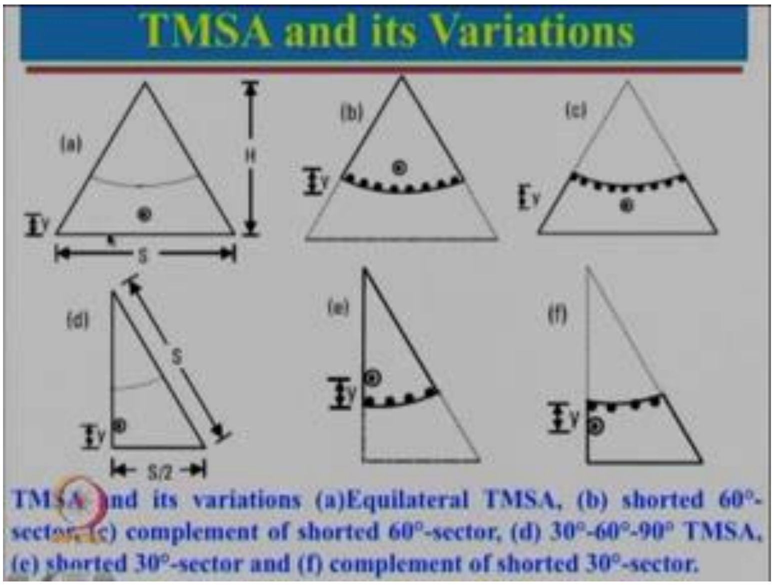
Antennas
Prof. Girish Kumar
Department of Electrical Engineering
Indian Institute of Technology, Bombay

Module - 07
Lecture – 30
Compact MSA-II

Hello, and welcome to today's lecture on compact micro strip antenna. In fact, we had started the concept of compact micro strip antenna in the previous lecture. And where we had seen that there are different techniques are there which can realise a compact micro strip antenna. One of the technique is to use high dielectric constant sub strip, but high dielectric constant sub strip gives rise to smaller efficiency as well as smaller bandwidth. So, but that still can be used. Then we looked at another technique which was by using short in post to put at appropriate places to reduce the size of the antenna. And we looked at 2 different variations. So, we looked at the variations of rectangular micro strip antenna and also we looked at variation of circular micro strip antenna.

So, today we will continue from the same. And will also look at some other configuration where by cutting a slot we can increase the path length and there by realise a compact micro strip antenna. So, let us continue.

(Refer Slide Time: 01:25)



Now, we had just started discussion on triangular micro strip antenna. So, here what we have we have an equilateral triangular micro strip antenna. And for equilateral triangular micro strip antenna we generally let us say if you want to feed along this axis here. So, we can actually feed over here on this side or we can feed somewhere here also. Both the possibilities are there. So, whether we feed here or here this will be the portion where there will be null along the triangular axis.

So, just recall what we had discussed, but when we discussed about equilateral triangular micro strip antenna we had taken a feed point here. And a general notion is that when you take a feed point you put a plus there. So, I had shown you that if this is 0 this is plus double plus triple plus. And along this then it will be 0 minus double minus. And so these will be the constant voltage contours. So, this will be 0. So, this will be let us say plus this will be double plus and this will be minus.

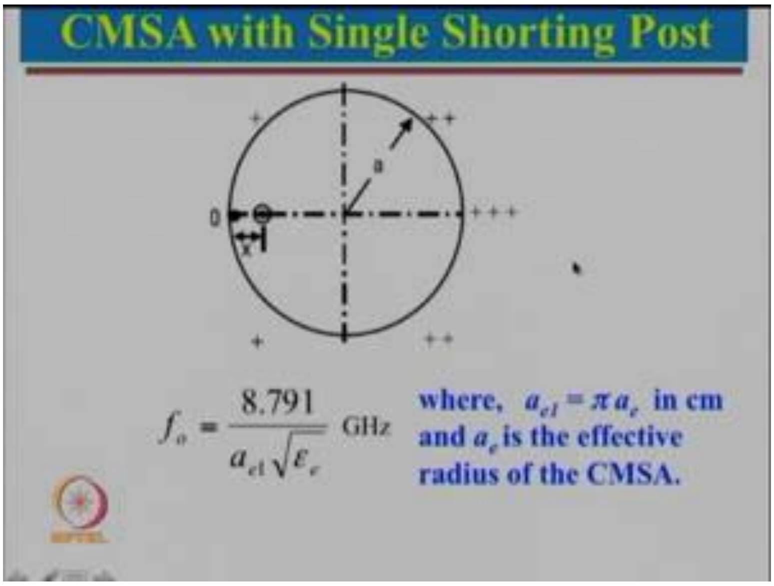
However, if we feed this side here then the notation will be generally then plus here than double plus here, then this will be minus then double minus and triple minus. Means the amplitude should be higher. So, now, since we have a null along this axis, if we short along this one over here and now there are 2 possibilities. Suppose we short here and use only this portion and discard this particular part here. So, this is still part of this over here. Boundary condition is satisfied. So, this will be 0 field and we can feed over here. So, this particular configuration will be nothing, but shorted 60-degree sector.

Instead of using this configuration, one can also use the other part of the configuration. So, here this is will be shorted here. Feed point will be somewhere here. So, this will be complement or this particular portion of the equilateral triangular micro strip antenna. So, here also we have the same possibility, instead of shorting the entire this axis here we can actually just short this single short can be put here, and thereby we can make this whole configuration even more compact. And just like circular micro strip antenna, we went to semi-circle.

Similarly, here equilateral triangular micro strip antenna has exactly the same resonance frequency as that of 30, this is 30 degrees 60 degree and 90 degrees. Or you can call it a half of time equilateral triangular micro strip antenna or generally known as 30, 60, 90-degree triangular micro strip antenna. So, for the point feed point shown over here again. There will be null like this here same way, just half the portion which is over here. So, again now there are 2 possibilities. One is we short this entire thing like this here and we put a feed point. The other is we can use complement of that here. So, we use only this portion and discard this particular portion over here.

So, I just want to mention here. So, the name we have given for this one is shorted 30-degree sector and you can see this is a complement of shorted 30-degree sector here. So, now, all these configurations actually came out from this or this or the concept of the circular micro strip antenna which was extended here.

(Refer Slide Time: 05:16)



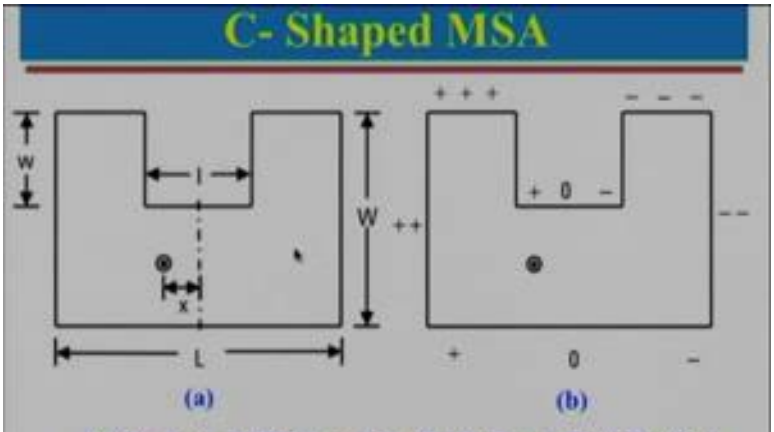
So, now let us just look at the other option for a circle where we just put a single shorting post. So, we had seen that for a rectangle if we put a single shorting post over here then we saw that for the case of rectangle putting a single shorting port suppose just imagine a rectangle over here. So, when we put a single shorting post, this length was like lambda by 4, but over here things are slightly different here. So, let us if you put a short here. So, we are putting the feed point along this for impedance matching. How will be the field variation? It will be 0. It will go to plus, double plus, triple plus, along this also it will be 0, plus double plus and triple plus over here.

So, effectively here now, this will be the mainly radiating edge you can say that. So, this is a curved radiating you cannot call it an edge, but I just said similar to the rectangular part where this will be edge at a slightly curved configuration. Now over here to find the resonance frequency for the fundamental mode, just to tell you this number has come mainly from the simplification k n m. For a circular micro strip antenna is 1.84118. So, the formula for s 0, there we had seen was k n m c divided by 2 pi a square root epsilon e.

So, k n m c divided by 2 pi gets modified to this number here, and the unit will be giga hertz, but this a has now been replaced because earlier this was the short and this was a and the field variation was from here 0 to plus, but over here now this is the effective a. So, this value can be obtained by simply taking a e1 as pi times a e. So, that will be the half of the circumference. So, by using this one here and if you use this particular formula you can actually realise the antenna very simply. So, again here let us say if you want to design an antenna for a given frequency and again if you want a larger bandwidth and good efficiency you can take epsilon e has equal to 1; that means, you take this circular dish in the air you will have a ground plain at the bottom and this one will provide support at one edge then this one will provide the support and that will actually work as a suspended circular micro strip antenna with a short over here.

So, for that given frequency epsilon e will be 1 you can calculate the value of a e 1 which is equal to this that gives the value of a e and that will complete the design of the compact circular micro strip antenna. So, similar thing can also be done for triangular micro strip antenna you can apply the same logic. So, suppose instead of a circle if it was a triangle like this here, then again you can put a short over here, and put the feed point like this, and you can obtain the impedance matching.

(Refer Slide Time: 08:35)



(a) C-shaped MSA and its (b) Voltage Distribution

So, let us just now look at the next configuration, which is by using the slots in the rectangular patch antenna. So, now, just to tell you here this configuration it looks more like a u shape antenna; however, it is popularly known as c shape antenna you just have to rotate your head by 90 degree or imagine this whole configuration is rotated by 90 degrees.

So, now in this particular case what it is. So, rectangular patch is there a slot has been cut like this here, and then we put a feed point over here. Now I want to mention here this configuration had been reported before we started looking into it. So, I just want to tell you a little bit story also over here. So, that you realise that we professors are also human being. So, actually I had a one MTech student. So, I had given him this particular configuration to look at it and even some of the triangular configuration to study and see how compact antenna can be realised. And he was a very good student, but yet he was struggling the reason for that is was that in the literature they had talked about compact micro strip antenna they mentioned about that c shape is compact and other thing, but the field distribution the real explanation what was happening was not there.

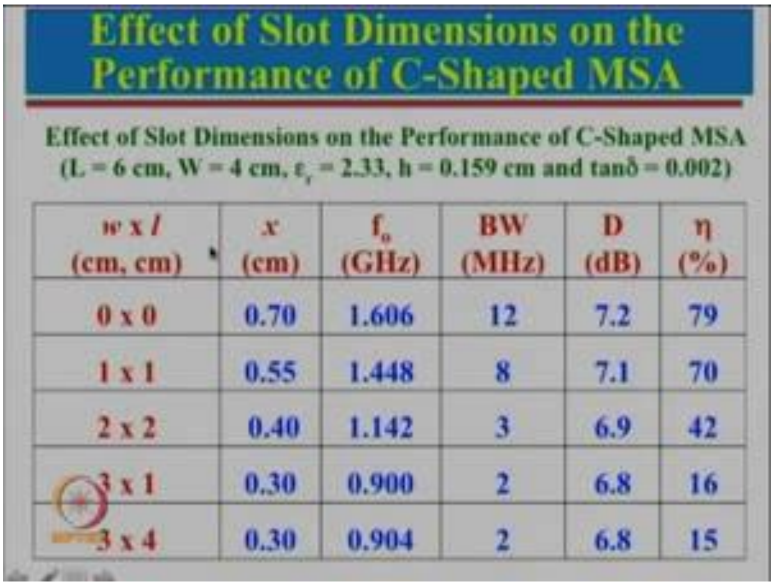
So, I actually told him. So, you had he had collected some 10 15 paper. So, I just told him that why do not you give me all those paper. So, one night after dinner I sat down with that bundle of the papers and by next day morning 4 am, nonstop study of about 7 hours or so. So I actually had my eureka moment right just like Archimedes. So, I had that eureka moment. So, next day I called that student and also I called another of my PhD student and I explained all these things how it works how it is done how the slot is cut and even for those micro strip antenna which I told you about the triangular one and how do we cut the slot there.

So, actually speaking since these are very good student dedicated student. So, within 2 months they actually were able to analyse do the experiment and we were able to publish 2 papers in the electronics letter. So, just from not knowing how things are working. So, just by spending that 7 hours. So, really I wish that I should get more of those eureka moments and we can do lot of good research work in time to come anyway. So, let us come back to this particular c shaped configuration and see what really happens over here.

So, now I can explain you in a much better way. So, you think about this is the antenna and this slot had been cut over here. So, by cutting this slot, what actually has been done? See earlier for a rectangular patch the way we have shown the feed point this would have been the length. So, that would be the length of the rectangular patch, but now this length is still there, but now the length is going to be for the other part. So, this part length is still L, but for this part from here the length is going to be like this here like this here like this and it will go like this so; that means, now effective length has increased. So, we actually came out with a very simple one-line formula also we put some 2 condition and that is I this depth is not much then what we do we take the average of this length as well as this length over here and that will give us an average length make that equal to lambda by 2 and you can find out the resonance frequency, but if the depth is very large and also if this is think about it is made something like this here. If that is the case, then the effective length is to be taken as like this here at this average and it goes over here and comes back here.

So, by this particular way you can calculate what should be the total length corresponding to lambda by 2, just to show you the field distribution, now since this is the symmetrical axis here. So, that is a field is 0 here 0 here and then the field varies from here as 0 plus goes to double plus goes to triple plus. Similarly, along this the field goes 0 plus double plus. And then this side here it is minus double minus triple minus and this is 0 minus double minus and then triple minus. So, this is how you can think about the effective length if this depth is less effective length is average of this length and average of this length here, if depth is more again then the average length to be taken as this to be equal to lambda by 2 here.

(Refer Slide Time: 13:40)



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

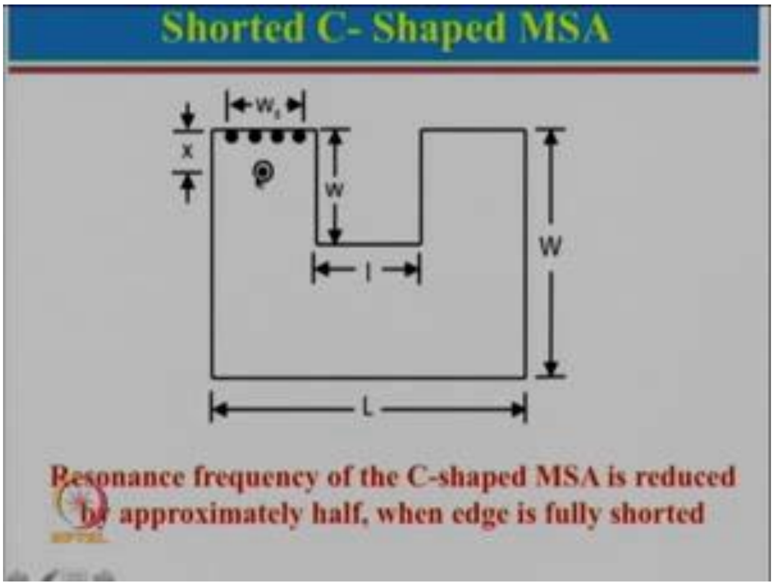
So, let us just see we actually came out with the lot of studies which we did, so that we can come out with these simple equations. So, we actually have here effect of slot time dimension. So, we took l equal to 6 centimetre w equal to 4 centimetre and these are the sub straight parameter and then what we have done over here w and l, just let us just go back here. So, w is this one here. So, that is w and this is the length of the slot, corresponding to this. So, if w is equal to 0 l is equal to 0; that means, no slot is cut. So, that represents a rectangular micro strip antenna. So, when no slot is cut this is f 0 we can see this is the resonance frequency, but as the slot depth is increased. So, 1 by 1, 2 by 2 and different cases here one can see that the resonance frequency is reducing from 1.6 to 1.4 down to close to 0.9 giga hertz.

So, there is not much of an advantage over here and feed point had to be shifted accordingly. So, 0.7 0.55 so; that means, these feed points are getting closer to the centre point. The reason is that impedance variation is increasing. Since impedance variation is increasing; that means, at the edges impedance is becoming large. So, if the impedance is becoming large we need to move towards centre point.

Now, what we can see over here the bandwidth. Now the bandwidth is drastically reducing for all these configurations you can see that. So, even that the frequency is reducing, but bandwidth is also reducing drastically. Now this directivity I just want to tell you. This directivity calculation has been done for infinite ground plain. And most of the time we may not be taking n finite ground plain. So, these directivity numbers please do not use it is only for infinite ground plain. For finite ground plain depending upon the size of the finite ground plain you have to calculate directivity or gain accordingly, but this we had taken it. So, that we get a reference that what happens if it is infinite ground plain.

Now, correspondingly we can see efficiency has gone down drastically from 79 percent efficiency it has gone down to about 15 to 16 percent efficiency. So, these are not really very good antennas from efficiency point of view, and hence they are relatively poor radiator and also bandwidth is relatively small. So, we need to use some broadband techniques to increase the bandwidth. So, few simpler things can be done first is we can reduce epsilon r equal to 1. So, that will help in increasing the bandwidth and h can be increased. So, by increasing h we can again increase the bandwidth, and if epsilon r is made equal to 1, we know that that will have a little larger curvature. So, efficiency will also improve.

(Refer Slide Time: 16:59)

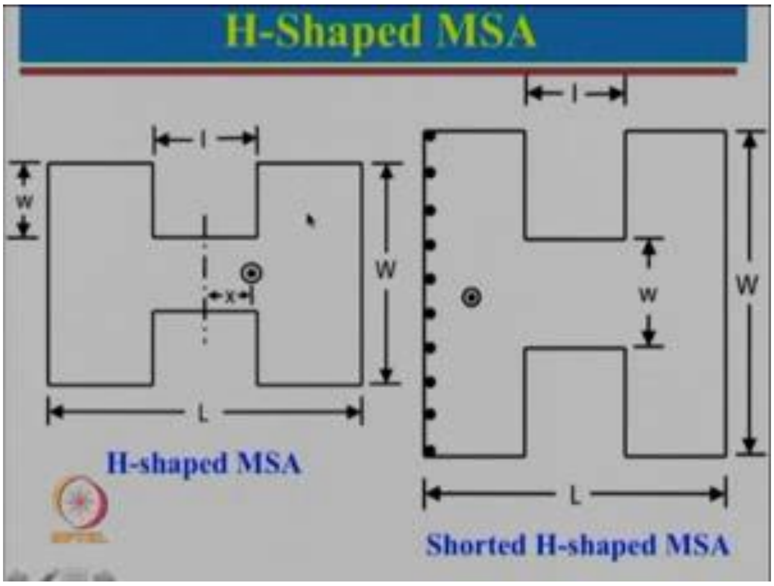


So, from here we can even realise another compact configuration. And that is by using combination of slot and short. So, if you put a short over here, now there are 2 ways to put the short let just go back for a minute. So, over here there is a one possibility is that we use shorted point over here. So, if we use shorted over here, then we can discard this particular portion and then this length will be roughly let us say equal to lambda by 4. And then instead of calling c shaped we can actually call this shape as a l shape. So, that will be a l shape antenna. Alternatively, we can put the shorting post like this over here. So, if you put the shorting post over here. So, the name is shorted c shaped MSA, you can actually call it a shorted u shaped MSA also nothing wrong with that also.

So, now this is a 0 field here we can put the feed over here, and then this length will be effectively equal to lambda by 4 instead of lambda by 2. So, size is again reduced by 50 percent. And over here also instead of shorting this entire edge here we can actually do a partial shorting also. So, if we do the partial shorting, suppose if we put a single feed point here then what will happen instead of lambda by 4 length like this, now the lambda by 4 length will like one path and this will be the another path here.

So, that can also be done to realize the compact configuration. So, you can say that this particular configuration uses combination of slot as well as short.

(Refer Slide Time: 18:55)



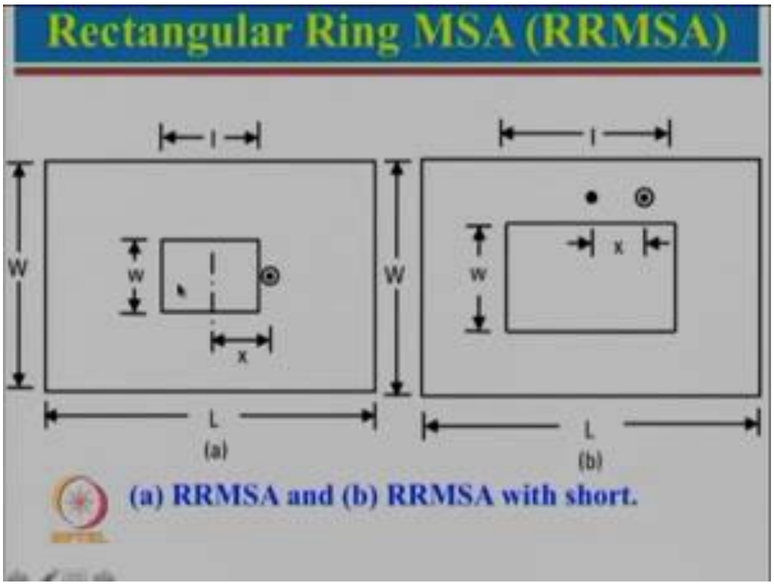
So, now will look into another configuration in fact, I prefer this configuration then a c shaped configuration. So, this one here more known as a H-shaped antenna. So, this is H-shape here, but if you look at a 90 degree angle you can actually also say it is a I-shaped antenna. So, whatever term you like, but in the literature it is known more as a H-shaped MSA. So, now, just to mention here, think about if this particular slot was not cut only this was cut. So, this will look like a c shaped antenna, but now by cutting this slot here, this is more symmetrical with respect to this particular axis over here.

So, now in this particular case how do we calculate the resonant length? So, here again there are 2 paths we have to see. One path is from here to here and that will give me the length l, and then there is another path is going from here to here and then this path here. So, what we need to do it is we need to take average of the 2 length and that average of the 2 lengths to be equated to lambda by 2, by doing that we can actually reduce the dimension. So, here also just like c shaped antenna we can change the slot that and we can change the resonance frequency and we can realise a compact antenna. So, let just see one more thing here. In this particular case I also want to mention efficiency of c shaped we had seen is not. So, good, but H-shaped has slightly better efficiency will look at a comparison little later, but just to tell you what really happens here. So, this is the 0 field, then let us say it is plus double plus and let us just use term this is a triple plus here and a triple plus minus here. So, because we have shown plus sign feed here that is why I have said triple plus this will be triple minus. So, triple plus means plus would mean field will be going in this direction and if it is minus again field will be in this direction. So, these 2 slot will be radiating effectively in the broad side.

However, starting from here there is a 0, there will be plus it will be going towards double plus and then go to triple plus. Same thing here 0 minus double minus tripled minus. So, now, just look at this here. So, this is plus. So, this plus is in this direction field. Now this is also plus. So, this plus will try to radiate in this direction. So, this plus and this plus they are in the opposite direction. So, some field gets cancelled, because of this particular region here. These 2 are not a big problem because they are anyway along the non-radiating edges. So, they do cancel each other which is the same thing as in the case of r MSA. So, over here then this is 0 plus again double plus triple plus. So, this portion cancels part of this one here this portion cancels part of this over here, and that is why these are not very effective radiator as good as let us say rectangular micro strip antenna, but that is the penalty we have to pay when we are going for a compact micro strip antenna.

So, again here now we can realize 2 possible configurations. One is we can just use the shorting along this entire axis and we can discard this particular portion here. So, if this is shorted here we can actually then call it let us say a t shaped shorted micro strip antenna. Or we can do the shorting along this entire edge. So, if we do the shorting along this entire edge. So, the now the name will be shorted H-shaped micro strip antenna. I can feed at this particular point over here for the impedance matching. Again one can change the number of shorting post over here instead of shorting the entire edge we can actually just short over here and in that case then the effective length will be increasing and that would mean that this length now should be equal to lambda by 4. So, the compactness will come. So, for a given frequency one can realise relatively a compact H-shaped micro strip antenna or shorted H-shaped micro strip antenna.

(Refer Slide Time: 23:33)

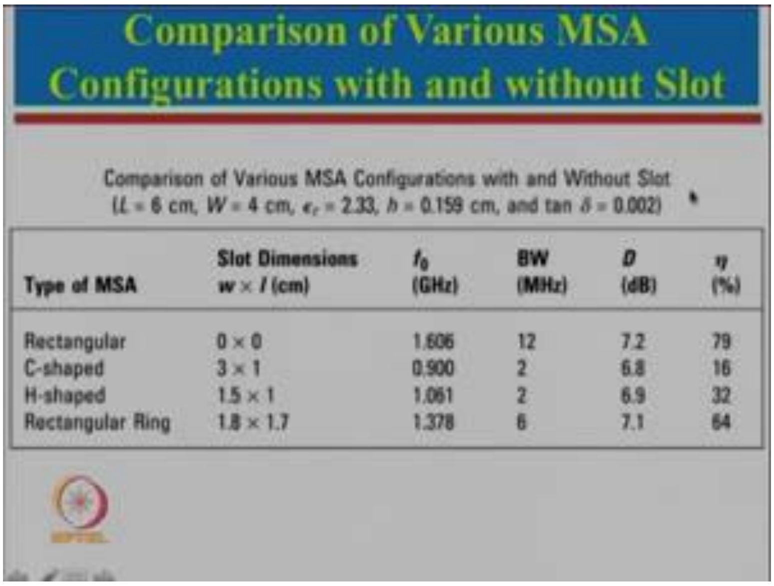


So, now let us just look at another configuration, which is a rectangular ring micro strip antenna. So, now, a ring is cut inside the rectangular micro strip antenna. So, if the ring is cut over here. So, now, what will happen if the ring was not there what happens, then this length is equal to lambda by 2 because the current will be flowing from here to here, but now what happens if we cut the slot like this here. So, in this portion effective length will be lambda by 2, but in this case here now the current will flow like this it will go up here and then it will come and then it will go like this here so; that means, the effective length is increased.

So, if the effective length is increased so; that means, now the total length should be equal to lambda by 2. So, I will just tell you. So, what we need to do take this length and then another length will be this plus this over here and take the average of the 2 and that should be equated to lambda by 2. So, now, in the literature they had reported, that when this particular slot has a larger dimension which is somewhat something like this here. So, they were not able to do the impedance matching, because see over here earlier the field was 0 and then the field was plus over here and then another double plus here. So, one could get a 50 ohm matching, but now if we have a larger slot dimension then at this particular point 50-ohm matching does not come, most of the time people actually just said if you take a larger slot you cannot get an impedance matching. So, we thought of an alternate solution. So, what we did actually we forced the boundary condition, we put a short circuit over here. So, now, by putting a short circuit what we did we actually compelled the boundary condition to be here to be 0, and now this will become plus.

So, now the total thing will be being the length should see, earlier now the length from here to here would have been lambda by 2. So, the total loop length you can think about now it is almost resembling a loop of course, a loop with a much larger width. So, this is like now a loop antenna and that dimension the median dimension should be here equal to lambda. And then by putting this here we can get the impedance matching. Now this is still here in this case also this is still a e plain. I will explain that also because this is not 0 plus let us say double plus double plus 0 then minus double minus double minus 0. So; that means, field is along this side along this direction and along. So, this is still the e plain. So, even though we are putting the feed over here, e plain still is in this particular direction. So, please do not get confused about that particular part.

(Refer Slide Time: 26:52)



Comparison of Various MSA Configurations with and Without Slot (L = 6 cm, W = 4 cm, ϵ_r = 2.33, h = 0.159 cm, and tan δ = 0.002)

Type of MSA	Slot Dimensions $w \times l$ (cm)	f_0 (GHz)	BW (MHz)	D (dB)	η (%)
Rectangular	0×0	1.606	12	7.2	79
C-shaped	3×1	0.900	2	6.8	16
H-shaped	1.5×1	1.061	2	6.9	32
Rectangular Ring	1.8×1.7	1.378	6	7.1	64

So, now let us see the comparison of different configurations. So, we can actually see that different shapes have been realised by cutting the slot. So, we started with the rectangular then we saw c shaped then we saw H-shaped and then we saw rectangular ring. Again for comparison we took exactly the same dimension, l equal to 6 centimetre, w 4 same epsilon r h parameter as in the previous case. So, what we have here different slot dimension so; that means, slot 0 by 0 is really nothing, but a rectangular patch. And we can see that the resonance frequency is about 1.6 giga hertz.

Now when we look at the c shaped if this is the depth which we had taken. In this case we can see that they have come down to 0.9 and that is about the bandwidth here and for H-shaped for the same cross section we need to cut half of this one, 0.5 into 1, that will be on the upper part and the lower part. So, the cross section will be same and in this case resonance frequency slightly higher than the c shaped bandwidth is also similar. So, you may say there is not much advantage.

But look at the efficiency of c shaped is only 16 percent whereas, efficiency of h is about 32 percent which is about double of that now in case of rectangular ring when we cut the slot in the centre the frequency reduction is not very significant. You can see that 1.6 has become 1.378. Unlike 1 or 0.9, since the frequency reduction is not significant, bandwidth is still higher than these 2, but yet much lesser than this bandwidth here. And efficiency is still comparable to this one here. So, these are configurations which can be obtained by cutting a slot and we also saw that by using the combination of the slot and the short frequency will reduce further or the size will reduce by 50 percent. Now the only limitation and the problem with these configuration is the bandwidth is very small.

No in the last lectures, we had talked about several broadband techniques. And those broadband techniques we had applied for rectangular patches or circular patches or triangular patches over there we what we had done was we added the patches next to each other and we went horizontally or we went vertically we start them. So, now, instead of using those rectangular or circular patches, what we are going to do in the next lecture we will use these compact configurations. And we will use these compact configurations by using gap coupled or directly coupled ore start configuration and will realise much larger bandwidth and yet overall size may not increase significantly as compared to rectangular or circular patches.

So, in the next lecture will talk about compact broadband micro strip antenna. So, with that thank you very much. We will see you in the next lecture, bye.