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Design and Analysis of Pyramidal Horn Antenna at 8 GHz Frequency

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Abstract **-- This paper discusses the design of a pyramidal horn antenna with high gain, light weight, linearly polarized, suppressed side lobes for may applications. The procedure is straightforward, and determines the physical dimensions of pyramidal horn that determine the performance of the antenna. The length, flare angle, aperture diameter of the pyramidal antenna is examined. These dimensions will determine the required characteristics such as impedance matching, radiation pattern of the antenna. The antenna gives decent gain of about 8.9 dB over operating range while delivering 8 GHz bandwidth. Personal Computer Aided Antenna Design (PCAAD) 6.0 software was used to simulate the design antenna.We describe the antenna structure and present the comparison of simulation results with experimental data.**

Keyword **--Gain, Efficiency, PCAAD 6.0 software, Pyramidal horn design parameter(flare angle, horn antenna) .**

I.INTRODUCTION

A **horn antenna** or **microwave horn** is an antenna that consists of a flaring metal waveguide shaped like a horn to direct radio waves in a beam. Horns are widely used as antennas at UHF and microwave frequencies, above 300 MHz. They are used as feeders (called feed horns) for larger antenna structures such as parabolic antennas, as standard calibration antennas to measure the gain of other antennas, and as directive antennas for such devices as radar guns, automatic door openers, and microwave radiometers. Their advantages are moderate directivity (gain), low standing wave ratio (SWR), broad bandwidth, and simple construction and adjustment.

Horn antennas have been widely used for space applications from the very beginning due to their capability of being best operation from Megahertz to Gigahertz to Terra hertz range. Advantages of horn antenna over other types of antennas are:

(a) High data rate systems needs to be operated at a higher frequency range in order to achieve higher bandwidth. This can be easily achieved using a horn antenna .

(b) Complexity involve in the design of horn antenna is less as compared to phased array antennas & corrugated cousins . **(c)** Feeding a horn antenna is less complex as compared to other antennas which require complex feeding techniques.

(d) If horn antenna is properly designed & optimized than side lobes can be suppressed to very low levels.

(e) Power handling capability of horn antenna is superior to other antennas as it is waveguide fed antenna, especially in the use of TWTs used in satellites, radars and many other applications making it an ideal choice for space applications. Horns have conventionally been used in terrestrial microwave communications. They can also be found on many Line-Of-Site (LOS) microwave relay towers . Horn Antennas are used in remote sensing satellites, communication satellites, geographic information & weather satellite. Various space programs in which horn antennas are

used by NASA, ESA.

II.DESCRIPTION OF PYRAMIDAL HORN ANTENNA

Antennas are one of the most important parts of a communication chain. In Modern times need for wideband applications has increased. The Horn Antenna is widely used in the EMC measurement, radar and communication system. Pyramidal Horn is the best horn as it has equal radiation patterns in both E-plane and H-plane along with its high gain and directivity. So, the need to develop a Wideband horn antenna for communication and calibration purposes. With the development of measurement, communication system, radar techniques and electromagnetic, the horn antenna has been widely used which made it one of the most practical antennas. this horn antenna can effectively extend the working bandwidth of the antenna and improve the impedance matching between waveguide and free space.

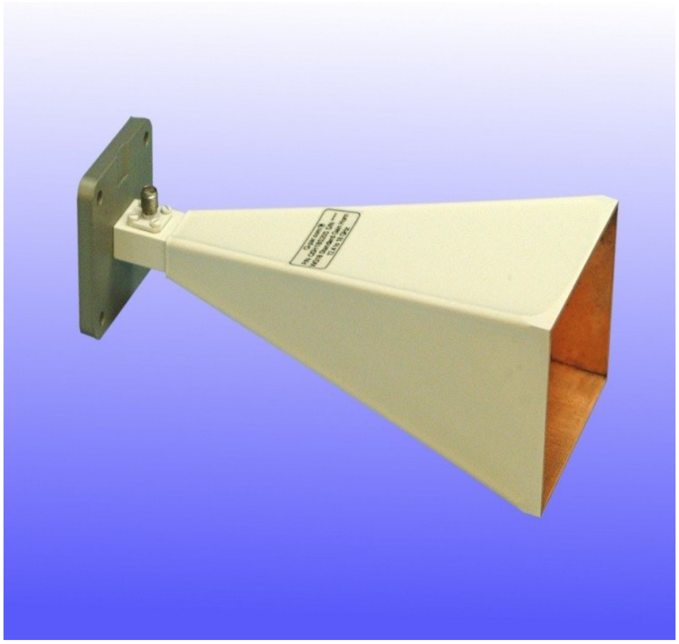

Figure 1: Pyramidal horn antenna

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III. DESIGNING EQUATIONS

The pyramidal horn is probably the most popular antenna in the microwave frequency ranges (from 1 GHz up to 18 GHz). The feeding waveguide is flared in both directions, the E-plane and the H-plane. All results are combinations of the E-plane sectoral horn and the H-plane sectoral horn analyses. The field distribution at the aperture is approximated as

$$E_{a_y} = E_0 \cos\left(\frac{\pi}{A}x\right) e^{-j\frac{\beta}{2}\left(\frac{x^2}{R_0^{E2}}+\frac{y^2}{R_0^{H2}}\right)}.$$

Equ. 1

The E-plane principal pattern of the pyramidal horn is the same as the E-plane principal pattern of the E-plane sectoral horn. The same holds for the H-plane patterns of the pyramidal horn and the H-plane sectoral horn. The directivity of the pyramidal horn can be found by introducing the phase efficiency factors of both planes and the taper efficiency factor of the H-plane:

$$D_P = \frac{4\pi}{\lambda^2}\varepsilon_t \varepsilon_{ph}^E \varepsilon_{ph}^H (AB),$$

Equ. 2

Where:

$$\varepsilon_t = \frac{8}{\pi^2};$$

$$\varepsilon_{ph}^H = \frac{\pi^2}{64t}\left\{\left[C(p_1)-C(p_2)\right]^2+\left[S(p_1)-S(p_2)\right]^2\right\};$$

$$p_1 = 2\sqrt{t}\left[1+\frac{1}{8t}\right],\ \ p_2 = 2\sqrt{t}\left[-1+\frac{1}{8t}\right],\ t=\frac{1}{8}\left(\frac{A}{\lambda}\right)^2\frac{1}{R_0^H/\lambda};$$

$$\varepsilon_{ph}^E = \frac{C^2(q)+S^2(q)}{q^2},\ \ q=\frac{B}{\sqrt{2\lambda R_0^E}}.$$

The gain of a horn is usually very close to its directivity because the radiation efficiency is very good (low losses). The directivity as calculated with the given above equation (1) is very close to measurements. The above expression is a physical optics approximation, and it does not take into account only multiple diffractions, and the diffraction at the edges of the horn arising from reflections from the horn interior. These phenomena, which are unaccounted for, lead to minor fluctuations of the measured results about the prediction of (Equ. 1). That is why horns are often used as gain standards in antenna measurements

OPTIMUM HORN DESIGN

Usually, the optimum (from the point of view of maximum gain) design of a horn is desired because it results in the shortest axial length. The whole design can be actually reduced to the solution of a single fourth-order equation. For a horn to be realizable, the following must be true:

$$R_E = R_H = R_P.$$

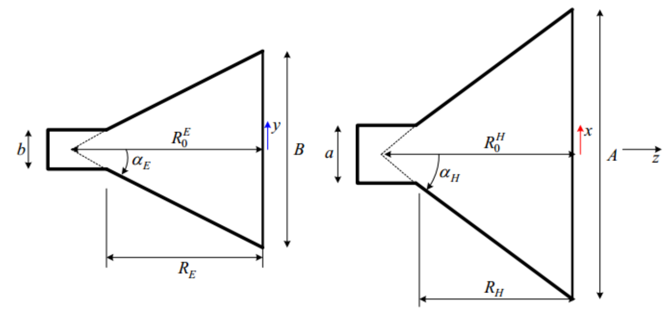

Figure 2

It can be shown that

$$\frac{R_0^H}{R_H} = \frac{A/2}{A/2-a/2} = \frac{A}{A-a},$$

$$\frac{R_0^E}{R_E} = \frac{B/2}{B/2-b/2} = \frac{B}{B-b}.$$

Equ. 2&3

The optimum-gain condition in the E-plane (Equ. 1) is substituted in toEqu. 3

produce

$$B^2 - bB - 2\lambda R_E = 0.$$

Equ. 4

There is only one physically meaningful solution to equ 4

$$B = \frac{1}{2}\left(b+\sqrt{b^2+8\lambda R_E}\right).$$

DIRECTIVITY

The directivity of the E-plane sectorial horn is found in a manner analogous to the H-plane sectorialhorn :

$$D_E = \frac{a}{\lambda}\frac{32}{\pi}\frac{B}{\lambda}\varepsilon_{ph}^E = \frac{4\pi}{\lambda^2}\varepsilon_t \varepsilon_{ph}^E aB,$$

Where

$$\varepsilon_t = \frac{8}{\pi^2},\ \varepsilon_{ph}^E = \frac{C^2(q)+S^2(q)}{q^2},\ \ q=\frac{B}{\sqrt{2\lambda R_0}}.$$

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IV.OBSERVATIONS

Design Parameters of pyramidal horn antenna

The Initial Design Parameters are:

Frequency = 8 GHz

E plane aperture = 1 cm

H plane aperture = 1 cm

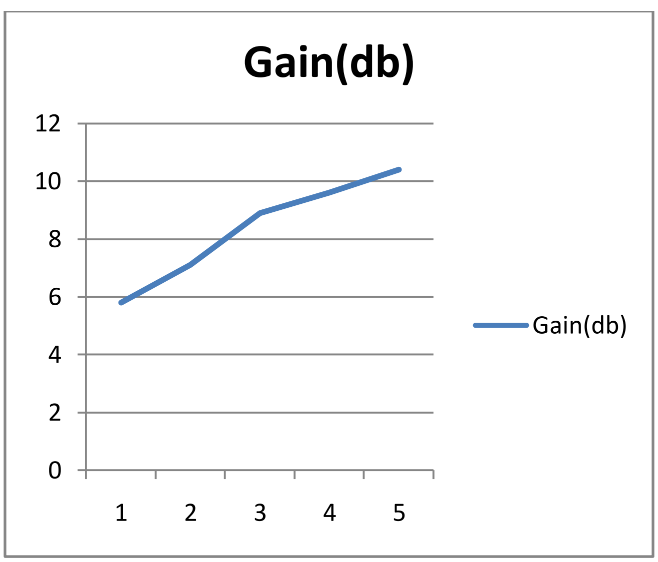
E plane axial length = 3 cm

H plane axial length =3 cm

a) Effect of variation in horn aperture:--When the horn aperture is increasing the gain is also increases as shown in table.1, graph.1.

APERTURE (CM)	DIRECTIVITY
1	5.8
2	7.1
3	8.9
4	9.6
5	10.4

Table. 1

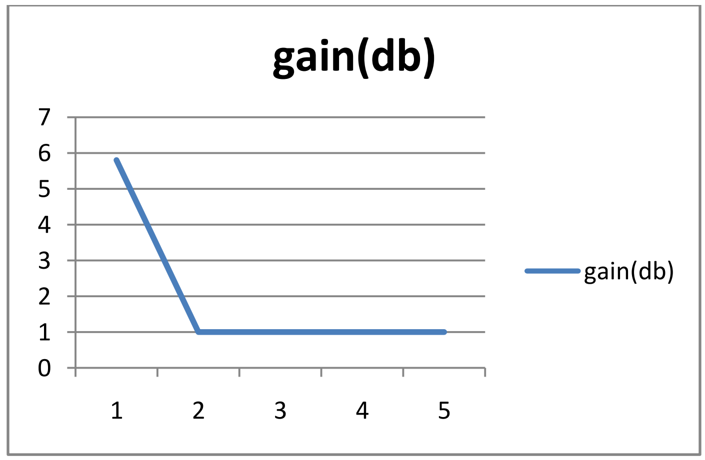


Graph 1

b) Effect of horn length:-- If the horn length is increases then Gain is decreases as shown in table.2 and graph.2.

E&H PLANE HORN LENGTH(CM)	GAIN (DB)
1	5.8
2	1
3	1
4	1
5	1

Table.2



Graph. 2

V. SIMULATION AND RESULT

The radiation pattern in 2-D and 3-D are shown in figure 3 and figure4.

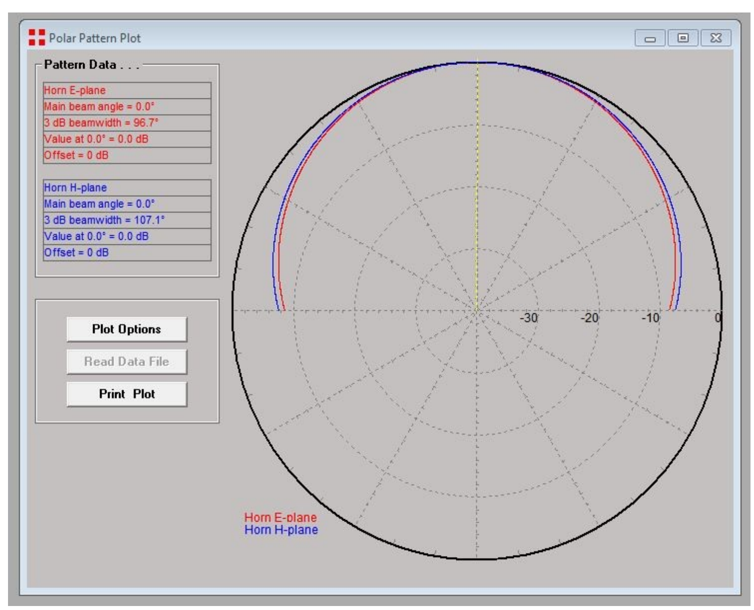


Figure3
2-D Polar Plot Pattern

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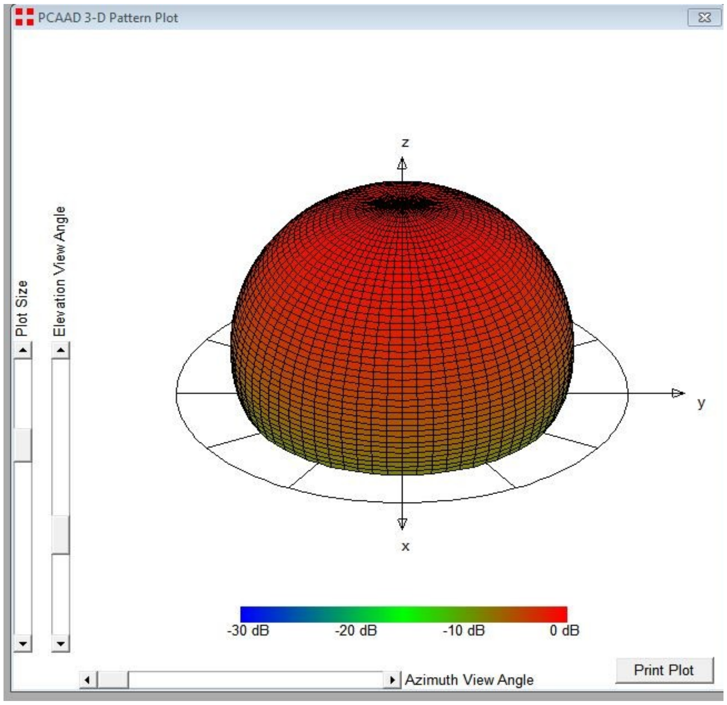

Figure.4

3-D Polar Plot Pattern

c) It can be observed from figure.3 and figure.4 that the radiation pattern of conical horn antenna is bidirectional. Gain increases when the E&H plane aperture increases and the gain decreases & then constant when the E&H plane horn length increases.

VI.CONCLUSION

The analysis of pyramidal horn antenna is studied in this paper. It is observed that on increasing E&H plane the aperture the gain increases and on increasing the E&H plane horn length of the horn gain decreases & then constant.

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