Antennas
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Module – 10
Lecture – 48
Horn Antennas-IV

Hello and welcome to today's lecture on horn antenna therefore, the last few lectures we have been talking about horn antenna. Until now we have covered E-plane sectoral horn antenna H-plane sectoral horn antenna and pyramidal horn antenna. So, let us look into other types of horn antenna and we will start with the conical horn antenna.

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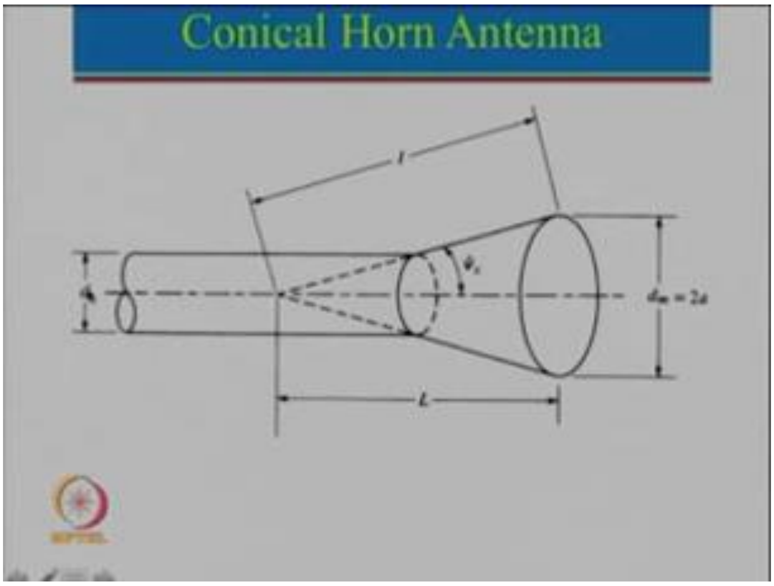

So, a conical horn antenna basically uses circular wave guide, which you can see over here. And then that circular wave guide is flared. So, in this particular case we actually have let say a small diameter D here, for the wave guide and then we have the diameter here t m which is the diameter of the aperture. So, we have only one dimension in this particular case in case of pyramidal we had dimensions a and b whereas, over here we are just increasing the diameter.

So, we have one less dimension to optimize. And over here then this is the length of the horn antenna. In this particular case place center will be only one, where as in case of pyramidal horn antenna the phase center for E-plane as well as for H-plane are slightly at a different position, but over here there is a one common all you would need to do if you just extend this dimension extend this dimension it meets at this particular point here. So, this is the length we can say and this is the slant length here and that is the diameter.

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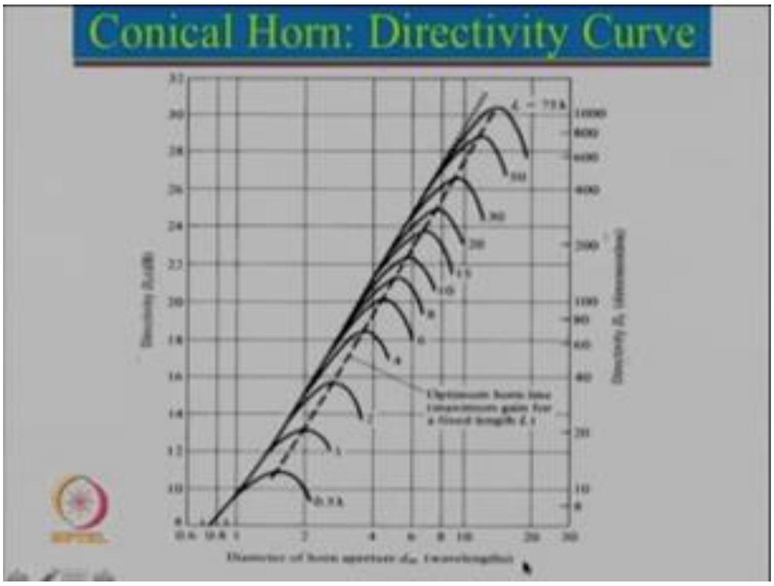

So, again for this particular case, this curve here shows the directivity curve. So, what we can see here directivity is along this axis and this one here shows the diameter of the horn aperture. And these are the various number of cases that is for L equal to 75 lambda 50 lambda down to 0.5 lambda that is the length of the horn antenna.

Now, one can actually see that for a given value of L let us start with let say 0.5 lambda, if we take this here when as we increase the diameter, one can actually see that directivity is almost increasing linearly. And then it actually becomes maximum here and after that it is decreasing. The reason for the decreases is as before phase error has increased significantly which results in reduction of the directivity. Now if we just take another other case of let say length equal to 2 lambda. Now if we you keep on increasing the diameter one can see that the directivity is increasing, but over here now this corresponds to the maximum value and then it is starts decreasing, but if you really see the corresponding maximum value which is close to let say 15.78 or let say less than 16 dB.

But had this thing gone up linearly, then instead of having this over here this linear would have gone like this. So, if you just look at the vertical line from here to corresponding to this that would have been close to 18 dB. So; that means, at this particular point we have lost directivity of close to 2 dB which really results in to the lower efficiency of the horn antenna. So, let just see corresponding to first what the text book say, and then will tell you what actually should be done. So, corresponding to these maximum values, one can actually say that the gain of the conical horn is optimum when the diameter is given by this particular expression. If you recall this particular expression is very similar to that of the pyramidal horn antenna or you can say sectoral horn antenna which was in H-plane

So, we had seen that in H-plane the variation is cosine. So, for cosine variation, what we notice, that the phase error can be little larger than for the uniform thing, but when we look at a circular wave guide, for a circular wave guide in this plane it is uniform, but; however, this value which is maximum that value keeps on reducing as we move towards circle. So, really speaking amplitude here is much smaller compared to the amplitude over here. And you can almost say it is relatively not uniform and we had also seen when we discussed about the error theory that if you take a square aperture versus circular aperture circle aperture always had a lower side lobe level.

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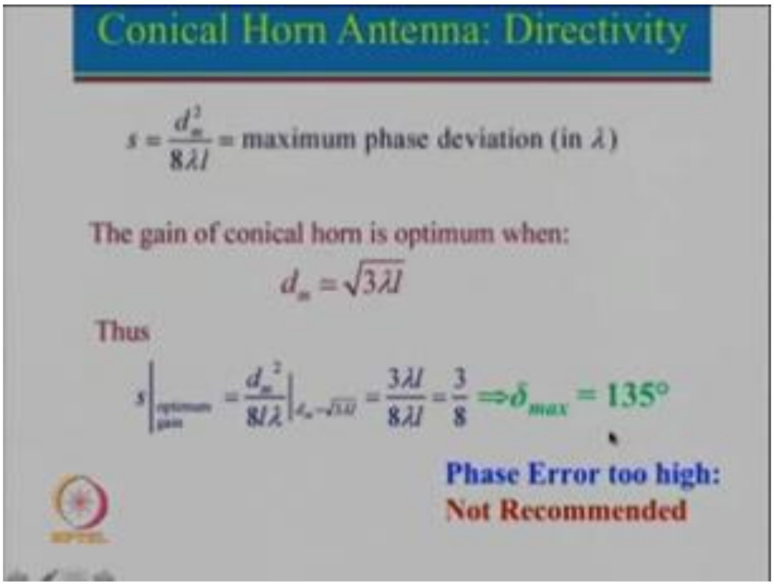

So, in this case also we can actually see similar thing happens here. So, this one is relatively closer to the expression, which corresponds to H-plane sectoral horn antenna and if in the maximum phase deviation if you put it again it comes out to be 135 degrees.

Now, my recommendation is that phase error is too high. So, I do not recommend this high phase error. In fact, again in this case we can see that phase error is very high 135 degrees. And I strongly say that I do not recommend this high phase error value. I generally recommend a phase error of about 45-degree absolute maximum can be 90 degrees.

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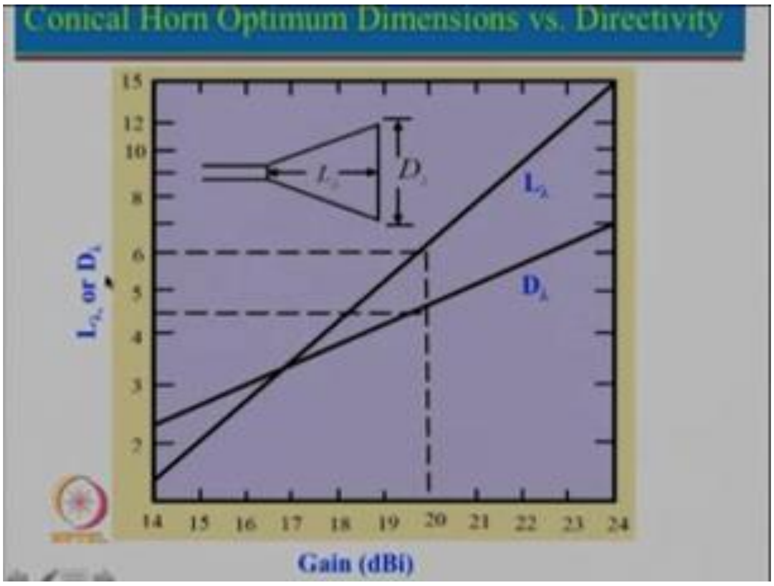

Now this is the one way. You can look into it the alternate way is you can actually look at the curve given in cross book, and here again very similar to the pyramidal horn antenna gain is shown along this axis, and over here it can be the length of the horn or the diameter of the horn. So, let say if our requirement is to design a conical horn antenna at 20 dB. So, at 20 dB draw a vertical line and correspondingly you can read the value of L lambda which you can see is 6 here. And corresponding to this you can read the value of D lambda which is between 4 and 5. And if you use this value you will get approximately gain of 20 dB.

However, I do not recommend this thing as it is, what I suggest is you can take little larger length which will reduce the phase error and hence improve the efficiency of the horn antenna.

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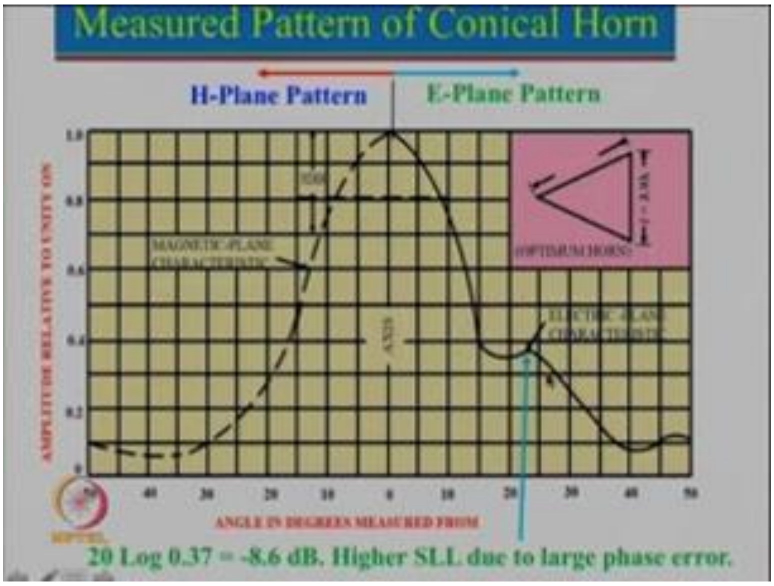

But; however, for this larger dimension what we can see here there is at the measured pattern of conical horn. So, here this side E-plane pattern is shown. You can see that E-plane pattern is over here. One can see big shoulder over here. And this is the H-plane pattern. Now this pattern is slightly different compared to the previous one which we have shown for pyramidal horn antenna. In a sense that this shows the normalized value, here you can see the normalized value is 1 and going to 0 here.

So, for example, if you look at the E-plane pattern, and again only half side of the E-plane pattern is shown same thing will be repeated on this side. So, just to save the space it is not shown over here. Similarly, H-plane pattern is given in this side it will be on this side also, but not shown over here. So, now, let just see corresponding to this particular case here for E-plane pattern one can actually see that there is a huge shoulder over here, corresponding to this value which is about 0.37 as you can read from here that is about minus 8.6 dB. And this higher side lobe level is mainly because of the larger phase error. So, if you reduce the phase error one can improve the performance and that is why I do not recommend phase error of 135 degrees. We should take phase error even less than 45 degrees.

In fact, I am going to show you some example where people have reported in the literature, and there they have taken much smaller phase error even of the order of 10 to 15-degree phase error. So, that is why I want to tell you. So, what we read theoretically, but practically people are not using these particular things, we will show you that practical example little later on.

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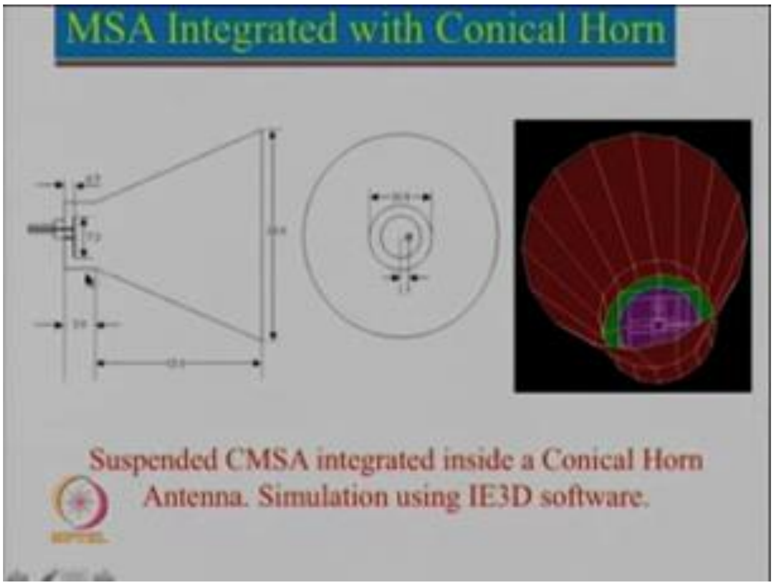

But now I am going to show you a conical horn antenna with the difference. And what is the difference here? So, what we have done instead of using a coaxial feed like this over here which I had given you the design detail for pyramidal horn antenna. What we have done for pyramidal horn antenna? We had put the coaxial feed like this here, now, when we were doing something like this here. So, what happens if you take a coaxial feed like this here, normal that will be the monopole antenna. So, monopole antenna will radiate like this here E-plane will be this, like this.

And then this one here reflects back and comes over here. So, we came out with them idea that instead of using this particular concept why not we use a micro strip antenna. So, if you look at this outer dimension that is a circular one, which you can see here, also that is a 3D view. So, that is this outer one here. And then you can see this particular thing here this is nothing, but suspended circular micro strip antenna. In fact, what we have done, we have provided a support to this particular suspended this thing using a metallic post at a suspended in the air and we have used a roughly about one mm thick metallic plate which is suspended and then you can see that this is being flared. Now I will just tell you what it does. So, basically we know that a micro strip antenna is relatively easy to design and whatever is the radiation pattern of the micro strip antenna that will get enhanced.

So, basically horn antenna actually enhances the gain of the micro strip antenna. And even though I am just showing you write now for a single feed, but will tell you what all the other things we can obtain and different types of polarization can also be obtained by modifying the circular micro strip antenna. So, first let see the results then will come back to this slide and see what all we can get.

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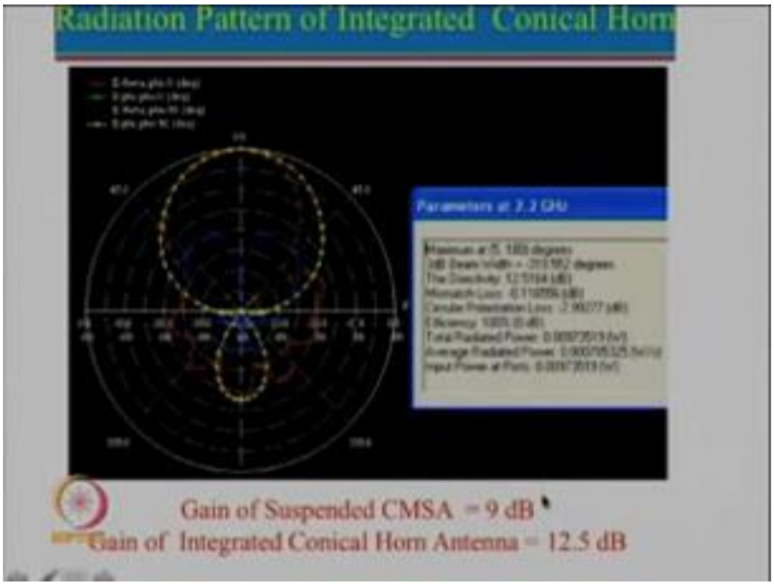

So, now just to show you the radiation pattern, which for comparison the gain of the suspended circular micro strip antenna was approximately 9 dB because it was suspended in air hence the gain is relatively large efficiency is very good. And then we use this circular micro strip antenna integrated with the conical horn, we got a gain of about 12.5 dB. So, you can see that the gain has been enhanced.

And this is the radiation pattern which you can see over here. So, you can actually see e theta e 5 plot here, and you can see that the back radiation is fairly small it is less than about 20 dB or so. And these are the parameters which has shown over here one can actually see we can increase the gain.

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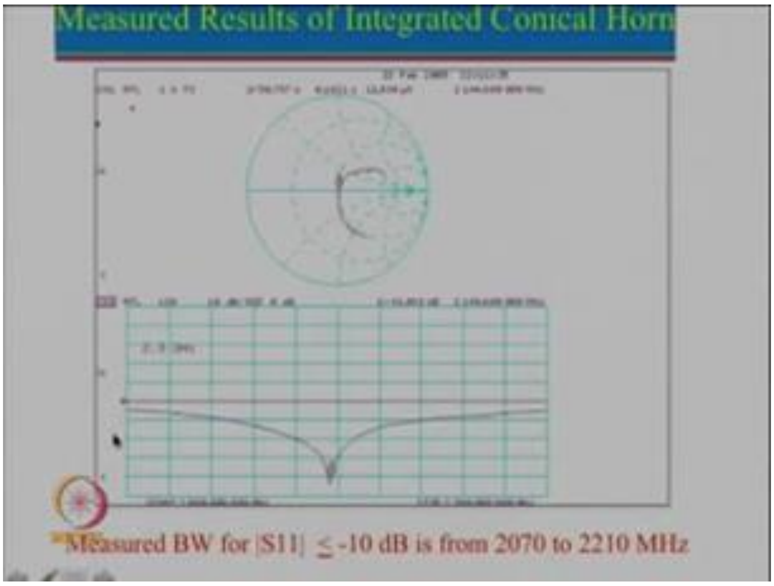

So, based on these then we did the fabrication and this is the measured result of integrated conical horn antenna which you can actually see here this is the smith chart plot one can get a fairly good impedance matching and this one is the S 11 plot. So, measure band width for S 11 less then minus 10 dB, is from 27 to 22, 10 megahertz. In fact, this one meets the band width requirement for 3 g transmission. A 3 g transmission takes place from 2110 to 2 170.

So, you can see that this one covers the entire 3 g transmit band so one can actually transmit very high power, also because we have use a metallic plate. In fact, one can even pump in even a kilo watt of power through this particular antenna. So, micro strip antennas if property designed can give raise to a very high gain. Now I just want to mention here we actually have done lot of other simulation we have just shown you one particular result, but just to mention now for example, for circular micro strip antenna we just use one feed, but now if you use 2 orthogonal feed, we can get both vertical as well as horizontal polarization whereas, if you use a conventional horn antenna with the monopole antenna it is very difficult to get both the orthogonal polarization.

So, one can get a single polarization, but not both the polarizing. Now again here what we also did, so that same circular micro strep antenna what we also did instead of feeding with one angle 0 one angle 0 which will give us 2 orthogonal polarizations we also use the feed as one angle 0, one angle 90 degree. So, that gives us circular polarization. So, we use that along with this conical horn antenna. So, again we saw that we could get circularly polarized antenna, but with the higher gain. So, depending upon the aperture which you take for horn antenna you can realize a fairly large gain also. Then the whole concept we also extended to the pyramidal horn antenna.

So, for pyramidal horn antenna, instead of taking a circular patch what we did we took square patch or rectangular patch we have tried with both. So, again with let say square patch or rectangular patch if we use single feed you will get linearly polarized horn antenna, but with a higher gain. And again there we can use 2 orthogonal feed and if it is square then you will get 2 orthogonal polarizations with higher gain and the isolation will depend upon whatever is the isolation of the circular patch. So, that particular application will be very useful for mimo antenna, which is multiple input multiple output, but it will give 2 orthogonal polarizations.

So, there also if we use rectangular way micro strip antenna of different dimension ley say L and w then these L and w can be resonant at 2 different frequencies if we again use 2 orthogonal feed again the same horn antenna can be used to enhance the gain of the antenna. So, this particular thing I just want to mention. So, from a point I did not know how to feed the horn antenna, and then we have had to do lot of study we studied the parametric study looked into the things we did the fabrication and later on we actually went on to invent a new type of a antenna itself. So, we actually reported this particular antenna for first time and we have even published paper where we have used micro strip antenna integrated with horn antenna.

In fact, I feel that the next research will be where you combine concepts of different antenna and put into different configuration. So, for example, we combine micro strip antenna with let say horn antenna. Similarly, you can do lot of other combinations to design you can say different type of antennas or you can design absolutely new type of antennas or you can even design exotic antennas and so on. And that is reason I have been saying many a times I have said that that antenna design is not just science it is also about art, and why I say art how you fit the whole thing in a given space available to you or for a different application where you need to put it.

So, now we notice that this horn antenna has a real problem and that real problem is that the E-plane and H-plane radiation pattern are not symmetrical. We notice that that E-plane and H-plane patterns are not very good. One can see over here that we have a basically major problem in the E-plane, because of the high shoulder. And because of the higher shoulder what happens lot of power gets radiated in this particular direction whereas, H-plane is relatively better. So, then lot of research has been done, and lot of papers are there where people try to reduce this shoulder. So, let just look at a few techniques today and then will also continue in the next lecture.

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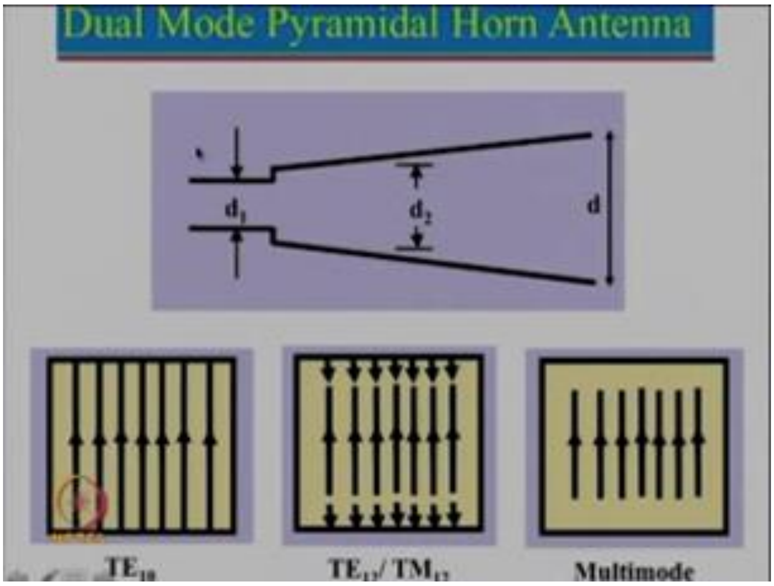

So, will start with the one of the technique where what it is known as a dual mode pyramidal horn antenna.

Now, what this really is now recall pyramidal horn antenna, we had seen that we operate that horn antenna for T 1 0 mode. And for T 1 0 mode we are seen the field distribution which is maximum at the center and has we go to the h field becomes 0 over here. So, field is 0 it goes to maxima it goes to 0 here, and since the variation along this plane is sinusoidal, that gives us a lower side lobe performance, but since the field is uniform along this access. So, that gives us a poor side lobe performance and also this problem gets more because of the larger phase error also. So, then the combination has been done instead of exciting this 1 0 mode which is coming over here step has been used over here.

So, that this particular dimension now supports the 1 2 mode. What is 1 2 mode; that means, field variation 1 means 1 half wave length variation right; that means, half wave length variation is there, but what 2 means; that means, 2 times lambda by 2 variations along this. So, one can actually see that if you will just put over here you can see the direction here. So, if I just say that this is minus than 0 plus 0 minus. So, that is the one wave length variation or you can say 2 times lambda by 2 variations, if you now excite this mode as well as this mode, and that mode is getting excited because of the change in the dimensions over here which supports this particular mode.

So, now when the wave which is launched over here, which is basically predominantly this and from here this mode gets excited which gets super imposed on this. So, one can see if we add these 2 thing, what one can see here this field is going in this direction and this one here is let say if I say all plus, plus maximum and here it is minus maxima. So, plus maxima minus maxima will give rise to close to 0. As we move along here this minus is becoming 0 and then it becomes let say plus now this is same as this here. So, field will get added up here.

And it will gradually have added up maximum field will be here it will reduce to this value here. Similarly, the same thing is happening here field is close to negative value here negative maxima this is let say positive. So, one can actually see that this is the T 1 0 mode which is uniform along this here and this higher order mode which is 1 2 modes the 2 means 2 half wave length variation along this direction. So, one can see that this is in the opposite direction of this. So, field gets cancel. So, we get a field 0 here and then fields getting added up. So, we get maximum field which goes to 0 maximum field which goes to 0, and again similarly we already know that in this direction field variation was anyway sinusoidal. So, if you look into this particular case here. So, this multi-mode pyramidal horn antenna basically will have a symmetrical radiation pattern.

And this kind of a symmetrical radiation pattern is required; just imagine that we have a parabolic dish antenna. And this horn antenna is being used as a feed. Now if the field is not symmetrical in both the plane then what will happen it will give raise to a asymmetry in the radiation pattern also. And these larger side lobe levels are very undesired when we are trying to feed parabolic dish antenna. So, that is why we need antenna which actually has a symmetrical pattern, because it is going to feed a symmetrical configuration with low side lobe level so. In fact, there are 2 main applications which I mentioned in the earlier lecture that horn antennas are known as standard gain horn antenna. So, we do not want also there that the radiation pattern should be relatively changing. Second thing is that it is used as a feed for reflector antenna. And most of the time we would like to have a symmetrical configuration and hence these corrections are required. So, that we get a symmetrical radiation pattern.

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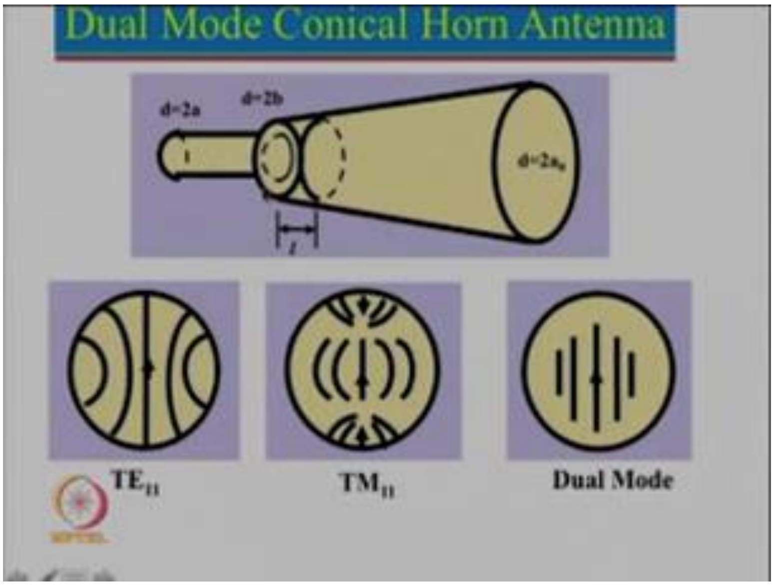

So, we just looked in to the pyramidal horn antenna. Similar concept has been also applied to the conical horn antenna also. So, what you can see here that it is starts with a circular wave guide and then other diameter circular wave guide is added to that and then flaring is done. So, basically this circular wave guide supports let say the fundamental mode then this particulars circular wave guides supports another mode here and if you look at again the field distribution say it is uniform over here and it is going to 0 over here, but even vertically it is uniform and then it is relatively becoming small, but now on this here if we super impose which is you can see here this is in the opposite direction and then we have a 0 in the same direction going there.

So, if you take the super position of the two. So, this one is in the opposite direction. So, we get field equal to 0 here. So, if you look at this particular thing this dual mode horn antenna has a symmetrical field distribution. And if the distribution is symmetrical radiation pattern will be also symmetrical. Now instead of using a step we can actually use also the tapered configuration also. In fact, I just want to show you that in then I will come back over here.

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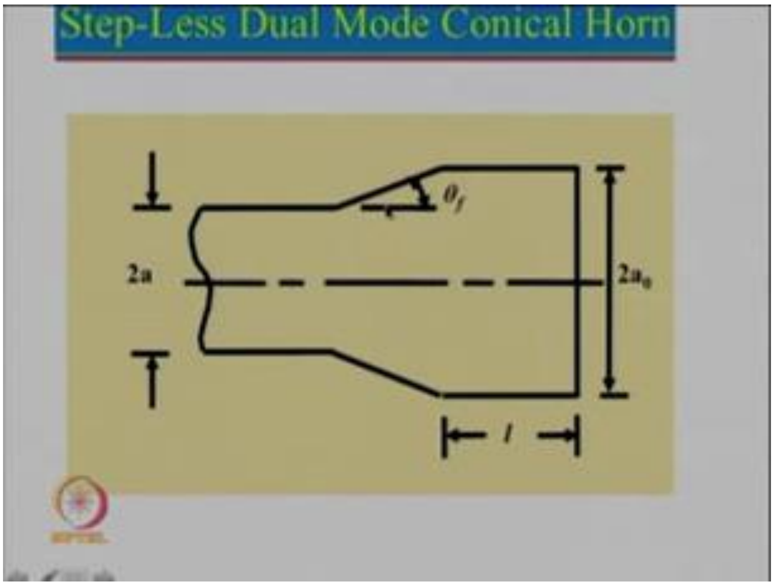

So, instead of that, instead of using a step over here one actually use a step less or tapered distribution here. So, what actually happens? If you take a step then let say the step will be somewhere here, now normally what is done let say if the step is here. So, just imagine this dimension like this here.

What is done you take the center point of that and draw the line like this here. So, basically if you see this particular area which is this part has been removed and this art has been added. Now performance wise this is very similar to the previous case, then you might wonder then why should I use the second case over this one here in fact, when we were working on very high power application. So, we found out that when you are looking for a very high power application, because of this step discontinuity and this particular point heating loss was much more. Because what happen? Think about let say the water flow. Suppose if you are injecting the water, let say water is coming and then there is a change in the diameter, what will happen water flow will be like this here, towards the end the water flow will be relatively less.

Or you think about that you are sending the water from the larger diameter to the smaller diameter. So, what will happen when you have a larger diameter at this portion water will try to reflect back, but instead of that if you use the taper thing then what will happen water will relatively smoothly go over here. So, you can apply the concept of the water flow in the micro wave also. So, basically now you can say current flow or power flow there will be less turbulence. In fact, we did the simulation for the stepped one as well as the tapered one. And we found out at the power losses were relatively much lesser for the smooth transition one. So, for the application where you are actually going to transmit very high power, and just to give you some example, there are some radars they transmit megawatt of power also.

Even the some of them are pulse, but even let say pulse power of one megawatt with the duty cycle of say 10 percent, still means 100 kilo watt average power. So, it really means lot of power may get lost at the interface and that may cause lot of heating at that particular joint then you have to provide cooling of that particular section. So, it is better sometimes to use this taper section.

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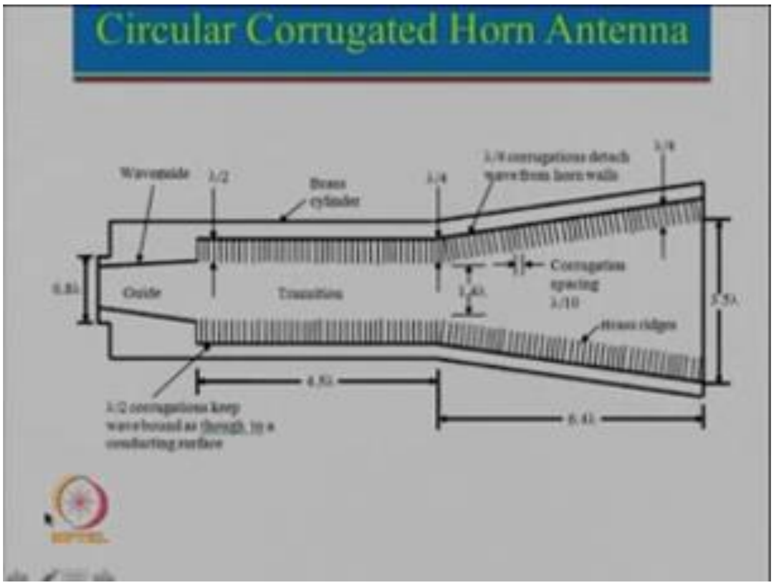

Or there is another thing you can use and this is known as a corrugated horn antenna. In fact, this is one of the practical example. I will show you and you can just look at the figure I will show you this thing in more detail, but I want you to just have those figure here. Say in this figure if you see we have lot of corrugations have been added over here.

In fact, I also call these things as a crocodile. If you look at the crocodile mouth looks like this here and these are also known as the teeth. So, that is like a crocodile tooth here, but what I want you to look into this here see what is the diameter over here that is about 3.5 lambda and what is the total length 6.4 lambda 4.5 lambda. And then there is a additional 1 here even if you just add over here that is about 10.9 lambda. So, if you just use this dimension as this dimension. Try to calculate what is the phase error, and you will see that the phase error of this is way before or much less than 135-degree phase error. So, you can see that people when they design practical things they do not use that kind of a high phase error.

So, I will continue from here in the next lecture. And we will look into more things about corrugated horn antenna how the teeth dimension should be chosen what should be the depth of the teeth what should be the diameter, what should be the thickness of the teeth, what should be the gap between the teeth and so on. And will also look at how to design very broad band horn antenna.

So, to summarize, today we talked about conical horn antenna, and then we also talked about micro strip antenna feed to the conical horn antenna, and I did mention to you about that instead of conical horn one can also use pyramidal horn, antenna along with rectangular micro strip antenna to get orthogonal polarization or circular polarization. So, all the advantages of micro strip antennas can be obtained by using this horn antenna. And the advantages of horn antenna would be it will increase the gain of the antenna without having any additional power divider network. So, with that we conclude todays lecture and will see you next time about more things on horn antenna. Till then, bye.