Antennas
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Module - 07
Lecture - 33
Tunable MSA-II

Hello and welcome to today's lecture on dual band micro strip antenna. In fact, we started discussion about dual band micro strip antenna in the previous lecture. So, where we had seen that a rectangular micro strip antenna can be used with a single feed or dual feed to realise dual band operation, but those 2 dual band polarisation also give orthogonal polarisation. So, let us start with that.

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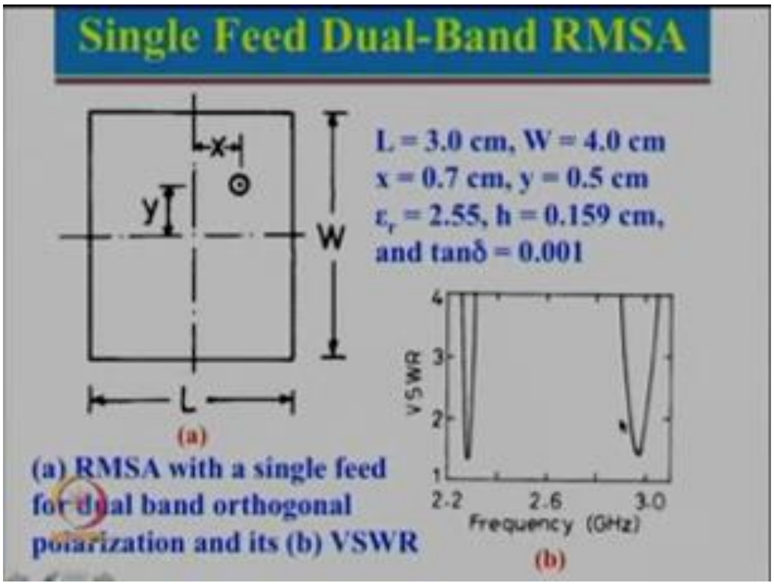

So, we had seen this configuration in the previous lecture by feeding along the diagonal. We could excite both the orthogonal mode. So, since width is large. So, this will be resonating at the lower frequency and since length is small this will resonate at higher frequency. And we saw this particular response here. So, instead of using a single feed point

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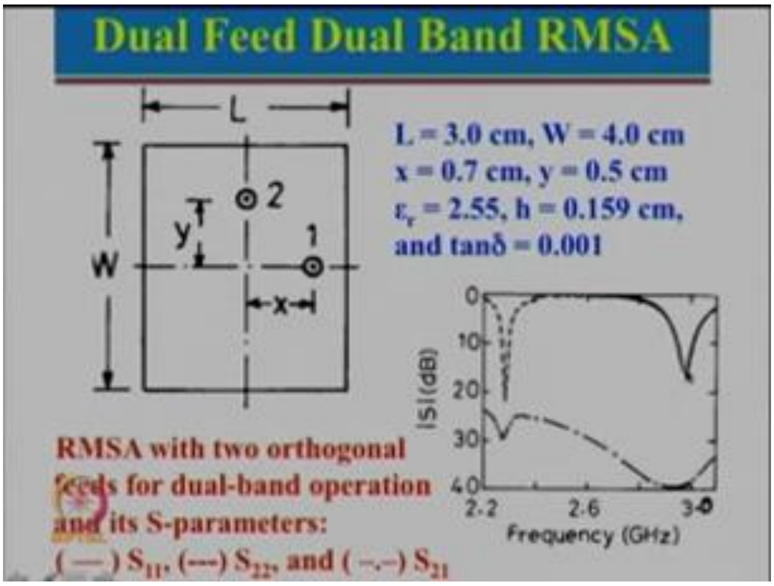

We could also use a dual feed here this for the same parameters. And we notice that the reflection coefficient for the corresponding 2 port is almost same as before, but now what is important is the isolation between the ports 1 and 2. And we can see that the isolation was about 27 28 dB over the bandwidth for which S 11 is less than minus 10 dB, and same thing we had seen over here, it was almost 37, 38 dB. Now it is not necessary that you have to use rectangular, you could also use an elliptical micro strip antenna also. So, think about an elliptical over here. So, it will have a major axis and then it will have a minor axis.

So, you can actually tune the minor and major axis and you can design those things corresponding to the dual band operation desired, but the only thing is that these 2 give orthogonal polarisation.

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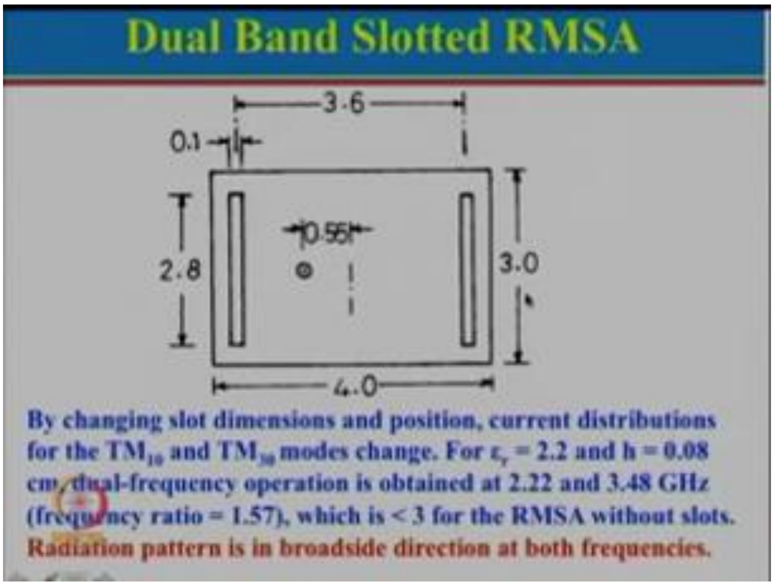

Today will look at alternate configurations, which actually give the same polarisation. So, here is a one configuration, where you can see that there is a one rectangular patch is here. The length of that is 4 centimetre width is 3 centimetre, and the 2 slots have been cut in this particular rectangular patch here. So, now, what is the concept? So, concept here is what we want for this particular feed point, we want dual band and the dual band should have same polarisation. Now suppose that if we had not cut the slot. So, then 2 bands which would have been there, one corresponding to TM 10 mode and another corresponding to TM 30 mode. Now those 2 modes will be exactly at a frequency ratio of 3 and, but they will give both broadside radiation pattern as well as the same polarisation. Here this configuration modifies these 2 mode. So, what is being done here is that by cutting the slot over here, and this slot is cut near the radiating edge. So, what we have here current is relatively 0 current is maximum over here.

So, what happens? For fundamental mode, now the path length will be like this. And it goes here and comes back comes over here, but for fundamental the higher order for TM 30 mode again. Now the path length is again going up here coming back and then going over here like this. Now when you cut the slot near the current 0, for fundamental mode effect is not very significant, but for third order mode the effect is fairly significant because the field will go from 0 to maxima to 0 and then maxima 0 will happen along this. So, there will be total 3 lambda by 2 variation along this particular length. So, by cutting the slot over here just to mention the dimension is 2.8 almost filling up the entire width, and the width of the slot is 0.1. And in this particular case one can see that the 2 bands are obtained at 2.22 gigahertz and 3.48 gigahertz and thereby giving a frequency ratio of 1.57.

Now if this was not their frequency ratio would have been equal to 3, by changing the dimension here. Suppose you reduce this here and then we also reduce here this is basically to make it symmetrical with respect to the feed point here or with respect to the central, over here.

So, by cutting the slot on both the side it is basically symmetrical with respect to the central axis. And if these dimensions are reduced or if the position is changed then this ratio changes so; that means, by cutting a slot between the 2 higher 2 modes f 1 and f 2 we can change their ratio to 1.57 to as high as 3. So, just think about an application or example GSM 900 and 1800. And we know that frequency is roughly 900 megahertz and 1800 megahertz so; that means, what is the frequency ratio between the 2 it is 2. So, by tuning these stub slot dimension and by reducing their size we can actually tune the frequency to 1 is to 2 or 1 is to 2.5 and so on.

So, this is the very good technique where you get the same polarisation, and the modes are of course, 1 0 and 3 0 mode here. Of course, gain will be different at the 2 different mode because for fundamental mode frequency is low aperture area is constant for both the cases. So, for this case just recall aperture area theory what it says gain is approximately equal to 4 pi a by lambda square multiplied by efficiency. So, 4 pi a is constant lambda is changing because of the frequency hence gain will be different at 2 different band, but other than that the polarisation will remain same and maximum radiation will be in the broadside direction. Now this antenna can be made compact also.

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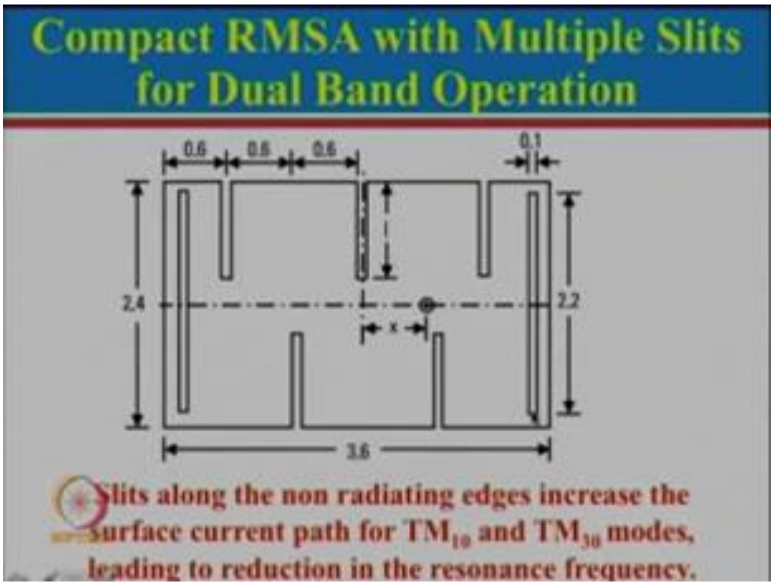

So, if you just see here this configuration is somewhat similar to the previous configuration. So, we have a rectangular patch and there are 2 slots over here, but now multiple notches have been cut. You can see here 3 notches have been cut over here and the 2 notches are cut over here, so there about 5 notches which have been cut along non radiating edges.

In fact, if you just think about now what has happened, current which would have been gone like this here, goes up here it would have earlier gone like this and come back here, but now the current path has changed it is going up it will come down then it will go up here it will go like this here, and then it will move so; that means, effective length has increased. And if the effective length has increased correspondingly resonance frequency will reduce. And basic idea of this configuration by cutting the slot is to reduce the overall size of the antenna. So, just recall for the previous case let just see what was the length, 4 what was width 3. These 2 have been reduced now. So, 4 has been reduced to 3.6 and 3 has been reduced to 2.4, but the slot is now as before reduced correspondingly. So, it is 2.2 and the width of the slot is 0.1.

Now, what is being changed in the next slide will show you is, the length of this particular notch. By changing this length, we can tune the resonance frequency as well as the frequency ratio for the 2 mode.

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Effect of Slit Length on Two Frequencies of Compact RMSA with Multiple Slits

l (cm)	x (cm)	Lower resonance		Upper resonance		f_2 / f_1
		f_1 (GHz)	BW(%)	f_2 (GHz)	BW(%)	
0.0	0.67	1.915	1.78	3.620	1.19	1.89
0.4	0.63	1.811	1.60	3.620	1.16	2.00
0.6	0.59	1.698	1.53	3.531	1.13	2.08
0.8	0.50	1.553	1.48	3.318	1.12	2.14
1.0	0.50	1.390	1.37	3.062	1.08	2.21
1.2	0.50	1.196	1.34	2.730	1.17	2.28
1.3	0.50	1.096	1.46	2.590	1.24	2.36

So, let us see. So, what we have here. The first case is when there is a no slot which has been cut that is the slot along the non-radiating edge. So, just go back here. So, what this L is we are talking about this length variation this slot. And this slot that remains for same for all the cases. So, now, here L for this L we are getting feed point at 0.67 the lower resonance is 1.15 upper resonance is 3.62 and if you take the ratio of the 2 the ratio is around 1.89, but now this length is changed.

So, the slot depth is being changed. So, 0.4 0.6 and if this is increased what will happen path length will increase and if the path length increases resonance frequency reduces. So, you can actually see by cutting these multiple slots along the non-radiating edges. The resonance frequency reduces from 1.9 to almost close to 1.1. So, that is a large you can say change in the frequency correspondingly even the upper resonance frequency changes. So, there 0.6 has almost become close to 2.6.

However, the ratio of the 2 is not constant in this particular case. So, this also varies from 1.89 to 2.36. So, now, depending upon the requirement you can actually choose any of these particular thing suppose that is the desired let us say we want an antenna at say 1 gigahertz and 2 gigahertz, this one will be a good choice or if you want something at 1 and 2.2 gigahertz. Then this will be the good choice here. And if you do not want any one of these ratios suppose we want a ratio of close to say 1.6 or 1.7. Or we want a ratio close to 2.7, 2.8. Then what you need to do it is you need to change the slot dimensions of this over here. So, if you reduce this slot dimension then frequency ratio will increase. So, by doing this you can actually tune the antenna and also realise a compact micro strip antenna and the dual band can be designed according to whatever the ratio of this L you take here.

So, this is very powerful technique to design dual band antenna which has the same polarisation and the radiation pattern is in the broadside direction.

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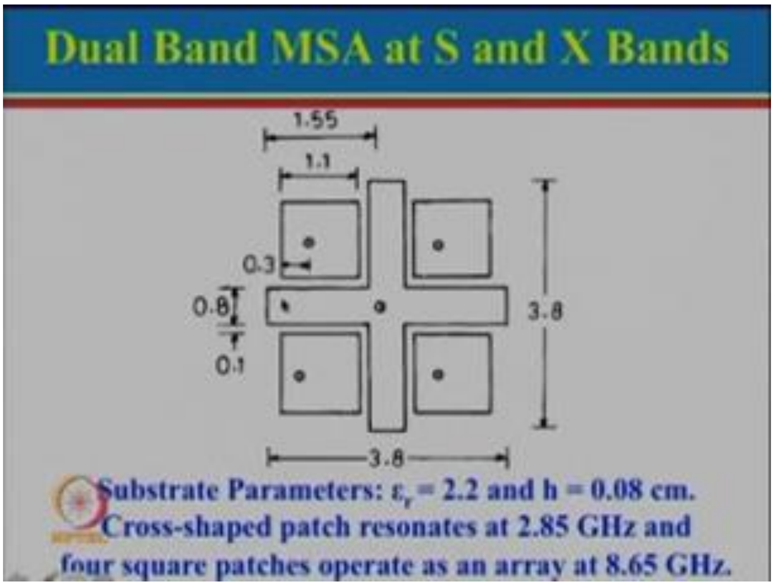

Now, there is another technique which we will look at. And this one here what it has of you see it has a patch which is known as a cross patch or you can also call it a plus patch depending upon whatever you like, but let us first focus on this here. If we actually increase this particular portion here this will be like a square patch, but out of that square patch if you cut this particular portion here then it becomes a plus patch or cross patch, now the resonance frequency of this patch will be governed by the length over here, and since it is this length is same as this length here, we can say that the resonance frequency in the either direction it will be same. So, it can be modified also to obtain dual polarised antenna also. That is why a square patch has been used here or modified a square which is cross here. So, now, there is an empty space there. In this empty space X band antenna has been put there. So, basically this configuration is very useful when the frequency separation between the 2 bands is very large. And just to tell you the nomenclature S band corresponds to 2 to 4 gigahertz, X band corresponds to 8 to 12 gigahertz, and just to give you some other nomenclatures also. There is a L band which is let us say if you put here L band, L band is 1 to 2 gigahertz s is 2 to 4 gigahertz there is a c band in between 4 to 8 gigahertz and then X band which is 8 to 12 gigahertz.

So, since the frequency separation is large. This is the situation which can be used. So, here 4 square patches have been put. These 4 square patches resonate at a different frequency which is 8.65 which is in the X band range. So, this cross patch is designed at 2.85 gigahertz X band patch which is at 8.65. These patches are designed at that particular frequency. Now the only important thing which we need to do it is that these 4 patches now actually form a sub array of 4 element. So, they will also give a larger gain compared to this particular patch over here. The important thing is having some finite gap between this patch and this patch. So, that the coupling to the 2 patches is reduced. Because there will be fringing fields from here and there will be fringing fields from here and that can get coupled to this here. So, if possible try to keep this gap greater than 2 h where h is the thickness of the substrate. Then the coupling between this and this will be relatively small now.

Remember there is a one issue that suppose if you take this here which is 2.85. The third order mode of this if you multiply this with 3 that will be close to 8.55 that is very close to this here. So, the third order mode of this may be you know getting excited or closed to this particular mode here. So, some interference or some coupling can happen. So, sometimes those precautions need to be taken. So, that the isolation between the 2 is relatively good.

So, there are several other possibilities are there. In fact, if you recall we had discussed about some compact antenna. Where what we had was we had a ring antenna. And in that ring we took 2 different cases of a square ring as well as circular micro strip antenna ring. So, in that ring what we had done, we had put another patch in between which was shorted. So, that the 2 resonance frequencies are closed to each other, but now for dual band configuration what we can have we can have a one ring, and inside the ring we can have another patch and that patch can resonate at any different frequency which is desired. So, ring can work at the lower frequency and the in between patch can excite at a higher frequency. So, that is actually a very good also candidate and there also by properly feeding the 2 patches, one can actually design same polarisation as well as orthogonal polarisation depending upon how you choose the feed point. There are many other configurations given in chapter 7 of my book broadband micro strip antenna. So, I encourage you to go through that.

So, now we will discuss about circularly polarised micro strip antenna. So, we have just discussed about dual band micro strip antenna. Now let us talk about circularly polarised micro strip antenna. So, if you recall the earlier lecture, when we were talking about antenna fundamentals, we did discuss about polarisation. We talked about linear polarisation, we talked about circular polarisation, we talked about elliptical polarisation, for example, if we take a case of a dipole antenna. So, this dipole antenna, what is the polarisation for this. The e field is varying like this here. So, that is a vertically polarised antenna. If I put it like this here, then it is horizontally polarised. So, if you want a circular polarisation what is the condition for circular polarisation? That there will be vertical component there should be a horizontal component and these 2 component should be fed with equal power and 90-degree phase difference now with dipole antenna it becomes very tedious also to design these kind of a thing, but for a micro strip antenna it is actually very convenient to design circularly polarised micro strip antenna, but first the question is why do we need circularly polarised micro strip antenna.

So, again assuming that let us say this is transmitting antenna let us say this is receiving antenna. Now if these 2 are properly aligned, then we will get full signal, but suppose if this particular antenna is rotated by let say in 90 degrees, then the signal received by this will be relatively very small, but suppose if this was a circularly polarised antenna transmitting, then in that case whether the field is antenna is like this or antenna is in any of this position it will still receive exactly the same signal.

Then the question comes why we not always transmit circularly polarised antenna. Now if we know that the alignment will be proper it is better to transmit linearly polarised antenna. The reason for that is see in order to transmit circularly polarised antenna what we need, we need one vertical component we need horizontal component. So, half power will be fed to one another half power will be fed to the other one, but suppose now we are now putting only half power in the vertical half power in the horizontal. And if the receive is always going to be vertical it will never ever receive the horizontal component so; that means, compared to linearly polarised both of them if it is circularly polarised and if it is linearly it will always receive half power less or 3 dB less; however, if it is circularly polarised and it is going to rotate if it is aligned it will receive 0, but if it is not aligned it may receive minus 30 dB, but by doing this circularly polarised and this can be anywhere, it will receive only minus 3 dB less compared to the other situation.

Of course, if it is circularly polarised antenna and this is also circularly polarised antenna, and if the polarisation is rotating same way then that will be a perfect match then there is a no loss of 3 dB. So, now, with that little introduction, let us talk about circularly polarised micro strip antenna, and how we can obtain circular polarisation using micro strip antenna.

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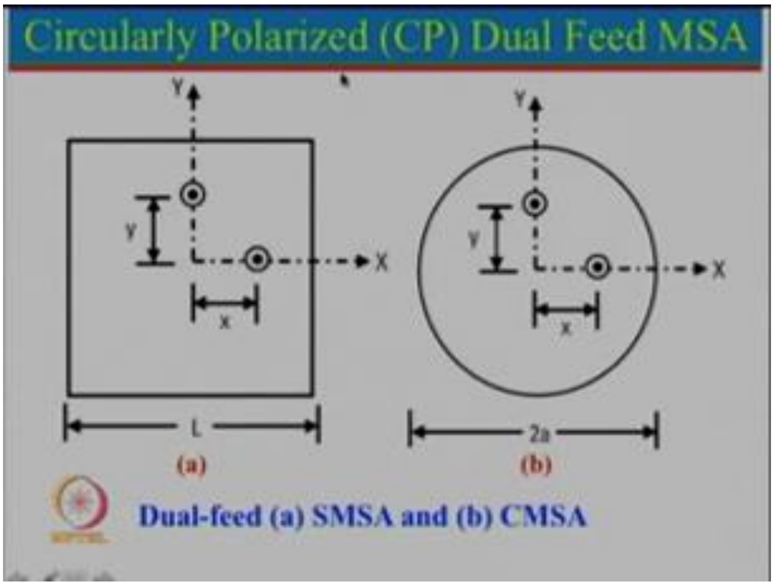

So, the first configuration is relatively very simple. This is a square micro strip antenna s is for square and this is circular micro strip antenna. So, let just look into this here for a square micro strip antenna what we do. So, length is equal to width. So, L will be equal to w and we find the feed point x, I had given you a general guideline that x for a rectangular patch can vary from L by 6 to L by 4 depending upon the bandwidth of the antenna. So, y will have the same value as x. Now what we need to do it is, we need to feed this antenna with let us say one angle 0; that means, amplitude is one angle is 0 and if we feed this one as one angle 90 degree or one angle minus 90 degrees. So, by changing say plus 90 degrees to minus 90 degree, we can actually make it left hand circularly polarised or right hand circularly polarised. So, we look into that in the next slide.

But here instead of using a square, we can also use a circle here. So, again circle can be designed for a desired resonance frequency x can be calculated, again I had given a general guideline that x can be from a by 3 to a by 2 for the given circular micro strip antenna depending upon the bandwidth. So, choose y equal to x.

Now, here the advantage is again just I mentioned in the dual band. So, if you feed along this here there will be null along this axis. And if we feed here there will be null along this so; that means, there will be a good isolation between these 2 feeds.

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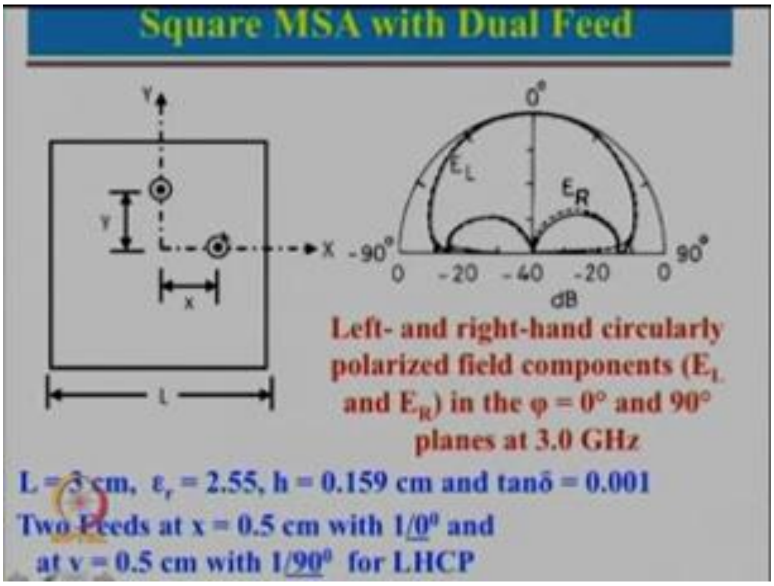

So, let us see now the example. So, here length is taken as 3 centimetre. These are the substrate parameters and the 2 feeds are taken identical x is 0.5 centimetre y is also at 0.5, but this is fed with one angle 0, this is fed with one angle 90 degree. And this is the concept for LHCP. If instead of 90 degrees if it is minus 90 degrees then this will be RHCP - Right hand circularly polarised. So, you can actually see here this antenna resonant approximately at 3 gigahertzes. So, we can actually see that left and right hand circularly polarised component. So, here do not look at E theta phi equal to 0 or E theta phi equal to 90. Which we normally see for linearly polarised antenna.

Here you should plot circularly polarised component. So, you can see that left hand circularly polarised component has a maximum value and right hand circularly polarised component has a lower value. So, now, ideally when this is getting excited this should not be getting excited. So, if you see in the broadside direction the isolation between the 2 polarised component is nothing, but closed to 40 dB.

Now, you might actually see that over here E L component and E R component are almost same. So, that is really not circularly polarised at this particular angle, but normally we do not care about that particular thing here. Most of the time what we are really interested in is half power beam width. So, along the half power beam width if you see, that this component is almost 25 to 30 dB or close to 40 dB over here. Which is considered very good isolation and also there is another thing which is defined that is axial ratio. So, will see in the next slide what is axial ratio and how it varies. And now just remember here that this is h equal to 0.159. We will actually take different cases in the next slide.

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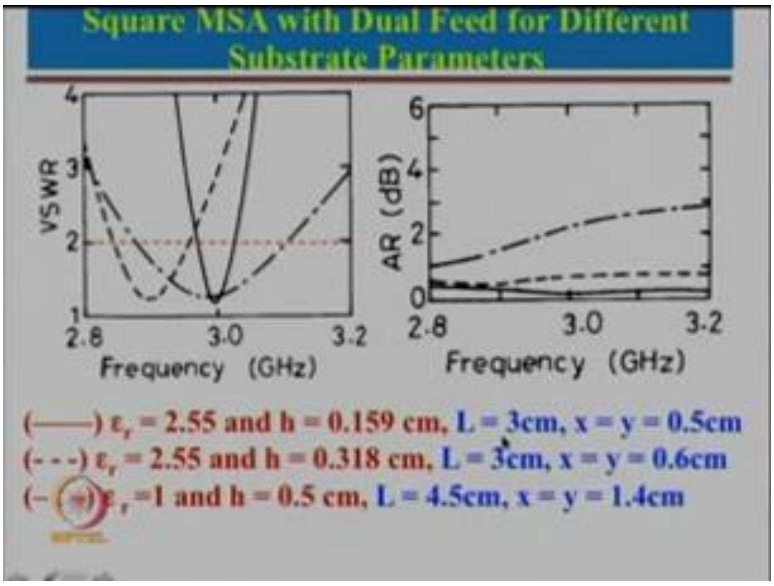

So, here is the case here solid line, which is for the previous case epsilon r 2.55 and h equal to this, just I have written again L is 3 centimetre x equal to y 0.5. Corresponding to this solid line you can see that this is the VSWR curve. You can see that the bandwidth is relatively narrow you can draw the line from here; you can see that is the VSWR less than 2 bandwidths is here. Now corresponding to this here, this is the axial ratio. How do we define axial ratio? Again since we discussed this long time back just to tell you, axial ratio is nothing but you can say that it is the major axis divided by minor axis. So, if it is elliptical polarisation if we take it. So, for elliptical polarisation major axis divided by minor axis will give us axial ratio.

Now, from that if the ellipse becomes circle. So, then what will happen major axis divided by minor axis will be equal to 1, and if we take logarithm of that that will be 0 dB. So, for circular polarisation axial ratio will be equal to 0 dB. What will happen for linearly polarised, for linearly polarised you can think about ellipse is compressed to single line. So, that will be linearly polarised. And in this case if you take the ratio a r will be equal to infinity. So, axial ratio theoretically can vary from one numeric value to infinity or in terms of axial ratio in dB you take a log of that that will 0 dB to infinity.

So, in this case now let us see the axial ratio. So, for this particular case here you can see that the axial ratio is really very good. And generally we define bandwidth for axial ratio less than 3 dB. That is acceptable for most of the application. You can see that over here it is actually even less than 0.5 dB. So, this particular configuration gives lesser bandwidth from VSWR point of view, but very large bandwidth from axial ratio point of view.

Now, here is a case where epsilon r is same, but h is doubled. When h is doubled we know that bandwidth should increase. So, x and y value has been shifted towards the edge which is 0.6 now. And for this particular case if h is increased what will happen fringing fields will increase, and if fringing fields increase resonance frequency will reduce. So, you can see this is the corresponding curve. So, this curve has a slightly lower resonance frequency than this curve here that is because h is increased which increases fringing field you can also see that the bandwidth is relatively large compared to this over here let us see the corresponding axial ratio. So, corresponding axial ratio is slightly worse compared to the previous, but still axial ratio is less than 1 dB, which is also fairly good. Again we can say axial ratio bandwidth is larger than VSWR less than 2 bandwidth.

Here is the next case, where we have done we have reduced the epsilon r. By reducing epsilon r, we know that bandwidth will increase. We have also increased h also. So, that will also help in increasing the bandwidth. Now since epsilon r is reduced and we wanted a resonance frequency around 3 gigahertzes. So, if epsilon r is reduced we have to increase the length. So, here length is increased again since it has a larger bandwidth we need to shift the feed point towards the edge or away from the centre. So, you can see that this is increasing.

For this particular case, now let us see the VSWR plot. So, this is the VSWR plot here. So, one can see that it has a very large VSWR less than 2 bandwidth. Let us see corresponding axial ratio plot. So, this is the axial ratio plot here. You can see that this axial ratio is worse than these 2 axial ratios, but still this axial ratio is less than 3 dB. So, we can say that it is again a very good antenna, but I want to just mention this is a hypothetical or just a theoretical thing because we have taken one angle 0 and one angle 90 degree as a perfect thing for simulation. In real situation this will not be the case. Always power will not be divided equally and always phase will be not 90-degree difference. So, this is an ideal situation, but even in this ideal situation you can see that this has become poorer.

So, what is the reason? In fact, there are lot of reasons given in the literature, some places it says because the antenna bandwidth has increased, that is why axial ratio has become poor, but that is not really the reason. Actual reason is if you see here probe height is increased basically substrate thickness is increased compact axial feed is there. So, probe height is increased.

So, now you think about probe is like a top loaded monopole antenna. So, there is a probe and the patch is acting like this thing. So, if this height is small the effective radiation from this monopole will be relatively small, but as the height increases, then what will happen? Effective radiation from the monopole will increase. And if that radiation increases, that is a linearly polarised radiation. And also the phases going to the 2 different ports will be different. So, what it results into only one component not both x and y component, but it also results into phase degradation.

So, because this probe is acting more effective radiator; that means, the component generated by that will be higher which is not circularly polarised component and hence actual ratio becomes poor, but yet the result is fairly decent it is still less than 3 dB and you can actually see over the desired bandwidth over here we can see that this is still less than 3 dB.

So, in the next lecture, we will actually talk about how to realise these 2 feet in the practical scenario. And also we will talk about several configurations which use only single feed point so, will talk about practical realisation of dual feed as well as single feed circularly polarised micro strip antenna.

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