Antennas
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Module – 03
Lecture – 11
Monopole Antennas-I

Hello and welcome. Today we are going to discuss about Monopole Antennas. In the last few lectures we have been talking about dipole antenna. Now, one of the biggest problem of dipole antenna is it requires Balunm especially if you have a single ended feed there. Of course, trappers can be used for example, we looked at an application where chip is there that chip requires differential input then that is fine, but majority of the time the source may be a single ended. So, in that case instead of using dipole antenna we use monopole antenna.

So, today we will look into various types of monopole antenna, what are the parameters which govern the performance of monopole antenna.

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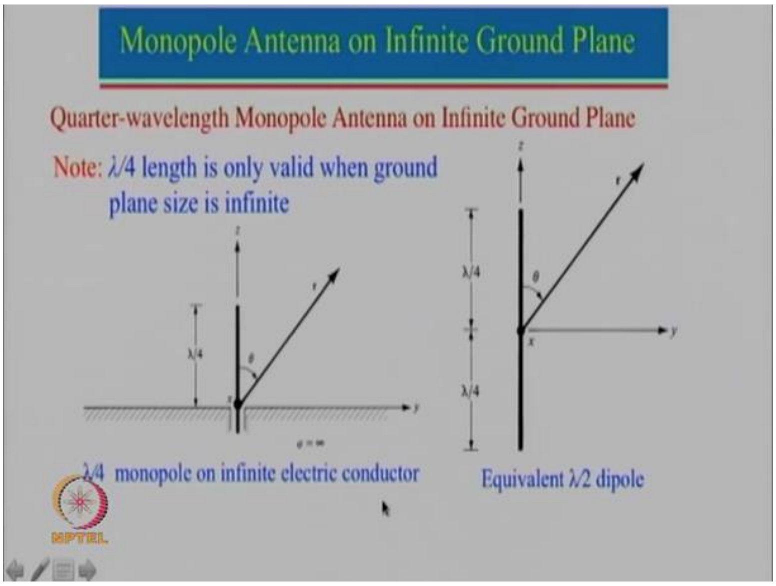

So, to start with actually take an example of monopole antenna on infinite ground plane. We know that infinite ground plane will never ever be there, but still just to start the concept we will take infinite ground plane. And generally speaking for a normal dipole antenna we take a lambda by 2 length, so for monopole it will be quarter wavelength.

And I want to emphasize that lambda by 4 length is only valid when ground plane size is infinite.

Finite ground plane length is never equal to lambda by 4, but in general it is slightly more than lambda by 4. But let us see here how we have a dipole antenna and equivalent monopole antenna. So, here it is a dipole antenna of length, let us say lambda by 2 where we feed over here using a balanced line; one can see that there is a symmetry here there is a current going in this direction this current is coming over here. So, if we replace this whole thing by a very large infinite electric conductor, then we can say that there will be a lambda by 4 antenna over here and we can use a coaxial feed here. So, the ground of the coaxial feed can be connected over here and the center pin will feed the monopole antenna.

So, we need only lambda by 4 monopole antenna on infinite ground plane and this is the equivalent configuration of a dipole antenna.

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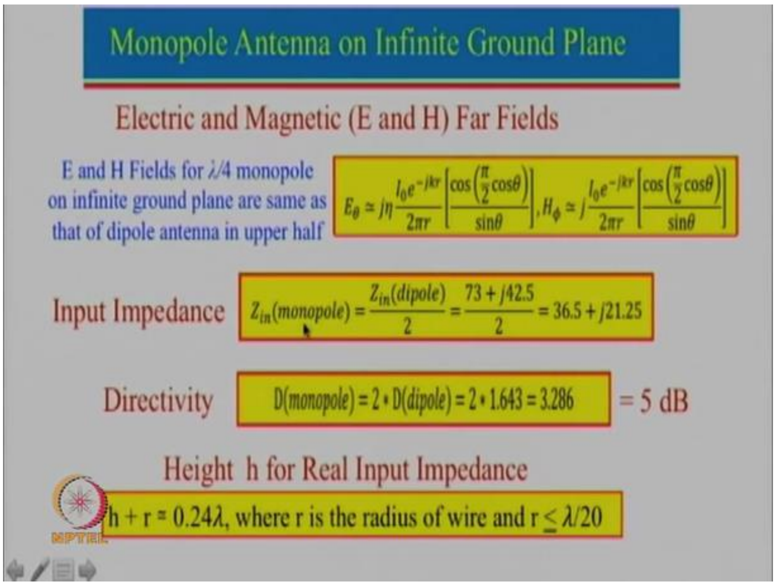

So, now for the monopole antenna on infinite ground plane: all the characteristics which are applicable to the dipole antenna are applicable here also. So, E and H field for lambda by 4 monopole on infinite ground plane are exactly same as dipole antenna but only in upper half, because below half there is a infinite ground plane so there will be no radiation. So, the E field and H field equations which were valid for the dipole antenna they are exactly valid for the lambda by 4 monopole antenna also.

But now that the total length is reduced by half and there is a symmetry with respect to the ground plane. So, the input impedance of the monopole antenna is half of the dipole antenna; we can actually just go back and look into this configuration here. So, think about this is where we were feeding and we found the input impedance. So, here the current was plus, this was coming as minus. Now if we draw the center line in between which is what is over here. So, that will be a 0 line here, the potential now which was plus here then 0 and minus. So, voltage will be changing if we take half the thing. So, basically you can say that half the voltage half the impedance, so that is why the monopole antenna input impedance is exactly half of the dipole.

So, if it is a lambda by 2 which has an impedance real part as well as imaginary part it will be the impedance given by this. But if it is designed as before that is for real input impedance we had seen that the dipole should be slightly smaller than lambda by 2 then this impedance was roughly about 68 ohm. So, then 68 divided by 2 it will be approximately 34 ohm. Now directivity of the monopole antenna will be 2 times dipole, but this is valid only if there is a infinite ground plane.

For finite ground plane this is not at all true. And since the radiation is only in the upper hemisphere, there is a no radiation in the below hemisphere that is why the directivity will be double of the dipole antenna. So, for dipole antenna directivity is approximately 2 dB, so now it will be 5 dB. But I am repeating this is only valid for monopole antenna on infinite ground plane and which will never ever happen. And we will study systematically what is the effect of the ground plane on the input impedance as well as on the frequency as well as on the directivity and radiation pattern.

Now, to start with we need to design the monopole antenna. So, in this case here now this design is again valid only for infinite ground plane or extremely large ground plane. So, earlier we had seen the formula was l plus D equal to 0.48 lambda we divide everything by 2. So, l h is half of l radius is half of D. 0.48 becomes 0.24. So, this is exactly same as the dipole antenna, just a factor of 2 is there. And for dipole antenna we had mentioned that the diameter should always be less than lambda by 10. So, here radius should always be less than lambda by 20, so that the assumption that along the radius or the diameter field is uniform.

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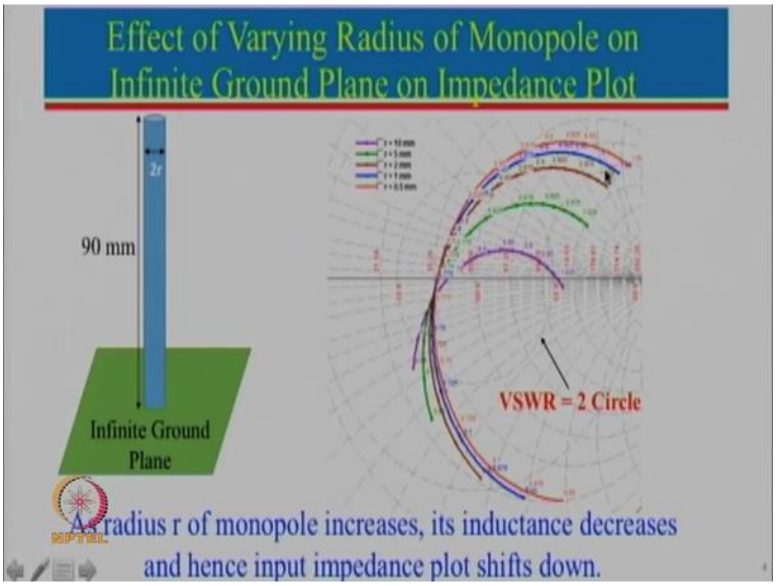

So, here now we will start with the different example; the first example which we have done is that is for infinite ground plane. So, we have taken a infinite ground plane, one thing I just want to mention the effect of the length is straightforward. That if you increase the length frequency will reduce; if you decrease the length frequency will increase. So, let us just see what is the effect of the diameter? So, here we have plotted for different values of radius, and one can actually see that as radius of monopole increases; that means very thin dipole to very thick dipole.

So, what happens? Its inductance will decrease; so if it is inductance decreases so this is the plot for the very thin radius. As you keep on increasing the radius it will come over here. Now, just to go back again think about the dipole antenna, we had seen that for dipole antenna impedance will be something like this here which is 73 plus j 42 which is of a lambda by 2. Now half of that will be 73 half which we just looked at here. So, that will be close to 36.5 plus j 21, but at real impedance will be around 34 ohm. So, one can actually see the plot is crossing around that particular point over here, which is valid for very thin monopole antenna.

As we keep on increasing the thickness, what we can see that it is shifting down because for a thin diameter inductance is large, for a thicker diameter inductance will reduce and if inductance is reducing the whole curve is shifting down here. So, this is the thing here. So, this tells us how the effect on the impedance.

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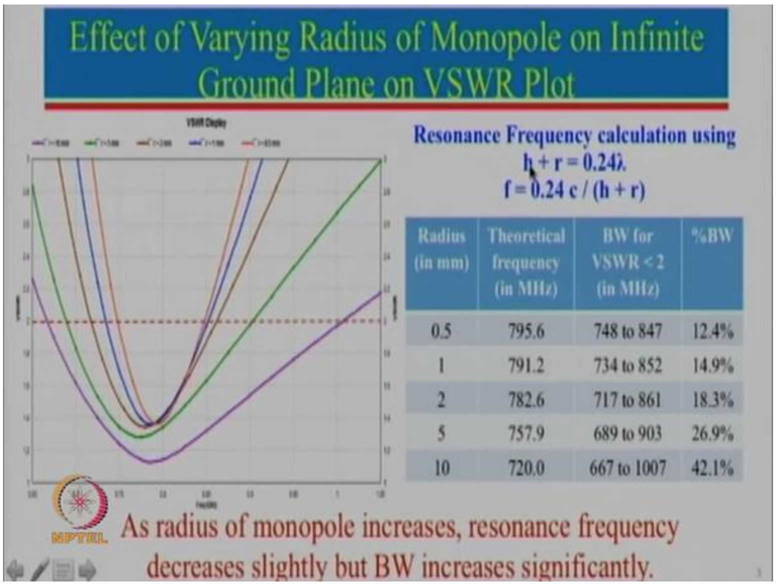

Let us see; what is the effect on the frequency as well as what is the effect on the bandwidth. So, first of all we can actually calculate resonance frequency, here h is fixed which is 90mm, you can just go back look into here. So, h is fixed which is 90mm; and then actually you have added a radius, so for different value of radiuses we have taken number of values here starting from 0.5mm which is very thin, to about 10mm diameter. So, from here we can calculate the frequency given by this expression here.

So, we have calculated these frequencies over here. So now, there are plots for different configurations over here; you can see that I have drawn the line over here corresponding to VSWR equal to 2. Just to tell you sometimes we draw VSWR equal to 2 curve sometimes we draw reflection coefficient curve, so where we draw generally a line around minus 10 dB or so. So over here is a plot, so this is the plot for the radius which is 0.5 one can see that VSWR less than 2 bandwidth is from 748 to 847 and you can see that this frequency is somewhere in between that. Or you can actually see here this is the resonance frequency somewhere here.

So, you can actually see that this very simple formula predicts reasonably for the resonance frequency calculation. So fairly decent one, in fact you can get a very good starting point by using this particular formula. So, you can see now here as we increase the diameter you can see that, this is now the response frequency is slightly decreasing which is expected over here and you can see that the bandwidth is increasing.

Now recall I did mention for a dipole antenna that bandwidth is proportional to the diameter. But there I did not show you too many cases, but here we are showing you systematically the cases for monopole antenna which is also valid for a dipole antenna. So, we can see the percentage bandwidth here. So, for this here percentage bandwidth is 12 percent approximately 15, then 18, then say approximately 27 and then for the 42 percent. So, one can really get a fairly broad bandwidth using a thick monopole antenna. So, you can say that this is the curve over here.

And even if you do not require a very large bandwidth, still sometimes it is advisable to use a little broader antenna. For example, suppose even though the bandwidth required is small. So, then what we can say if this smaller bandwidth is required we can actually say that over this bandwidth VSWR will be much lesser which is actually good. So, taking a larger diameter is always a good idea; however a larger diameter also creates only one problem, it will have a larger weight. So, you can actually speaking use a hollow cylinder also which will reduce the weight as well as it will give you a better bandwidth.

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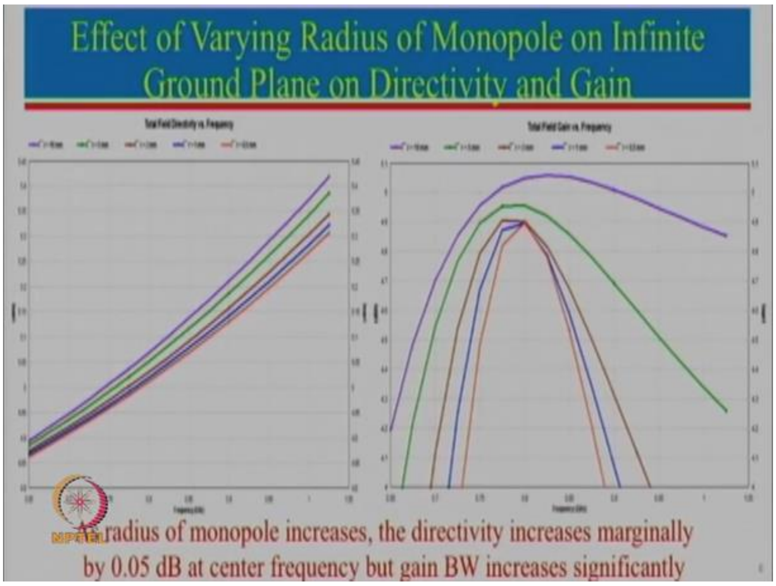

So, now let us see the directivity. Actually speaking we have really enlarged the scales significantly, but in reality what you see here this is the frequency with respect to directivity for different radiuses. Actually, even though it may look like it is significant it is not at all significant, at the center frequency it is only changing by about 0.05 dB. So, in reality we can say that directivity of the monopole antenna does not depend upon the radius, specially for infinite ground plane.

So, directivity will not change. In fact, in the next slide we will see that even radiation pattern does not change. But this is the plot of the gain now the gain is what gain is efficiency multiplied by directivity now efficiency of the antenna is still pretty good, because it is using simple metal. So, the metallic losses are very small dielectric losses are not there; however, what you see over here it actually accounts for VSWR variation over the frequency. So, if VSWR varies a lot; that means, reflection coefficient will vary and; that means, effective gain. So, the gain which is shown over here is not accounting only for efficiency, but it is also accounting for the reflected power.

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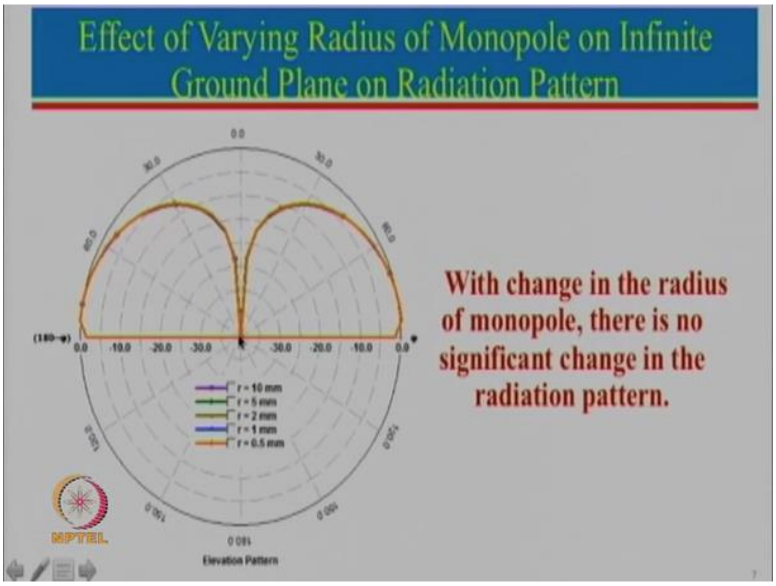

So, this the radiation pattern for different radiuses you can actually see that one can hardly make any difference. So, the radiation pattern hardly changes and that is where the directivity of the antenna hardly changes the gain is changing only because of the variation in the VSWR.

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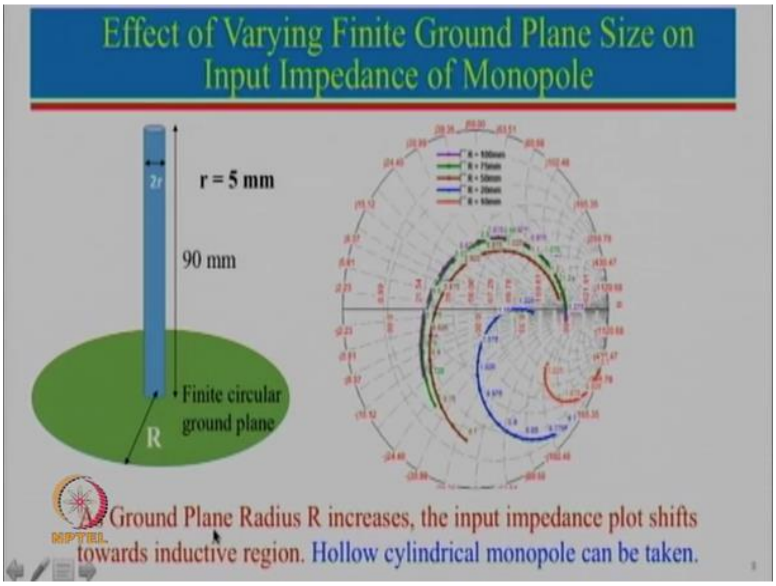

Now, let just see the effect of varying finite ground plane size. So, here what we have done we have fixed the radius equal to 5 mm and the length is also fixed as before which is 90 mm, and now we are changing the ground plane. Now for the simulation we have a circular ground plane and we have put the monopole antenna right at the center. I just want to mention here, if we take a rectangular ground plane performance will be slightly different and also placement of the monopole antenna is also important.

So, what results I am going to show you they are all the results for the monopole antenna kept at the center of the circular ground plane here. But suppose it is put over then the results will change or it will be put here or put over here. So, results will change if the location is changing and suppose if it is a let us say rectangular ground plane or let us say smaller width and the larger length then again the placement of the monopole antenna plays a very very important role and one really has to properly simulate these cases here.

So, here what we have shown or we have actually shown the various cases taking from a very small ground plane to little larger ground plane and in the next slide we will show you even much larger ground plane. Almost tending towards infinity also but let us see what we are noticing. So, as ground plane radius r increases; that means, if this is increasing what we can see that the input impedance plot shifts towards inductive region. So, this is for a extremely small ground plane then it is shifted over here, then it is shifted over here and then it is shifting like this here now we had actually seen that if the ground plane is extremely large just recall the previous slide r equal to 5 this was roughly the plot here. So, if you make smaller smaller ground plane, the whole curve is shifting over here. In fact, sometimes it might be optimize you can optimize very carefully if you do it.

So, if this is the ground plane which is of course, very capacitive then this one here is still capacitive. If you take a ground plane size between this and this you can actually get a response which will be something like this here and that may get perfectly matched with the 50 ohm line also over a coaxial feed. So, one can judiciously use this curve to design an optimally designed monopole antenna also, but let us see now what are the other effects with this here.

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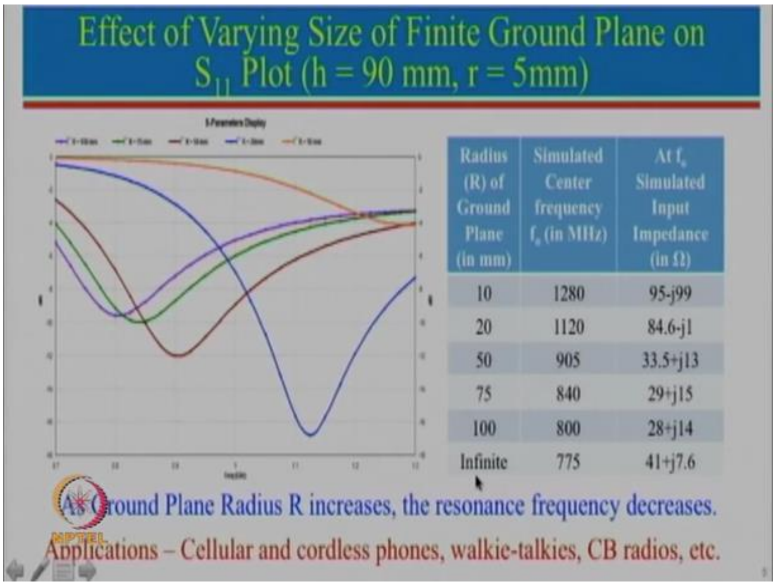

So, the resonance frequency changes drastically. So, just to show you here, this is the radius of the ground plane we have taken from a very small value 10, 20 all the way to infinity and these are the simulated frequency. So, for infinite ground plane this was the frequency which was simulated and then if we reduce the ground plane size from infinite to 100 mm radius, this is 800 and you can see that if it is made. So, small then frequency has increased substantially, you can actually see the plot here. So, these are the plots for the largest ground plane then ground plane is reducing. So, we can see that the frequency is increasing. Of course, here the matching is very very poor and that is why we are seeing it somewhere here, here the matching is still decent enough. So, one can use something like this here.

Now, one can actually see these are the corresponding impedance values at the center frequency. In fact, these values are actually taken from the smith charts which are plotted over here. So, what we really note from here is that as ground plane radius increases the resonance frequency decreases and for very small ground plane resonance frequency is very high and let me just explain that also let us come over here. So, if we are actually feeding it assuming that this ground plane is very very small and if this ground plane is very very small, it almost looks like that see first let us think about if it is infinite ground plane this is lambda by 4 there will be reflected image here. So, that will be lambda by 4, but now what is happening as we keep on reducing the ground plane size. So, this one almost looks like a dipole antenna from here to here.

So, you can effectively think like this is a very approximate way to tell you can approximately think this as a dipole length only for finite ground plane not for infinite. Infinite it will be very very large, but for dipole length which is radius is less than lambda by 4you can use that approximation. So, now, when we keep on reducing assume that it is close to 0 ground plane size then this whole thing can be actually thought about end fed dipole antenna.

So, this length will tend towards lambda by 2, but since the length is we started as a lambda by 4 length, but it is tending towards that lambda by 2; that means, really speaking frequency is almost tending towards the double the value. So, that the lambda will be changed, one can actually see here. So, it is around 775 this is tending towards double of this one here had we taken even more smaller you would see that this it is increasing and also end of dipole antenna are again similar to let just go back see if I feed at end fed assume that if it is just the dipole and there is a no ground plane if I feed here.

For a dipole it would have been 0 current would have been maximum and current would have been 0. So, if you are feeding now at a very low current value impedance will be very high which you can see over here, in fact had we taken even a smaller ground plane this impedance will increase further which is not really a practical case hence we did not show you this case over here.

So, now these finite ground planes only are required in most of the practical cases. So, in fact, these monopole antennas are used for cellular and cordless phone. In fact, all the

Wi-Fi’s which you see they generally use monopole antenna walkie talkies, CB radios and so on and so forth.

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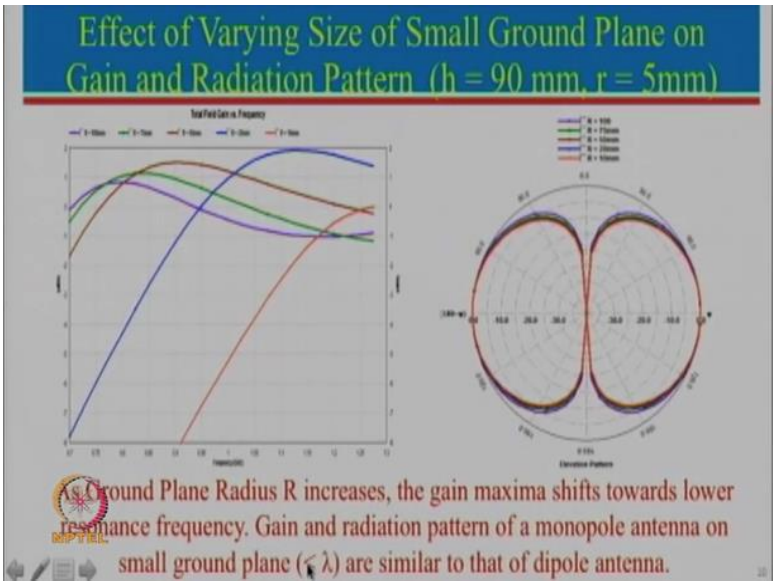

Now, let us see the radiation pattern. Now, I have actually divided the radiation pattern into 2 categories one category where the ground plane size is less than lambda. If it is less than lambda you can see we have plotted the radiation pattern radiation pattern of monopole antenna almost looks like the radiation pattern of a dipole antenna now. So, that is where my point is. If the radiation pattern of a monopole antenna on a finite ground plane is similar to dipole antenna, where a dipole antenna has a problem it requires a balun it requires impedance matching network over here you do not require any such thing.

So, it is actually better many a times to use a monopole antenna with finite ground plane where it is less than lambda now here is the gain plot now gain plot maximum gain you can still get is close to about 2 dB one can see there is a lot of shift in the frequency. The shift in the frequency is mainly because the resonance frequency of the antenna changes with the ground plane radius. So, that is why you see the shift here, but in general if you see the peak is getting around close to 2 dB or so.

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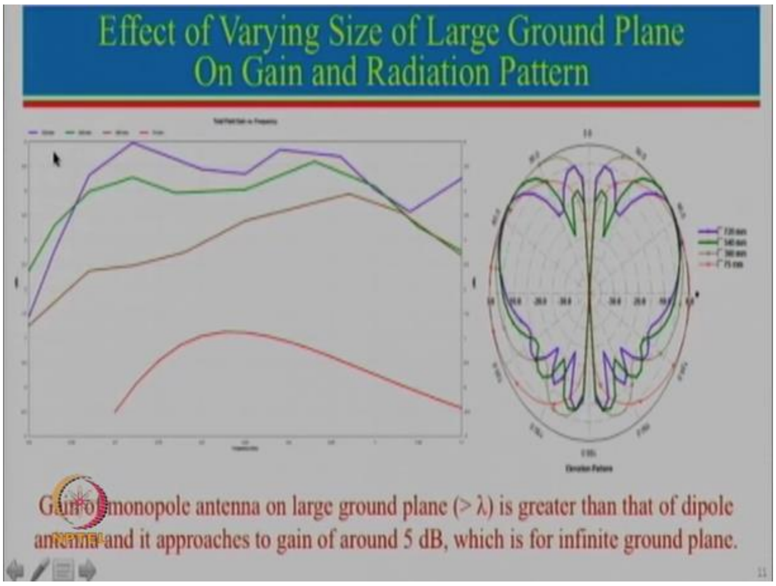

But if we take ground plane size larger now things change. So, here we have plotted the cases where the ground plane is larger than lambda, but just for comparison also I have taken a relatively smaller ground plane also. So, for relatively smaller ground plane this is the radiation pattern which is something similar to figure of 8, but as we increase the ground plane radius one can see that the pattern is now getting skewed up there is a relatively lesser radiation on the backside and also the b maxima is not in this direction any more b maxima is actually changing over here and you can see there is a shift in the b maximum also with the change in the ground plane you can actually see this is for a very small ground plane.

So, the gain is less you increase the ground plane greater than lambda then one can see that gain is increasing then gain is further increasing and here is the gain which is approximately equal to 5 dB which is what should be the directivity of a monopole antenna on infinite ground plane. So, until unless you take a very large ground plane it would not happen and. In fact, sometimes these are the real situations also. Think about antenna which is put on the let us say car rooftop. So, if we assume that the car rooftop is let us say metallic. So, on that metallic large body one has put a monopole antenna sometimes they put as a slight slanted here. So, this particular monopole antenna is really nothing but on a very large ground plane. So, it will have a relatively larger gain in comparison with the monopole antenna on very finite ground plane or a small ground plane. In fact, many a times you would actually see that many antennas monopole antennas are available which have a magnetic base over here.

So, basic idea is that even though the ground plane of that monopole antenna is very small, but because of that magnetic base you will be putting it on some metallic body. So, that metallic body acts as a ground plane for that monopole antenna.

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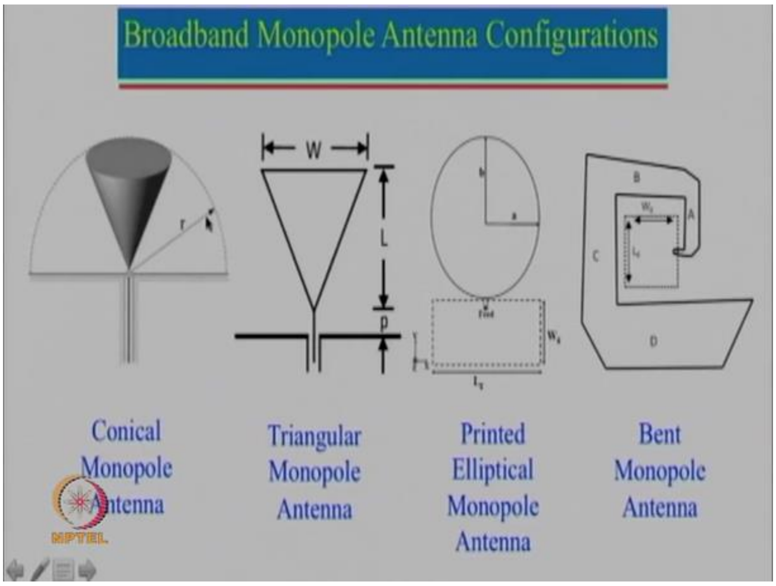

So, now let us see different cases of the monopole antenna how we can increase the bandwidth of the monopole antenna. So, here we are just taking an example of a conical monopole antenna which is nothing but the half of the bi-conical dipole antenna. So, it is fed with the coaxial feed here. This is the thinner version of that instead of using the full cone we have only used the triangular.

So, this is known as a triangular monopole antenna here is an example of a printed elliptical monopole antenna and we will see that it is really a ultra broadband antenna and then we will show you another example of a bent monopole antenna. In fact, the reason why we have chosen this particular configuration that for these antennas the polarization is vertically polarized antenna these are vertically polarized antenna. Now, many a times signal may be coming which may have a vertical or horizontal component. So, this particular antenna which we had designed it has both horizontal as well as vertical component.

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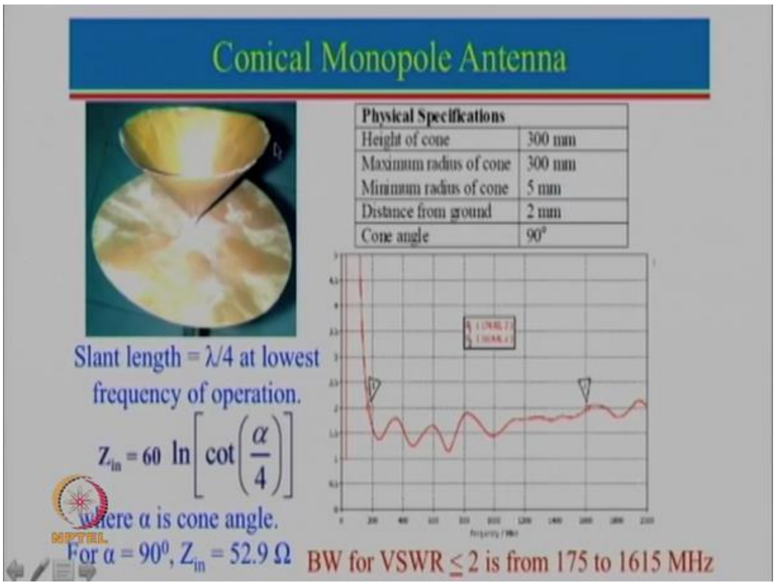

So, we will see one by one these configurations. So, here is a variation of the conical monopole antenna. So, one can actually see that we actually designed this only the outer part of the cone here there is not a solid cone that would have a very large weight and here is a ground plane and this particular thing we had actually designed for a requirement there was a one defense requirement where they wanted an antenna a broadband antenna starting from 200 megahertz to 1000 megahertz or so, but what we have achieved is much much larger bandwidth. So let us see now; what are the design principles.

So, design principle over here is that the first thing is corresponding to the lowest frequency slant length should be approximately lambda by 4. So, that is the first design principle. So, let us say we want antenna at say 200 megahertz. So, at 200 megahertz what will be wavelength it will be 150 centimeter. So, 150 by 4 we can say that will be about 37.5 centimeter and we can see that that is exact lambda by 4, but we have taken this length as roughly. Height is about 300 mm and you can see that the radius of cone we have taken as this here. There is a reason for that because, the input impedance of this particular monopole antenna is given by this particular expression over here and since we wanted to design an antenna with the 50 ohm coaxial feed.

So, if we take angle alpha equal to 90 degree alpha angle is this complete angle here. So, if we substitute this value alpha equal to 90 degree here we got input impedance of about

52.9 which is very close to 50 ohm impedance. So, for alpha equal to 90 degree what the thing is alpha 90 means half angle will be 45 degree and we know that tan 45 is nothing but this dimension divided by this here. So, this we took as 30 this becomes 30 centimeter this will be 300 by 300 and this one all we did was we actually took copper coil we just wrapped it around and put it over here fed over here fed over there.

We can see that this foil also has lot of these bends and other thing it is a very crude form antenna, but yet because it is very broadband antenna one can actually see the fabricated or measured result. So, that is the fabricate antenna these are the measured results. So, you can see that this is v s w 1 to over this entire frequency range VSWR is less than 2. So, we did achieve a very large bandwidth by using this conical monopole antenna, but it is a three dimensional structure.

So, in the next lecture we will talk about some printed monopole antenna which are very flat just printed on a substrate very you can say volume occupied is very small low cost configuration and so on. So, in the next lecture we will talk about printed monopole antennas and some of the other characteristics.

Thank you very much and see you next time. Bye.