Pyramidal Horn Antenna for S-band Application

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***Abstract*— Horn antenna is used as a feeding element to a parabolic reflector as it provides high directivity, gain, wide bandwidth and a well-matched voltage standing wave ratio. The paper consists design of an efficient Pyramidal horn antenna at the center frequency of 3.14GHz. A Standard-Gain horn antenna designed for S-band applications as the band provides high-quality transmissions even in the worst of a condition using the standard waveguide WR-284 (2.60GHz-3.95GHz). Pyramidal horn antenna is designed with improvisation in parameter result. The designed antenna consists of reduced side and back lobes which intends to high directivity and a significant reduction in cross polarization.**

***Index Terms*— Horn Antenna; Antenna Efficiency; Antenna Measurements; Antenna Gain; Antenna Radiation Pattern**

I. Introduction

One of the first horn antennas was constructed in 1897 by Bengali-Indian radio researcher Jagdish Chandra Bose pioneering experiments with microwaves. [01] [02] The horn antenna designed for its practical application i.e. weather radar, surface ship radar, satellites communication, radio astronomy, GPS, amateur radio. Accurate gain measurements are important for the applications and so the standard gain horn is designed. The antenna is designed for S-band application as similar performance is not economically feasible with comparable Ku or C band as these bands require more power to penetrate in the moist atmosphere say for DTH satellite systems. The function of horn antenna is to produce a uniform phase front with a large aperture than that of the waveguide and hence greater directivity. An antenna designed is simulated in ANSYS HFSS software, which is the industry standard for simulating high-frequency electromagnetic fields. Its gold-standard accuracy, advanced solvers, and high-performance computing technologies make it an essential tool HFSS offers state-of-the-art solver technologies based on the finite element, integral equation, asymptotic and advanced hybrid methods to solve a wide range of microwave, RF, and high-speed digital applications. [03]

II. Design

Design Parameters:

The frequency range over which the system operates is bandwidth. An antenna designed working on center frequency requires defined bandwidth. More specifically considering antenna operating from f_{max} and f_{min}, the bandwidth, in general, is calculated as

$$\%Bandwidth = 200\frac{(f\max - f\min)}{(f\max + f\min)}$$

Using the definition given above, the bandwidth below 40% is generally considered as Narrowband whereas for bandwidth above 40% is considered to be Wideband.Design frequency of the antenna can be summarized as

$$fc = \sqrt{f\max f\min} \quad \text{for narrowband operations}$$
$$fc = 1.2 f\min \quad \text{for wideband operations}$$

Wavelength: The distance over which the wave's shape repeats. A design parameter frequency dependent.

$$\lambda = \frac{c}{f}$$

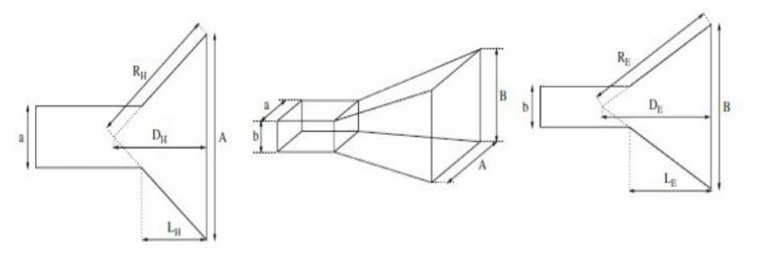

Fig. 1 Pyramidal Horn [04]

The basic geometry of horn antenna is shown in Figure 1. To design a standard gain horn of the desired frequency and gain, it is essential to choose a standard input waveguide dimensions for the frequency band. For that desired frequency and gain with dimensions of a and b obtained from a standard waveguide WR-284 (2.60GHz-3.95GHz), Where WR waveguide system is EIA designated US standards using a WR designator to indicate the size. To obtain the dimensions of a horn that will closely match the requirements follow the below procedure. [05]

$$G_l = 10^{G_{dBi}/10} \quad (1)$$

$$A = 0.096aG_l^{0.232} + 0.42\lambda G_l^{0.503} - 0.193b \qquad (2)$$

$$R_H = A\sqrt{\frac{1}{4} + \left(\frac{A}{3\lambda}\right)^2} \qquad (3)$$

$$L_H = (A - a)\sqrt{\left(\frac{R_H}{A}\right)^2 - \frac{1}{4}} \qquad (4)$$

$$D_H = \sqrt{{R_H}^2 - \left(\frac{A}{2}\right)^2} \qquad (5)$$

$$B = \frac{1}{2}\left[b + \sqrt{b^2 + 8L_H\lambda}\right] \qquad (6)$$

$$R_E = \frac{B}{2}\sqrt{1 + \left(\frac{B}{\lambda}\right)^2} \qquad (7)$$

$$L_E = (B - b)\sqrt{\left(\frac{R_E}{B}\right)^2 - \frac{1}{4}} \qquad (8)$$

$$D_E = \sqrt{{R_E}^2 - \left(\frac{B}{2}\right)^2} \qquad (9)$$

Note that quantities a, b and λ are expressed in meter. [06] Equation (2-5) are of H-field and Equation (6-9) are of E-field direction.
A= Width of the aperture in the H-field direction
L_H= Slant length of the aperture in the H-field direction
R_H= Half subtended angle length in the H-field direction
D_H=Axial length from apex to Center of aperture in H-field direction
B= Width of the aperture in the E-field direction
L_E= Slant length of the aperture in the E-field direction
R_E= Half subtended angle length in the E-field direction
D_E= Axial length from apex to Center of aperture in E-field direction

Design Dimension in HFSS Software

To provide a design for a range of standard waveguide and horn radiators that can be modified further to meet specific needs, we need to design the structure of antenna accordingly using HFSS the designed structure of antenna is simulated with accurate results as the software uses finite element method to solve electromagnetic structures. Designed structure of pyramidal horn antenna using HFSS software is shown in below given figures.

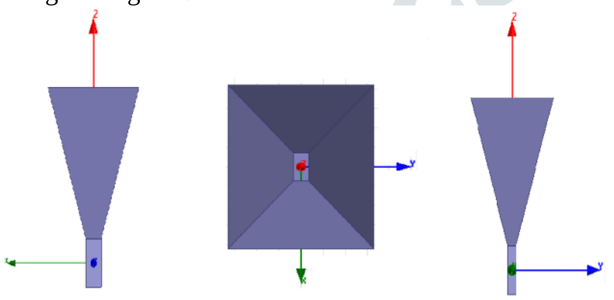

Fig. 2 Designed Pyramidal Horn (HFSS)

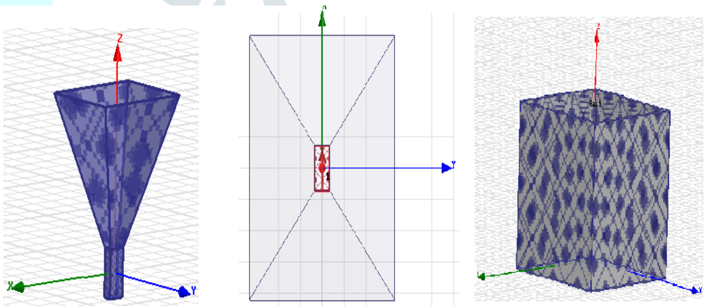

Fig. 3 Assigned Boundaries and Excitation (HFSS)

III. Simulation Result

The Standard-Gain horn antenna designed for S-band application on simulation results in improvised parameter as given below.

1. ***Voltage standing wave ratio***

Standing Wave Ratio also referred as Voltage Standing Wave Ratio is a measure of the impedance matching of the transmission line to an antenna to transmit power. It describes the power reflected from the antenna.

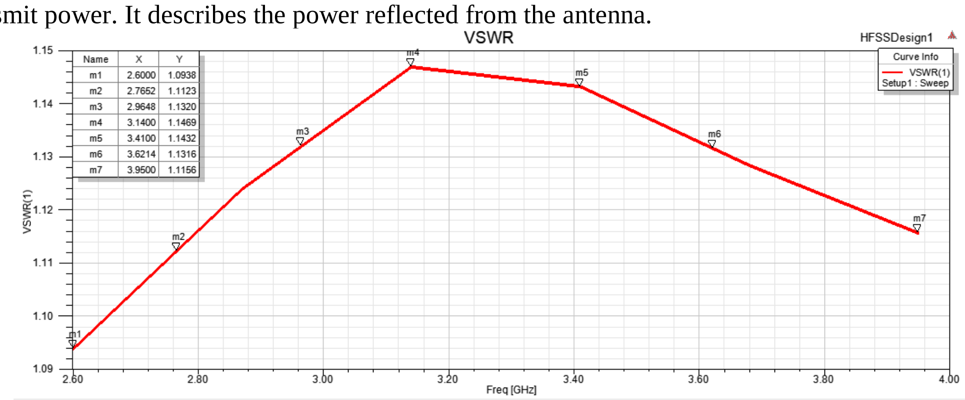

Fig. 4 VSWR

2. *Scattering parameter S_{11}*

S_{11} parameter is the measure of voltage reflection coefficient of input ports.

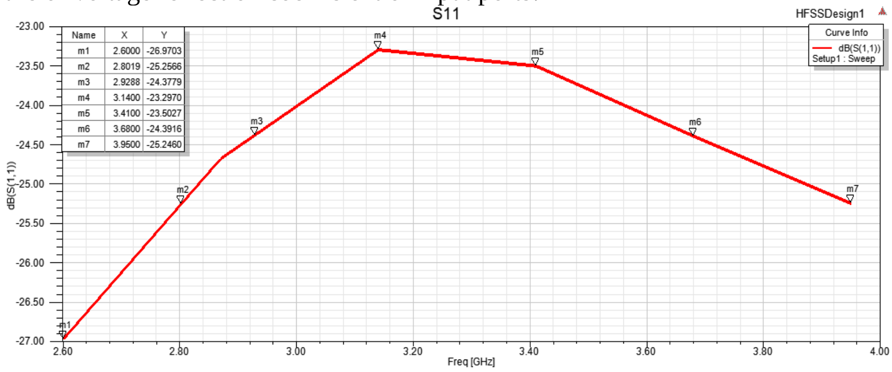

Fig. 5 S_{11} Parameter

3. *Gain*

Gain is an important parameter to determine the performance of the antenna. Gain defines the efficiency of the antenna as well as its directional capabilities.

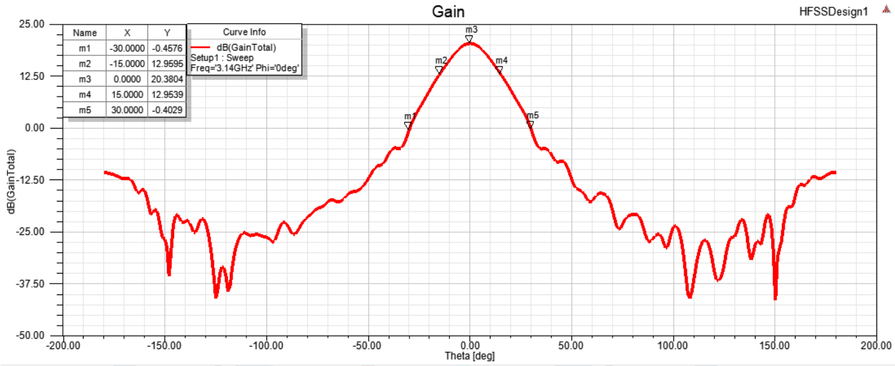

Fig. 6 Gain (G_{dBi})

4. *Cross-polarization*

Cross polarization is the polarization orthogonal to the polarization being discussed.

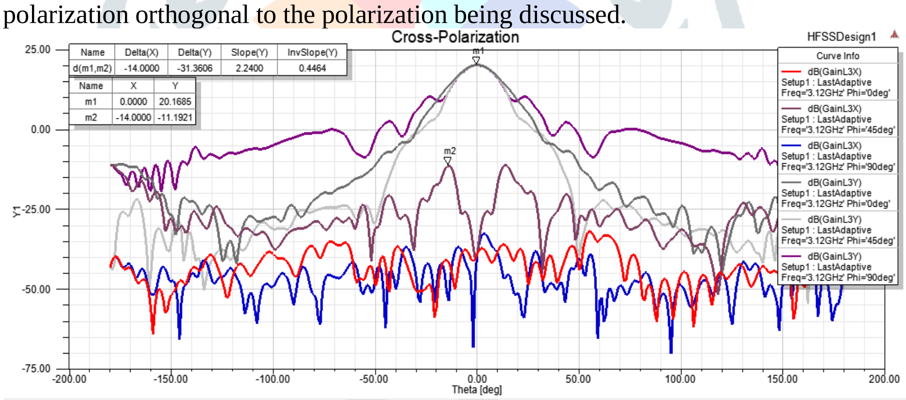

Fig. 7 Cross Polarization

5. *Radiation pattern*

The radiation pattern is a graphical representation of the radiation properties as a function of space coordinates of an antenna. Principal E- and H-plane patterns of a pyramidal horn antenna is shown below.

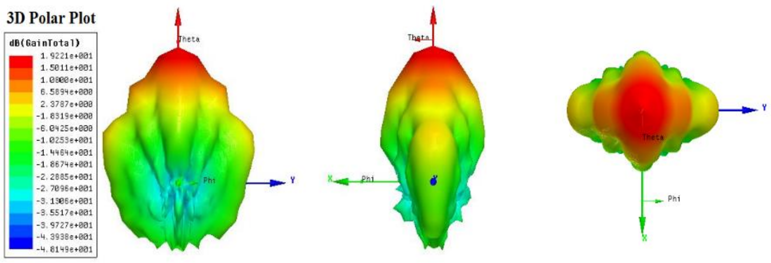

Fig.8 (a) 3D Polar Plot

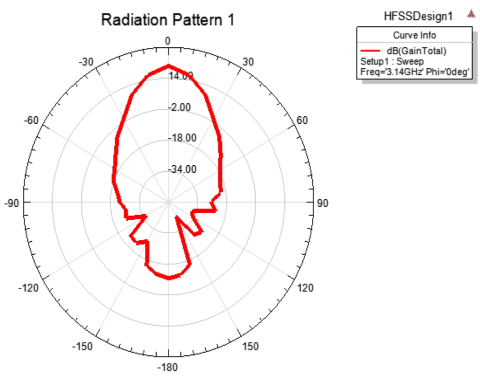

Fig.8 (b) Radiation Pattern

IV. Conclusion

Pyramidal Horn antenna for S-band application results with the improvised parameter. The Standard Gain Horn antenna designed for 20dB gain on simulation, resulted in a good system matched VSWR 1.1903 at 3.14GHz, S11 ranging -24.63dB, shows Cross polarization -31.3606dB and radiation pattern directive consisting of the minor back lobe and side lobe.

V. Acknowledgment

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References

[1] Rodriguez, Vicente. "A brief history of horns." Compliance Magazine (2010).
[2] Emerson, Darrel T. "The work of Jagadis Chandra Bose: 100 years of millimeter-wave research." IEEE transactions on microwave theory and techniques 45.12 (1997): 2267-2273.
[3] Ansys, H. F. S. S. "v15." ANSYS Corporation Software, Pittsburgh, PA, USA (2014).
[4] Modern Antenna handbook by Constantine A. Balanis Copyright. 2008 John Wiley & Sons, Inc. page 101
[5] Title: IEEE Trans Microwave Theory Techn Month: Oct. DOI: 10.1109/TMTT.1956.1125063
[6] Guney, Kerim, and Habib Hancer. "Improved formulas for narrow and wide aperture dimensions of optimum gain pyramidal horn." 13.3 (2003): 239-245. Month: May. DOI: 10.1002/mmce.10081