Antennas
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Module - 06
Lecture - 24
Broadband MSA-I

Hello and welcome to today's lecture; a today we are going to discuss about circular micro strip antenna and triangular micro strip antenna. Now in the last lecture we had seen a how circular micro strip antennas work, and what are the different modes. So, we started with the fundamental mode which is a TM 1 1 mode then we looked at TM 2 0 mode; 2 1mode as well as TM 0 2 mode and we saw that for fundamental mode radiation is in the broad side direction, and for TM 2 mode and 0 2 mode radiation is in the conical direction; however, TM 0 2 mode is not useful as an antenna, in fact most of the time we do not use that, but however, tm is very good as a power divider. And then we started taking an a example of broad band circular micro strip antenna, which was suspended in air.

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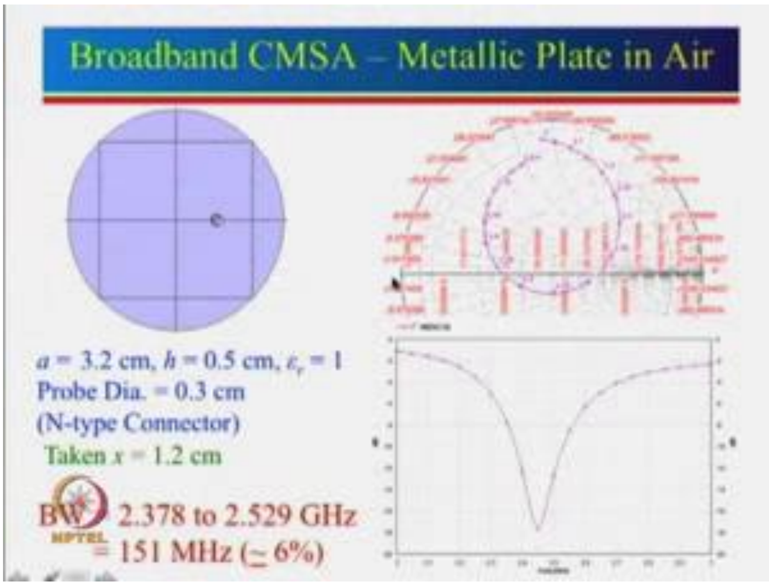

So, today we will see what are the practical implementations, and how we do suspend a circular micro strip antenna in air. So, let just continue from the point where we left. So, we had started discussion on the broad band micro strip antenna, where we had used metallic plate in air. So, the radius of the air circular was taken as 3.2 centimeter, h was 0.5 centimeter epsilon r 1, we have taken slightly higher thickness and epsilon r 1 both of these you will as said broader bandwidth. A probe diameter was taken as 0.3 which is nothing, but a n type connector. A many times where question also comes what type of connectors to be used where? So, generally speaking N-type connectors are good up to about 3 gigahertz, a people do use at higher frequency also, but that is the general thing. SMA connectors which have a probe diameter of 0.12 centimeter, generally they are used up to about 18 gigahertz, and in millimeter ways we use k connector the diameter of the k connector as 0.03 centimeter.

So, now since we know it is a broad band antenna, which you could verify from the graph which we had given for the different values of h, so we can see that it will give us a broad band. So, starting point for the feed point we had taken approximately 0.4, which is about point 1.2. One can see that impedance plot here matching these fairly decent, and this is the reflection coefficient plot and bandwidth for s 1 1 less than 10 dB is about 151 mega hertz. This antenna was specifically design to cover the wi fi region which is 2.4 gigahertz to 2.483. So, you can see that from 2.4 gigahertz we have almost the 22 mega hertz bandwidth margin on this side, and compare to 2.483 we have almost 46 mega hertz on the margin on the other side.

Now, let just see how we use this metallic plate? This metallic plate cannot be suspended in air on its own. So, what is actually done practically is that, one uses a shorting post over here because we know that the voltage as 0. So, at 0 if you put any shorting post or any load, it does not matter. So, this shorting post over here provides one support to the this patch here, and this feed point also provides another support. Now many a times one can also do we can use a little larger diameter shorting post over here, but one has to be careful that if you just use a shorting post of let say very small diameter, because field is actually 0 only at this point, field is not 0 here, field is not 0 here.

However we also know that field here will be plus, here it will be minus along this is 0. So, we can still take a little bit of a diameter here, so one can take 2 to 5 mm diameter shorting post here without effecting the performance and that is going to provide good support. Then there is another thing that is a metallic plate will have some thickness, which let say define as thickness t we cannot have a metal plate of 0 thickness of course, we can think of taking the thickness of let us say 0.1 mm, but a 0.1 mm a circular disc will not remain stable, it will start working and it will actually come down.

So, what we actually can do it is instead of using the 0.1 millimeter, we can use 1 millimeter thick, or may be 2 millimeter thick or half millimeter thick. So, now, what happens? Since the substrate is down below and then there is a patch fringing field will be from the patch to the ground, but now it has a finite thickness. So, fringing field will be not only just from the lower side, but the fringing field will be also from the upper side of the thickness.

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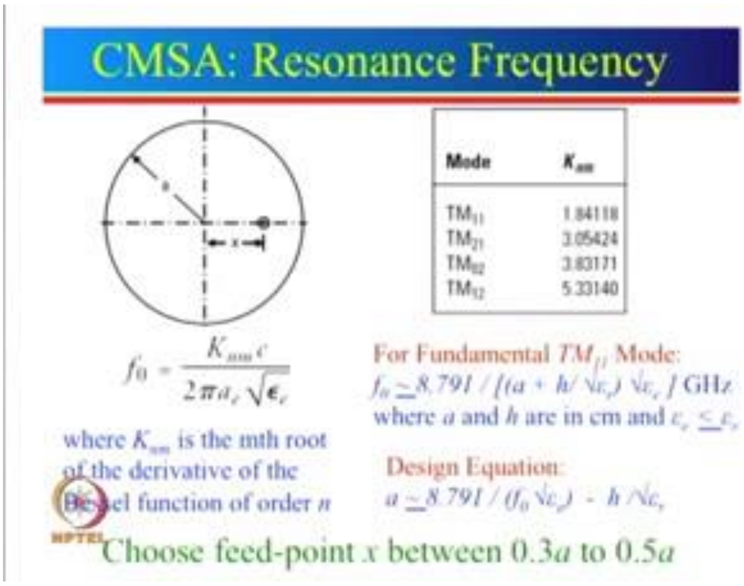

So, generally speaking what one can do it is this can be modeled in a very very simple way, that instead of using a in the expression all we need to do it is we use for a effective I just show you; what you need to do it is you just add the term here a plus t plus h by square root epsilon r. So, where t in this case can be 1 mm or 0.5 mm or 2 mm whatever is the thickness. So, that is all you need to do the modification and then the results will come and you can calculate accordingly. So, infact if you add a little bit of a thickness here, what will happen? Effective a will increase, which will reduce this resonance frequency as a I mention I had taken a larger margin on the higher side. So, that will do the job. So, if you use this particular dimension with a proper support it will easily cover the Wi-Fi.

Then comes the next part also and that is this one here in the beginning we simulated it for to infinite ground plane, but one cannot use infinite ground plane, one as to use a finite ground plane. Now if you recall I had mention for rectangular patch that the ground plane size should be at least 6 times h. So, here h is 0.5. So, if we take 6 times h which will be 3 centimeter. So, if you take a 3 centimeter extra as a ground plane size, then the results for infinite ground plane will be exactly same as that of finite ground plane. However suppose you have to use a smaller ground plane then we need to re simulate this whole thing using a finite ground plane.

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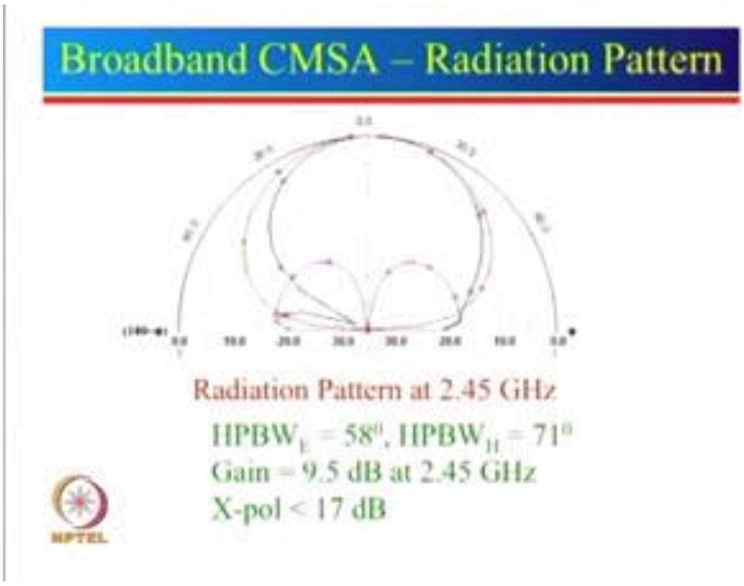

But now let see what is the radiation pattern; now this simulation as been done for infinite ground plane, now one can again see that the radiation is in the broad side direction, and the beam width has reduced because of the reduction in the beam width, we have a gain which is equal to 9.5 Db. If you see this gain is 3 Bb more, then the gain of a circular micro strip antenna on a duroid substrate. Now the duroid substrate cause 30 to 50 times more, then even FR 4substrate. So, this actually your very low cost antenna required some mechanical work, but you can get a very good gain. you can good bandwidth also.

Now, over here one thing I want to bring out at the cross polar level is about 17 db whereas; earlier it was 27 dB for thin substrate. So, what is happening over here? So, the substrate thickness is increased, so the probe which is feeding. Now the probe length total is increased. So, what happens? This acts as a top loaded monopole antenna. So, this becomes little more efficient monopole antenna. So, monopole if you think like this here monopole antenna will radiate very little in the broad side direction, it will radiate maximum like this here.

So, if you see here this cross polar is nothing, but corresponding to the probe radiation. So, since h is increased; that means, the probe is acting as a more efficient monopole antenna and hence this component has increased, but other than that results are pretty good.

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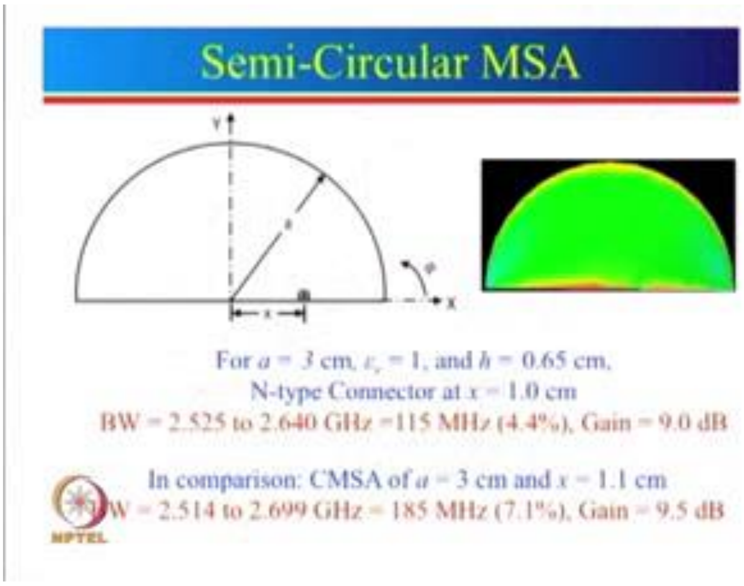

So, now let just look at the next one here which is the semi circular micro strip antenna. So, a semi circular micro strip antenna is somewhat similar to circle in the sense it is half of the circle. So, we actually remove the bottom part here. So, semi circle is still defined by its radius A; now over here the feed point, if you notice here feed point is not exactly on this horizontal line, it is shifted up here and we always advise that do not feed part of the thing to the dielectric material, the feed should always be connected to the metallic patch here.

So, just shift it slightly above there and for the comparison now we have taken a is equal 3 centimeter, epsilon r 1. Here h is equal to 0.65 centimeter, for this particular case here a bandwidth is from 2.5 to 2.64, which is about 115 mega hertz. And gain is about 9 Db, we have done the comparison with this circular micro strip antennas of same type, the feed point is slightly different compared to the feed point for semi circular micro strip , and the gain over here of course is much larger. So, now, one can actually see that the gain of the circular patch is almost 9.5 dB whereas; the gain of the semi circle is 9 db.

So, even the area of the of semi circle is reduced by 50 percent, gain has only reduced by half dB; the reason for that is that now the radiation is not just taking place from the circumference, but the radiation is also taking place from this particular edge also; whereas, for the circle the radiation would be from this as well as from this particular circumference here. So, this is the current distribution it is very similar to a circle. So, this is also fundamental tm 11 mode, you can see the current is 0 going to maximum coming back to 0 here, and along the diameter current is 0 going to maximum and then going back to 0 here.

So in fact actually speaking just to mention later on when we talk about a broadband technique, we will show you that were we had replaced a circle with 2 semicircles which are gap coupled; and we got much better bandwidth in comparison with the circular patch. So, for that you have to wait for some time ok.

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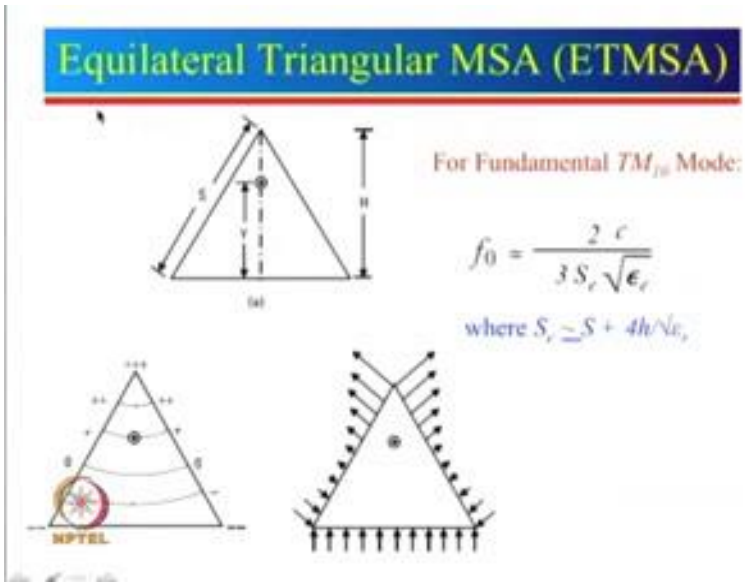

Now, we will go to the next configuration which is an Equilateral Triangular Micro strip antenna ETMSA. So, again here there are several modes are possible. So, we will look at now only fundamental mode which is a tm 1 0 mode, I will explain where is 1 and where is 0.

But let just look at the equilateral triangular geometry first. So, equilateral triangular is defined by its length s, and all the 3 lengths are equal. So, this is s s and s, and the angle over here for each of this angle will be equal to 60 degree. So, this is 60 degree, 60 degree, 60 degree; and over here we have shown feed point along the center if you recall every time we put feed point in the central axis for rectangular patch also for circular, the reason is if you put in this center with respect to this feed point it becomes symmetrical antenna; and if it is symmetrical then cross polar components got cancelled.

Now, for the circle and for the rectangle the null was at the center of the circle or the rectangle. In case of triangle also the null of the triangle is at the null, where there is a centroid of the equilateral, and the centroid of the equilateral is formed somewhere here. So, that will be the centroid point that will be the 0 field point. Now whereas for a rectangle or a circle this null point was exactly symmetrical it was in the center, but in case of equilateral this is the null point. So you can see that compare to this null, so field will be distance is less here, so field variation will be less, and over here distance is more so field variation will be more here.

So, now let me define what is 1 0 mode? So, 1 here actually imply that the field variation is one half wavelength on this here, and one half wavelength on this side; and the 0 here implies that the field variation along this axis is relatively not there, so that is what 0 implies. So, now, let just see how the field distribution varies and how things are. So, over here now coming back here, so this is the null point here, so that null point is you can see here that is the null point here. So, with respect to this feed; so that is a symmetrical. So, field will vary continuously along this one will be continuously 0 whereas, for rectangle it was more like horizontal line, but here it is a curved line. So, along this one here it will be plus, along this it will be double plus, and along this will be triple plus.

Now, just to tell you a convention which we generally follow that if you show a feed point, we show that as a plus; even though we know electromagnetic wave will vary sinusoidally. So, if it is plus in the next half cycle it will be minus, then it will become plus, but it is just a convention that to start with we show this as plus here. So, since this is a plus here, this is 0 this will be minus and this will be double minus. I have shown here as double minus here it is triple plus here the reason is that this length is much more compared to the length over here. So, that also determines then how to choose the feed point. So, one can actually look at for this particular feed point these are the distribution.

Now, it does not really always mean that you have to feed here, you can also choose a let us say axis like this. So, if you choose a axis like this, then null will be somewhere here and then you need to feed point along this one here or you can think about rotating this triangle by 60 degree, and that will change the null location. So, over here now we know now the feed variation is that, now this I have shown in a slightly different way. So, pluses here will show that the field is going outside and then it is reducing. So, it is reducing it becomes close to 0 here and then minus sign means field will be coming from the ground plane to the patch. So, it shows here.

Similarly, field is minus here. So, the field is coming from the ground to this, so the component will be shown in this particular direction, and the same way it is shown over here. So now if you look at it effectively; a one additional thing I just want to mention this is double minus. So, even though this is shown like this here, but in the reality it is actually this will be same potential. So, this potential is not really ideally equal to this one here, this potential will be slightly larger than this value in terms of amplitude, because you can see that the length will be slightly more here.

So, now coming back here then how do we resolve the component? So, for this particular field let us say this is we know this is in this direction. Now we start resolving these components and this component. So, this will be now resolve it into horizontal and vertical component. So, this will be one, and the other component will be down below; now this one here will be in the opposite direction compared to this here. So, these opposite direction will cancel each other in this plane, but over here if you see this is in this direction, this is also in this direction.

But however, these components are down below so, but since the amplitude of these is relatively smaller than amplitude of these here. So, we can say that net result will be that there will be more amplitude in this direction, and there is another slot which is this one has a larger amplitude. So, these 2 then effectively act as slots radiating in this direction. So, the pattern of this one here will be again similar to that of circular or rectangular pattern except that the way we have chosen the feed point, E Plane will be in this direction here.

Now, how to calculate the resonance frequency? Well the resonance frequency is now calculated using this expression here, you can see there is a small difference. In case of the rectangular patch it was C divided by 2 LE, over here the triangle it is 2 by 3 S c and again as before we can find out the L effective, here it is S effective. So, S effective is now S plus 4 h by square root epsilon r. whereas, for L effective it was only 2 ways. So, why over here we use 4. So, we have to actually start thinking, so if this is the physical dimension, so, let say effective dimension will be like this here and then going here and then completing. So, that will be effective triangular dimension.

Now, see delta L is actually calculated as a perpendicular to this one here. So, that will be perpendicular this direction, but in a reality S effective is going up to this point. So, that point has to be accounted for and that is why we use 4 h. So, if we use this particular value for the derivation let us see what do we get now.

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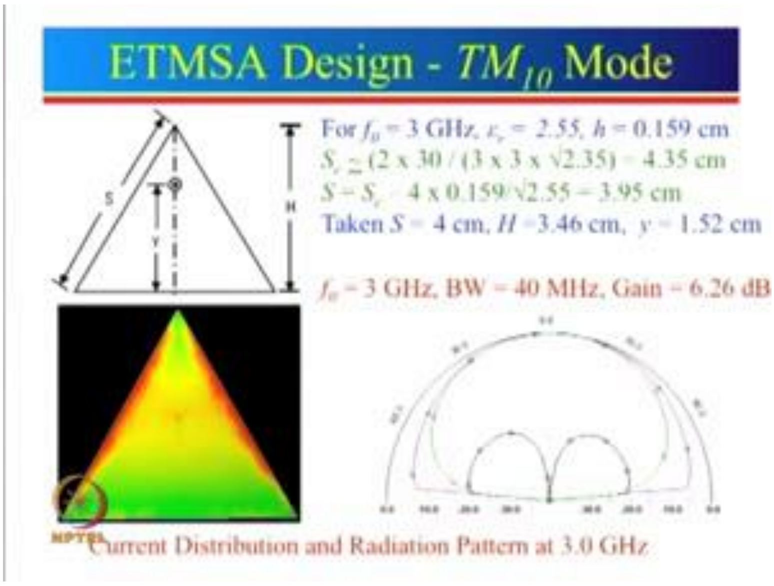

So, here we have taken an example. So, this is a ETMSA design for the fundamental mode, we have taken as 1 0 mode. We have taken f 0 as design frequency 3 gigahertz, which was epsilon r 2.55, h is 0.159; tan delta has been taken as 0.001. So, if we calculate now S e which is effective length S S is nothing but we can calculate using the expression will just go back here.

So, S e from here will be 2 C divided by 3 f 0 square root epsilon e. So, 2 C I have written as just 30, which actually takes care of that gigahertz which is 10 to the power 9 divided by 3 into 3 gigahertz. Now epsilon effective I have taken smaller than 2.55, but I have taken not like 2.45 into for circle, but we have taken for 2.35 smaller than that, there is a reason for that. See now this is the effective you can say propagation. So, corresponding to this now what we need to do it is if you look just along here, what is width? Very very small what is width here? Much larger.

So, one can use an approximation if you want to find out; because the feed is along this. So, we have find out what is the effective area of this triangle, we equate that with the effective area of a rectangle of this length and calculate corresponding width. For that width we need to calculate epsilon effective, and since the effective width will be small epsilon effective will be relatively small. So, I just took 2.35, but you can always do a little longer method, but this one generally works quite. So, from here S e is calculated to be 4.35, and then we calculated S that comes out to be 3.95 centimeter. So, we just took an approximation for simulation; with the coincidence it just happened we got a very good result.

So, corresponding to 3.95 we took S equal to 4 centimeter. Now what will be H? H will be square root 3 by 2 into S that comes out to be 3.46 centimeter. Now this is desired to draw the figure of the equilateral triangular micro strip antenna. Now in this case we have taken a feed point as 1.52 centimeter, and for this feed point we got a decent match and the calculated resonance frequency came out to be 3 gigahertz as I said it just happened a coincidence, but fairly good one because what we have calculated was 3.95.

We just took approximately 4, but one can see that even if I have taken this value the error would have been very very small, and for these case bandwidths obtain is 40 megahertz, and gain is about 6.26 dB and let just look at the current distribution. So, since we are feeding along this here, you can say that the current is going through the 0 value maximum and then going to 0 here. So, we know that this is the null point, corresponding to the null point current will be maximum. So, that is why you can see that the current is maximum here, and then it goes to 0 and it also goes to the 0 here, and you can also see that the current variation is very little along this one here implying voltage variation is also very little here

Now, one can also see the radiation pattern of the antenna. So, in this case here you have to only remember that E Plane is in this side, earlier when I had shown you the pattern for rectangle or circle we had always taken feed point in this side. So, when you take feed point in this side for circle as well as rectangle this was E Plane, but here we have taken the feed point on this side. So, this is the E Plane perpendicular to that will be H Plane. So, here if we say this is e theta earlier for rectangular patch, it was e theta n pi equal to 0 plane, but now it will be e theta n pi equal to 90 degree plane.

So, one can actually see here, but I also want to bring one additional point that this function is also going to 0, this is actually happening because there is a small problem in I 3 D simulation, when we take a infinite ground plane with infinite dielectric, this actually boundary condition does not get satisfied in their software that software always gives a wrong value along theta equal to 90 degree. So, in reality I just want to tell you that this value goes over here. However, in I 3 D if you used finite ground plane as well as you take finite substrate, a this error will not be there. So, for the orthogonal mode this is going precisely to 0.

You can see here the cross polar level is slightly higher compared to the rectangular patch and circular patch, because the patch itself is not 100 percent symmetrical, it is symmetrical with respect to this axis here, but with respect to this it is not symmetrical and hence cross polar levels are slightly high. So, that is why I generally do not prefer equilateral triangular micro strip antenna until and unless the geometry is such that you can do it. Now similar to ETMSA just to tell you which is in angle term we define 60 degree 60 degree 60 degree angle, half of that is also there which is 30 60 90 degree triangle, the resonance frequency of that is also very similar to ETMSA.

But that also has a problem of a higher cross polar. So, just like circular micro strip antenna and semicircular micro strip antenna are somewhat similar, gain is different; similarly ETMSA and half of ETMSA or 30 60 90. As far as the resonance frequency is there it is almost similar, but the gain bandwidth would be less. Now similarly there are many other types of triangular micro strip antennas are there like 45 45 90 degree angle similarly there are different configurations like hexagonal antenna. Now I think hexagonal antenna is nothing, but if you take a circle and you divided into since it becomes hexagonal. So, there is not really much advantage of using hexagonal micro strip antenna. There are octagon micro strip antennas are there, but again that is very similar to circular micro strip antenna.

In fact, at one time pentagon micro strip antenna also came into picture, and the pentagon micro strip antennas became popular because they gave circular polarization; however, ,later on many new techniques came up where people modified the circular patch or triangular patch or rectangular patch to obtain circular polarization. So, now, a day's pentagon patch is not so popular. So, in general a most poplars' configurations are rectangular and circular; sometimes one can use triangular depending upon where you need to fit the antenna.

Then there are lots of other variations are there for example, circular ring antenna, triangular ring antenna or rectangular ring antenna, but when I discuss about compact to micro strip antenna I will cover those things.

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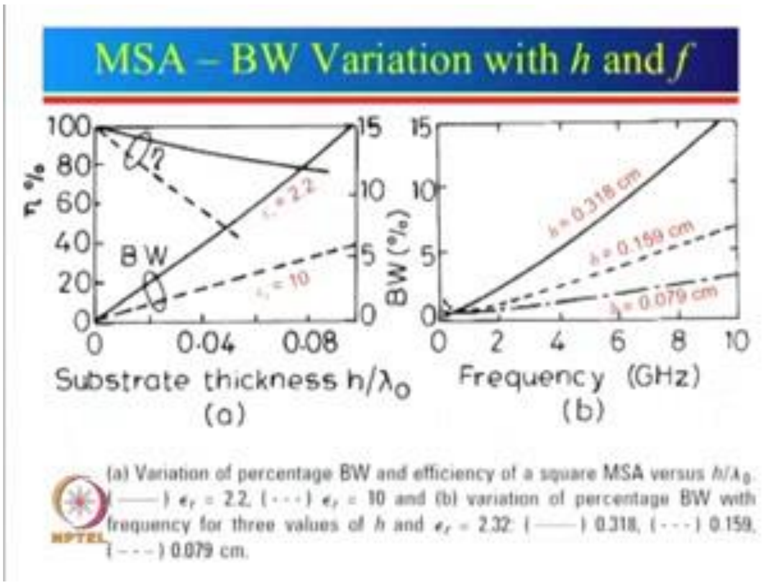

Now, in the next lecture what we are going to do? We are going to talk about broadband techniques, and why we need to talk broadband techniques the reason is that when we look at this curve here, we actually notice that one can get absolute maximum as 15 percent bandwidth for a given simple patch. In fact, most of the time 5 to 10 percent is only achieved.

Now, suppose we require bandwidth of 20 percent, 30 percent or more. So, the technique is to use multiple patches, so that they excite close to each other. Now just think about let say a filter theory or filter concept. So, suppose if I have a one filter which is resonating at f 1 and if the other filter is also resonating exactly at f 1 and cascaded, then the 2 filter will coincide frequency will coincide that gives a narrow band filter. But is frequency is f 1 and there is another filter which is designed at f 2 frequency then the overall response becomes a broadband filter.

So, in case of antennas we generally do not try to get narrow bandwidth as it is micro strip antennas are narrow band. So, what we do? We will actually speaking use multiple antennas or resonator. So, one of them will resonate at let say f 1 frequency, another can resonate at f 2 frequency and thereby if we design them properly, feed them properly we can get broadband antenna. Of course, one can use f 1, f 2 f 3 also, but in the next lecture we will start with the concept of 2 resonators and how to get the broadband width and there are various configurations are there to obtain large bandwidth. So, in the next lecture it will be all broadband micro strip antenna.

Thank you very much bye.