Antennas
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Module - 06
Lecture - 27
Base Band MSA-IV

Hello; and welcome to today's lecture on broad band micro strip antenna. In the last few lectures we have been talking about broad band micro strip antennas, and we saw there are certain techniques to increase the bandwidth of the antenna. So, you can increase the bandwidth of the antenna by increasing the substrate thickness or by reducing the electric constant of the substrate or we can use the multiple resonator techniques. In the last lecture we had seen how we can increase the bandwidth by putting the multiple resonators in the same plane.

So, for example, if you have a one patch here, you put another patch here and we put another patch over there. So, there were 3 patches which were coupled to the radiating edges of rectangular patch, or we put 3 patches which were coupled along the non radiating edges, then we looked into 5 patches which were coupled along all the 4 edges of the rectangular micro strip antenna, and we saw that bandwidth can be increased from 10 percent to about 18 to 20 percent.

Then we also saw the gap couple circular micro step antennas can be also used, similarly you can use other shapes also you can use triangular, you use hexagonal and other shapes also and then we also saw that a u slot can be cut inside a rectangular patch. So, idea is that resonance of u slot should be similar to that of the rectangular patch. So, if the 2 frequencies are close to each other, we can get broadband here. Now today we will look into the situation, where instead of increasing the patch dimension in this thing by adding another patch. So, total dimensions are in increased in the planar way, but now what we will do will put a patch here then we will put another patch here on top of that. So, this will be the stacking of the patches. So, by increasing the total thickness of the substrate or you can call it antenna we can increase the bandwidth.

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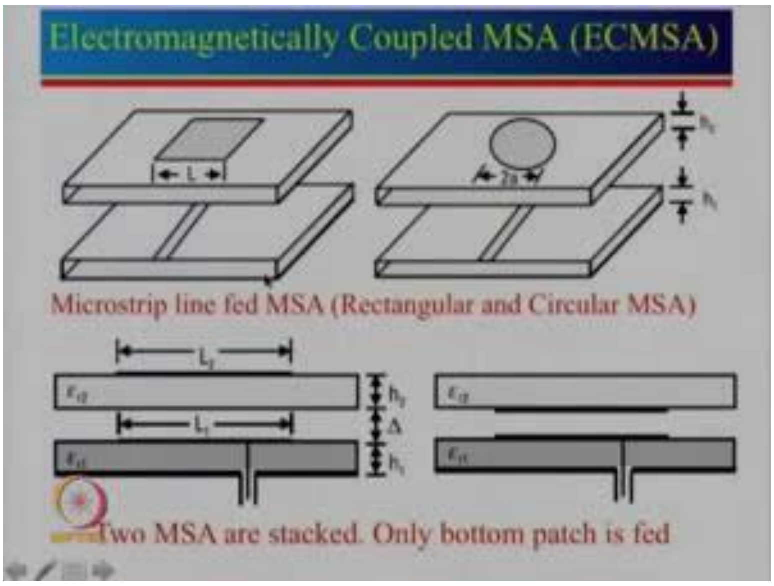

So, let us just look at various configurations how we can increase the bandwidth by stacking the antennas. So, to start with we will look at electromagnetically coupled configuration in the top. So, over here you can see these are micro strip line fed micro strip antenna, which are rectangular or circular shaped. So, here is a one substrate on that substrate there is micro strip line is connected, generally this micro strip line width is chosen in such a way that it corresponds to the characteristic impedance of 50 ohm, then we have a patch on the substrate. Now there is no ground plane over here, ground plane is only at the bottom side here. So, we have a ground plane then micro strip step feed line and then a patch.

Now, instead of rectangular patch or a square patch we can take circular patch, electrical patch triangular patch and so on and so forth. Now over here there are 2 possibilities are there, that is that this substrate can be directly sitting on this here or there can be a an air gap in between. So, there is an air gap in between that would mean that effective dielectric constant seen by this patch will be relatively less, and that leads to the larger bandwidth. Now there is also option that instead of printing the substrate on the top side, we can print the substrate on the underneath also.

Now, this kind of a configuration is actually very popular in a sense, that we can have on this substrate amplifiers or oscillators or mixers or power divider couplers and so on and so forth, and we can optimize this substrate parameter according to the micro strip line.

See for the micro step line what we really want the radiation from the micro strip line should be as low as possible. So, what we generally do it is we use generally a higher epsilon r substrate, and the thin substrate; so that fringing feels relatively less and here if we have air gap, we can also use another substrate of a low dielectric constant, so that the effective dielectric constant seem by the patch will be relatively small, and the total height will be more that would lead to a larger bandwidth.

Now, there is a another possibility is there, that is instead of having a micro strip feed line, we can also have a one micro strip antenna here and that is being fed using let us say coaxial feed in this case, and we can have a another patch on the substrate. Now patch can printed on the upper side or it can be printed on the underside also. So, basic idea here is that now the bottom patch will be resonate at one frequency, and the top patch will resonate at some other frequency, so there will be 2 patches which will be excited; only one patch is being fed other patch is getting excited through the electromagnetically coupling and that why the name is electromagnetically coupled micro strip antenna in short ECMSA.

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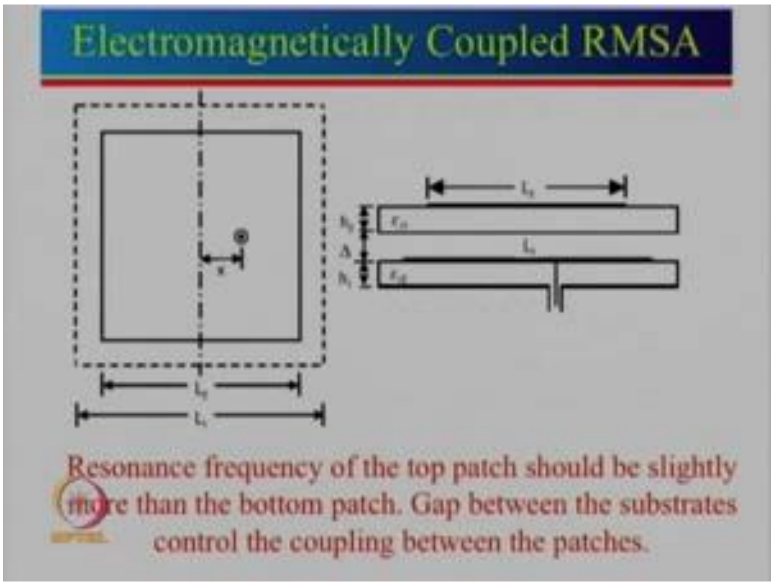

So, now again the patch shape can be anything, it can be rectangular, square, circle triangle and so on and so forth. So, let us just see an example. So, here is a example of a 2 square patches, which are put in top of each other. So, there is one patch over here which has the length L 1 there is another patch which is put on the top substrate here which has the patch L 2. Now many time the option can be whether we put the patch on the top side or we put the patch underneath. So, I can just tell you some pluses and minuses. So, if you put the patch on the top, then what it actually sees? It sees a larger thickness and we know that larger thickness is good for the bandwidth, but then it sees relatively less than dielectric constant compared to if the patches over here, because now this patch will see one dielectric clear than air and then dielectric clear.

So, one needs to calculate what is the effective epsilon seen by this particular patch; but if this patch is printed underneath over here, then what happens? The top substrate act as a red home also. So, one can simply you know use this top substrate as a red home. So, we do not need an external red home, and simply pack this antenna in some box which can be metallic from the side or can be plastic balls. So, this is the one of the advantage of using the patch underneath it. So, now, what we need to do it is, let us say now we want to design abroad band antenna. So, generally speaking for a given bandwidth, which we need to do; so divide that bandwidth roughly into about say 3 different part. So, at the low part you design the lower patch here, and for the upper one third part you design this patch over here ok.

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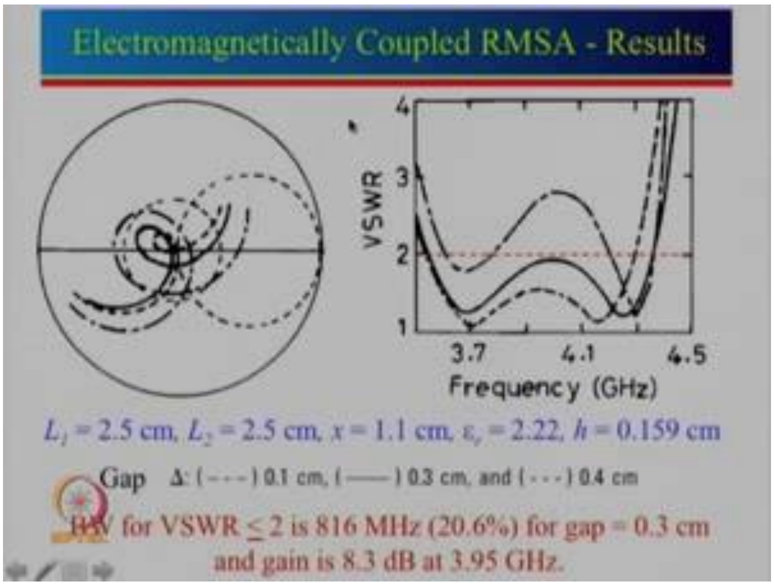

So, generally resonance frequency of the top patch should be slightly more than the bottom batch, and gap between the substrate controls the coupling between the patches; let us see an example. So, here is an example of the different values we have taken, So we have taken a a gap delta which is 0.1 centimeter 0.3 centimeter and 0.4 centimeter. So, this is the gap between the 2 substrate, and we have taken the 2 substance as same which has dielectric constant epsilon r equal to 2.22 and individual substrate thickness is 0.159 and tan delta for this case this 0.001.

Now, for the gap for air tan delta is equals to 0, and here are the examples where we have taken L 1 equals to 2.5, L 2 is also 2.5. Now x is very close to the h you can see that 2.5 is the length, so half of that will be 1.25 centimeter. So, one can see that 1.1 is very close to the edge there. So, let us see what is the result and response for 3 different gaps. So, we can see here there are 3 different curves are given. So, one curve which has a small similar loop then the little large loop and then this is the much larger loop in the smith chart. So, much larger loop corresponds the lowest air gap, which actually means that the coupling between the bottom patch and 2 other top patches is very strong.

So, if there is a stronger coupling then the loop size will be much larger; and as the gap increases we can see that the loop size is reduced; as the gap increase further the loop size is reduced further. Corresponding to this one can see now the VSWR plot here. So, one can see for the larger loop VSWR is less than 2 here and less than 2 here. You can even thing about that this antenna also acts as a dual band antenna. So, we have one resonance here, another resonance over here; but for broadband you can actually see that both these loops are within VSWR equal to 2 circuits.

Since this loop is relatively smaller. So, number of frequency points within VSWR 2 circle will be relatively small, and for here number of frequency points within VSWR 2 circle will large. So, we can see that this for the smaller loop which is for delta e equal to 0.4, and this is for larger loop for which delta is 0.3 and we can see that this is an larger bandwidth. So, for this particular case here we can say that the bandwidth is about 816 megahertz, which is 20.6 percent bandwidth. So, we can say that it is the much larger bandwidth and can be used for design of various antenna, this is the case for 0.3 centimeter. And correspondingly here one of the nice thing with this configuration is gain is relatively flat over the bandwidth, and the gain is about 8.3 dB at 3.95 giga hertz which is approximately the center frequency.

Now, even this smaller loop size is sometimes useful; one can actually see that this is the response here. So, this loop here which is the peak at this is actually slightly below 1.5.

So, many a times antenna are required not to have just VSWR less than 2 bandwidth; but sometimes it is required that we need VSWR less the 1.5, and I will tell you the reason. VSWR less than 2 implies 11 percent reflected power; VSWR less than 1.5 requires about 4 percent reflected power and 96 percent transmitted power. So, many stringent applications do require where we want VSWR to be less than 1.5. So, this can optimized even further if one require, because you can see that this loop is slightly outside the 50 ohm points. So, slightly this can shifted this side and that can be done by slightly shifting the feed towards the edge. So, the whole curve will shift from here to this side.

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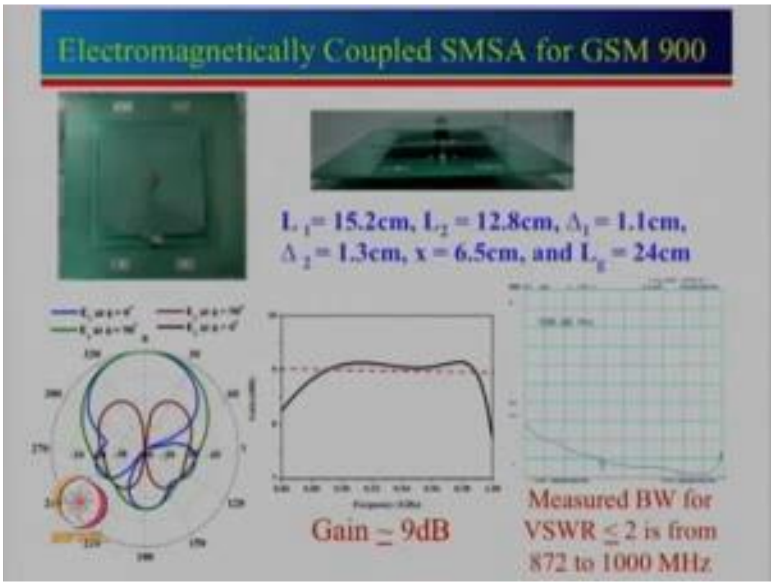

So, little bit optimization can be done also if VSWR less than 1.5 is required; so now let us just see one practical application, this antenna we have designed it for GSM 900 band. So, GSM 900 band is form 890 megahertz to 960 megahertz. Now for this particular application we did not choose any dielectric material, because either requirement was for the low cost antenna, this is actually especially for the seller band and for seller application generally telecom industry prefers a very low cost antenna to save overall cost and yet they wanted rugged antenna also. So, we actually chose metallic plate instead of using dielectric thing, and metallic plate can also handle much larger power, so power requirement was not much. We had a major challenge was how to suspend the metallic plat in the air.

So, what we did that instead of suspending in the air, see if it is a dielectric substrate it is not a problem, you just take a dielectric substrate you have a ground; and if you have another dielectric substrate you can put 4 screws at the end and we can support that, but here we have a metallic plate. So, what we decided? We supported this 2 metallic plates here by using a shorting pose at the center, you can see over here. So, let us just go step by step here. So, L 1 is 15.2 centimeter, and corresponding to L 1 this height is delta 1, which is equal to 1.1 centimeter that is an air gap and this metallic plate is chosen of a thickness of 2 mm so that it becomes rugged and also it can handle a very large power also.

The top patch is length is L 2 is 12.8 centimeter and the air gap between the 2 is now 1.3 centimeter basically this gap has been chosen such a way so that the loop size is optimized and feed point is again very close to the edge which is at six point five centimeter. So, you can see that the this is the feed point over here and the ground plain size is taken as 24 centimeter. So, it is basically everything is square. So, on top middle and the bottom subs ground plan the all are square. So, these are the dimensions which we had chosen now just to tell you, so in order to do that design what we need to do it is. So, we know frequency 890 to 960. So, corresponding to the lower band, this length was decided and we chose the gap here so that we can realize the larger bandwidth to meet the requirement.

So, that is how we do the design here and since at air is has epsilon is equal to 1. So, effective dielectric constant is equal to one for this case; and just to tell you how to take care of the thickness 2 mm. So, this is the thickness is 2 mm here and what you can do that you can account for the thickness by adding to this length additional 2 mm on this side, and additional 2 mm one this side. So, L 1 will be nothing, but instead of 15.2 to account for this finite thickness of the plate you can actually say 2 mm is equal to 0.2 centimeter, and 0.2 centimeter on this effectively you can think this is 15.6 and then to account for the fringing feed, we have actually told you that fringing field can be encountered or approximated as delta L equal to h by square root epsilon r.

But I had also mentioned at the maximum value of the delta L should not taken more than 0.9 h. So, we know h here multiply that with 0.9, and effectively take the length which accounts for the thickness of the plate and that will then determine the resonant frequency, and this delta 2 basically controls the loop size and the impedance block. So, this antenna has been fabricated this is the photograph of the fabricated antenna, and these are measure results. So, one can actually see that the measured bandwidth is from 872 to 1000 megahertz, infact this is the general thing which I generally do, the bandwidth requirement for this is 890 and the lower is 872. So, we have margin of about 18 mega hertz that is about 2 percent.

The upper one for this is 960 we have margin of roughly about 40 megahertz here. So, idea is that there can be tolerance in the fabrication of these patches. So, if there are some error, the resonance frequency will drift this way or that way. So, we have decided to design the antenna which has the little more bandwidth as compared to the desired bandwidth. But we can also see that the gain is almost flat over the desired bandwidth and that is close to about 9 dB. So, you can see that this patches are really good nice because in this particular case unlike in the case of planar configuration, where what actually happens that where is a one patch in the planar, another one here and another one here. So, there is the some phase shift happening because the phase center is at this point.

So, compared to this this patches experiences certain phase delay; but in this case stack configuration, phase centered remains same and that is why the radiation pattern variation over the bandwidth is very small, gained variation over the bandwidth is also very small, one can see that is almost flat. And this is the radiation pattern, so one can see that E Plane H Plane are there, cross polar is slightly less than about 817 to 18 Db, back radiation we can say is about 15 dB below the front. So, we can say that the front to back ratio is approximately 15 dB, and this front to back ratio can be controlled by changing the ground plane size.

So, instead of 24 centimeter suppose if we take 30 centimeter, that front to back ratio will be approximately 20 dB; or the other the another way is instead of using a flat plat, one can use a cavity or you can think about a box. So, if you take the cavity like this then; that means, the metal plate is really extended in this particular fashion. So, back radiation can also be reduced by using that configuration, but for our requirement 15 dB front to back ratio was sufficient, if you want was efficient if you want them more take larger ground plate or cavity back thing over here.

Now, this particular antenna had been supplied to the telecom operator, and they used this particular thing infact this can handle even 1 kilowatt of the power. So, generally when people micro strip antennas cannot handle too much power, which is true because if we use a thin dielectric substrate then that cannot handle too much power, but to take care of the power handling problem, what we did we used thick metallic plate to do the job. Of course 2 mm is not necessary, one can use even one mm also and we used those central support which had almost the diameter of 1 centimeter, so that could support the entire configuration.

Instead of that one can even use 2 different support also or one can use support at the 4 edges also that can also be done, but we choose because I just want to mention many a time these antennas which are mounted on the top of the tower, they are also required to have dc ground, so that it provide a path in case a there is lightening. So, center shot does that job also. Now when you do a center shot, so what happens? Remember for a rectangular patch field is precisely 0 at the center, so you can put a shot over there, but since we put a larger diameter to give a support. So, some changes in the resonance frequency does occurs, so you need to do that in the simulation itself so that you can account for those slight different changes.

One additional thing I want to mention about the plate. Now in the beginning we thought we will use a copper plate or brass plate, because then when we are putting a connector from the bottom, that connector center pin can be connected to the top over here, but the brass or copper plate cost is much more their weight is also more; so we decided to use the aluminum plate. Now if you use aluminum plate there is actually a problem, you soldering of this coaxial probe which is of a copper with that aluminum is not really a very ideal, you cannot really solder properly. So, what we decided to do it is we actually used a brass ribbet on top of that so that ribbet was actually put on the top and this one went over there and we solder that ok.

So, that is the difference how you can make into a low cost antenna. So, just by using little simple gimmicks here and there, one can do the thing and also use the oxidation here. So, you can see that we chose a green color its more to do that environment looks little green, green is always pleasing to more to the eyes, but you can always put any other color also, and also we also design this antenna to have little higher side frequency also, that in case we need to put that side a let us a say plastic box, or we need to provide a cover to protect from the environment. So, whenever we put a cover invariably that will reduce the resonance frequencies.

So, even if the resonance frequency reduces slightly, it will still cover 890 to 960 megahertz. So, the way we design the antenna, so whether you put a cover or you do not put a cover it will work in either of the situations. Now similar thing can be done I just showed examples of square patches, but you can use a circular patches here circle patch here, circular ground plane and other thing depending upon the space or depending upon the place where we need to install these antenna.

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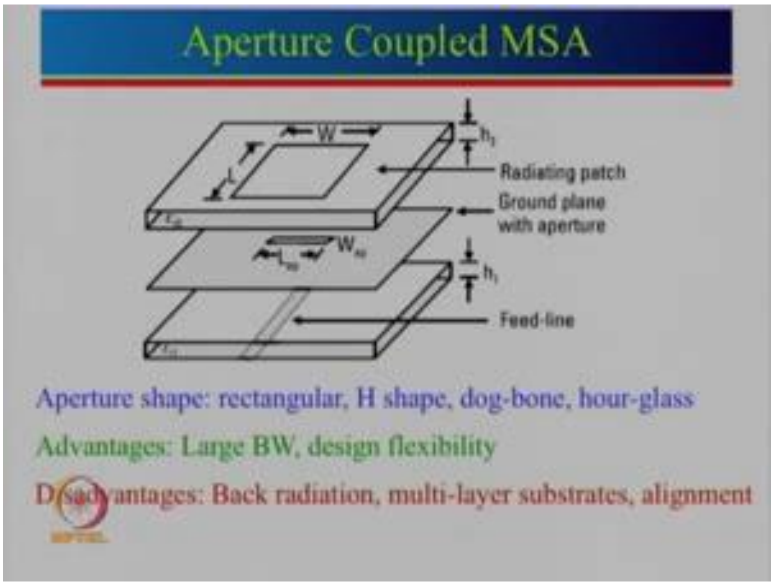

Now, we will look at another configuration which is a aperture coupled micro strip antenna. So, let us see what it really is. So, here we have a one ground plane, and in that ground plane in this particular case here, you can say that a rectangular slot is cut over here. And other side of the substrate, so there is a dielectric substrate here, this ground plane you can think about ground plane of the side substrate. So, that can be a substrate metallic portion can still remain there and one can cut a slot over here.

And on the other side this is the micro strip line feed. Generally this micro strip kit is again taken for 50 ohm characteristics impedance and the length of this one here is very critical to this height of coupling between the micro strip line and the above patch. I will just come that one by one. So, there is a micro strip line here. So, this micro strip line there is an open end over here. So, that open end would mean current will be close to 0.

So, somewhere at a distance of lambda by 4 from the open, current will be maximum so it will have a maximum magnetic field; that magnetic field will go through the center, and then it will interact with the patch which is printed on the other substrate, so for this substrate now there is no ground plane ok.

So, patch can be again fabricated on the upper side or it can be fabricated on the lower side, and there can be a gap between you can say between the ground plane and this substrate here, and that can be utilized to increase the bandwidth of the antenna. Again others patch can be printed on the top side, underneath the substrate also, so then this substrate will act as a red home for that. So, now, let us see what is really happening one more time. So, this is the micro strip line, and generally speaking this one here if you look from this side. So, this one will be roughly lambda by 4 extended so that the maximum coupling can be done through the slot.

Now, it is not always necessary that you take that always lambda by 4, sometimes if the coupling is too strong to the top patch here you can either reduce the slot dimension or you can change the length of the micro strip line also. But majority of the time in order to get better bandwidth, we generally what we do; we use a higher gap over here, so that the patch seizer larger substrate, thickness in this case it will be dielectric constant and here also so that fringing fields will be more and that would give rise to larger bandwidth. Many a times one more substrate is put on top of that, one more patch is put on top of that so that will give even more bandwidth.

So, here slot dimensions play a very very important role not only the dimension, but its shape also. So, in the earlier stages people had used circular slot here, also use rectangular slot and then there were cases were by changing the width of the slot you can actually change the coupling. So, coupling is more to the top patch if the width is more, infact sometimes people had also used this length as resonant length, but there are disadvantage of that I will tell you.

So, if you use a resonant length of the slot then that give a one another resonance which gets coupled to the other resonances of the patches, it will give over all much larger bandwidth. However if we choose a resonant length here, then since it is becoming resonant it also radiates in the backside. So, infact one of the major disadvantage of the aperture coupled micro strip antenna is that there is a back radiation, and that is why majority of the aperture coupled micro strip antenna they have a very poor front to back ratio, and to increase the coupling many other configuration have been used. So, for example, rectangular shape or H shaped or even a you can think about H shape will be something like this here, you can cut put a slot over here and cut slot over here.

So, if you look from this side it will look like I shaped, but if you look from this side here it will look like a H shaped; then people had also used a boat eyed shaped slot also, dog bone shaped slot also and then we have studied all these different different configuration, and we studied one by one and then we proposed another configuration which was an hour glass shape configuration, and this actually speaking used the advantages of both H shape, dog bone shape, boat eye shape and this particular configuration of the slot aperture gave the maximum coupling to the top patches here, and by using that we could get even a much larger bandwidth.

So, here the advantage of aperture coupled is it gives very large bandwidth, and there is design flexibility is there. There are so many design parameters are there some times it is good sometimes it is not too good. So, people do not know which one to do and which configuration to use. But design flexibility is that you can optimize this substrate for the best performance of micro strip line you can use different shapes or the dimension of the aperture so there are lot of design parameters are there to do the optimization, but the disadvantages are back radiation. So, front to back ratio as I mentioned is always going to be poor it also uses the multilayer substrate. So, there are so many layers of substrate are there and alignment is also a issue.

So, these are the problems which are associated with aperture coupled micro strip antenna, and also this substrate here does radiate in the other side because that micro strip line. So, infact they have actually found different solutions also, sometimes instead of using a micro strip configuration, a strip line configuration is also used so that the back radiation is reduced significantly; but then that adds one more substrate layer. So, the overall cost of the antenna increases, overall thickness of the antenna increases. So, depending upon the application to application, so one can use a electromagnetically coupled or one can use aperture couple.

Today we talked about antennas which are stacked on each other. So, in the next lecture we will talk about the antenna configuration which uses combination of plainer as well as stack. Because we saw in the previous lecture bandwidth can be increased by putting multiple antennas in the same plane. So, we have a one patch, put another patch, put another patch and so on and today we saw that you can increase the bandwidth by putting one patch on top of the another patch.

So, in the next lecture we will see we use combination of that. So, we go horizontally as well as we go vertically. So, we will see in the next lecture how to get even more bandwidth and also little more gain and yet the performance remains very stable. So, will see you next time bye.