Antennas
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Module - 08
Lecture – 34
Circularly Polarized MSA – I

Hello and welcome to today's lecture on circularly polarized microstrip antenna. In fact in the last lecture, we discussed about why we need circularly polarized antenna and then we looked at simple configuration of square and circular microstrip antenna which can generate circular polarization by feeding at to orthogonal point. So, let us just continue our discussion.

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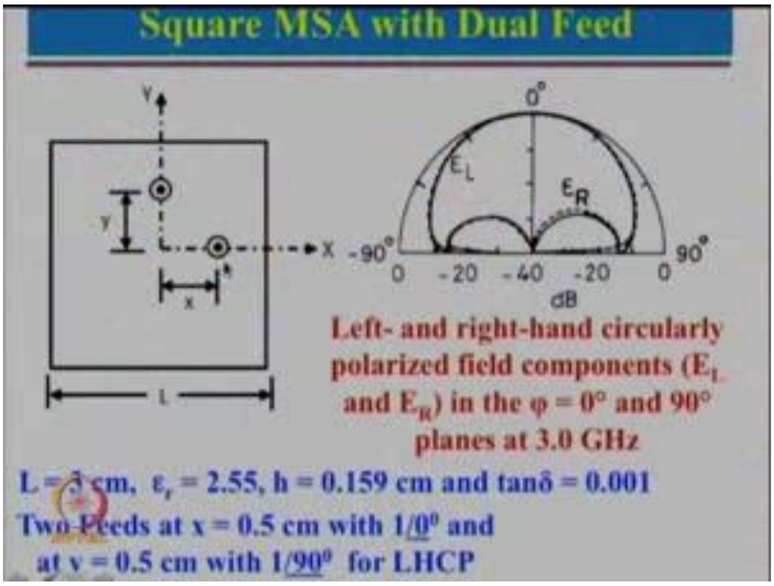

We had seen that here is a square patch and we had fed at 2 orthogonal points and by feeding this 1 angle 0 1 angle 90 degree which is this is 1 angle 0, this is 1 angle 90, we got LHCP, alternatively if you make 1 angle 0, 1 angle minus 90 then it will become RHCP.

And we had seen the component; LHCP component and RHCP component and we noticed that in the half power beam width, your component is very small and then we had taken 3 different cases.

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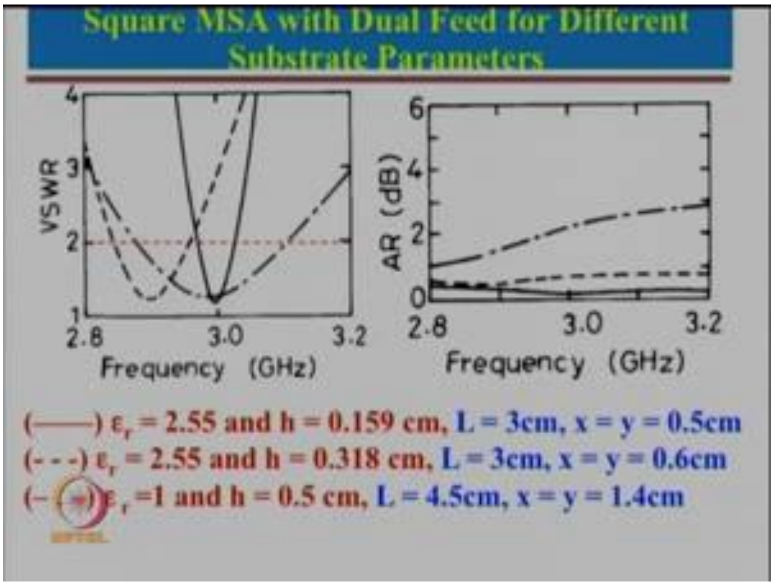

Epsilon 2.55 with 2 different h and then epsilon r 1, so what we notice that by increasing the substrate thickness and reducing epsilon r, we could get a much wider VSWR bandwidth; however, actual ratio becomes slightly poorer for epsilon r equal to 1 and h equal to 0.5, but still it is within AR less than 3 dB. Now in this particular simulation, we had assumed ideal condition of 1 angle 0 and 1 angle 90 whereas, in practice it will never really happen. So, let us see today, what is the practical way of realizing these configurations.

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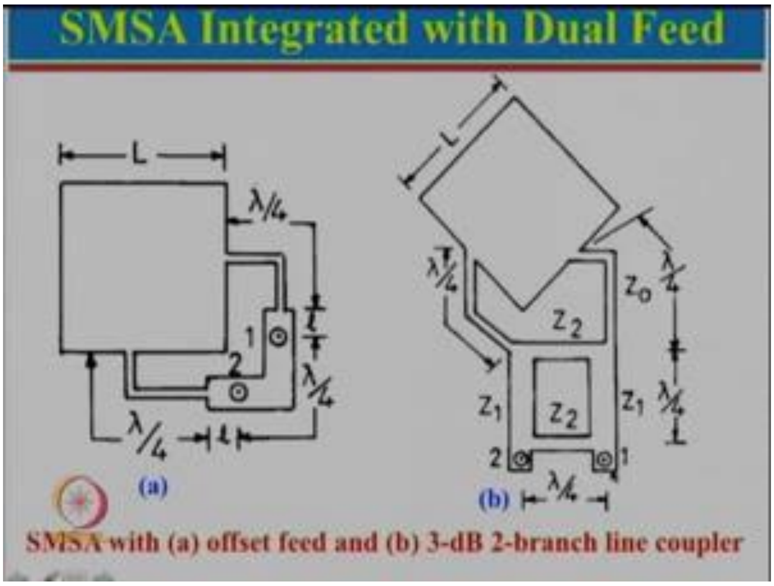

Here it is 2 different possibilities are shown over here. So, what we have here? This is a square patch and then a quarter wave transformer has been used, I will tell the reason also. So, we know that impedance is 0 over here and impedance is maximum; this impedance is much more than 50 ohm. So, it is a larger impedance, say quarter wave impedance, transformer has been used over here and similarly a quarter wave impedance transformer has been used here. Now both feed 1 and 2 are never used it is just to show you if you feed at 1, you can get LHCP or if you feed here, you can get RHCP. Now between the 2 feed, the distance you can see is lambda by 4. Lambda by 4 gives us additional phase shift. So, if you see now, this is symmetrical with respect to this here. So, you can say that the power going here will be equal to power going over here.

But between this and this you can say distance wise the phase difference is 90 degree. So, by changing this position from here to here, we can either have a leading or lagging phase shift which will give rise to LHCP or RHCP, but I generally do not recommend this particular configuration, I recommend this particular configuration and even for this configuration, will show you some other single feed point configuration which gives actually similar response as compared to this here. So, I strongly recommend that please do not use this configuration.

Now this is a much better configuration than that; what is the difference here? This part is remained same here and that is a lambda by 4 transformer is used here, lambda by 4 transformer is used here. So, this is high impedance; high impedance that high impedance is transformed to 50 ohms, here 50 ohm. Here now what we really have here? This is actually at 2 branch coupler. So, let me explain, what is a 2 branch coupler? So, for that we have to first understand the microstrip line. So, think about if there is a 1 microstrip line here. So, if I feed at this particular point, power will go to this end here, which is straight forward. So, now, if I put another microstrip line which is in parallel with this line here; with this small gap so what will happen now? There will be a microstrip line will have some fringing feel.

That fringing feel will get couple to the other microstrip line. So, what will happen? Something field will get induced into it. So, think about if you have a current carrying conductor then generally what happen? Induce EMF in the opposite direction. So, here also if you feed in this direction output mainly will go there, but part of the power will get couple to this side and this one theoretically is a isolated port. It will not get any power; practically it may be minus 30 dB or minus 40 dB or more depending upon the configuration which you have used. So, here we feed power, part of the power gets reflected back here and generally this is used in many applications. In fact, this is actually known as the coupled line directional coupler and the coupling between the 2 is optimum when the length is equal to lambda by 4 or odd multiple of lambda by 4 then coupling is maximum.

But the problem with this configuration is even though coupling is we say very large, the coupling is still about maybe minus 6 dB, minus 10 dB or minus 20 dB, now that has application for example, let us say if I am transmitting say 20 volt of power and we want to really know whether is it exactly 20 volt or it is less or more. So, suppose we have designed it say 10 dB coupler then 10 dB coupler would mean 10 percent power so; that means, out of that 20 volt, 2 volt will be getting coupled over here, but that is too high. So, that is why a 20 dB, coupler would mean 1 percent power is coming here and that can be used to monitor the power or it may be used for automatic gain control or this thing maybe going to some other circuit, now that is a coupled line. But for circularly polarized antenna; what we need? We need output which has equal amplest film. So, this is not going to do the job.

To increase the coupling, now what you think about is that instead of having a gap between the 2, if we now physically connect a line like this and physically connect a line like this. So, what we have achieved is 2 branches which are following from here to here and over here to here that is what the configuration is known as, this is known as 2 branch line coupler. So, here is a one microstrip line here is another microstrip line and what you can see here, there are 2 branches are connected in between. Now in this case, this length is lambda by 4, this is lambda by 4, this is lambda by 4, this is lambda by 4. So, let us just have a quick analysis in a very simple way.

Suppose if I feed a power here then part of the power will go here part of the power will go to this side here then this part of the power; part of the power will go over here and the rest of the part will go over here. Similarly the power which is coming here, partly it will go there, partly it will come here. So, now, let see what happen. So, there are 2 parts from here to here. The 2 parts are one here which is let us say lambda by 4, lambda by 4. Now each lambda by 4 gets phase difference of 90 degree. So, this is 90 and 90; 180 degree. This part also travels 90 degree, 90 degree; 180 degree. So, the 2 parts get added up. So, we get some power here, now for this particular port here actually speaking nothing comes here that all depends how we choose the impedance. So, in this case what happens? The path over here gives us 90 phase difference and then this is 90 degree, another 90, another 90.

That is 270 degree 270 degree is also equivalent to you can say minus 90 degree. So, this one here and this one here; these 2 cancel each other and hence power is coming which is 0. Now for this side, here also you can see that the power goes here which is lambda by 4 which is 90 degree from here to here to here, again it is going as 270 degree. So, then the question comes, why this is not becoming 0? The reason for that is you have taken a larger width here. So, larger width means larger power goes, here fraction of the power goes here, out of this fraction power, some fraction is going and then fraction of that is going. So, it is like this is also minus 90 degree phase delay this here is minus 270 degree phase delay which is plus 90 degree. So, even though that the 2 parts have opposite phase, but cancelation does not extinct this way suppose.

If this is coming at to be let us say a number, if we say 0.8 and if this is coming out to be let us say 0.1. So, that will be 0.7. In fact, that is what is the s 21 value here, but otherwise half power will be there corresponding to 0.707. So, basic idea is larger power is going. So, part of the power is only getting over here which is subtracting. So, now, between the 2, what it is the phase difference between the 2 is 90 degree which is what is require and these impedances Z 1 and Z 2 are chosen such a way that half power goes here and half power goes here and if half power goes here and there that is known as a 3 dB 2 branch coupler and just to tell you. So, if this is a 50 ohm, 50 ohm then Z 1 for 3 dB coupler comes out to be 50 by square route to which is 35.35 ohm. So, these 2 are same and Z 2 comes out to be 50 ohm say if we choose 50 ohm and 35.35, this become say 3 dB 2 branch line coupler.

Now if we feed here, this will be relatively isolated port or if we feed here then this will be isolated port. So, here we can do something interesting, you feed here; let us say we will get a LHCP, if we feed here then we will get RHCP. So, when you feed here, this should be terminated with the 50 ohm match load or if you feed here then this should be terminated with 50 ohm match load and now you can see that the power gets divided, if we are feeding here, half power here, half power here which is getting impedance matched to this impedance and hence it is properly matched and get its circular polarization. Now the only problem with this particular configuration is it occupies lot of area because already there is a patch over here which is lambda by 2 by lambda by 2 and we have a lambda by 4 another lambda by 4. So, the size of the antenna becomes large. So, that is the only disadvantage, but now this disadvantage, we have used for advantage; will show you the next configuration now.

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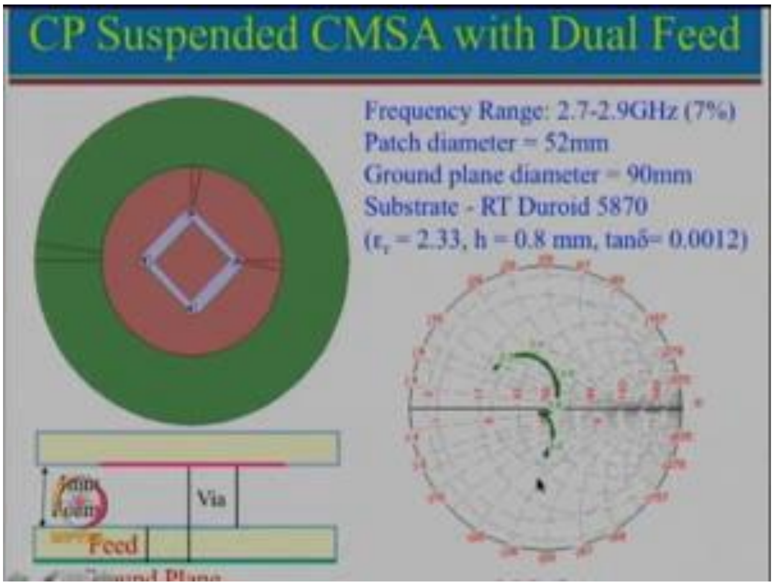

Now, what is this configuration here? This configuration actually is circularly polarized suspended circular microstrip antenna with dual feed. So, what we have done here? Here entire green which is here that is down, here also that is acting as a ground plane. So, that is a circular ground plane which we have taken and then we have a circular patch here which is printed underneath of this substrate over here and that is suspended instead of in the air, we have actually used a foam to provide a proper support otherwise we can use air also then we have to provide support over here. So, this foam provides a support and these 2 are substrates. So, this we have used for this example RT Duroid 5870 substrate whose parameters are epsilon r, h we have taken a 0.8 mm thickness substrate. So, these are the 2 identical substrates over here.

So, now, the patches suspended over here are printed and the underneath side of the substrate, now what we have done this 2 branch coupler that has been designed on this particular substrate here. So, this grace color comes over here, you can see that is getting merged with this line over here and then we are feeding at these 2 port here port 1 or 2.

That is the port 1 corresponding to this over here and this is another port. So, depending upon again, we feed here or here, we can change LHCP to RHCP or RHCP to LHCP. So, now, these 2 point here are connected via this here. So, you basically connect 1 solder your wire here to here and solder another wire over here and that is what the proper connection. So, in this case, you can see that a real state has increased in the vertical plane, but not in the horizontal as in the previous case here and by using this configuration we are actually getting a much broader bandwidth also because effective dielectric constant seen by this is very small, foam had a typical dielectric constant of 1.05 and this one had a epsilon r of 2.33, but since this is 4, this is only 0.8 effective dielectric constant seen by this patched is just approximately around 1.1.

So, low epsilon r seen by the patch and also higher h so which gives rise to the larger bandwidth. Now will show you the actual design and requirement, so the requirement was we wanted to have a circularly polarized antenna in the s band to cover 2.7 to 2.9 gigahertz which is about 7 percent bandwidth. So, that is why we choose this configuration.

Corresponding to this frequency and knowing what is the effective dielectric consent patch diameter comes out to be 52 mm, a ground plane diameter is taken as a 90 mm. So, this is the input impedance response corresponding to the feed port here. So, whether you feed at this port or this port, since everything is symmetrical both are responses are identical.

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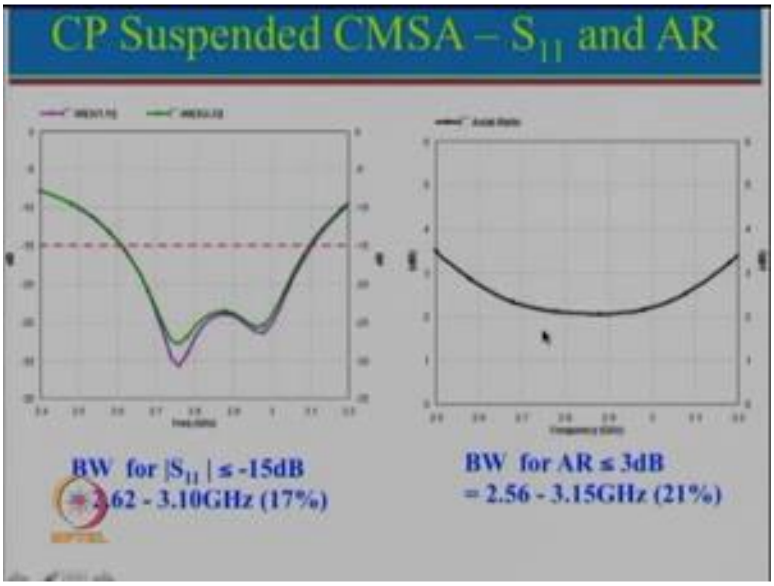

Now, let just see what is the reflection coefficient responds? So, here 0 minus 5 minus 10, so instead of defining bandwidth for S 11 less than minus 10 which would be very large bandwidth, we have actually defined it S 11 less than minus 15 dB. So, even for this value, you can see that the bandwidth is from 2.62 to 3.1 which is 17 percent.

Our desire requirement was only 7 percent. So, you can see that there is a lot of margin on both left side and right side and S 11 less than minus 15 dB corresponds to VSLR less than 1.5. So, it is a much better matched antenna. Now corresponding to this here, let us see this is the plot for actual ratio verses frequency. So, what can see that this is the actual ratio 3 here? So, actual ratio less than 3 dB bandwidth is very large that is about 21 percent whereas, our requirement is only about 7 percent. So, you can see that for that requirement from 2.7 to 2.9 actual ratio will be better than about 2.3 or so. So it meets all the requirement as such further desired design.

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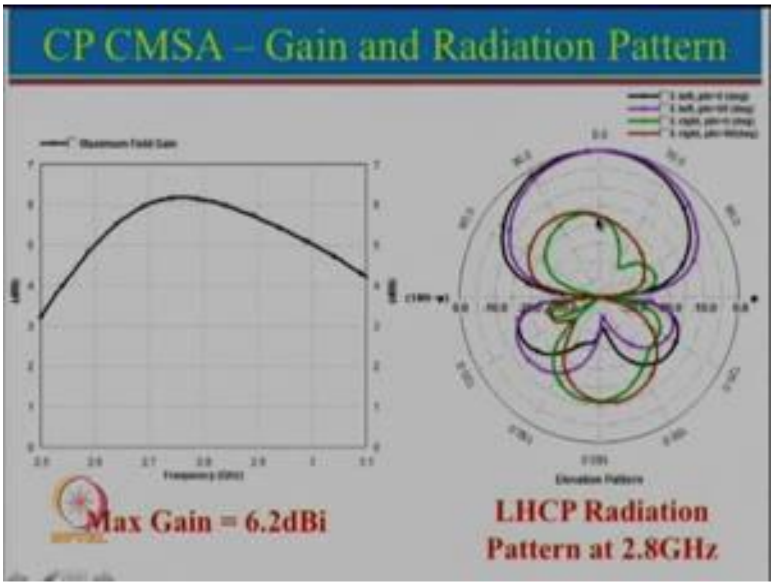

Let us just now look at the gain plot. So, for this particular case gain is about 6.2 dB at the center frequency and the gain variation over 2.7 to 2.9 is relatively very small here is the radiation pattern. So, LHCP radiation pattern at 2.8 gigahertz. So, this is the LHCP component that is n 5 equal to 0 and 5 equal to 90 degree, you can see that.

In fact, ideally if you take 5 equal to 0, 10, 15, 20, full 360 degree, the variation should be relatively very small and you can see that the variation is small specially over the half power beam width, the range we can see that the cross polar is slightly higher here. Here the cross polarize component is right hand circularly polarized component, but still that is about 17 18 dB below the normal thing. So, why cross polar is slightly poor the reason for that is again we can just see that the total height is quite significant and the feed is coming over here these are the thing and this will act like again a top loaded monopole antenna and that will not be circularly polarized that is a linearly polarized. So, this is getting super imposed on the radiation pattern of circularly polarized antenna hence there is a slightly poor actual ratio.

We are not getting close to 0 dB or one dB it is close to 2, but yet we can see that actual ratio is less than even 2.3 dB over the desired band and the isolation is still better than about seventeen dB in the desired frequency range now these are the situation which are for you can say the 2 feed antenna.

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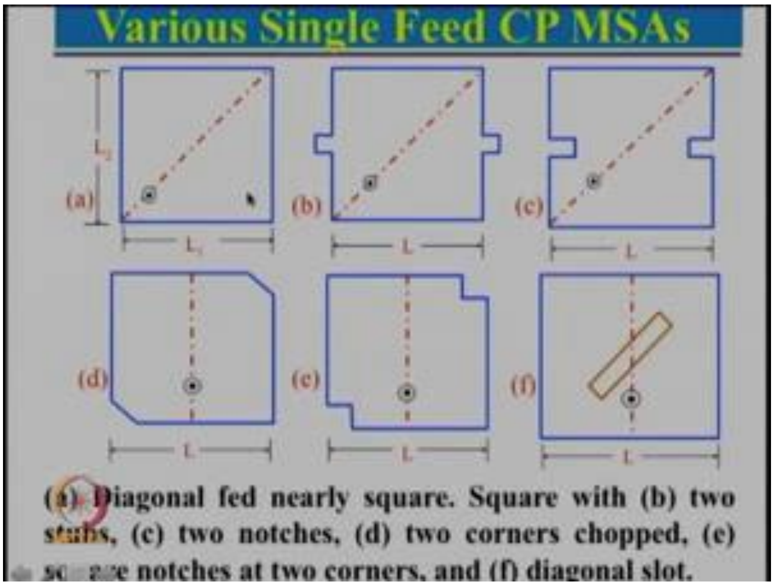

Now, there are many configurations available, the actually use single feed circularly polarized microstrip antenna and there are n number of variations are there for the circularly polarized microstrip antenna. Let me just say what these are. So, this is a nearly square microstrip antenna where this is length L 1 and this is length L 2 and L 1 is approximately equal to L 2, but not same and this is being feed along the diagonal.

I will just explain this particular thing how it is working. So, what happens? Let us say if we feed along the diagonal and we have to just take a case here. So, let us say L 1 is larger than L 2, but slightly larger than L 2. So, what happens if L 1 is larger than L 2 that at lower frequency which will correspond to f 1 then this length will be resonant and we have feeding it along diagonal. So, this length is resonant so; that means, there will be a phase difference of 45 degree at slightly higher frequency this length will be resonant because L 2 is small. So, now, this will act as a resonant now between the 2 resonance is this is 45 degree and this is also 45 degree. So, between the 2 orthogonal resonance is phase difference will be 90 degree. So, that satisfies the criteria that the 2 orthogonal polarization should have a 90 degree phase difference. So, how that particular thing is achieved that can be explained. So, let us just look at corresponding to L 1 we look at the resonance curves here.

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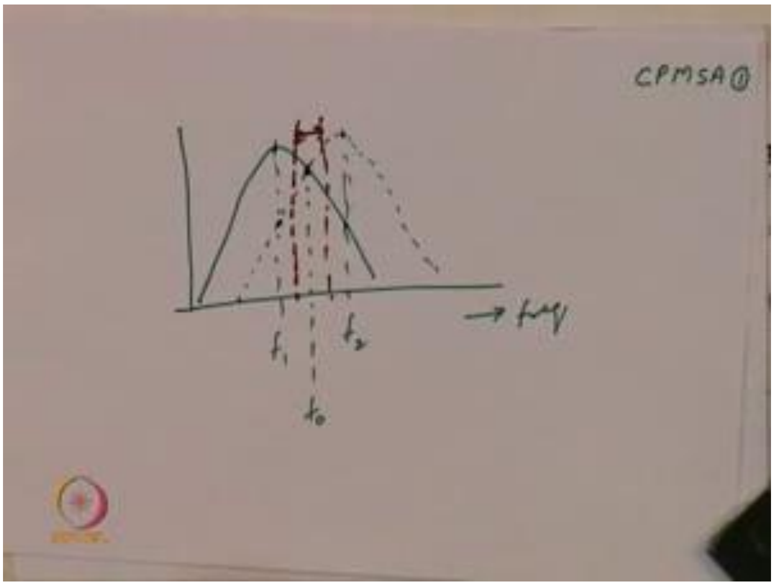

Let us say corresponding to length L 1 as I said, length 1 L 1 is more. So, here is the resonance curve corresponding to L 1 which is equal to f 1. Now corresponding to length L 2, this is the resonance curve for f 2. Now you can see that if we look at this curve here when this patch is resonant f one corresponding resonator value of f 2 is very very small. So, this cannot give us a circularly polarization because circular polarization has condition that the amplitude for the 2 orthogonal mode should be equal and that condition is getting satisfied only at this particular point. So, at this particular point which let me call now as f 0, we get circular polarization why at this point the 2 amplitudes are equal and also the phase difference between them is equal to 90 degree now as the frequency increases you can see here this amplitude is maximum, but corresponding to this; this amplitude is very very small.

So, for you can say 3 dB variation let me use some different color. So, you can see that for 3 dB amplitude, variation will be over this. So, this is the frequency range over which we can say actual ratio will be relatively less than 3 dB beyond that actual ratio will not be very good. So, this is the general concept so just to repeat that and look at this particular configuration again. So, what we would like to see that at frequency f 1, this length becomes resonant at frequency f 2, this length becomes resonant and as I mentioned that at f 1 when this is resonant that will be dominant e plane will be in this here let us say horizontal and at f 2 the dominant will be vertical polarization, but in between as we change the frequency from f 1 to f 2.

What we can see the dominant horizontal polarization changes to vertical polarization, but in between there is a circular polarization. So, this particular configuration as such gives larger bandwidth from impedance matching point of view, but it gives very small actual ratio bandwidth. So, now, once you have understood this you will actually see that these all configurations are very simple to understand. So, here it is a square patch length L here, this is also length L here, but here this stuff is attached. So, if by adding this stuff what happens? This length will be slightly more than this length here. So, since the 2 lengths are approximately equal slightly different and this is spread along diagonal; that means, the phase difference between this and this will be 90 degree enhance it can give circular polarization.

Instead of nearly square, we can use a square width to strip instead of adding strip, we can also cut a notch by adding a notch again what happens this length will be changing through the part here and this length will be changing through another part so that 2 length should be different. Now this is the configuration where diagonal is change you can see that a triangular segment has been removed from here and here. So, you look at this diagonal and then you look at this diagonal. So, you can see that the 2 diagonals have a different dimension and between the 2 diagonal set is put the feed over here. So, for this feed this will be let us say at 45 degree this also will be at a 45 degree one will be leading and one will be lagging.

But the 2 diagonal will have a phase difference of 90 degree instead of getting a triangular segment, we can also cut a notch like this the concept is similar. So, again this length will be different then this length here then there is another possibility that is we cut a slot like this here. So, now, what happens? This diagonal length will be going like this and reaches here whereas, this diagonal length now will be going like this going around and then coming back here so; that means, now the 2 diagonal lengths are different and repeat in between. So, this is minus 45 degree this will be let us say plus 45 degree between the 2 phase will be 90 degree. So, it will give circular polarization, but all of these configuration actually speaking give very less actual ratio bandwidth. In fact, you will see that typical actual ratio bandwidth of ten by these configuration may be 1 to 2 percent. So, let just now take an example.

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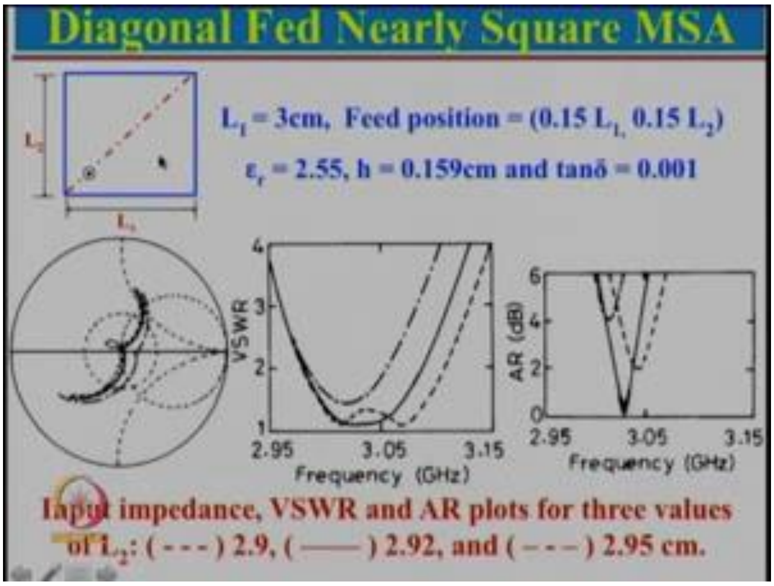

Here is an example where length is taken as 3 centimeter which is L 1 and what we are actually to going to show you here for different values of L 2, what happens? So, here L 1 is taken feed point has been kept fixed as 0.15, L 1 and L 2; these are the substrate parameter. So, now, let us see what we get for different values of L 2, there are 3 cases are there, 2.9, 2.92, 2.95, I just want to mention here, how to choose these particular values here. So, remember corresponding to this here since substrate is very thin the bandwidth of this antenna is just about less slightly less than 2 percent, first let us just see the result then will come back to the ratio. So, for 2.9, you can see that there is a small loop over here for 2.92 that loop has almost become a kink. In fact, the definition of the kink is when the loop size is almost close to 0, it becomes a kink and the kink is the point which is which actually gives us the best actual ratio because kink is the point.

Where 1 resonance frequency shifted to the another resonance frequency and that is where the amplitude of the transition is exactly equal leading rise to the kink and if the value is increase to 2.95 which is getting close to 3 centimeter, you can see that the loop has completely disappeared. If this is equal to 3 centimeter then will be no even bend also here that will be going to the simple response will be of that of is square patch now corresponding to this let us first just look at the actual ratio. So, we can see that the best actual ratio is obtain when there is a kink and you can see that the actual ratio is relatively poor for other 2 cases. So, for optimization of this configuration I always advice look at the smith chart plot and if it is a kink that is what will give you the best actual ratio. Now corresponding to these cases this is the case for VSWR here for the kink, this is the VSWR plot and for the small loop here this is the VSWR plot.

You can see that this plot gives me a larger VSWR bandwidth, but that is not the useful bandwidth because here then polarization changes as frequency changes since we have taken L 2 as small. So, that will have a higher resonance frequency. So, at lower frequency this will be a resonant. So, let us say that will be horizontally polarized and that at higher frequency that this will get excited that will be vertically polarized. So, it will go from horizontally polarized to circularly polarized to vertically polarized antenna. So, VLSR large bandwidth is not useful because in this case, it will be horizontally polarized then this will be linearly polarized only in this region we are getting circularly polarized given by that actual ratio over here.

This particular configuration gives us LHCP left hand circular polarization, if we change that diagonal position feed along this diagonal that will give us right hand circular polarization, but even here if we have taken L 2 small if you take L 2 larger than L 1 then for this feed, it will be right hand circular polarization. So, it is important to know in which direction the field is moving and that is what determines our left hand or right hand circular polarization.

In the next lecture, we will see many more configurations of circularly polarize antenna will also see how to realize compact circularly polarized antenna, we will also talk about broadband circularly polarized microstrip antenna. So, we are going to see lots of variations of circularly polarized microstrip antenna and this material has been taken mostly from my book broadband microstrip antenna chapter 8. So, see you please read this portion again before attending my next lecture.

Thank you, bye.