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SIMULATION RESULTS OF RECTANGULAR 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 rectangular horn antenna. We will be simulating basic sectorial and pyramidal antenna.

KeyWords: Horn Antenna, Sectorial Horn, Pyramidal Horn, Conical Horn, Circular Horn& Elliptical Horn

Introduction:

A horn antenna can be realized as an opened out or flared out waveguide. Anopened out waveguide is capable of radiating radiations into free space provided thatwaveguide 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.

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.

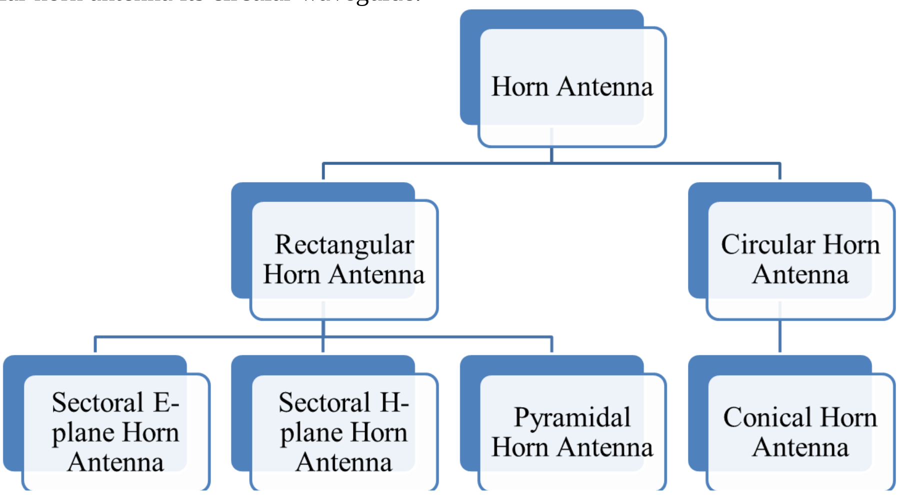

Figure 1: Classification of Horn Antenna

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.

Horn antenna may be treated as transition region where guided wave becomes free space wave or finite wave front wave starts becoming infinite wave front 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.

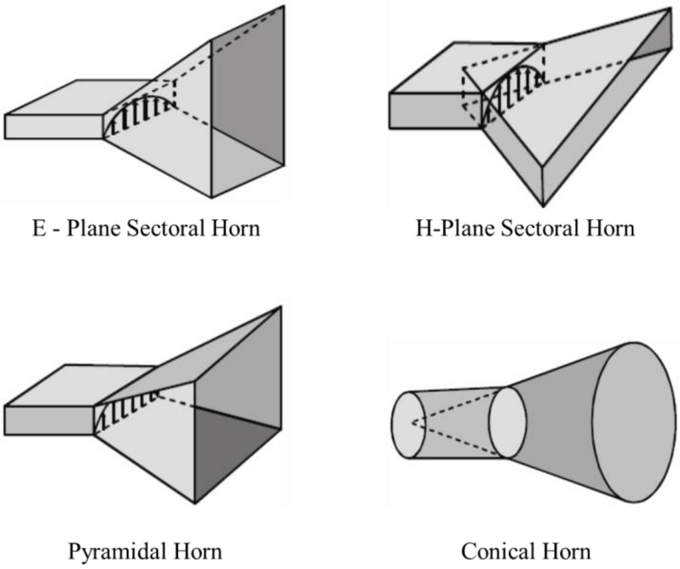

Figure 2: Types of Horn Antenna

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

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

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

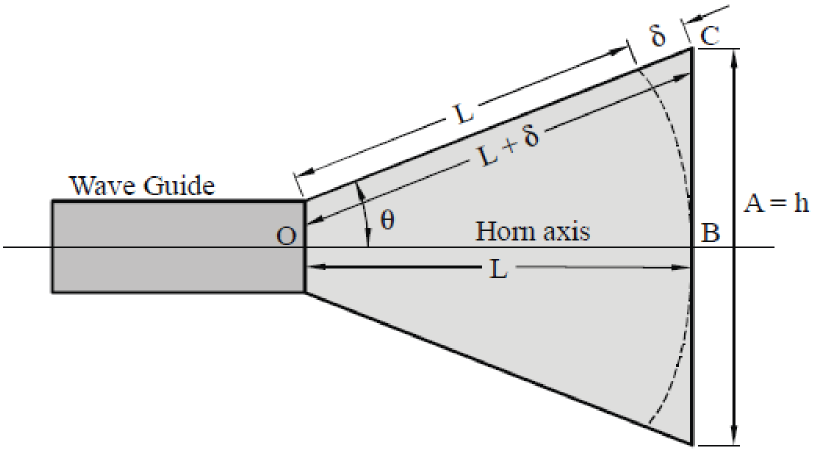

Figure 3: Horn Antenna path difference

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 δis 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 resultsdecreased directivity and increased beam width, similarly very small flare angle results in small aperture area for specified lengthL.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 exceeda specified value. Typical values of flare angle are 0.25, 0.32, and 0.42 for plane horn antenna, conicalhorn, and H-plane horn antenna respectively.Directivity with pyramidal or conical horn antenna increases as they have more than oneflaring angle. Although derivation of exact relation for beam width of horn antenna is possibleyet approximate formula for the half power beam width 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 Beam width (HPBW) in E and H direction.
Directivity is given by

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

Where$A = h \times w$ = horn mouth opening area
Power gain can be given by

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

Applications of Horn Antenna:

- ✓ If power gain needed is moderate, horn antennacan be used microwave frequencies
- ✓ 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
- ✓ It is used as feed antenna for paraboloid reflector at microwave frequency range
- ✓ Used for astronomical studies

Simulation Results:

In this paper we have simulated following horn antennas

- ✓ E-plane Sectorial Horn Antenna
- ✓ Pyramidal Horn Antenna
- ✓ Circular/ Conical Horn Antenna
- ✓ Elliptical Horn Antenna

For above four types of Horn antennas have been simulated in HFSS.

E-Plane Sectorial Horn Antenna:

We have designed the E-plane sectorial horn antenna with the dimensions shown in figure 4. Figure 5 and 6 shows electric and magnetic field distribution lines respectively. Figure 7 shows return losses E-plane sectorial horn antenna and resonance frequency is 10.75 GHz. Figure 8 and 9 shows the radiation pattern of E-plane sectorial antenna in 3D and 2D respectively. Following are the calculated parameters after simulations:

Table 1: Parameters after simulations for E-plane sectorial horn antenna

Quantity	Value
Max U	0.910287 W/sr
Peak Directivity	11.27585
Peak Gain	11.489449
Peak Realized Gain	11.43927
Radiated Power	1.014493 W
Accepted Power	0.995633 W
Incident Power	1.000000 W
Radiation Efficiency	1.018943
Front to Back Ratio	88.707987
	E_r Field
	Value(Theta, Phi)
Total	26.198400 V(0deg,170deg)
X	4.031466 V(140deg,130deg)
Y	26.198254 V(0deg,170deg)
Z	6.671578 V(-34deg,45deg)
Phi	26.198254 V(0deg,0deg)
Theta	26.198254 V(0deg,90deg)
LHCP	18.463649 V(0deg,90deg)
RHCP	18.586281 V(0deg,170deg)

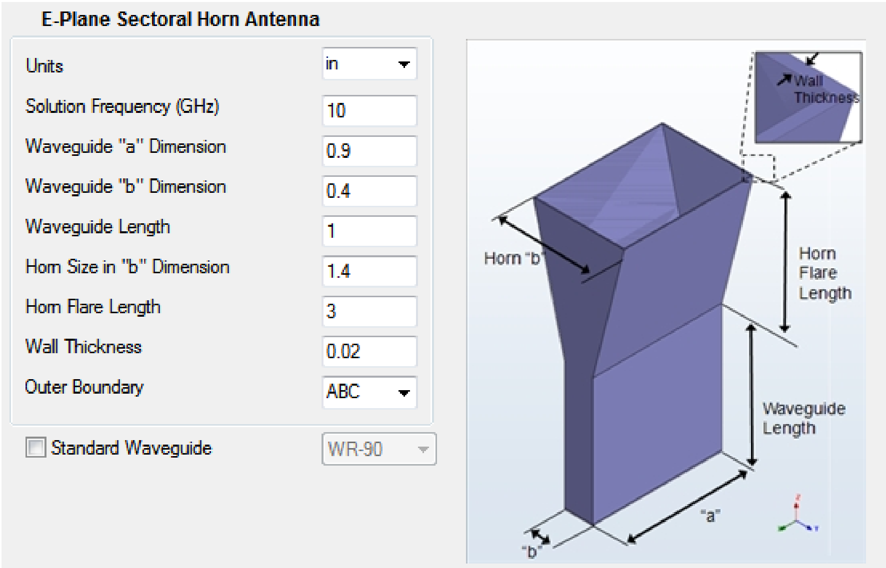

Figure 4: E-plane Horn Antenna - Antenna design and its parameter

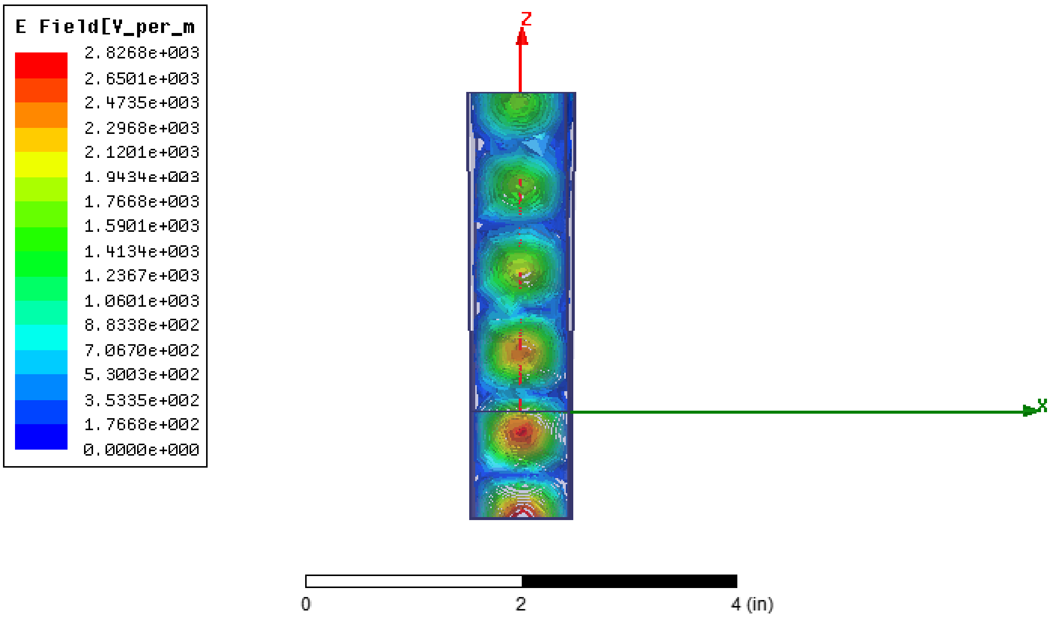

Figure 5: E-plane Horn Antenna – field distribution

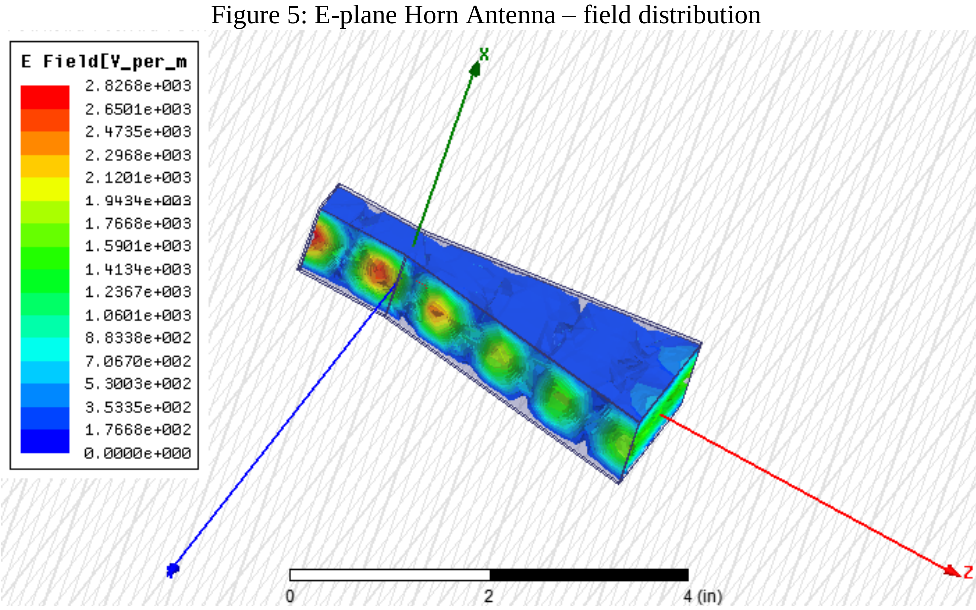

Figure 6: E-plane Horn Antenna – field distribution

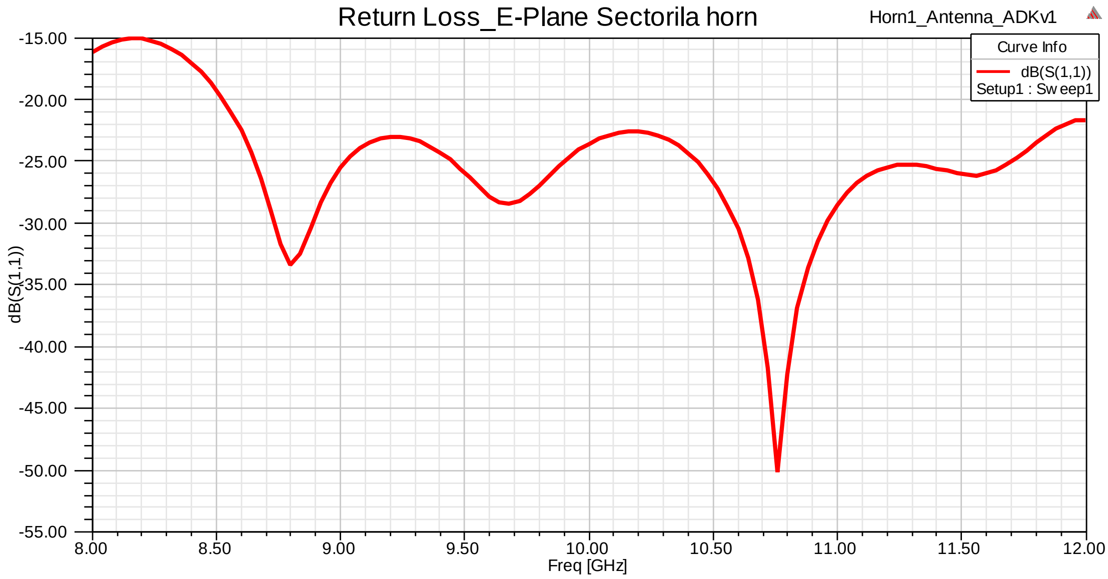

Figure 7: E-plane Horn Antenna – Return Loss

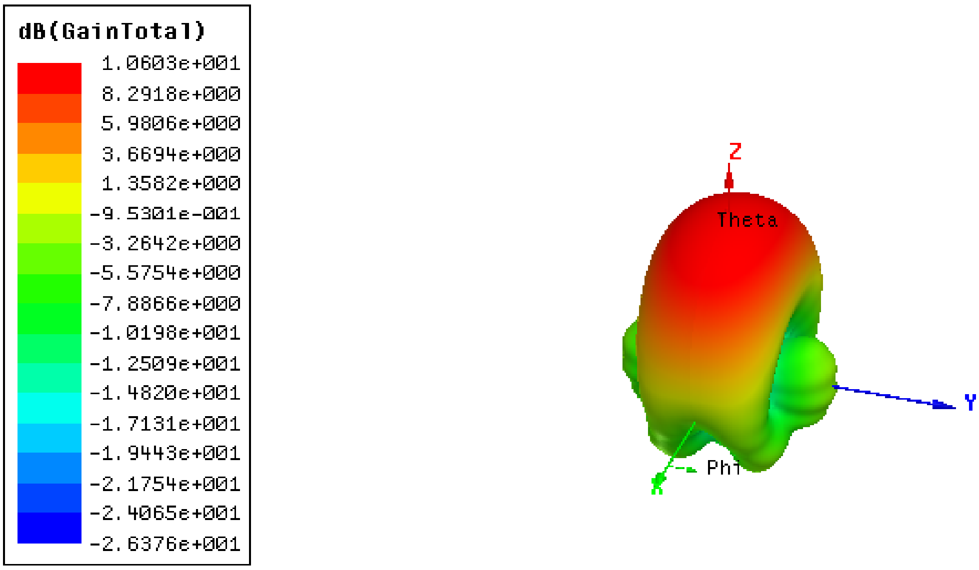

Figure 8: E-plane Horn Antenna – 3D Radiation Pattern

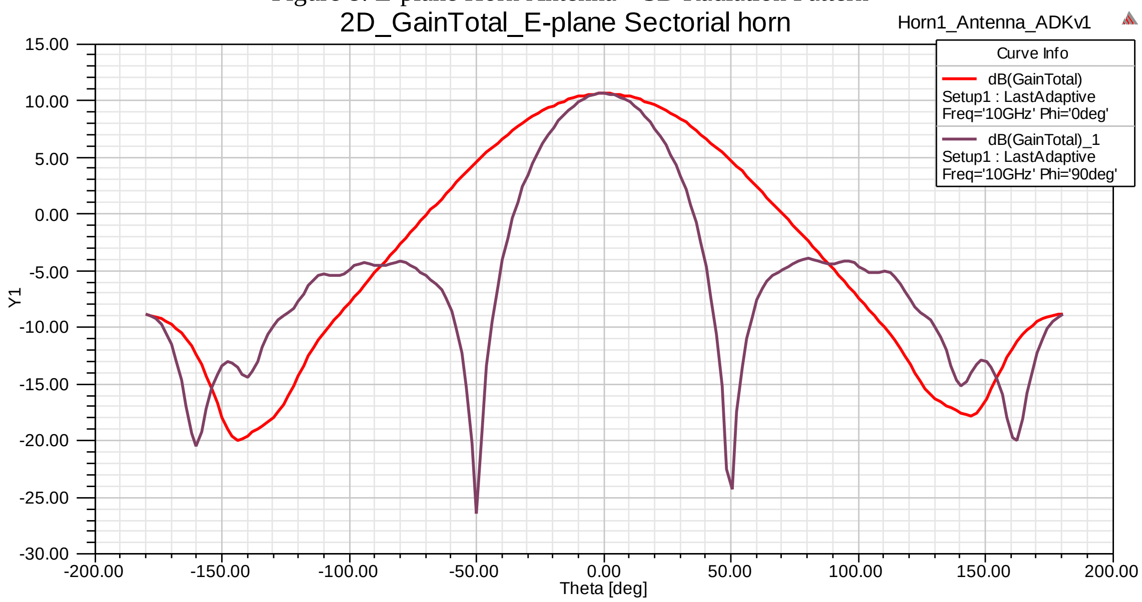

Figure 9: E-plane Horn Antenna – 2D Radiation Pattern

Pyramidal Horn Antenna:

We have designed the pyramidal horn antenna with the dimensions shown in figure 10. Figure 11, 12 and 13 shows field distribution on outer surface, and inner surfaces of pyramidal horn antenna respectively. Figure 14 shows return losses pyramidal horn antenna and resonance frequency is 9.90 GHz. Figure 15 and 16 shows the radiation pattern in 3D and 2D respectively. Following are the calculated parameters after simulations:

Table 2: Parameters after simulations for Pyramidal horn antenna

Quantity	Value
Max U	1.573699 W/sr
Peak Directivity	19.407033
Peak Gain	19.782776
Peak Realized Gain	19.776149
Radiated Power	1.019020 W
Accepted Power	0.999665 W
Incident Power	1.000000 W
Radiation Efficiency	1.019361
Front to Back Ratio	241.811964
	E_r Field
	Value(Theta, Phi)
Total	34.446610 V(0deg,70deg)
X	1.667285 V(-40deg,130deg)
Y	34.446521 V(0deg,70deg)
Z	9.208537 V(24deg,90deg)
Phi	34.446521 V(0deg,180deg)
Theta	34.446521 V(0deg,90deg)
LHCP	24.372745 V(0deg,130deg)
RHCP	24.342109 V(0deg,45deg)

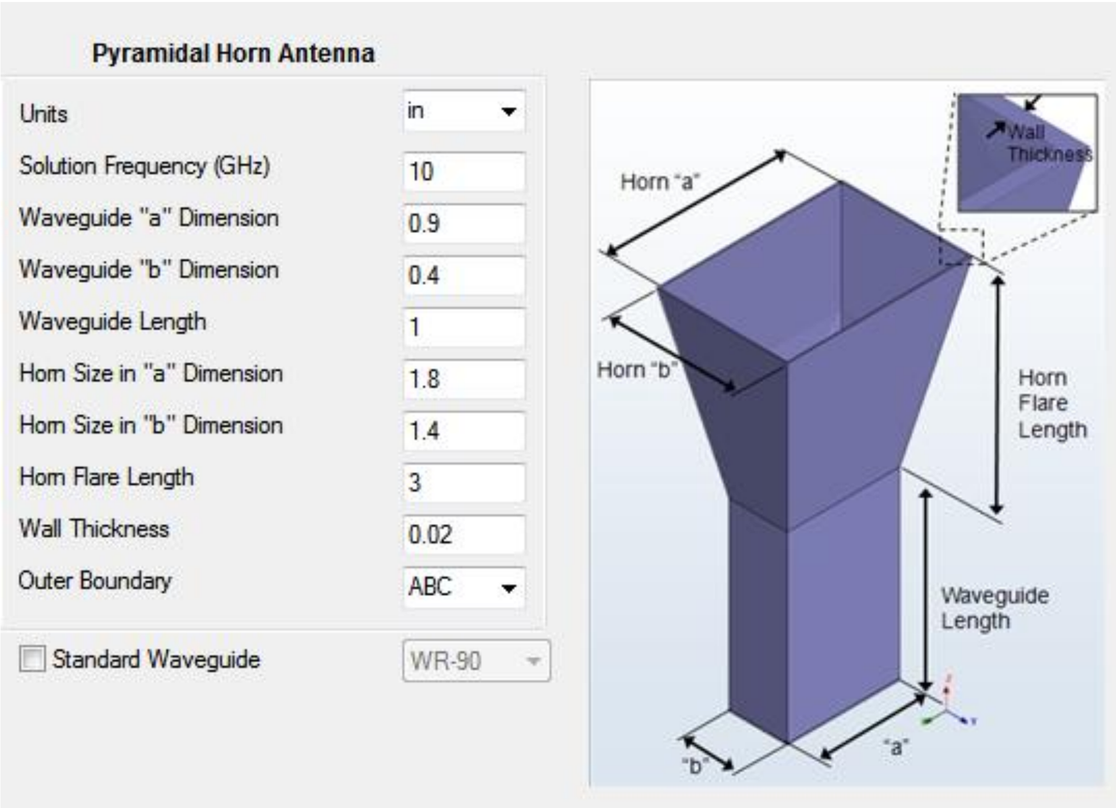

Figure 10: Pyramidal Horn Antenna - Antenna design and its parameter

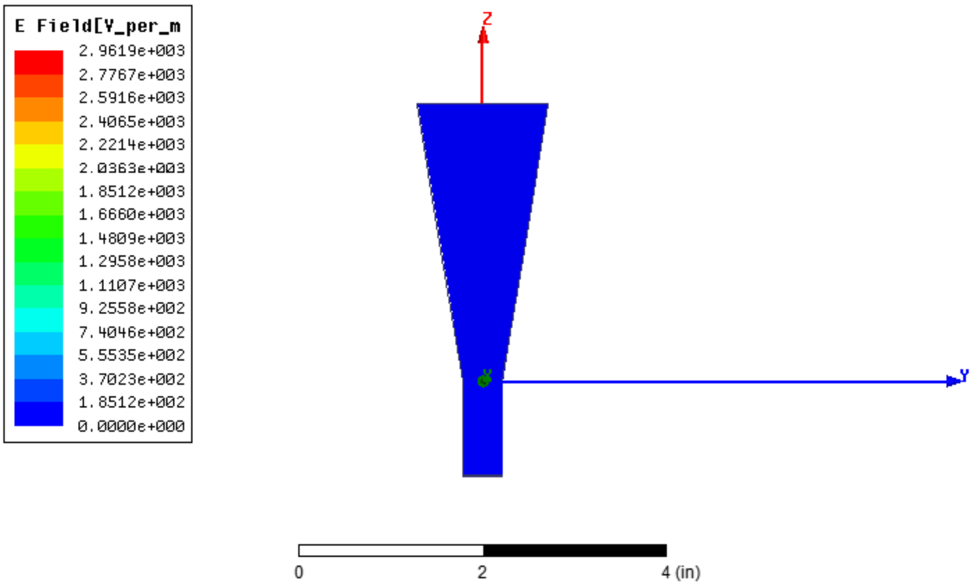

Figure 11: Pyramidal Horn Antenna – field distribution

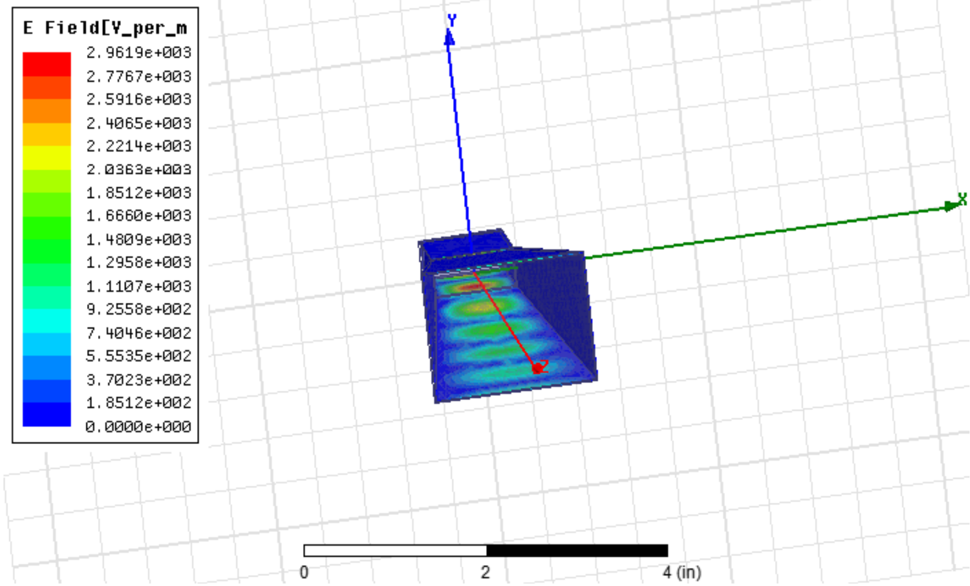

Figure 12: Pyramidal Horn Antenna – field distribution

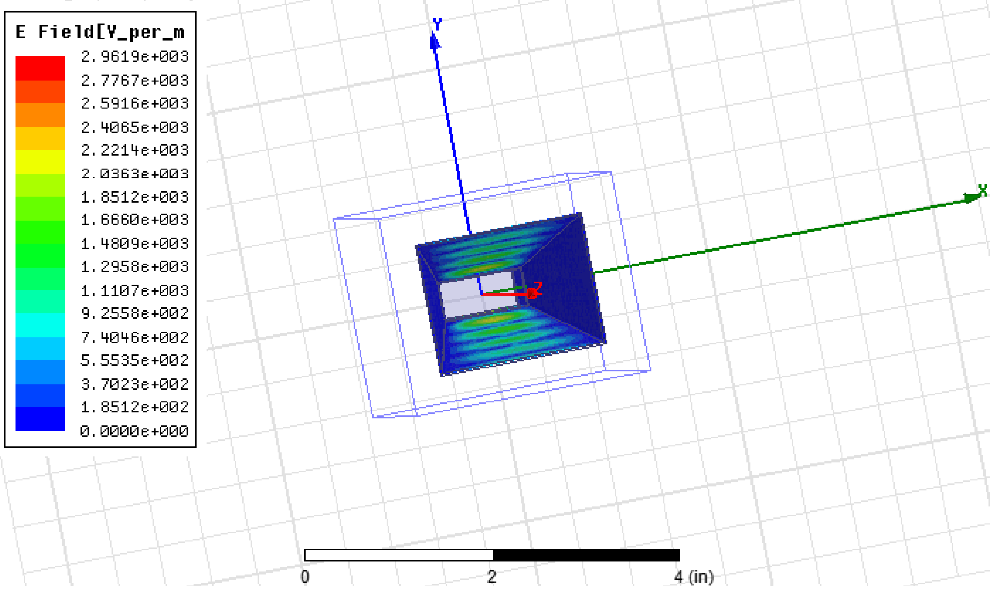

Figure 13: Pyramidal Horn Antenna – field distribution

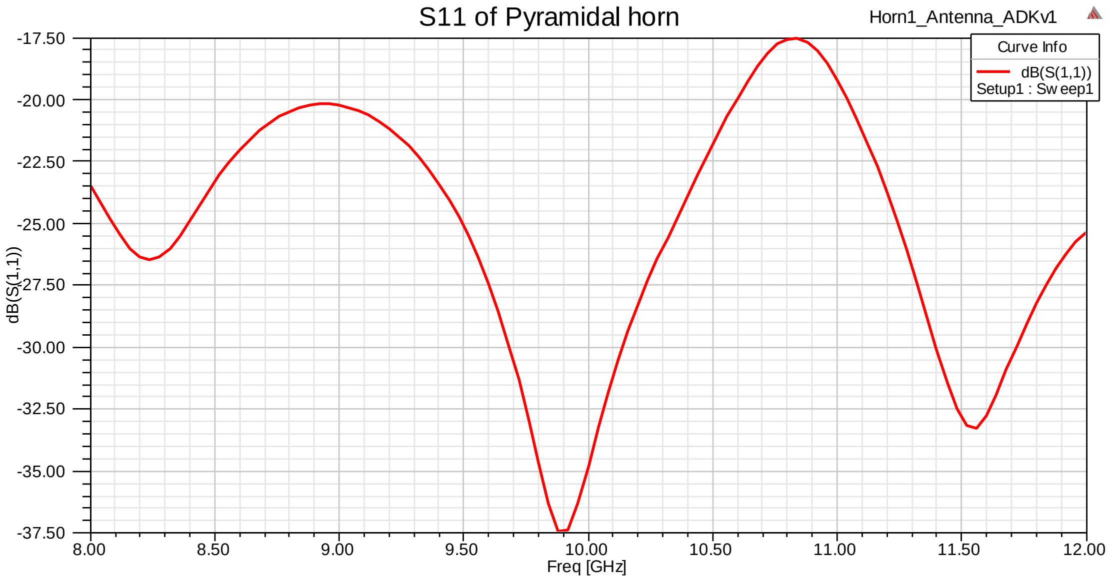

Figure 14: Pyramidal Horn Antenna – Return Loss

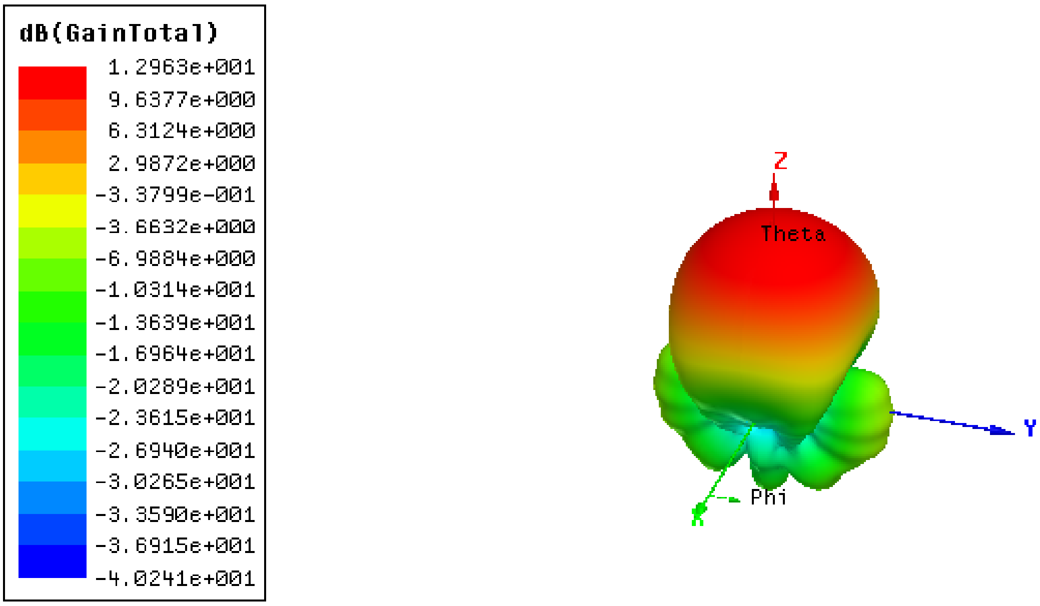

Figure 15: Pyramidal Horn Antenna – 3D Radiation Pattern

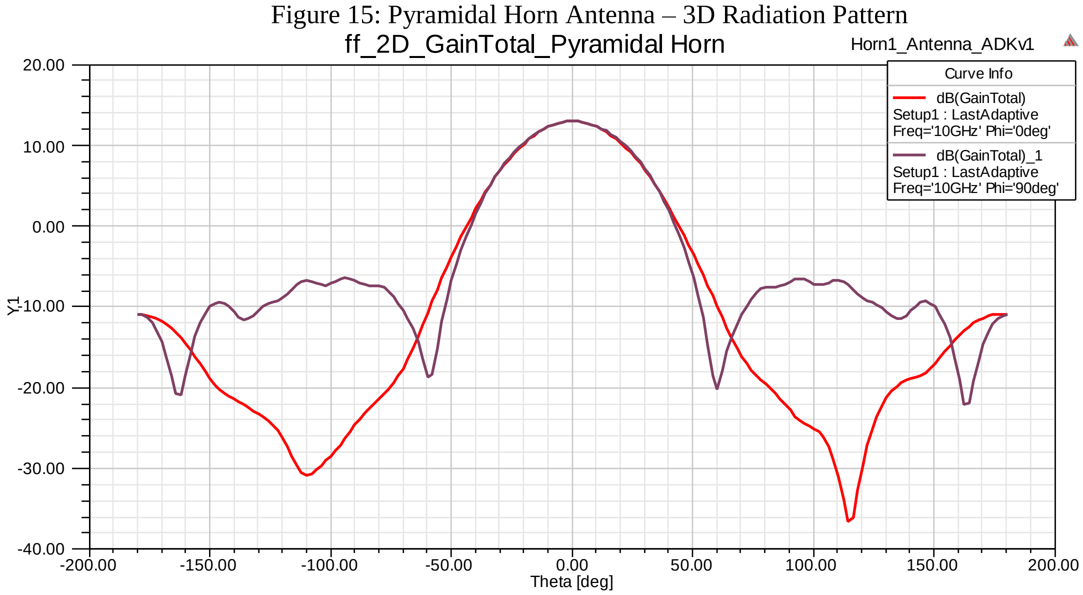

Figure 16: Pyramidal Horn Antenna – 2D Radiation Pattern

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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