we can say that as loss tangent increases the whole configuration becomes more lossy. More lossy means bandwidth will increase, but this is not a good bandwidth, please remember that because even the bandwidth increases, but effectively efficiency decrease and gain also decreased. So, it is not a good idea to use a lossy substrate, because both efficiency and gain of the antenna will reduce; however, if it is coming to a low cost antenna application, we sometimes tend to use this low cost substrate, but which has a tan delta will see some of the techniques how this low cost substrate can be used to get a very good performance. So, we will see that after studying the parametric study.

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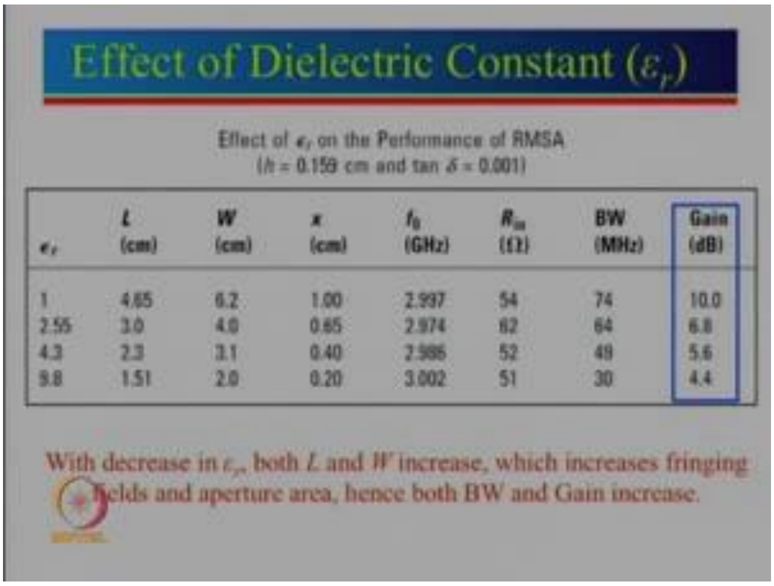

Now, let just see what is the effect of the dielectric constant. So, here almost everything changes. Will see why everything changes. What we have done is we have taken a center frequency as roughly 3 gigahertzes. You can see that it is approximately 3 gigahertzes. Corresponding to 3 gigahertzes we have designed the antenna separately, for different values of epsilon r 1 2.55 4.3 9.8. These are the commonly available substrate with small variation. So, what we have done? We have already studied the case for 2.55 L was 3 W was 4. We have used the same thing. So, just the scaling if their surface epsilon r equal to 1 length will increase. Correspondingly W will increase. Similarly, here if epsilon r increases length will decrease, correspondingly W will decrease.

Now, for all these cases then we have found out the value of x. Again you can see that we see this one here for smaller bandwidth, x will be starting will be L by 4 and if the larger bandwidth it will be something close to L by 6. And for all these feed point value we have given what is the input impedance, as you can see that we have not optimized exactly for 50 ohms anything 50 to 60 ohm or 65 ohms is acceptable. And when can see bandwidth also here. So, for epsilon r equal to 1 bandwidth is 74 megahertz. And for as we keep on increasing epsilon r we can see that the bandwidth is decreasing.

Now, there is an interesting thing that for epsilon r equal to 1 gain is around 10 dB for 2.55 gain is around 6.8 dB. Now think this way if you have to design an antenna. 2.55 is a very expensive substrate, whereas epsilon r 1 that corresponds to air. So, if you design an antenna for air you can get very good gain you can also get very good bandwidth. Now the only problem is how do you have a metallic plate suspended in air. So, we will see the techniques how to make the metallic plates suspended. In fact, we use many a times metallic post to support that particular antenna, but just to see here that with general decrease in epsilon r, both L and W increase. And because both L and W are increasing that increases the fringing field as well as aperture area. You can see that the aperture area is L multiplied by W which is much larger. So, because of the larger aperture area we get more gain. And because of more fringing field we get better bandwidth.

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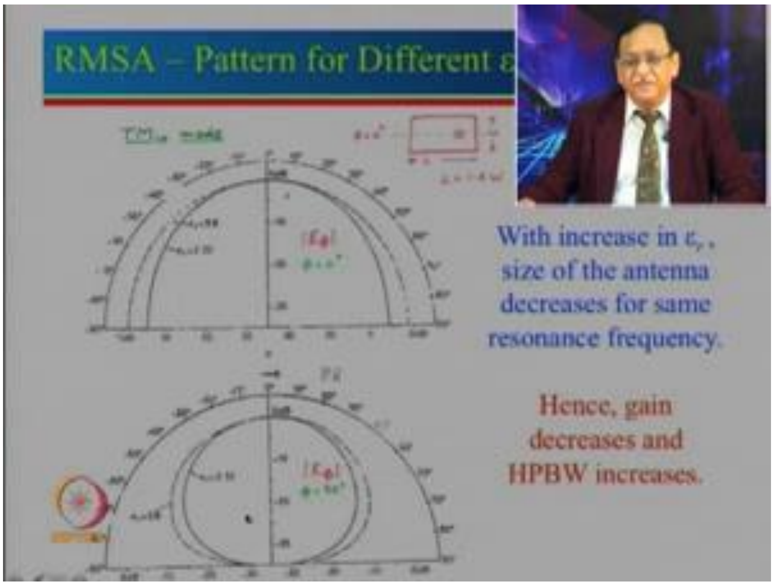

So, now let just see radiation pattern for different mode. So, here is a simple patch slightly dimensions are different. So, here length is actually much larger than W L is about 1.5 W, but what is shown over here radiation pattern for 2 different value of epsilon r. Now the 2 different values are 2.32 and this for epsilon r 9.8. So, before we think about how these things are coming why this pattern has a relatively narrow bandwidth this is more spread out or it has a higher half power bandwidth, we have to actually think about that if epsilon r is small; that means, it is aperture will be large if epsilon r is higher; that means, aperture area will be small. So, if the aperture area is small; that means, gain will be small and if the gain is small half power width will be large and that is why this one we see as a larger half power beam width, and for this here because the aperture area has increased compared to 9.8. So, half power beam width is reduced.

Now, this is the pattern for E theta, this is pattern for E phi. And now suddenly you might start thinking about we were talking about E-plane and we were talking about H-plane from where E theta and E phi they have come and what is this pi is equal to 0 and 90. So, just want to tell you when we do the simulation many times the software actually tells gives us E theta E phi and then we have to visualize which is a E-plane and which is H-plane.

So, just to tell you now, this is phi equal to 0 and we have feeding here. So, this is the radiating h here of voltages maximum here. And voltage is of from plus maxima, this is a minus maxima or minima you can say. So, from here this determines the E-plane So, that is the E-plane So, this E theta n phi equal to 0-degree plane and that is E-plane, perpendicular to this will be phi equal to 90 degrees. So, phi equal to 90 degrees now is nothing, but the H-plane pattern, but over it shows E phi why again E theta is perpendicular to E phi. So, it is a notation E theta E phi, but in reality it is a E-plane and phi equal to 0 degree and this is H-plane pattern and phi equal to 98 degree let us also look at the different mode now. This is a TM 30 mode.

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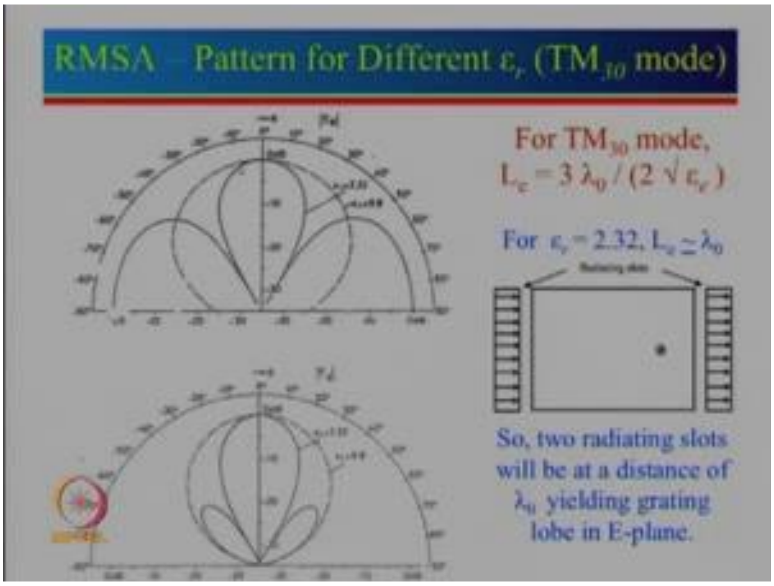

So, what is TM 30mode TM 30mode will come when the length of the patch here will actually become equal to 3 lambda by 2. So, lambda 0 by square root epsilon E is lambda. So, 3 lambda by 2; that means, along this length the variation will be 3 half wavelength, if you think about this is plus. So, then from plus it will go to 0 here, then it will go to minus, then it will go to 0 and then it will go to other minus here. So, that is how 3 half wavelengths are completed here. Now for this if you see the radiation pattern it kind of looks very different. So, what we have here again 2 substrate parameter epsilon 2.32 and that is the pattern for this here and for epsilon r 9.8, this is the pattern. Now the 2 pattern looks very different whereas, if you look at the previous case 2.32 9.8 2 for fundamental mode they look almost similar, except that half power beam width was slightly different, but here they look drastically different. So, what is the reason? Well let just look at the reason now.

Now, for the 3 0 mode this is 3 lambda by 2. Now epsilon r 2.32, if we put here epsilon effective is roughly we had seen about 2.23 and for that let say square root of that will be roughly 1.5. So, 1.5 multiplied by 2 will be 3. 3 lambda by 0 will be lambda 0. So, what we have here we have a one radiating slot here another radiating slot and the separation between them is lambda 0. And from array theory we had seen that if the separation between the 2 antennas is lambda 0 then there will be grating lobe. So, what we see here, this is the maximum radiation, it comes to 0, and then we have another radiation. So, that is nothing, but grating lobe in this direction and the grating lobe is in this direction.

Whereas for epsilon r 9.8 if I just approximately assume 9.8 is epsilon r then epsilon E is approximately 9 square root of 9 will be 3. So, 3 lambda 0 divided by 2 into 3 will be lambda 0 by 2. So, array factor will not have any grating lobe, and that is why we do not see any grating lobe here.

Now, the similar thing you can see here, but here we see that there is no grating lobe coming into picture. And the reason why grating lobe is not come in picture here, we have to actually visualize along the H-plane for the slot element pattern actually has a 0 value. So, this 0 value if that 0 value gets multiplied by the larger array factor value 0 multiplied by any number is 0. So, that number is coming close to 0 here. So, that is why you do not see the grating lobe, but we do see a side lobe. Whereas, the pattern for epsilon r 9.8 is similar to that of the earlier case it is starting from maxima here going to 0 of course, the beam width of this will be relatively small, compared to fundamental mode the reason for that is because aperture size is again large.

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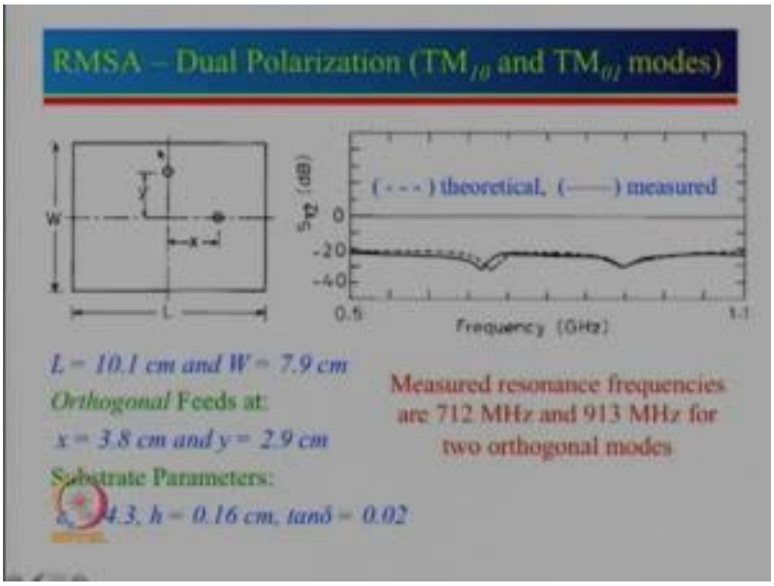

So, let just take another case. We can actually realize a dual polarization. This is now fundamental mode 1 0 and 0 1 mode here. So, here a case we have taken which is a rectangular patch here. So, this is length L which is 10.1 centimeter W which is about 7.9 centimeter. So, what we are trying to show here is that, if we have a feed point over here which is x. So, for this feed point just for a moment think that y is not there. This feed point is not there. So, if this is only x then what will happen, it will excite a fundamental mode which is 1 0. So, 1 0 means this will be plus v going to 0 and this will be minus v which is the maximum.

So, since this is 0 this entire thing is 0. So, 0 means almost equivalent to short circuit also. And that short circuit you put any load, whether you out 10 ohms 50 ohm or inductance or capacitance it does not make any difference. So, that is why if you feed here this feed does not load this feed at all.

Now, just think about this feed points. So, fourth is feed point along this here. Now width will be resonant length and that width resonant length corresponds to this 7.9 here and that will correspond to 0 1 mode, for the 0 1 more. So, when we feed here now the field will be 0 along this line. So, if I feed anything here it does not matter. So, for this feed point it does not matter what you put along this axis, and for feed at this point it does not matter what you put over here because this is a 0 access for this particular feed. And that is why if you look at the isolation between the 2, which is very good. So, what it shows here it is the; if we say this is the 1 and 2. So, S 12 or which is same as S 21 you can see that this is the plot from frequency 0.5 to 1.1.

So, we see the 2 dips over here these are theoretical and measured value. You can see that predicted value is much better here slightly less here, but what one can see here that isolation between the 2 is less than 20 dB across the band, but along the resonances if you see that is close to 30 dB so; that means, if we feed at these 2 points there is a roughly isolation of above 30 feed a few other things I want to mention that when we design this antenna what we need to do it is consider this length. So, calculate what is the resonance frequency for this here. And for this length this is the width here. So, you're since this is width is smaller in this case.

So, feed point will be relatively closer to L by 6. So, for this feed point now, this will be actually length and this will be width since width is large. So, now, the feed point will be slightly towards the higher or towards the edge here. So, these are the substrate parameters. You can see that a lossy substrate has been used just for the study performance. So, corresponding to 10 centimeter resonance frequency is around 712, corresponding to 7.9 resonance frequency is 9 13. You can do this quick calculation by using the design equations which we have given earlier.

So, by using this technique you can get a very good isolation between the 2 frequency, but remember one thing, this one will give E field in this direction this will give E field in this direction. So, this is nothing, but dual polarization or orthogonal polarization of course, just to mention here this can be also applied to square patch also. So, where L will be equal to W and then the 2 resonance will merge into single resonance and that would be something like a square patch with 2 orthogonal polarizations at exactly the same frequency. In fact, many of the mimo antenna which is nothing, but multiple input multiple output, they use horizontal and vertical polarization. In fact, many a times for channel capacity enhancement what we do? We try to use both horizontal as well as vertical polarization. So, if you want to use both the polarization, then we get signal from both the side. And what is important it isolation between the 2. So, generally a 30 dB isolation is considered pretty good.

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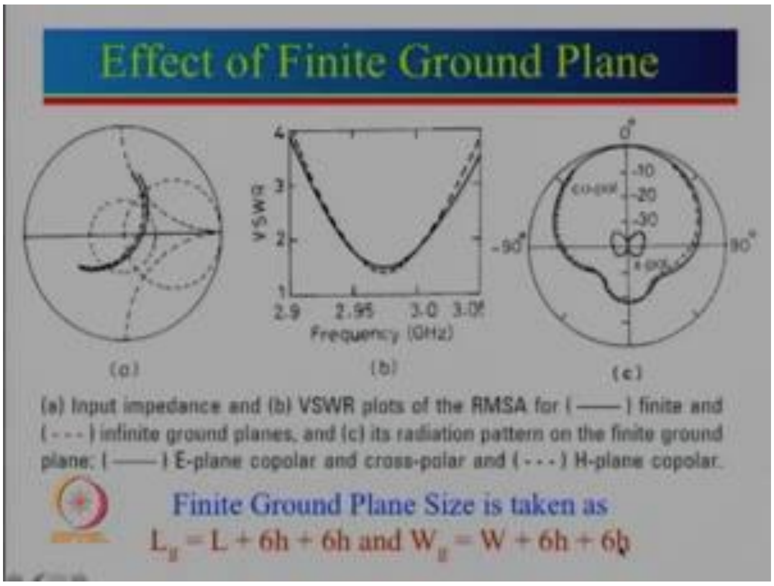

Now, till now we have studied the effect of the finite ground plane. Now in reality we will never ever take a infinite ground plane, we will always take a finite ground plane. So, then the question comes what should be the finite ground plane. So, we studied that the effect of the various ground plane and here is a result which we have shown. So, what we realize that if the ground plane size is more than length, and that is 6 h on one side 6 h on the other side. Similarly, for width of the ground plane 6 h on one side 6 h on other side.

Or in reality you can think about if L and W are the patch dimension you have 6 times the substrate thickness all around. If you do that then let us see what happens here. So, this is the impedance plot for infinite ground plane and finite ground plane. You can see that the 2 results are pretty close to each other. Even for VSWR for resonance frequency L also the effect is almost negligible if you do infinite or you take finite ground plane.

However, there is a difference in the radiation pattern. For infinite ground plane there will be 0 radiations, but for finite ground plane we are taken this size over here, in that case you can see the scale is 0 minus 10 minus 20, so 0 minus 10 minus 20. So, that is about minus 18 dB. So, front to back ratio is 18 dB now many a times 18 dB is acceptable, but sometimes 15 dB is also acceptable sometimes 30 dB is also acceptable. So, here just to tell, if you want a front to back ratio to be high instead of 18 dB what we got let us say we want 20 dB or 30 dB all you need to do it is take a larger ground plane size, or sometimes the ground plane can be in the cavity form also to reduce the back radiation. And here one additional thing I want to tell.

So, what happens if the ground plane is exactly same as length? So, if you take L is equal to L g what you will actually notice that whatever is the front radiation back radiation is almost same so. In fact, the pattern will be something like this here. And then it will increase become maximum, and then it will come back here. In fact, so, this actually becomes a bidirectional antenna.

So, just to tell you we were actually looking for an application where we wanted an antenna along the corridor. So along the corridor you know that the corridor is long and we wanted an antenna to be put in between. So, that it cover this side of the corridor as well as the other side so. In fact, in the beginning we thought of a solution that will have a one rectangular micro strip antenna facing this side, there will be a ground plane and then we will put another rectangular micro strip antenna, but then you have design a power divider also. So, when we were studying these effect.

So, we actually looked at what is happening to the ground plane. And the moment we started reducing the ground plane size, we could see that just single patch is radiating equally. So that means, if you take L equal to L g you can design a very simple bidirectional antenna. Remember there is a disadvantage of that because now it is radiating in the front as well as in the back the overall gain reduces, but that is the property of the bidirectional antenna.

So, just to summarize today what we have seen, we have seen how to study the parametric effect. So, what are the effects of the various parameter on the performance of the antenna. We change the feed point location we noted that the impedance curve is shifting towards the edge then we looked at the effect of the W. So, if you increase the W bandwidth increases gain increases then we also looked at what is the effect of tan delta.

Now, we saw that if you use a lossy tan delta you get good bandwidth, but that is not a good bandwidth. Because gain is reducing efficiency is reducing we also saw what is the effect of the probe diameter. So, if the probe diameter increases; that means, it is inductance is reduced. So, the curve will shift towards capacitor. We also saw what is the effect of the substrate thickness. So, if you keep on increasing the substrate thickness bandwidth increases, but there is a limit to up to how much you can increase the substrate thickness. And also if you increase the substrate thickness the probe inductance increases. So, the whole curve shifts towards inductive region. So, in the lecture we will see what are the band width criteria. How do we choose for a given specification of bandwidth what kind of a substrate we should choose? And then we will look at some practical implementation and see how to design antenna. And after rectangular micro strip antenna will also look into how to design circular micro strip antenna triangular micro strip antenna and so on.

Thank you very much, will see you next time, bye.