Antennas
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Module - 06
Lecture - 26
Broadband MSA-III

Hello and welcome. In the last lecture we have seen how we can increase the bandwidth of the antenna. So, we had actually notice that the bandwidth of the antenna can be increased by increasing the substrate thickness or by reducing dielectric constant. Then we also look at the multiple resonator techniques, where we had put one patch on the one side of the rectangular patch antenna, and this was the parasitic antenna not fed only one patch was fed, and we actually notice that the bandwidth of the antenna can be increased. We also saw the parametric effect what is the effect of the gap; that means, if the gap is increased coupling is reduced, and there by loop size is reduced; you also saw what is the effect of the feed point. That means, if we shift the feed point towards the edge, the whole impedance shift towards the higher impedance value.

We also saw what is the effect of the length of the parasitic patch. So, as the parasitic patch length increases it is resonance frequency will decrease, so the loop will shift in the anti clock direction; of course in the last lecture I had mentioned if the patch dimension is decreased from 3 centimeter to 2.8 centimeter, it is resonance frequency increase hence the loop moved in the clock wise direction. So, you understand that what happens if the length changes. So, then what we had seen instead of 2 gap coupled, we have put three gap coupled antenna because by putting three gap coupled antenna the pattern variation was relatively less over the bandwidth, and the radiation pattern was in the broad side direction.

Then we talked about non radiating edges, so where we have put the patches along the non radiating edges and again we saw that the bandwidth can be improved. So, now, today we will see that how we can put patches on all the 4 sides to get the better bandwidth compared to the earlier 2 things.

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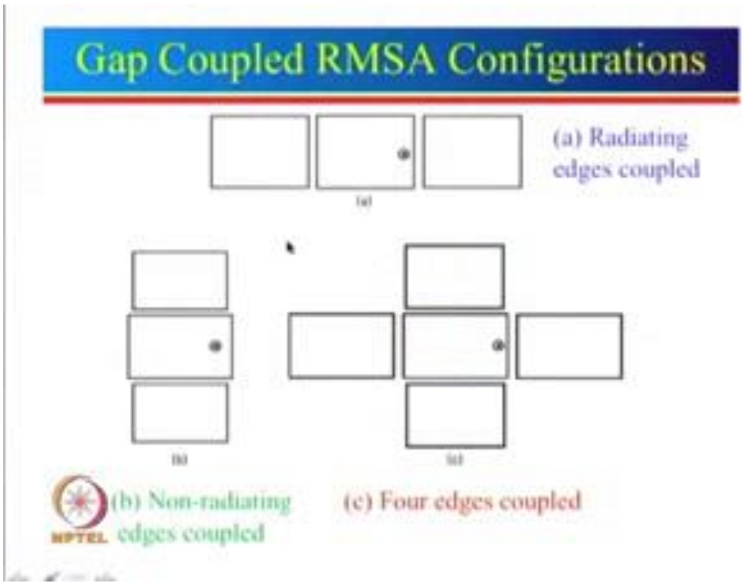

So, let us see the configurations now. So, we had actually looked at radiating edges coupled, where we have put the antenna along the radiating edges and what we have also noticed that the radiation pattern varies in E-Plane, but there is no change in the radiation pattern in the H-Plane. Then we have put parasitic patches along the non radiating edges and again in this case we had mentioned that this case now the pattern variation in E-Plane will be not there, but pattern variation in the H-Plane will be there because parasitic patches are along the non radiating edges.

So, here we have now 4 edges coupled rectangular micro strip antenna, where antennas have been put on both the sides here. So, here now again we can choose patch length here let us say L 1 L 1 so that this will be symmetrical; we can take these 2 patches as L 2 L 2. So, what that would really resultant into? At L 1 these patch will be resonate and it will be symmetrical, and at the slightly frequency then this patches will be resonant and since it still symmetrical pattern variation will not be there over the bandwidth, and by choosing the 2 lengths different L 1 and L 2, we will see that 2 different loops can be obtained in the smith chart plots.

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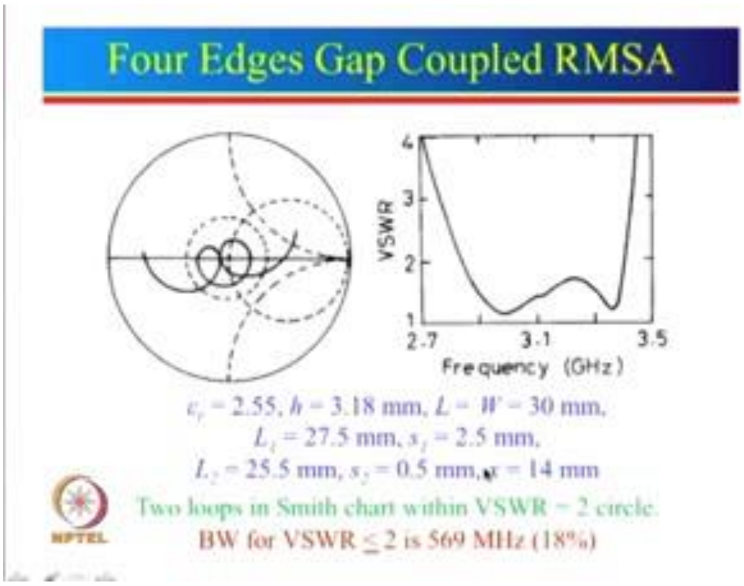

So, let us take one of the examples now. So, we will take similar example as before which is the substrate parameters are same epsilon 2.5. We have taken thicker substrate as an example, so that we can get a larger bandwidth. But compared to the previous case width has been reduced, the reason why we reduce the width. Actually we were not able to get the impedance matching by using a simple co axial feed point, so that is why we reduce the width here and now L 1 which is along the radiating edges is 27.5 mm and the gap is 2.5 mm.

So, I had mentioned that along the radiating edges, gap can be little larger; whereas, as along the non radiating edges we have kept this dimensions smaller than this here, so that it will have the slightly higher frequency, along the radiating edges gap has to be small then that is reduced to 0.5 mm. I just to mentioned again earlier we were taking in centimeter, here we have mentioned the dimension in millimeter. Now the feed point is 14 mm, you can see that L is 30. So, half of L will be 15 mm. So, this is almost at the edge of the patch. So, now, we can see there are 2 loops in smith chart, so let us see this is the loop response over here.

So, this loop is corresponding to length L 1, and then that is appearing at the lower frequency and then while it is completing another loop is formed because of this length here, and hence we see 2 different loops here. And one can see that both the loops are within VSWR equal to 2 circle, and that gives us a larger bandwidth. So, this is the

VSWR plot versus frequency. So, if we draw a line from here, you can see what will be the VSWR less than 2 bandwidth, which we can see here that the bandwidth is about 569 mega hertz that is close to 18 percent, and this is much larger bandwidth infact in case of radiating edges we had got a bandwidth of roughly around 12 percent, and again for non radiating edges we got around 12 percent, now we are getting about 18 percent bandwidth ok.

Now, of course, here it require slot of optimization techniques to bring both loop inside the VSWR equal to 2 circle. So, these lengths can be optimized; so, just to give little bit the concept here. So, if this length is taken let us say larger than this, if it is large what will happen? It is resonance frequency will reduce. So, the loop will be formed somewhere here and the gap over here controls the size of the loop here; so one can actually reduce or increase the gap.

Similarly over here now this loop dimension if we take let us say slightly larger, then what will happen? If this is larger this loop instead of coming over here it will actually form right over here also, but if we take less dimension then this, then the loop will go outside that VSWR equal to 2 circle. So, it is really important to optimize the gap the width of the patch also plays an important role, because by reducing the width we can actually try to optimize the feed point location. So, no external impedance matching is required there.

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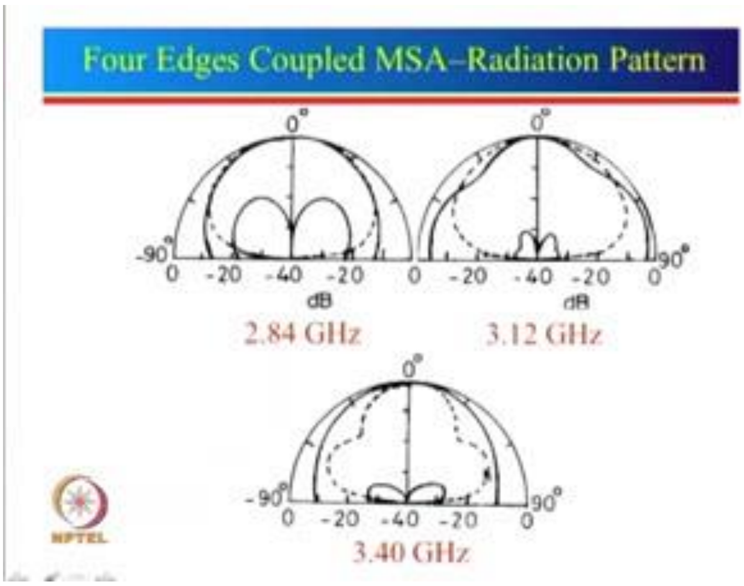

So, let us see the radiation pattern. So, here we have shown the radiation pattern at 3 different frequency; one is near the center and this is on the lower band edge and this towards the higher band edge. So, at the lowest frequency it is central patch which is resonant, so the radiation pattern is in the broad side direction. Now at in between frequency now just to recall, this is the patch dimension along the radiating edges. So, this will be the intermediate frequency and this will be the highest frequency. So, you can see that that H-Plane pattern is not changed much, but E-Plane pattern has changed, but it is still in the broad side direction. Because the patches long the radiating edges are more dominant over here, at the higher frequency patches along the non radiating edges are more dominant.

Now, one can see that E-Plane pattern has not much changed here you can see somewhat similar; but now H-Plane pattern has changed. So, one can see that this is the H-Plane pattern. Now you can actually notice one additional thing, that for the H-Plane pattern this one has a much higher value compare to the H-Plane pattern. Now see this can be explained in the simple way along the E-Plane we have a pattern, which is relatively has a higher value. But along the H-Plane the element pattern is relatively going towards 0. So, it is this value here which is getting multiplied to the array of the element, and that is what it is bringing back to close to 0 here. Otherwise it would have also had followed the similar trend going out, but since the patter of the element itself is going towards 0. So, 0 getting multiplied with this array factor point here it tries to bring to 0 here.

So, hence the H-Plane pattern looks relatively better compared to the E-Plane pattern. So, now, because of these multiple patches gain also a slightly more than the single patch; so that means, by using the 4 gap coupled antennas what we can achieve? We have achieved a much larger bandwidth and we have also achieved higher gain. I also want to mention here if we had taken this length L 1 L 1 L 1 L 1 all of these are taken all of these are taken as L 1, then what would have been happen there would have been only 1 loop in the smith chart plot, but then all the patches will be resonating simultaneously.

So, it actually gives rise to higher gain. So, there is a trade of between the gain bandwidth, you know that in general bandwidth product is relatively constant in the case of an amplifier; well it is not always not applicable 100 percent to antennas, but somewhat applicable here. So, over here just to repeat this is L 1 L 1 and If this is L 2 L

2 we will get a broader bandwidth, but slightly less gain, but if we take this L 1 L 1 L 1 L 1 then bandwidth will be slightly less, but gain will be slightly more.

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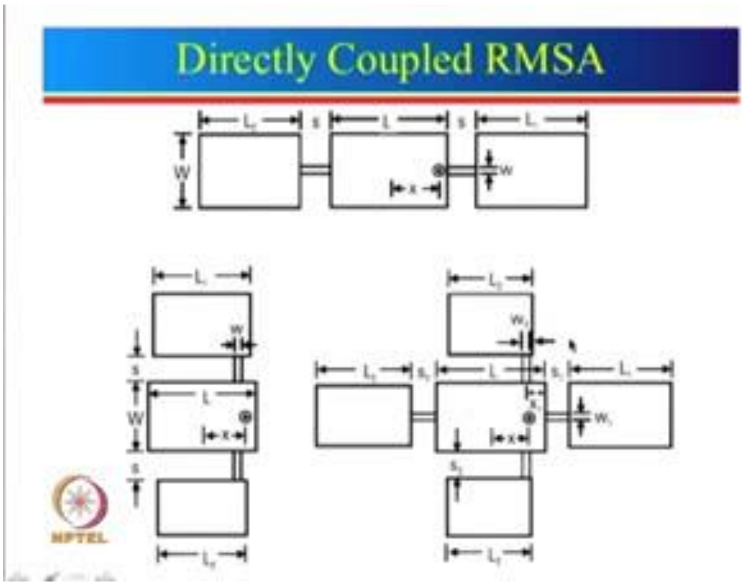

So, instead of using this gap coupled one can go to the next configuration, and which is known as directly coupled RMSA. So, here just to show. So, this is a radiating edge coupled, this is non radiating edge coupled and this all 4 edges coupled. Let us just look at 1 by 1 now; for the radiating edge couple you can say that a line strip is connected over here. So, here the coupling is controlled of course the gap s, what we have try to do here? You have taken this gap as now greater than 2 h where h is substrate thickness; because you recall absolute maximum of the fringing field can be extend to a about edge and thus can be extended to s.

So, if we take greater than 2 edge gap coupling will not be there. So, direct couple where the gap is generally taken as larger; however, we can also use the hybrid coupling where s will smaller than 2 h, then there will be gap coupling also and there will be direct coupling also. And here the coupling depends upon the width of the connecting strip over here, and by optimizing now this gap and this width of the thing one can actually optimize the coupling between the patches, and hence one can optimize the bandwidth in a very similar way as that in the case of the gap couple.

Now, in non radiating edge there is there is one additional parameter, which controls the coupling between the patches. So, over here it was generally the width of the strip here which was controlling the coupling. But over here the location of the strip also controls the coupling; the reason for that is over here the radiation is uniform along the width, but along this length here field variation is sinusoidal; that means, this is plus here, 0 here, minus here. So, it varies sinusoidally plus 0, and going to minus here. So, if we connect right at the center here and center here, actually speaking there will be absolutely no coupling to this particular patch because the field is 0 here. So that means, now if we move this strip here along this side, since the field is increasing so as we move this connecting strip along this direction coupling will increase.

So, here coupling to this patch or this patch here will increase, if we shift the coupling strip location along this edge and also what will be the width of the strip over here. So, now, we have many more parameter which can be optimized to get a broader bandwidth. Now over here the same concept is extended, so the edges are coupled along this here, and the edges are coupled along this one here. Now I want to mention here that this concept is different than the array, infact I just want mention.

So, we had written paper on directly couple RMSA almost more than 30 years back in 1984 also, and I also want to mention that what we have covered about the directly coupled and so as well as gap coupled rectangular micro strip antenna, all these were part of my PhD thesis, which I stared working in 1979, and submitted the PhD thesis in 1982. And I just want to mention that see micro strip antenna practical part came only in about 1974, when Manson had proposed micro strip antenna. From 74 to 79 hardly 5 years had passed and very little literature work was available. So, in the beginning it was really a lot of struggle, so we really had to do lot of optimization we had to do, lot of programming also; and those days I have written program on FORTRAN, and it did PhD from IIT Kanpur. So, when I started working on this.

So, we did not had this fancy terminals and we could work on that, and those day we had to punch each and every line on a separate card and we will have the stack of these card, we will go to the computer center give it over there and then if there is even a small mistake it will just give the errors, then you get the print out of error you go through that, you correct the thing and you again submit it and then even if the order changes again you will get all the error messages. So, it use to take lot of time, those days when we were working on these things and of course, while I was doing PhD then these terminals came, and then we started having you know enjoying luxury of using the terminals.

But the computers were really really slow and during the day it was really difficult thing computers were so slow, the terminals were fully crowded, students were working. So, just to tell I always use to be a morning person use to get up early 4.30 A.M would study for 2 hours then do my class work and other thing, but then during the PhD program then I have actually became an night person, because I realize that computer center was relatively free because less students were going during the night time, I am talking about 1980 also. So, then I developed the habit of going after dinner and then work almost whole night and then come back to hostel, take breakfast and then start the day.

So, from those days now we have the luxury of the computers desktop right on our rooms here and we can actually use the power of the computer. But never the less when we submitted this paper here, so the reviewers had asked us one questions, how this particular thing is different than arrays of antennas; because in a array what we do? We also feed all the elements, it also looks like it is not really a parasitic element we are feeding this one here and this one.

So, I actually gave the explanation that this is different than the array. So, in the case of array what we do? We have all the patches of equal dimension, and then all the patches are fed with let us say if you want a broad side radiation, then all the patches are fed with equal amplitude and equal phase, and that would mean that the phase difference between this and this should be. If I connect here it should be 180 degree phase shift to be given, or if I feed here and here then this should be 360 degree phase difference, so that that will amount to 0 degree phase difference.

So, over here we have optimized further bandwidth, not for the gain. In the case of the array we do not optimize for the bandwidth, but we optimize for the gain here. So, it is not same as array antenna. So, here we have chosen the patch dimensions slightly different, so that we can get the broader bandwidth. So, these details now you can also see in my book broadband micro strip antenna and in fact that book is freely available now through the internet. So, you can download also and you can purchase it or it is available from the (Refer Time: 18:43) also it is your choice.

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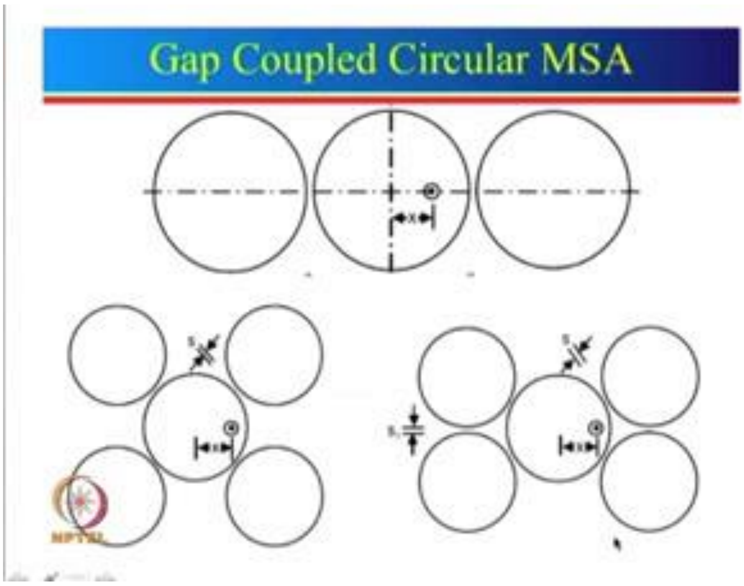

Let just move to now the next configuration, which is gap coupled circular micro strip antenna. So, here we have a circular patch here, and the 2 patches are put on the left and right side, just like a radiating edge here. Now here I just want to mention here that during my PhD thing I had worked on mainly on the rectangular micro strip antenna, and we had proposed some broad band configurations using rectangular micro strip antenna, or circular micro strip antenna.

Fortunately for us nobody really had the work on this configuration, and I revived this configuration almost you can say 15 years later then my PhD. So, it was much later we started working on this here, and I now just want to tell you. So, those days I did not have this fancy commercial software like I 3 D or CST, microwave studio, ADS, HFSS and so on. So, we thought why not we do one experiment. So, we put the patch over here and we put the patch on this side, and infact what we did of first experiment we actually made this patch let us say radius A 1, this we made as A 2, this we made as A 3 so that the 2 patches are resonating at the different frequency to obtain the larger bandwidth.

However when we made the first experiment and we fed over here actually speaking we did not get any loop. We only got the response of this particular thing; these 2 actually did not do any contribution because they were not getting coupled properly. So, then we did another experiment were we reduced the gap significantly, and now we could see a very small kink instead of a loop in the smith chart plot. So, then we started thinking what is happening. So, at that time I used the concept of the direct coupling. So, what we did? We put a copper strip and we put those copper strips along the gaps. So, we put copper strip 1 by 1. So, we put one copper strip on the right side, then we put another copper strip on the left hand side and we could see that the coupling is increasing.

So, by using the concept then we could increase the coupling on this side, or we could increase the coupling here and then we started thinking why this is not happening. So, just to tell you what is really happening here? Compare to the rectangular patching, in case of a rectangular patch this is the entire width is there and for the parasitic patch also so there was a entire width. So, coupling is there along full width of the rectangular patch, but over here because of this curved surface here, coupling is mainly due to these closer points here. The moment we see over here the coupling is almost is reduced to negligible value. So, hence the gap has to be reduced very significantly.

I also want to mention gap is also related with the thickness of the substrate, it is always s by h which is important and not s alone. So, what we did later on then we optimize this particular thing, we took a little thicker substrate and of course, by that time we procured the I 3D software, we did the simulation, using I 3 D and then what we did? We kept this patch and this patch same radius, so that we get a similar radiation pattern which is in the broad side direction, and pattern variation will be less. So, that is how we did the optimization for this case here, the results are very similar to the radiating edge gap couple, we could get a broad bandwidth as well as higher gain.

Now, for the non radiating edges one has to do little more thinking, one should not just put over here the patch along the non radiating edge, because see field is 0 here which goes to plus. So, if we put here another patch in this side right here and here, coupling to that patch will be close to 0. So, we found the alternate way by knowing the field distribution. So, we know that this is let us say 0, if I say this is plus it is double plus, and then this will be say 0 minus double minus. So, double plus means higher amplitude then the lesser amplitude and the 0 amplitude.

So, here now the patches are put along 45 degree from this axis here, and these are placed symmetrical and by placing this symmetrical and what we also have done? We took all the 4 patches out equal radius and then this is the slightly different radius here. So, all these patches then resonate simultaneously; now then we also came out with the slightly different configuration over here, you can actually think about this configuration as kind of combination of this, but you can actually think that this is the radiating edge that was the term which we have used for the rectangular patch; this is of course, not the edge here. So, we can say that it is put along the E-Plane, instead of calling it a radiating edge couple.

Now, what we have done here? We have put 2 patches over here and so the coupling is through this side, through this side and they are also getting coupled with each other. So, these results we have optimized these results are very similar to that of the rectangular patch, and for more details you can see that broad band micro strip antenna book ok.

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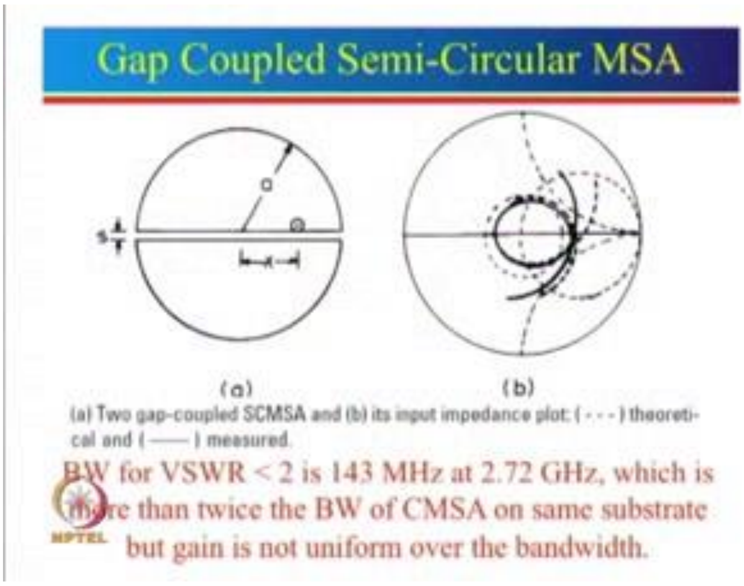

Then we actually came out with the other idea when we discuss about a circular micro strip antenna as well semi circular micro strip antenna. So, what we have seen that the resonance frequency of circular micro strip antenna is same as that of a resonance frequency of semi circular micro strip antenna ok.

So, here what we have done here? This is of the same radius as this here. So, now, you might wonder if this radius is same as this then their resonance frequency will be same; actually not really at this patch is being fed. So, it is fed with a co axial probe, the co axial probe will have some inductance. So, because of that inductance resonance frequency of the fed patch is slightly less than the resonance frequency of the non fed pair. So, one can actually say that these 2 are getting coupled and one can see that there is a loop in this smith chart, and this one here gets a bandwidth of about 143 mega hertz which is about twice the bandwidth of circular micro strip antenna on same substrate.

However I want to mention here that in this particular case gain is not uniform over the bandwidth. So, yes we are getting more bandwidth by using 2 gap coupled semi circular micro strip antenna, but gain varies over the band width; if that is acceptable then only one can use this particular configuration. So, similar to that we have also reported something like which I mentioned about a equilateral triangular in the last lecture. So, in the equilateral triangle and the 30, 60, 90 degree triangle also they both have same resonance frequency. So, they can be get coupled also and one can get a broader resonance frequency.

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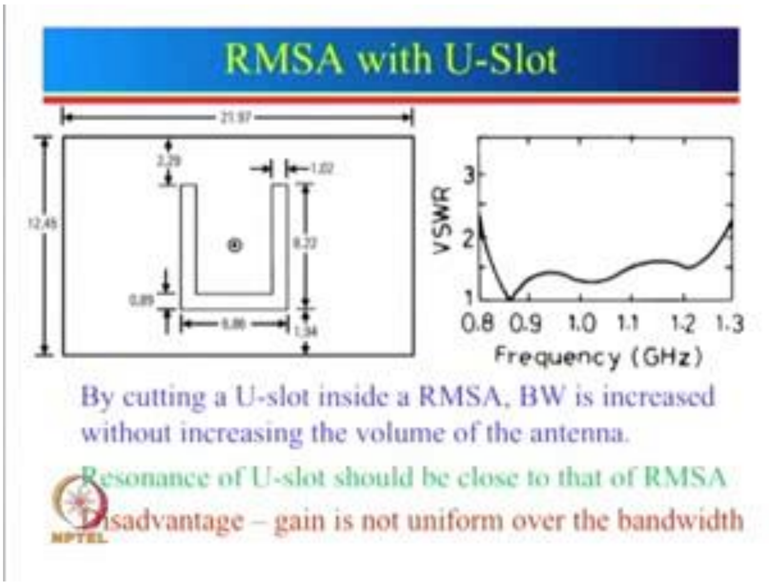

Now, similar to a rectangular and odd circle one can also put triangular patches which are gap coupled, and you can still get a larger bandwidth or gain. So, their effects are very very similar. So, now, let me show another configuration; this configuration was reported longtime back, where what was done is that this is the rectangular patch here, and over here the resonant length is t12.45 width is very large, which is you can say close to 22 here; now what has been done here a slot has been cut over here.

Now, by cutting this slot here one additional resonance has been obtained. So, the resonance frequency of this slot should be close to the resonance frequency of the patch here, and then one can get a much broader bandwidth. Infact this configuration became very very popular at what one time, the reason for that is that this particular configuration achieved wider bandwidth without increasing the volume. So, if you recall the bandwidth can be increased by increasing the substrate thickness, so that means, volume is increased or bandwidth can be increased by reducing the epsilon r, that will increase the aperture area; that means, again volume is increased or we look at the gap coupled configuration or directly coupled configuration.

Again the overall patch dimensions are increasing; that means, volume is increasing that became. So, this became a very very famous configuration, where volume was not increased exactly the same volume was there, and in that volume itself other slot was cut over here to increase the bandwidth. So, we also got carried away the lot of things have been done here. So, instead of using the U-slot we also use the v slot instead of using the 1 U-slot, 2 U-slots were used to that even better bandwidth and lot of slots were cut in between, the tooth brush slot and many other things have been reported. But I want to mention here again the major problem with this configuration is that the gain is not uniform over the bandwidth.

So, yes within the same volume one can get a larger bandwidth, infact the same thing was also you can say here the volume is same here as that of a circular patch, bandwidth is increased, but gain is not uniform over the bandwidth. So, please remember that when you are designing the antenna, it is not VSWR bandwidth is important, but it is also the gained bandwidth is important; pattern variation over the bandwidth is also important.

So, today we have discussed about how to increase the bandwidth, by using gap coupled configuration, along radiating edges, along non radiating edges, along 4 edges we also looked at the directly coupled configuration, but in all these cases we saw that the dimensions were increasing in horizontal or you can say in planar direction.

In the next lecture we will now see how the bandwidth can be improved by increasing the thickness overall thickness of the antenna, where we will have a one bottom patch, we will put another patch on that on the top, and these 2 patches will be resonate at the similar frequency to get wider bandwidth. And after that we will also see how to use combination of this. So, where we will go in the planar dimension either in this plane or that plane or we will go in the vertical direction. So, by using combination of that, we can get even larger bandwidth. So, we will see lot of more broad band configurations in time to come.

Thank you bye and we will see you a next time.