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Simulation Results of Circular Horn Antenna

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Abstract - *Horn antenna is very important part of antenna microwave antenna family. It works as very efficient feed antenna for some of most widely used microwave antennas, parabolic reflector antenna and lens antenna. Horn antenna is used as feed antenna in both front feed and Cassegrain feed. In this paper we are simulating circular horn antenna. We will be focusing on simulating conical/ circular horn antenna and elliptical horn antenna.*

Key Words: **Horn antenna, sectorial horn, pyramidal horn, conical horn, circular horn, elliptical horn.**

1. INTRODUCTION

A horn antenna can be realized as an opened out or flared out waveguide. An opened out waveguide is capable of radiating radiations into free space provided that waveguide is excited at one side and flared at other side. Though radiation will be much less in case of two wire transmission line compared to waveguide. In waveguide a small portion of the incident wave is radiated and the larger portion is reflected back by the open circuit. The open circuit is discontinuity which matches the waveguide to free space very poorly. Besides, diffraction around the edges will provide a poor, and a non-directional radiation pattern. Hence in order to overcome these difficulties, the one end of the waveguide is flared out in a way that it takes the shape of electro-magnetic horn, just like an opened out transmission line which gives a dipole. If the waveguide is terminated by horn antenna, the gradual transformation takes place of abrupt discontinuity, which radiates the energy incident in forward direction, under the condition that, there is impedance matching between horn antenna and free space. This increases directivity and decreases diffraction.

1.1 Types of Horn Antenna

Figure 1 shows classification of horn antennas. It is broadly divided in two categories rectangular horn antenna and circular horn antenna. Feeding mechanism for rectangular horn antennas is rectangular waveguide while for circular horn antenna its circular waveguide.

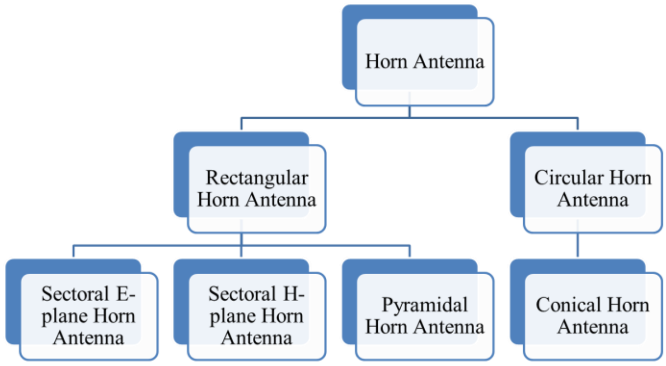

Fig-1: Classification of Horn Antenna

Rectangular horn antennas are further classified depending upon the direction of flaring as sectoral and pyramidal horn. Sectorial horn is formed if flaring is only in one directional. If this flaring is in the direction of electrical vector it is called sectoral E-plane horn antenna and if the flaring is in the direction of magnetic vector then it called sectoral H-plane horn antenna. If flaring is done in electrical as well as magnetic vector of rectangular waveguide, then we get pyramidal horn antenna. Conical horn antenna is formed by flaring of circular waveguide. All four types of horn antennas are shown in figure 2.

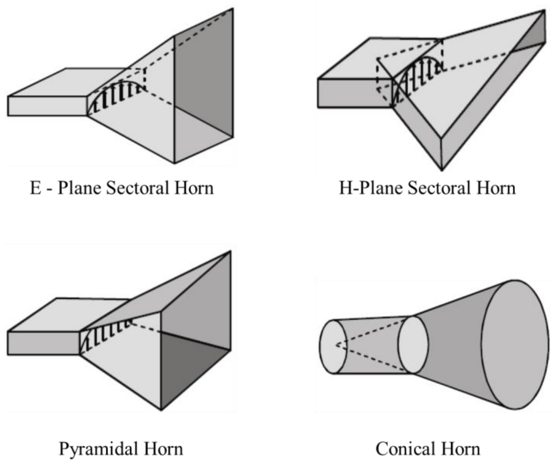

Fig-2: Types of Horn Antenna

Horn antenna may be treated as transition region where guided wave becomes free space wave or finite wavefront wave starts becoming infinite wavefront wave. As impedance of waveguide & impedance free space are not matching, hence flaring of waveguide walls is done to avoid SWR. Other than increasing impedance of waveguide flaring also concentrates radiation in a particular direction, as a result horn antennas are highly directive and has narrower beam-width.

1.2 Design Equation of Horn Antenna

The function of the electromagnetic horn is to produce a uniform phase front with a large aperture in comparison to waveguide and thus the directivity is greater. Although the principle of equality of path length is applicable to horn design but in different sense i.e. instead of specifying that the wave over the plane of the horn mouth is in phase exactly, we allow that phase may deviate but an amount less the specified amount. From the geometry of the figure 3, we can write

$$cos\theta = \frac{L}{L+\delta}$$

and

$$tan\theta = \frac{h/2}{L} = \frac{h}{2L}$$

$$\theta = cos^{-1}\left(\frac{L}{L+\delta}\right) = tan^{-1}\left(\frac{h}{2L}\right)$$

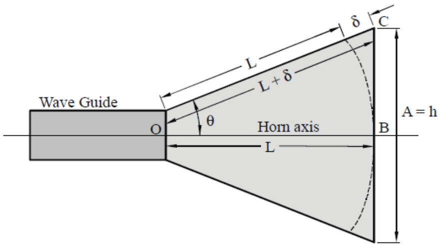

Fig- 3: Horn Antenna path difference

Where δ is permissible phase angle variation expressed as fraction of 360°. From triangle OBC (using Pythagorean Theorem)

$$(L+\delta)^2 = L^2 + \left(\frac{h}{2}\right)^2$$

$$L^2 + \delta^2 + 2L\delta = L^2 + \frac{h^2}{4}$$

If δ is small, then δ^2 can be neglected, after solving

$$L = \frac{h^2}{8\delta}$$

Above equations are the design equations of horn antenna. The wave front at the mouth of horn will be curved instead of plane if flare angle (2θ) is very large. The Non-uniform phase distribution over the aperture of horn results decreased directivity and increased beamwidth, similarly very small flare angle results in small aperture area for specified length L. For a given aperture distribution, the directivity is proportional to the aperture size. The maximum directivity is achieved at the largest flare angle for which does not exceed a specified value. Typical values of flare angle are 0.25, 0.32, and 0.42 for plane horn antenna, conical horn, and H-plane horn antenna respectively. Directivity with pyramidal or conical horn antenna increases as they have more than one flaring angle. Although derivation of exact relation for beamwidth of horn antenna is possible yet approximate formula for the half power beamwidth of optimum flare horn are given by

$$\theta_E = \frac{56\lambda}{h}\ degrees$$

$$\theta_H = \frac{67\lambda}{w}\ degrees$$

where θ_E & θ_H are Half Power Beamwidth (HPBW) in E and H direction.

Directivity is given by

$$D = \frac{7.5hw}{\lambda^2} = \frac{7.5A}{\lambda^2}$$

where A = h × w = horn mouth opening area

Power gain can be given by

$$G_P = \frac{4.5hw}{\lambda^2} = \frac{4.5A}{\lambda^2}$$

1.3 Applications of Horn Antenna

1. If power gain needed is moderate, horn antenna can be used microwave frequencies
2. For high power gain, since the horn dimensions becomes larger, so the other antennas like lens or parabolic reflector etc. are preferred rather than horns
3. It is used as feed antenna for paraboloid reflector at microwave frequency range
4. Used for astronomical studies

2. Simulation Results

In this paper we have simulated following horn antennas

1. Circular/ Conical Horn Antenna
2. Elliptical Horn Antenna

For above simulation of Horn antennas have been simulated on HFSS.

2.1 Circular/ Conical Horn Antenna

We have designed the conical horn antenna with the dimensions shown in figure 4. Figure 5, shows field distribution on inner surface of conical horn antenna. Figure 6 shows return losses conical horn antenna and resonance frequency is 10.95 GHz. Figure 7 and 8 shows the 3D radiation pattern of right hand circularly polarized and left hand circularly polarized conical horn antenna respectively. Figure 9 and 10 shows the 2D radiation pattern of right hand circularly polarized and left hand circularly polarized conical horn antenna respectively.

Following are the calculated parameters after simulations:

Table-1: Parameters after simulations for conical horn antenna

Quantity	Value
Max U	7.752706 W/sr
Peak Directivity	47.652766
Peak Gain	48.749475
Peak Realized Gain	48.712835
Radiated Power	2.044491 W
Accepted Power	1.998497 W
Incident Power	2.000000 W
Radiation Efficiency	1.023015
Front to Back Ratio	112.788172
	E_r Field
	Value(Theta, Phi)
Total	76.456132 V(0deg,120deg)
X	54.155282 V(0deg,170deg)
Y	53.969858 V(0deg,165deg)
Z	7.893246 V(-14deg,125deg)
Phi	54.157853 V(0deg,95deg)
Theta	54.157853 V(0deg,5deg)
LHCP	76.456013 V(0deg,145deg)
RHCP	9.686929 V(24deg,5deg)

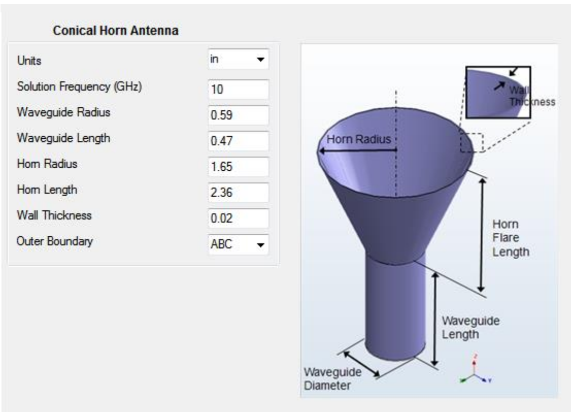

Fig-4: Circular/Conical Horn Antenna - Antenna design and its parameter

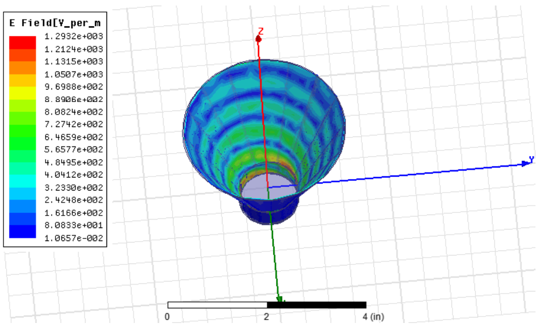

Fig-5: Circular/ Conical Horn Antenna – field distribution

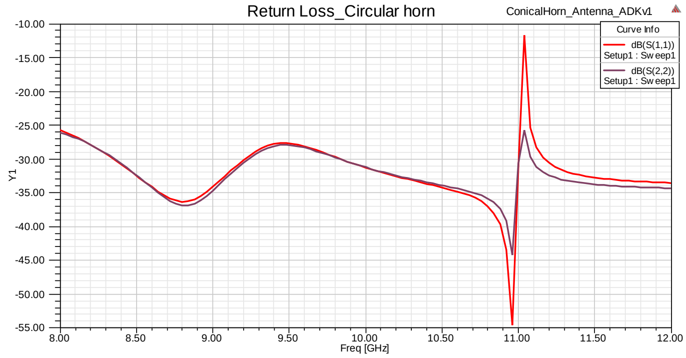

Fig – 6: Circular/ Conical Horn Antenna – Return Loss

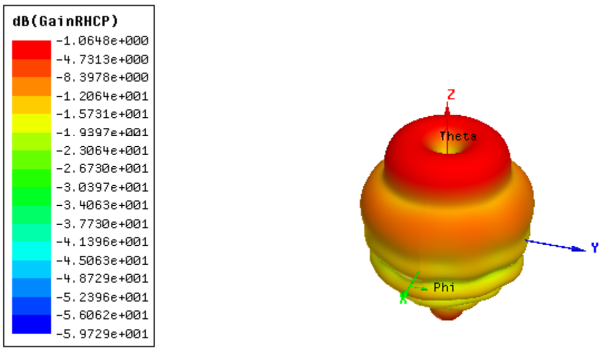

Fig-7: RHCP Circular/ Conical Horn Antenna – 3D Radiation Pattern

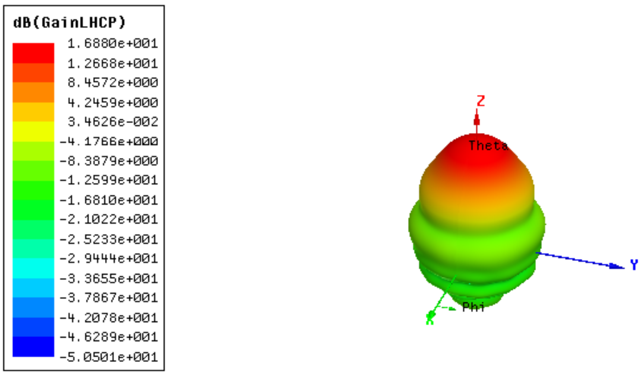

Fig 8: LHCP Circular/ Conical Horn Antenna – 3D Radiation Pattern

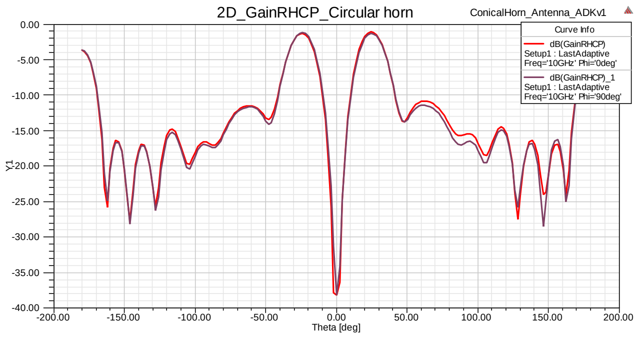

Fig-9: RHCP Circular/ Conical Horn Antenna – 2D Radiation Pattern

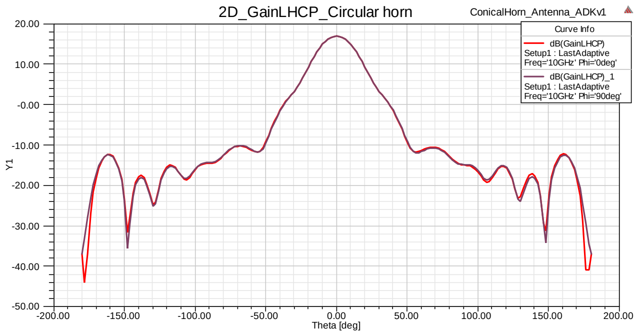

Fig-10: LHCP Circular/ Conical Horn Antenna – 2D Radiation Pattern

2.2 Elliptical Horn Antenna

We have designed the conical horn antenna with the dimensions shown in figure 11. Figure 12, shows field distribution on inner surface of conical horn antenna. Figure 13 shows return losses conical horn antenna and resonance frequency is 9.05 GHz. Figure 14 shows the 3D radiation pattern of right hand circularly polarized in respectively. Figure 15 and 16 shows the 2D radiation pattern of right hand circularly polarized and left hand circularly polarized conical horn antenna respectively.

Following are the calculated parameters after simulations:

Table 2 Parameters after simulations for Elliptical horn antenna

Quantity	Value
Max U	4.991389 W/sr
Peak Directivity	30.765393
Peak Gain	31.388849
Peak Realized Gain	31.362559
Radiated Power	2.038821 W
Accepted Power	1.998325 W
Incident Power	2.000000 W
Radiation Efficiency	1.020265
Front to Back Ratio	314.905901
	E_r Field
	Value(Theta, Phi)
Total	61.347429 V(0deg,90deg)
X	42.588376 V(0deg,180deg)
Y	44.155830 V(0deg,105deg)
Z	11.907139 V(-22deg,75deg)
Phi	55.695684 V(0deg,135deg)
Theta	55.695684 V(0deg,45deg)
LHCP	57.555280 V(0deg,105deSg)
RHCP	21.234332 V(0deg,75deg)

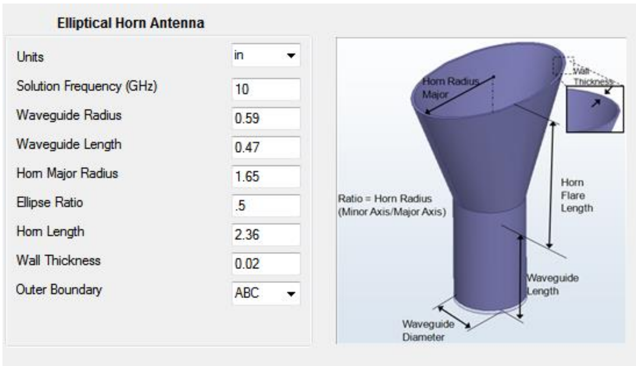

Fig-11: Elliptical Horn Antenna - Antenna design and its parameter

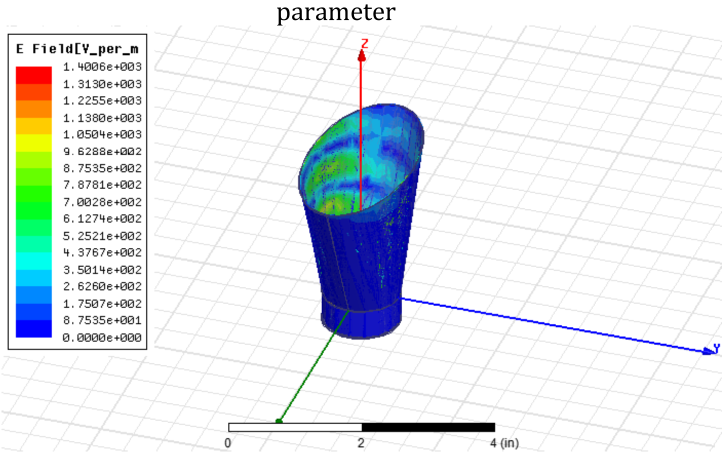

Fig-12: Elliptical Horn Antenna – field distribution

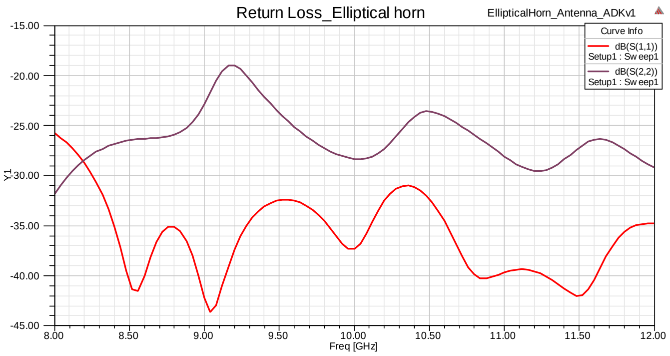

Fig-13: Elliptical Horn Antenna – Return Loss

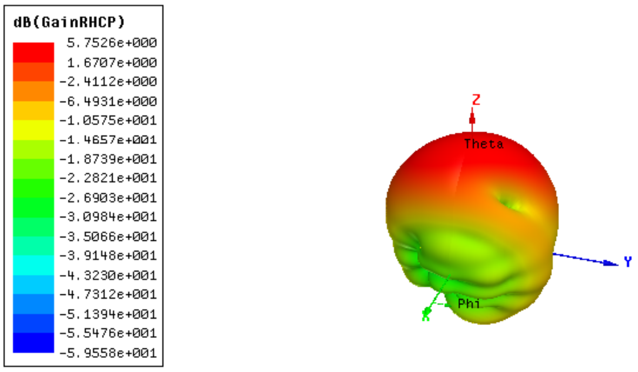

Fig-14: RHCP Elliptical Horn Antenna – 3D Radiation Pattern

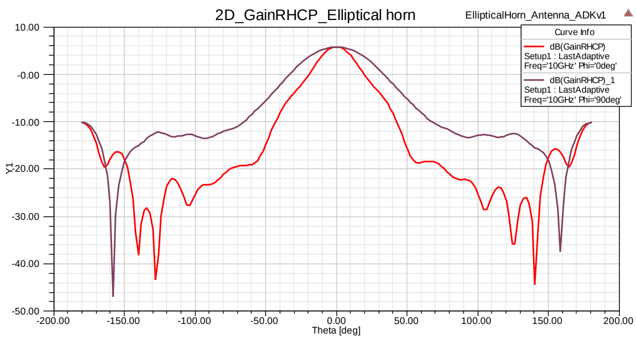

Fig-15 RHCP Elliptical Horn Antenna – 2D Radiation Pattern

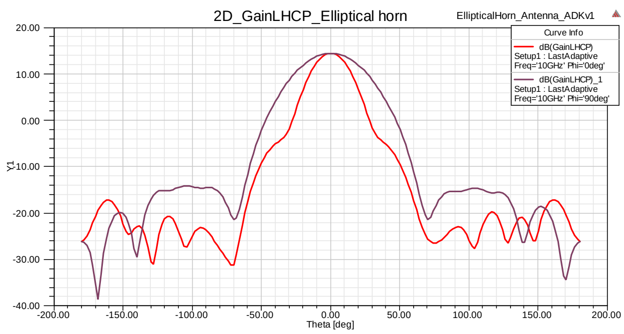

Fig-16 LHCP Elliptical Horn Antenna – 2D Radiation Pattern

3. Conclusion

The results of simulation are quite similar to what we have studied in theory of Antenna. The simulation gives great deal of understanding. By varying size of horn opening we can very gain, bandwidth and resonance frequency of antenna.

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