Antennas

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Module - 09
Lecture – 41
Helical Antennas-II

Hello, and welcome to today’s lecture on Helical Antenna, which is continuation of the previous lecture. So, in the previous lecture we saw that the helical antennas can operate in three different modes; normal mode, axial mode and conical radiation pattern mode, but most of the time third mode is not used, so mainly normal mode and axial mode antennas are used. So, we started discussion on axial mode. So, today we will continue from the same thing.

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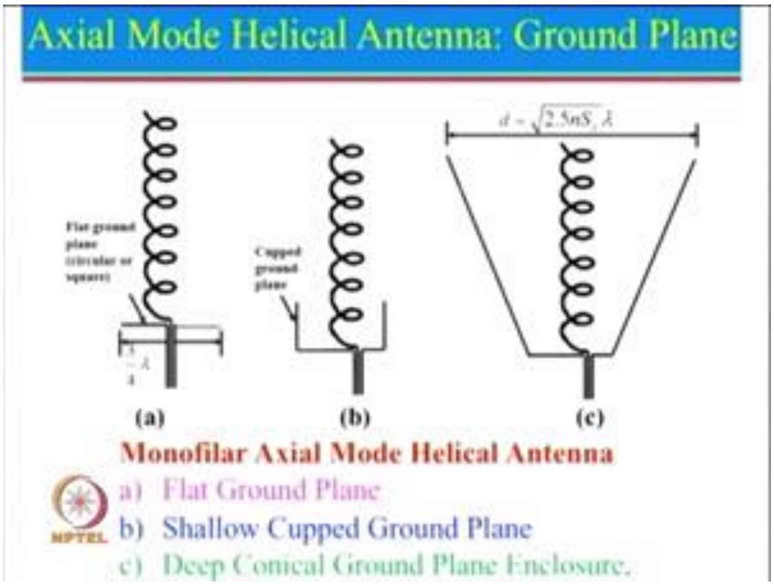

So, let us start with the previous slide which we had seen. So, this is the simple helical antenna and we can say that the ground plane size should be at least 0.75 lambda.

But let us just see what is really happening here. So, we are actually feeding it over here I will also mention quickly today about the impedance at this particular point, but let just see the concept wise is power is thread from here, it going from here to here and then it moves forward. So, if you look at the current here so current is coming here and finally the current becomes equal to 0 at this particular point. Now when the current is becoming 0 where part of that will get reflected back, but while all this thing is happening this antenna is also radiating in the free space over here, because each of the turn here is effective radiator.

So, really speaking what happens the current which is going through over here the reflect the current which is reflected back the amplitude of that is really very very small, because most of that has already radiated. So, the power reflected back from here is relatively small, and hence this particular configuration is also known as travelling wave structure. So, in case of travelling wave basic idea of travelling wave is that of wave which is being sent here, it is getting out it is very little is getting reflected back. And in general travelling wave antennas had broad band antenna, because the reflected wave form is very very small; so with this simple concept here and also just to mention, if we can wind the wire like this or we can wind the wire like this here.

So, by just interchanging the wire from the here to here we can actually get left hand circularly polarized or right hand circularly polarized antenna. So, we saw the effect of the diameter, there is a hardly any effect of the diameter on the performance of the axial mode helical antenna.

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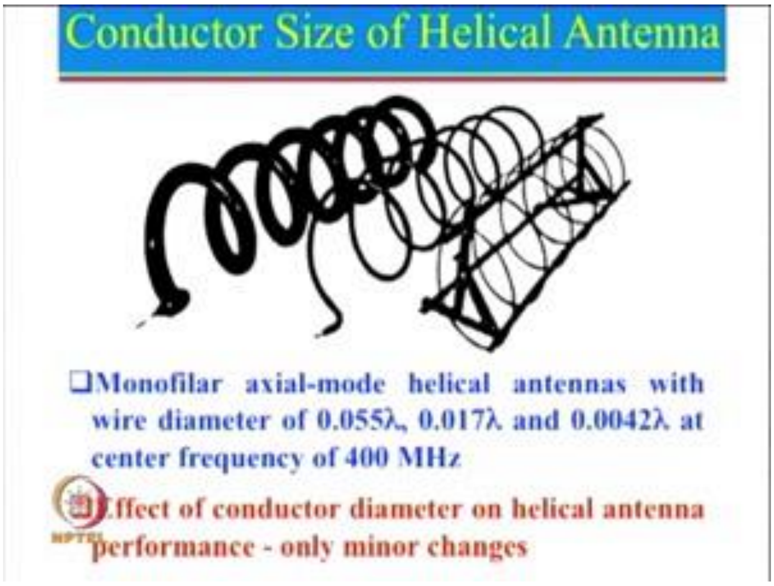

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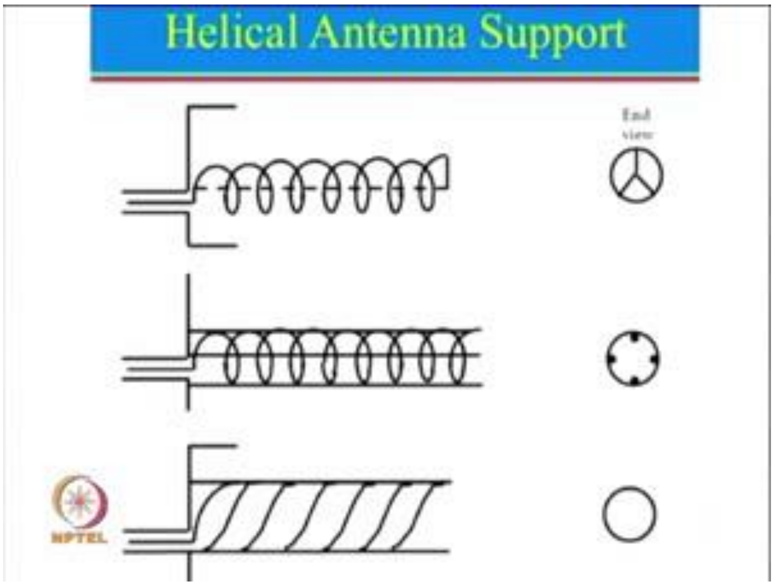

We saw the support structure, and now we will look at the input impedance. So, since it is a travelling wave structure, it has a fairly large band width and its résistance is constant over a very large band width.

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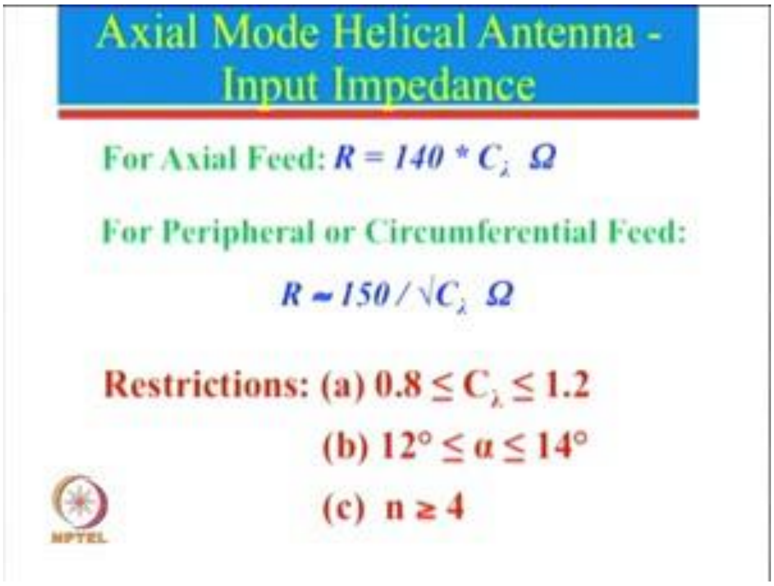

So, if the feed is axial feed; that means, if this is the helical axis which is the axis here if you feed like this here, than it is known as axial feed.

Whereas, if you think about a helix like this and if you feed along this which is peripheral or circumferential feed; that is known as a peripheral or circumferential feed.

So, for axial mode R is approximately given by this particular formula and for peripheral R is given by this particular formula. And the beauty of this axial mode helical antenna is that the imaginary part is close to 0 or it has a very small component and hence it gives broader band width, and if you look at the condition for axial mode is that C lambda should be approximately equal to 1.

So, if it 1 that will give 140 ohm, and if this is 1 that gives about 150 ohm; so 140 150 the percentage difference between the 2 values is not very significant. So, one can actually see that the impedance variation is not too large; however, there are restrictions. So, it is not that this will be valid for any particular case here, but these are valid these are the restriction that C lambda can be between 0.8 to 1.2. In fact, if you recall I had shown the mode chart and where we and shown you that C lambda can vary between 0.8 to 1.2.

Alpha angle is required to be between 12 to 14 degree, this condition is mainly there so that we can get good circularly polarized wave form. Because what alpha determines? Alpha determines the rise of the helix, and that gives us the finite value of s for a given value of the diameter. So, this is important because let us say helix which is rising like this. So, if it raising like this here it will have a horizontal and vertical component and we want these two components should be equal, as well the phase difference should be 90 degree. So, this condition ensures that; and also than other condition is number of terms should be greater than 4.

The reason for that is if you just imagine again a helix here. So, at this point current will be 0, so that current will get reflected back. So, if the number of terms is very small then that will come back and effect of performance of the helical antenna. So, if at least n equal to 4 terms are there, than the reflected current from the open and from here and coming down over here will be relatively small.

So, these are the simple condition for which we can get merely constant input impedance with reactive part close to 0; however, we can see that this is not really matching with the 50 ohm, so we need to match this impedance with 50 ohm. So, for that get two different techniques have been used. So, input impedance matching technique. So, what is done this is actually very old thing, which is what has been reported earlier.

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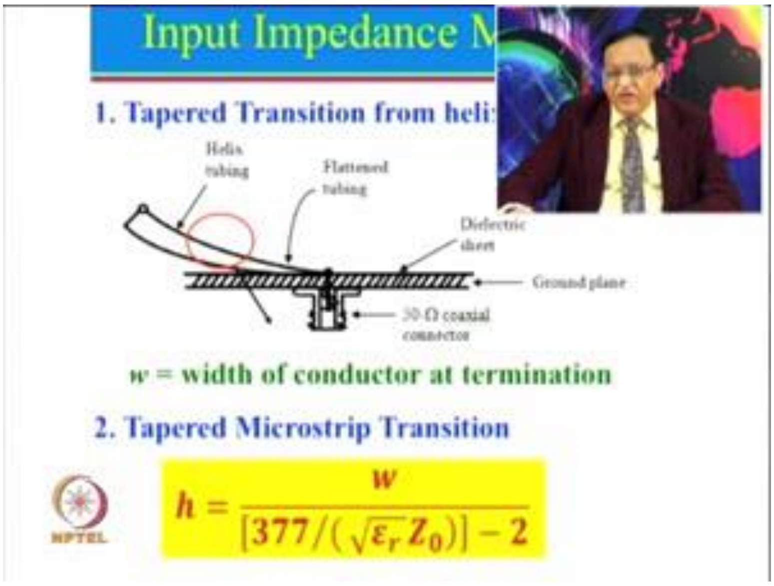

So, I am just telling you that. However, I do not use this technique right now, I use actually the second technique; but let just see what is the first technique. So you can actually see that this is that helix tubing which is coming up here, and that helix tube which is mostly circular and that has been actually made flatter. So, you flat than the tube and that become flat over here, and this is the dielectric sheet which is put in between and then when this flattened over here and that flattened value actually is determine by this particular equation here, just to mention here. So, we know that we would like to get a 50 ohm line, epsilon r will be given by the dielectric substrate, h will be the thickness of the substrate, and for this corresponding this Z 0 50 ohm one can calculate what should be the W and that is how it should be flattened to.

And that becomes a very very difficult thing also, and it is a lot of mechanical work which needs to be done. So, I prefer this particular second thing which has been use by several people also; what in this technique is done as that we know that this is the peripheral feed. So, we actually this is of course axial feed here, I am talking about now when we use this micro strip transition generally that will be peripheral feed.

So, let say this helix tube will come over here, and then generally what is done? We put dielectric sheet here with the ground plane, just like a substrate and then what should do? You print a micro strip line on this. So, on this particular side micro strip line impedance should correspond to 150 ohm, which is for periphery feed and on this particular side the impedance of the thing should be about close to 50 ohm, which is what we do like to feed and then the coaxial feed can be put like this over here.

So, what it important is that from here which is let us say 1 50 ohm, this is here 50 ohm, then this length is very very important. So, one can use quarter wave transformer, but that is not recommended; because a quarter wave transformers will not have a very good impedance band width. So, generally what is recommended is use tapered microstrip transition. So, from here to here, use a transition from 150 ohm to 50 ohm, and typically this length should be approximately equal to lambda by 2 at the lowest frequency, then we can get a very good matching and. In fact, we have done this we use the low cost substrate over here. So, we used f r pore substrate, or glass epoxy substrate, whose dielectric constant is 4.4 can delta of course, was high which is 0.02.

But since we are using only small portion, that loss was not very significant and one can use the thickness here which can be 0.8 mm or it can be 0.6 mm depending upon what is available.

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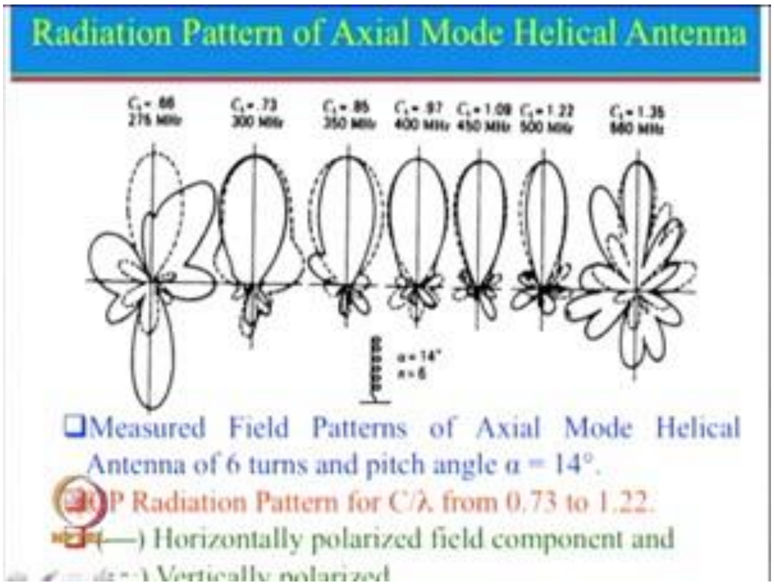

Now, we are going to show you the different radiation pattern. Now this particular study I just want to tell it is reported several decades back, again the main reason as I mentioned earlier there software tools where not there. So, people did lot of experimental work, so they have design this particular antenna around 400 megahertz. So, corresponding to 400 megahertz, you can just say that if you take C lambda 0.97 it can be 1 also approximately.

But at this particular thing, so 400 megahertz is equal to 75 centimeter. So, 75 divided by pi. So, you can say roughly about 25 close to that centimeter is the diameter. So, as clearly large diameter even though it may looks small over here, they had taken n equal to 6; that means, 6 terms are there and they took alpha equal to 14 degree. In fact, I normally recommend since this circular polarization ranges from 12 degree to 14 degree. So, I generally recommend take middle value which is about alpha equal to 13 degree, nevertheless they took this value and now I am just want to show the pattern which they had a measured. So, you can actually see here that what it shows here horizontally polarized component, and vertically polarized component.

So, solid line is horizontally polarized. So, we can see that both horizontally polarize and vertically polarize components are very good giving rise to very good circular polarization. If you look in to here again the values are fairly close, even here the value is pretty close. At this particular thing when see lambda is about 1.35 or you can think about frequency increase. So, basically the ellipse remains same, it is just that frequencies being change; you change the frequency C lambda changes. So, one can say now that there is a deviation between horizontally polarized component, and vertically polarized. But one can actually see here for C lambda 0.66 or at a much lower frequency the 2 patterns are very very different. So, that is not really a good circularly polarize field here. So, one can actually see write from C lambda 0.73 up to about 1.22 one can get good circularly polarized radiation pattern.

So, it is a very very simple way to design the helical antenna, but yet they had to do lot of experiments. So, these are the experiments which they had done. So, here there are 2 turns, 4 turn, 6 turn, 8 turn, 10 turns.

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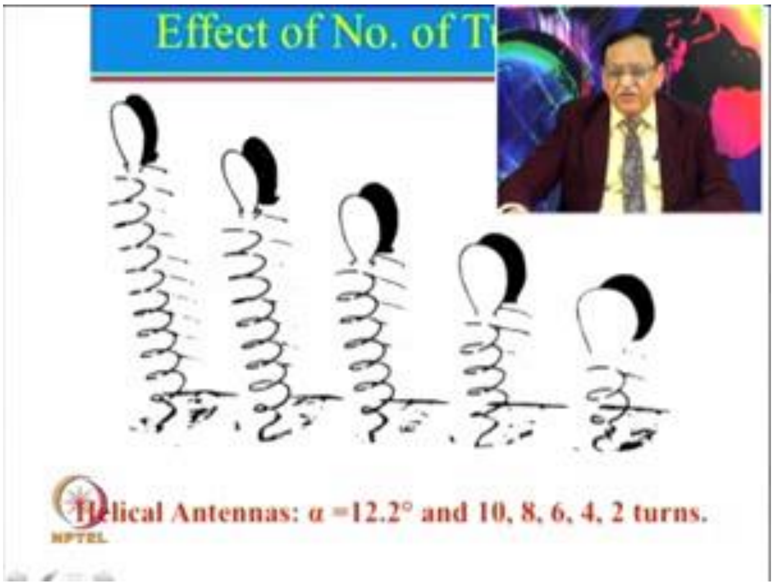

Now, we know that if numbers of elements are increased, then the gain will increase and if the gain increases beam width will reduce. So, one can actually see here this one has a larger beam width compared to this one here, you can see it has a very narrow beam width. So that means, this particular antenna will have a larger gain compare to this particular antenna over here and then all these things were happening there was still lot of confusion was there how to calculate a radiation pattern, why things are happening here, then later on simulations where also done; so here are the simulations for single turn.

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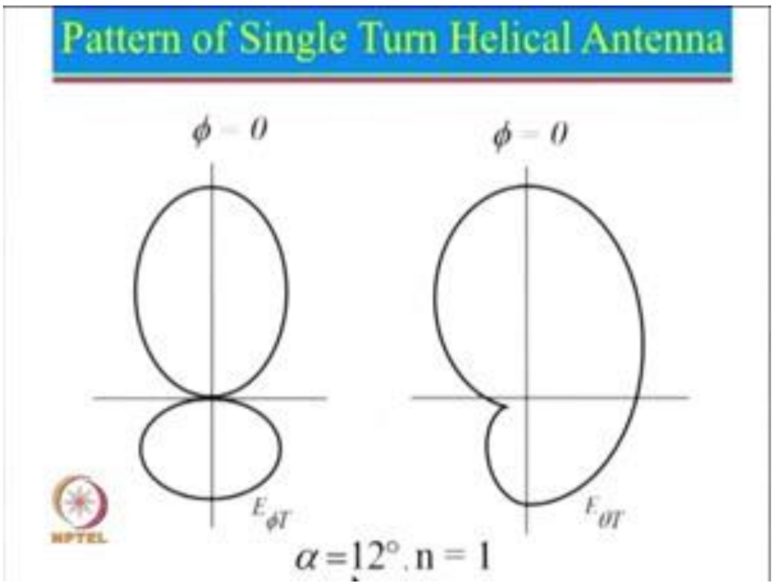

So, for single turn they took at angle alpha equal to 12 degree, n is equal to 1 and you can actually see plane is phi equal to 0, but here this is a phi turn and this is a e theta; so e phi e theta, which are perpendicular to each other. So, now, these are the two patterns, now you can actually see that these two pattern look very different, but; however, if you just look at to the half power beam width area, if you see in this particular thing this is where is the actual mode is going to happen.

So, if it see in this particular region the two pattern look almost similar to each other. And also even though this particular turn is there, but this whole thing will get we will get read out especially because of the array factor, because there are number of turns are there. So, number of turns will actually ensured that the maximum radiation is in this direction, and we will have side lobes in this particular direction, so hence this turn will be actually negligible.

So, here this is the approximation made. So, this whole pattern was actually approximated to be cos phi, because phi is shown. So, cos phi cos 0 will be 1, and phi is equal to 90 degree or plus minus 90. So, field will be 0 over here, and we are not really concerned about the back radiation because this back radiation will be taken care by putting appropriate ground plane.

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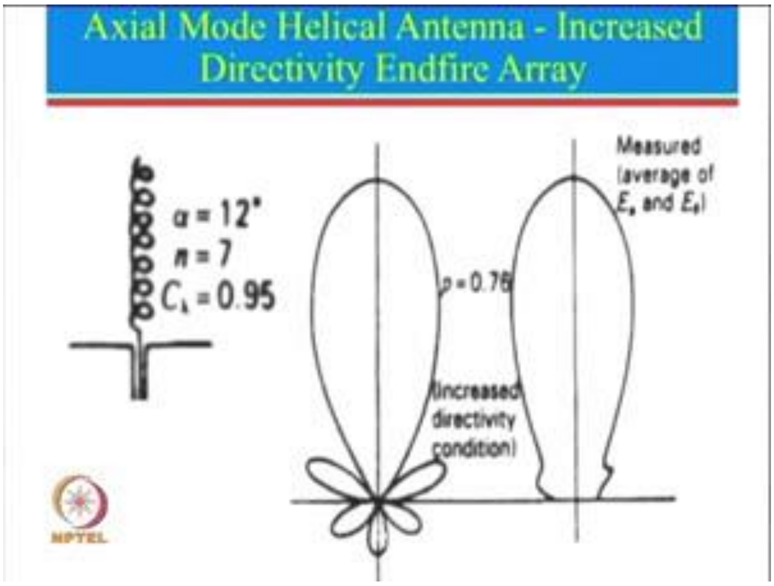

And then there was a lot simulation done, lot of measurements where done. So, here is a case where axial mode helical antenna actually was fabricated, you can actually see the case studied is C lambda was 0.95, n is 7, alpha is 12 degree. So, we know that for this situation we will get circularly polarized antenna; and for this particular thing by actually found this to be the measured E theta and E phi average of that.

So, now this particular thing was obtained this is nothing, but you can actually also think about and end fire array. And now if this is and end fire array, you can think about one element here, second element here, third year, fourth year, fifth year, sixth year, seven and from here to here there is a phase delay. So, from here delay, delay, delay and that delay condition should be satisfied such a way that it gives us the end fire.

Now in the beginning people were all trying to use the concept of the end fire array, and by using the concept of the end fire array the results were not matching with this particular configuration. So, then used lot of permutations and combinations, and then they actually when they used this particular value of phase delay 0.76, which also corresponds to increase directivity condition and suddenly these two patterns look very very similar to each other.

Except for of course, there is a not resembles in the side lobe level, but if you look in to this particular thing here resembles is pretty good. So, in reality this axial mode helical antenna is by default, an increased directivity end fire array. So, they did try to do many things to do the simulation, ultimately this thing matched very well. And once this particular fact was established, after that all the design equation all the other things became very straight forward.

So, will start to with this thing that yes helical antenna is a natural increase directivity condition, and I also want to mention here helical antennas are also known as slow wave structure. So, if there is a bend over here. So, the phase delay is getting different, and that why the number 0.76 has been used instead of normal, if you just use increase normal directivity it would have been equal to one, but for that the results are very very different.

So, this is the condition for the increased directivity. So, once this was established everything else was very very straight forward.

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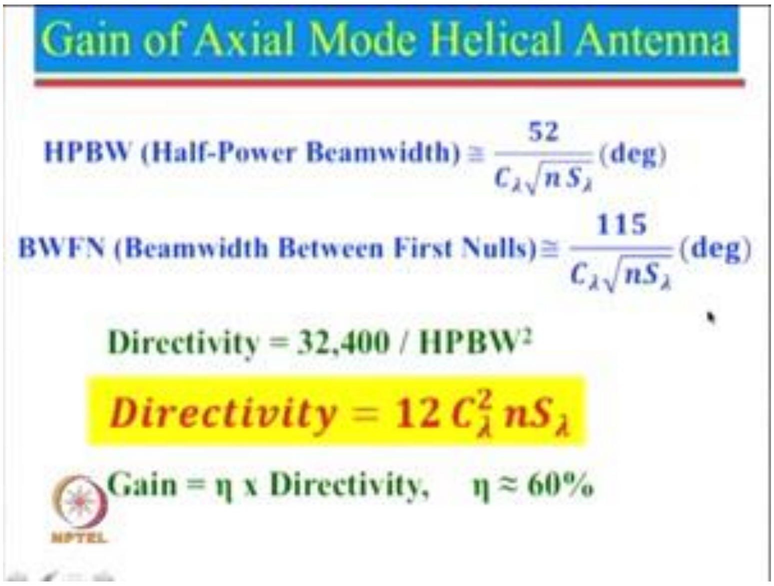

So, one can actually now find out by establishing that this is a axial mode helical antenna follows the increased directivity end fire array, then for the increased directivity end fire array we can actually use straight forward the formula for half power beam width, which is given by this particular expression over here, and then we can also find out what is the beam width between the first null which is given over here. Now if you take the ratio of the 2 that is approximately 2.25. In fact, many books write that half power beam width is about half of this here, or this is two times half power bema width.

Now, I do not agree with that, generally beam width between the first null is about 2.25 to about 2.29 for majority of the cases which we actually have done the simulation. So, after that finding directivity is very very easy. So, we have already seen the directivity formula and we know the directivity formula is given by 4 pi divided by theta e theta h; where theta e theta h will be in radian, but add also mentioned that formula to be used only for smaller arrays. For larger array we are told you that you use 32400 divided by theta e theta h; where theta e theta h are in degrees. So, looking in to this particular thing here, so if will actually take 32400 defined by half power beam width square, and in this particular case here we had seen that horizontal and vertical components where exactly same.

So, half power beam width will be same for both e and h and since that is same we put this value over here. So, one actually if you simplify this here this divided by 52 square comes approximately equal to 12, and this is a square turn here which goes then this denominator goes up. So, C lambda become C lambda square, square root turn gets removed that is n S lambda. Now at this point now I differ from the cross book; in the cross book in general they have written this as a gain of the antenna, but actually we have found out that is not really the gain, it is actually directivity of this particular antenna. In fact, I also want to mention several papers have been reported later on and there was a one paper which we notice that they had done experiments using 5 turns, 10 turns, 15 20 25 30 35 and based on all those number of turns they did the measurement, they did lot of work and they actually then derived certain approximate formulas for half power bema width, gain and other thing.

However we looked in to all of those things also, and what we find out that conventional things which are given by cross; still will work very fine except for this one small modification that use all of those things as directivity. But gain is given by efficiency multiplied by directivity and we found that the efficiency is approximately 60 percent. So in fact, when we use this particular concept, then our results matched very closely with all those different studies which have been reported. So, actually speaking if you use this concept the design of the helical antenna becomes extremely simple. So, hence I still recommend that you can use this and I can also tell you that majority of the time maximum error in the directivity will not be more than 0.5 dB.

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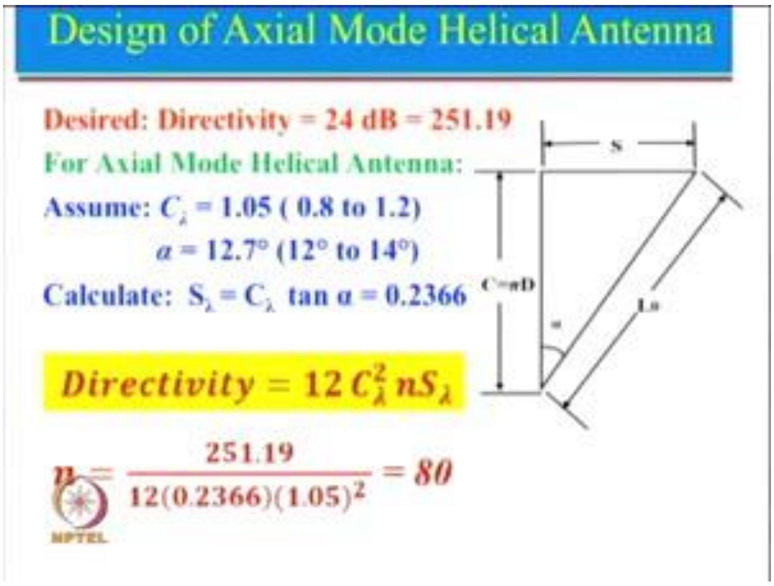

So let us look in to now; how we can design axial mode helical antenna. So, let us say it is given to us the directivity is equal to 24 dB, again this example is given is in the cross book. Only difference is that the cross book it is written as gain equal to 24 dB, I have modified that to directivity equal to 24 dB. So, gain will be actually less so if you multiplied this number, this number you get it 24 dB corresponds to 251, I just to tell you if it was 10 this would be 10 dB; if it is 100 this will be 20 dB, if it is 1000 it will be 30 dB. So, that you please remember these some simpler things how to convert from dB to the numerical value.

So, now if you look at the gain of this, you multiplied this with 0.6. So, 250 into 0.6 is approximately 150. So, you can actually think about you are designing for a gain of 150 correspondingly you can calculate the dB value, but nevertheless we will go with the directivity equal to 24 dB. So, we need to do the design. So, we know for axial mode we can choose the value of C lambda between 0.8 to 1.02. So, in this example they have chosen as 1.05, but in fact.

Generally I take the center value which is about 1. Now alpha can be between 12 to 14 degree; now they have taken 12.7 I would generally take about 13 degree always take the middle path, but anyway these are the things which are given in that books. So, I am just repeating those. So, here once we alpha and we know C lambda, you can use this particular figure here. So, we know that from here we can say tan alpha is nothing, but S divided by C.

So, S is nothing but C lambda into 10 alpha, we can multiply C lambda which is 1.05 tan 12.07 degree that comes to 0.2366. Now I want to mention that this entire design is very generic in nature, everything is normalized with respect to the wave length. So, just depending upon whatever is the wave length, you can choose the values correspondingly. So, for example, let us say you want to design antenna at 1 gigahertz; at 1 gigahertz lambda will be 30 centimeter. So, then this will be 1.05 multiplied by 30 will be equal to C and then correspondingly you can find the value of d which is will be C by pi.

And then from here we know S lambda is 0.2366. So, S will be equal to this multiplied by lambda, and for 1 gigahertz lambda is 30 centimeter you multiply this with 30 and then you can calculate the value of S from that. So, now, we know that directivity formula is given by this particular value here. So, if you use this expression what we know, we know directivity which is given; we have chosen C lambda as this value, you can chose 1 also. Now S lambda has been calculated based on these two chosen value, so only unknown is n. So, that is now n becomes now equal to 80. Now you can actually see that too many turns are there, and if we take too many turns like this here again think about this. So, total what will be the total height of the helical antenna that will be n time S.

So, we can now see 80 times S lambda which is 0.2366. If you are designing get one gigahertz, you have to multiply this with 30 and suddenly you will that it is a very tall antenna. So, one way is that we can actually design an antenna using 80 turns to realize directivity of 24 dB, other thing is we can actually use arrays of these helical antenna.

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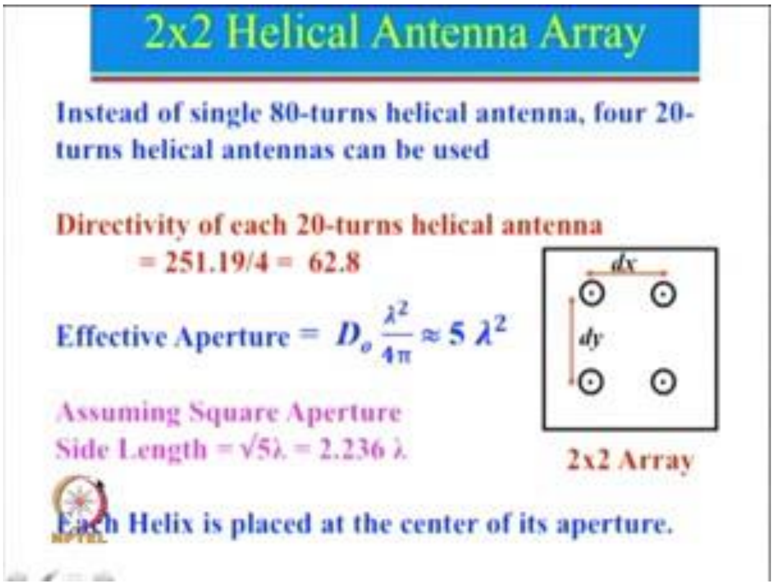

So, let us just look at the concept of how we can use this array form. So, here what we are going to look at is a 2 by 2 helical antenna array which will replace single element this thing. So, instead of using single turn 80 turn helical antenna, one can use 4 20 turn helical antenna. As we know that if we because the directivity is directly proportional to the number of turns so; that means, if we reduce the turns by 4 times direct will be reduce by 4 times.

So, directivity of each 20 turn will be now divided by 4 time. So, we need to put these 4 helical antennas in the form of 2 by 2 array. So, it is now very important that where should be keep these helical antenna; should we keep them very close to each other or should be keep them far away, is there a rule to put these helical antennas at a particular thing. Yes there is a rule at what spacing these antennas should be put. So, over here we also know that directivity is given 4 pi a by lambda square.

So, directivity is given by 4 pi aperture by lambda square. So, we can find effective aperture by using this formula we know what is D we put this value here that comes approximately 5 lambda square. So, if we assume that this aperture is square, then we can take that as a side length; and that becomes square root 5 lambda. So, this is the value here, so then if you put these 4 helical antennas at this particular spacing then that can realize array.

So, we will continue from here in the next lecture we will see little bit more detail about, what happens if you use different number of elements and if we go for different arrays sizes, and we will see how we can optimize this and how that aperture is there and then we will also look at the practical aspects of how to realize, and how to design these helical antennas; and after that we will also talk about normal mode helical antenna. So, with that we will conclude today’s lecture.

Thank you, bye; and we will see you next time.