**Antennas**
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**Module – 03**
**Lecture – 12**
**Monopole Antennas-II**

Hello, and welcome to today's lecture on Monopole Antennas. Now in the last lecture we discussed about various characteristics of monopole antenna. So we saw; what is the effect of the diameter of the monopole antenna on infinite ground plane, and what we notice that if you increase the diameter of the monopole antenna bandwidth increases. Then we saw the effect of the finite ground plane and we actually saw that if the ground plane size is very small then the frequency is higher; that means for the same frequency you have to take a larger length monopole antenna than lambda by 4.

Then we also saw that by change in the radius of the monopole antenna which is inductive effect also is changing; that means, if you take a very thin monopole antenna it has more inductance where as if you take a thicker dipole inductive part is less. So, the impedance plot shifts towards the capacitive region and for the ground plane effect we saw that when the ground plane size was very small the antenna input impedance was high as well as capacitive and as we increase the ground plane radius then we could also see that impedance plot is shifting towards the inductive part and thereby properly choosing the ground plane size one can have a perfect match with 50 ohm coaxial feed also.

Then we also looked at the broadband configuration. So, one of the configuration we looked in the last time was the variation of the conical monopole. So, where we did not take a solid conical monopole, but we just took the outer part of the cone and that gave us a fairly broadband and we looked a practical example of a requirement from the deference which was from 200 mega hertz to 1 Giga hertz plus and we saw that we achieved much larger bandwidth than that.

Today we are going to see some other configurations which are even much larger bandwidth than what we saw in the last lecture. So, these are known as ultra broadband antennas.

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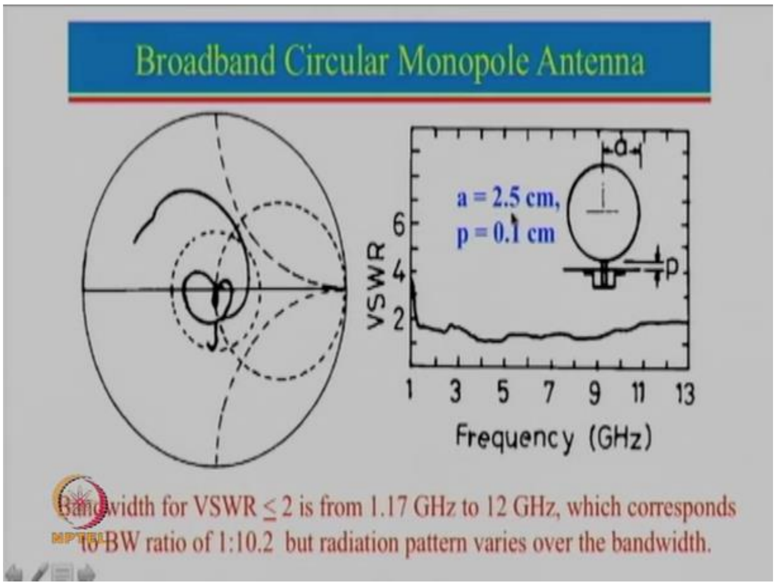


Now, let us see today we will start with the broadband circular monopole antenna. In fact, I just want to mention, this particular paper we saw almost about 15 years back where a paper was reported that, they actually reported this circular disk only circular one circular you can say a plate and which was being fed by the coaxial connector through a finite ground plane and they reported a very large bandwidth, but they had not given any explanation why it is happening so, so we actually decided that let us just investigate this particular configuration and those days we did not have sophisticated software tool to do the simulation. So, we actually decided to do lot of experiments and we carried out huge number of experiments on this particular configuration.

So, first of all we actually made circular dishes of different radius. So, this is the result for a equal to 0.5 centimeter, but we did take different configurations also for all the cases we got the broadband. So, here let just see what result we are getting. So, a is 0.5 centimeter which is the radius and this is the p which is the distance between the coaxial probe which is from this feed point with respect to the ground plane. So, that is the probe dimension which is protruding and one can see the response, this response is really really broad if we draw a line here from VSWR we can actually see that the bandwidth here for VSWR less than is right from 1.17 mega hertz to all the way 12 gigahertz even you can see that even thirteen gigahertz is almost within VSWR it is slightly more than 2, but practical purpose this is still within the this entire bandwidth is there.

However, there is a one major problem with this configuration that is the radiation pattern varies over the bandwidth, but we will come to that part a little later let us see quickly how we can do the design, how we did the design what are the other cases which we studied.

So, even though we started with the circular dish here, but then since we saw very good result and we wanted to understand what is really happening? So, then we took elliptical dimension with the ratio of let us say a by b major axis divided by minor axis. So, we took that as 1.1 1.2, 1.3, 1.4 we studied that then we actually made circular shape then we made the square shape we made rectangular shape we made hexagonal shape triangular shape and so on. So, we studied all these different different configuration and then we came out with a very simple one line expression to predict the lower resonance frequency of the antenna and the concept we used was very very simple.

For a larger ground plane we know that the height of the monopole antenna is given by h plus r equal to 0.4 lambda. Now r here is defined more if it is a monopole antenna of a cylindrical shape, but over here the shape is not cylindrical, but the shape is let us say circular or it could be elliptical. So, what we did was for that circular shape we found out what is the equivalent radius by equating the area of the circle what is the area of a circle which is equal to pi r square what is the area of the let us say cylindrical dipole antenna it is pi r multiplied by the length.

So, that is the area of that. So, what we did? We used the combination of the two, equated the area, but what we kept the height of the circular dish is taken as the length of the monopole antenna and then the radius was calculated. So, by putting that and then we actually put this thing concept into different configuration for circle for elliptical, for triangle and we got the result within 5 to 8 percent accuracy.

So in fact, this pre published paper in the IEEE journal also, starting from knowing nothing about this antenna we did extensive study and we could publish and in fact, that paper has been referenced by very large number of people, but very quickly you can think about here, so a is 2.5. So, this length will be roughly 5 centimeter effective length will be slightly more than that, but let just for a quick calculation if I take this as a 5 centimeter, 5 centimeter if that is lambda by 4, so, lambda will be 5 into 4 that will be 20 centimeter and 20 centimeter will correspond to the wavelength of roughly 1.5 gigahertz. So, that is where it will come.

So, just to give you an idea, but effective length will be not just lambda by 4 it will be used that formula has to be used which is l plus r equal to or rather in this case h plus r equal to 0.4 lambda. So, if you do that you will get very close to what we have got over here. Now of course, this is a 3 dimensional configuration where this particular circular dish is placed perpendicular to the ground plane over here we had taken a circular ground plane. So, after that lot of research was actually reported where they came out with the printed monopole antenna.

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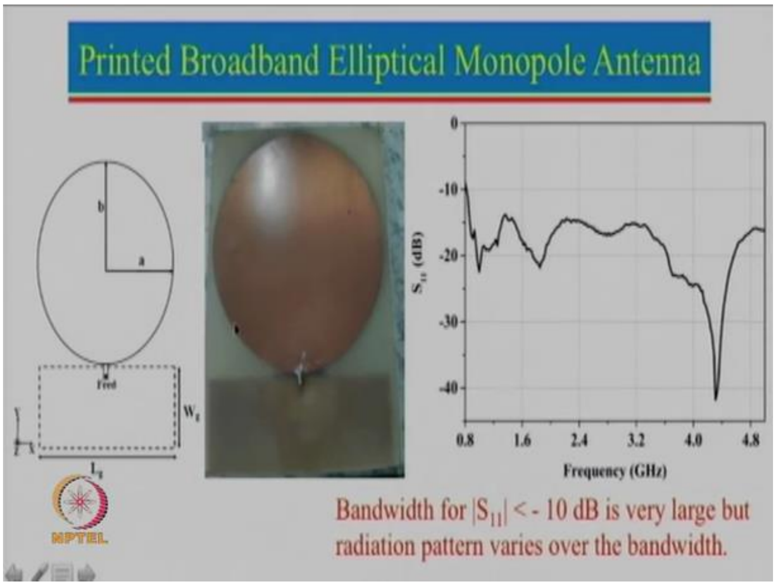


So, here is an example. So, what it is that, this is a monopole antenna which is printed on a dielectric substrate, so what you see over here this is printed at the top side and this is the ground plane which is on the other side of the substrate, a coaxial connector is connected here which is feeding the this particular antenna which is fed back and, for this you can actually see that S 11 minus less than 10 dB bandwidth is very large you can actually see here this is a minus 10 here it is going all the way we have not done the simulation beyond this, but you can actually see that the bandwidth starts from almost say 0.8 gigahertz it is going beyond 4.8 gigahertz. So, it is a very large broadband antenna.

In fact, the only problem with this particular antenna is that the radiation pattern varies over the bandwidth. So, why that is happening? So, again one can actually think about a circular shape or in this case elliptical shape will have many higher order modes that will start with let us say circular shape we saw that a fundamental mode will be at one frequency as we go to the higher order modes which will happen at higher frequency. So, all these higher order modes will come together and they give the broadband response.

In fact, when I discuss about broadband microstrip antenna then I will talk about this particular configuration in much more detail how the higher order modes of a circular patch antenna giving a very large bandwidth, but if you are curious right now you can refer my book which is broad band microstrip antenna book it is available freely now from the internet, you can simply say broad band microstrip antenna pdf and you can download and you can read chapter 9 of that particular book here. But here are the printed versions of that which are really broad band; again the concept is used in a similar way you can find out the resonance frequency in a similar fashion which I described earlier.

Now, based on these things here many other variations have been reported. So, some people have reported here where instead of this curve shape they have used a step configuration over here, some people have reported instead of using a square ground plane they have used a circular ground plane or some people have used a tapered ground plane over here sometimes this particular shape has been not taken a full circle here, one can take half semi circle also here, one can actually take a may be a shape like this here. So, many variations have been reported for this particular configuration there probably are thousands of papers today which report about electrical monopole antenna or variation of that and in fact, there are floods of paper specially for UWB band which is designated from fcc from 3.1 to 10.6 gigahertz. So, we require a bandwidth ratio of 1 is to 3.5 or so.

Now, for that this is a absolutely perfect ideal antenna because it can give a very large bandwidth. However, majority of the time people only talk about VSWR bandwidth one should also be concerned about the radiation pattern what is the radiation pattern over the given bandwidth see it is not just important to design a broadband antenna.

So, let us see how we can do what are the different techniques we can apply to get a uniform radiation pattern over the desired bandwidth. But before we move there I also want to mention that lot of things which are coming on UWB band which is say from 3.1 to 10.6. So, first of all I want to tell this is the band approved by fcc this band is not approved by Indian government and counterpart of fcc in India is WPC - wireless planning commission which is a branch or comes under the umbrella of DOT - department of telecommunication. So, you can actually do Google search say WPC DOT and then you can download their document you can see which frequency can be used for which purpose. So, that you become more practical when you are designing a antenna and then only the dream of our current prime minister who is saying make in India.

Now as I said before make in India will happen only when first you do design in India and before you do design in India you must know that what frequencies are used for which application. So, until unless you know that it is not going to do it and also another thing I want to mention in that UWB band also which is from 3.1 to 10.6 lot of other things are coming in between which are let us say 5.8 gigahertz. So, then they integrate within that band reject filter or antennas with some slot which will reject that particular band also. So, basically first you design broadband antenna then you reject certain portion. So, that you can reject undesired configuration, but please remember that UWB band of 3.1 to 10.6 is not available in India.

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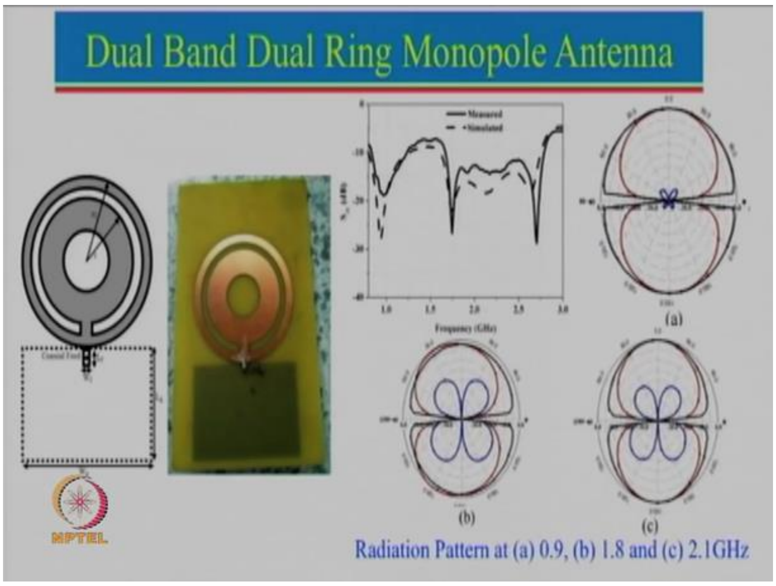

So, now let us see how we can do something. So, just to tell you we have actually designed a dual ring monopole antenna the applications were mainly for you can say GSM900, 1800 and 3G. Now we notice that if we had used just a simple circular monopole antenna, it was not giving us a stable radiation pattern at this desired frequency. Now when we were doing the simulation and we also can tell you that the current is generally confined in the outer region and there is a very little current in the central area.

So, what we did it is we made instead of a circular antenna we actually made it a circular ring antenna and within that ring then we added another ring antenna here and just to tell you. So, the outer ring was designed around 900 mega hertz and the inner ring was designed around 1800 mega hertz and since we wanted to cover the other band also. So, we made it little more broader inner ring.

You can actually see the response over here. So, one can actually see that the it has a decent bandwidth at the lower band h and then also one can see that at the higher frequency range also the reflection coefficient is less than minus 10 dB, this band was not of interest not of our interest for this application. So, VSWR is more than our reflection coefficients is more than minus 10, but let us see the pattern here.

So, you can see that at 900 mega hertz it is a very good pattern here symmetrical over here the pattern is fairly good there is a little bit asymmetry is there, but that is still within 1 to 2 dB which is acceptable for most of the application and then at 0.1 gigahertz also you can see that the pattern is very symmetrical very similar to that here. So, by using this configuration we could get a relatively symmetrical pattern.

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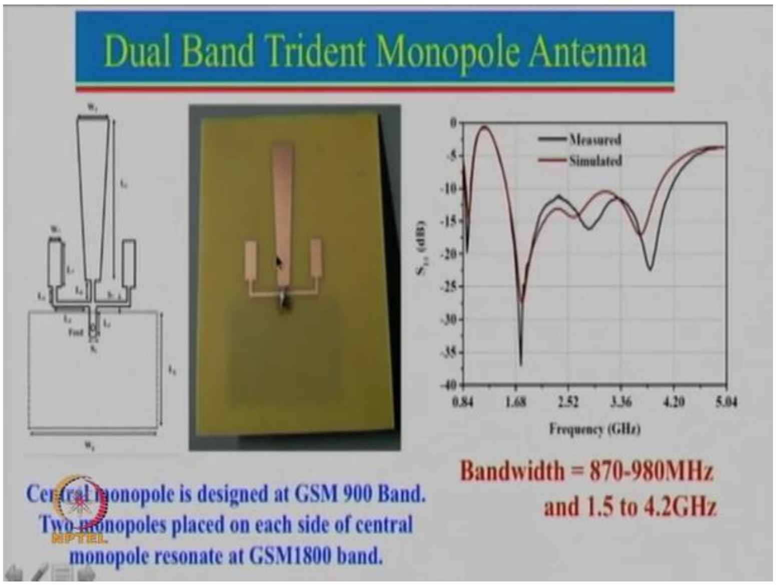


Now, let me show you one another configuration in parallel we worked on it this is actually dual band trident monopole antenna. So, what we have done here is we have designed a antenna at the center over here which resonates around again 900 mega hertz.

And then we designed this antenna here which is at the higher band which is to cover the 1800 to 2500 mega hertz, but we have to put of these things over here they are both symmetrical, the reason for that is if just this was used then this particular antenna will act as a reflector for this here and that means, then the radiation will be less in this direction radiation will be more in this direction and that will not be a symmetrical radiation pattern like a monopole antenna.

So, by putting this symmetrical here so for this here let us say this acts as a reflector for this, but then this is also acting reflector for this also. So, it will still gives us a symmetrical radiation pattern in this particular plane here. So, the trick here is you design the central point which is at GSM900 band and you put the symmetrical antenna which are required at the higher band. Now I have taken 900, 1800 it can be any other frequency range the focus should be this should be at the lower frequency these should be at higher frequency.

So, approximate dimension this length is approximately lambda by 4 and this length is approximately lambda by 4 at higher band. So, one can actually see that at 900 mega hertz our requirement was from 890 to 960, we got 20 mega hertz extra on this side 20 mega hertz extra on the other side which is a good thing to do when you are doing the design and you can see that measured and simulated results are matching pretty good and then at the higher response you can see that right from here 1.5 up to 4.2 gigahertz we are getting broad bandwidth.

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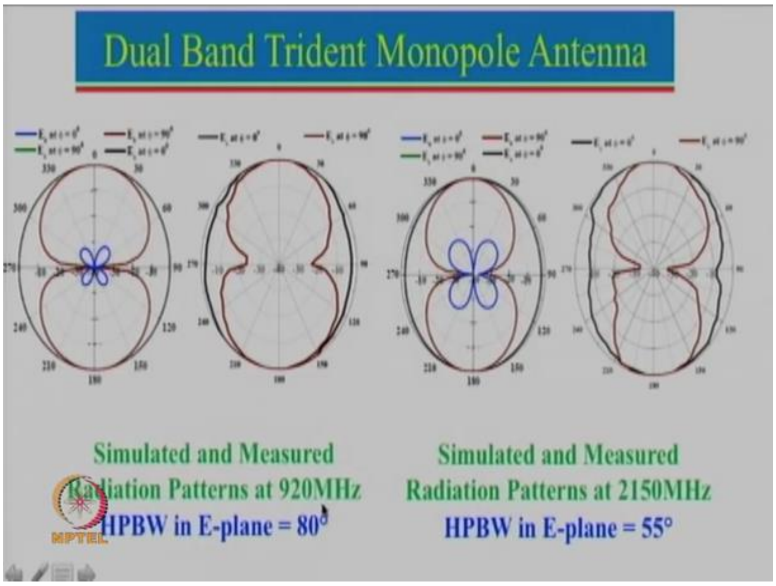


Now, let us see our goal was to look at the radiation pattern. So, let us see what is the radiation pattern. So, here we have shown the radiation pattern at frequency 920 which is between that 890 to 960 you can see that it is a very good symmetrical pattern these are the measured results you can see that they are close to this simulated results and these are the results which we have plotted at 2150 which is between that 3G band of 2110 to 2170 megahertz. So, one can actually see that again the pattern is symmetrical and even the measured pattern is relatively symmetrical.

Now I just want to mention these are the antennas still which gives us the vertically polarized antenna and this is a dual band antenna.

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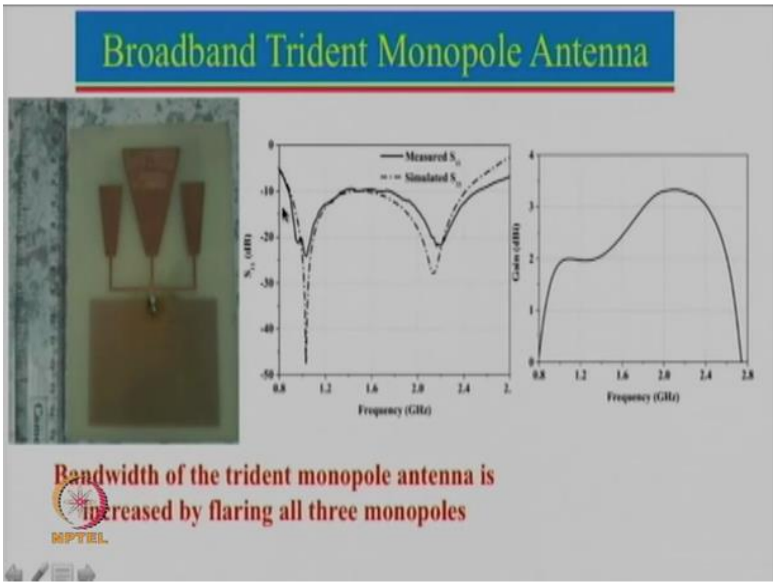


So, we actually got little carried away. So, we decided why not we do little bit of a broadband antenna right from low frequency to the end frequency. Now in order to realize a broadband antenna what one needs to do instead of using a simple monopole antenna we have used a triangular monopole antenna and even for the side patches we use the slightly tapered antenna so that we can get a broad bandwidth. So, this gave little more broader bandwidth, this one also gave little broader bandwidth. So, one now see that the response is right from here to here reflection coefficient is less than minus 10 dB over the entire band.

Here is the gain plot also so that is the gain from variation from 0.8 to about 0.8, one can actually see that the gain of the antenna is around 2 dB at the lower frequency, but it slightly increases at the higher frequency. So, which is close to about 3-point - 3.3 dB, but the pattern is symmetrical over the entire frequency range and you can see from here.

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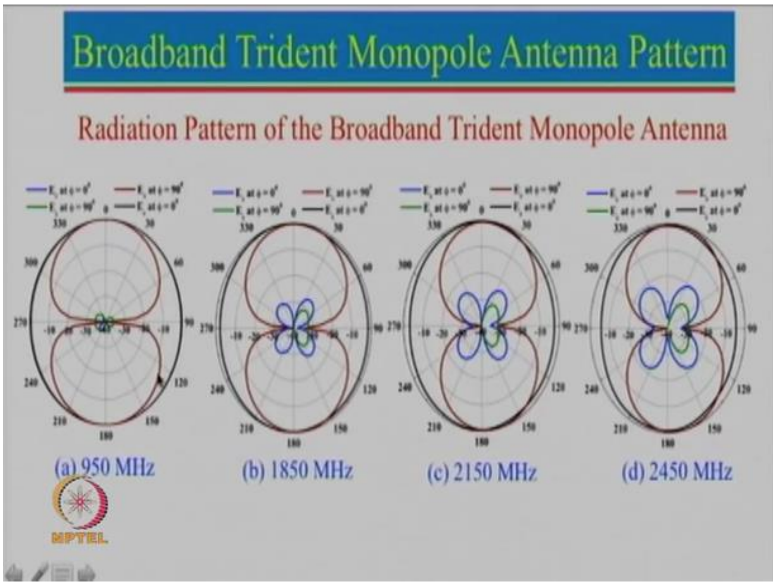


So, we have shown the pattern here at 950 megahertz, 1850 megahertz, 2150 mega hertz, 2450 megahertz which is for Wi-Fi application. So, one can actually see that you know this is the Omni-directional pattern that you can see here. So, that is also an Omni-directional here it is still considered Omni-directional even though there is a absolute maximum variation is about 5 dB over the band and yet the pattern over here it is forming that 8 shape here this is also forming similar thing and you can still see that cross polar level here is of course, is less than 35 dB, here it is still less than about 25 dB, here less than 20 dB less than 20 dB so we can see that it is a fairly good antenna which has a symmetrical radiation pattern, it is Omni-directional at various frequencies of interest and hence very useful antenna, but these are all vertically polarized antenna.

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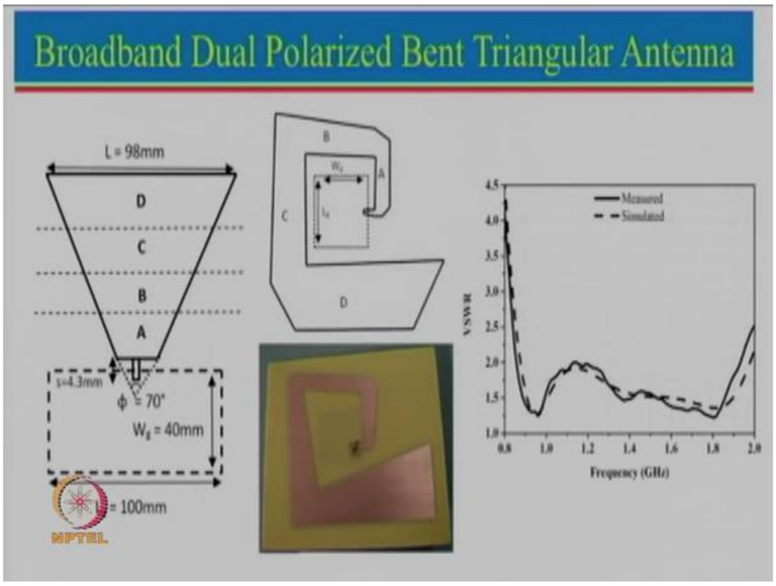


Now, for some application we also need a antenna which actually has a dual polarization also. So, just to tell you the application we were actually looking at is again for RF harvesting. Now for RF harvesting when we wanted a design an antenna for RF harvesting or even sometimes we want to measure let us say radiation intensity at a particular place. So, for example, let us say there is a cell tower which is transmitting there multiple cell towers are there CDMA, GSM900, 1800, 3G, 4G now and Wi-Fi.

Now you want to measure what is the radiation coming from there what is the radiation intensity. So, what we had done? We had designed the radiation monitor. So, earlier we had used a vertically polarized monopole antenna because let us say the antenna is transmitting from this side here and then you put the another antenna, but now we have actually noticed that the pattern does not remain vertical all the time specially after multiple reflection pattern changes and also if this is mounted over here there will be components which are horizontal as well as vertical component. So, we needed an antenna which should receive both horizontal as well as vertical component not just vertical component only. So, we were looking into some configuration which should give us some broadband configuration also as well as it should give us some multiple polarization.

So, let us just look at an example here. So, what we did I will just mention first what is the starting point here. So, the starting point was we know that this particular antenna a triangular monopole antenna is relatively broadband antenna. So, what we did and here is a ground plane. So, this ground plane we reduced the size here which is coming right over here and you can see that the triangular antenna is flaring up. So, we started with the small which is over here then the dimension is increasing then the width is increasing, width is increasing and width is further increasing.

So, we actually started with this particular concept not 100 percent same as this here, but the concept is coming from here. Now what is really happening this one will radiate let us say vertically polarized, but now those vertically polarized components have been bent around. So, let us say this is radiating like this, this then this is radiating like this, this is radiating like this here, this radiating like this here. So, we are getting both horizontal as well as vertical component.

So, let us see here the result. So, this is the designed simulated one here, this is the fabricated antenna and here we have the results which are both measured as well as simulated result. So, one can actually see that both measured results and simulated results are in good agreement and you can see that bandwidth which we are getting is a fairly large bandwidth starting from say less than 900 megahertz to up to beyond 0.2, 0.3 Giga hertz or so, which is actually meeting both GSM900 and 1800.

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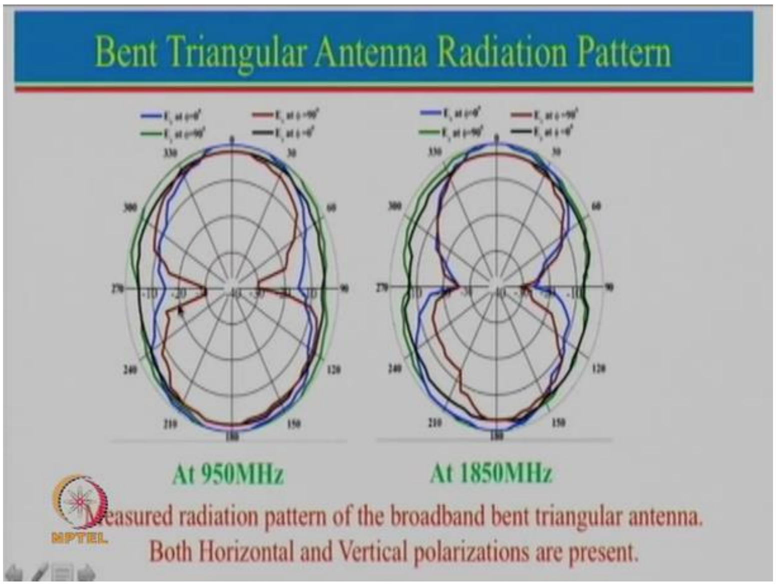


Let just see now the radiation pattern. So, here we have shown the radiation pattern at 950 mega hertz which is in between the GSM band and this is in between the GSM1800 band. So, one can actually see that now there are all 4 components are there, these are the components which are E theta in phi equal to 0, E theta in phi equal to 90, E phi in phi 0 E phi in phi equal to 90 or in other terms you can it that E polar E cross polar, H polar H cross polar all 4 components are now present over here and one can also see that pattern is relatively symmetrical.

Now this is the pattern at 1850 mega hertz. So, you can see that the pattern is relatively symmetrical. So, one can actually say that this particular component has both horizontal as well as vertical polarization. So, this antenna can also be said that this is a polarization insensitive antenna so; that means, if you have this particular antenna as a receiver you can actually orient in vertical direction or in horizontal or any other plane it will still receive the signal. In fact, just think about it.

Let us say if in a mobile phone antenna if we just use this particular thing here which will be a normal monopole antenna that will have only vertical component so that means, if it has to be perfectly aligned with the transmitter and which should come over here. Now we all know that nobody uses mobile phone like this you know we use mobile phone like this or we may use mobile phone like this here. So, we need an antenna which can actually receive various polarization. So, that is why earlier when we had a mobile phone they invariably had a monopole antenna like this and then receiver will have a sometimes problem depending upon on the orientation.

Later on because this length was too large they came out with a normal mode helical antenna which had a height only of about centimeter which was actually put over here. Much later than that what happened? A microstrip antenna came or printed monopole antenna came which are now behind the mobile phone only so you really do not see the antenna and in fact, sometimes they even use a slot antenna also. So, where they put the metallic ring here and they cut the slots in the ring so that you can get a radiation pattern.

So, that is what I am going to discuss in the next lecture. So, in the next lecture we will talk about loop antenna and slot antenna and we will also see very interesting thing loop antenna is again can be derived from the dipole antenna we will just see that how a small loop antenna can be equivalent or equated to a magnetic dipole instead of electric dipole. So, electric dipole has let us say H field like this, we will see that small loop antenna will be actually equivalent to a magnetic dipole and then electric field be like that. And then we will see slot antenna in fact, slot antenna is nothing but a complement of the dipole antenna.

So, whatever we have studied for dipole antenna so E field in the dipole will become H field for slot antenna and vice versa. So, please read carefully dipole antennas, monopole antennas and come prepared for the next lecture which is going to be on loop antenna and slot antenna. So, prior knowledge is very very important.

Thank you and we will see you next time.