Antennas
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Module - 06
Lecture - 25
Broadband MSA-II

Hello everyone and welcome to today's lecture on broad band micro strip antennas. To the last few lectures we have talked about micro strip antennas its advantages disadvantages and applications, then we talked about rectangular micro strip antenna and the parametric effect for example, effect of the feed point location, effect of the width of the patch, effect of the substrate parameter for example, epsilon r h tan delta; then we talked about circular micro strip antenna and triangular micro strip antenna.

We also looked at the curve which give us the substrate parameter versus bandwidth and deficiency, and we saw that the bandwidth is proportional to the substrate thickness as well as it is inversely proportional to one by square root epsilon r. So, we have also noticed that the bandwidth increased to level only of about 5 to 10 percent, and if we try to increase beyond that efficiency reduces. So, today we will look into various technique how to get bandwidth of 10 percent 20 percent 30 percent or more ok.

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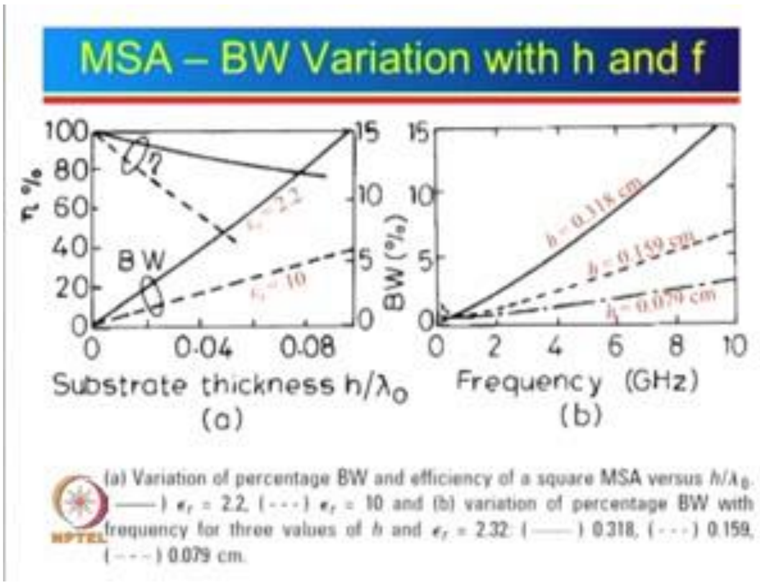

So, let start with the formal introduction of broadband micro strip antenna that is the today’s topic; now in the last lecture we had seen this particular curve. So, just for a quick brush up, so here is a curve which shows percentage bandwidth and efficiency on this axis vertical axis versus substrate thickness which is h by lambda 0. Now we can see that the percentage bandwidth can be as high as 15 percent for epsilon r 2.2, but corresponding to this case here efficiency is going to be poor. So, even if you want let us say a 10 percent bandwidth, so 10 percent bandwidth can be achieved here, but again efficiency is slightly lower, but if you want more than 20 percent or 30 percent we can see that it is not easy to achieve using a single micro strip antenna. So, the concept of multi resonator is used to obtain broad bandwidth.

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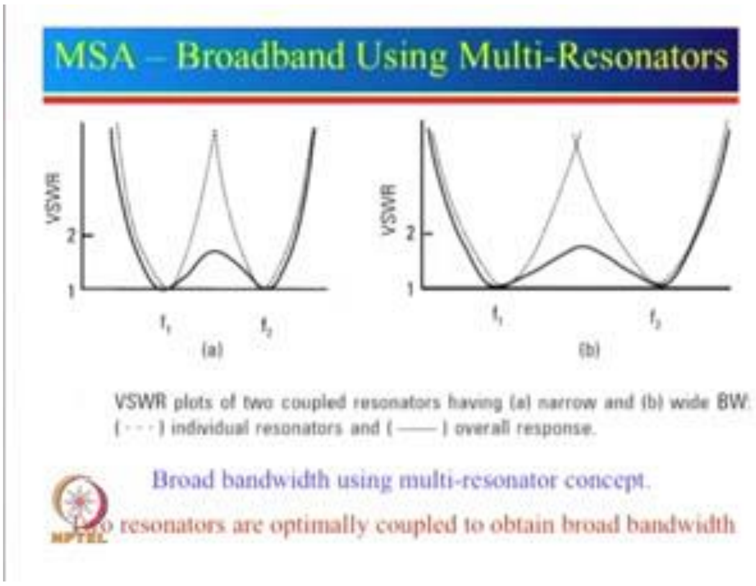

So, for example, let us say this is the VSWR curve for one of the antenna, which is resonating at f 1 if we now suppose excite another antenna which is resonating at frequency f 2, and if we do such a proper way of excitation and if we can now see that the overall curve will be a much broader curve, and if we look at a VSWR less than equal to 2 bandwidth, it will be much more than a single patch.

So, infact one can see that a single patch has a this much bandwidth, the another single patch has a this bandwidth over here, but the overall bandwidth is more than the bandwidth of the individual patches. Now this curve here shows slightly different than this. So, here one antenna has let us say lesser bandwidth, here antenna has a wider bandwidth. So, if antenna has a wider bandwidth then the next antenna should be designed at a slightly larger separation between the 2 frequency, compare to this over here; so that when we have a slightly larger separation each individual antenna has a larger bandwidth. So, we can get a much larger bandwidth by using the cascading of these 2 thing. So, let us see how we can realize these configurations. So, there are many ways we can use the concept of the multi resonator. So, let us see one by one. So, the first configuration which we are going to look at is a gap coupled rectangular micro strip antenna.

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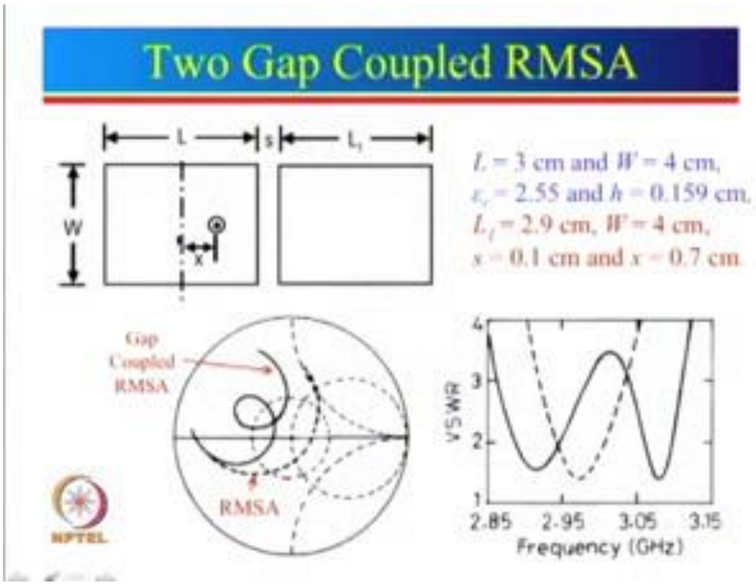

So, what we have here it is only one patch is fed, and these patch dimension we had taken earlier. So, we have kept same as the earlier dimension. So, which was L equal to 3 centimeter, W 4 substrate parameters are also same as before.

Now, what we have done here that we have put another patch of length L 1, and width we have kept same as this patch here. So, anyway it is going to have this much width. So, might as well use the same width. So, then what happened the coupling to the second patch is through the entire width of the patch. Now this second patch is not at all excited, so it is actually known as parasitic patch. So, this patch is being fed and from here there will be fringing fields, and there will be fringing field on this side also, but this fringing field will get coupled to this particular patch here, and they will excite this particular patch.

So, now, there will be 2 resonances we can actually see here this is the response for a single patch. So, we can see there is a one resonance frequency, but because of the loading of another patch here. So, the resonance frequency of this is slightly reduced. So, which is over here and then we have another resonance coming over here. So, just I had shown before that if we have a frequency f 1 and if we have a frequency f 2 we can try to get broader bandwidth, but of course, this one here does not show that proper bandwidth. So, we have to see now what is happening to the impedance plot.

So, this one here is the impedance plot for rectangular micro strip antenna for a feed point of x equal to 0.7 centimeter, this is the same as we had discussed earlier for rectangular micro strip antenna. Now we have used the same feed point for this particular also. So, what we see here that if we use the same feed point the curve is given over here, one can see that there is a loop in the impedance plot, this loop is because of the resonance of the another patch over here. We can also see that this impedance is much lower compare to the impedance over here. So, let us see what is the reason for this impedance to get lower. So, what we have here this is the fed patch, earlier it was seeing the radiation resistance over here and here, but now what is happening this patch is also going to radiate. So, there will be some radiation resistance here, now this length is approximately equal to lambda by 2.

So, what happens this is the property of a transmission line of length lambda by 2, that if there is load resistances here that load resistance also becomes the input resistance over here, so lambda by 2 actually only transforms the same impedance at this particular point. So, now, what happens for this patch there was a radiation resistance of this path and the radiation resistance of this path is coming in parallel, so, the 2 resistance will give us a less impedance and if impedance is reduced, so naturally if this is 0 ohm impedance, and this impedance is reduce by close to let us say half then the impedance variation will reduce. So, what we need to do? We need to shift these feed point towards this edge here, so that we can get a impedance plot shifted from here to here. Now just to mention here we have kept gap as a s equal to 0.1 centimeter, will see what is the effect of the gap in the next few slides.

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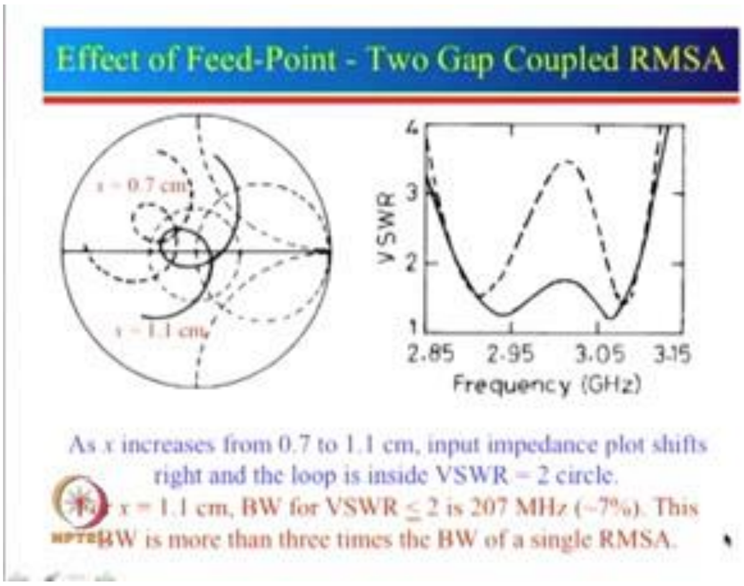

So, let us first look at the effect of the feed point. So, here is the plot which we saw earlier that is why x is equal to 0.7 centimeter, we simply shifted the feed point towards the edge, and by shifting the impedance towards the edge so we increase the value of x from 0.7 centimeter to 1.1 centimeter. And now we can see that the entire loop is within the VSWR equal to 2 circle. Now just to tell you generally this VSWR 2 circle is not shown on the smith chart, so that can be plotted on the smith chart, so on smith chart we know that this is 0, this will be one this is infinity, somewhere here there will be 2. So, this one here and 2 with that particular radius you draw the circle. So, the idea is to put this VSWR, in the within in the VSWR 2 circle we should try to bring this loop over here and if that is the case now we can see that the VSWR less than 2 responses this here.

So, we can from here we can see VSWR less than 2 bandwidth will be starting from this point to this point here and it actually get us a bandwidth of about 207 megahertz that is about 7 percent. Now this bandwidth is more than 3 times the bandwidth of a single RMSA, and we can actually see from here the previous one if you just see; you can see that this is the individual bandwidth of RMSA, this is the bandwidth of another RMSA, over all bandwidth is much larger. Here I also want to mention that L 1 is taken slightly less than L, because if L 1 is less that means, its resonance frequency will be more. So, if we say that this resonance frequency corresponds to f 1 then this will be f 2 which is slightly higher, and we can see that we are getting a larger bandwidth.

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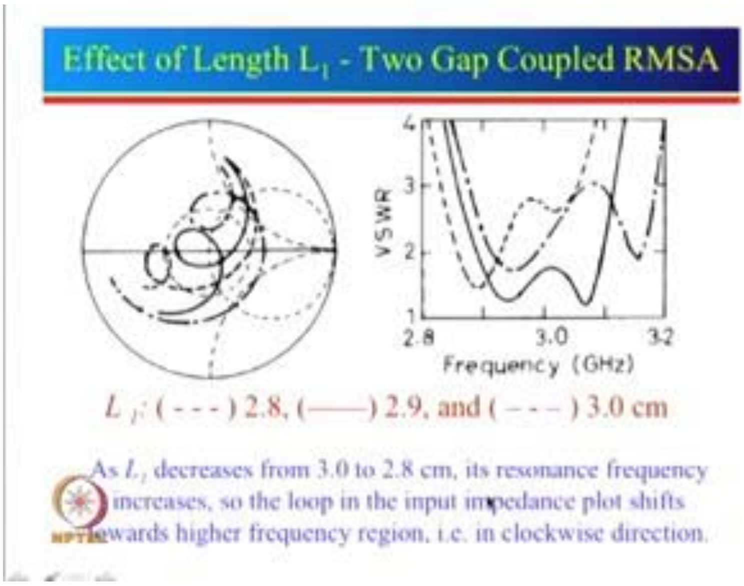

Let us see the effect of the other parameters also. So, just to show the effect of the L 1, so we have plotted here for 3 different values of L 1, 2.8, 2.9 3 centimeter. Now if you look into here what we are having here they are corresponding to these 3 length, we are getting 3 different impedance plot and one can see that the loop position is getting changed. You can see that it is almost rotating like in the clockwise direction. So, what is really happening? So, as L 1 is higher, so its resonance frequency will be small, so the loop is formed at the lower frequency value. Now just to remind you for a normal rectangular micro strip antenna, this is a lower frequency and frequency increases in this particular fashion. So, if L 1 is 3 centimeter, its corresponding frequency will be lower so the loop is formed at the lower frequency; then length is reduced frequency increases. So, now, the loop is formed at a higher frequency; when length is further reduced its resonance frequency increases. So, now, the loop is shifted to the higher frequency, we can see that for L 1 equal to 2.9 centimeter, the loop is within the VSWR 2 circle.

Now, I just want to tell also that if suppose length was 2.92 or 93 then what would have happen? Corresponding to this frequency would have reduced. So, this loop which is over here it will be now somewhere like this here. Now that is not a very good thing to do, generally try to optimize the loop position which is centered around the central point we also call it a bulls eye. So, we would always like to be close to the bulls eye. So, then we have a VSWR or you can say loop here circling the central point here.

Now had we seen this same thing only using this VSWR versus frequency, you cannot really make out what is happening where the loop is shifting and how it is shifting; but it is very clear from here how the loop position is shifting. So, I always recommend that when you want to become a good antenna designer try to master the smith chart, so that you really know how the impedance plots are moving, from here you cannot really get too much of a information.

So, just to summarize then that as L 1 decreases from 3 to 2.8, corresponding resonance frequency from here to here it increases so the loop is moving in the clockwise direction.

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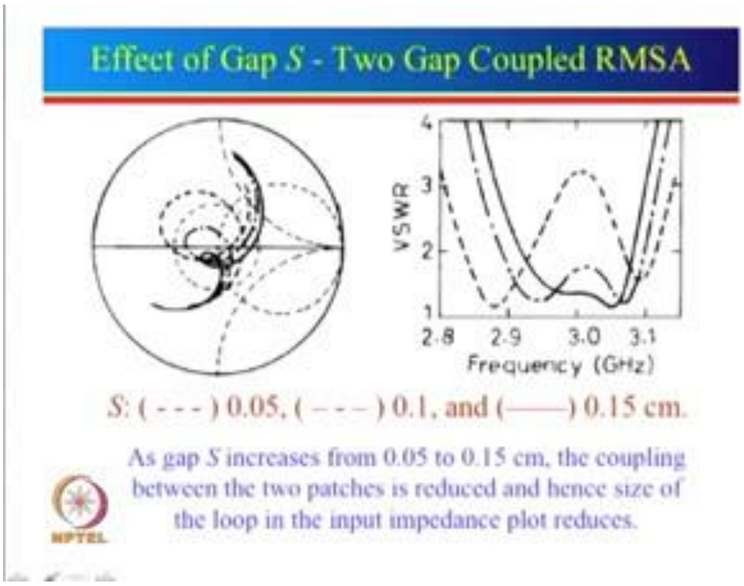

Now, let us see the effect of the gap. So, earlier I had shown you the graph for 0.1 centimeter, here we have taken 3values of the gap 0.05, 0.1 and 0.15 centimeter. So, now, if the gap is small, what will happen? The coupling between the 2 patches will increase, and if the coupling increases then the loop size will be larger as we increase the gap to 0.1 the coupling will reduce slightly loop size will reduce slightly. If the gap is increased to 0.15, now the coupling is further reduced one can see that the loop size is further reduced. Now if we increase beyond let us say 0.2 0.3 centimeters, this loop will disappear and infact the response will look very similar to that of a rectangular micro strip antenna.

Now, in this particular case here we can see that the loop is within VSWR two cycles, for both 0.1 as well as 0.15 centimeter. Now definitely since the loop size is larger here bandwidth will be larger, which we can see here for 0.15 this is the VSWR curve so that will be the bandwidth; for 0.1 this is the VSWR curve; so you can see that this bandwidth is larger than the bandwidth corresponding to 0.15 centimeter. So, it is really important to optimize different parameters.

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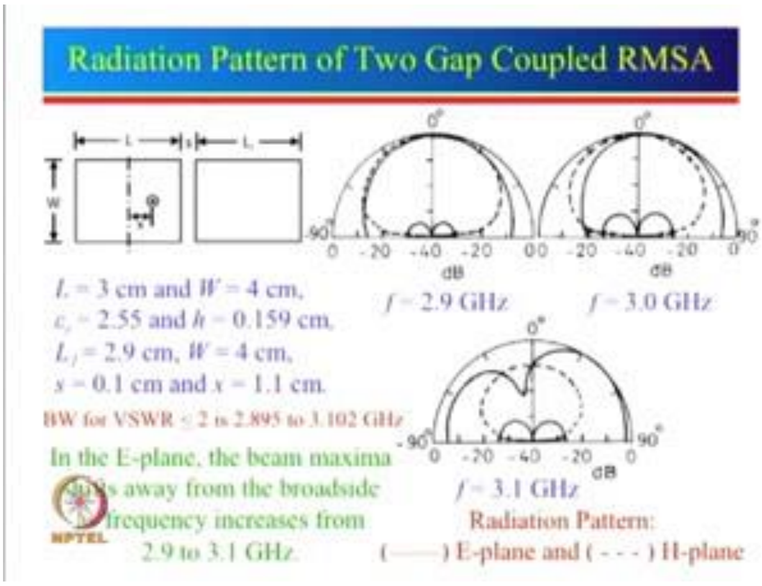

So, we saw till now that we can get a very good bandwidth, and one can very happy that you got a better bandwidth, but bandwidth of just defining from VSWR is not a good idea, we should also see what is the radiation pattern. This radiation pattern stable over the bandwidth or not, or is the pattern changing over the bandwidth, its gain stabled over the VSWR less than 2 bandwidth or not. So, all these things are important, the study is incomplete if we do not look at the radiation pattern and gain performance. So, let see here what is the radiation pattern. So, over here now we can see that this the same patches the optimized one. So, s is 0.1, x 1.1 for which we had seen that the bandwidth was roughly about 2.7 megahertz.

So, this is the frequency range 2.895 to 3.102. So, here we have shown the plot at 3 different frequency, one is roughly at the center of these 2 which is around 3, this 2.9 is close to the band edge here, and 3.1 is close to the higher band edge. Now let see how is the radiation pattern. So, at the lower frequency one can see that the radiation pattern is in the broad side direction, the reason is at lower frequency this patches only resonating and this is the dominant resonance. As we increase the frequency, this patch is now getting little bit resonant and if this is higher frequency because this length is smaller, so the resonance of this patch is more dominant. So, now, what is happening? At the lower frequency since this patch resonant, this is resonating and this is what is more effective radiator, so the radiation is in the broad side direction. At in between frequency this is radiating, this is also radiating little bit and you can see that there is a very small shift in the beam.

But when we go to the higher frequency, now this patch is more dominant. So, this is what is resonating. Now if you recall array theory if there are 2 patches; patch 1 and patch 2 and if there is a phase difference between one patch and the second patch, what will happen? The beam will be shifted towards this particular direction here. So, this is what is happening, with reference to this patch this one is seeing a phase delay from here to here, we can actually take the central distance from here to here. And because of the phase there the maximum has shifted to the direction of along almost 45 degree. So, even though this antenna is very good from VSWR bandwidth, but it is not so good from the radiation pattern point of view.

So, now, what is the remedy? So, we got one solution we have not got the other solution of the pattern. So, now, we need to think about so what is really happening; when this patch was getting resonant, so the beam shifted towards this side. So, suppose now we put another patch which is same as this over here on the other side of the patch here, then what will happen? This patch will try to shift the beam in the right direction, but this patch on this side will try to shift the beam in the left side direction; so we can hope that this one will try to shift on this side other patch will try to shift on this side, and in reality the radiation pattern may be in the broadside direction.

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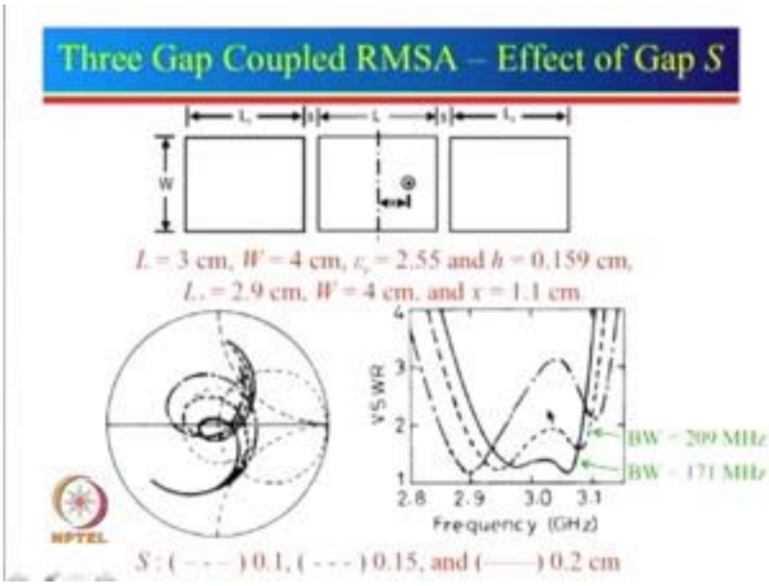

So, let see what happens if we put another patch on the other side. So, what we have here? So, we have a one patch here exactly the same patch has been put on the left side here, and now we have also shown the curve for 3 different gaps here. So, 0.1, 0.15 and 0.2; the gap has to be slightly optimized in this particular case. So, one can see that for 3 different gap for 0.1 the loop size is bigger because coupling is strong, for 0.15 that is the loop size is within VSWR 2 circle and if we increase the gap further, now the loop size is relatively smaller over here. So, one can actually see corresponding to this impedance plot we can see the VSWR plot over here. So, this one here, the solid line is the plot corresponding to this one here which is for 0.2 centimeter. So, we can see that this is the plot here.

For s equal to 0.15 we can see that the plot here is this one here, you can see that the bandwidth for this is about 209, bandwidth of this is 171 megahertz, so this bandwidth is slightly lesser. But now we should not always rule out that this is a lower bandwidth. In fact, one can actually see that this particular curve is going to be within VSWR equal to 1.5, and there are many requirements that where people may require not just VSWR less than 2, because VSWR less than 2 actually imply about 11 percent reflected power and many a times the requirement is stringent, they actually put that VSWR should be less than 1.5, and VSWR 1.5 corresponds to reflection coefficient equal to 0.2 and that means, reflected power is only 4 percent. So, many a times requirement are stranger, so this particular response may be more prefer if VSWR less than 1.5 bandwidth is required.

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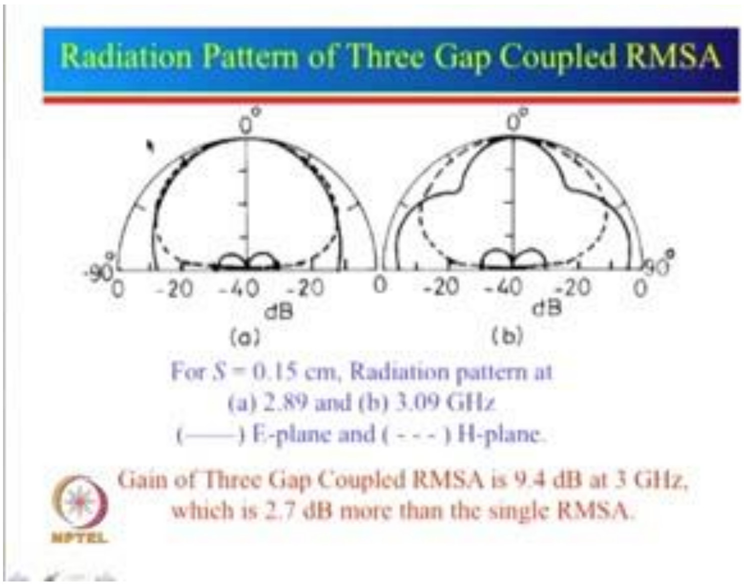

So, let see what happens to the radiation pattern. So, here I have shown radiation pattern at 2 frequencies; one on the lower band edge and another one on the higher band edge. So, one can actually see at the lower band edge radiation pattern is in the broad side direction, which was expected as in the case of the 2 gap coupled. For 3 gap coupled what we can see that the radiation maxima is in the broad side direction. So, what one patch try to do, then one patch try to shift the radiation in this side another patch try to shift the radiation on this side. So, hence the resultant still remains within in the broad side direction. However we do have some radiation in the side over here. In fact, this radiation one can actually correlate with another factor, let us see now at the lower frequency this patch is more resonant so we have the 2 slots over here. At higher frequency when these patches are dominant, then we have a one slot over here and one slot over here and of course, there are 2 slots here which are also radiating. But these are now little more dominant radiating thing and if you look at the distance between them the distance between them is now quite large, which can give rise to somewhat grating load, but that is getting multiplied with the pattern, and hence we see that there is a little bit higher radiation.

But yet we can say that the maximum radiation is in the broad side direction for both the frequency ranges here. So, this is a better thing we can actually see the gain of the antenna, now the gain of the antenna here is 9.4 dB whereas; the gain of the RMSA was around 6.7 dB. So, we also get a better gain which is about 2.7 dB more than the other bandwidth. One can also notice that there is not much change in the radiation pattern of H Plane, the reason for that is the patches are not put in the H Plane, the patches are put along the E Plane. And we also know that this is known as a radiating edge, and this is where the E Plane is. So, these E Plane pattern will only change H Plane pattern will not get effected. So, now, then the next concept is that instead of putting patches along the radiating edges, can we put the patches along non radiating edges ok.

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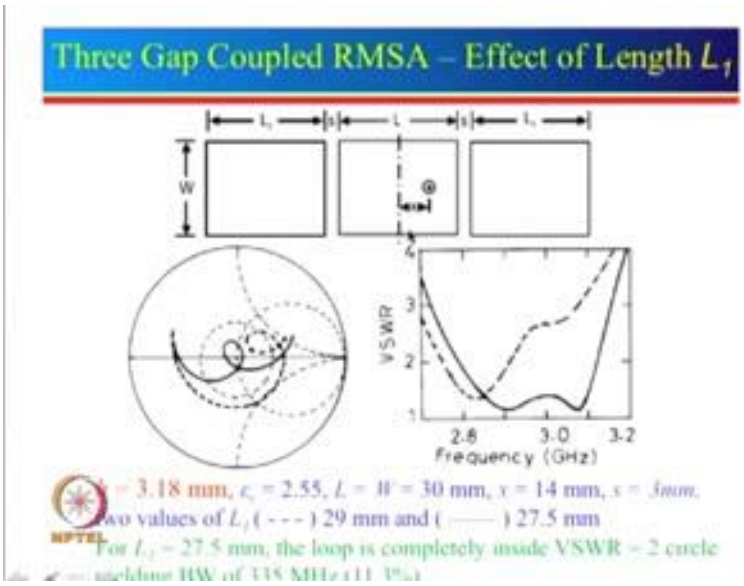

So, here the patches have been put along the non radiating edges, and one can now see that here we have a feed point and the patches are put on the other side over here.

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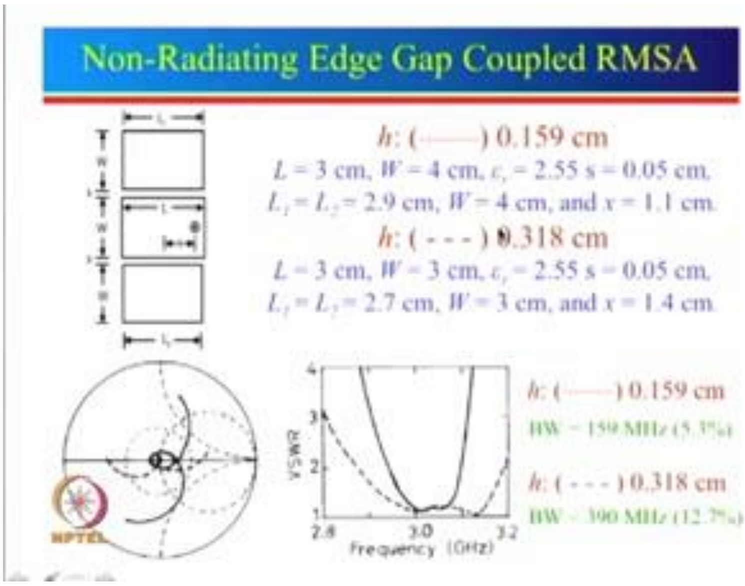

So, now we have shown 2 different cases here, one is for 0.159 centimeter, another one is for 0.318 centimeter. So, what has been done? Substrate thickness has been doubled. So, the substrate thickness is doubled; that means, the bandwidth of individual patches will increase, and if the bandwidth of individual patches increase that means, we should have larger difference between f 1 and f 2. We can actually look at earlier curve which I had shown you that if individual bandwidth is more separation between the 2 frequency should be also more. So, one can see that over here for 2 different thicknesses we have actually given here, and I have also mentioned here this is L 1 this is L 2. First I will discuss about what happened if L 1 is equal to L 2, and then I will tell you what happens if L 1 is not equal to L 2.

So, here it is 2.9 centimeter, and since the thickness is not doubled. So, the separation between the 2 frequency should be larger. So, hence you can see that L 1, L 2 we have taken as 2.7 centimeter. Now the resonance frequency still will be closer, because you can think about the extension in the length. See always physical length is not important what is more important is the effective length. So, effective length here will be 3 plus delta L and delta L on this side. So, that will be 3 plus 2 delta L. So, by doubling the edge delta L also gets roughly doubled. So, that is why here the curve is for 2.9, now for this particular non radiating edges coupled the gap has been reduced significantly. The reason for that is that for radiating edge the field is uniform along this here. So, when you put the patch on this side, uniform field will get coupled to uniformly to the other patch.

But along the non radiating edge field is plus here it goes to 0, it goes to minus. So, field is varying sinusoidally along this edge here, and since field is plus 0 minus coupling to this one will be relatively less. So, hence we need to have a larger gap to increase the coupling between the 2 patches. So, here we can see the curves here 0.05, this is the curve you can see here this is the curve for the 0.159 centimeter, and this is the response for the doubled one which is 0.318 centimeter. One can still see that the loop size is relatively small for both the cases; so one has to reduce the gap even more to get a larger loop, but nevertheless there is an advantage one even define a nice bandwidth even for VSWR less than 1.5 also, but let us see what is the bandwidth we are getting. So, we are getting about 5.3 percent bandwidth for smaller thickness substrate and almost 12.7 percent for larger thickness substrate ok.

So, one can optimize the bandwidth, now in this particular case what will happen the radiation pattern will now vary in this direction. So, H Plane radiation pattern will vary, but E Plane pattern will remain same. Now by the way just to tell you see this double thickness example is also there for 3 gap coupled also. So, for 3 gap coupled now this is doubled the thickness, now earlier we had seen for a H 0.159 we have taken 29 mm or 2.9 centimeter, but for double the thickness if we take 2.9 it would not be proper. So, one can see that this is the curve for 29 mm.

Now since this is the curve here which is on the frequency side, so in order to bring the loop within VSWR 2 circle, what we need to do? We need to reduce the length and if we reduce the length you can see that 29 mm has been reduced to 27.5. If we reduce the length frequency will increased, so the loop will be formed in the higher frequency rang, and one can see that this loop is encompassing the central point here and giving rise to a larger bandwidth. So, we can see that the bandwidth obtained here is about close to 11.3 percent.

So, one can actually see that the bandwidth can be improved by putting the patches along the radiating edges, but the pattern will change along the E Plane and not change in the H Plane, and we can see that by putting the patches along non radiating edges now bandwidth can be increased further, but the pattern variation will be now along the H

Plane and not in the E Plane. Now just to mention if we take the 2 dimensions equal L 1 and L 2, it is not a very good idea I do not recommend see what happens then? If these 2 lengths are different then what will happen that at one frequency pattern will try to shift on this side, another frequency pattern will try to shift on this side. So, what we will really see that the pattern is not stable over the bandwidth. So, yes by choosing L 1 and L 2 different one can get larger bandwidth, but the pattern variation will be more, but by choosing L 1 equal to L 2 we will get slightly lesser bandwidth, but pattern variation over the bandwidth will be relatively less.

So, in the next lecture we will see that we can now put the patches on the both radiating edges as well as along the non radiating edges. So, will see that bandwidth even gets further increased, if you put the patches along the radiating as well as non radiating edges. So, in the next lecture will also see other configurations of gap coupled and directly coupled configuration and many more things in time to come.

Thank you very much see you next time bye.