Antennas
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Module - 09
Lecture - 40
Helical Antennas-I

Hello and welcome to today's lecture on helical antennas. In the last several lectures we have been talking about micro strip antenna, broadband micro strip antenna, compact micro strip antenna, circularly polarized micro strip antenna and micro strip antenna array. So, today we will talk about helical antenna and will see what are the different modes in which we can operate helical antenna and what kind of a radiation pattern we can get out of helical antenna. So, let us start with helical antennas.

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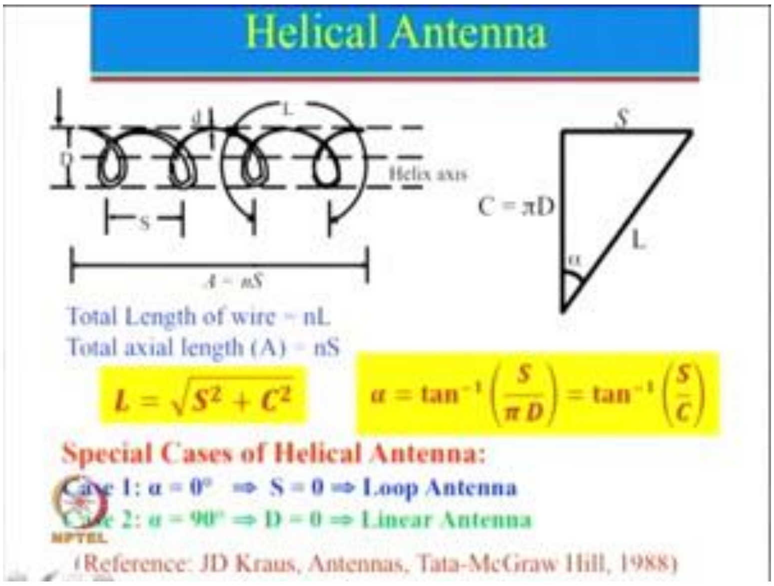

So, helical antenna is nothing, but a take a wire and you wrap it around in this particular fashion and speed it at one of the side here depending upon the mode we want to excite and there can be a ground plane in this particular side over here. So, that the radiation can be in this direction or it can be in this direction depending upon the mode of operation.

You can really in a very simple manner think about a helical antenna as an inductor. So, just like we take a wire and we take that wire and wrap it around, assuming that this is a wire. So, if you wrap it around something like this here then that will become a helical antenna. In fact, you see inductors also look in a very similar manner, but; however, in case of inductor we use inductor as a circuit element here we use helical antenna as an antenna which is going to radiate in different mode. And helical antennas were actually invented by Kraus several decades back so in fact, I am going to pick up lot of material from John D Kraus book on antennas. So, let us look into the helical antenna again.

So, we define the helical antenna in this particular fashion where this is the diameter of the helix and this is known as a helical axis. So, if the radiation is in this direction we actually call it axial mode, and if the radiation is in perpendicular direction to this axis then we call it a normal mode antenna. So, here we define this, the diameter that is a diameter of helix and this is the diameter of the wire which we have taken.

Now this is the spacing between the 2 turns, and generally this spacing is kept constant between the different turn. And here length L is the length of one single turn. So, if we try to put these things in the triangular form here we can actually say circumference will be equal to pi times diameter of the helix. So, that will be this whole thing is the circumference, but since there has some change from one point to another point. That is why we have a S. Suppose if S is equal to 0 then this particular thing will be 0 here L will be equal to C, and that would be if this precisely 0. Then length of the one turn will be equal to the C which is circumference and this is known as a spacing between each turn which is S.

So, we can actually apply a simple rule here since it is a perpendicular over, here we can say L is nothing, but square root of S square plus C square. So, this gives the length of one turn helical antenna. And now here we can find out total axial length will be equal to n times S, because you can see that S is equal to spacing between one turn. So, we can say total axial length will be n turns multiplied by S. And the total length of the wire will be n times which is the number of turns multiplied by length of the one single turn. So, we can actually use this formula to calculate the length of the wire, and we can also find out what is the angle. So, what is this angle at which it is changing from here to this one? So again if angle is equal to 0, what will happen? S will be equal to 0 and this one will be moving just at that particular place only. So, we can actually take tan alpha. So, 10 alpha will be nothing, but equal to perpendicular divided by base here. So, perpendicular is S divided by base which is equal to pi d or C and so, we take tan inverse of that that gives the value of angle alpha or you can call it a pitch angle at which it is rising.

So, there are special cases of helical antenna. One case will be when alpha is equal to 0. So, alpha equal to 0 means that there is a no increase in the value of S will remain 0. And if S is equal to 0 these things will be repeating at the same place here, and that will give rise to loop antenna. So, for this particular case alpha will be 0 S is equal to 0 and that will be a loop antenna.

Case 2 will be a case when alpha is equal to 90 degrees, suppose instead of moving around this this whole thing is just going in this direction only. And if it is going in this direction we can say that the diameter will be equal to 0 and this will be nothing, but a linear antenna. So, in a simpler way one can also think about a helical antenna is a combination of loop antenna and linear antenna. In fact, that gives rise to very interesting characteristic also. So, linear antenna will be in this direction and loop antenna is in this direction which is perpendicular to this. So, hence we will see later on that axial mode which is in this particular direction here gives rise to circularly polarized component for certain condition.

As I mentioned most of the material are taken from the John D Kraus book well he is the original inventor and I will highly recommend that you please read this book and specially the chapter on helical antenna. The reason is that he has actually described how he actually invented helical antenna, helical structures were known earlier. In fact, helix is known as a slow wave structure and these were used earlier in microwave tube. And when we proposed that about helical antenna there were a lot of opposition, and in general it generally happens, that anything somebody proposes which is new there is always some opposition or there is a hesitation to accept that.

So, then John D Kraus had to do lot of experiments to prove the validity of helical antenna, and hence I feel it is a very appropriate to teach from that particular book, but am going to add lot of things to what is already in that book because when he invented that antenna those days we did not have very strong computational problem. We did not have very strong good computers and we could not do simulation, but today with the power of the computers we can do lot of simulation. So, I will show you after the simulation and also we have done several experiments also on helical antenna. And will tell you where there are changes which need to be done in the helical antenna chapter of Kraus book.

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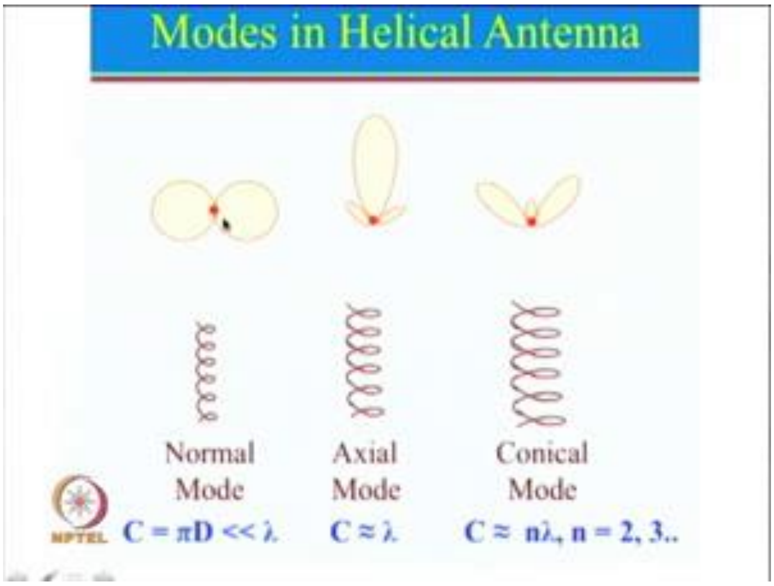

So, let us just look the different modes in which helical antenna can operate. In general, helical antenna can operate in 3 different modes normal mode axial mode and conical mode. So, for normal mode what we really see this is the helical axis and one can see that the radiation pattern maximum is in this particular direction. If you actually see this mode here this looks very similar to if you think about a monopole antenna like this. So, monopole antenna will have a maximum in this direction and minimum in this direction here. So, a normal mode helical antenna the condition for that is the circumference which is equal to pi d it must be much less then lambda.

Axial mode is obtained when circumference is approximately equal to lambda, and one can actually see that this is the helix axis and the maximum radiation is along the helical axis, and that is why it is known as axial mode. And when C is approximately equal to n lambda where n can be 2 or 3 or more, in that case we see that the pattern is of conical. So, you can see that neither it is in this direction maxima nor it is in this direction maxima, which are the cases for these 2 cases. So, the radiation is maximum in the conical mode. What I want to tell you here that majority of the time this mode is not really used. So, we will concentrate mainly on these 2 modes over here.

And just to again tell you what is the difference will take a wire again. And let say if this wire we wrap it along let us say a small diameter that is how it will be a normal mode, when the circumference which is equal to pi d is much less then wave length, but now if we take another situation here where let say the diameter is relatively large and now we have this. So, now, if this circumference is equivalent to lambda value in that particular case it will give rise to the axial mode.

So, in a very simple way for normal mode the diameter will be very small and for axial mode diameter will be relatively larger, from this simple concept.

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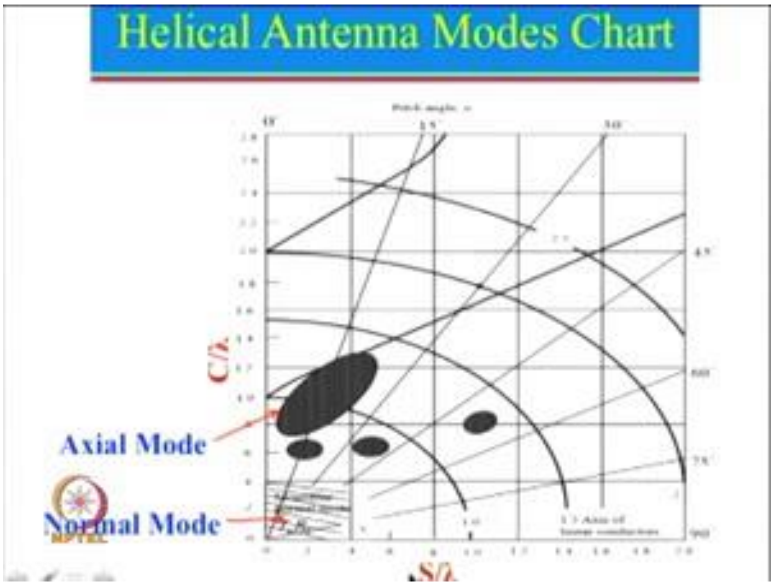

Let just see now what are the different charts. So, this is the helical antenna modes chart and what you can actually see here this one here the axis along this is C by lambda that was normalized circumference, along this it is S by lambda which is normalized spacing between each turn, and here is the normal mode. One can actually see for normal mode C by lambda is much smaller, as you can see here C by lambda is less than 0.4. And S by lambda is also relatively small. So, in this particular zone we can actually operate the helical antenna in the normal mode. Normal mode would really mean if this is the helical axis radiation will be maximum to normal to the helical axial.

Now, this is the axial mode. If you see axial mode here that C by lambda is approximately equal to 1 along this point here. And S by lambda is given correspondingly. And these are the angles which are given here, this is the angle which pitch angle alpha. You can see that that is about 15 degrees, and this particular region here actually shows that in this particular region helical antenna can work in the axial mode and one of the nice thing about this mode also that this gives us circularly polarized helical antenna. And how we wind the wire we just tell you also how to do that. So, if you wind in one particular way then it may get LFCP, if you do opposite winding then it can give RSCP. So, it is a very simple way to obtain circular polarization mode.

And one can also see that since this entire area can give a circular polarization one can actually see here. So, this is 1 and that is about 0.8 over here and this is 1.2 so; that means that it can give circular polarization in the range from 0.8 to 1.2 if you look in this particular direction. Also if you see this center point here this angle which is going on. So, that is about alpha equal to 15 degrees.

So in fact, there are certain conditions to obtain circular polarization, and generally it is defined if alpha is between 12 to 14 degree, then it gets about circular polarization. And correspondingly then we can calculate what is the value of S by lambda. We will look into these things one by one. Now these are the other modes you can say these are the higher order mode where we can get a conical pattern also. These are the things which are normally not used actually. And the conical patterns will be obtained when this is 2 or 3 as you can see most of the time that is not really used. So, practically higher order modes are not used for helical antenna.

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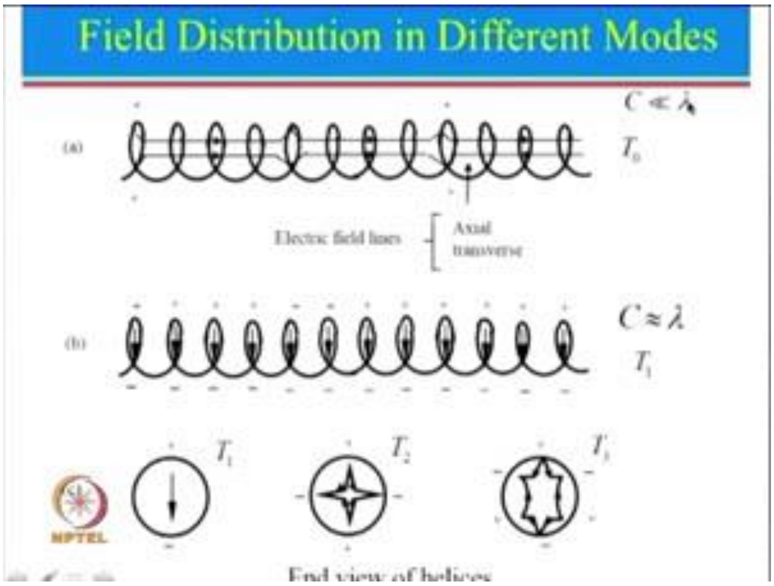

So, let us just see the field distribution. Let me start with the center of attraction which is right over here. And this is the case where the radiation is in the axial mode here and in this particular case circumference is approximately equal to lambda. So, this mode is known as a T 1 mode, but we just see what is really there. So, C is equal to lambda. So, let us just start from this particular point here. So, if you look at this point assuming that the field is equal to plus.

So, from here if we just complete one full turn that would be equal to approximately lambda, we know that the property if the wave length is equal to lambda then the field will vary from plus it will go to 0 then it will go to minus where the length will be lambda by 2, and then it will become plus then again it is repeated. So, this plus will again come because this distance is an approximately equal to lambda. So, if we actually see that all these pluses are in this particular side all these minuses are in this particular side here.

So in fact, in reality what happens? So, these pluses and minuses they add up and give radiation in axial direction over here. Another thing which is to be noted here that you can actually see that plus to minus, so we can see the one field component here another field component here, we can actually replace one turn with just this particular thing here, and then you can actually think about there is an array of these particular element. So, helical antenna can be approximated as n element array, and this is of course, in this direction. So, we can actually think about as an end fire array. So, we know that end fire array there should be a phase delay. So, one can actually think about the wave which is coming over here there is a progressive delay is there.

Now, one additional thing I want to tell this as it is rising here. So, there will be 2 components. So, one component will be let say you can say that if this is going like this. So, it will be having a horizontal component as well as vertical component. So, at every point there will be horizontal and vertical component which we can resolve. So, if we choose the rise angle appropriately, one can actually ensure that the horizontal and vertical component are approximately equal and the phase between them will be equal to 90 degrees, and that is how we can get a circularly polarized radiation pattern.

And over here then if you just look at the wire, if it is wrapped in this particular fashion that may give a one type of a polarization and if it is wrapped in this particular fashion it will give orthogonal polarization. So; that means, getting a LHCP left hand circular polarization, or right hand circular polarization is very easy. In one way you wind the wire like this another way you wind the wire like this. So, this is the mode which actually corresponds to the axial mode, now we will look at the normal mode

So, normal mode circumference is much smaller than wave length. So; that means, now if we start with the plus here since the circumference is very small. So, this plus here, remains plus here, it remains plus over here. So, this is like just imagine and the current will actually go to 0 over here. So, just imagine for a minute that this is nothing, but let say monopole antenna like this here. So, in monopole antenna what we see. So, there is a plus here which gradually decreases to 0 value. And what is that typical length of a monopole antenna that is approximately lambda by 4, 4 infinite ground plane.

Now, over here also the general concept is that if we put an infinite ground plane on this side, then the wire length of helix according to the text books they say it should be equal to lambda by 4, I do not agree with that. In fact, the length should be always greater than lambda by 4. When I discuss about normal mode helical antenna I will give you more details of that, now, for this particular configuration if I look at the end view. So, can see that end view of this will look like plus here, it is going to 0 it is going to minus it is going to 0 plus that is the T 1 mode.

Now, the second order mode will happen where what will happen instead of plus 0 minus 0 plus there will be 2 lambda variation along the circumference. So, you can actually see here it goes to plus here, then let say it goes to 0 minus 0 plus. So, this completes one wave length. And then from plus it goes to 0 minus 0 plus. In fact, this is also represented here you can see that field is more over here, then it is going to the lesser value that it increases it is actually showing the amplitude. So, phase is shown over here. So, you can see that amplitude is becoming maximum going to 0 maximum going to 0 becoming maximum.

And then the similar thing is happening over here, this is a t 3 mode. So; that means, So, starts with plus minus plus that completes one wave length variation, then plus minus plus another wave length variation, then plus minus plus. So, the total variation is 3 lambda, but as I mentioned these 2 modes are generally not used. So, these are the 2 modes which are used most commonly. So, we are actually going to start first with the axial mode, and then we will talk about normal mode. In fact, this is the order in which even in the Kraus book, he has discussed in that particular manner. So, I thought will follow that in the similar fashion.

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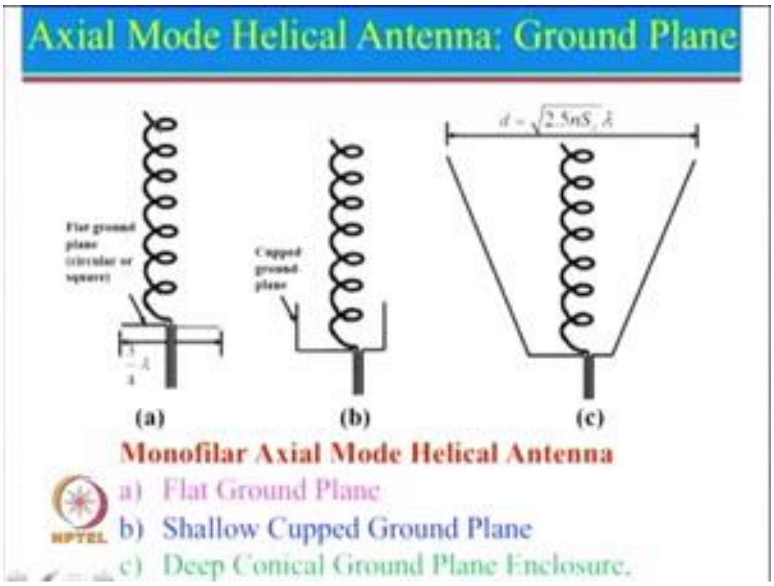

So, let just look into the axial mode helical antenna. So, for the axial mode helical antenna let us start with the ground plane. We can have varieties of ground plane depending upon the requirement. So, here we have a helical antenna, which is actually fed over here and this is the flat ground plane. Now we know that this particular diameter should be approximately equal to lambda by pi. Because the circumference should be equal to pi d is equal to approximately lambda. So, d should be equal o lambda by pi which is approximately let say 0.3 lambda.

So, the ground plane has to be larger than this value here. So, generally the recommended value is that the minimum diameter of the ground plane should be equal to 0.75 lambda. Anything larger than that is perfectly fine. And in fact, actually speaking this much ground plane is required to reduce the back radiation. So, we would like the radiation to be more in this particular direction. And if we take a smaller ground plane then front to back ratio becomes poorer, and that also reduces the value of the gain. So, that is the minimum thing you can take anything larger than that fine, now if we cannot really take larger than this, but we know that this area is anyway occupied.

So, instead of using a flat ground plane one can actually use a cupped shaped ground plane also here. So, you can actually see that. In fact, this is also known as a cavity also. So, one can actually have this helical antenna inside the cavity. There are 2 ways to think about it. So, you actually can think about that the whole ground plane has extended more over here. Or other way you can actually think that whatever the back radiation which could have gone from this here fringing wheel now they get blocked by this particular thing.

So, by using this kind of a shape here, the front to back ratio is improved. Now; however, if in certain application it is really very important and critical that front to back ratio should be very large; that means, we want very little back radiations. In that case one can actually use this particular shape here that is a deep conical ground. In fact, some I call it also a bucket shape, or we can even call it a glass shaped ground plane here. So, what happens if the ground plane is in this particular fashion? Then you can actually see that the back radiation will reduce significantly and there is an advantage. If there is a less back radiation, then where will that radiation go that will radiation will go only in the front direction. So, from here to here to here slightly gain of the antenna also improves.

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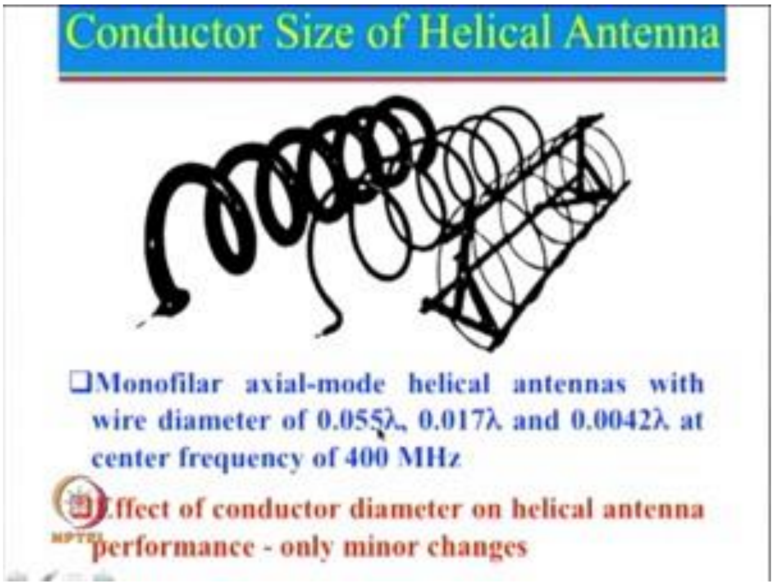

So, then comes the next part. That is what should be the size of the conductor. We will look into that design one by one. We are just looking at just step by step thing here. So, the conductor size of helical antenna and right now our discussion is only on the axial mode and not on the normal mode. So, here these are the reported thing. So in fact, the antennas were designed at 400 megahertz 3 different diameters were taken. So, you can actually see that at 400 megahertz wave length will be 75 centimeters. So, 75 centimeters if you put it over here 75 multiplied by 0.004, we are talking about 0.3 centimeter or 3 millimeter wire here. And then slightly bigger diameter here and then even more bigger diameter.

Now here I just want to tell you those days since they did not have too many sophisticated software. So, instead of doing too much simulation they actually used to do lot of experimental work. So, people really knew how to work with their hands. So, now, you can see is since this wire is relatively small. So, on it is own this helical antenna cannot sustain. So, it requires some supporting structure.

Now, the supporting structure cannot be a metallic supporting structure because that is not really recommended it can be used wooden or it can be used some dielectric material over here which can provide the support. If you see over here if you take a slightly larger diameter then it is self-supporting, and if we take even much larger diameter you can see that it will actually be there, but this has a disadvantage compared to this. The disadvantage is that the weight of this will be very large, because these diameters will be much larger here. So, that will have a more weight.

Also bending such thick wire is also a very difficult thing to do practically, but; however, it has a one of the biggest advantage in this particular cases, it can handle very large power because the diameter is large. And we know that if the wire diameter is small. So, it is resistance will be relatively large. So; that means, i square r loses will be large over here. Resistance will be small. So, i square r loses will be small. So, for very high power application one can use here.

But however, the one thing which we want to mention, whether you take this diameter or this or this, there is a very minor change in the performance of the helical antenna. And when we talk about the performance; that means, a radiation pattern does not vary much, gain does not vary much, even bandwidth does not vary much in this particular case here; however, in case of normal mode helical antenna will see that the bandwidth is almost proportional to the diameter. So, compared to this this will have a much larger bandwidth, but that is only for normal mode. For axial mode there is a only very minor change and then just to show you the another support structure for this here.

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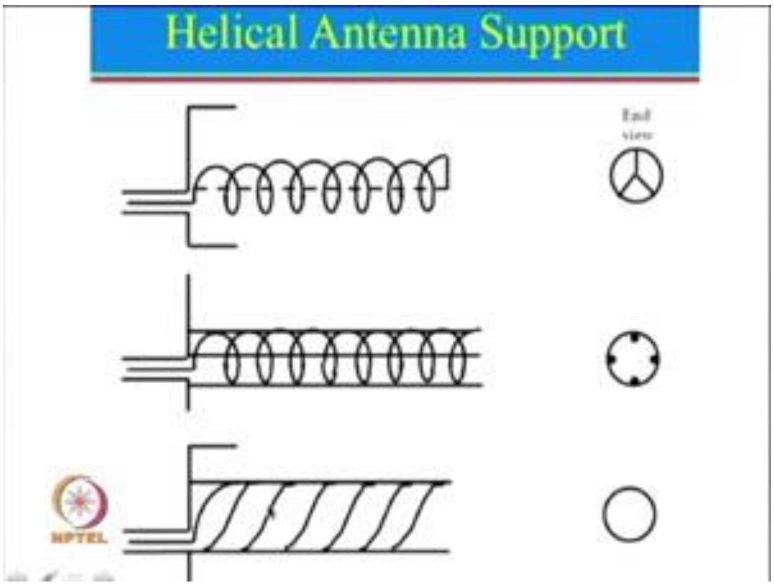

So, one can actually see here similar thing. So, there I said you can see that there is a ground plane here. This is a cavity type; this is a flat type, cavity type. You can always mix it over; it can also be, you can say bucket shape also. So, in this particular case thin wire has been taken. So, since thin wire has been taken it requires a supporting structure. So, one can actually see here 3 different things have been used and then the wire has been put around that. Over here 4 different rods have been put and the wire has been put around that. I mean this particular case here what is shown here is a solid dielectric material these wires have been wrapped around. It is not important that we should have a solid cylinder here. In fact, it can have a hollow cylinder also.

In fact, the first antenna which we designed we actually used the hollow cylinder. And in fact, when we wanted to do we were looking for some hollow cylinder I used to play badminton those days. So, we actually removed out shuttles of the badminton and we used that box which is a hollow cylinder made of the paper and we put the wire around that and simply put the tape. So, that it stays over there. So, that is how we actually improvised our first antenna, when we wanted to see how helical antennas work. So, will actually discuss about more of these axial mode how we excite what is the input impedance, how we design the helical antenna how do we calculate radiation pattern and other thing in the next lecture.

So, just to summarize that helical antennas can operate in 3 different modes. Normal mode, then we can talk about axial mode, and then conical mode. For normal mode diameter is relatively very small or you can say circumference is much smaller than wavelength. For axial mode circumference should be comparable to wave length, and for conical mode circumference is actually equal to 2 or 3 times lambda, but as I mentioned we do not use conical modes. So, we will focus only on these 2 mode. So, I just talked about little bit about axial mode, how we support the helical antenna what kind of a ground plane we use it, but in the next lecture will see lots of details of axial mode and how to design axial mode helical antenna. So, with that will see you next time.

Thank you, bye.