Antennas

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Module – 09
Lecture – 44
Helical Antennas-V

Hello, and welcome to today's lecture on Helical Antenna, which is going to operate in the normal mode. So, in the last lecture we did discuss about normal mode helical antenna and we actually saw that a normal mode helical antenna should have a length of approximately lambda by 4 that is the textbook style for infinite ground plane.

But in reality for very large ground plane or infinite ground plane, the length of the wire of the helices should be 0.3 to 0.4 lambda. And basically 0.3 lambda to be taken if alpha is large and if alpha is small. That means, which angle is small corresponding to that s lambda will be small, in that particular case the wire length should be about 0.4 lambda and then we had started the discussion about the helical antenna on a very small ground plane, and as I mentioned earlier that this particular thing we actually found out experimentally so that's why keep doing experiments, and keep playing with these things you will always find something interesting.

So, based on that initial experiment, we are what we had done? We took a very small ground plane, and we took a helical antenna and connected directly to the feed and we saw there was a decent impedance matching. So, then we have done very exhaustive calculation simulations. So, today we will present you those things which have actually being just communicated for conference. So, it is really speaking totally new not reported yet, so absolutely new results.

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So, let us see what we have got to show you. So, here we are presenting a normal mode helical antenna design on small circular ground plane, and we choose resonance frequency as 1.8 giga hertz. The frequency chosen was mainly because there is a GSM 1800 is there. So, GSM 1800 corresponds to 1.8 giga hertz. So, we will just tell you the steps which we had taken. So, this is a 1.8 giga hertz. So, corresponding to this wavelength, that will be very simple to calculate.

Wavelength is C divided by lambda where C is velocity of light, so that is about 166 mm and I just start with a length of the wire we took as 0.75 lambda as I mention because here ground plane size is very very small, and even for infinite ground plane I had recommended length of wire to be between 0.3 to 0.4 lambda. For very small ground plane the length of wire has been taken larger and we will see; what is the effect of that here.

So, here if we take 0.75 lambda we know what is lambda, so this dimension is taken over here. We chose alpha as 14.6 degree, you can choose any different value also and then corresponding to this here we calculated the diameter. So, we took diameter of the helix to be 0.03 lambda, a basic idea is that the circumference which is phi times d should be much lesser than the wavelength. So, that value came out to be this over here, and then for this value of the diameter and for this chosen angle, we could calculate what is the spacing and then to design this length of the wire number of turns came out to be 7.

So, these are the parameter I have kept these things as generic; so that instead of designing antenna 1.8 giga hertz, if you want to design antenna at any other frequency, you can use these generic parameters to design any different antenna. So, then the next step was to study the effect of the ground plane size as you can see here I have not mentioned what is the size of the ground plane, and also another thing which I have not mentioned what is the wire diameter or what is the radius of the thing, because these are the two parameter which are not very obvious other things are actually obvious.

Suppose if I take length of the helix wire total wire length is large, we know frequency will reduce. So, that is very very obvious, and also seen that if s lambda is taken very small then frequency increases. And if I take s lambda little larger then frequency reduces. So, these were the very obvious parameters which were known to us. So, then specifically what we did, because the ground plane size as well as the radius they were really unknown factor, but once we did the simulation I can tell you the results were very very obvious, and we could explain it in a very simple manner.

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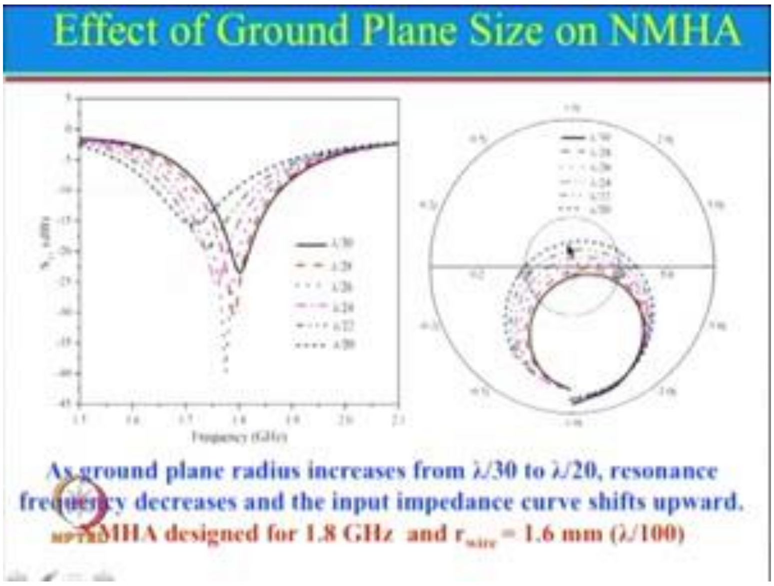

So, let us just look at some of the simulated result. So, here first we studied the effect of the ground plane size on normal mode helical antenna. Now as I said here our objective was to use very small ground plane. So, here are the cases we will just go one by one. So, here is a ground plane size is nothing, but we can just mention here just this is the ground plane radius. So, the ground plane radius is lambda by 30, and we varied it to lambda by

20. So, corresponding to this radius the ground plane size diameter will be lambda by 10, now let us see what we actually notice.

So, for lambda by 30 you can actually see that matching is fairly decent at 1.8 giga hertz. But as we increase the size of the ground plane, then one can see that if the ground plane size increases, one can see that the frequency is reducing. In fact, so we can just write here as ground plane radius increases from lambda by 30 to lambda by 20 resonance frequency decreases, which is kind of obvious if the ground plane size is large. So, if we increase the ground plane, then effective length from the helical to these increases. So, hence resonance frequency reduces.

Now, let us just look at the impedance plot; what we can see here this is a lambda by 30 is here, and this is lambda by 20 which is shifting up here. So, one can actually see that as the ground plane radius is increased from lambda by 30 to lambda by 20, the entire curve is shifting up; which is actually speaking the reason is if the ground plane size is very small that means, if we just look at the input point of view at the central point, then this radius will actually appear to be highly capacitive. And as the ground plane size increases; if it is increasing to about lambda by 4, then that is more like a open will acts as a short circuit, and if it is beyond lambda by 4 it will be inductive.

But; however, here now we can see the capacitive effect is reduced, and for this curve if the capacitive effect is reduced it will shift towards inductive region. Not only the phenomena there that it is shifting up towards the capacitive region, one can also see that input impedance. You can see if you look here input impedance is also reducing, which is also kind of a thing again that if the ground plane size is increasing so that means, my speeding point is shifting towards the in between value where impedance will be relatively smaller. So, that is what it is there. In fact, if the ground plane size becomes infinite, we had seen that input impedance will be even very very small it will come some over here, and that it why we could not do the matching we have to use the center tab here.

But nevertheless one can see that for any one of these ground plane value is if we choose, we can get approximate impedance matching by directly feeding the antenna. So that means, we do not need any central tapping of course, by little bit optimization of the ground plane we can do a very good impedance matching.

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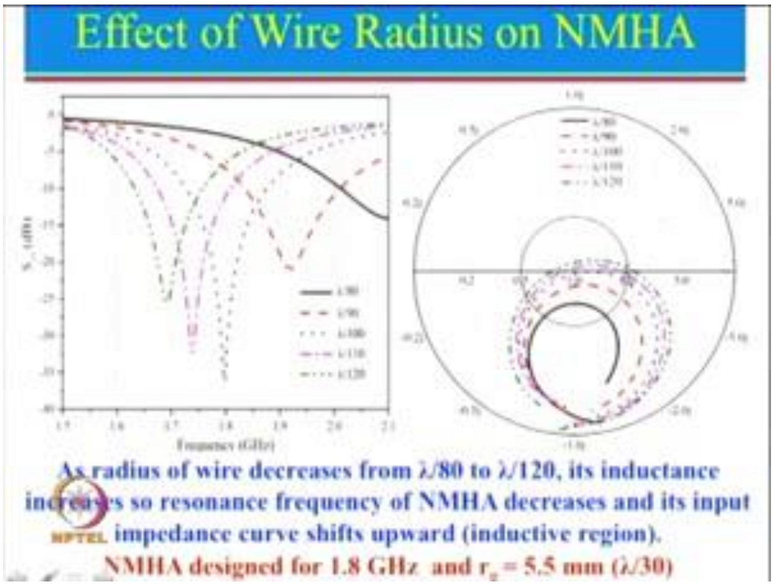

So, after studying the ground plane effect the next we study it is effect of the wire radius, and in fact this we are really surprised us in the beginning because the effect was very very drastic. So, just to show you here, so we started with a wire radius. So, there are different cases are there. So, wire radius here is lambda by 80, that is the response curve over here and this is 80, this is lambda by 90, then this lambda by 100, then 110, and then lambda by 120.

Or just to remind in the previous case when we had taken we had actually taken the r wire to be 1.6 mm, which corresponds to lambda by 100. So, over here let us see where is that lambda by 100. So, lambda by 100 point is this one here that corresponds to this one over here. And we had seen earlier that for this particular value, and for the chosen ground plane which is over here lambda by 30. So, we have kept ground plane size constant for this particular study.

So, this result is same as the previous case, for this particular case here and for r equal to lambda by 100. But now if you look at the effect of the wire radius, it actually frequency changes from 2.1 to 1.9 to 1.8 to all the way to 1.7. Now that is a very huge difference and if you really think about this particular difference, does not come anywhere if we look at the earlier concept which they had mentioned that the wire length should be equal to lambda by 4. You can see that in this particular case effect of diameter does not even come into picture.

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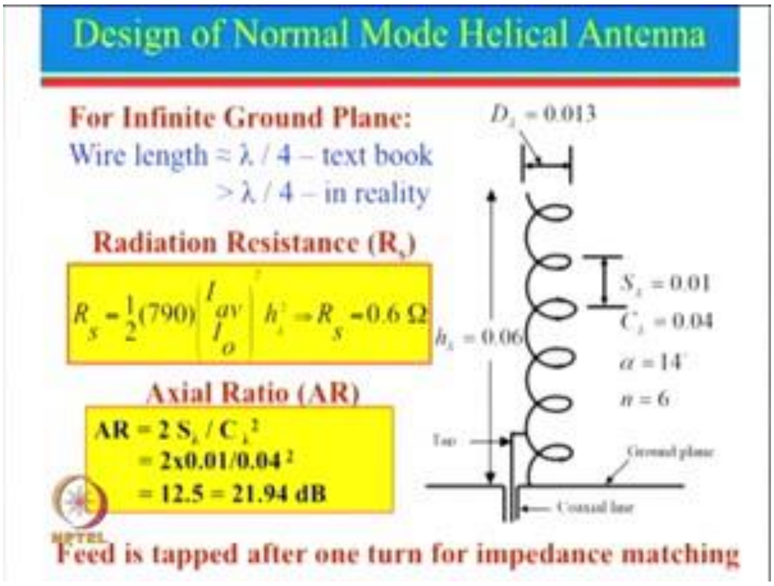

So, here wire diameter plays a very very important role. So, one can actually see that as the radius of wire decreases from lambda by 80 to lambda by 120 what we are seeing what is the main effect? So, if you reduce the wire diameter or wire radius same thing, so if you reduce the wire diameter or radius then what will happen? Its inductance will increase; we know that for a thin wire it has a larger inductance, for thick wire it has smaller inductor. So, if its inductance increases so resonance frequency will decrease. But the decrease will be so significant we did not except that much. So, that is why many a time simulation tools are very important to see what is the real effect, how much is the effect which is happening; and then correspondingly what is the another thing we can see here since the wire radius is decreased its inductance is increasing.

So, if the inductance is increasing then what will happen? The whole curve will shift inductively up. So, we can see that this is the curve for lambda by 80 and this is the curve for lambda by 120. So, you can see that the whole curve is shifting. So, by studying this effect and the previous effect, one can actually do the optimization of the antenna. But now let just see if you other things also. So, as the wire radius is increasing you can actually see here if you just look at this line here which is the reflection coefficient less than minus 10, you can actually see that this is the curve here then this is the curve, then here is the curve you can see that this particular has a much larger band width compared to the previous case here.

So; that means, in general if we increase the wire diameter then band width increases. So, over here it is not so obvious because the matching is not very good, you can see that matching is relatively poor in this particular case. So, now, if you want a larger band width then we need to optimize this particular configuration. So, let us just see how the band width varies.

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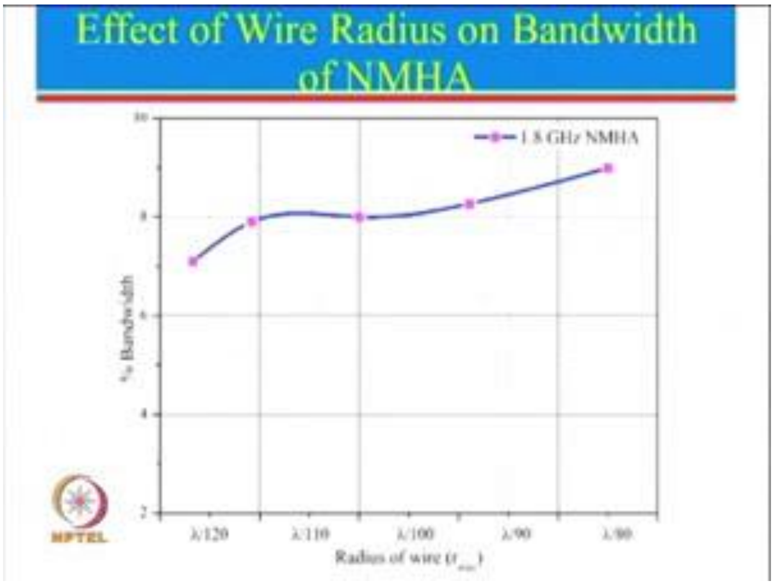

So, here is a effect of wire radius on the band width of the normal mode helical antenna. So, one can see that this is the percentage band width along this axis, and this is the radius of the wire. So, if the radius of the wire is taken as lambda by 120, you can see that the band width realize can be about 7 percent also, and this band width increases if we increase the radius of the wire.

So, depending upon the requirement, one can choose appropriately the radius of the wire. But just to tell you now again with the help of these two curves, one can do a proper optimization; let us say we need a larger bandwidth. So, for larger bandwidth what we need to do? We need to take this particular case here where this is lambda by 80. Now for lambda by 80 we can see that impedance is not properly matched. So, how do we do the matching for this particular thing? This particular curve should be shifted up, but if we reduce the radius then bandwidth will also reduce. So, we do not want to do that we do not want to reduce this thing, but we would still like to shift this particular thing up here. So, now, what we need to do it is, we need to see what was the effect of the ground plane.

So, one can actually see that here is the lambda by 30 is the ground plane, and from lambda by 30 if you go to lambda by 20 the whole curve shifts up here. And also if you do that from lambda by 30 is this the frequency reduces. So, now, if you just look at these two things, and then look at these two curves here. So, now, what is the conclusion then how do we do the optimization. So, instead of taking a ground plane size as lambda by 30 for this particular case, what if you take this ground plane size as lambda by 20, what will happen this curve will shift up? One can actually just go back again, we can see that this curve will shift up from here you can see how much is the distance where it is shifting up.

So, if that much distance is shifted up here, we can see that it will be decently matched; then other thing is that if we increase the ground plane size, we will notice that if we increase the ground plane size, the frequency reduces from here to this value. And in fact if we look at this curve here, corresponding to this here frequency was any way very high. So, by choosing the larger ground plane this can shift over here; however, it may not shift exactly to 1.8 which may be the desired band, it may shift up to here; after that you have a choice one choice will be that you increase the ground plane size even more, so that the curve will shift up which will reduce the frequency, or the choices we can increase the length of the wire slightly, which will reduce the frequency mode.

So, by doing this kind of a thing, we can do a proper optimization, we can get a good impedance matching also. So, by combining all these things, so finally we optimize the antenna and looking at this bandwidth here, so I am going to now show you that results which we had optimized.

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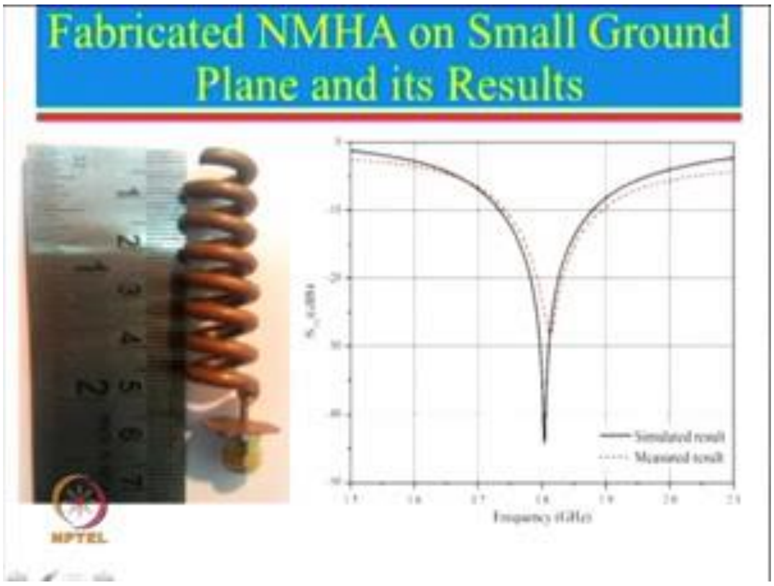

So, here we fabricated the antenna. So, let just see here simulated result, one can see that we design this antenna at 1.8 giga hertz, one can also see that the matching was pretty good actually, you can see that we are getting a very nice reflection coefficient over here and you can see that that is the bandwidth for VSWR less than 2 or in this case, reflection coefficient less than minus 10 dB. So, you can see that this is the bandwidth which we have obtained in this particular case over here, and then we did the fabrication so you can see that the measure results are fairly close to the simulated results here. But I just want to tell here. So, what you can see over here as a very thick wire which has been bend like this here it is not so easy to bend such thick wire, you can actually see the number of turns you can count here.

So, from here 1 2 3 4 you can count a number of turns, and you can see that here the ground plane size is relatively small, and this small size ground plane actually we had optimized for proper impedance matching, you can see over here the antenna is directly faired with the connector. So, there is a no tapping is required in this case, it is being directly fed over here, and you can also see the total size of the antenna. So, the total height of the antenna is actually less than 6 centimeters, actually it is close to slightly more than 5 centimeter.

Now, how do we design this particular antenna at 1800 mega hertz; as a monopole antenna for these kinds of a small ground plane, the height would have been much larger compared to this particular case here. Now this particular antenna in fact since we have used a very thick wire, a large power can be fed through this particular thing, and it can handle that large power also. High square are losses will be very very small, and there is another reason also taking the thicker wire, because a thick wire can support itself. Had we taken a very thin wire, then there would have been two effect the thin wire would have a very less bandwidth, and also a very thin wire would not have supported by itself, then we would have to put a some kind of a supporting structure in between and then we would have to put a take over here, or in the supporting structure we need to cut the (Refer Time: 19:46) and then this would have gone here in between.

Of course the total weight of this antenna is slightly more than has we taken a very thin wire, but nevertheless one can see that the matching is fairly good, and depending upon your requirement you can choose a thin wire or thick wire and as I said for thin wire you need to provide a support, for thick wire weight becomes more, but it actually is a self sustaining structure.

Now, for the radiation pattern of this one here; so most of the time normal mode helical antenna here, it is almost the radiation pattern if this is almost like a dipole radiation pattern; however, in this particular case there is a small difference than the dipole pattern. For a ideal dipole pattern which is like a figure of 8 right, because maximum radiation will get this and minimum radiation will be in this direction. So, had it been a normal dipole antenna, it would be figure of 8 like this here, and the cross polar in case of the dipole antenna is very very small, but in this case cross polar component is not small it is almost as high as close to 20 dB instead of a 40 dB, which is practically realized by a dipole antenna or you can think about a monopole antenna over a very small ground plane size.

So, helical antennas are very good, it can actually speaking it can give us a small height antenna, it also as a little bit of the other polarization also, it is not just complete vertically polarised e, but it also as a horizontal polarized component also. So, it is ideal for indoor application and in fact, in some applications where we need to have a circular polarization. I can just tell you the thing is that you take this diameter little larger you take C lambda little larger, and in that case you will be able to design circularly polarized antenna.

We can actually go back and look into the slide, if you want circularly polarized or other component. So, just look at this component over here. So, if you look at this one here, so this is a 2 S lambda by C lambda. Now suppose if we take C lambda large, if we take this as larger value if this is large, then this will reduce and if this reduces my actual ratio will improve. So, by increasing this particular value; in fact, just to tell you here. So, suppose if we take instead of 0.04, if we take let us say double of this as a circumference. If we take double of this it will be four times, this will reduce to about 3 here; and instead of doubling if we let us say make it 3 times like this here. So, if it is 3 times then correspondingly one can actually see here if I take C lambda as 0.1 suppose, so which will be 2.5 times more. So, if it is 0.1, 0.1 square will be 0.01 that will give us actual ratio of 2, and if we take slightly more than that we can even get actual ratio smaller also.

So, basic thing is that C lambda can be increased, and if we increase C lambda if we just look into here the curve which we have shown. So, if the requirement is of a better horizontal as well as vertically polarized component, or we want closer to the circularly polarized; all you need to do it is increase this diameter significantly, of course, correspondingly you may have to increase the ground plane size little bit so that impedance matching and other thing can be done, but you can use the software tool to design helical antenna properly.

So, just to summarize the result, so today what we have seen; we saw normal mode helical antenna we started with a on a very large ground plane, and there generally speaking we can take the total wire length between 0.3 to 0.4 lambda, but then that requires a tap feet and also matching becomes difficult. But many places when we require a very small ground plane, then what we can do it is we can take a very small ground plane and then feet the helix directly no tapping, no other impedance matching network nothing is required, but you need to do proper parametric study for the case which you want to do that. However, the design equations the curves given by us should really help you. So, even if you do not have sophisticated software tool, you can still use these curves which are given to you and these curves can be used to design antenna at any frequency.

So, because you have kept everything in the form of lambda, so you can take any frequency calculate the lambda, and calculate the corresponding value. So, let us say you want lambda by 20 or lambda by 30 as a ground plane size, or you want to wire diameter which can vary from let us say lambda by 80 to about lambda by 120, or correspondingly you can take thinker or thicker wire also. So, these are the things which are very easy to design you can utilize this thing to design optimum helical antenna. And as I said helical antennas have multiple applications, so most of the time normal mode helical antennas are replacing conventional monopole antenna, so that it as a reduce high; and also there is a lot of research potential on the normal mode helical antenna, where these can actually replace a linearly polarized monopole antenna into somewhat circularly polarized monopole antenna or you can say modified normal mode helical antenna.

So, there is a lot of research scope. So, you need to do that and if you do that you can publish papers, you can do lot of research, you can get M. Tech or PhD by choosing this particular topic. So, just to summarize overall, so helical antenna 3 different modes are their normal mode helical antenna, which is a compact antenna; then axial mode helical antenna, which gives us circular polarization, and it can gives us left hand or right hand circular polarization simply by wiring like this or wiring like this. So it so convenient to get circular polarized component, and as I said circularly polarized helical antennas have been used as a feed or the reflector. So, this is circularly polarized antenna, if it is right hand side it goes there after reflection it become left hand circularly polarized, so that the enterprising is very very little.

So, circularly polarized antennas of course, have lot of application, and you can see here four helical antenna you do not need a separate power divider, you do not need a equal power division, you do not need a phase shifter, you do not need 0 to 90 degree; and the another beautiful thing is that you can get fairly decent bandwidth, you can get 30 to 40 percent of the bandwidth of course, there are many other things have their for example, in axial mode helical antenna we talked about basically the symmetrical thing, where number of turns are increasing like this; however, we also know that at the end current will go to 0.

So, some disturbance is created by the top one or two turns. So, they are lot of papers people have done the work. So, instead of having a state normal, the last two turns they have actually reduced the dimension. So, that the effect of that is nullifies that current, and then it becomes a better circularly polarized antenna. There are lot of other things are also there for example, instead of using a uniform helix, people have also used papered helix like this. So, the papered dimension should not vary too much, because we know for circularly polarization, we need the condition should be that C lambda is between 0.8 to 1.2. So, slightly tapered helical antenna gives us even better bandwidth, and better both bandwidth. VSW are bandwidth as well as axial ratio bandwidth.

So, these are the different things which are coming out in the literature, and I still feel there is a lot of scope to do optimization because when these theories were reported several decades back, people did not have computational power, but they did lot of experimental work. In fact, what I find that today's generation does not do too many experimental works, but they do lot of simulation. Well you got the good simulation tool, so generate lot of curves, do parametric study, but I also want to tell you that when you do the parametric study computer will give you some results.

Software will give you the result, it is your responsibility that you should understand what is going on and also you should explain why it is happening. So, these are the two things which are very very important and my basic definition of engineers is that engineer should have logical and analytical ability. So, apply your logic to explain those results which you are getting from the simulation, and then analyze those results to actually come out with a proper design. So, if you do the proper design and simulation, then only our prime minister mantra which has been broad cast repeatedly, and he has been always saying "make in India" but in fact, I have added one sentence before that make in India will happen only when we do design in India. So, we have powerful software tools, so do that design, do a proper optimization, understand the concept behind the antenna, and do the practical thing.

I want to mention that in India we import several lakh [FL] of worth of antenna. So, there is a lot of scope that before that you need to do that design and then once you do that design do the optimization, and then do the fabrication. And in fact, I also want to mention for normal mode helical antenna; as I mentioned one of the option is to go like this here, however people have come out with the printed version of helical antenna also. So, what they have done is they take a let us say flat PCB.

So, on one side here let us say they print a ground plane, and then over here let us say a line goes like this and then underneath another line goes like this, then on the top lines goes here and then underneath lines goes here and then what you do you have a plated through whole here, platted through whole here, plated through whole over here.

So, of course, it is not going in a circular fashion, but it goes like this goes down, comes here goes down. So, there is a printed version of helical antenna is also possible today, so one can actually do the design of that also. So, you do the design, do the simulation and that would be a very very low cost helical antenna, and if you design one of those, fabricate one of those and that can be put in much production to realize the requirement of the industry.

So, thank you very much and we will see you next time, and in the next lecture we will start talking about horn antenna; and we will talk about various types of horn antenna, and then we will also see how to design horn antennas. So with that bye and we will see you next time.