Antennas

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Module – 05
Lecture – 22
MSA Parametric Analysis – II

Hello and welcome. Now in the last few lectures we have been talking about micro strip antenna and also we talked about rectangular micro strip antenna. We actually saw what are effects of various parameters on the performance of rectangular micro strip antenna. We studied what are the effects of the variation of feed point location we studied what is the effect of W what is the effect of h epsilon r tan delta probe diameter and so on. We also looked at the different modes of the rectangular antenna.

We looked into fundamental mode as well as third order mode. Now you might wonder why I did not discuss about second order mode, because second order mode actually has a broad side radiation pattern going to null because the broad side pattern actually cancels it gives raise to the conical pattern. So, majority of the time second order mode is not used. In fact, I also want to mention try to avoid even third order mode also. So, even the third order may give us a little higher gain, but instead of using 3 lambdas by 2 lengths what you can do it is you can use 2 rectangular patches of lambda by 2 length used in the array form you will still get about the same type of a gain. So, generally speaking these antennas are used for their fundamental mode operation only.

Now, today we will look into how to choose a proper substrate to meet the design guideline to see what should be the bandwidth of the antenna for a given thing and for given frequency range given bandwidth, how to choose the value of the substrate parameter.

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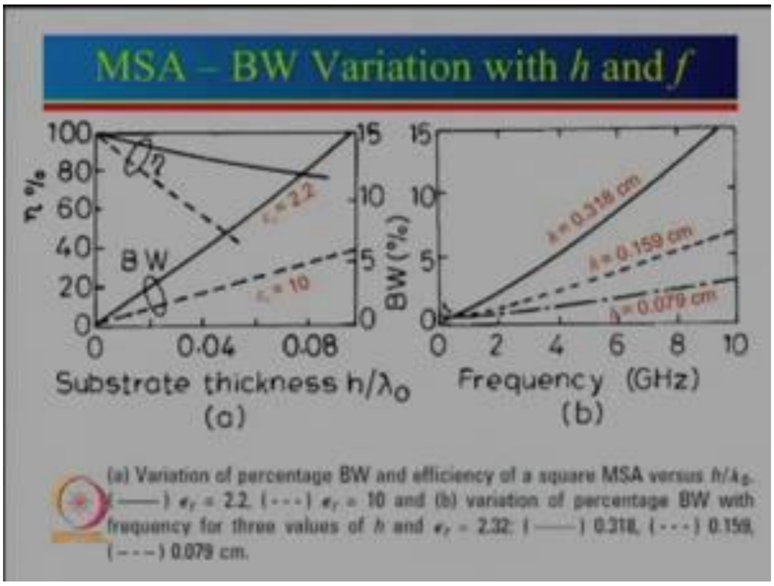

So, let just see there are 2 curves here let just first look at the one of curve over here. What is this curve here it actually shows bandwidth variation with substrate thickness right here and with frequency which is shown over here? Now here we just want to tell you what we have. So, we have substrate thickness shown along this side and this is a normalized substrate thickness. I have been always telling absolute value should not be considered always a normalized value. So, what we can see here h by lambda 0 varies from 0 to up to 0.1 here and we have 2 things here for vertical this side shows here efficiency this side shows here percentage bandwidth.

So, now first just look into this access here which is a percentage bandwidth and corresponding to these bandwidths here, these are the 2 curve one is for epsilon r 10 and other one is for epsilon r 2.2. So, we are actually showing for 2 different values of epsilon r what is the effect on the percentage bandwidth, as we increase the substrate the thickness. So, let just see one by one. So, this is the case for epsilon r equal to 10. So, we can see that as substrate thickness increases one can see that the percentage bandwidth is increasing; we can even get about 5 percent bandwidth over here. Let us take a case of epsilon r 2.2; one can see the bandwidth is increasing like this here. So, we can see from here that if epsilon r is reduced from 10 to 2.2 my percentage bandwidth is increasing.

Then comes the next part which is the efficiency part, here are the 2 curves for epsilon r again the solid line that is same here. So, one can see that this is the efficiency for epsilon r 2.2 and efficiency decreases drastically for epsilon r equal to 10. So, for example, now let us say we want to design an antenna for say for example, 5 percent. So, if we take as a 5 percent then we can see from here. So, the if we draw horizontal line somewhere here; that means, for epsilon 10, I should take 0.09 lambda h 0.09 as a substrate thickness; however, corresponding to this you can see that efficiency plot is not even given. And if we try to extend this here it will go follow if I do the linear extension somewhere around here 0.09 efficiency will be even less than 20 percent. So, it is not a good substrate at all to design for 5 percent bandwidth.

Let just look at epsilon r 2.2 corresponding to 5 percent here, let us say again from here we draw the horizontal line come slowly here come somewhere here. So, corresponding to this that is about substrate thickness and corresponding to this if you look up of here you can see that efficiency is about 90 percent. So, this is still a good choice to use 2.2 and correspondingly we can use this value here for the substrate thickness, but let just think and imagine that if this is epsilon r 10 and if this is curve for epsilon r 2.2 where will be the curve for epsilon r 1.

So, if we just imagine this is 10 this is 2.2 that epsilon r 1 equal to 1 curve will go probably like this. So, that will have a better bandwidth. Similarly, from efficiency point of view, if we again imagine if this is epsilon r 10 efficiency and this is for epsilon r equal to 2.2 efficiency for epsilon r equal to 1 it is almost close to 100 percent. So, epsilon r is equal to 1 is a very good substrate what is epsilon r equal to 1 it is air. So, all we need to have is a air as a substrate, and will see how to suspend a metallic plate in an air in the next slide.

But now let just look at another thing also that is a variation of percentage bandwidth with respect to frequency and here 3 hs are different hs are taken point 0 7 9.15 9.318. In a reality if you see this curve is actually similar to this here why I say. So, see this is h by lambda 0. And here is a frequency variation which is nothing, but frequency is C by lambda and this is for different h this is for different h by lambda zero, but; however, many a times you know when you want to design an antenna let say we want design antenna 3 gigahertz. So, what you normally do you use this curve here at 3 gigahertzes this is the point and you draw the vertical line from here and if you draw the vertical line let say point 31.8 you look at here that is about 4 percent bandwidth. Of course, this curve is for epsilon r equal to 2.32. So, please remember that again this curve epsilon r 2.32. If I take epsilon r 1 my bandwidth will be much more compared to this one here.

So, now based on this particular information in fact, I strongly encourage that when you need to design an antenna please look at this curve and see what should be the substrate parameter. In fact, it is the substrate which is a good starting point to design the antenna what should be the bandwidth, and then what is the given bandwidth what should be the substrate parameters.

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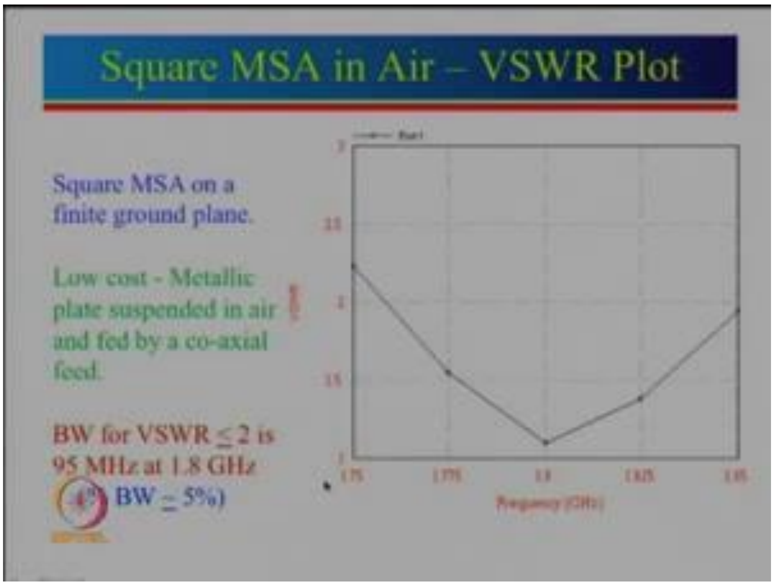

So, here we have designed an antenna and given the result here. I am not included what is the length and width that is an exercise for you people to do it. So, what we have done here it is a square micro strip antenna in air. So, for simulation we have used epsilon r equal to 1. So, what we have taken is square micro strip antenna on a finite ground plane. So, what is done here a low cost metallic plate is suspended in air and fed by a coaxial feed and here are the results. So, you can see that the resonance frequency is designed to be 1.8 gigahertz and this is the VSWR less than 2 bandwidths can be obtained from here which is roughly about 95 megahertz approximately 5 percent.

So, now this is the result which we have given you or this you can think about as a problem which is given to you that design and antenna at 1.8 gigahertz with 5 percent bandwidth. So, we chose epsilon r equal to 1. So, you look at the previous particular slide where we have set that 5 percent bandwidth and you imagine where can be epsilon r equal to 1. And from that approximately you can try what should be the value of h epsilon r is already known which is equal to 1, and then you can find out what is l. So, we already know that L effective is nothing, but C divided by 2 f 0 square root epsilon i epsilon e is equal to 1, because epsilon r equal to 1 so; that means, L effective is nothing, but C divided by 2 f 0 or you can say it is simply lambda 0 by 2. So, f 0 is known which is 1.8 gigahertz you can find the value of L e and then L e is equal to what that is L plus 2 delta L or what is delta L delta L is h by square root epsilon e.

Now that would give us equal to h now here I want to add another thing. So, that fringing field will never be equal to the substrate thickness. So, this formula of h by square root epsilon e has to be modified for the air substrate. For air substrate take maximum delta L as 0.9 h. So, now, you know the L effective h you can get an idea from the bandwidth. So, find out the value of L and since it is a square patch now you can find out W is equal to l. And then we have taken a metallic plate. So, you add 6 h on all 4 side and that will give you the value of the ground plane. So, please do that and you can do the simulation also using some of the commercial software.

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So, now let just see the radiation pattern. So, we have done the simulation. So, this is the radiation pattern at 1.8 gigahertz. And one can see that there are e plane and h plane. So, this is the e plane pattern, and this is the h plane pattern we know that h plane pattern will tend towards 0 or; this is a 0 dB minus 10 minus 20 minus 30. So, you can see that it is less than minus 25 dB of course, there is a back radiation. So, that is giving us what is the value of front to back. So, that is about roughly about 20 dB. You can see this yellow curve here which is actually nothing, but cross polar here. So, the cross polar level here is approximately 20 dB.

Now if you recall we showed you the simulation for a thin substrate also and there the cross polar level was about 27 28 dB. Here cross polar level is more the only reason because for this is because now the substrate height is more because we realized a larger bandwidth. And for larger bandwidth substrate height is more and that would mean probe length is more and if the probe length is more; that means, the it is a better monopole radiation and there will be a little larger component of the cross polar.

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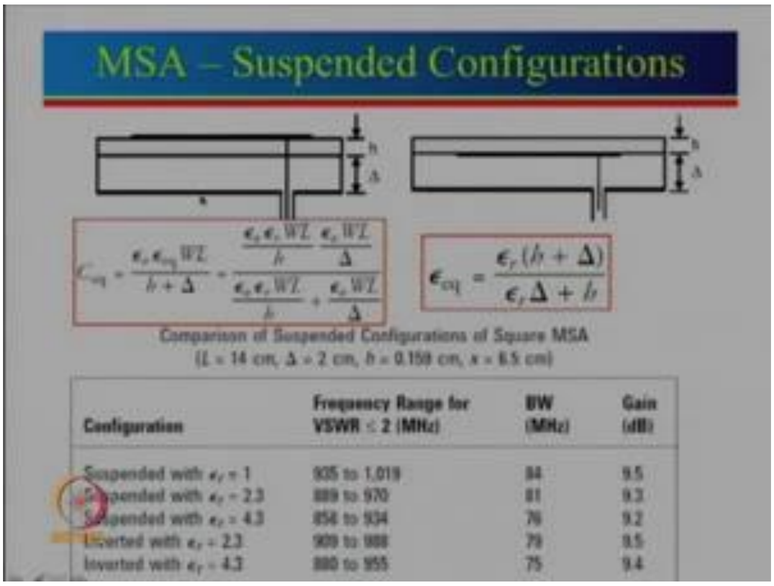

So, now let us see how we can design an antenna using a low cost glass epoxy substrate also. So, we have actually shown you different configurations of micro strip antenna, which is known as a suspended configuration. Now that 2 configurations we have shown let just first look into the first one here. So, what we have here we have a substrate here or you can just take about any ground plate also just a metallic plate you need not have a any substrate as such just the metallic plate will do the job here. And that metallic plate again the question is what type of a metallic plate well you can take a aluminum metal plate or you can take copper or brass or you can get a gold plated aluminum plated, if you have lot of money to spare or a very difficult application is required where the tolerances are high from as far as the tem extreme temperature variations and other things are required may be you need to do or you need to reduce the conductor losses.

So, over here then we have a substrate and on the substrate what we have there is a substrate over here and a patches printed on the other side and a probe is fed. In this case here patches printed underneath the substrate and then the probe is connected to this one here. So, first let just analyze this and then I will come to this. So, in order to analyze this here what we need to find out what is the epsilon equivalent of this particular patch seen see this is air. So, epsilon r is equal to 1. So, this is the substrate we have taken 2 substrates here one is expensive substrate which has a 2.3 epsilon r another one is a lossy substrate which we have taken as epsilon r 4.3 will see what are the results. So, over here this can be any epsilon r.

So, now we would like to find out what is the epsilon equivalent of this particular now combination of the 2. We can actually find out the first effective capacitance. So, the effective capacitance between this plate and this plate will be given by epsilon 0 epsilon equivalent multiplied by area which is W into L divided by total height total height will be h which is the substrate thickness plus delta which is air cap. So, that is the total effective capacitance. And this can be now equated to there is a capacitance between this one and this here and there is a capacitance from here to here. So, we can actually imagine now calculate capacitance between this and this layer, and that will be the capacitance given over here and then capacitance between this and this layer and in this case epsilon r will be equal to 1.

So, now, these are the 2 series capacitance. And for series capacitance we use parallel formula of the resistance which is nothing, but C 1 C 2 divided by C 1 plus C 2 and this expression is modified or simplified by cancelling many of these W L term which are appearing. And this is the expression for epsilon equivalent. In fact, you cannot right to put different value of epsilon r for h and delta we have given an example here taken delta as 2 centimeter h as 0 0.1 5 9 which is over here. You substitute the value for these cases here and you can find out epsilon equivalent and what you will find epsilon equivalent is almost of the order of 1.1 for both of these substrates.

So, epsilon equivalent to 1.1 means epsilon is less; that means, bandwidth will be more. So, here we have case here a first let just look into the suspended case. So, here to start with we have a case of epsilon r equal to 1. Epsilon r 1 means that we have just in simulation we have taken this also 1 this also 1 and then epsilon r 2.3 with tan delta 0 point 0 0 one and this is 4.3 with tan delta 0.02 and here there are result. So, let just see what results we are getting. For epsilon r equal to 1 we are getting 9.5 dB. Now you just recall earlier I had shown you for epsilon r equal to 1 in the previous lecture were we had taken epsilon r 1 epsilon r 2.5 then epsilon r 4.3 epsilon r 10 and we had seen there the gain was 10 dB, but here it is 9.5 dB which is less. The reason for that is here we have taken a square patch. So, L is equal to W, there we had taken W larger than L and since W was larger than L gain was larger in the previous case.

Now, coming back over here this is a epsilon r 1. Now you can see that if you use 2.3 4.3 my gain is just about 9.3 9.2. So, if I take a very lossy substrate, which is very low cost. You can see that the gain change is hardly significant; that means, this configuration can be used with the low cost substrate, without losing much of a gain. Let just look at the bandwidth you can see that the bandwidth changes also relatively small. In fact, bandwidth in megahertz may look difference by 5 megahertz, but in reality if you see the resonance frequency let just look at that. So, the lowest frequency was 935 for epsilon r 1 when we took epsilon r 2.3 it reduced to 889. Why because epsilon equivalent instead of one it has now become roughly close to let say 1.1 that is why this frequency is reduced for epsilon r 4.3, one can calculate epsilon equivalent and then you can see that for larger value epsilon r epsilon equivalent will be slightly high. So, hence resonance frequency is slightly low. So, if take the percentage bandwidth the change will be very small.

Now, let just look the other configuration which is a inverted configuration. Now this inverted configuration, in this particular case the patch sees the height of the substrate as delta and this one acts as a there is a term known as superstrate also. One is a substrate this is a superstrate because substrate is above the radiating facts that is why the name is. In fact, this can also be thought of as a radome. So, we have a patch and this substrate acts as a radome. So, one can actually use this antenna as it is. In fact, if we look at the performance of this. So, one can see that the gain is 9.5, 9.4 you can see that this gain is almost same as this gain here, but even with the lossy substrate the reduction in gain is very small so; that means, we can use a low cost substrate compared to expensive.

Now, you might wonder what is that cost difference. So, just to tell you compare to the cost of f r 4 or glass epoxy substrate. These substrate here low loss can be 30 to 50 times more than this substrate here. So, overall cost of the antenna increases, generally for commercial application one uses f r 4 substrate. And commercial applications can be let say if you want to design GPS antenna or you want to use for cellular communication cell tower radiation and all that, but for defense and satellite communication generally performance is much more important and also thermal variation and other things are important. So, for those kind of applications generally one uses high cost substrate, but nevertheless cost is always a good thing. So, if one can design an antenna with low cost without effecting the performance significantly, and we did not notice that the gain just reduces slightly by about 0 0.1 to 0.2 dB. So in fact, this is a very good way to design an antenna by using this here.

So, now comes the next part how do we support these antennas, and what if this has a good thing then why use this one here. So, first of all the major problem with this is let us say we put a ground plane here and we have put an antenna there, and need to solder here. So, sometimes it becomes very difficult I have to bring this solder either from the side here and all that. So, soldering becomes a big issue to this one here whereas over gear you drill a hole put the probe will come out here one can solder over here. So, sometimes manufacturing part this is relatively easier to do it, but if one can do soldering over here or find an alternate way then this has a better performance and also substrate acts as a radome.

Now, comes the next part what if it was a metal plate only. We have shown the configuration with epsilon r equal to 1. So, for metal plate one of the common missed approach is that you put a shorting post right at the center. Now by putting a shorting post here at the center we can provide a support to the patch. Now by putting a shorting post we get additional thing also that is that this short here can also provide DC ground to the antenna which is sometimes required from protection from lightening. So, DC grounding is good, and that will also act as a support also.

Now may be sometimes you can put one shot at the center or sometimes you can put multiple shots at the center and the putting a shot at the center it does not difference to the performance because field at the center is any way 0. So, at 0 if you put a short circuit it is not going to make any change. So, that is the one way to do it of course, in many a times what people also do they take metallic plate and they put 4 dielectric screws at the 4 edges and these 4 dielectric screws will provide support.

Now, in this just want to tell you, these dielectric screws also provide loading. So, when you are doing the analysis, you must design and calculate what should be the diameter of that dielectric screw which you are putting what is it is tan delta what is it is epsilon r and the put it. If you do not do that calculation and you design antenna and then just put a plastic screw the loading effect will come and that will reduce the resonance frequency. So, for the substrate suspended or inverted there are additional things can be done also. We can actually provide a metallic cavity like this here.

So, on this metallic cavity you can just put the substrates. So, that cavity all around the metal plate can provide support and if we do not have this metallic plate we can even use a dielectric screw here and dielectric screws here and that can provide the support or many a times people also use foam substrates right over here. So, you put a foam substrate then put a dielectric substrate and you can realize the antenna using this particular fashion to provide the support.

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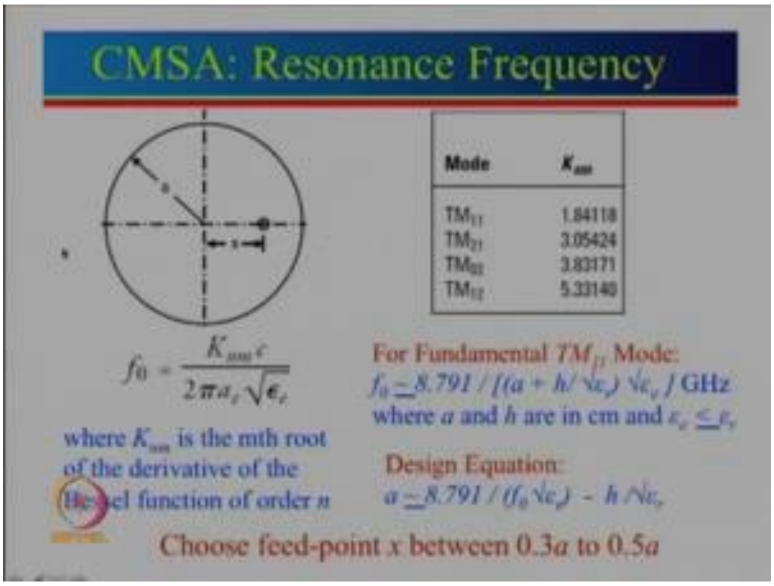

So, we will now go to next configurations. So, we have so far discussed only about rectangular micro strip antenna or square micro strip antenna. Here is a now a circular micro strip antenna sees full form here is a circular micro strip antenna. And let us see how we can calculate the resonance frequency. So, first of all here is a circle with the radius and here is a feed point. So, we need to find the value of x, so that we can get a good impedance matching as before. Now the resonance frequency of the circular patch can be obtained by using this formula here. You can see some new term here which is K nm what is K nm, K nm is the mth root of the derivative of the Bessel function of order n.

Now I just want to mention earlier when we had taken a rectangular micro strip antenna or square. So, for rectangular dimension generally speaking the field variation is defined by the sin or cosine, but over here we have to take sin of sin which is defined in terms of Bessel function. And the whole thing then is governed by the Bessel function of the different order. So, this is how need to do it. And here I have given the value of the K nm which is again mth root of derivative. So, we have different mode 1 1 2 1 0 2 1 2. These are the different mode you can go to 0 3 0 4 and so on. What we need to do most of the time we are interested in the fundamental mode for that K nm value is 1.84118.

So, now I am going to give you some very simple way to do the design and that is that put the value of K nm which is 1.84118 multiplied by c, c is nothing, but 3 into 10 to the power 10 centimeter per second and 2 pi a e. So, a e is nothing, but effective radius just like earlier we had L effective now we have an effective and then we have epsilon e as before. So, the value of K nm is known here for the fundamental mode. So, for fundamental mode you put the value here 1.8 4 into c divided 2 pi. If you simplify this, it comes out to be 8.791 that factor of 10 to the power 9 is merged here.

So, this value will come out to be in gigahertz and here also it is there that a n h r n centimeter. So, here we have use approximate formula for a e, a e is nothing but a plus h by square root epsilon r to the similar thing earlier we had taken L total L was this here L was L plus delta L and delta L and here since it is half of that which is radius here a. So, a plus delta a which will be all around. So, delta a is given by this here and then we take epsilon e. Now again epsilon e can be calculated by using the earlier formula from W. We do not know W, but we can take effective area of the circle we can calculate the effective area of the rectangle and then from that one can calculate what will be the epsilon i, but in general will take things little simple in a way all we say is that epsilon e should be slightly less than epsilon r. So, based on this equation this is a analysis equation where a is known h is known we can convert this to design equation. So, we can find the value of a using just modification of this here.

So, for a given value of f 0 all we need to do for a given value of f 0 can choose epsilon r and h once you have calculated epsilon r and h. This is known f 0 is known you can find the value of a. So, that will simply give you the design parameter for this here. Now comes the next part we need to choose the feed point. Again as before we modify to typically x is 0.382 about 0.58 by using this here you can get approximate match with 50 ohms.

So, we will continue from here in the next lecture. So, just to summarize today we studied about rectangular micro strip antenna. We studied the effect of the substrate parameter. So, how bandwidth and efficiency are related to the substrate parameter? So, we saw that as h increases bandwidth increases, or as epsilon r decreases bandwidth increases; however, we cannot keep on increasing h or decreasing epsilon r because both of these things result into poor efficiency. Then we also looked at the curve for a given frequency how to choose different value of h for a given epsilon r to realize that desired bandwidth.

Then we looked at the design example where we had designed the antenna for 1.8 gigahertz, we saw or what is the bandwidth and what is the radiation pattern then we looked at the suspended configuration and inverted suspended configuration and we actually notice that you can use a very low cost substrate without compromising on the performance of the antenna significantly. There is a very small effect, but the cost advantage is huge and then we just looked at the how to calculate the resonance frequency of a circular micro strip antenna, will see in more detail in the next lecture, how to design circular micro strip antenna what are the different modes how these modes are excited an what are the typical radiation pattern of different modes and so on. And we will also look into the triangular micro strip antenna. So, with that thank you very much see you next time, bye.