Antennas

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Module - 07
Lecture – 31
Compact MSA-III

Hello and welcome to today's lecture on compact micro strip antenna. In fact, it is a continuation of the previous 2 lecture. So, in the previous 2 lectures we had seen compact micro strip antenna techniques. For example, we can higher epsilon r or we can use shorting post or we can do cutting slots or we can use combination of shorting post and cutting slots and we saw that very compact micro strip antenna can be realised; however, the disadvantage we noticed that the bandwidth of those antennas were not very good. Of course, those bandwidths can be increased by using a thicker substrate or using a dielectric constant instead of normal material we can use air. So, we can suspend those metallic plates in the air at a certain height so that we can realise a broadband antenna.

But today we will look into various broadband techniques which we had studied earlier. For example, we studied about gap couple configurations we looked into the configuration where gap coupled were along radiating edges or along non radiating edges we looked at the configuration stacked configuration and other thing.

So, all those broadband techniques which we had used earlier they are also applicable to the compact micro strip antenna. So, will just look at a few of this configuration and see how we can increase the bandwidth and how much we can increase the bandwidth and yet area is not significantly large.

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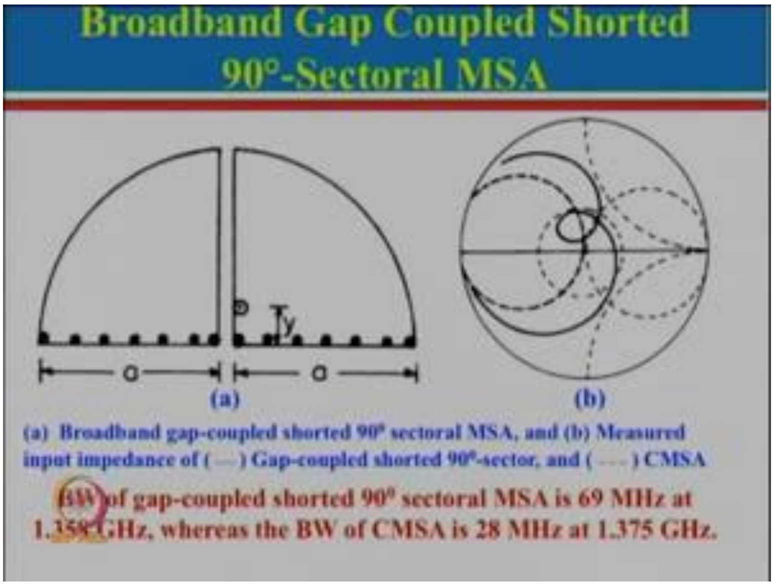

So, let us start with our first configuration. So, the first configuration I have shown over here this is basically you can actually think about these are the 2 shorted 90-degree sectoral micro strip antenna. If you recall the previous lecture there I had put a shorting over here and then feed point was put like this here. But here we have made the changes, we have put the shorting post over here and this is the feed point. And think about this as a parasitic patch here.

So, this is the one patch which is fed and this is the parasitic shorted patch. And we know that this particular configuration is about one 4th of the circular micro strip antenna. Now you might wonder why I did not put the shorting over here and put shorting over here because if I put a short here, then fringing field from here are actually shorted to ground. So, that will not get coupled properly to this particular patch here. So, coupling to this patch will not be significant, but by putting a short over here, now the field is varying from 0 to double plus here. Because 0 plus double plus and 0 plus double plus. So, fringing field will be more strong and they will get coupled to this particular patch here. And we have actually given one example also here. And this is the comparison of this particular patch here. So, here we have taken whatever this radius a is taken for the same radius of circular micro strip antenna this is the plot over here.

So, you can see that would be the response for a circle and for the circle we got 28 megahertz at 1.375 gigahertz. But by using this particular configuration, coupling this one over here you can see that over here is the loop. And this loop is because this patch is acting like a parasitic element and there is a loop over here. And for this particular case we can see that the bandwidth is 69 megahertz. If you see here this is 28 it is more than double the bandwidth of this particular here. So, you actually think about for a circle the area will be double of this entire thing. So, for half the area we are getting a bandwidth which is more than 2 times.

So, really speaking you know there has been always a discussion at one time, that you cannot increase the bandwidth without increasing the volume of the antenna, but over here we can see that the volume is reduced by almost 50 percent and yet bandwidth is increased by more than 200 percent. So, by using this gap couple configuration we can increase the bandwidth; however, just to tell also not everything is in gain. Here the gain of this particular antenna will be much lesser than the gain of the circular micro strip antenna because first of all the aperture is half of the circular micro strip antenna.

And also here the radiation pattern variation I want to mention is not very significant. Unlike in the case of the rectangular patches where we had seen that when the patches are put on the one side, what we noticed when we had 2 gap coupled configuration. So, this patch was getting excited. So, it gave broad side radiation pattern at the lower frequency. At the higher frequency when this patch started radiating the beam was shifted on this direction. And that is why we actually started with 3 gap coupled configuration. This one tried to shift the beam in this direction this one tried to shift beam in the other direction and the resultant was broadside pattern.

But in this particular case here we have a one patch and then we have another patch. Now this patch is of course, parasitic as we have seen over here, but in this particular case centre to centre distance, from this centre to this centre, to centre distance is much smaller compared to the patches when we are using. Earlier the patch size itself was lambda by 2, and then if you look at that gap couple centre to centre distance was more than lambda by 2, but here the patch size is very small. And since the patch size is small centre to centre spacing is also small. And the phase is given by theta equal to beta l where beta is 2 pi by lambda into l or you can say here it is the spacing.

So, phase difference will be theta equal to 2 pi by lambda into the spacing. And spacing is much small so; that means, phase shift will be very small. And that means, beam shift will be lesser. Also one additional thing, for a rectangular micro strip antenna the beam width was relatively narrow. And when this is shifted you can see the notice, but in this particular case since the antenna itself is a compact antenna. So, what happens it has a very large beam? So, if it has a large beam and if you do a little bit even of a tilting of that large beam the effect is not really appreciable; in this particular case here what we have noticed that the radiation pattern variation over the bandwidth is not very significant, but yes overall gain is small, but these antennas are useful where you want a wide beam coverage. So, gain smaller is required.

Now, just as a passing note over here, we can see that this particular loop is somewhere over here it is not centred around the central point. So, how we can do the little bit optimisation? Well optimisation can be done is if you want to shift this loop down below; that means, it is to be shifted to the higher frequency. So, if we reduce the parasitic dimension slightly, then what will happen? It is resonance frequency will increase and if the resonance frequency increases this curve will come right in the centre over here. So, now, instead of using this configuration, we can make even more compact instead of suing. So, many shorting things here we can use a single short here or we can use single short here, and by doing that we can realise a more compact broadband antenna.

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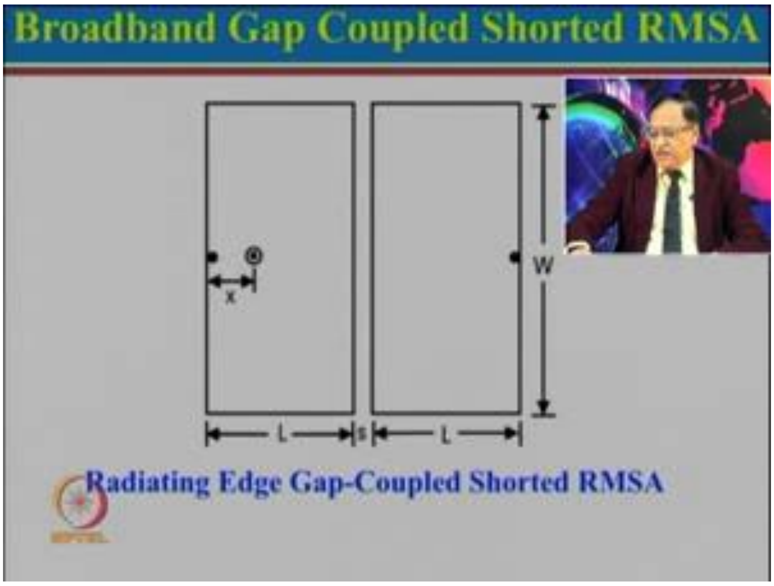

So, here we started example with a 90-degree sector, but we can use the similar thing for rectangular patches also here. So, here what we have since we are more concerned about compact antenna. So, we have actually taken an example here a rectangular micro strip antenna length is l this is the width here and since a single shorting post has been put here. So, from here going like this here and this, so that will be the total length should be equal to lambda by 4. So, we can say that lambda by 4 should be equal to l effective plus W by 2. So, that will be the lambda by 4 length.

Now, what we have done? We have put the gap coupled configuration. We have put the short on the other side. So, basic idea is again. So, that the field gets coupled maximally to this particular patch. So, if we put a short over here, that will have a 0 field force the boundary condition. So, that is not a very good idea, by putting this over here. So, field will be maximally coupled to this particular patch over here. So, by using this particular concept we could again get much larger bandwidth than corresponding rectangular patch antenna. And feed point again can be optimised to obtain a much better bandwidth.

Now, instead of putting this one we have used a term radiating edge because this is the radiating edge. So, we have put the radiating edge gap coupled shorted rectangular micro strip antenna. Now instead of that putting here we can also put it along non radiating edges also, or we looked into an example of just sector and rectangle, but we can do lot of other variation we can use all those triangular micro strip antennae shorted variations of those and thereby we can realise larger bandwidth.

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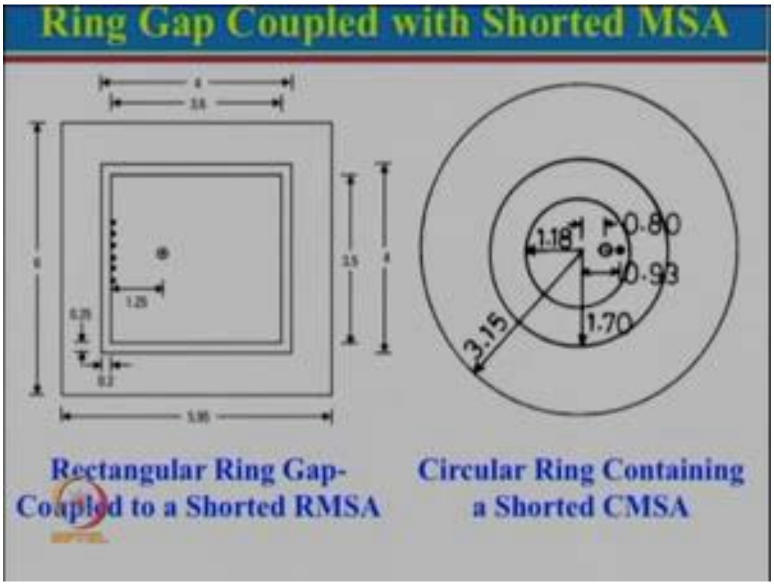

So, these are the things where we have used gap coupled concept to increase the bandwidth of the antenna. Now let just look at another very interesting concept where antennas have been put inside the other antenna. So, let us just first look into this configuration here. So, we know that a rectangular ring is relatively compact antenna. So, this is the rectangular ring you can see here, and then we also know that a partially shorted rectangular patch also has a compact nature has a lower frequency. So, here what we have done. So, first we have chosen this particular ring micro strip antenna, and then within that ring we have placed this another rectangular patch over here, and what we did it is the resonance frequency of this should be close to the resonance frequency of this. So, the resonance frequency of this can be controlled by changing number of shorting post here. So, what we need to do since we are feeding it over here. So, that will be our fed patch and this ring here acts as a parasitic patch here.

Now, if you recall for ring micro strip antenna, when it is very thin rectangular ring in that case we had seen we had to put a short circuit here and put the feed over here. Here we do not have to do anything like that because it is acting like a parasitic patch. So, field is set by this here. So, this is 0 it goes here plus it is double plus double plus, plus 0. So, that double plus here induces the thing here. So, field gets induced to this particular axis here, and then from here then since the field is determined by this coupling here, it will actually flow around here and that is how the loop gets excited.

So, by using this concept if you think about just this patch it would have given me a narrow bandwidth, just think about this rectangular ring that would have given me a narrow bandwidth, but now putting this particular antenna within this particular ring over here, what we have done we have not increased the size at all. So, if you think about a rectangular ring, which was compact configuration by putting this particular thing over here inside and making the resonance of that close to this, what we have really achieved much broadband antenna.

So, just by using some concepts you can actually increase the bandwidth of the antenna very significantly. We have given these dimensions over here, now the same concept has also been extended for a circular ring also. So, here is a circular ring which is not being fed. So, that is again acting as a parasitic element. Now we have another circle in between, but this circle has a short circuit, by putting a short over here as I mentioned in the previous lecture. So, now, the effective a, instead of taking just the radius you actually take now that as a circumference. So, again now by optimising the dimension of this patch along with the short circuit and the dimensions of this ring here we actually should ensure that the 2 resonance frequencies are close to each other, and if these 2 frequencies are close to each other we can realise broadband antenna. And again we have not increased the overall dimension of the antenna, if you think about circular ring as the basic antenna.

So, now just using this concept, one can actually think about n number of shapes. In fact, I just want to mention here one of my PhD student I will take his name also. So, his name is Amit Deshmukh. He did his PhD with me and he had submitted is this is around 2004 or so. And he had studied on several configurations variations of compact micro strip antenna then broadband micro strip antenna. I will not mention to you about stacked configuration the concept is very simple. So, you have a compact antenna at one layer, then you put another compact layer on the top layer, and by coupling that particular thing you can get a much broader bandwidth. So, their aperture size does not increase at all, you are only increasing the height of the antenna. And in his PhD thesis, in fact, I did not notice also, but his examiner actually came when that person came as an examiner and that person told me that there are 81 new configurations reported in his PhD thesis, and based on just his PhD thesis, we published somewhere around 8 to 10 journal paper and 8 to 10 conference paper.

So, we would like to have such kind of a PhD student and we really came out with lot of new configurations by adjusting the simple concept again. One compact antenna coupled with another compact antenna also we studied how the radiation pattern varies. And coupling is very strong which is important, and also you should ensure that the overall size does not increase radiation pattern does not take place and also what is important is that placement of the element is very important, so that you can really optimise the configuration. So in fact, his PhD thesis can be accessed or you can actually go through my book broadband micro strip antenna, where we have reported many of these configurations. So, compact micro strip antennas have been taken from chapter 6 of my book. So, what we have presented.

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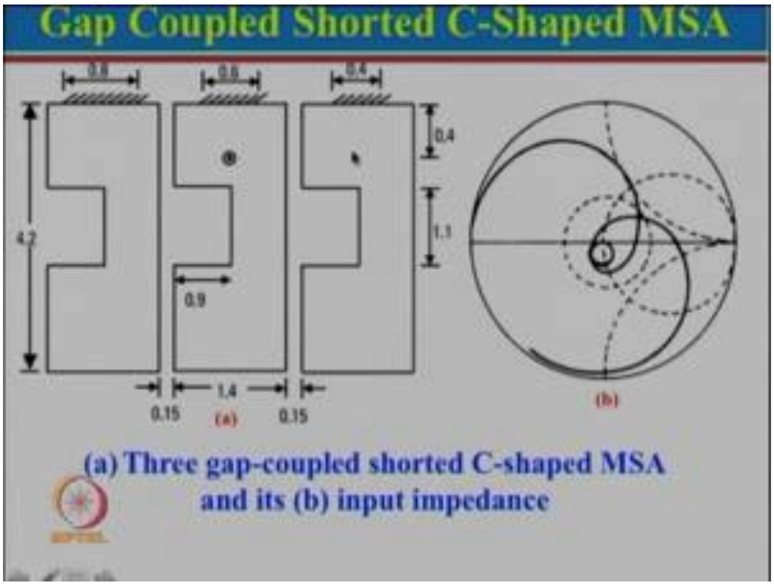

Now, I am going to present you one another configuration where we have used 3 different gap coupled configuration. Again what has been reported here these are the c shaped antenna? So, you can now think about this as an if you look from here 3 u shaped antenna or you think here 3 inverted c shaped antenna. Well you can take a mirror image also there will not be much of a performance difference, but I what I want to highlight over here is, that all the c patches are identical. So, if you see here the height of this is 4.2 and all of these patches the length over here is 1.4 gap is also. So, these are 3 symmetrical identical you can say patches except for one major difference. And the major difference is that shorting width has been changed.

So, if you notice over here, this shorting width is 0.6 this one over here is 0.8 and this one here is 04. And now just recall if this shorting width is changed, then what happens path length will change. And in this case just to remind. So, if this is the short here. So, from here to the opposite end length should be lambda by 4. And if this one is reduced; that means, what will happen path length will decrease. So, resonance frequency will reduce and in this particular case if this is increased path length will reduce. So, resonance frequency will increase. Now this is the patch which is fed here these 2 are the parasitic component. Now since that there are 2 parasitic patches both the parasitic patches have different resonance frequency because of the shorting variation. So, one can actually see over here that there are actually 2 loops. So, one is there and then another loop is between and then it comes like here.

It all depends upon how we choose these dimension. So, if you choose these shorting post slightly different then what can also be done. So, you can go like this here loop can be completed then it can come out then another loop can be there and then it comes here so; that means, you can do the little bit of that optimisation. Now in this case now you might wonder in case of a rectangular patch. This is something very similar to gap coupled rectangular patches. And now in case of a gap coupled rectangular patches I had to mention, that if the dimensions are taken different; that means, the resonance frequency if we take this length as l, then l 1, l 2, we had to mention that the with the change in the frequency the beam was shifting on this side or the beam shifts here pattern symmetry was not there, but in this particular case this problem is not very significant. First of all, the patch itself is a very compact antenna. So, since it is compact antenna, it is gain will be less it will have a very broad beam. Then from here centre to centre distance is very small. So, since centre to centre distance is very small phase delay experienced by this particular element will be very small.

So; that means, beam shift will be relatively small, but also beam width itself is very large, even for a very large beam width if we see slightly shift. You will actually not even notice much think about this if the beam is very narrow, and if it is shifted it looks like broad side there is a very less radiation, but if the beam is wide like this, then even if there is a small shift it does not really make too much of a difference, it looks like there is a very small difference may be half a dB gain variation may take place in the broad side direction. So, here we have 3 patches 1 2 3.

So, we will have a one patch which is resonating then another patch resonating and then another patch. So, it is possible that the beam will try to shift this side and then the beam will try to shift this side, but since the phase delay is relatively very small. So; that means, delay or the shift is small second as I said half power beam width is very wide. So, if it is a wide beam like this. So, small shift is not very noticeable. Or if at all change will be there it will be less than 0.5 dB.

So, it is a very good configuration here and some of the variations of these things have been used in the typically in the mobile phone. If you recall earlier when mobile phones were launched, mobile phones actually had a large monopole antenna which was ticking out of the mobile phones. So, remember earlier models more than 20 years back there were antennas which was sticking like this here. There was typically lambda by 4 monopole antenna. And that was breaking very often. And then people came out with the normal mode helical antenna. In the normal helical antenna, the height was only 2 centimetre where the antenna wire was wound around this.

Do not worry after some lectures we will talk about normal mode helical antenna, and will tell you how to design normal mode helical antenna, but then later on. In fact, there was an advertisement in the TV where a scissor comes and it comes like this here and it cuts the antenna like this and then it says there is no outside antenna. In fact, no outside antenna story is then, in fact, these gap coupled antennas were used in the earlier model and these earlier models were inside the mobile phones.

So, let us say if this is the mobile phone, then these antennas were earlier hanging like this then they became small then these removed and on backside of this one here these compact gap coupled micro strip antennas were put over there. And that is how it started, but of course, now technology has changed significantly earlier mobile phones used to have generally just one band, but now a typical mobile phone may have several bands it may work at GSM 900 1800 1900 2100 and then also it may be having a Wi-Fi which will be 2.45 gigahertz. That will require another antenna, then many of the mobile phones have a GPS then they need to have a GPS antenna.

So, typically inside a mobile phone these days we have quad band antenna or penta band antenna. So, actually speaking in the next lecture, we will start talking about how to realise multi band antennas. Will start with of course, a dual band, but before that also we will also look into a few other things; for example, let us say you have fabricated the antenna, and if antenna has been fabricated and let us say you want frequency to be just as a number let us say one gigahertz. Now let us say you did the experiment we instead of 1 gigahertz you got 1.1 or 0.9. Let us say now the error is almost close to 10 percent.

So, of course, you can use the concept which I mentioned to you earlier which is f 1 into l 1 is equal to f 2 into l 2 so; that means, let us say you chose a 10 dimension for which you got let us say 1.1. So, l one you know f one is 1.1 what is desired 1. So, calculate the value of l 2, then use that dimension fabricate another antenna, but that actually becomes very tedious how many antennas you are going to fabricate. So, there are techniques with which you can use tuning of the micro strip antenna.

So, in the lecture will talk about how to tune the micro strip antenna. And also we will look into how to realise broadband antenna and in fact, a little bit of a preview I can tell you today itself. So, we looked into the configuration for example, over here.

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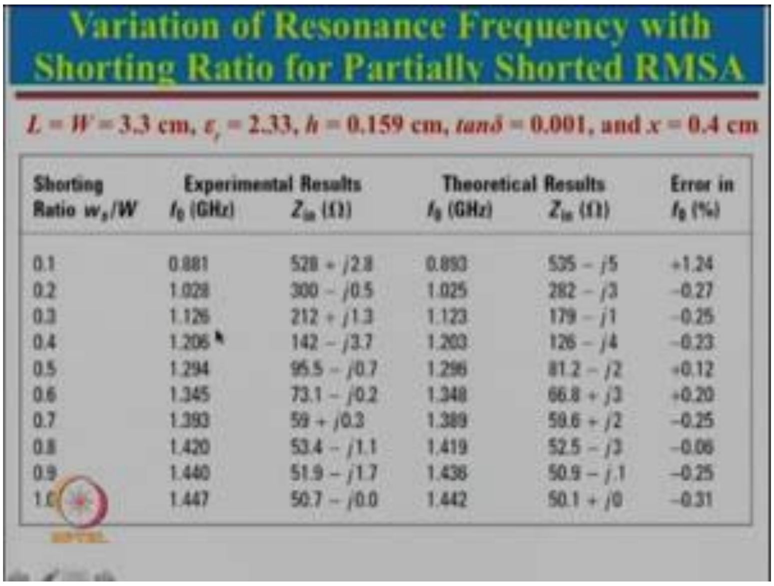
Variation of Resonance Frequency with Shorting Ratio for Partially Shorted RMSA

$L = W = 3.3$ cm, $\varepsilon_r = 2.33$, $h = 0.159$ cm, $\tan\delta = 0.001$, and $x = 0.4$ cm

Shorting Ratio w_s/W	Experimental Results f_0 (GHz)	Experimental Results Z_{in} (Ω)	Theoretical Results f_0 (GHz)	Theoretical Results Z_{in} (Ω)	Error in f_0 (%)
0.1	0.881	528 + j2.8	0.893	535 − j5	+1.24
0.2	1.028	300 − j0.5	1.025	282 − j3	−0.27
0.3	1.126	212 + j1.3	1.123	179 − j1	−0.25
0.4	1.206	142 − j3.7	1.203	126 − j4	−0.23
0.5	1.294	95.5 − j0.7	1.296	81.2 − j2	+0.12
0.6	1.345	73.1 − j0.2	1.348	66.8 + j3	+0.20
0.7	1.393	59 + j0.3	1.389	59.6 + j2	−0.25
0.8	1.420	53.4 − j1.1	1.419	52.5 − j3	−0.06
0.9	1.440	51.9 − j1.7	1.436	50.9 − j.1	−0.25
1.0	1.447	50.7 − j0.0	1.442	50.1 + j0	−0.31

So, you can actually see that by changing the shorting ratio, what we notice here by changing the shorting ratio frequency changed considerably. So, suppose if you are using a compact shorted micro strip antenna, then you can change the shorting width since you are dealing one hole you can deal another hole. And by doing that another thing here what you can do you can see that from here to here the frequency shift is close to 0.1 which is approximately 10 percent. Or from here to here you can see that it is about 8 to

9 percent. So, one can actually use these shorting technique, to do the tuning of the micro strip antenna. So, you need not fabricate another antenna just by changing this shorting thing you can tune the frequency.

Then we looked at another configuration where we actually have got these configurations here.

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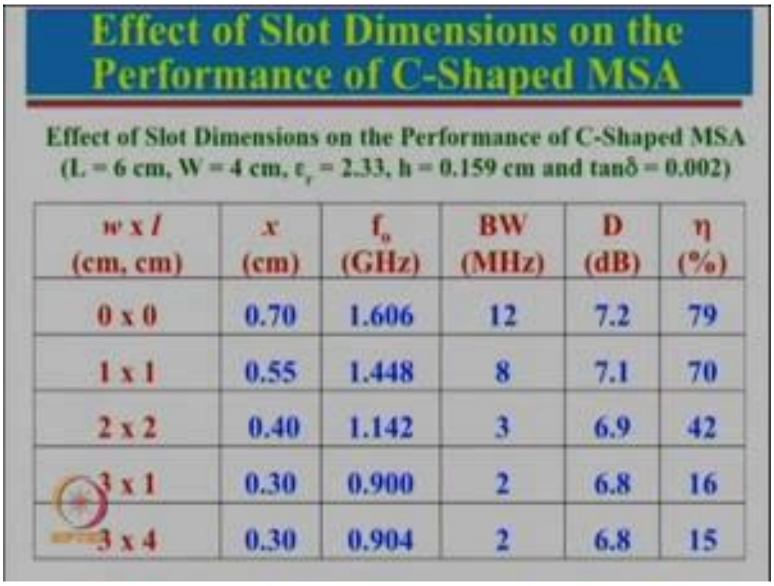

Effect of Slot Dimensions on the Performance of C-Shaped MSA

Effect of Slot Dimensions on the Performance of C-Shaped MSA
(L = 6 cm, W = 4 cm, ε_r = 2.33, h = 0.159 cm and tanδ = 0.002)

$w \times l$ (cm, cm)	x (cm)	f_0 (GHz)	BW (MHz)	D (dB)	η (%)
0 x 0	0.70	1.606	12	7.2	79
1 x 1	0.55	1.448	8	7.1	70
2 x 2	0.40	1.142	3	6.9	42
3 x 1	0.30	0.900	2	6.8	16
3 x 4	0.30	0.904	2	6.8	15

And let just say by cutting the slot here, by cutting the slot we can actually see that by changing the dimension of the slot, we are able to change the frequency. So; that means, just suppose we have fabricated this particular antenna and that we got 1.6 may be let us say the desired frequency is 1.55. So, what you can do you can just change the slot you cut a little slot here and you can reduce the frequency and thereby you can get the desired result.

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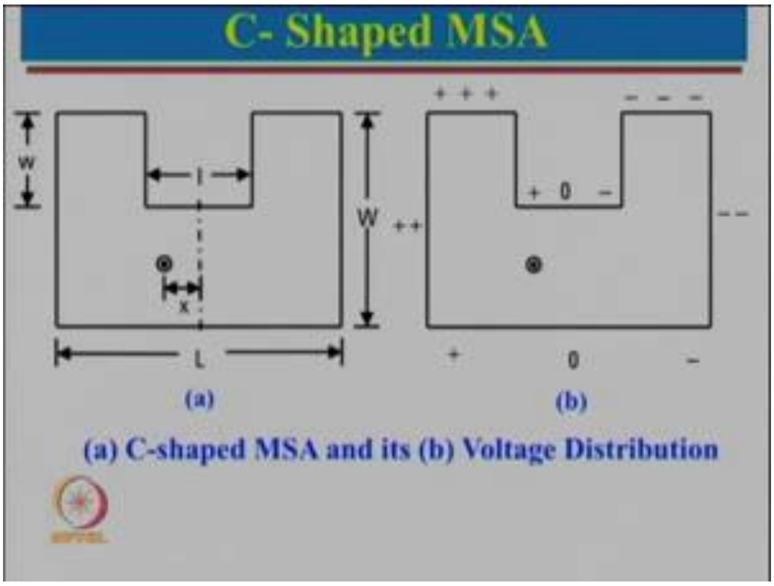

So, sometimes we can cut the slot or sometimes we can even add a stub over here to do the tuning. And many times we can actually have a larger coupling we can realise a broadband.

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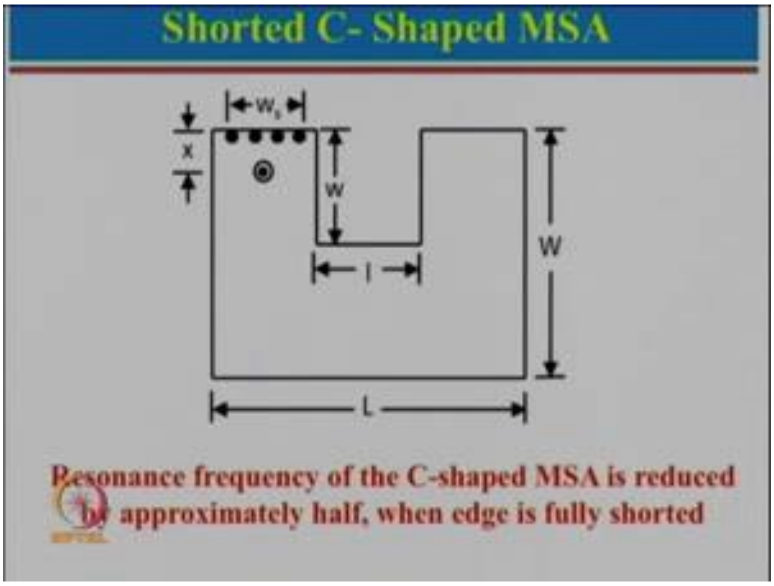

So, let us say on dual band also. So, for example, in this particular configuration, if we choose the 2 frequency very differently then what we will see here one loop very large loop if it is gap is very small or we can get a resonance of this here or there is a possibility of using this kind of an antenna, where this patch can resonate at one frequency we can sue this one to resonate at another frequency and thereby we can realise a dual band antenna.

So, in the next lecture we will look about different techniques of tuning the micro strip antenna, and then we will also look into multi band antenna and after that we will talk about how to get circularly polarised micro strip antenna. So, todays lecture mainly you can say we discussed about compact micro strip antenna and how we can get broad bandwidth by using these compact micro strip antenna, I gave you more examples of planar configuration, but the same concept can be applied for the stacked configuration also you can see for more detail chapter 6 of my book broad band micro strip antennas.

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