Antennas

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Module – 10
Lecture – 49
Horn Antennas-V

Hello and welcome to today's lecture on horn antenna, which will conclude the topic of horn antenna. In fact, in the last several lectures we have been talking about horn antenna we started with the rectangular wave guide, than we talked about E Plane sectoral horn antenna H Plane sectoral horn antenna and then we went to pyramidal horn antenna after that we talked about conical horn antenna and we saw that the phase error given in the books is not very good in general that is very high one should take lesser phase error to obtain better efficiency.

Than we also looked in to use of micro strip antenna as if feed inside the horn antenna. So, then in that case we can obtain all the advantages of micro strip antenna, and the advantages of horn antenna which is of higher gain. So, we can get multiple polarization or we can get multi band with higher gain without using any feed network. And then we had seen that E Plane and H Plane sectoral horn antenna in combination with pyramidal horn antenna, we notice that the E Plane pattern is actually not very good, it has a higher side lobe level compare to the H plane.

So, then there has been a lot of research which actually focus upon how to make E Plane pattern relatively more symmetrical with H Plane, and also get read of that high side lobe level performance of E Plane. So, we started with that we looked in to a few possible configurations, which one nothing but using a dual mode horn antenna. By using dual mode horn antenna what we did was that you excite 2 different modes within the horn antenna, so that it creates symmetrical radiation pattern in both E Plane as well as H Plane.

And then we started looking in to the corrugated horn antenna. So, today we will continue from the point where we left. So, we will start with the corrugated horn antenna and we will also look in to the different design, which actually gives very broad band characteristics.

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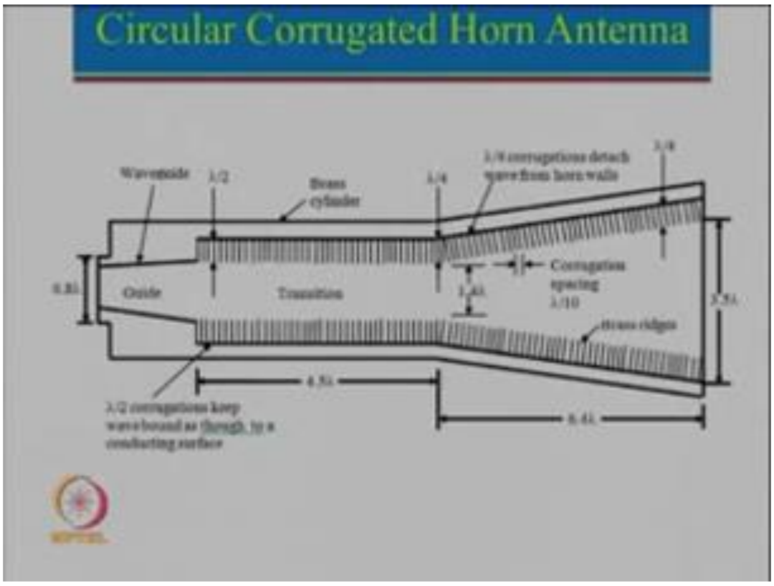

Circular Corrugated Horn Antenna

So, with that let us start with Corrugated horn antenna I had shown you this picture in the last lecture now I will elaborate upon that. So, what we see over here? Here is the point where things are getting launched here; so that you can see here this is the guide wave guide and then you see here all these teeth are here number of teeth are there.

And you can see that the total length is very large compare to the diameter, and which really gives rise to very less phase error, you can actually calculate that what will be tan alpha? Tan alpha will be half of this which is 1.75 lambda divided by more than 11 lambda, and that gives us a very small phase error. Now let see how this corrugation has been done, it has been done very beautifully I want to just mention now one by one. So, if you see here its starts with that this particular dimension is equal to lambda by 2; now what are this really signified.

So, see over here it is a short circuit and if this dimension is lambda by 2, if we apply transmission line theory looking from this point. So, transmission line theory says if the characteristic impedance of the line may be anything, but if the length is lambda by 2 then the load impedance becomes the input impedance. So, load is short circuit it will become also short circuit. So, if this particular depth is lambda by 2, this whole thing will act as a short circuit even though it may not be short circuit.

But that is really not at all a useful thing that is not corrugated horn antennas are supposed to do. What corrugated horn antenna supposed to do? That they should make the feel symmetrical in the E Plane; so now, if you see what has been done. So, this lambda by 2 transition slowly becomes lambda by 4, now this may not give you true picture, but this dimension shows over here. So, this dimension is lambda by 4, what does lambda by 4 really does? So, anything which is short circuit here and if this dimension is lambda by 4 a short will act as an open circuit.

So, that mean something which was seen short over here, now it sees a open circuit; and if it is open circuit over here, you can say that in case of open circuit current will be equal to 0. So, now, you recall E Plane and H Plane even though this is a conical horn, but just recall E Plane and H Plane what was the situation? For E Plane we had a uniform field here, and H Plane field goes from maxima to 0 maxima to 0.

So, now over here we can see that since there is short circuit, which behaves as an open circuit that boundary condition of short circuit is satisfied. So, now, the question is then why use from lambda by 2 continuously tapering it down to lambda by 4, and after this lambda by 4 it continues a lambda by 4. So, there is a basic reason is that when we take this lambda by 2, it almost acts like a short circuit. So, the wave sees continuity, than slowly slowly these dimensions are changed, instead of abrupt changing. See in fact, there are some applications where we have seen, that they do not even use this particular section at all.

They state by go continuous from here to here, and then they use lambda by 4. So, in that case what happens? Lambda by 4 means this short circuit will act as an open circuit. So, what happens if the wave is launched if it is short circuit sees an open circuit? So, what will happen? There will be a discontinuity. So, then power will try to get reflected back from here, and that causes problem with the reflection coefficient. So, hence this is one of the very beautiful thing, which people have done there from lambda by 2 gradually changing it to lambda by 4; so that the current does not see abrupt this continuity and hence reflection does not take plates.

See is a very slow discontinuity happening and then here this particular entire length provides kind of an open impedance at this particular point, which actually reduces the current, which has done gradually from here. So, then this particular thing will actually make E Plane relatively symmetrical with that of H Plane, or you can say E field here will go to 0, E fill will go to 0 and it will be maximum in this particular region. So, this is a nice transition which they have done, you can actually see here some of the points which are written there that lambda by 2 corrugation keeps wave bounded and then it is gradually reduced to lambda by 4.

So, this is the transition state, this is the guide state when the wave is guided in to this particular conical horn antenna, and then basically it is transmitted through here. Then comes the next point and that is how many teeth should be there in the wave length, what should be gap over here?

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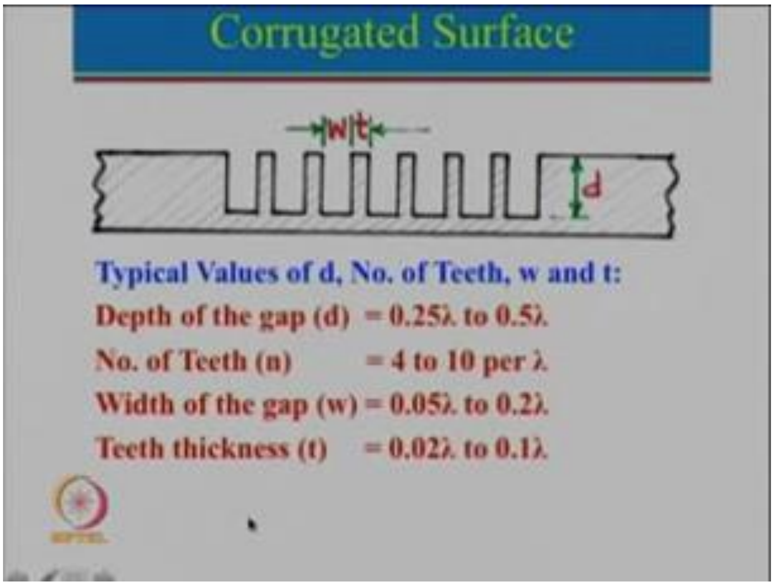

Corrugated Surface

Typical Values of d, No. of Teeth, w and t:

Depth of the gap (d) = 0.25λ to 0.5λ

No. of Teeth (n) = 4 to 10 per λ

Width of the gap (w) = 0.05λ to 0.2λ

Teeth thickness (t) = 0.02λ to 0.1λ

So, for that let see the next slide. So, here we have just shown one of the segment here; one can actually see that these are the teeth as I mentioned we call it crocodile teeth also.

So, the thickness of teeth is given by t, and the width of the gap is w. And we have written here some general guidelines. So, what we should do here? I will start with the depth of the gap which is over here. So, depth of the gap which is given here that should vary between 0.25 lambda to 0.5 lambda. So, now, if it is 0.5 lambda, that means if this thing is 0.5 lambda. So, short here will act as a short so; that means, there will be low attenuation at all and then if 0.25 lambda is there then this short here will act as a open over here; that means, a larger attenuation.

So, as we saw in the previous example what they had done was they started with 0.5 lambda and then went on to make it 0.25 lambda, but; however, many applications they do not use that large transition. So, sometimes they straightaway use 0.25 lambda, it is acceptable it will provide a large you can say decay in the current along this access there may be a little problem with the VSWR, but other than that you can use a shorter this thing here, then comes the next part how many teeth should be there?

So, our recommendation is that there should be 4 to 10 teeth per wave length, you need not take more than that and definitely do not take less than that. So, depending upon the application you can choose between 4 to 10 per wave length. Now you might wonder well that is a lot of variation. So, I will give you certain recommendation also. So, depending upon the frequency of operation you can choose these values. Suppose let say we are operating at say 30 gigahertz. So, at 30 gigahertz la lambda will be 1 centimeter; and if you take number of teeth has 10 then that means, there will be 10 teeth or every teeth will be perhaps to be port at a distance of one millimeter, which may become very difficult to realize it experimentally.

So, for very high frequency well lambda is small, you can take smaller number of 10. Now similarly if you think about at design at 3 gigahertz, at 3 gigahertz now wave length is 10 centimeter. So, if you take n equal to 10 that at every one centimeter you need to put one teeth, then comes the next part what should be the width of the gap and teeth thickness. So, width of the gap in general can vary between 0.05 lambda to 0.2 lambda, depending upon how many number of teeth one has taken. So, corresponding to that one can choose again between this value.

And in general teeth thickness should be less than the width of the gap. So, that can be you can say less then this and this is also less than that. So, correspondingly w and t and you can chose it and again first you need to design the frequency of operation, then you decide number of teeth and after that you chose the value of the width and the teeth.

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Corrugated Conical Horn

So, we will just show you one of the practically available corrugated conical horn antenna, this is commercially available. There is only one difference here I just want to high light that we can see that the corrugation has been obtained in the entire circumference.

So, it is not like as I mentioned corrugations are really important to more in the E Plane over here, it is not really important to do it in H Plane. But here the corrugations have been done in the entire circumference this is more for the manufacturer ability, so that easy manufacturing can be done. Again if you just visually see the phase error of this is not very large, in general which should choose smaller phase error for better and more efficient horn antenna.

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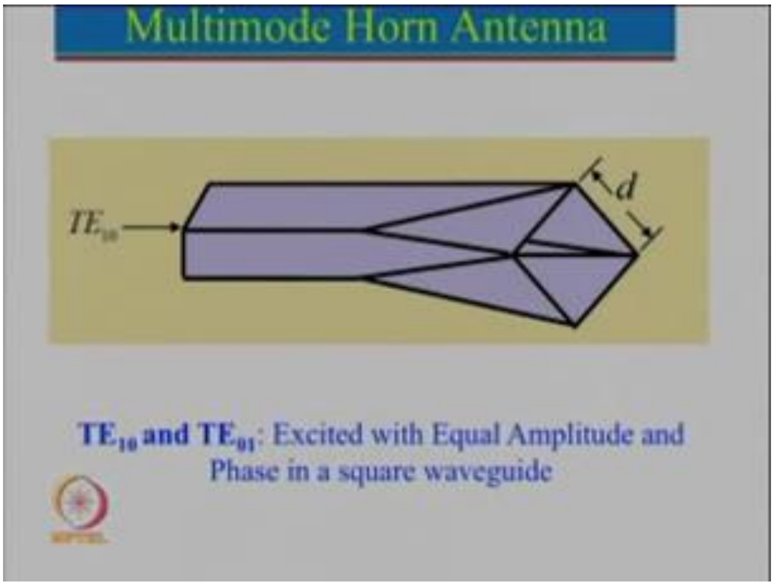

Multimode Horn Antenna

TE_{10} and TE_{01}: Excited with Equal Amplitude and Phase in a square waveguide

Let us look at another application. So, this particular thing here is a multi mode horn antenna again, what this you is actually it is not using a conventional wave guide, it uses a square wave guide; and if you use a square wave guide then both TE 10 as well as TE 01 mode can get excited with equal amplitude and phase in square.

So, what you need to do? So, if we just use of normal probe, then we have to put a probe over here and we have to also put a probe over here; and then that particular thing has now been change. So, 45 degree angle bent has been done, so what happens? So, even the 1 0 0 1 mode are exited, and now here the sum is there. So, you can actually see the summation of 1 0 0 1. So, for example, 1 0 E field will be uniform like this, for 0 1 E field will be uniform like this, H Plane field variation will be sinusoidal for this H Plane variation will be sinusoidal in this.

So, the net result will be that field will be symmetrical like there, but; however, this configuration is not use very commonly mainly because of the manufacturing problem. In fact, over here the proposed configuration which I had mentioned about using a micro scrip antenna is fantastic. So, you can use a square micro strip antenna with 2 orthogonal feed, which will excite one 0 mode as well as 0 one mode and then we can use a wave guide.

So, micro strip antenna will be definitely a very good solution in this particular case, which will be actually speaking utilizing the advantages of micro strip antenna as well as horn antenna now we will want to show you another configuration.

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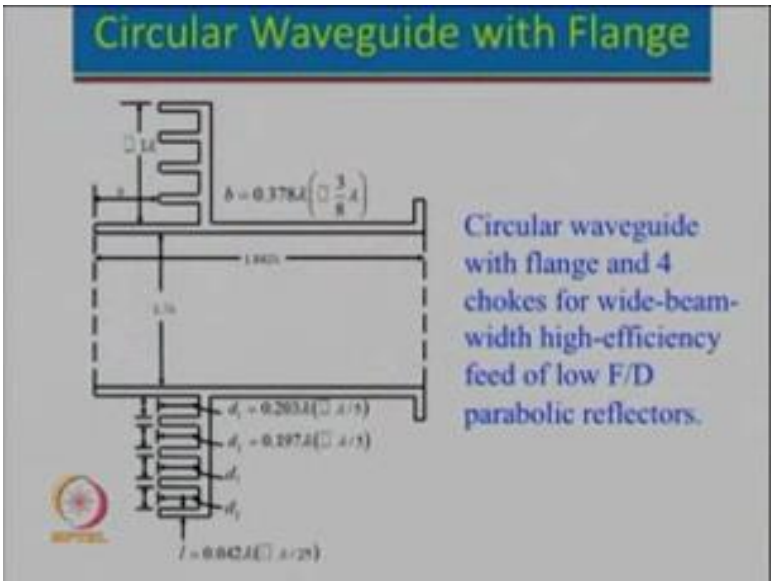

Circular Waveguide with Flange

Circular waveguide with flange and 4 chokes for wide-beam-width high-efficiency feed of low F/D parabolic reflectors.

Now, this particular thing is actually speaking does not really you can call it a conical horn antenna, it is more like a circular wave guide with flange; but the purpose is somewhat similar to the conical horn antenna. Now what this particular thing is, what you actually see here; that this is a circular wave guide; and along this wave guide these are the circular flanges all around.

So, the circular wave guide with flange and there are these 4 chokes are their actually. So, that what happen suppose if the wave is coming through here, then the scattering will not be much; also most of the time this particular wave guide actually has been use as a feed for the parabolic dish antenna. In fact, we actually have seen this particular this. So, several years back we use to have large parabolic dishes which of the 8 feet diameter or even 16 feet, and this 8 feet diameter dish antenna they use to receive the signal at 4 gigahertz. Nowadays of course, we have a different type of dish antenna they are receiving the signal at 11 gigahertz.

But 4 gigahertz was very common tell about a decade back. So, there this is a let say parabolic dish antenna and this horn antenna along with flanges was use; and in fact this particular antenna was supposed to work from 3.7 to 4.2 gigahertz. So, that is a fairly large band width of 0.5 gigahertz, and just to tell you little bit about. So, that particular bandwidth was enough to accommodate 70 TV channels. So, each TV channel in India occupies bandwidth of approximately 7 megahertz. So, 7 into 70 that is about 490 megahertz which is approximately 0.5 gigahertz.

And. In fact, actually speaking we had talk to the space application center people and they mention that they had some requirement, and they wanted to use this as extended C band. I just you tell you C band is from 4 to 8 gigahertz, but yet 3.7 to 4.2 gigahertz is known as C band. So, again practically something's are little bit different. So in fact when we were looking in to this particular thing, so we came out with an idea, why use this wave guide circular wave guide with flanges which has a very large area? And remember if this is a reflector, and if my this size is large.

So, let say the wave which are coming from the satellite, they will reflect from the reflector and it will come here, but at the focal point if this aperture is large, there will be lot of aperture blockage. So, it is always a good idea to have the feed as very very small. So, we came out with an idea why not we use micro strip antenna. So, what we did? We actually removed this wave guide; we had this think put on the tarries of our department electrical engineering department at IIT Bombay.

So, we remove that feed brought it in lab measured the VSWR, measured the radiation pattern of that and than once we knew what are the parameters we are looking at and then we design micro strip antenna. And in fact our micro strip antenna design since we have already covered that in much more detail, I just tell you quickly what we did. So, we just use the one circular micro strip antenna, and then we use another circular micro strip antenna, which was suspended in the air and these 2 antennas where electro magnetically coupled, and that gave us the bandwidth of 3.7 to 4.2 gigahertz; and then to get the beam symmetry and the radiation pattern symmetry what we did, on this circular substrate which we had cut we actually put a copper file a rounded.

So, that created a kind of a cavity, and this was use to get symmetric radiation pattern. Then later on to realize that extended C band what we did? Though bottom circular patch was also suspended in the air, and then the top circular patch was also suspended in the air and we got the band width right from 3.7 gigahertz tell 4.5 gigahertz and just to mention now the size the size of this antenna was just about 6 centimeter diameter, compare to 18 centimeter diameter and also the total height of this antenna was just support 1.2 centimeter whereas, the other diminution was close to 12 centimeter.

So in fact, after we made this fabricated tester, then instead of putting that horn antenna well I will still call it a horn antenna even though it is a circular wave guide with flanges. So, we replace that put our micro strip antenna, and we actually watch TV on that day, and all our students gather together and we watch the TV because this one was using our own micro strip antenna along with the available dish antenna. So, it was really nice enjoyable experience and the size was reduce and the picture clarity who was fantastic.

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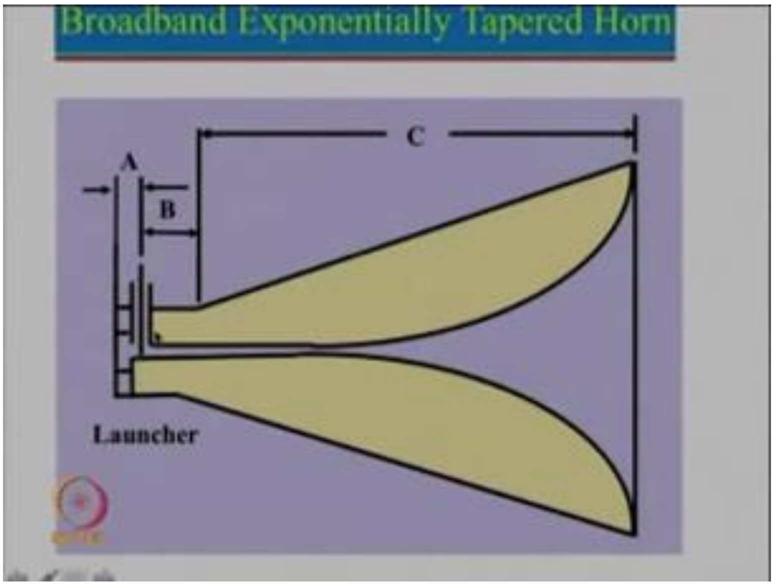

Broadband Exponentially Tapered Horn

So, now we will look in to the next configuration which is broad band horn antenna. So, basically what is the principle behind getting a braid band width? So, let see over here what you actually see over here is a this is the normal horn, which you can see here this is a pyramidal horn and in this particular dimension here you can actually see that this whole thing is a metal, and that is exponentially tapered. And now let see at this particular point you can see that there is a feed over here, feed is connected to this particular point, and over here this is a short circuit shorter wall and the coaxial feed is connected over here; and this particular thing gives us a fairly broad band horn antenna and just to show you the picture of commercially available horn antenna.

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Broadband Dual Ridged Horn

So, can actually see here this is the coaxial feed that feed is connected over here that goes all the way connects to this part, and you can see that this is the actually E Plane, and the exponential taper is provided along this thing here.

H plane nothing to be done as such. Now over here when the feed you can see here this feed here sees a very narrow dimension, and as you move along the feed sees a relatively larger dimension. So, basically this exponential tapper provides a very good impedance matching. So, at higher frequency you can say matching is provided here, lower frequency matching gets provided over here and this exponential tapper in general they are known for braid band impedance matching. Now these kind of an antennas have been designed for very broad band operation, and these are commercially available for band width from 1 to 12 gigahertz or even 1 to 18 gigahertz or 2 to 18 gigahertz, we have also seen very large horn antennas which are match from 300 megahertz to 3 gigahertz also.

So, these are really ultra broad band horn antenna, and these are use as standard gain horn antenna in the laps in general. So, using this concept you can either design your own broad band horn antenna or you can buy it choices yours, but this is the real standard antenna which is used in most of the practical applications. Now the principle just to tell you little bit in more detail about this also. So, majority of the time impedance matching is fairly good; however, the gain of the antenna is not uniform over the let say bandwidth of 1 to 12 gigahertz, you can actually even understand that let say my aperture is fixed.

So; that means, if you look at it what is the directivity? Directivity is given by 4 pi a by lambda square; now A is area, in this case A will be A1 multiplied by B 1; and now lambda is varying, and lambda is varying from what 1 to 12 gigahertz corresponding to 1 to 12 gigahertz what will be lambda, 30 centimeter to 2.5 centimeter, and if you take a square of that gain varies very drastically over the bandwidth. So, at 1 gigahertz gain is relatively small, and at 12 gigahertz or 10 gigahertz gain is relatively large, but again it is not very large as we have seen the length is fixed. So, if the length is fixed and if this dimension is also fixed, but we are changing the frequency.

So, frequency means lambda is getting change. So, phase error will be dependent on that. So, for very high frequency because of the accumulated phase error, gain does not increase too much. So, general 1 to 10 gigahertz bandwidth may have a gain which is increasing like this, and then it becomes relatively flatter or there is a small variation over here. So, this is the one thing which we normally use it.

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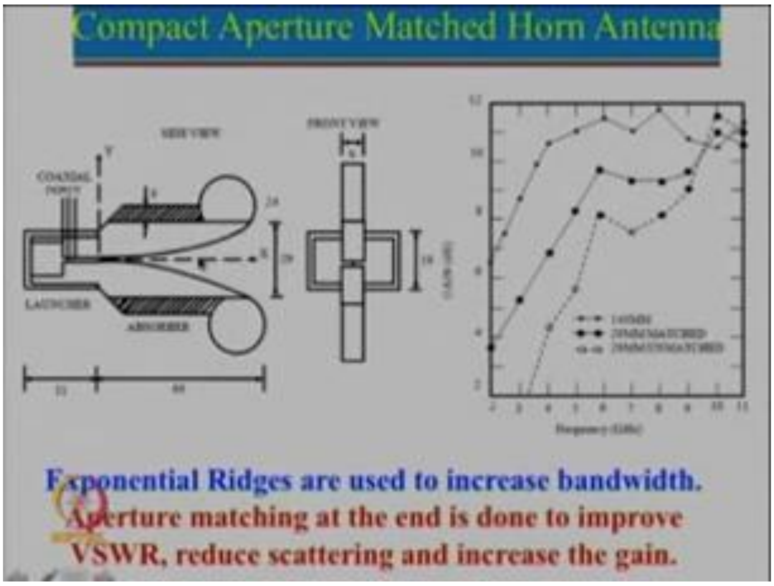

Compact Aperture Matched Horn Antenna

Exponential Ridges are used to increase bandwidth.

Aperture matching at the end is done to improve VSWR, reduce scattering and increase the gain.

Then there is a another concept of designing the horn antenna; over here if you see it is actually a combination of the previous one, and a new concept has been added over here. So, let see what it is. So, here actually speaking if you see this is the; you can see relatively a flatter configuration over here, as you can see this is the thing and this dimension here is exponentially taper, and which if you see from the this side here you can see that this is the portion over here.

I will just go back to this particular thing here, if you look the side view from here what you will see? This rectangle and then you will see this particular portion as the metallic portion. So, the same thing over here you can actually see this has that metallic portion, and that is the rectangular and this is a made of a solid, so that is the thickness of the metal. Now again there are a few things are also there question is now which metal to be used. So in fact, there are 2 popular metal which are use to make these horn antenna, one of them is made of aluminum mainly because aluminum has a light weight, and another one generally metal use is a brass metal is use, the problem with the brass is that it actually has a higher weight.

So, many a time’s people do use aluminum to make the horn antenna. So, over here now let just look at this figure. So, one can actually see that this is being tapered over here, you might wonder then what is the difference in this and the previous case. Even the feed is very very symmetrical, you can see that this is the short here coaxial feed is put over here, the difference you can see that here the tapering is not done, this is relatively compact also; and what is the compactness here? You can actually see this dimension is only 29 mm, that is really really small and compact, but this dimension is exponentially tapering.

However there is a additional concept over here, and that concept is of aperture matched what is this aperture match concept. So, even the way is launched here if this is dominated write here, then there is a lot of diffraction takes place and also it sees an open discontinuity, so part of the wave will get reflected back; however, instead of having a sudden open this whole thing is given a curve shape. So, what happens? That the current which is being coming over here, that starts rolling around this, there is a no h diffraction taking place, and then this current here rolls around and this one here actually is a micro wave absorbing material.

So, whatever they think roles around here that gets absorbed here. So, what is the reflected value? Close to 0, so nothing gets reflected back. So, one of the beauty of this particular configuration as that the reflection coefficient is very very good. In fact, most of the time for this kind of a configuration one can actually easily get VSWR less than

1.1 over a very large bandwidth. The another thing is because of this matching, there is a no you can say h diffraction, and because of that also the gain is relatively better all these h diffractions do not cause too much of the phase error problem.

So, let see the results here. So, here the results are shown here, you can see there are 3 different curves and gain is shown over here versus frequency. You can see frequency varies from 2 to 11 gigahertz. So, let see the result without this aperture first. So, here is the result which is without the aperture, you can see that the gain is relatively small then this is the configuration where aperture has been added, so by adding this aperture you can see that the gain has improved. At certain point you can see that corresponding to let say this here value which is 4 gigahertz, if this is about say 4 point something.

Correspondingly this point is close to 7; you can almost see 2 and half to 3 dB improvement in the gain and then of course, at this point improvement is not much. Now this has been compared with the horn antenna of dimension, instead of 29 mm very large which is about 140 mm. Now 140 mm if you see for that gain starts at a higher value, but after that the gain remains kind of saturated even it is falling down. The reason for this 2 fall down here because of the large phase error. So, if you just look at this performance here, performance of 140 and 29 they are almost same where as the size if you see approximately 32140 that is more than 4 times the size, and gain is not even more. So, you can see that there what large phase error can create problems to the gain. So, by using this compact antenna, one can actually realize fairly decent gain plot and very good impedance matching.

So, with that I would like to conclude the chapter on horn antenna of course, there are lot of other things are available on horn antenna, there are books written on horn antenna, but for a course like this I think our idea is to give you the idea about various types of horn antenna, and the most important thing I want you to remember that in general try to keep the phase error small, so that you can improve the efficiency, and the same time do not go over board also. As we saw that if you keep on increasing the aperture length significantly, the efficiency remained constant error 80 percent. So, follow the guidelines which we have presented in our parametric study and other thing, and hopefully you design your next horn antenna without much difficulty.

So, with that thank you very much and in the next lecture we will talk about new topic, new types of antennas till than enjoy yourself and have a good time bye.