Antennas

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Module – 09
Lecture – 43
Helical Antennas-IV

Hello, and welcome to today's lecture on Helical Antenna. In fact, in the last few lectures we have been talking about helical antenna, and in the last lecture we saw in detail how to design axial mode helical antenna, and we saw that how to feed the axial mode helical antenna, then we also saw how we can feed the arrays of the helical antenna, and how a larger gain helical antenna can be designed either using a single element or we can use multiple arrays of that. Then we also looked at the parasitic effect of the helical antenna and we saw something very interesting that is the linearly polarized antenna can be converted to circularly polarized antenna, by using helical antenna in the axial mode.

So, today let us talk about normal mode helical antenna. In fact, normal mode helical antenna has been a very important of let, especially in the beginning when the mobile phones were launched. These mobile phones actually had a monopole antenna at let us say 900 megahertz the height of the monopole antenna will be lambda by 4 approximately. So, if lambda is about 33 centimeter, it will be about 8 to 9 centimeter.

And on the mobile phone if you put this thing here it was not very convenient, then later on people started redesigning the mobile phone and what they did? They actually made a cavity in that, and this 8 to 9 centimeter will go inside that; however, that was the point when the normal mode helical antenna came and so what they did instead of having a monopole of 9 centimeters height, what they actually do they took a wire around, this one here and wrapped it around; and the total height was reduced to about 2 centimeter.

So, basic purpose of that was that you use a smaller height helical antenna to realize the concept of the monopole antenna. So, how monopole antenna radiates that was the purpose that you now have a compact monopole antenna you can say, or normal mode helical antenna.

So, let us see today in detail what is a normal mode helical antenna and what is the first simple theory about normal mode helical antenna, and then we will look at the design of the normal mode helical antenna.

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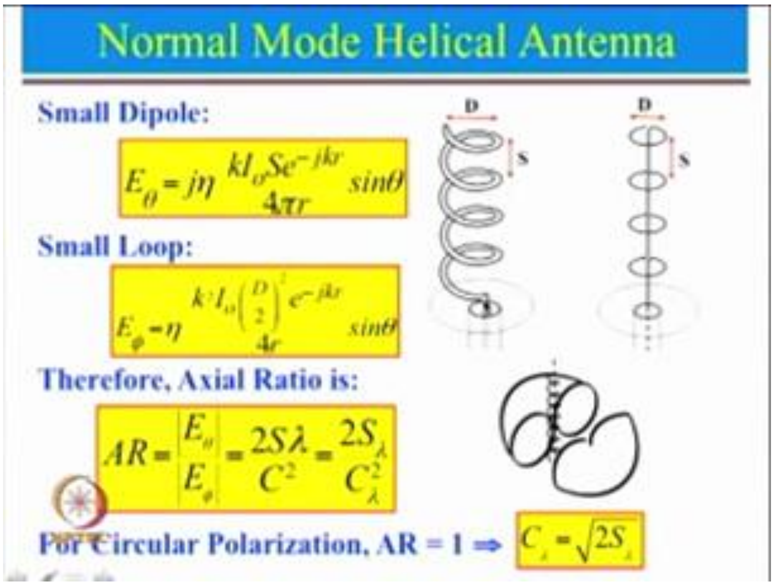

So, let us look at the normal mode helical antenna. So, here what we have? There is a helical antenna and that is being fed you can see here, here it is being fed directly, but will show you a different way of feeding this particular normal mode helical antenna. Now the condition which is there is that the diameter of this should be much much lesser than lambda or in reality circumference should be much less than lambda and circumference is equal to pi times D. So, D has to be much smaller than the wavelength and here we can actually see the approximation of this as this here, where what one can see that from here to here that is being approximated by let us say linear wire and then this part is approximated to a loop, then a linear wire then approximated to a loop, then another linear wire approximated to loop.

And we can actually see; what is the spacing between the each turn which is given by S here. And then we can now apply the concept of the small dipole. So, for this particular thing here we can actually consider that this as the part of the small dipole, and for that we already know what would be the radiation pattern in this particular case; you can see that this is about sin theta. So, theta is equal to 0 in this; that means, there will be a 0 radiation here and for theta equal to 90, which is over here sin theta will be maximum. So, that will be like a dipole kind of a pattern maximum here and minimum here.

Then all these loop they can be thought about n turn loop antenna. So, for a small loop you know what is the E phi, you can see there is a difference this is E theta this is E phi; because for loop what we consider a loop antenna to be a magnetic dipole. So, for electric dipole for this portion this is electric dipole this will be h field, but for loop we consider this to be magnetic dipole then this will be E-Filed. So, E theta e phi change otherwise you can see that the pattern part here is same, same sin theta sin theta coming over here which is true for small dipole and small loop.

Now, if we take the ratio of these two which generally will give rise to axial ratio. Now why axial ratio? Because one can actually think about set for the linear this is in this plane and for loop it is in this plane. So, we can say that the two fields are orthogonal to each other. So, we can actually take the magnitude of these two ratio; if we take the ratio over here, one can actually see majority of the components gets cancelled and what we left with this some of these term here is D is written in the form of C, C is equal to pi D one can see that there is a pi here which comes into picture.

So, then if we take the ratio; so that would be a axial ratio now here in fact, one can get a circular polarization provided we take C lambda equal to 2 s lambda. If this is equal to this then axial ratio will be equal to 1. So, from here we can get this condition for axial ratio; however, earlier no antenna was designed for circularly polarized performance, most of the helical antennas earlier were designed basically to replace a long monopole antenna with a compact helical antenna.

So, for that particular case to happen axial ration should be theoretically infinity, because linear polarized antenna should have a infinite axial ratio. However, practically anything better than 20 or 30 dB is a good linearly polarized antenna; however, this particular normal mode helical antenna actually has a lot of advantages, when we want to use it for let us say mobile phone. The reason for that is let us say this component here the linear component will give us E-Field, and this loop component will give us the orthogonal parameter over here.

So, if we even design this particular antenna for let us say axial ratio equal to say 10 dB, or 5 dB, or even 20 dB it is still better than a linearly polarized antenna, the reason for that is for mobile application; specially suppose when you are indoor, in the indoor there will be lot of multiple reflections coming from the wall. So, any linearly polarized antenna suppose the signal which is coming up after multiple reflections from various wall or from other object, it will also have you can say instead of this vertical here it may become angular and then it will have both vertical as well as horizontal component. So, in that case a helical antenna operating in a normal mode is better because now it can not only receive the linearly polarized waveform which can be vertical, but it can also get the other waveform which is horizontally polarized.

So, of course, “something is better than nothing” a linearly polarized antenna will only receive linearly polarized. Suppose if the angle is perpendicular then the received power will be almost negligible. So, sometimes helical antennas are preferable one; however, off let there is a lot of research going on where people want a monopole kind of an antenna, but with circular polarization. So, this concept of the normal mode helical antenna can be utilized very properly to design circularly polarized monopole antenna.

So, let us just look at this thing one more time. So, here is the condition which needs to be satisfied. So, what it really means that? C lambda here whatever is the value that is the square of this if you take it equal to this, and choose things appropriately one can actually get the axial ratio close to one. So, it is if one uses this concept it becomes easier to design circular polarization, and it is a very good research topic currently going on. So, if you just work on this do the simulating do some fabrication, you will be able to publish some papers also.

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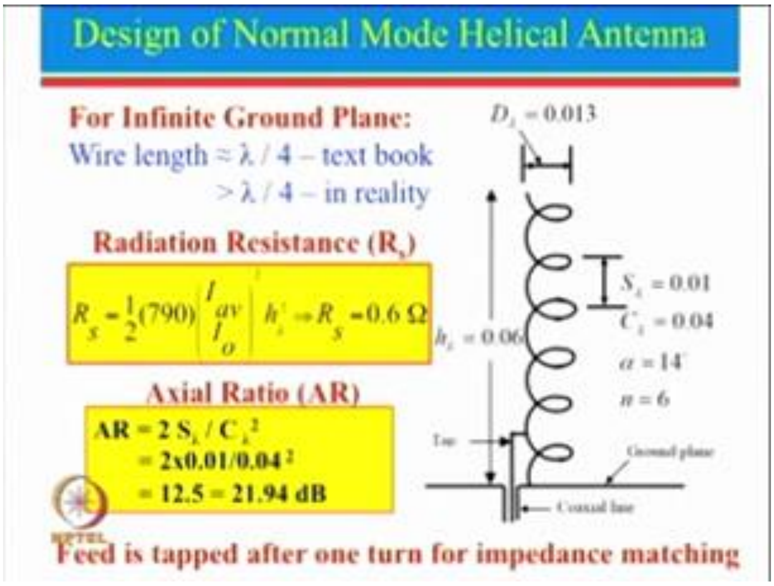

So, let us just see now the some examples which are given. So, this example I have taken it from the cross book who is the original inventor of the helical antenna, but I will just mention to you where I do not agree with this particular example here and where I agree. So, let us just start with this here. So, what they have given the design, they have given the design for infinite ground plane and they have assumed that the wire length should be approximately equal to lambda by 4. I have written that that is given in the text book, but in reality it should always be greater than lambda by 4. So, but let us just go first with this particular example and then I will tell you what corrections need to be done or what modifications need to be done.

So, let us start with this here lambda by lambda by 4 length. So, basically now if you see the helical antenna, 1 end is shortened with respect to the ground plane and the other end is open circuit here and this entire wire length is approximately equal to 0.25 lambda. So, let us see now how we do the next step here. So, here in general we know that the seal would be much lesser than lambda. So, here C lambda has been chosen as 0.04, and if C lambda is 0.04 then what will be D lambda? That will be this divided by pi. So, if you divide this by pi, D lambda will be approximately 0.013; then alpha has been chosen as 14 degree. So, once alpha is known we can calculate S lambda, S lambda will be C lambda multiplied by tan alpha. Now again I want to mention here it is not necessary that you choose alpha equals to 14 degree, this condition is more appropriate for axial mode helical antenna, where alpha should be 12 to 14 degree.

For normal mode helical antenna there is no such condition or restriction you should take alpha equals to 14 degree you can take any different angle also. But for this value of alpha taken S lambda comes out to be 0.01 and then we wanted the total length to be equal to lambda by 4, so one can actually see what so here then we need to take this total wire length to be equal to 0.25 lambda, again that is a text book thing not what I believe in; but never the less let us complete this part here. So, this is equal to lambda by 4. So, now, what C lambda is known? Now S lambda is calculated and if you now calculate l lambda, l lambda will be nothing, but S lambda square plus C lambda square so that will be slightly more than 0.04 and that multiplied by 6 will give us a value of 0.25 lambda.

So, that is how the design has been given here. Now why this is being shorted here, why it is not being directly fed? The reason for that is if we feed it directly it will give us a very low impedance. So, if you feed it directly here it will actually give us a very low impedance, the reason for that is if we just think about this as a let us say a monopole antenna of certain height here, then we can actually calculate what will be the radiation resistance.

Earlier we had used the symbol R R it is a same thing that R R or here it is written as R s. So, radiation resistance is actually calculated by using the concept of the same you can say that the dipole antenna with a half of that which is a monopole antenna, and I average has been taken and that gives us a radiation resistance of only 0.6 ohm; and if you try to feed this thing directly with the 50 ohm line, that would have a real big mismatch most of the power will get reflected back.

So, to avoid that particular problem they had proposed this particular concept here. So, if this helical antenna is shorted at this point here with the ground; that means, input impedance will be 0 here, and if you look at the open end over here input impedance will be very high. So, assuming that is approximately since the free space impedance is about 377 ohm, so assuming that is about roughly about 377. So, 377 if you divide that by roughly 6; so after about 1 turn, that gives us roughly close to about 50 ohm impedance.

So, how it is being fed? So, this is shorted here take a coaxial connector, extend it and then connect at this particular point; and that would give us a relatively a decent matching for this particular antenna. And for this particular antenna design axial ratio can be calculated which is given by 2 S lambda by C lambda square. So, 2 into S lambda is 0.01, C lambda is 0.04 square and if you see that number is 12.5. And for axial ratio we should take 20 log of this. 20 log of this is about 21.94 dB, which is a fairly decent axial ratio for linearly polarized antenna and one can see that the feed has been capped after one turn of impedance matching.

Now, based on this particular concept we actually made antenna also almost you can say close to 2 decades back. So, what we did? We actually took designed a normal mode helical antenna around a 100 megahertz, that 100 megahertz wavelength is about 3 meter or so, and what we had done? We actually took a badminton shuttle I used to play badminton those days. So, the cover of that which is a hollow cylinder, we put that over here and then we put the wires something like this over here.

Now what we notice? We did exactly the same thing as reported in this particular book, and we used the tap over here also. So, what we realized that the impedance was decently matched, we still got very close to 50 ohm, but the resonance frequency was shifted considerably and in fact, then we did multiple things also, we stressed the wire straightway then we could get the frequency for which we had designed it; and we had taken it for this experiment fairly large ground plane, so which can replace you can say or assume that it is infinite ground plane; but then we realize that because helical antenna is known as slow wave structure.

So, if it is this slow wave structure then how can this length be only equal to lambda by 4? So, this length must always be greater than lambda by 4, it cannot be equal to lambda by 4. If you choose like this here your resonance frequency will always be off. So, then the question comes then how much we should take it. So, if this is 0.25 lambda, I generally recommend this to be between 0.3 lambda to 0.4 lambda. Now again you may say that is a lot of difference that also depends up on what is the pitch angle you use.

So, if you use smaller pitch angle that is if s lambda is small, in that case this length should be close to 0.4 lambda, if you take a larger pitch angle then this can be close to 0.3 lambda and nevertheless. So, you make this and take always I recommend take slightly larger length then desired value, and then do the measurement using let us say vector network analyzer or something, and see what is the frequency you are getting, and if you take a larger length than this then frequency will always be lower. So, you can just cut that little bit, and you can use the concept which I have been telling always that when we have made one antenna we need to make another antenna, all you do it is you use the concept of f 1 l 1 equal to f 2 l 2. So, if you take a little larger length then frequency will be little smaller.

So, now you know how much reduction in the frequency is there and then you take f 2 which is the desired one, calculate the value of l 2 and you cut that much; and that way you will be able to design this antenna in a very decent manner and the tap can always be adjusted little bit up here and there to do the impedance matching. So, suppose you put a tap over here, let us say that you got an impedance of say 45 ohm, then all you need to do is you take the tap little bit higher because impedance will be higher over here, or suppose you have measured the impedance to let us say 60 ohm, then in that case you go little lower and then do the tapping and that because this will be higher impedance this is the lowest impedance. So, if you have measured higher impedance take little lower value, if it is measured lower impedance go little up here; so little bit of a tuning is required.

Of course all these things are I am mentioning when you are doing straight way experimental work, but these days we have very sophisticated tools are there. So, for example, you can use I e 3 d, you can use microwave studio, you can use HFSS and so on and by using that software you can do the optimization much better and in that case your experimental iterations will reduce significantly.

Now this is the situation when we have the larger ground plane, but in reality majority of the time ground plane size may be very very small. So, for very small ground plane I want to tell you something very different unique and that also we did it experimentally first, and then we came out with some theoretical explanation.

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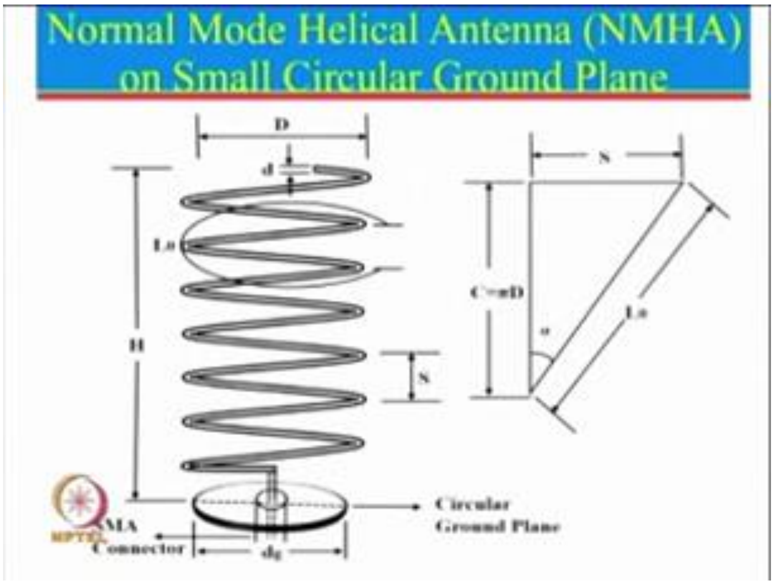

So, let us see the concept of helical antenna on very small circular ground plane. So, here you can see that this is a circular ground plane, and you can actually see it is very small it is even smaller than the diameter of the helix here. In fact, this has a lot of practical application, because many a times we actually have a very small antenna, and in fact I just want to tell you that this is you can see here SMA connector is there, and then that SMA connector there is a helix one around this particular thing here.

Of course diameter should be very very small compared to the wavelength, we know that height will be governed by how much the spacing we have taken, how many numbers of turns we have taken, and over here now since the ground plane is very small. So, you actually need to visualize this whole thing first in the form of the let us say dipole antenna. So, just imagine that dipole antenna first, so let us say this is a dipole antenna. So, in the case of dipole antenna we know that this length should be approximately equal to lambda by 2, and then we talked about monopole antenna.

So, for monopole antenna we knew that the light will reduce by half that should height should be about lambda by 4 for infinite ground plane, but we had seen for monopole antenna that if you take the ground plane size very small and if you feed from here, the input impedance of this increases and also we had seen that for a very small ground plane for a monopole the frequency was changing drastically; and for very small ground plane this height was not taken as 0.25 lambda, it almost became close to 0.4 lambda also if the ground plane size is very small. Now these things I have already mentioned when we talked about monopole antenna you can read that again.

So, now the same dipole antenna coming back here; so if you think of this as a dipole antenna. So, this is a open current here open current here. So, input impedance will be very high. So, now, you can think about a monopole antenna with a very small ground plane as a end fed dipole antenna, and the length here is not really lambda by 2 for dipole, but because of the small ground plane this length is about 0.4 to 0.45 lambda also. And then we saw that the impedance was very high here exactly the same concept has been used to design normal mode helical antenna for small ground plane.

So, all the other things remain same again we have a C which is equal to pi D this is the spacing between each turn, and this is the length of the one turn, the total length will be n times this particular length here. And total height will be nothing, but n turn multiplied by S over here. Now for normal mode helical antenna the diameter of the wire plays very very important role whereas, this particular thing has not been considered even in the text books, where they just mentioned that the total length should be equal to lambda by 4. We will actually see one by one the effects of all these parameter.

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NMHA Design on Small Circular Ground Plane

Resonance Frequency	1.8 GHz
Wavelength	166 mm
Spacing = 0.027λ	4.5 mm
Diameter of Helix = 0.033λ	5.5 mm
No of Turns (N)	7
Pitch Angle (α)	14.6 Degree
Length of Wire = 0.75λ	124.5 mm

So, our starting point was we actually took that as a challenge that this is a normal mode helical antenna designed on very small ground plane, and even though I am telling about this design here for 1.8 gigahertz, but I just want to mention that the beginning did not happen like this, a beginning actually happened there was a requirement at 433 megahertz; and 433 megahertz we did the calculation. So, at 433 megahertz lambda by 4 length is about 17 centimeter. So, I knew by that time that one should not take lambda by 4 distances.

So, what I took I just took a very long wire, and then I needed to wrap that around. So, what I did I just took out a ball pen took out a refill of that, and I just took a wire and put it around there; and then we actually used a SMA connector and even though I had thought that I will use the tap, but I just connected it like this at that time and we took the wire and suddenly we noticed that the impedance was coming very close to 50 ohm and then we even used some touching thing.

So, we touch the ground plane side we actually tried to make it little larger by putting some other metallic copper thing and all that, and we could see that the impedance was varying quite a lot. So, anyway at that time I just designed 433 megahertz only using experimental techniques, no theoretical no simulation nothing. So, simply the refill of the pen worked as the supporting thing took the wire thin wire round it put it around put a cello tape on that, connected with the network analyzer and using my concept of f 1 l 1 equal to f 2 l 2.

So, we did the measurement and then cut the wire little bit and we got perfect match with 433 ohm. So, it was much later we decided that why not we study this thing very carefully and see how this performance is varying, what are the effects of various parameter and specially now that we have very good software simulation tool. So, why not we simulate this thing and come out with the decent concept how it works, why it works, what are the parameters, how things are radiating, how matching is done, what is the effect of the various parameter. So, all these things we will see in the next lecture.

So, just to conclude today’s lecture. So, today we discussed about a normal mode helical antenna for infinite ground plane, even though the text book says the wire length should be equal to lambda by 4, which is 0.25 lambda, but over experience is that you must take always larger than that, the wire length should be at least between 0.3 to 0.4 lambda, because if you choose that then you can get a decent matching. And in that case we also saw that you can use the taping for impedance matching, and it works very nicely; and then we started looking into the concept of very small ground plane, and where we can feed the antenna directly no tapping is required.

So, all these things will see in the next lecture in much more detail. So till then bye will see you next time.