Design of Horn Antenna Using HFSS

By

Aditya Bhattacharya	13BEC1005
Aks-e-Zehra	13BEC1009
Prithvish Nembhani	13BEC1100
Shraddha Agrawal	13BEC1138
Manan Narula	13BEC1085

A report submitted to the

Dr. Chitra K

SCHOOL OF ELECTRONICS AND COMMUNICATION ENGINEERING

for

ECE306: Antennas and Wave Propagation

B.Tech. ELECTRONICS AND COMMUNICATION ENGINEERING

VIT UNIVERSITY, CHENNAI

Vandalur – Kelambakkam Road

Chennai – 600 127

November 2015

BONAFIDE CERTIFICATE

Certified that this project report entitled **"Design of Horn Antenna Using HFSS"** is a bonafide work of Aditya Bhattacharya(13BEC1005), Aks-e-Zehra(13BEC1009), Prithvish Nembhani(13BEC1100), Shraddha Agrawal(13BEC1138), Manan Narula(13BEC1085)who carried out the Project work under my supervision and guidance.

Dr. Chitra K.

School of Electronics Engineering (SENSE)

VIT University, Chennai

CONTENTS

Chapter: 1
ABSTRACT

Horn antennas are extremely popular in the microwave region. An aperture antenna contains some sort of opening through which electromagnetic waves are transmitted or received. One of the examples of aperture antenna is horns. The analysis of aperture antennas is typically quite different than the analysis of wire antennas.
So in this project, the team decided to simulate a pyramidal horn antenna in HFSS 13, since pyramidal antennas are widely used for communication purpose.

The resonating frequency was fixed at 10GHz and the 3D Polar plot, rectangular plot for impedance of horn antenna, Gain v/s Frequency plot, directivity plot and antenna parameters were obtained for a practical design of pyramidal horn antenna

LITERATURE SURVEY

The Following antenna horn design was taken from a website slide-share explaining in depth straight from what an horn antenna is to designing of an horn antenna in HFSS . Although the document didn't contain proper steps for a newbie to get the results at a first instant. But further survey of Research articles helped us figure out our mistake.

Chapter: 2
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.

A horn antenna is used to transmit radio waves from a waveguide (a metal pipe used to carry radio waves) out into space, or collect radio waves into a waveguide for reception. It typically consists of a short length of rectangular or cylindrical metal tube (the waveguide), closed at one end, flaring into an open-ended conical or pyramidal shaped horn on the other end. The radio waves are usually introduced into the waveguide by a coaxial cable attached to the side, with the central conductor projecting into the waveguide to form a quarter-wave monopole antenna. The waves then radiate out the horn end in a narrow beam. In some equipment the radio waves are conducted between the transmitter or receiver and the antenna by a waveguide; in this case the horn is attached to the end of the waveguide. In outdoor horns, such as the feed horns of satellite dishes, the open mouth of the horn is often covered by a plastic sheet transparent to radio waves, to exclude moisture.

A horn antenna serves the same function for electromagnetic waves that an acoustical horn does for sound waves in a musical instrument such as a trumpet. It provides a gradual transition structure to match the impedance of a tube to the impedance of free space, enabling the waves from the tube to radiate efficiently into space.

To improve these poor characteristics, the ends of the waveguide are flared out to form a horn. The taper of the horn changes the impedance gradually along the horn's length. This acts like an impedance matching transformer, allowing most of the wave energy to radiate out the end of the horn into space, with minimal reflection. The taper functions similarly to a tapered transmission line, or an optical medium with a smoothly varying refractive index. In addition, the wide aperture of the horn projects the waves in a narrow beam

The horn shape that gives minimum reflected power is an exponential taper. Exponential horns are used in special applications that require minimum signal loss, such as satellite antennas and radio telescopes. However conical and pyramidal horns are most widely used, because they have straight sides and are easier to design and fabricate.

POPULAR VERSION OF HORN ANTENNA

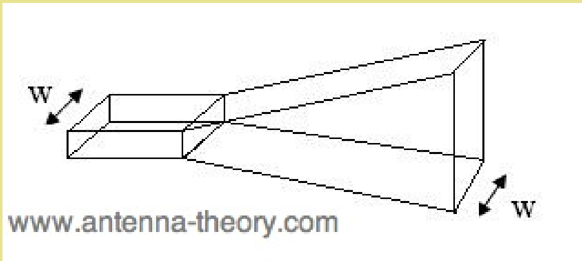


Figure 1. E-plane horn antenna.

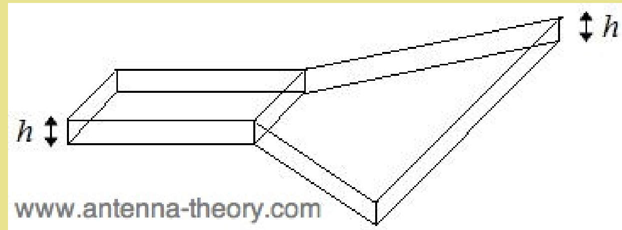


Figure 2. H-Plane horn antenna.

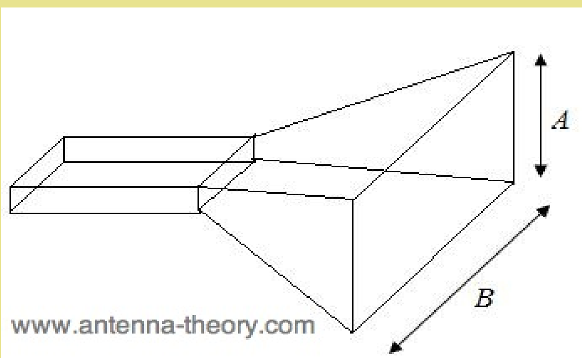


Figure 3. Pyramidal horn antenna.

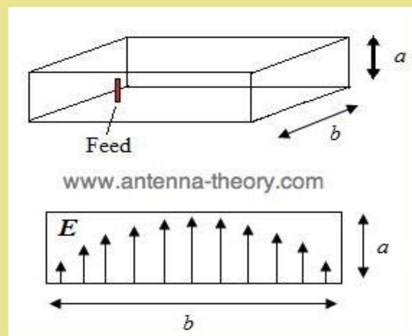


Figure 4. Waveguide used as a feed to horn antennas.

TYPES:

Pyramidal horn (a, right) – a horn antenna with the horn in the shape of a four-sided pyramid, with a rectangular cross section. They are a common type, used with rectangular waveguides, and radiate linearly polarized radio waves.

Sectoral horn – A pyramidal horn with only one pair of sides flared and the other pair parallel. It produces a fan-shaped beam, which is narrow in the plane of the flared sides, but wide in the plane of the narrow sides. These types are often used as feed horns for wide search radar antennas.

E-plane horn– A sectoral horn flared in the direction of the electric or E-field in the waveguide.

H-plane horn – A sectoral horn flared in the direction of the magnetic or H-field in the waveguide.

Conical horn – A horn in the shape of a cone, with a circular cross section. They are used with cylindrical waveguides.

Exponential horn– A horn with curved sides, in which the separation of the sides increases as an exponential function of length. Also called a ***scalar horn***, they can have pyramidal or conical cross sections. Exponential horns have minimum internal reflections, and almost constant impedance and other characteristics over a wide frequency range. They are used in applications requiring high performance, such as feed horns for communication satellite antennas and radio telescopes.

Corrugated horn – A horn with parallel slots or grooves, small compared with a wavelength, covering the inside surface of the horn, transverse to the axis. Corrugated horns have wider bandwidth and smaller sidelobes and cross-polarization, and are widely used as feed horns for satellite dishes and radio telescopes.

Dual-mode conical horn – (The Potter horn) This horn can be used to replace the corrugated horn for use at sub-mm wavelengths where the corrugated horn is lossy and difficult to fabricate.

Diagonal horn – This simple dual-mode horn superficially looks like a pyramidal horn with a square output aperture. On closer inspection, however, the square output aperture is seen to be rotated 45° relative to the waveguide. These horns are typically machined into split blocks and used at sub-mm wavelengths.

Ridged horn – A pyramidal horn with ridges or fins attached to the inside of the horn, extending down the center of the sides. The fins lower the cutoff frequency, increasing the antenna's bandwidth.

Septum horn – A horn which is divided into several sub-horns by metal partitions (septums) inside, attached to opposite walls.

Aperture-limited horn – a long narrow horn, long enough so the phase error is a negligible fraction of a wavelength, so it essentially radiates a plane wave. It has an aperture efficiency of 1.0 so it gives the maximum gain and minimum beamwidthfor a given aperture size. The gain is not affected by the length but only limited by diffraction at the aperture. Used as feed horns in radio telescopes and other high-resolution antennas

Chapter: 3
Horn antenna Equations and Parameters:

Pyramidal Horn antenna is mostly used for feeding microwave dish antenna and for calibrating them. So we are simulating Pyramidal Horn Antenna for our project.

Equations:

For a rectangular horn antenna the formulas are:

$$aperture_E = \sqrt{2 \lambda L_E}$$

$$aperture_H = \sqrt{3 \lambda L_H}$$

Then for a conical horn antenna the formula is:

$$diameter = \sqrt{3 \lambda L}$$

Where:

$Aperture_E$ is the width of the aperture in the E-field direction.
$Aperture_H$ is the width of the aperture in the H-field direction.
L_E is the slant length of the side in the E-field direction.
L_H is the slant length of the side in the H-field direction.
diameter is the diameter of the cylindrical horn aperture.
L is the slant length of the cone from the apex.
λ is the wavelength of the signal.

Horn antenna gain formulas

It is easy to calculate the gain of a horn antenna with the knowledge of a few of its parameters.

Pyramidal horns are normally constructed to provide optimal gain. The gain of a pyramid horn antenna over an isotropic source, i.e. one that radiates equally in all direction can be derived from the formula:

$$\boxed{Gain = \frac{4 \pi A}{\lambda^2} e_A}$$

Then for a conical horn the gain formula can be shown to be:

$$\boxed{Gain = \left(\frac{\pi d}{\lambda}\right)^2 e_A}$$

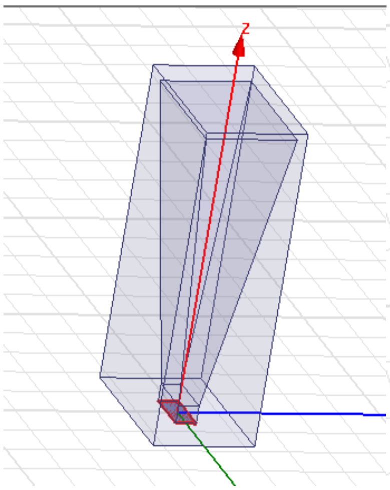
Where

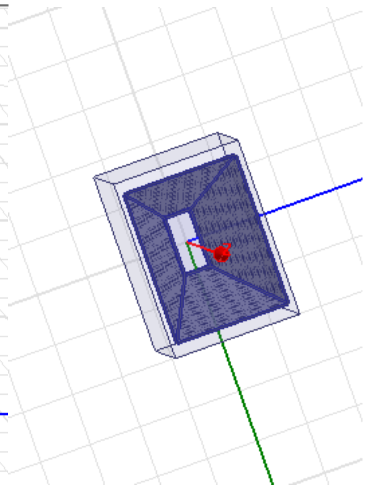
A is the physical area of the aperture
d is the physical diameter of a conical horn aperture
λ is the wavelength
eA is the aperture efficiency and is a figure between 0 and 1

Parameters Used for the simulation:

Resonating Frequency: 10GHz
Waveguide Dimensions: 22.86mm and 10.16mm
Horn Top: 60mm * 45mm
Distance from horn top plane to the bottom: 120mm
Distance from top plane to the base of the horn is: 132mm
Air Box: 145mm*70mm*50mm

Chapter:4
Snapshots:





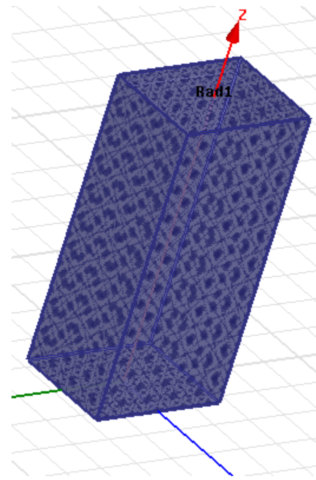
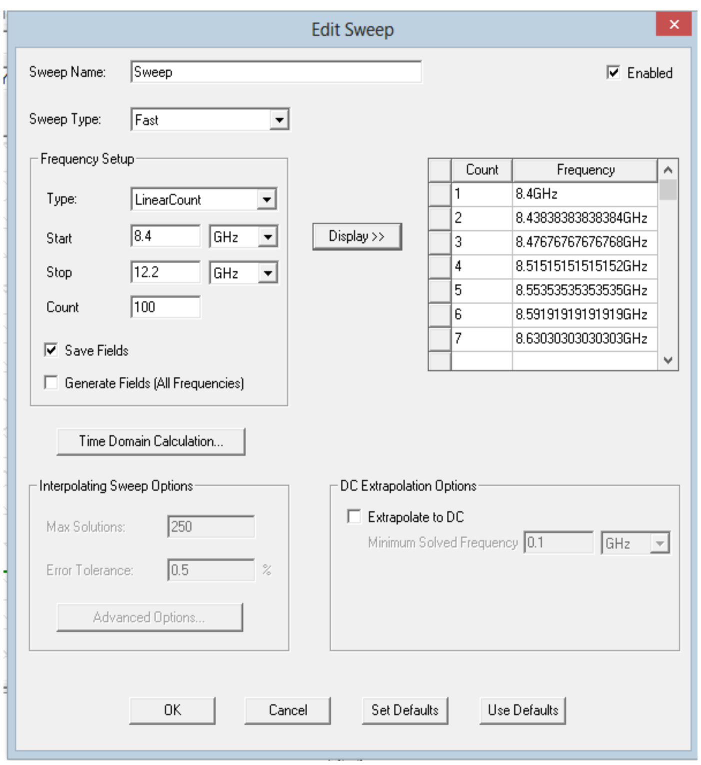


Fig.1: Excitation

Fig. 2: Perfect E boundary

Fig 3: Radiation Boundary



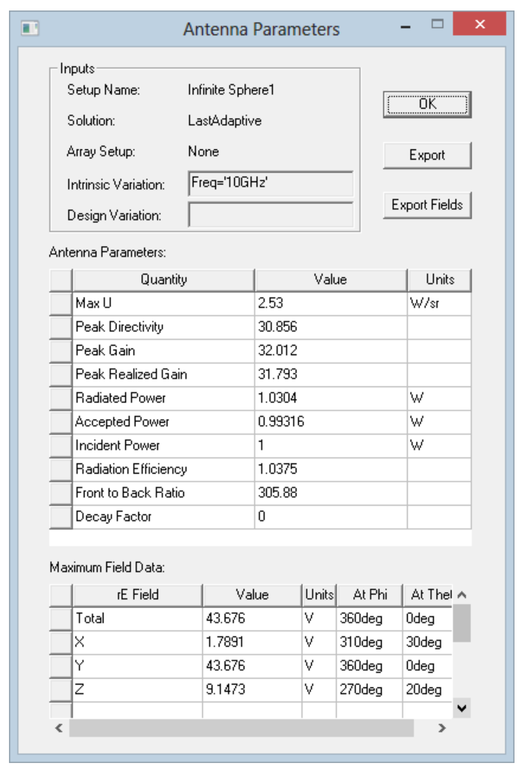


Fig.4: Analysis Setup

Fig5: Antenna Parameters

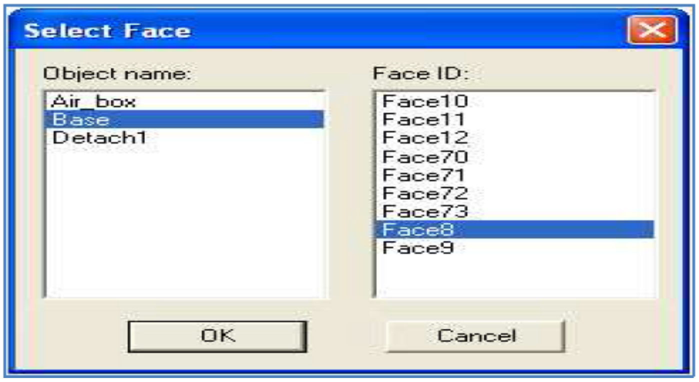
Steps for:

1. Excitation:

Assigning Boundaries and excitations

Create wave port

1. Select the menu item ***Edit > Select > Faces***.
2. Select the ***Edit > Select > By name***.
3. Select the ***Base > Face 8***(Bottom face).

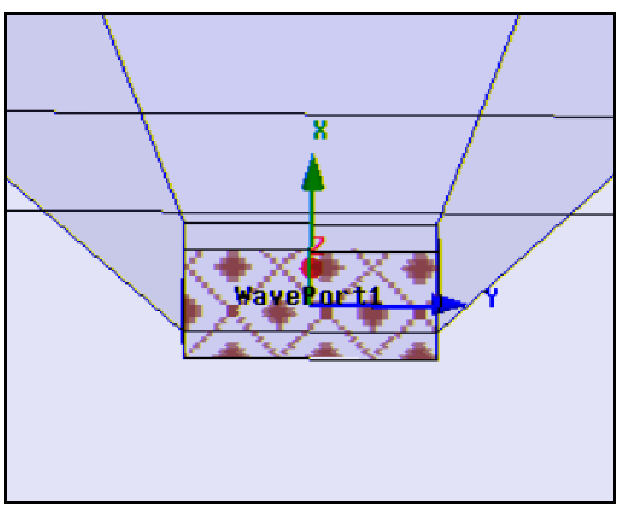


To assign wave port excitation

Assign Excitation to the bottom face of the horn.

1. Right Click > Assign Excitation > Wave port

2. Name it **WavePort1**.



2. Radiation boundary and Perfect E-boundary:

: Create Radiation Boundary

To create a radiation boundary

1. Select the menu item ***Edit > Select > By Name***
2. Select Object Dialog,
    1. Select the objects named: **Air**
    2. Click the **OK** button
3. Select the menu item ***HFSS > Boundaries > Assign> Radiation***
4. Radiation Boundary window
    1. Name: **Rad1**
    2. Click the **OK** button.

To Create a perfect electric field boundary

1. Select the menu item ***Edit > Select > By Name***
2. Select Object Dialog,
    1. Select the objects named: **Base**
    2. Click the **OK** button
3. Select the menu item ***HFSS > Boundaries > Assign> Perfect E***
4. Radiation Boundary window
    1. Name: **PerfE_horn_sides**

3. Analysis Setup and Sweep Setup:

: Analysis Setup

To Create an analysis setup

1. Select the menu item ***HFSS > Analysis Setup > Add Solution Setup***
2. Solution Setup Window:
    1. Click the **General** tab:
        Solution Frequency: 10.0 GHz
        Maximum Number of Passes: 20
        Maximum Delta S per Pass: 0.02
    2. Click the **OK** button

To create sweep setup

1. Select the menu item ***HFSS > Analysis Setup > Add sweep***
2. Solution Setup Window Click **OK**:
    1. Edit sweep window:
        Sweep type: Fast
        Type: Linear count
        Start: 8.4; Stop: 12.2; Count: 100.
    2. Click the **Display** button and Click **Ok**.

Results:

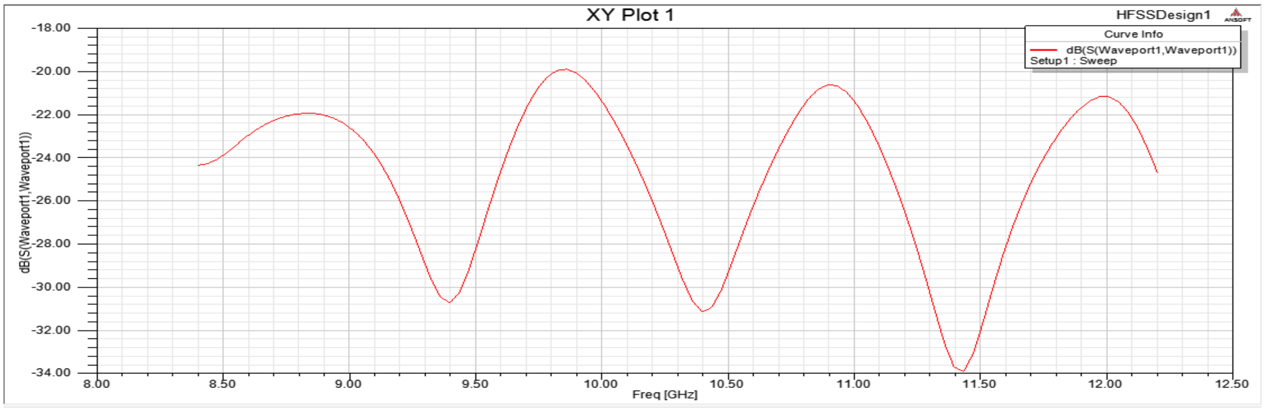


Fig 6. S Parameter

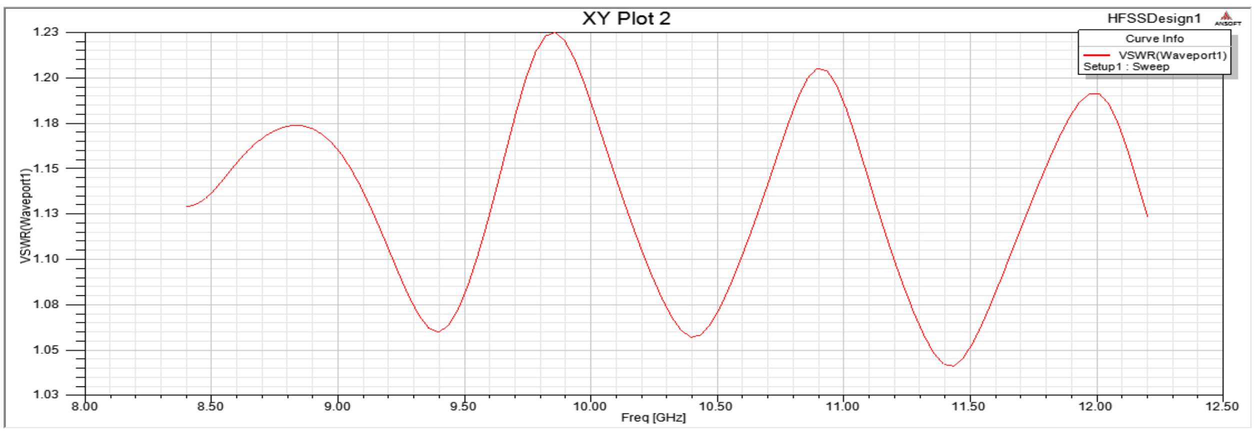


Fig 7. VSWR

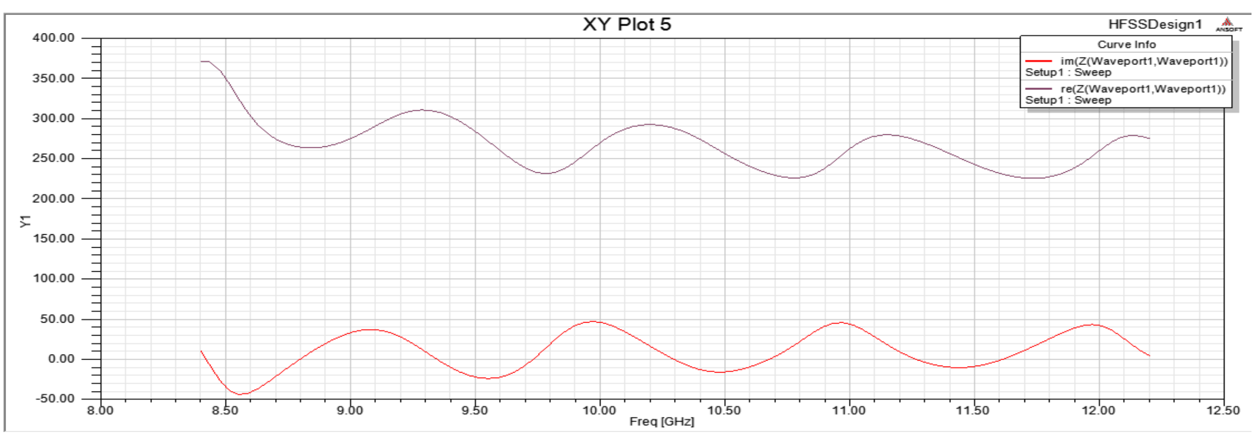


Fig 8. Z Parameter

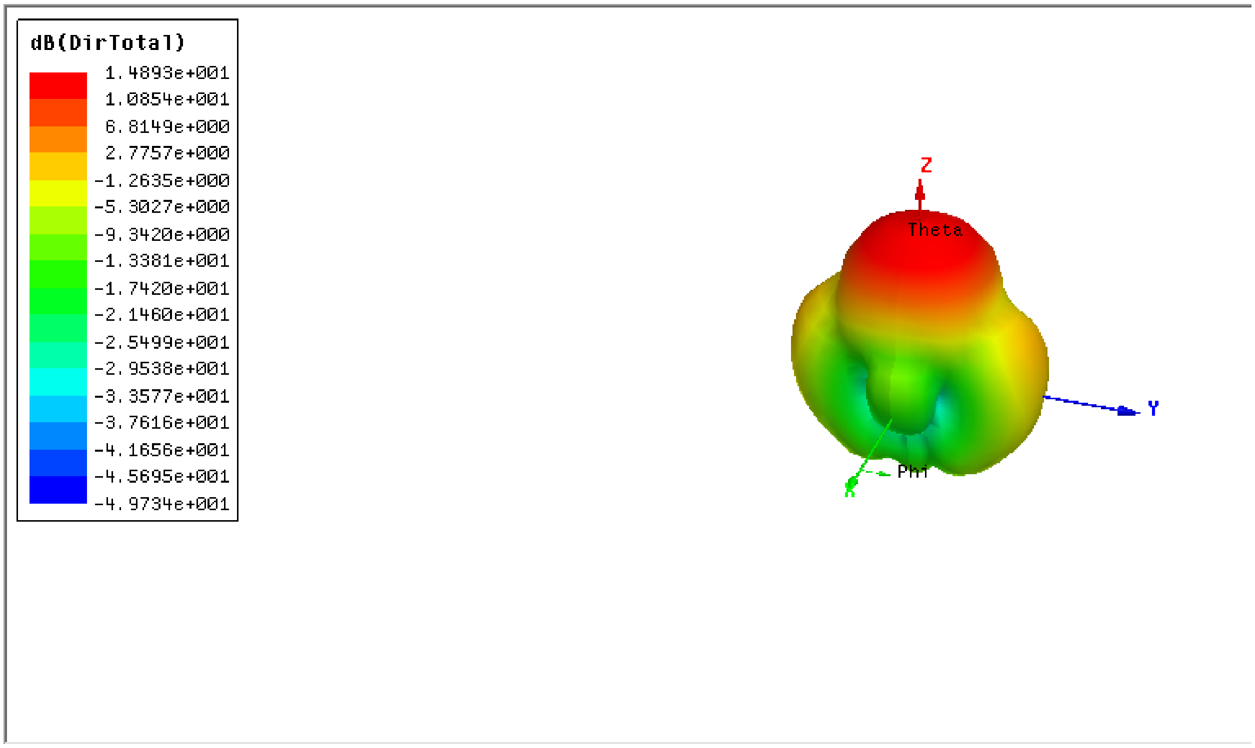


Fig 9. Directivity

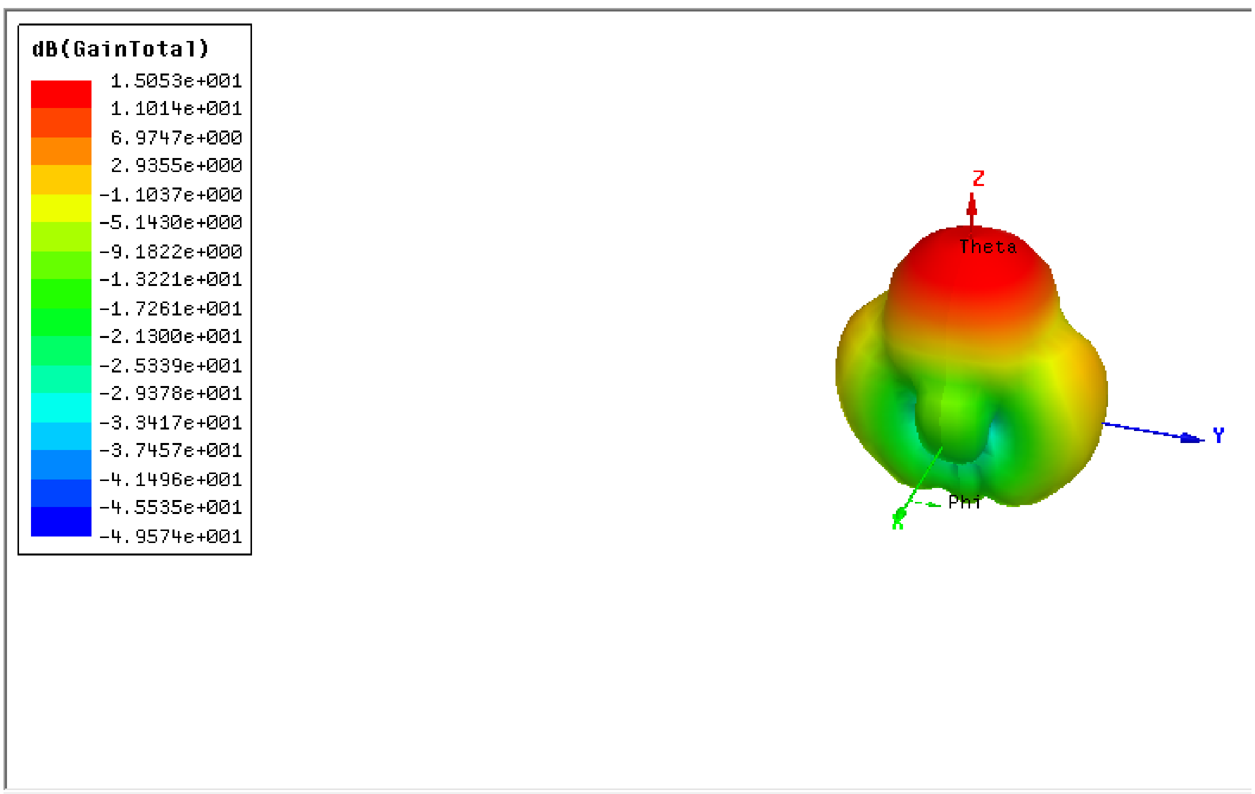


Fig 10. Gain

Chapter: 5
CONCLUSION

A Pyramidal Horn Antenna operating in frequency range of 10 GHz is designed and optimized using HFSS. The actual value of gain was obtained to be 12.1 GHz. This linearly polarized antenna regardless of its size gives decent gain of about 35 dB over operating range. This pyramidal horn antenna can be used in space applications. All the parameters of antenna have been carefully optimized to achieve superior performance with in the limited constraints. The antenna's gain is 35 dB, with return loss of - 24 dB, side lobe level of -23 dB. These measurement results confirmed the results of the simulations and satisfied the design requirements. Desired results are achieved and the simulated structures are suitable for our applications. Structures are yet to be fabricated and measurement results will be presented accordingly. Efforts are going on to further improve bandwidth so as to accumulate even wider frequency range. Also the radiated power obtained was 1.0304 dB, accepted power = 0.99316, radiation efficiency =1.0378, and VSWR= 1.23

Chapter: 6

REFERENCES

1. “Design of Pyramidal Horn Antenna for UWB Applications” (http://ijarece.org/wp-content/uploads/2015/03/IJARECE-VOL-4-ISSUE-3-488-493.pdf)
2. “Design and Analysis of X band Pyramidal Horn Antenna Using HFSS.“ http://www.ijarcce.com/upload/2013/july/30-h-pandimadevi%20muthuramu-design%20of%20pyramidal%20horn%20antenna.pdf
3. “Design and Implementation of Horn Antenna using UIU Microwave Test Setup” http://www.slideshare.net/musbiha/design-hornantenna-using-hfss-38093884
4. Design & implementation of a standard gain horn antenna for optimized gain and radiation pattern using MathCAD & HFSS(http://www.researchgate.net/publication/4347051_Design__implementation_of_a_standard_gain_horn_antenna_for_optimized_gain_and_radiation_pattern_using_MathCAD__HFSS)
5. Constantine A. Balanis, “Antenna Theory and Design”, John Wiley and Sons, New York , pp 769- 780, 3rd edition, 2005.
6. Mathew N.O. Sadiku, ” Principles of Electromagnetics”, 4th Edition, International Version, Oxford University Press, 2011