Antennas
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Module - 07
Lecture – 29
Compact MSA-I

Hello and welcome to today's lecture on Compact Micro Strip Antenna. In the last few lectures we have been talking about micro strip antenna then we talked about broadband micro strip antenna. Now compact micro strip antennas are required where space is a big limitation and we know that in general let us say if we are using a rectangular micro strip antenna then its length should be lambda by 2. Now that lambda by 2 may be very large at lower frequency which we cannot fit in a let us say given size, let us say for a mobile phone. If we take a frequency of say GSM900, which is from 890 to 960. Trying to fit that antenna of lambda by 2 length is going to be very difficult inside a mobile phone.

So, what we need to do? We need to come out with techniques which actually realise compact micro strip antenna. So, welcome to today's lecture on compact micro strip antenna. So we are going to discus about various techniques, how to make the antenna compact?

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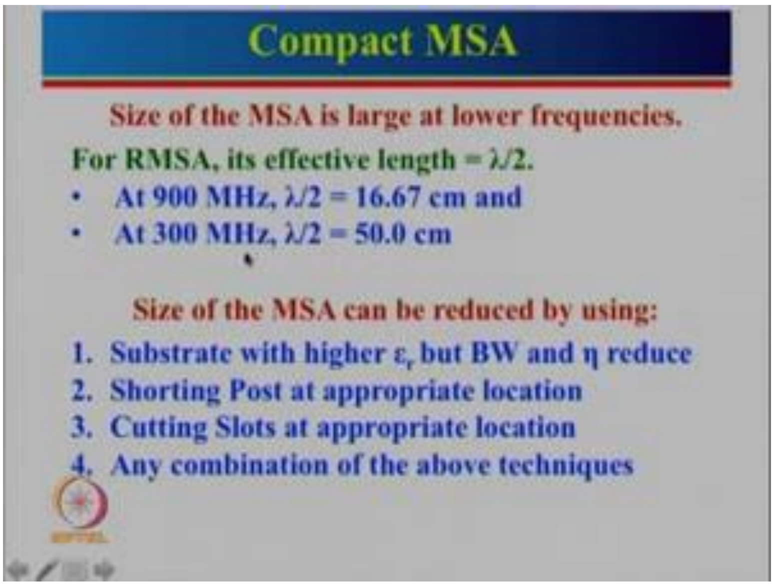

So, let us first look at the need. So, size of the micro strip antenna is large at lower frequency. For example, for RMSA, the effective length should be equal to lambda by 2. So, if you take an example of 900 mega hertz which fall under the category of GSM 900, when lambda by 2 is equal to 16.6 centimetre and if we have to design a antenna at let us say 300 mega hertz then lambda by 2 is 50 centimetre.

Now, of course, this is lambda by 2. Now where as a if epsilon r is high then the size will be reduced. So, what we need to do it is? We need to do some changes so that we can make the size compact. So, the size of the micro strip antenna can be reduced by using substrate with higher epsilon r. So, suppose if we use a epsilon r of say approximately 9.8 or 10. Now effective epsilon r may be let us say 9. So, square root of epsilon r will be 3. So, this dimension will be reduced by three times.

But problem is that bandwidth and efficiency reduce and these are the things we had seen when we discussed about a basic rectangular micro strip configuration. So, now, we need to discuss about some other configuration. So, one of the very popular configuration is using shorting post at appropriate location. So, we will see that where shorting post should be put so that we can reduce the size of antenna. Another approach is to cut slot within the Rectangular or circular or triangular patch at appropriate location. So, that we can increase the path length and hence reduce the size of the antenna. And another possibility is that use combination of all the above techniques.

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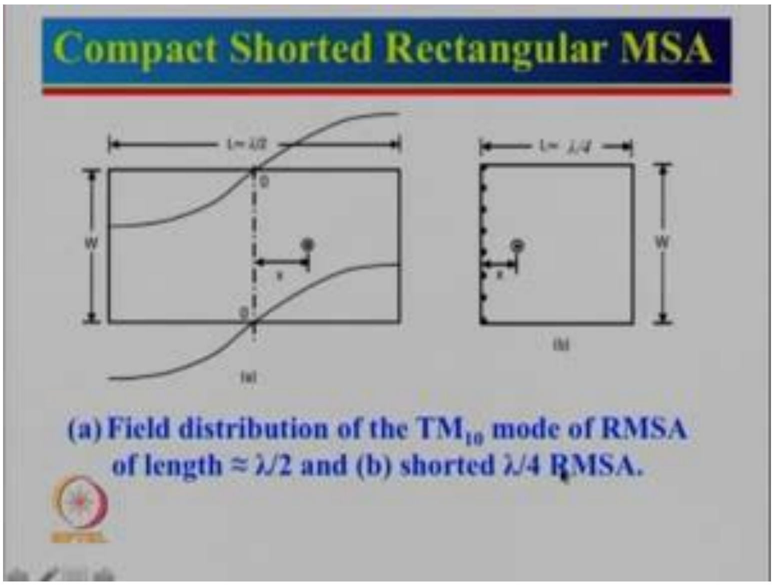

So, let us see one by one. So, we will start with Compact shorted rectangular micro strip antenna. So, here is a configuration which is a rectangular micro strip antenna and for the fundamental TM 10 mode, you know that for 10 mode there will be half wavelength variation along the length and 0 means that there is a no variation along the width. Now for this particular mode, if we look at the field distribution set is going to plus, then it goes to 0, then it goes to minus. Now along this central axis field is equal to 0, now voltage 0 really means that this is nothing, but a short circle. We can actually replace this entire configuration to this simple configuration here where, the total length l equal to lambda by 2 is now reduced to l equal to approximately lambda by 4 where, all these things are shorter.

So, how do we achieve shorting? So, in a micro strip antenna achieving shorting is very very simple. So, all we do it is either we can use a PTH technology which is a plated through hole. So, we have a multiple platted through hole here along this axis and that will connected to the ground plain or PTH facility is not there then drill hole and put the wire solder at the bottom side as well as on the top side. Or instead of putting multiple hole one can also put a full shorting plate over here, a metallic plate can be put from here to the ground and solder all around. And now here is the field point location. So, how will be the voltage distribution? Well now the voltage distribution will be 0 along this axis and it will go from 0 to if I say plus it will be double plus, 0 plus double plus and this will uniform along the width.

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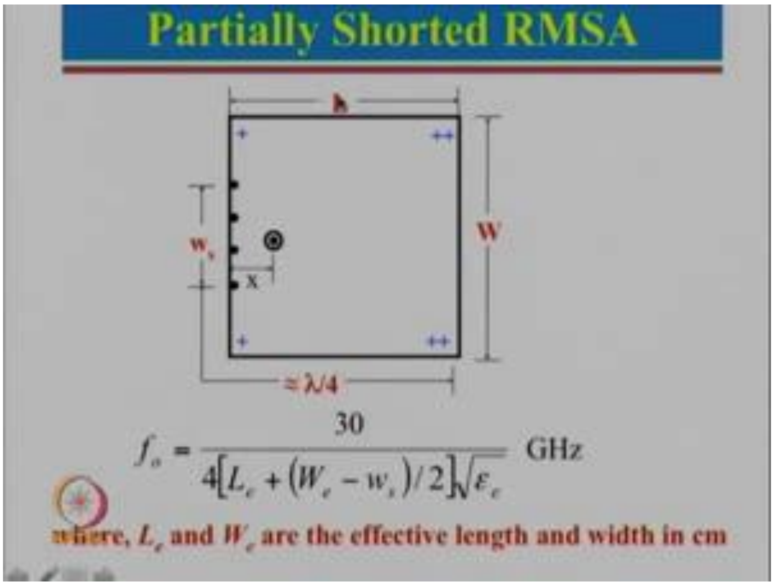

So, now let us see what are the different possibilities we have? So, now, the possibilities what we have either one can do it is we short the entire width. If we short the entire width then this length will be equal to lambda by 4; however, we can do partial shorting of the width also. So, instead of connecting the full width doing a plated through hole, we can just have a smaller number of plated through hole, let us say near the centre. Then what happens now? Now the field is 0 here, which will go to plus then it will go to double plus. Similarly along this field is 0 it will go to plus, it will go to a double plus and field will be uniform over here.

So, now for this particular cases the field is starting from here to 0 to going this to double plus; that means, this length will be approximately equal to lambda by 4. And if this length is equal to lambda by 4, we can find out the frequency. So, this is c. So, c is nothing, but 3 into 10 to the power 10 centimetre in per second. So, that has been converted to Giga hertz and here we have written L e and W e are the effective length and width in centimetre. So, this configuration is nothing, but corresponding to lambda by 4. So, 4 is coming here and what is the total length now, L e will be the effective length corresponding to this and plus W e minus w s that is coming. So, this total W minus this w s and divided by 2 because we are taking only this portion. So, that length has to be added to this length L e and the rest is same as before where, it will be square root of epsilon e.

So, one can actually see that effectively now for the same frequency length will be less. If this particular portion higher and if w s is equal to W e then L e will be the maximum value and if w s is reduced then L e will have a lower value. So, let just see what we have.

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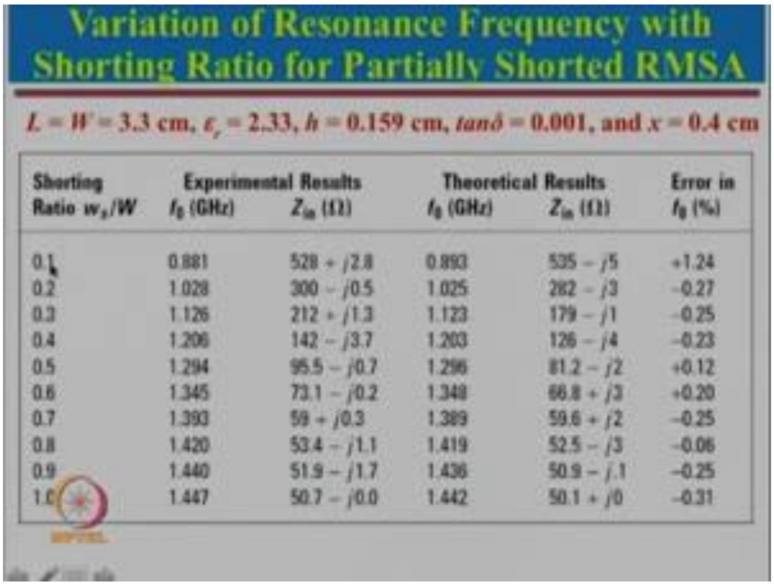

Variation of Resonance Frequency with Shorting Ratio for Partially Shorted RMSA

$L = W = 3.3$ 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, here I have shown a particular case here, there length is equal to W equal to 3.3 centimetres. So, we have just taken a square part and epsilon r is 2.33, h 0.159, tan delta and we have actually kept fixed x equal to 0.4 and we have not tried to optimise for different values of this ratio here. This is just to give you an idea what really happens if the feed point is fixed.

So, what we have done here? We have given a several cases here; shorting ratio which is w s by W. So, that varies from 0.1 all the way to 1. 1 would mean entire width is shorted and 0.1 would mean very small portion of the width is shorted. So, now, let us see if we short the entire width then this corresponds to L equal to approximately lambda by 4. So, that gives me a resonance frequency of 1.447. So, now, if we use lesser number of shorting one can see that the frequency is reducing.

Now, these are the experimental results and these are theoretical results which we have found by using the previous equation which is over here. So, we know over here what is W, then from W we can find W effective. We know what is W’s. So, putting these values since these values are fixed here f is going to change. So, we can see over here frequency is changing and if you look at the experimental frequency over here and if you look at the theoretical they are fairly close to each other. In fact, we have calculated percentage error in f 0. So, if you see except for this case here, for all the other case percentage error is actually less than 1 percent so; that means, this formula is really good and can be used to design an antenna.

So, now let just see what happens to the impedance. So, x is equal to 0.4 for this value of x equal to 0.4, we can see that for fully shorted width we can get approximately matching with the 50 ohm, 52, 53, even 59 are reasonably good as far as the matching is concerned. But then we can see that the impedance is increasing very significantly. Now this does not mean that we cannot do impedance matching for these particular cases here. All we need to do it is since impedance is higher, what we need to do? We need to shift x towards the shorted point because along the shorted edge impedance is 0. So, instead of 0.4, suppose we take 0.3 then these things will be matched. If we take that as 0.2 then these things will get matched and if we take close to 0.1then we can obtain matching for these cases here.

So, just by changing the feed point location we can obtain matching for any of these shorting ratio. So, one can see that this is the case here, which gives rise to the lowest frequency or for a desired frequency you can say this will give rise to the lowest length.

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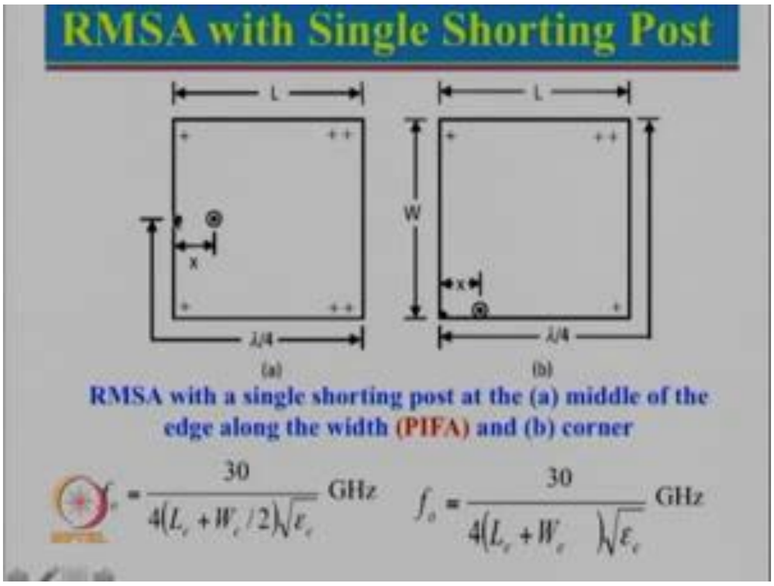

So, then what we have done here? Since we know that w s is small will give us the Compact size. So, here we have used single shorting post. So, single shorting post has been used at the centre. So, then what will happen now? Now this length will be equal to lambda by 4. How will the field vary? It will be 0 here, plus here, double plus here, this will be 0, plus double plus.

So, basically now if you think from the radiation point of view. See earlier just recall for a Rectangular patch we had a one slot here which was radiating and there was another slot over here which was radiating. Assuming if this was the full length, there were two slots which were radiating and we could find the total radiation pattern for a RMSA without any shorting that will give rise to a slot radiation pattern multiplied by the array factor. So, now, there is a only one slot which is effectively radiating and I just want to mention here also. So, this is double plus. So, field will be going outside.

Now, here the field is going out, but this is also going out. So, along these edges will cancel each other. Now over here now this is going from 0 to plus. This is also going to 0 to plus. Plus would mean it is radiating in this particular direction whereas, this is also radiating in this, since this field is relatively small compared to the field over here. So, what we will see that, this actually will result in cancelling the field due to this particular component here and that is why single shorting post generally have a poor efficiency. But will tell you some techniques where we can improve the efficiency, but first let just find out how we can calculate the resonance frequency.

So, in this case we know that this is the length which is equal to lambda by 4. So, then f 0 will be 30 by 4. Again 30 corresponds to c which is 3 into 10 to the power 10 centimetre per second, 10 to the power 9 term has been removed put here in Giga hertz and L e and W e will be in centimetre. So, now, let us see what will be the lambda by 4 length. So, lambda by 4 length will be this length here and along with that fringing field. So, we take L effective from here and this will be nothing, but half of W effective. So, that is a half of W effective. So, this will be now the total length which should be really nothing, but lambda by 4. Square root epsilon e comes as before and again epsilon e has to be calculated corresponding to this particular width here.

So, there is another way to do it also. Instead of putting a shorting post over here, suppose we put a shorting post over here, now how the field variation takes place? It is actually now 0 here, plus here and double plus here. It is 0 here, plus here, double plus here. So, now, effectively the length is actually this length is equal to lambda by 4. So, if this length is equal to lambda by 4. So, now, this expression will get modified. So, now, the length will L effective plus W effective. So, you can see that this will be the expression. So, suppose now you want to design an antenna for a given frequency. So, frequencies do not, sometimes it is easier that you take L equal to W here or here depending upon whether you want to use this configuration or this one.

So, let us say suppose we want to use this one. So, you take L equal to W. So, this whole thing will be 3 by 2 multiplied by L e f 0 is known epsilon e will be known for a given substrate. So, we can calculate what should be the length and that will complete the design. Now based on this concept only there is another concept which is known as PIFA. PIFA is nothing but its stands for Planar Inverted F Antenna. In fact, this whole concept came from, that it actually came from the concept that if we have let us say a monopole antenna. So, this is the monopole antenna. Now monopole antenna will have larger length. So, people came out with the normal mode helical antenna, which has a normally small height. Then another option is that instead of using a monopole antenna of this height, we use a monopole antenna which is bent like this here.

So, the height is reduced, but if we feed at this particular point here then what actually has been seen that the input impedance is not very good; it is very low, in order to get an impedance matching. So, what is normally done? So, this is shorted with the ground plane which is down below. So, from the ground plane it goes up and then this total length is approximately equal to lambda by 4.

So, now since this point is shorted, impedance will be very small and this is an open circuit impedance will be very high. So, somewhere from here to here we can find out 50 ohm impedance and that is what had been done. So, you put a feed point like this. So, this whole configuration looks like not I would not it is a inverted F antenna, it is like F antenna rotated by 90 degree, but that terminology which has been used is inverted F antenna. So, now, this is a normal monopole antenna with inverted F configuration for impedance matching

Now, instead of inverted F monopole, if we make this whole thing as planar, this is planar and then we are still feeding it like this here. So, that is why it is known as planar inverted F antenna. So, now, let us just go back see the configuration here. So, really speaking if this width is reduced significantly this whole configuration will look like a planar inverted F antenna, but if we increase the width here. In fact, what happens if we increase the width, there will be more fringing fields here and that will also give rise to a little better bandwidth also. So, we can use either this configuration or this particular configuration to realise broader bandwidth.

But now I mention to you about the efficiency. So, to improve the efficiency the concept of PIFA is that we actually do not use a dielectric substrate we just use air. So, for air epsilon e will be equal to 1. So, just think about there is metallic plate which is hanging in the air. So, one support is provided by this shorting post with respect to the ground and another support is provided by this feed point.

If some additional support is required, one can put some supporting things over here may be by suing foam or very low dielectric material screw or otherwise if we still use some dielectric, then we need to do simulation of that. But we can put a small these two screws over here and do the simulation. So, that we can note down the effect, but in general just to tell you if you put a dielectric screw here and here to support the antenna then resonance frequency will slightly reduce because now effective dielectric constant because of these dielectric screw will increase. So, it is better to use screw with very low dielectric constant or support can be provided just underneath this, one can use foam substrate which can provide the support.

Now, foam has a dielectric constant of the order of 1.05, which will not make too much of a difference, but even that can be simulated and optimised. So, this is a very popular configuration. So, of course, now there is a only one effective slot which is radiating. So, gain of this antenna will be much lesser than the gain of the rectangular micro strip antenna. But one should look from different point of view; smaller gain also means it will have a very wide beam so. In fact, let us say for a mobile phone we do want an antenna which has a very wide coverage. So, we do not want a narrow beam which will have a high gain. So, since lower gain also imply wider beam. So, it will have coverage. So, suppose if you want to use a mobile phone like this.

So, what you can really do it is that this will be shorted, but we want a mobile phone to have a much wider coverage. So, shorting configurations have been used in the applications where Compact antennas are required and where wider beam coverage is required. So, that we can have coverage all around, but of course, gain is relatively less and by using air and suspended metal what we actually achieve efficiency is very good.

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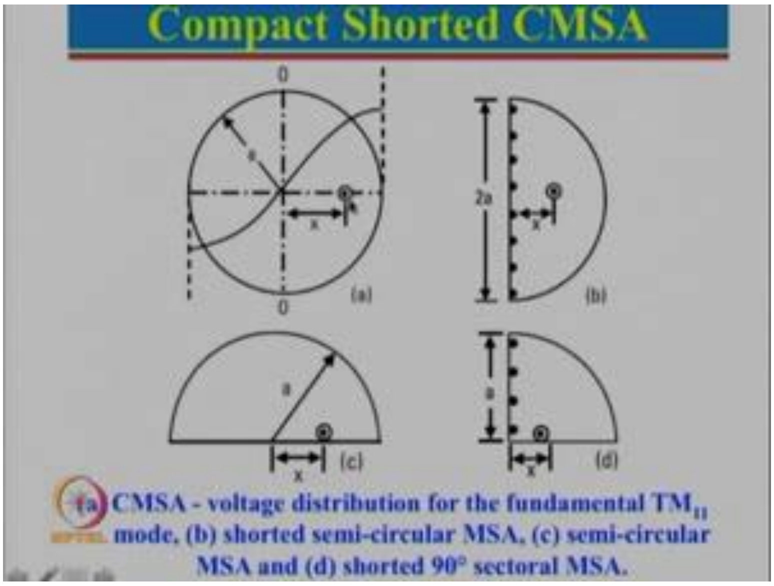

So, now let just look at the alternate configuration also. So, here is a configuration instead of using a rectangle, we can actually use a circular micro strip antenna. So, here is a circular micro strip antenna. So, for a circular micro strip antenna we generally feed somewhere over here and for the fundamental TM 11 mode. So, we know for fundamental TM 11 mode, how is the field variation? It will be plus here, 0 here, minus here. You can see that this is the field distribution and also field distribution will be plus here, 0 here, minus here, 0 here plus then. So that means, along this particular axis field is nothing, but equal to 0 and if the field is 0 and if the field is 0 over here then we can replace this configuration by half of this configuration; that means, this is a shorted semi circle and along this then we can put the shorting post.

So that means, now size is reduced precisely by half and here also one can do one another thing that instead of shorting the entire edge, one can only use single shorting post or one can have a smaller w s like this much here or increase that. So, one can realise a compact, circular or semi circular micro strip antenna which is shorted either fully shorted or partially shorted.

The alternate way to do it is also is that we can use a semi circular micro strip antenna. We had seen that for semi circular micro strip antenna the size is actually half of the circular micro strip antenna. Now for this particular case again we can put a feed point here. Again for the fundamental mode what will happen? So, this will be plus, it will be

0, it will go to minus and along the circumference also it will be plus, 0, minus. So; that means, along this axis field will be 0 and if the field is 0 along this axis we can replace this configuration by this one over here, where now this is one half of this one here where we are putting all these shorting post along this here. So, this would have a one-fourth of the size of this particular circular micro strip antenna. And again here instead of using number of shorts here, we can actually even use a single short over here and by using single short here we can make the configuration even more compact.

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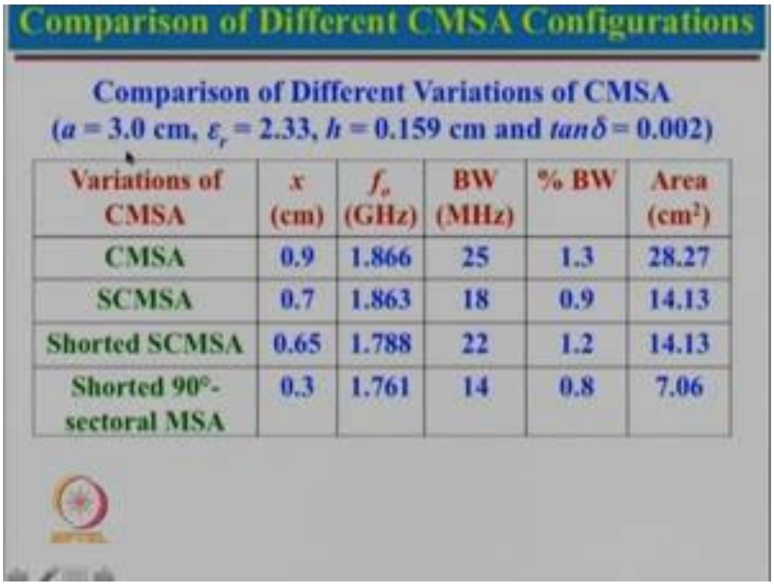
Comparison of Different CMSA Configurations

Comparison of Different Variations of CMSA
(a = 3.0 cm, ε_r = 2.33, h = 0.159 cm and $tan\delta$ = 0.002)

Variations of CMSA	x (cm)	f_o (GHz)	BW (MHz)	% BW	Area (cm^2)
CMSA	0.9	1.866	25	1.3	28.27
SCMSA	0.7	1.863	18	0.9	14.13
Shorted SCMSA	0.65	1.788	22	1.2	14.13
Shorted 90°-sectoral MSA	0.3	1.761	14	0.8	7.06

So, let just look at the comparison of various circular micro strip antenna configurations. So, over here we can just see the case taken is a as 3 centimetre, epsilon r h are given and tan delta is given over here. So, let us say circular micro strip antenna, Semi circular micro strip antenna then Shorted Semi circular micro strip antenna, shorted 90 degree sectoral micro strip antenna. Now in this particular case we optimise the feed point for each of these cases, but first let just see the area y. So, circular micro strip antenna we know what is a. So, we can calculate what is the area which is given by pi a square and for these two the area is half of this here and for this configuration area is one-fourth of that.

So, now let us see for all these cases we had to optimise the feed point. So, one can see that for circular micro strip antenna it was at 0.9 and for shorted it is almost at point 3. Now the resonance frequency for all these four configuration, you can say that there is a very small variation in the frequency and yet the area is reduced by 25 percent. One can that the bandwidth in mega hertz has reduced and one can see also percentage bandwidth is reduced, but if you really try to look at over here this is 0.8 and this is 1.3. So, if you see that area reduction is four times; however, bandwidth reduction is not even 50 percent.

If you see this configuration and this area is reduced by half; however, bandwidth reduction is very very small. So, these are the nice compact micro strip antenna configuration which can actually give rise to the better bandwidth, similarly instead of using a circular micro strip antenna and variation.

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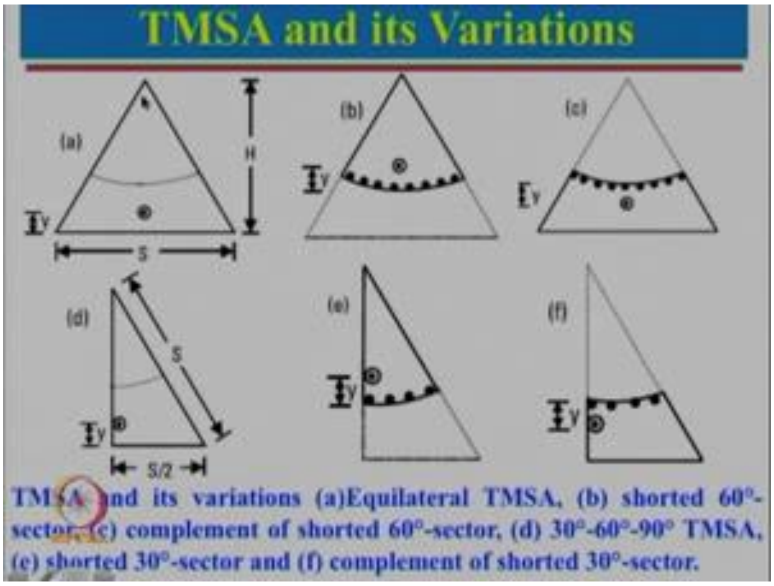

We can actually use the triangular micro strip antenna variation also. Again one has to see what is the field distribution of the triangular micro strip antenna? So, we will actually look into this particular configuration in the next lecture. So, but just to tell you and then will continue from here. For a triangular micro strip antenna again what we need to do it is; we should know where the field is going to be 0 and wherever field goes to 0; that means, voltage is 0 here. We can replace that portion by a shorting strip or shorting post.

So, by using these configuration, we can actually realise a compact micro strip antenna. So, today we have looked into various techniques of using shorting post to reduce the size. But in the lecture will continue triangular micro strip antenna and will see how we can put shorting post at different places. So, that we can get a more compact configuration, but we will also look at other possibility which is by cutting slot and then will use combination of short and slot to realise even more compact micro strip antenna. So, with that bye for now and we will see you in the next lecture bye.