ENHANCEMENT IN DESIGN AND ANALYSIS OF KU- BAND PYRAMIDAL HORN ANTENNA USED FOR SATELLITE BEACONING, USING HFSS.

DISSERTATION II

Submitted in partial fulfillment of the

requirement for the award of the

Degree of

MASTER OF TECHNOLOGY

IN

(Electronics and Communication Engineering)

By

Arvind Roy (11008122)

Under the Guidance of

Mrs. Isha Puri

(School Of Electronics and Communication Engineering)

Lovely Professional University
Phagwara, Jalandhar. G. T Road (NH-1),
Punjab, 144402, India.

MAY, 2015.

ABSTRACT

In the report, a brief review of horn antenna is given. The further report will include design,analysis and enhancement of the pyramidal horn antenna that will be analyzed and simulated with a Finite-Element Method software package that is HFSS. The software used for designing purpose is Ansoft HFSS V12.1. Along with the HFSS other software'sthat were used are Matlab 2010b for the numerical part and the DigiGraph V.2 for the Graph designing. To make these designs more practical many more adjustments to horn antenna are possible.The key design will remain pyramidal horn antenna in the research. The antenna parameters will be thoroughly described and the next step towards filling the gaps left behind in literature review will be made. These adjustments may comprise more complexcalculations and implementation techniques. They can be designed in a variety of shapes in order to obtain enhanced gain and bandwidth. The effect of flare angles of pyramidal horn in the emission of electromagnetic wave will also be explained. The gain and directivity of the antenna will be more adequate and the designed antenna structure will work for all Ku band frequency i.e. 12-18 GHz submissions as for the specific, we can say satellite beaconing and television broadcasting. The beamwidth of the designed pyramidal horn antenna will be narrow that will increase the position accurateness for detection and reception of the signal. The antenna should perform profoundly with little power intake. The loss in the signal should be very small and the designed pyramidal horn antenna would be cost effective. Optimum design method for the designing of pyramidal horn antenna is considered.

CERTIFICATE

This is to certify that the Thesis titled "**Enhancement In Design And Analysis of Ku-Band Pyramidal Horn Antenna Used For Satellite Beaconing, Using HFSS**" that is being submitted by "**Arvind Roy**" is in partial fulfillment of the requirements for the award of **Master of Technology Degree**in Electronics and Communication Engineering, is a record of bonafide work done under my guidance. The contents of this Thesis, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Mrs. IshaPuri

____

Project Supervisor
Lovely Professional University,
Phagwara, Punjab.

Objective of the Thesis is satisfactory / unsatisfactory

ExaminerI **Examiner II**

ACKNOWLEDGEMENT

I would like to thank my project supervisor**Mrs. IshaPuri** for her continuous support and encouragement. It was she who provided an aim and course to the research and compilation of the Dissertation II. She relentlessly pushed me to work harder on it.Her support was invaluable. I would like to thank the Ansoft Corporation for providing essential software tools required for implementation of this design.

I would also like to thank **Lovely Professional University** for providing me with the adequate infrastructure in processing the research more interestingly. I am thankful to every person who had helped me in solving critical problems/doubts and in providing relative data essential for this research.

Last but not the least I would like to thank my family for their love and moral support so that I could complete this research.

Student Name :**Arvind Roy.**

Registration no**: 11008122** **Signature**

DECLARATION

I hereby declare that the work entitled **"Enhancement in Design and Analysis of Ku-Band Pyramidal Horn Antenna Used for Satellite Beaconing,Using HFSS"**is an authentic record of my own work carried out as required for the award of degree of "**MASTER OF TECHNOLOGY" in Electronics and Communication Engineering"**, from Lovely Professional University, Phagwara, under the guidance of **Mrs. IshaPuri**. The content of this Dissertation II haven't been submitted to any other Institute or University for award of any degree or diploma.

Arvind Roy. **Signature**

Registration No.:11008122 ________________________

It is certified that the above statement made by the student is correct to the best of my knowledge and belief. The **Dissertation II**is fit for submission for the award of the degree of**Masterof Technology**in Electronics and Communication Engineering.

ISHA PURI

Assistant Professor

____

Date: _______________________

Lovely Professional University

Phagwara, Punjab.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF FLOWCHARTS

LIST OF ABBERVATIONS

HFSS	High Frequency Structure Simulator
HPBW	Half Power Beam Width
FNBW	First Null Beam Width
BW	Bandwidth
CMB	Cosmic Microwave Background
SWR	Standing Wave Ratio
VSWR	Voltage Standing Wave Ratio
GSM	Global System for Mobile
GRF	Gain Reduction Factor
DSP	Digital Signal Processing
FEM	Finite Element Method
EM	Electromagnetic
CMB	Cosmic Microwave Background
RHCP	Right Hand Circular Polarization
LHCP	Left Hand Circular Polarization
LOS	Line Of Sight
UWB	Ultra Wide Band
PTFE	Poly Tetra Fluoro Ethylene
SIW	Substrate Induced Waveguide

CHAPTER 1

INTRODUCTION

1.1 ANTENNA THEORY AND BACKGROUND

The beginning of the study about the different antenna structures, more specifically antenna engineering, dates back to 1900's. The antenna engineering gained its popularity in 1940's to 1990's. James Clerk Maxwell combined the theoretical study into mathematical equations which have better valid explanation of electric and magnetic fields. These equations were very informative that they formed the platform for electromagnetic studies. These equations were named after him known as Maxwell Equations. He published his first work in 1873. After him the Guglielmo Marconi was the second person who experimented on the transmission of the signals over far distances. But at that time the antenna engineering was mostly based on the wire based communication system under UHF band. With the era of wireless communication the study about the antenna structures was boosted. Different types of radiating structures were designed and tested. The invention of aperture antennas, log periodic antennas, fractal antenna, and microstrip antennas are responsible for the success of the wireless communication systems. The World War II further pushed antenna engineering to explore for new antenna technologies [1], [3], [5]. But advancement in the science and technology was the main element in the success of antenna technology, like advancement in numerical computation methods and discovery of compact faster computers. Nowadays, many advance technologies are being used which were discovered in the early stages. No doubt, we are facing many difficulties with the demands for system performances but still antennas are playing great role in modern communication systems.

1.2 DEFINITION OF ANTENNA

First question that strike to us is that what is an antenna and how it radiates. Many researchers define antenna but a proper definition for an antenna could be it is a conductor that can transmit or receive electromagnetic signals such as radio or satellite signals [1]. In other words it is an electrical device that converts electrical power into radio signals. Ariel is a alternate word for an antenna. It is one of the most important components in any wireless systems. Most antennas can be said to be resonant devices that operate efficiently over a relatively narrow frequency band. However, for wide angle transmission low gain antennas are preferable to transmit or receive where on the other hand, if strong signal is requirement for the system then high gain antennas are the best choice. An antenna under transmission, as the transmitter provides the antenna a proper excitation, that is, an electric current signal to the antenna’s terminals then the element radiates in the form of electromagnetic waves or electromagnetic energy. However, in case antenna is under reception, the amount of received electromagnetic energy is transformed into voltage at terminals of the antenna. If the received signal is weak it can be amplified using a proper amplifier at the receiver. Type of antenna differs with the needs and type of system in which it has to be used. For instance, broadcasting system need isotropic antenna, radar system require directional antenna, mobile communication systems require sectoral antenna, communications data receivers need aperture antenna and satellite communication require super enhanced antennas for their proper working. Classically, an antenna involves a prearrangement of metallic conductors electrically connected. Common elements that an antenna may require for its proper working include transmission line, waveguides, end transmitter or receiver for proper transmission and reception. Now let us understand how an antenna radiates. To generate radiation any antenna must satisfy certain conditions, refer (Appendix A.1). When the time varying current of electrons injected in antenna through its terminals using transmitter then it generates an oscillating magnetic field surrounding the antenna structure. In the mean time, the electrons charge also generates an oscillating electric field in the antenna structure [1], [5]. When these fields are produced in the appropriate manner the radiation can be caused in the particular direction as electromagnetic field wave. Whereas, throughout reception the electric and magnetic fields formed due to received electromagnetic signal exerts force on the electrons present in the antenna element leading them to oscillate which generating oscillating currents in the antenna structure.

1.3 HISTORY OF HORN ANTENNA

Before we start exploring our research about the pyramidal horn antenna let us just take our small time to know about the history and development of the horn antenna. The discovery of horn antenna is ancient. It is great misconception today about electromagnetic technology as a new or modern development. The discovery of the horn antennas is linked with the discovery of waveguides. Sir Oliver Lodge in 1894 presented his microwave waveguide transmission lines. After three years after, in 1897, Sir Jagadish Chandra Bose designed first form of horn antenna [1]. The design horn was based on circular waveguide with circular funnel. His experiments were in the 60 GHz range which is becoming more popular nowadays. His designed horn was operational in the millimetre wave range. The emitted radiations from the horn were powerful enough to ring bells and ignite gun powder placed at a distance. These experiments were performed in Calcutta now Kolkata. Other discoveries in antenna technology conducted by the 1890's were also taken under consideration. The rectangular horn antenna is supposed to be an ideal antenna radiator for the frequencies that were encountered throughout World War II. After that, the rectangular waveguide became the most common transmission line for the centimetre wavelength. Waveguide was then broadening creating the standard and common pyramidal horn shape. For the improvement in directivity and beamwidth the dielectric lenses were used. These dielectric guiding structures are called Dielguides. This technique is cost efficient and provides broadband operation. One of the biggest drawbacks of horn antennas is that their size is dependent on their operating frequency. As we move towards the higher ranges of frequency the dimensions of horn become significantly large. We can enhance the bandwidth of horn antennas mainly by the use of ridges. The inserted ridges improve the bandwidth similar to the concept as they improve it in waveguide technology. However, the exponentially inserted ridges are required where radiating mode has to be kept same for the antenna operation without compromising with the bandwidth. The double and quad ridged horn antennas continued as originally introduced for about 20 years.

1.4 INTRODUCTION TO HORN ANTENNA

Horn antennas are preferred in the microwave frequency range of frequencies as these provide high gain, minimum VSWR with rectangular waveguide feeds, wide bandwidth. Another advantage of using horn antenna is that they induce low losses and are not tough to design. With the increased complexity in the design horn antenna are more familiar today than in the early times. These horn antennas are very useful for aircraft and spacecraft appliances. They are rigid structures made of metal and can be easily mounted on the surface of the space vehicles and aircrafts. However, they can be protected from the hazardous effects of environment that may affect their operation. Their walls can be coated with dielectric material. The horns antenna can be flared in an exponent manner by doing so the antenna delivers enhanced correspondence in a large frequency range. However, they are scientifically more sophisticated and high-priced. The horn antenna exhibits a laborious changeover from a waveguide mode into freespace mode. Rectangular pyramidal horns are preferably for rectangular waveguide feeders, whereas, for a cylindrical waveguide the antenna is usually a conical horn. The point that concerns us is why it is necessary to consider the horns separately instead of applying the theory of waveguide aperture antennas directly. We cannot relate the physics of waveguides with the horn antennas. It is because of the phase error that occurs due to the variation in the lengths from the centre of the feeder to the centre of the funnel aperture and the edges. This causes the unvarying phase aperture grades unacceptable for the horn apertures. The practical bandwidth of pyramidal horn antennas is classically in the order of 10:1 and may approach to 20:1.

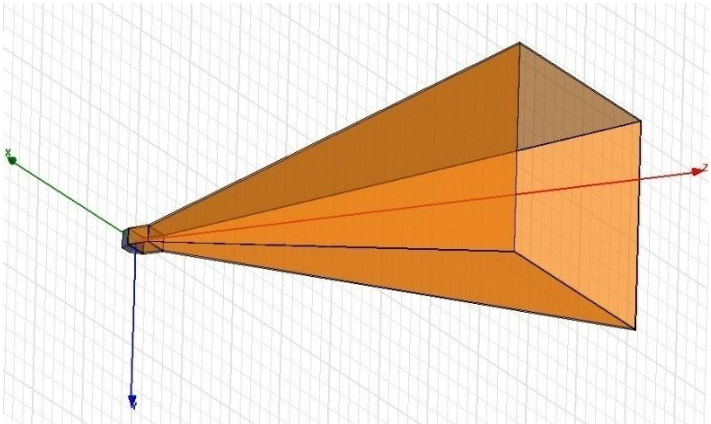


Figure 1.1 Horn antenna

1.5 TYPES OF HORN ANTENNA

Generally, four basic types of horn antenna are present. However, many different enhanced structures for the horn antennas are possible. Inside the waveguide the fields propagate in the same manner as they propagate in the free space the main difference is that inside the waveguide the fields are forced inside the walls of the waveguide such that there is no spherical spread of the field radiations. When the fields reach the brim of the waveguide the wave front becomes more complex. This region can be considered as the transition region. The difference in the impedance of the waveguide and the free space exists hence broadening of the guide is done which provides impedance matching as well as strengthened radiation in terms of higher directivity and narrow beamwidth.

1.5.1PYRAMIDAL HORN ANTENNA

A horn antenna with the horn in the shape of a four sided pyramid, with a rectangular cross section is termed as pyramidal horn. These are the most common type of horn antenna and are constructed with rectangular waveguides that emit linearly polarized electromagnetic waves. The pyramidal horn antenna contains two flare angles and hence have large aperture than sectoral horns. Pyramidal horn is widened in both E plane as well as H plane. Pyramidal horn antenna has larger directivity and can achieve large gain due to greater aperture area.

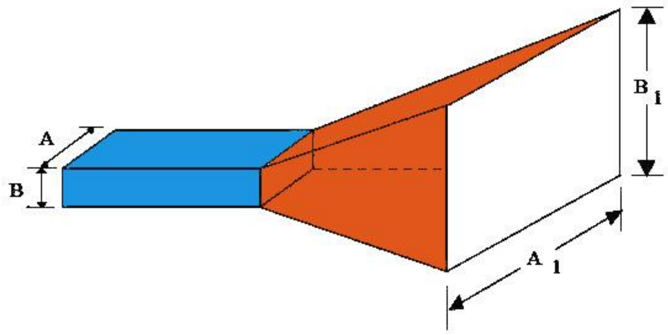


Figure 1.2 Pyramidal horn antenna.

1.5.2 E PLANE SECTORAL HORN ANTENNA

A sectoral horn widened in the direction of the E field plane only of the waveguide is called an E plane sectoral horn antenna. The radiation patterns for the E plane sectoral feed horn antenna are represented with the phase error as parameter for E plane. They have less directivity and gain compared to pyramidal and conical horn antennas. But the phase error is more than pyramidal horn antenna.

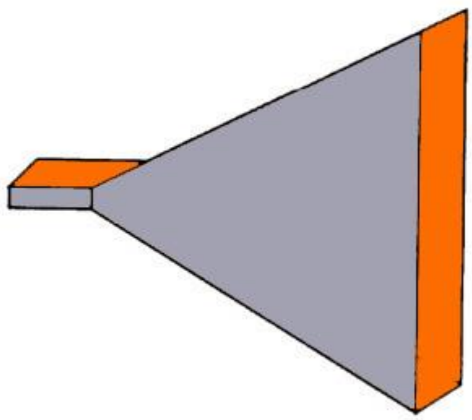


Figure 1.3 E plane sectoral horn antenna

1.5.3 H PLANE SECTORAL HORN ANTENNA

A sectoral horn widened in the direction of the H field plane of the waveguide is called the H plane sectoral horn antenna. The H plane sectoral horn is the one where the wider dimension of the input waveguide is broadened and keeping the other dimension of horn and waveguide unflared. These antennas have less gain and directivity then the E sectoral horn antennas.

The phase error is greater than the pyramidal horn antenna but almost similar to that of E sectoral horn.

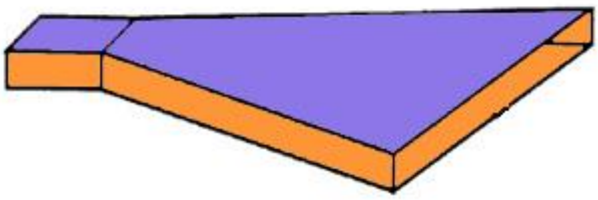


Figure 1.4 H plane sectora horn antenna

1.5.4 CONICAL HORN ANTENNA

These are the first type of horn antenna constructed. This type of horn antenna is designed with circular waveguides. When such type of waveguide is flared the funnel takes the shape of cone with circular aperture area, hence the name. These conical horn have uniform flare angle in both E and H plane.

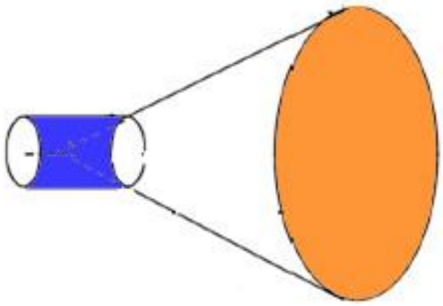


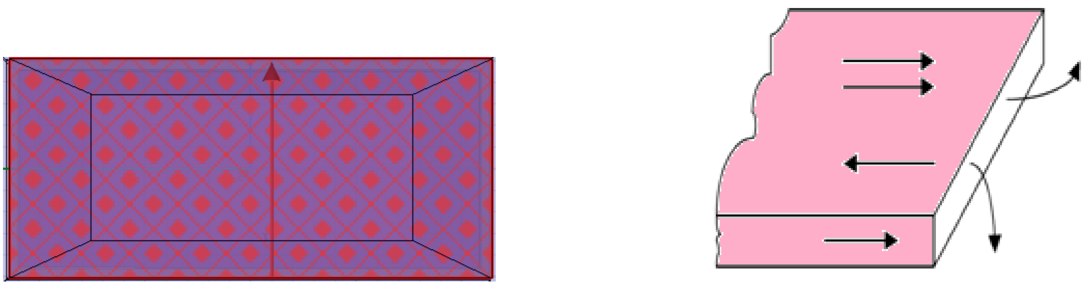
Figure 1.5 Conical horn antenna

The pyramidal horn antenna is the one of the most popularly used antenna for feeding huge microwave parabolic antennas. The pyramidal horn antenna may also be applied for the standardization of other radiating structures, reason being they are very less prone to errors and losses occurring during the operation. In the horn antennas the resonant element is not present hence these antennas can work in a very broad range of frequencies, in other sense provides a broad bandwidth over the operation frequencies.

In this report only pyramidal horn antenna will be our main topic of concern and will be analyzed in the next coming chapter part of the report.

1.6 WAVEGUIDES IN PYRAMIDAL HORN

The transmission and reception of microwave signal through free space in microwave communications is very important. For the purpose we can use transmission line that transmits electromagnetic energy from source to destination. If described in a more practical manner from generator to the load. A waveguide can be said to a transmission line but in reality waveguide is different from the transmission line in some aspects. A wave guide can support different field configurations as supported by the transmission line. At microwave frequency range we cannot use transmission lines due to skin effect and dielectric losses however, at these frequencies a wave guide can be use for lower signal attenuation and obtaining broad bandwidth. The waveguides are dependent on the cutoff frequency and can only operate greater than this frequency. A waveguide may act as an antenna if its open end is matched to free space intrinsic impedance. Many organizations supply different waveguides of different materials. Some of the materials used for the construction of the waveguides are aluminium, brass, Pec or copper. The waveguides manufactured are manufactured with the standard dimensions selected for waveguides by some standard organizations. For different frequency range the size and shape of the waveguide changes. Hence, the horn used with the waveguide differs with the choice of the waveguide that is used for the construction of the horn antenna. The waveguides are matched accurately to higher accuracy. For example, metrology grade products have their waveguide sections machined to a very high accuracy from solid material. But we cannot apply the science of waveguides emission to the pyramidal antenna emission. Depending upon the application in which horn antenna has to be used the waveguide is selected accordingly. For rectangular waveguides the accepted limit of operation is between 125% and 189% of lower cutoff frequency. If the flare angle is small then the structural wavefront of waveguide is approximately equal to that of the aperture of the horn, which is not well suited condition for best operation.



(a) (b)

Figure 1.6 (a) Waveguide excitation, (b) Energy radiated from an open waveguide

The waveguide used for the construction of the Ku band pyramidal horn antenna is WR-62. In the base paper implementation the waveguide selected is WR-137 for the design. The Table 1.1 gives for the specification of rectangular waveguide WR-90, WR-137, WR-62 and WR-42. The dimensions are standard values and are standard values decided by IEEE.

The WR is the nomenclature abbreviation used for the rectangular waveguides and it stands for Waveguide Rectangular.

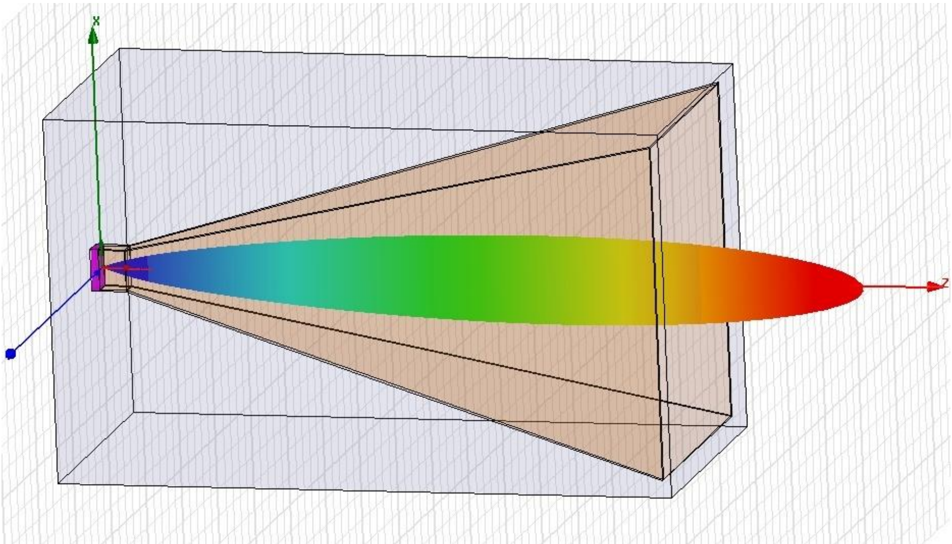


Figure 1.7 Energy radiated from a horn antenna

TABLE 1.1 Specifications of the WR90, WR137, WR42 and WR62

Model no	**Start Frequency (GHz)**	**Stop Frequency (GHz)**	**A (mm)**	**B (mm)**	**Inside Tolerance**	**Material**	**Wall (mm)**
WR-90	8.20	12.5	22.86	10.16	0.003	Aluminum	0.5
WR-137	5.85	8.20	34.85	15.799	0.004	Aluminum	1
WR-42	18	27	10.668	4.318	0.002	Aluminum	0.5
WR-62	12	18	15.799	7.899	0.001	Aluminum	0.5

Datasheet for different waveguides used in microwave ranges and there specifications has been given in the Appendix A.3. By going through the data sheet presented in the report one can easily know about the dimensions and description related to waveguide. It is easy to decide the waveguide in what range of frequency his antenna is operating.

CHAPTER 2
TERMINOLOGY

Before going for the designing and analysis we must know some of the scientific terms to what they refer and important definitions that may be important in the processing of research. This chapter will include important terminology that plays an important role in antenna designing and analysis.

2.1 ANTENNA CHARACTERISTICS

As we know by now antenna is an electromagnetic device that is manufactured for efficiently radiating and receiving transmitted electromagnetic waves. Certain important antenna characteristics which must be taken in consideration when selecting an antenna for an application are as follows:

a) Antenna radiation pattern.
b) Beamwidth.
c) Gain.
d) Directivity.
e) Polarization.
f) Field Regions.
g) Input impedance.

2.1.1 ANTENNA RADIATION PATTERNS

An antenna radiation pattern can be well defined as a mathematical function or in other words a pictorial representation of the radiation characteristics of the antenna as the function of space coordinates. The radiation pattern of the antenna is a radiation plot for a radiating element in the Fraunhofer region in three dimensional vectors representation. The radiation pattern includes two patterns, the elevation pattern and the azimuth pattern for its proper definition. When we combine the two graphs we have a three dimensional illustration of energy radiation from the antenna. It is three dimensional representation that relates the variation of radiated power with theta and phi (θ and ϕ).The Figure 1.8 presents a generalized radiation pattern for a radiating antenna. Antenna radiation pattern may consist of different emission lobes known as side lobes. For an ideal antenna the back lobe and side lobe does not exists. The radiation pattern is the superlative way to understand how antenna radiates. Radiation pattern can be energy field radiation pattern and power radiation patterns. Use of decibel unit to optimize the radiation pattern is advantageous because it provides us with better optimization of side lobes. The observation of radiation pattern also provides us estimate of beamwidths. One can easily optimize half power beam width (HPBW) and first null beamwidth (FPBW) just by analyzing the radiation pattern. It is clear from the Figure 1.10 how beamwidths can be estimated form the radiation pattern plot. Most commonly we generate radiation pattern as 2D plots hence to get better visualization and optimization of the antenna emission.

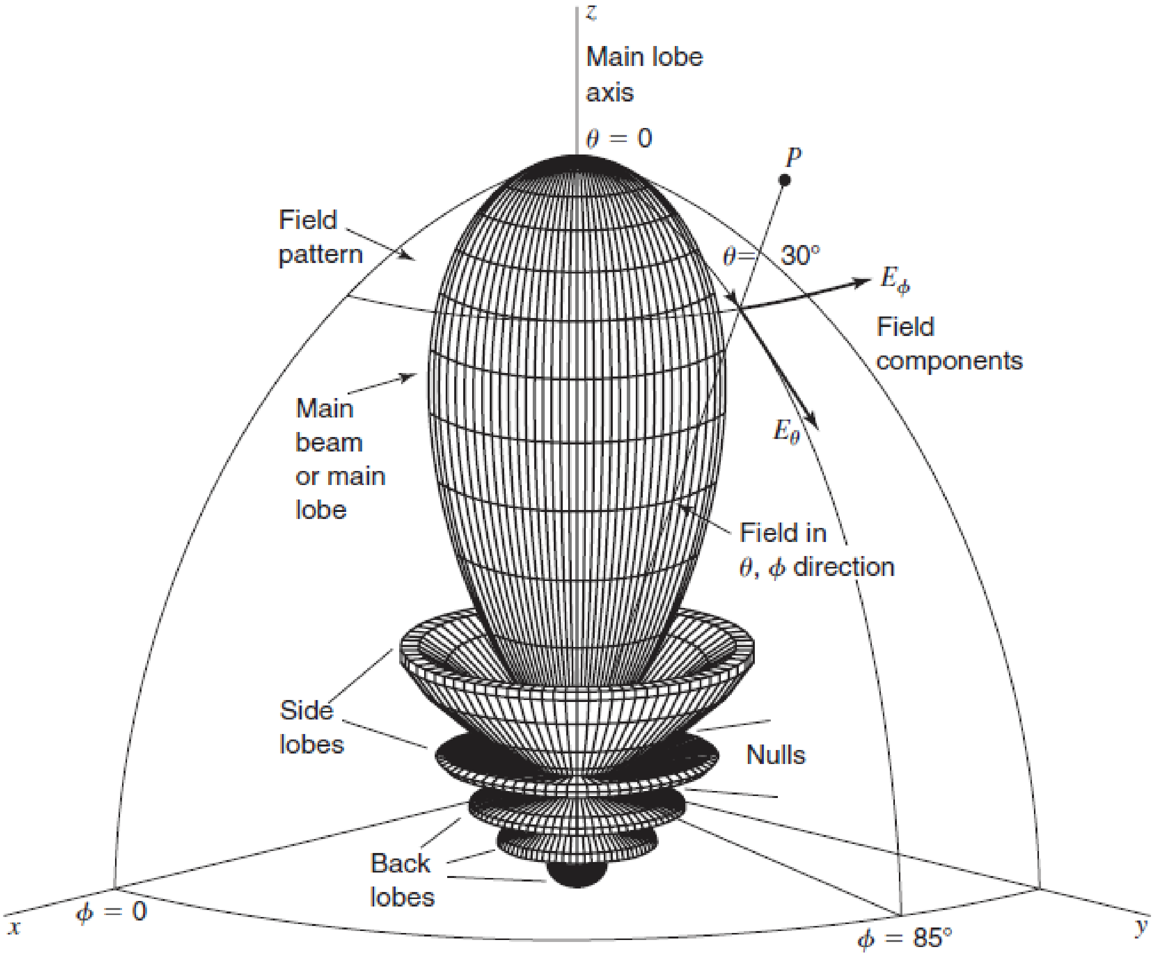


Figure 2.1 Understanding radiation pattern.

2.1.2 MAIN LOBE

The main lobe is defined as the lobe with maximum power. It is the biggest lobe present and is directed towards the direction of propagation of the generated electromagnetic wave. The antenna engineers make their effort so that the size of the major or main lobe increases and to minimize the other minor lobes present. The main lobe is generally the point of concern in the study of the antenna parameters as it includes 92% of total transmitted power.

2.1.3 MINOR LOBE

The lobes other than main called the minor lobes. The minor lobe includes back lobe. The other lobes except back lobe are called side lobes. The side lobes can be in any direction. These side lobes are adjacent to the main lobe .The above given figure provides good visualization in understanding lobes present in the radiation pattern of the antenna. The level of minor lobes can expressed in terms of ratio of power density in the lobe under observation to the power density in the major lobe. This is also termed as side lobe level.

2.1.4 BACK LOBE

The lobes containing minimum power are called the back lobes. The back lobe is the smallest lobe and is because of back reflection of the signal caused due to improper mismatch or ill construction of antenna structure. Another easy way to detect back lobes is that they are in the opposite direction to the main lobe. The axis of the back lobe makes an angle of $180^o$with the beam of antenna. The back lobe contains only 1% of total transmitted power and hence also called redundant lobe.

2.1.5 NORMALIZED FIELD PATTERN

Normalized field component can be obtained by dividing the obtained field components with its highest value. The normalized field pattern is a dimensionless. The normalized field pattern has a maximum value of one.

$$E_\theta(\theta,\phi)_n = \frac{E_\theta(\theta,\phi)}{E_\theta(\theta,\phi)_{\max}} \tag{2.1}$$

The obtained graph with the maximum value of unity is called the normalized field pattern for an antenna element.

2.1.6 NORMALIZED POWER PATTERN

Moreover, in case of power patterns for an antenna, the power patterns can also be represented in provisions of the power emitted by an antenna element per unit area or in other words, with respect to of poynting vector $S(\theta,\phi)$. Now by standardizing this power emitted with respect to its highest value gives us a normalized power pattern which is a function of angle a dimensionless quantity that can achieve a maximum value of one.

$$P_n(\theta,\phi)_n = \frac{S(\theta,\phi)}{S(\theta,\phi)_{\max}} \tag{2.2}$$

Where,

$$S(\theta,\phi) \quad = (E_{\theta}^{2}(\theta,\phi)_{n} + E_{\phi\theta}^{2}(\theta,\phi)_{n}) / Z_{0}, \text{ Wm}^{-2}$$

$S(\theta,\phi)$ = Defines a pointing vector.

$S(\theta,\phi)_{\max}$ = Maximum value of $S(\theta,\phi)$, Wm^{-2}

2.1.7 BEAMWIDTH

The beamwidth of the radiation pattern for an antenna can be described as the angular separation between two same points on contrary side of the obtained major lobe. Basically, two of the most generally used beamwidth are half power beamwidth and first null beamwidth. The value of FNBW is twice the HPBW for an antenna. Regardless of these two beamwidths many other beamwidths do exist for a single antenna radiation patterns. But the most important beamwidths that should be taken under consideration are the HPBW and FPBW. For better understanding both of the beamwidth are defined below

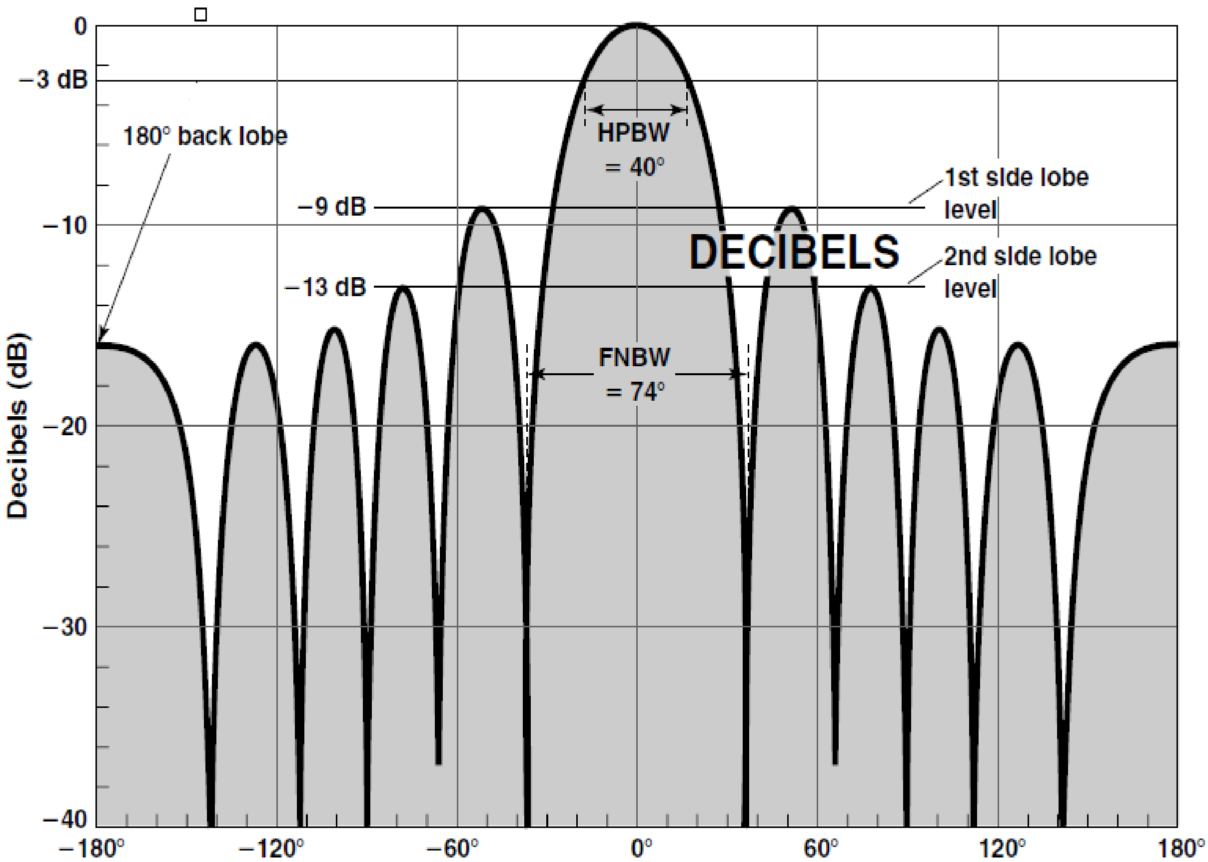


Figure 2.2 Measurement of beamwidth using radiation pattern.

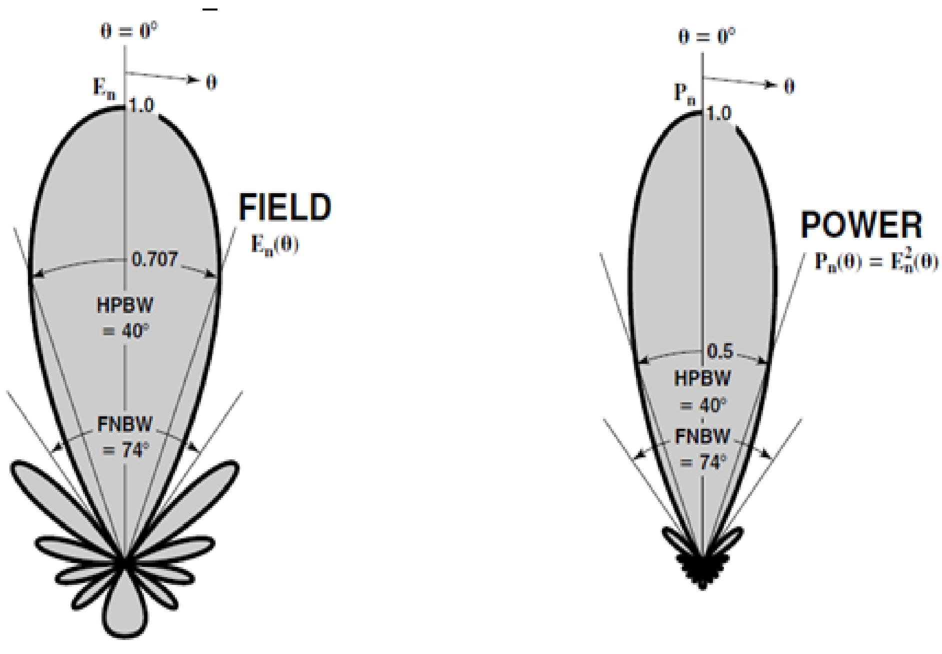
2.1.8 HALF POWER BEAMWIDTH (HPBW)

There may be a number of beamwidth present in an antenna pattern. HPBW is defined as measure of angle between the two contrary sides of the major lobe where the radiation intensity, $U(\theta,\phi)$ is half of energy in the front lobe. It is also referred to as −3 dB beamwidth. The half power beamwidth occurs at angles θ and ϕ for which

$$E_\theta(\theta,\phi)_n = \frac{1}{\sqrt{2}} = 0.707 \tag{2.3}$$

2.1.9 FIRST NULL BEAMWIDTH (FNBW)

FNBW can be said to be the angular separation between the former two nulls that occur in the radiation pattern. As the beamwidth decreases the side lobe level increases and vice versa occur. The FNBW of the antenna is an important parameter and can be considered to measure the HPBW for a given antenna structure.



(a) (b)

Figure 2.3 HPBW and FNBW for (a) energy pattern (b) power pattern.

2.1.10 RADIATION INTENSITY

As per the definition, the amount of power generated from an antenna element and emitted per steradian is known as the radiation intensity U of an antenna. It is considered in watts per steradian which are SI units for measurement. The above defined normalized power pattern can also be represented in terms as the ratio of $U(\theta,\phi)$, the radiation intensity in terms of θ

and ϕ as a function of angle to its greatest value. Also, the poynting vector $S(\theta,\phi)$ has its dependency on the measure of distance from the antenna to the point of measurement. And its variation in the inverse proportionality to the second power of distance considered. However, the $U(\theta,\phi)$, doesn't depend on the distance. If we assume, the measurements in both the cases are being done in the far field region of the antenna. The radiation intensity can be for the antenna can be represented and calculated mathematically as

$$P_n(\theta,\phi) = \frac{U(\theta,\phi)}{U(\theta,\phi)_{\max}} = \frac{S(\theta,\phi)}{S(\theta,\phi)_{\max}} \tag{2.4}$$

Where,

$P_n(\theta,\phi)$ = Normalized radiation intensity.

$U(\theta,\phi)$ = Radiation intensity (W/steradian).

2.1.11 DIRECTIVITY

One of the antenna parameter for an antenna is its directivity, and it gives the knowledge about the concentration of the radiated power in a particular direction. In other words, it may be defined as the ratio of amount of antenna radiation in a given direction from the antenna termed as radiation intensity to the average of radiation intensity in all direction [1], [3], [5]. It may be regarded as the ability of the antenna to direct emitted radiation in a given direction. The total power radiated by the antenna divided by 4π can be equated as the average power radiated by an antenna. The directivity of non-isotropic sources is the measure of the ratio of $U(\theta,\phi)$ in a given direction to that of an isotropic source, $U_0(\theta,\phi)$ [1]. Directivity is dimensionless and is denoted by D.

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} \tag{2.5}$$

Where,

D =Directivity.

U =Radiation intensity (W/unit solid angle).

U_o =Radiation intensity of isotropic source (W/steradian).

P_{rad} =Total radiated power (W).

2.1.12 GAIN

The power gain of an antenna is measures as the ratio of the power intake of the antenna to the power output from the antenna. Obtained gain is most often referred to with the units of dB. It is logarithmic gain relation to an isotropic antenna [1], [2]. As we know, isotropic antenna has an ideal spherical radiation pattern and a linear gain of one. Hence, mathematically we can define antenna gain as ratio of the amount of radiation emitted by an antenna in a particular direction to the intensity that would be emitted by an isotropic antenna with zero loss that emits radiation equally in every direction. Assuming, power density emitted by an isotropic antenna having an input power P_0 at a distance R meters which is given by

$$S = \frac{P_o}{4\pi R^2} \tag{2.6}$$

As we know an isotropic antenna radiates equal amount of radiation in all directions, hence its radiated power density S can be found by dividing the calculated radiated power with the surface area of the sphere which is equal to $4\pi R^2$. The gain of an antenna amplifies the radiation power density in the direction in which the maximum radiation from the antenna takes place. Mathematically, it can be given as

$$S = \frac{P_0 G}{4\pi R^2} = \frac{|E|^2}{\eta} \tag{2.7}$$

$$|E| = \frac{1}{R}\sqrt{\frac{P_0 G \eta}{4\pi}} = \sqrt{S\eta} \tag{2.8}$$

It can also be obtained by directing the emission of antenna far from the parts of the Gaussian emission sphere. We can also plot gain of antenna in the representation of the radiation pattern. Using the dB scale we can precisely observe the backward gain caused due to the side lobes of the antenna

$$S(\theta,\phi) = \frac{P_0 G(\theta,\phi)}{4\pi R^2} \tag{2.9}$$

$$U(\theta,\phi) = \frac{P_0 G(\theta,\phi)}{4\pi} \tag{2.10}$$

Where,

$S(\theta,\phi)$ = Represents power density.

$U(\theta,\phi)$ = Represents radiation intensity.

2.1.13 POLARIZATION

Polarization is the alignment of electromagnetic waves away from the source. There are many types of polarization that apply to antennas. Polarization of the radiated wave is defined as that property of an electromagnetic wave that describes the instantaneous variation in direction and comparative magnitude of the electric field vector while propagating. The above statement can be interpreted as the pictorial pattern traced as a function of time by the farthest point of the vector at a fixed location in space and the manner in which it is sketched, in the direction of propagation of wave is polarization. In case of radio antennas, it corresponds to the orientation of the radiating element in an antenna. From antenna construction we can predict what type of polarization it is going to provide. However, in case of directional antennas the polarization of radiated wave can be bit different from that of the major lobe radiation. Polarization may be classified as linear, circular or elliptical. Linear polarization includes vertical, horizontal and oblique polarizations. The circular polarization is the special case of elliptical polarization. Circular polarization takes place when the major and minor axis of the elliptical pattern becomes equal. The clockwise rotation of the electromagnetic wave is right hand polarization and on the other hand counter clockwise rotation is left hand polarization. Circular polarization can be Right Hand Circular Polarization (RHCP) or Left Hand Circular Polarization (LHCP) and vice verse applies for the elliptical polarization

Also for best performance we need to match up the polarization of the transmitting antenna and the receiving antenna else the performance degrades. Polarization is most important if you are trying to get the maximum performance from the antennas. The below diagram given in figure 1.10 represents in what manner radio propagated wave gets polarized as a function of field and time.

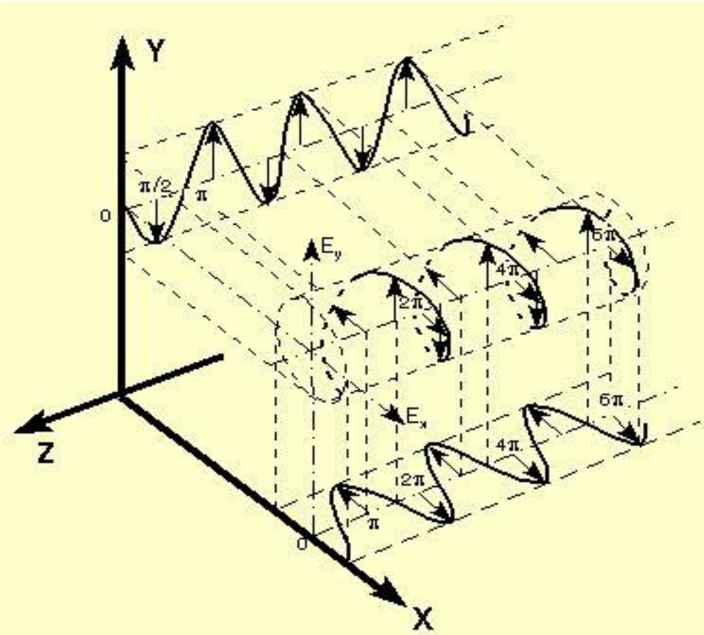


Figure 2.4 Propagation of wave and polarization

2.1.14 FIELD REGIONS

The properties and variation of an antenna radiation can be studied in three different regions namely

i. The reactive near field region,
ii. The Fresnel region (Near-field region) and
iii. The Fraunhofer region (Far-field region).

These later two regions are valuable to gain knowledge about the field structure in antenna designing and analysis. However, there are no precise boundaries specified for any antenna. But these boundaries can be approximated by using the relation that depends on the dimension of the antenna under study. In the far field of an antenna structure, we are far enough from the antenna so that we can discard the shape and dimensions of the antenna under study. We suppose that the electromagnetic wave is present and we make our analysis with respect to propagated wave only. Generated fields are in phase with each other. We know that fields are orthogonal to each other and also towards the propagation direction this simplifies the mathematical analysis as the dot product will lead to null. The relation used to specify the field regions is

$$d > \frac{2D^2}{\lambda} \tag{2.11}$$

The distance 'd' is called the far field region for an antenna if it satisfies equation (2.11) otherwise the distance is called near field region. Where D denotes the maximum dimension of antenna. One another point that is of great significance is that if the antenna's maximum dimension is not large enough with respect to wavelength then the field region may not exist. Hence, we need better results in the Fraunhofer region of the antenna.

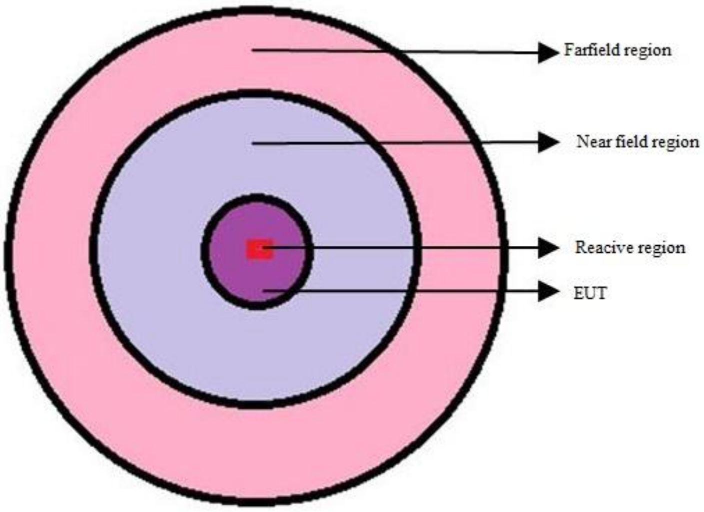


Figure 2.5 Field regions.

2.1.15 INPUT IMPEDANCE

Input impedance is defined as the impedance present by the antenna at its termini or can also be defined as the ratio of the voltage to the current at a pair of the terminals which are the input terminals of the antenna [1], [2] and can be given as

$$R_a = R_r + R_l \tag{2.12}$$

Where,

R_l = Loss resistance of antenna.

R_r = Radiation resistance of antenna.

R_a = Total antenna resistance.

The mathematical equation for the input impedance is

$$Z_{in} = R_{in} + jX_{in} \tag{2.13}$$

Where,

Z_{in} = Impedance at the terminals.

R_{in} = Resistance of the terminals.

X_{in} = Reactance of the terminals.

The imaginary part, X_{in} present in the equation represents amount of power preserved in the near field. The resistive part R_{in} can be studied in two parts, one R_r, called as radiation resistance and another R_l known as loss resistance of an antenna. However, the nature of power linked with the radiation resistance is emitted in a certain direction. Whereas, the power linked with the loss resistance is librated as heat by the radiating structure because of the dielectric or conducting losses [1], [3], [6]. Typically, 50 ohms is required for efficient and secure operation of the transmitting circuitry. For maximum power transfer requires proper impedance matching of an antenna system. In case a transmission line is present between the antenna and the transmitter or receiver then an antenna system must be selected with resistive impedance.

CHAPTER 3

LITERATURE REVIEW

BOOKS

[1] C.A. Balanis, 2005. This book of antenna theory is designed to meet the needs of electrical engineering and physics students at the senior undergraduate and beginning graduate levels and those of practicing engineers. The book presumes that the students have knowledge of basic undergraduate electromagnetic theory. This book contains all of the striking features including the three-dimensional graphs to display the radiation characteristics of antennas. A vast theory of the horn antenna is given in chapter 13 that has helped in clearing the doubts and furthering the research.

[2] Samuel.Y.Liao, 2011. The purpose of the book is to present the basic principles, applications of commonly used microwave devices and their characteristics and explain the techniques for designing microwave circuits. This book provides profound knowledge about the microwave frequency distribution, microwave transmission lines and microwave waveguides. The selection of the waveguides and there specifications were important part of the research. However, the selection of waveguide on the basis of frequency distributions was easy now.

[3] Mathew N.O. Sadiku, 2011. This book provides well described theory about microwave devices and its components. The antenna characteristics, transmission lines, impedance matching, different waveguides and electromagnetic wave propagation are well discussed and are used in the research.

[4] Samuel Silver, 1947. This book is concerned with the microwave antenna designing and has an elaborate explanation of the significant parameters about the designing and analysis of the microwave structure. Higher engineering concepts are explained hence it is important for a reader to have the basic concept of the subject so that he can understand the description of the book.

[5] S. J. Organdies, 2002. In this book the author has described about the electromagnetic waves and antenna theory. A thorough explanation of the both is given in the book. The reader can enhance his knowledge about the basics that concern electromagnetic wave propagation and elements by going through the book.

PAPERS AND JOURNALS

[6] M. A. Othman, M. Z. A. A. Aziz, N. Saysoo, A.R. Othman, 2012.

The paper deals with the designing of the wideband pyramidal horn antenna by using Approximation method for microwave imaging in detection and targeting systems. The designed antenna is operational in the C band of frequency range. This antenna can also be used in medical imaging system as it is operational in the medical frequency range too. The results from the simulation in the papers are well defined. The amount of return loss from 5.85 GHz to 8.2 GHz is below -10 dB which represents there is very low signal loss and hence antenna is good for use for the applications. Gain obtained after simulation is 15.19 dB. The gain produced must be around 15 dB as to achieve the target of approximation and to ensure the size of the horn antenna is small. The directivity is always proportional to the gain. As the gain increase the directivity also increases as well. Future works, the horn antenna design can be improved in terms of its structure. For this operational frequency range to be used and to increase the gain and directivity an exponential tapered ridges can be added inside the funnel of the horn antenna. As from the observations it is known that lower VSWR improves the return loss and signal transmission. Narrower beamwidth ensures the antenna propagate its signal accurately and concentrated in one direction with strongest emission. Thus, detection will be more precise that can be applied in medical imaging system. The antenna is designed and simulated using CST Microwave Studio which is another antenna designing tool.

[7] Christian Bruns, Ruediger Vahldieckand Pascal Leuchtmann, 2008. In the paper author describes a broadband double ridged horn antenna operational for 1 to18GHz. The horn is excited using a coaxial input feed. He in his paper described that when ridges are inserted in a horn antenna funnel the radiation pattern obtained does not maintain a single major lobe in the direction propagation of wave throughout the frequency range. Henceforth to simulate the horn antenna he had used a method of moment’s method. He also presents that the frequencies > 12 GHz, major lobe of the designed horn antenna in the radiation pattern splits into four other secondary lobes directing in other directions with a slight undulation of approximately 6 dB each from the major lobe. The results in the paper show better conformity with the simulation over the 1 to 18GHz frequency range. The operational bandwidth obtained is fair enough such that the horn can be caused for the signal transmission in the range. The ridges inserted in the horn however introduces the phase error in the structure but simultaneously enhances the bandwidth of the horn antenna. Moreover this paper indicates that other similar horn antenna with ridges also shows degradation in the performance at higher frequency. For this paper the drawback in the designing can be considered as the insertion of ridges as it increases the phase error, bulk of the antenna and instead increases the cost of antenna. Other methods can be used so that the antenna works efficiently and maintain its efficiency.

[8] Sohaib Ikram, Ghulam Ahmad, 2008. This paper presents the designing procedure and simulation of the horn antenna with optimized gain. The author has used MathCAD & High Frequency Structure Simulator, Ansoft HFSS software for the simulation of the structure. Simulation technique used for the purpose is finite element method which is efficiently employed by the use of HFSS. The simulated results present in the paper show great agreements with the calculated results. The analyzed and simulated horn was manufactured and tested. The results of the simulation and actually manufactured horn have very close agreement to each other. The purpose of this paper was to design a standard gain horn that can be used over a C band uplink wireless communication system.

[9] E. Palantei, L. Ramos Emakarim, A. Nugraha, N.K. Subaer, 2010. The author in the paper had designed various virtual horn antennas that can operate over various frequency ranges. This paper also presents how to numerically implement the horn antenna before it is to be designed. The software used is HFSS for the simulation and optimization of the horn antenna. This paper focussed on the variation of the flare angles of the horn and the response of these changes on the operation of the horn antenna. The flare angles decided for the horn antennas designed are the optimum flare angle hence the value of scattering parameter, desired gain and directionality, bandwidth and impedance matching are optimum. Other parameters for horn such as waveguide dimensions are kept constant. Additional modifications of horn antennas like double and quad ridges and both linear and circle forms and horn with cavity insertion are also outlined in the paper. Different structures of horn antenna with optimum gain and enhanced directivity have been constructed. The effect of these variations on the horn properties was found in the form of radiation patterns and scattering parameters. The author in this paper observes that every 2.5^o change of flares angles results the substantial variation of the impedance, voltage standing wave ratio and bandwidth. Certain change in flares angles setting within the interval 7.5^o to 20^o considerable variation in the operational bandwidth and the radiation properties for the pyramidal horn antenna. From the paper it was concluded that the optimum value of flares angles to achieve the large bandwidth, high gain and directivity was found at the range 35^o to 37^o.

[10] D. U. Nair1 & Chetan Zele, 2012. The author in this research about horn antennas presents an enhanced design for horn antenna. The horn funnel is filled with the dielectric named PTFE, poly tetra fluoro ethylene with the thickness of 3 mm. By using this enhancement the author was capable of reducing the dimensions of the pyramidal horn. Designed horn resulted in narrow beamwidth and higher directive gain. He had compared the two distinctive horns first with no dielectric involved in the design and other with the dielectric loaded funnel. The designed horn antenna has an operational frequency of 26 GHz. The waveguide used with the funnel of the horn is a waveguide integrated with the substrate. Such waveguides are also referred to as SIW's. This type of horn antenna is best suited for detecting and targeting applications.

[11] Liu Guochang, Shao Jinjin, Ji Yicai, Fang Guangyou, Yin Hejun, 2013. The author in the paper has designed and analysed a wideband horn and had achieved agreeable antenna parameter calculations. The designed antenna structure is based on the Ground Penetrating Radar application. The author had proposed that the insertion of tapered structures and dielectric materials with the higher relative permittivity might be preferred to decrease the size of horn radiator. By doing so the bandwidth of the antenna can be increased efficiently also. In this paper if the reflection of the radiation from the aperture is to be done then the dielectric loading of funnel can do the job. Dielectrics can also be used from outer side of the horn walls so as to reduce the extra radiations from the external walls. The author had also made a comparison of his design with the basic horn antenna design. The results attached shows that the proposed design has better antenna performance than the basic design. The designed horn antenna was simulated for the complete frequencies ranging between 0 to 12 GHz. Obtained VSWR, is found to be in the range below 2, which is a mandatory condition for microwave structures to operate properly in the microwave frequency range. TEM wave was injected into the horn antenna that has to be transmitted.

[12] Kerim Guney, 2002. The author has presented two design methods for designing pyramidal horn antennas. For the designing of optimum gain pyramidal horn initially equations are solved numerically. The author had determined the gain by not approximating the path length error. All the design constraints are calculated from the simple and explicit analytical formulas. Other designed structures are given in the paper to demonstration the performance of the design methods.

[13] Sadia Khandaker, Monika Mousume Haque, 2010. The authors in this paper have worked on the design of rectangular horn antenna for microwave test setup. Simulation of the designed pyramidal horn is done using HFSS. Along with the simulation the journal also provides explanation about the different characteristics and parameters of the antenna. An explanation on the basics of antenna is also given. Results and analysis obtained are valid and can be used for the test of the other horn antennas. However, the construction of the horn antennas is simple in terms of paper and pencil. But according to author when it comes to fabrication it was far more difficult than anticipated. For the test of the designed pyramidal horn transmission of a wave is illustrated.

[14] Konstantinos B. Baltzis, 2010. In his study of the rectangular horn the author was capable in improving gain of the rectangular horn radiator. Improved formulae for the gain obtained by of the pyramidal horn antenna are presented. This paper had concentrated his attention only on the Gain of the antenna. Lot of calculated values for the plane gains are attached in the paper. The authors have also focused on the significance of the gain in the communication. According to the authors the tapering induced in the antenna aperture applies limitation on the gain of antenna in Fraunhofer region. For the precise calculation for the gain reduction for antenna under transmission include complex formulation like Frensel integrals. Thus, for proper computation of this efficient numerical solving techniques must be applied. The author in this paper has used polynomial equations that can be used to approximate GRF for the horn antennas. Gain reduction factor for sectoral horns have also been calculated in the paper. The formulas derived in the paper are computed using regression polynomial analysis. These expressions require least mean square algorithm to justify the solution of the polynomial equations. The obtained results are exact and justify the exactness as they are compared with the previously obtained results. Previous work in the literature was extended. These computations provided in the paper can be applied to the horn antennas which are more prone to high values of phase errors.

[15] Yahya Najjar, Mohammad Moneer, Nihad Dib, 2007. The horn antennas does have an optimum values for their dimensions and results however different techniques can be used to compute these values. New technique to calculate the dimensions of the horn antenna is described. For this they have used differential evolution technique and the particle swarm optimization technique to obtain the dimensions of the new design for the pyramidal horn antenna. Length approximation is not required for this design method for the horn hence the new method is better than the previous design methods. The drawback in this design technique is that it requires large input intake for the computation and for exactness of this method the correctly designed neural network is required. Along with the new design equations the paper also includes the specifications of the waveguides that are being used with the rectangular horn antenna.

[16] Marco Antonio Brasil Terada, Leandro de Paula Santos Pereira, 2011. This research familiarizes a procedure for determining the optimum design of pyramidal horn antennas. For the optimum design new design equations are proposed which can be resolved numerically or analytically. Usually, design procedures for pyramidal horn antennas employment constant values for the quadratic phase errors. According to the research the efficiencies and phase errors of the optimum design are variables and be contingent on the design requirements. According to the research made, the variations rely on the anticipated gain of the antenna. Anticipation can be mad that the aperture efficiency is close to 0.49 for long antennas on the other hand for small antennas the efficiency can reach values as low as 0.42.

[17] Daniyan O.L, Opara F.E, Okere B.I, Aliyu N, EzechiN, Wali J., Eze K., Chapi J, Justus C. and Adeshina K.O, 2014. The main focus of the author remained on the considerations of the horn antenna which are fundamental principle employed in the design of the compact horn antenna suitable for astronomic applications at L Band. The author also used the approximation but excited the antenna structure using coaxial cable. The approximation of the slant heights and coaxial feed are well defined. No simulation results are provided but the paper provides profound mathematical equations for designing. The paper also concludes that microwave communication system where horn antennas are employed the integrity of the signal received or transmitted depends on the design considerations of the horn antenna. It is necessary to define critical parameters upon which such design would be predicted for example deciding the frequency of operation and the bandwidth of the antenna.

[18] Shubhendu Sharma, 2014. A linear polarized high gain pyramidal horn antenna is presented in the paper with suppressed side lobe levels. According to the author the dimensions of the horn will define the characteristics of the horn antenna. For the designing and simulation purpose he has used Personal Computer Aided Antenna Design (PCCAD) version 6. He had compared is results with the previous experimental data. His conclusion of the study is that when the E plane and H plane aperture length of pyramidal horn antenna gain increases on the other hand if E plane and H plane horn length of the horn are increased the gain first decreases and then remains constant.

[19] Arvind Roy, Isha Puri, 2015. This paper is on the designing and analysis of the X band pyramidal horn antenna applying Approximation method. The method of designing is same as we will use in this report for the enhancement and design of the Ku band Pyramidal horn antenna. The calculation of dimensions and the validation of the approximation method are done on the Matlab and the designing of the pyramidal horn is done on the HFSS. The results obtained when compared with the calculated values are extremely close to each other. The design method is for optimum pyramidal horn configuration. The designed horn antenna results in optimum antenna characteristics. The flare angles of the horn calculated are optimum and validate the optimum flare angle that a horn antenna must have for specific application.

CHAPTER 4
ABOUT THE RESEARCH

4.1 SCOPE OF THE STUDY

Pyramidal Horn antennas have several advantages over other conventional antennas such as their light weight volume and higher directivity. The main limitation in the ever increasing applications of these antennas is their size. Also the pyramidal horn antennas have to be considered as per the designated waveguide. Therefore, selecting a specific waveguide is significant. There is increasing demand for compact antennas structure. However, from communication point of view pyramidal horn antenna are playing important role. This antenna can be used for applications in wireless communications, for cosmological experiments based on the study of the Cosmic Microwave Background sometimes termed as astrophysical experiments. These pyramidal horn antennas are significant where directivity of the signal or information is of main concern. These pyramidal horn antennas are still underneath significant improvements and advance more changes may be obligatory for their better performances. The designed antenna can be used with the auto tracking systems for the correction of position of satellites in space. This can be done by considering the propagation of the received signal. The error signal generated from the auto tracking system providing information about the satellite's position relative to the centre of the beam due to antenna

4.2 OBJECTIVE OF THE STUDY

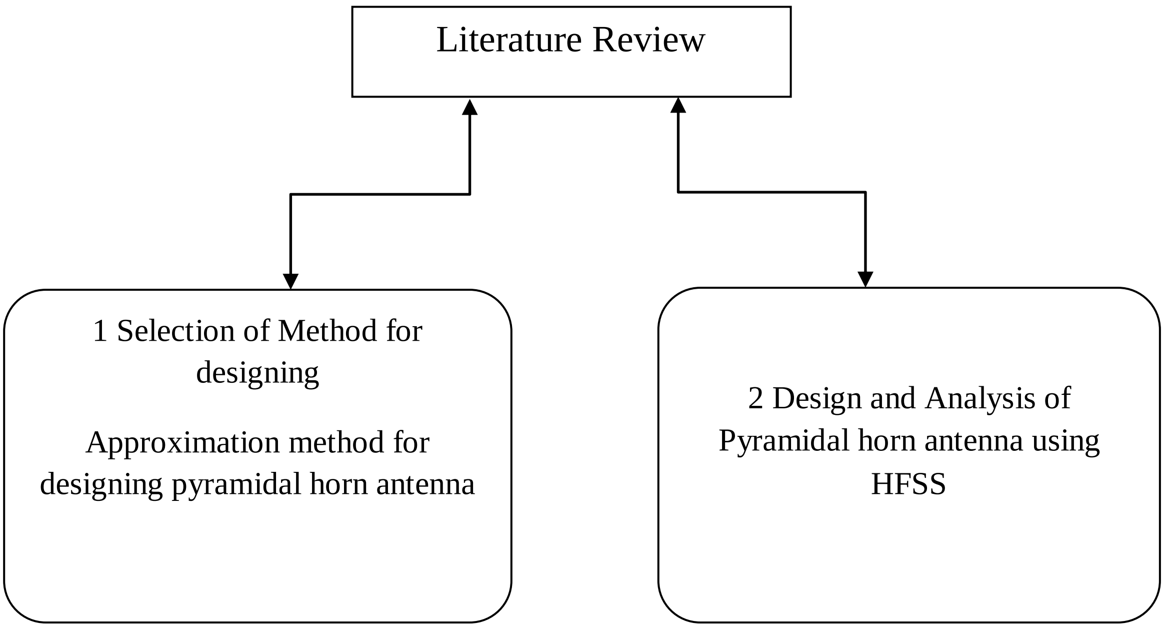
The pyramidal horn antennas are vastly used in satellite communication. Their ridged structure and low losses make it a better choice for the use. The objective of this research is to enhance and design Ku band pyramidal horn antenna used in satellite beacon (application) using high frequency structure simulator (HFSS). The question arises why the enhancement is required the answer is increase in demand for better services and low signal losses. The first objective will be to validate the design of pyramidal horn antenna using Approximation method. The second objective is that the pyramidal horn antenna must operate efficiently with the small power intake. The signal loss should be minimized such that signal transmission from the designed antenna is enhanced. The beamwidth of the antenna should be small such that position accuracy for the transmission of signal can be achieved. Last but not the least the design should be cost efficient

4.3 EXPECTEDOUTCOME OF THE STUDY

The designed pyramidal horn antenna is supposed to have better performance in terms of reception and transmission. The gain and directivity of the antenna will be more satisfying and the designed antenna structure will work for complete Ku band frequency applications as for the specific, we can say satellite beaconing and television broadcasting. The beamwidth of the designed Pyramidal horn antenna would be narrow that will increase the position accuracy for detection and reception of the signal. The antenna should perform profoundly with low power intake. The loss in the signal would be very small and the designed pyramidal horn antenna would be cost efficient. The pyramidal horn antenna will be designed keeping in consideration that the design of pyramidal horn is optimum. We will try to maintain the size of the horn antenna as small as possible because in case of horn antenna the size of the antenna increases as we increase the operational frequency. One another main aspect that we will work on is that the ridges are excluded as they increase bulk to the horn funnel and may cause impedance mismatch. The antenna should operate better without including ridges to the design. If the operation is profound then the antenna may not require any complex intake of ridges. The efficiency of the rocket is directly proportional to the weight of the satellite. Hence, by doing so, the designed antenna would be more preferable for the satellite communication. Thus, light weight pyramidal horn antennas are preferred without any compromise on its efficiency.

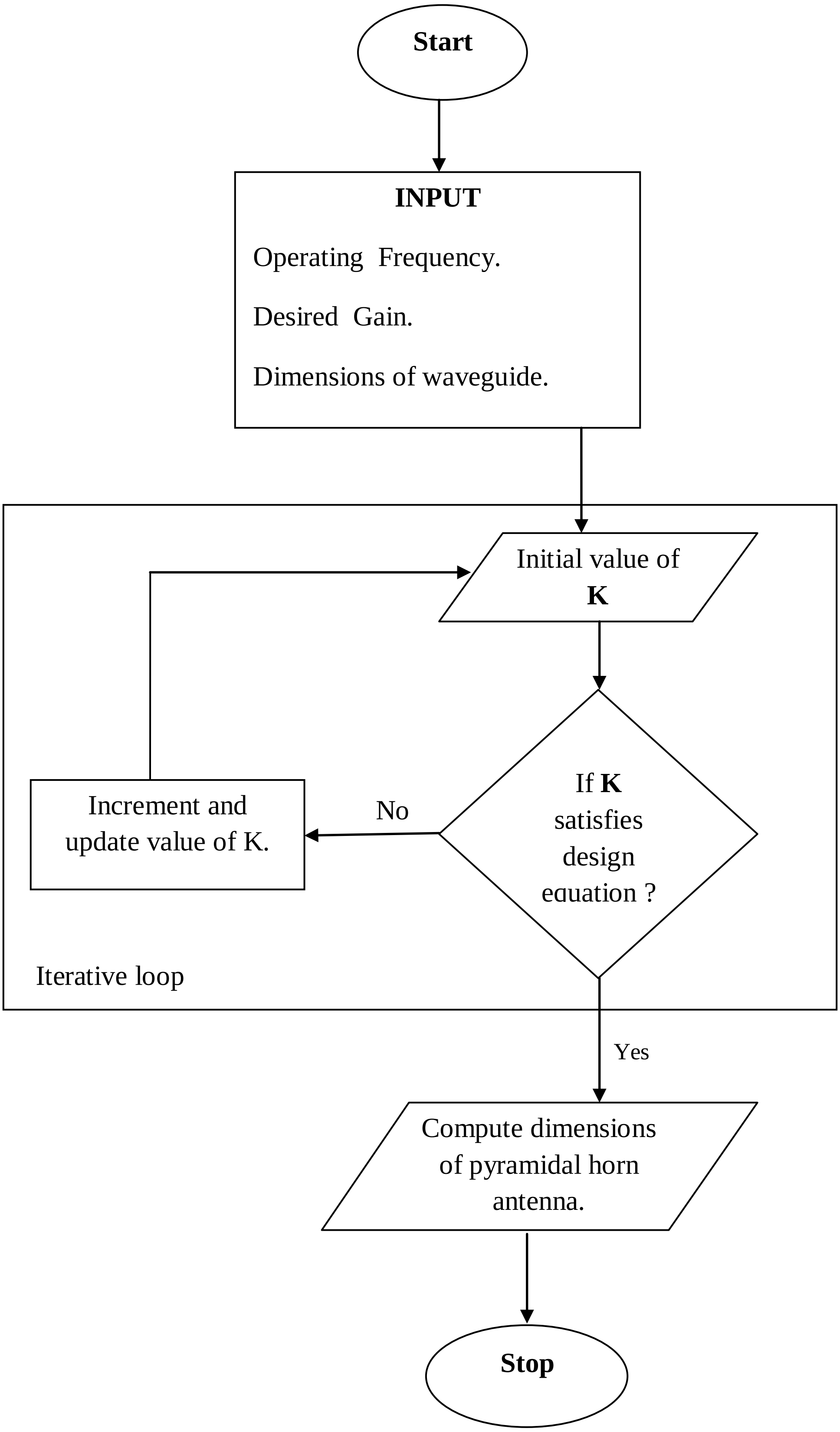
4.4 RESEARCH METHODOLOGY

The research done is an exploratory research sometimes also called as formulative research. The problem is formulated for more precise investigation and for developing the working hypothesis form an operational point of view. Firstly, the literature survey was made about the subject of the problem. For this the secondary data collection methods was chosen. After we are done with the literature survey then the problem is formulated using Approximation method. What we actually require in this method is operating frequency which is probably one of the Ku band frequencies, the dimensions of the waveguide used in that frequency range and the desired gain which we want our antenna to possess. The design equation of the horn antenna contains the approximated variable. What we need from the equation is the value of that approximated variable. This value is selected in a manner that it satisfies the design equation, else the minimum positive value that does not affect the integrity of the design. This approximated value is then used to calculate dimensions of the pyramidal horn antenna. To find the approximated value an iteration method is required as, we don't know for which value of the variable the equation may converge. For the iteration technique MATLAB 2010b was used and below is the flowchart that defines the working of the iteration loop and implementation of the approximation method. After we had our dimensions we have to implement and simulate the design using HFSS software tool such that we can analyze or simulate our constructed pyramidal horn design. The design process in the HFSS is also defined in a flow chart so that a better understanding in designing using HFSS can be constructed.

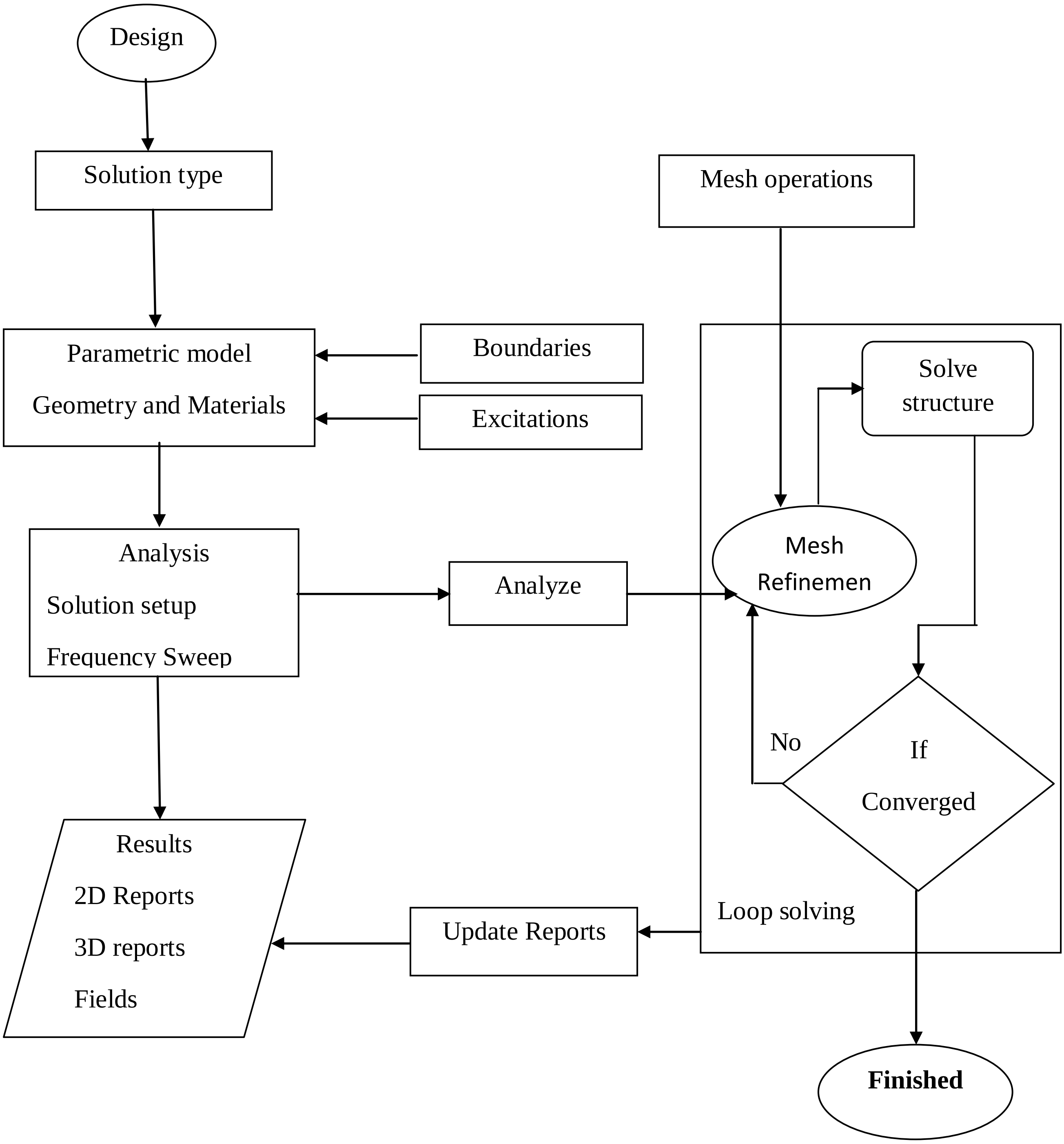


Flow chart 4.1 Research Process.

The above flow chart represents how the research was processed. First of all, after reviewing literature we selected the method that we are going to use for designing of pyramidal horn antenna. Afterwards, we will construct the design and simulate the structure for the results using High Frequency Structure Simulator. We will try to enhance the parameters that can be of significant use over the Ku band frequencies such as sharp beam, improved signal transmission and reception the enhancement include insertion of microwave dielectric cavity. The flowchart 4.2 describes how the approximation method works and how it is implemented to compute the dimensions of the horns structure. The flowchart 4.3 describes the design procedure that should be followed in the HFSS to simulate the radiating antenna structure.



Flowchart 4.2 Validation of Approximation method.



Flow chart 4.3 Design process of EM problems in HFSS.

Above given are flow charts for representing research methods and research process. Supposing that the reader had understood the method of implementation and designing using HFSS we move forward for the implementation of the experimental work done earlier on the pyramidal horn antenna designing. This experimental work done includes the implementation of pyramidal horn form the selected base paper. We will compare the simulated results with the simulated results from our base paper and then we will use the process to design Pyramidal horn for the Ku-band frequency range and enhance it.

CHAPTER 5

EXPERIMENTAL WORK DONE

5.1 IMPLEMENTATION OF THE BASE PAPER:

The design from the base paper was designed and simulated with HFSS. For the designing of pyramidal horn Approximation method is used. The design equations most commonly used for designing of pyramidal horn antenna is

$$(2\xi - 1)\left(\sqrt{2\xi} - \frac{B}{\lambda}\right) - \left(\sqrt{\frac{3}{2\pi}}\frac{G}{2\pi\sqrt{\xi}} - \frac{A}{\lambda}\right)^2\left(\frac{G^2}{6\pi^3\xi} - 1\right) \tag{5.1}$$

This design equation has to be solved iteratively for the value of ξ which is defined as K in the Flowchart 4.2, using trial and error method, which is difficult and time consuming. However, the first value of ξ can be taken as

$$\xi = \frac{G}{2\pi\sqrt{2\pi}} \tag{5.2}$$

The dimensions of the design are given as; the waveguide used for the design is WR-137 with A = 34.3 mm and B = 15.55 mm. The value of ξ calculated by using equation (5.2) is 2.0078. After applying the iterative process to find the value that satisfies the equation (5.1) the value of ξ is found to be 2.7833. As the computed value of P_E is equal to P_H hence, the design is valid. The design can have realistic model.

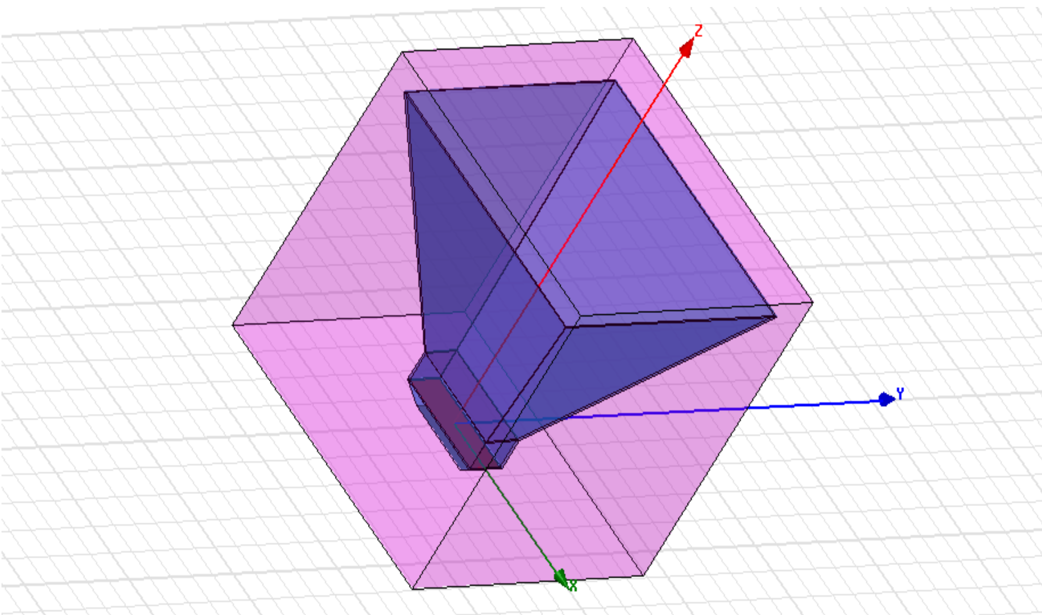


Figure 5.1 Designed pyramidal horn antenna.

TABLE 5.1 Dimensions of Pyramidal Horn antenna (L band).

A (mm)	B (mm)	A1 (mm)	B1 (mm)	L_E (mm)	L_H (mm)	L_1 (mm)	L_2 (mm)
34.3	15.55	89.1	101.1	119.3	62.1	108	43.1

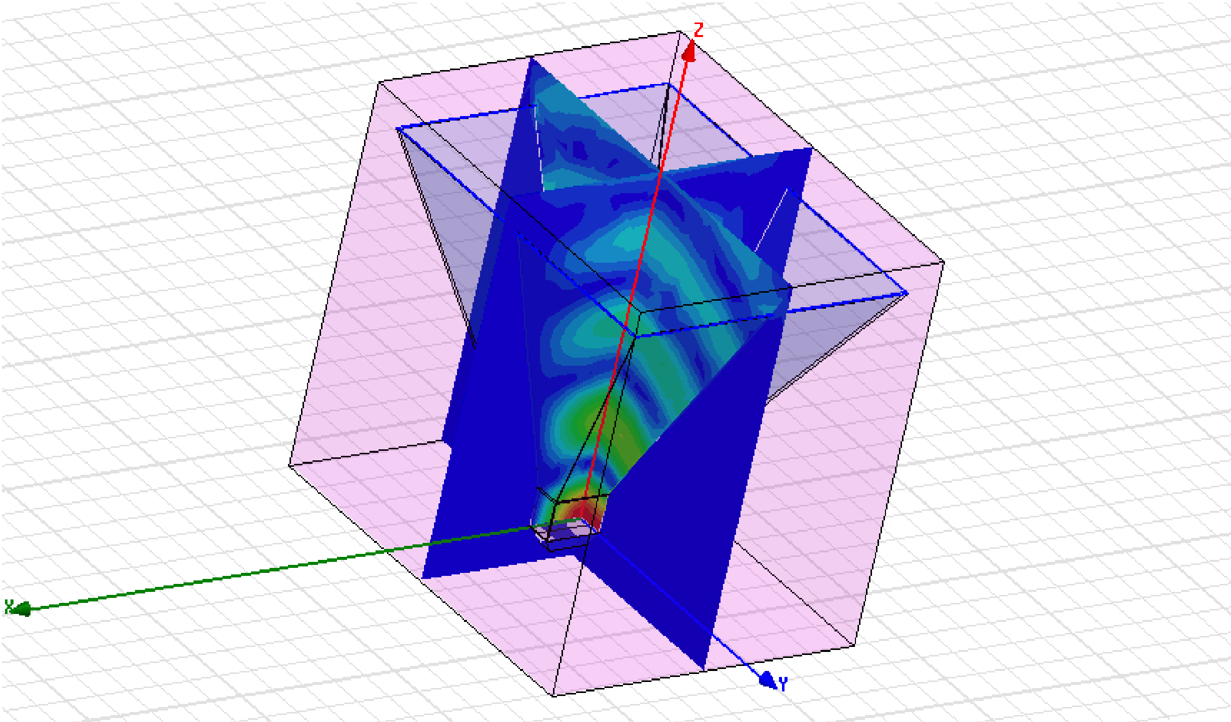


Figure 5.3 Emission from designed pyramidal horn antenna.

From the base paper same values of rectangular waveguide have been taken. The operating frequency is taken to be 7 GHz for the design in the paper. Thus, same is taken for our simulation. The desired gain of horn antenna is assumed to be 15 dB. Now, it is easy for us to construct solid model of the computed pyramidal horn antenna, having in hand all the dimensions required to be representing in a proper Cartesian coordinate system. The comparison between the results obtained after simulation are the return loss, obtained directivity, voltage standing wave ratio (VSWR), and radiation pattern of the base paper and designed pyramidal horn are represented below. The results when compared are in very close agreement with each other. That justifies the method is applied correctly. Also due to use of different software approaches for simulations there may be some variation in the values representations. On the other hand if better system specification was there then the results would have be more accurately calculated and represented. The simulation of the design validates our approach of design. Now, we will design for the Ku band frequency range and will try to enhance the operation of the Pyramidal horn antenna.

5.2 COMPARISON OF RESULTS

The compared results with returnloss, VSWR, gain and radiation pattern of the base paper and the designed pyramidal horn are shown next.

5.2.1 S-PARAMETER VS FREQUENCY

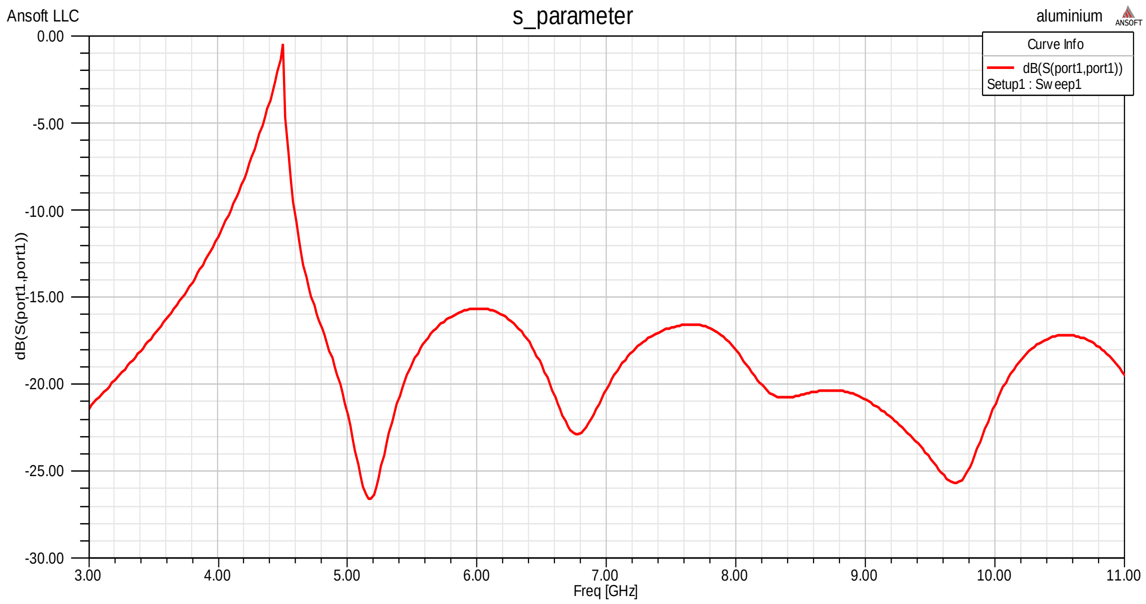


Figure 5.4 S-parameter Vs Frequency.

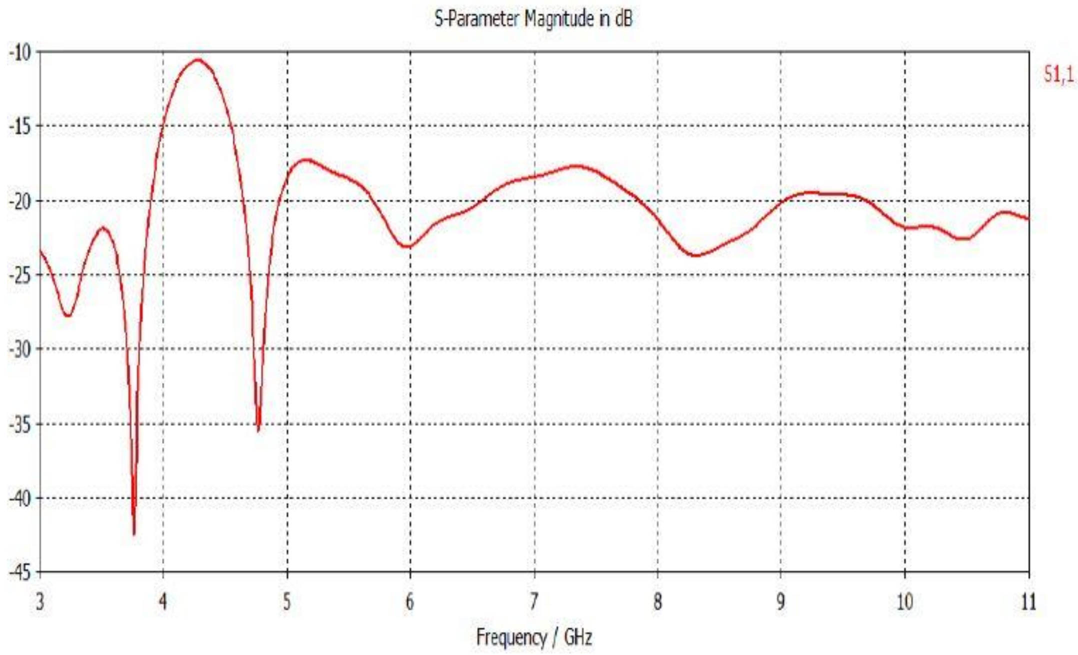


Figure 5.5 S-parameter Vs. Frequency (Base paper).

The returnloss obtained is below -10 dB and antenna is working in the range for the desired C band of frequency.

5.2.2 VSWR GRAPH

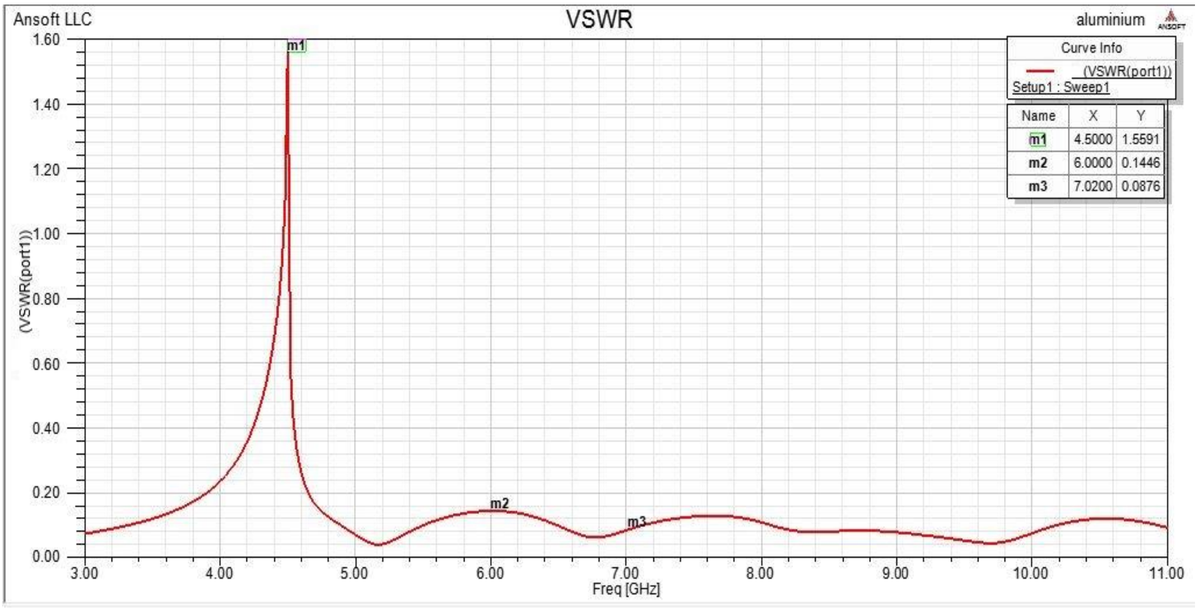


Figure 5.6 VSWR Vs. Frequency.

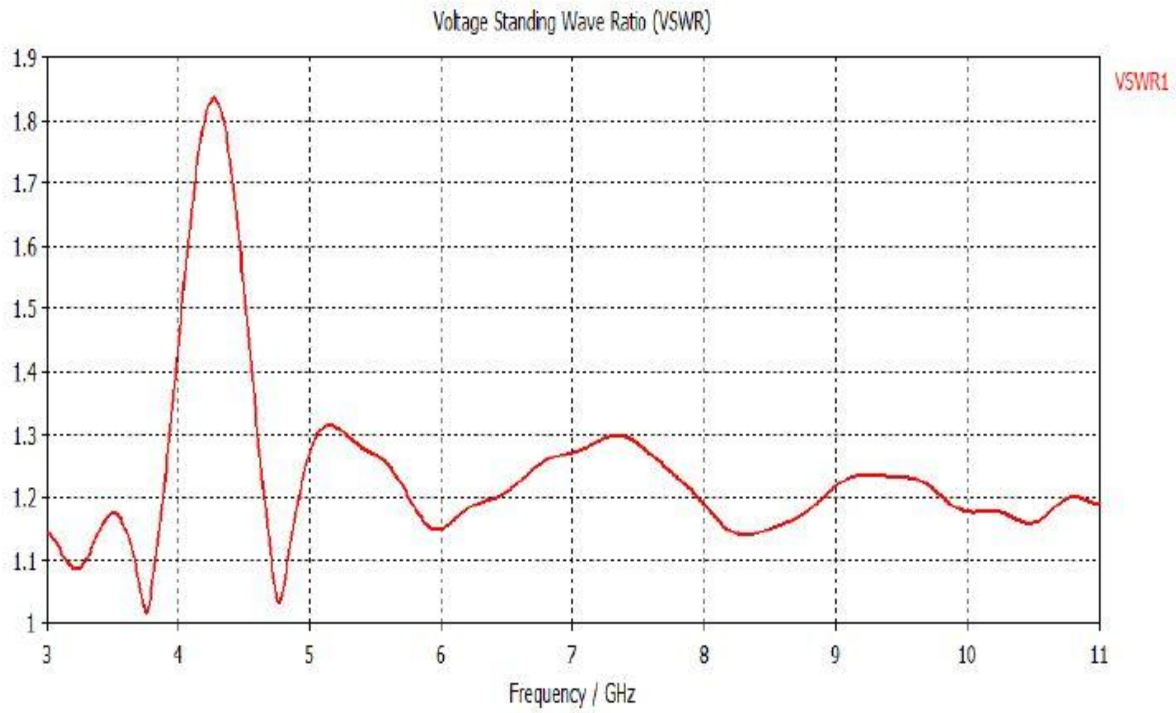


Figure 5.7 VSWR Vs Frequency (Base paper).

As we can see from the figures, the value of VSWR for our simulated design is better than the VSWR obtained by the base paper simulation. The value of VSWR is below 2 and acceptable for the operation of antenna. It also tells us that there is no mismatch in the impedance of the designed antenna and antenna can operate properly in this frequency range.

5.2.3 3D RADIATION PATTERN AND GAIN

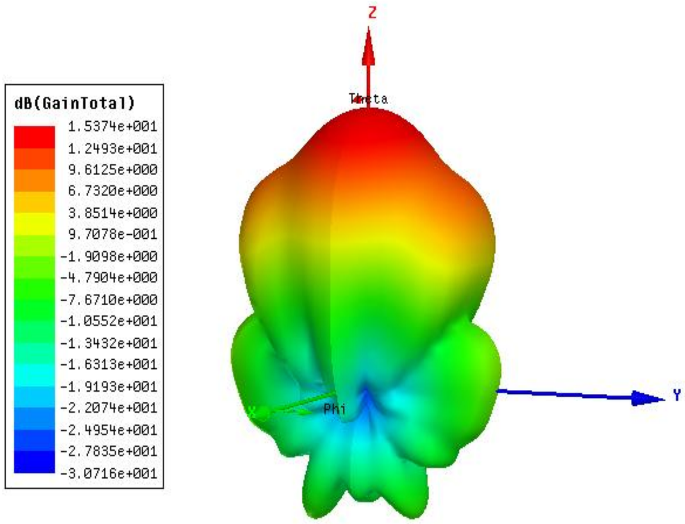
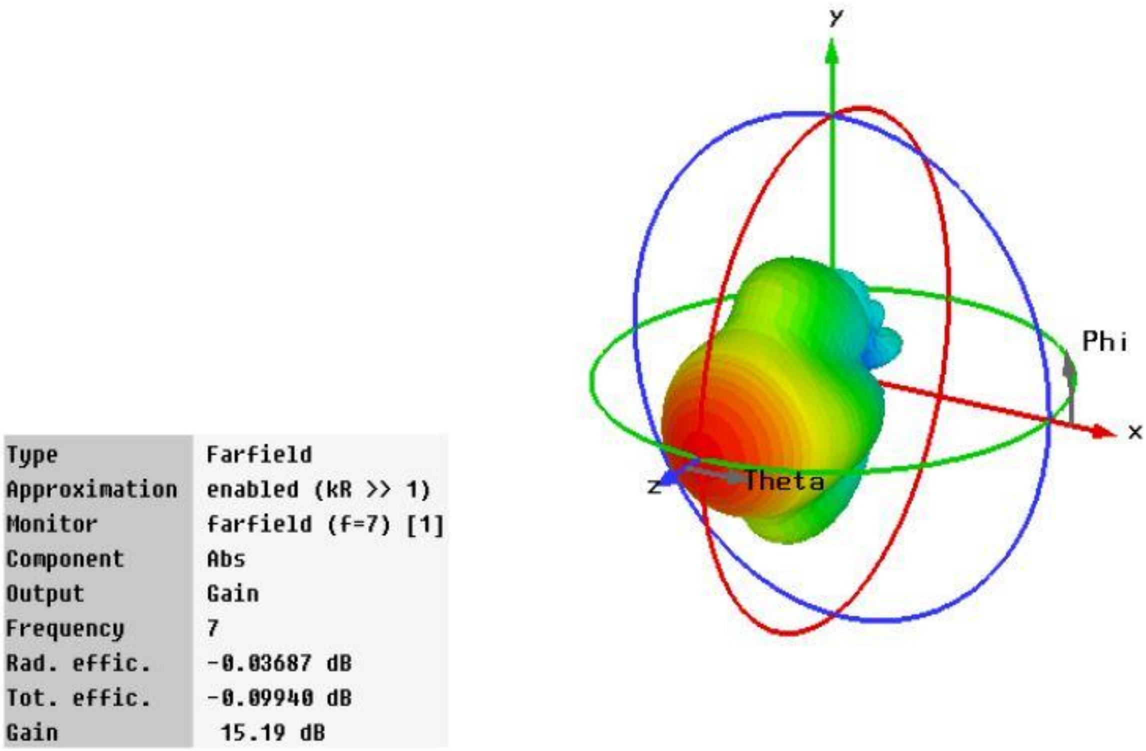


Figure 5.8 3D Radiation Gain Plot.



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=7) [1]
Component	Abs
Output	Gain
Frequency	7
Rad. effic.	-0.03687 dB
Tot. effic.	-0.09940 dB
Gain	15.19 dB

Figure 5.9 3D Gain Plot (Base paper).

The value of gain obtained is 15.37 dB and is better than the gain in base paper in which maximum gain of 15.19 dB is obtained.

5.2.4 RADIATION PATTERN

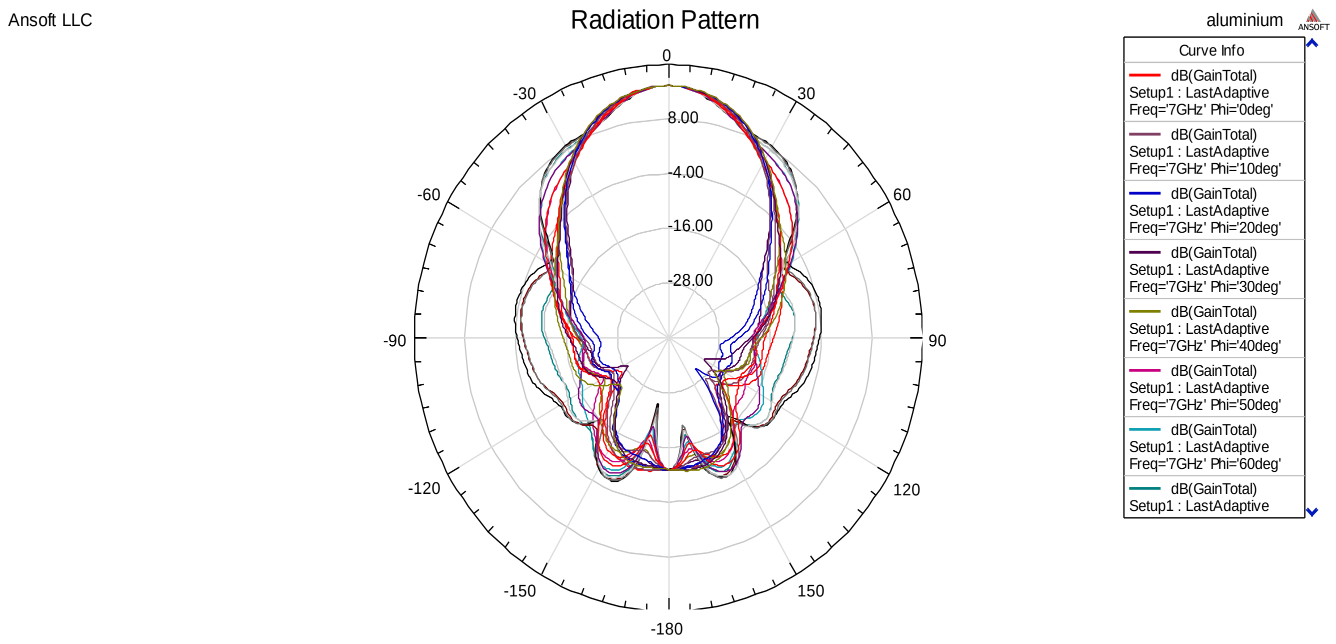


Figure5.10 Radiation pattern

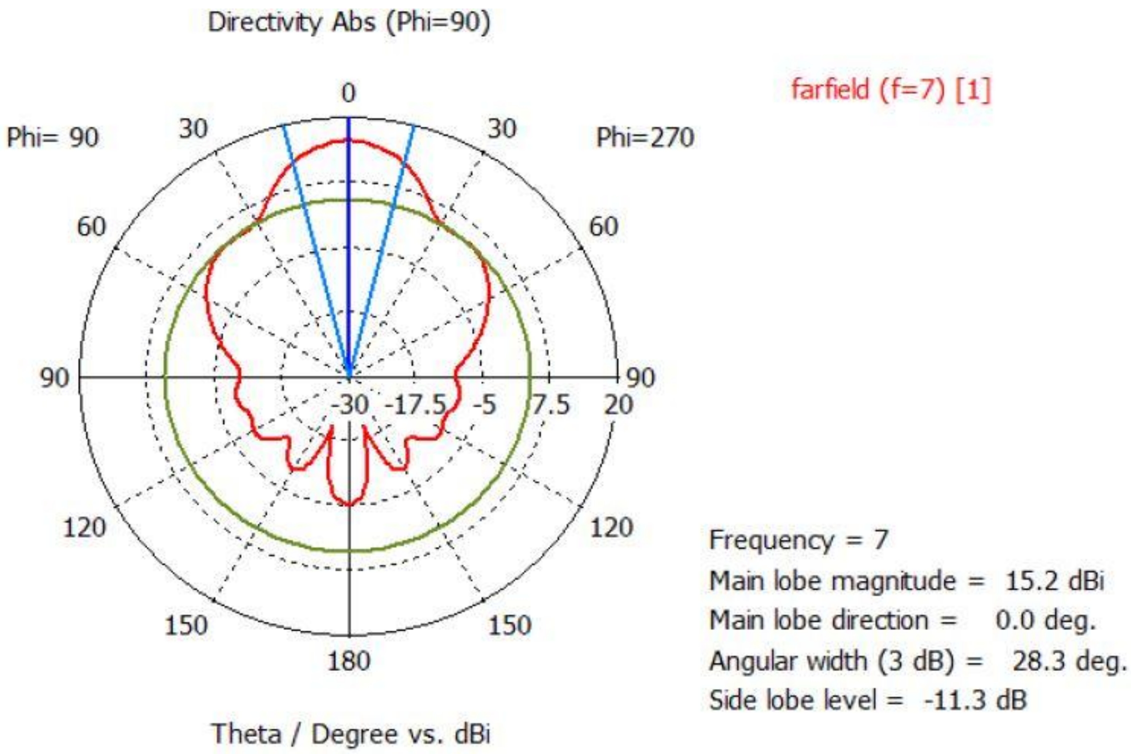


Figure 5.11 Radiation pattern (Base Paper)

The obtained radiation pattern resembles radiation pattern of the base paper to a great extent.

CHAPTER 6
FORMULATION AND DESIGNING OF ANTENNA

6.1 FORMULATION OF PYRAMIDAL HORN ANTENNA

For representation, very commonly used notations for the variables are used such that we can easily understand which variable refer to which plane of the pyramidal horn antenna. In the notations subscript E and H refers to the E plane and H plane respectively. Further explanation about the variables is done below.

To design a pyramidal horn with E-plane, the dimensions are B, B_1, L_E, L_1 and P_E. On the contrary the H-plane dimensions are A, A_1, L_H, L_2 and P_H. The Pyramidal horn is connected with feeding rectangular waveguide having inner dimensions A and B, gain G which is generally known through the use of waveguide data sheet can be up to the requirement of application. The values of A and B are standard values for the waveguide decided by the IEEE. The other parameters are then can be formulated and calculated knowing these three values. The method for the designing used is Approximation Method. The name is so because in this method we need to approximate value of ξ initially assumed by equation (6.2). Now, one can manually calculate the value but the easy way is to calculate the using a fast and programmable computing tool such as Mathcad, Matlab, Turbo C, or Dev C++. The reason to use such source is because the convergence of the design equation may require thousands of iterations for profound approximation. Then pyramidal horn is designed easily having each parameter in hand. The parameters in this report are calculated using MATLAB 2010b.

There are different design methods used for designing pyramidal horn antennas as used in [1], [3] and [7]. The design equations most commonly used for designing of pyramidal horn antenna is given by equation (6.1).

$$(2\xi-1)\left(\sqrt{2\xi}-\frac{B}{\lambda}\right)-\left(\sqrt{\frac{3}{2\pi}}\frac{G}{2\pi\sqrt{\xi}}-\frac{A}{\lambda}\right)^2\left(\frac{G^2}{6\pi^3\xi}-1\right) \tag{6.1}$$

This design equation has to be solved iteratively for the value of ξ using trial and error method, which is difficult and time consuming. However, the first value of ξ can be taken as

$$\xi=\frac{G}{2\pi\sqrt{2\pi}} \tag{6.2}$$

Using equation (6.2) in equation (6.1) the design equation becomes

$$(2\xi-1)\left(\sqrt{2\xi}-\frac{B}{\lambda}\right)-\left(\sqrt{3\xi}-\frac{A}{\lambda}\right)^2\left(\frac{G^2}{6\pi^3\xi}-1\right) \tag{6.3}$$

Now we can assume that the actual value of ξ that satisfies the design equation is near to value of ξ calculated by (6.2). The equation is solved using MATLAB 2010b as for the faster solution in case of iterative process. In the report the pyramidal horn is designed optimally using design equation (6.1). Once ξ is calculated the other dimensions of pyramidal horn can be calculated as

$$L_E = \lambda\xi \tag{6.4}$$

$$L_H = \frac{\lambda G^2}{8\xi\pi^3} \tag{6.5}$$

Where,

L_E = slant height of horn in E-plane.

L_H = slant height of horn in H-plane.

The width in both the electric and magnetic plane direction for a pyramidal horn antenna are dependent upon the measure of intended wavelength λ and are given by [1], [6], [19].

$$A_1 = \sqrt{3\lambda L_H} \tag{6.6}$$

$$B_1 = \sqrt{2\lambda L_E} \tag{6.7}$$

Where,

A_1 = Horn width in H-plane.

B_1 = Horn width in E-plane.

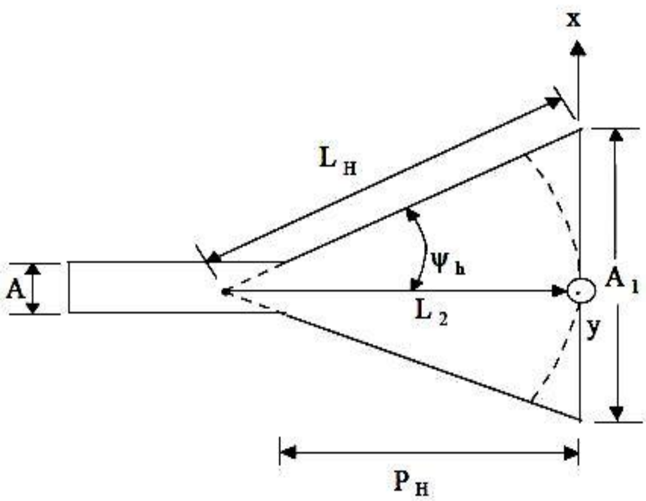


Figure 6.1 H plane view

The dimensions can be easily understood by the interpretation of the Figure 6.1 and Figure 6.2. The following diagrams show how the configuration of the horn looks like and what are the conditions that should be satisfied for the optimum design for a rectangular pyramidal horn antenna.

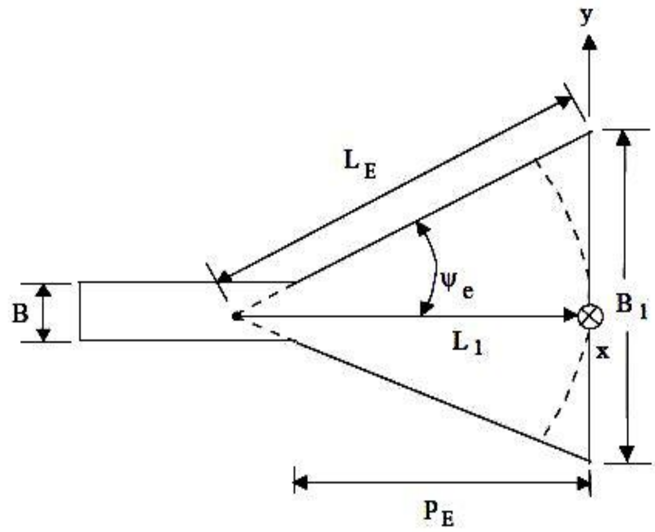


Figure 6.2 E plane view.

The other dimensions of the pyramidal horn can be calculated using following formulae

$$P_E = (B_1 - B)\sqrt{\left(\frac{L_E}{A_1}\right)^2 - \frac{1}{4}} \tag{6.8}$$

$$P_H = (A_1 - A)\sqrt{\left(\frac{L_H}{B_1}\right)^2 - \frac{1}{4}} \tag{6.9}$$

$$L_1 = \sqrt{P_E{}^2 - \left(\frac{B_1}{2}\right)^2} \tag{6.10}$$

$$L_2 = \sqrt{P_H{}^2 - \left(\frac{A_1}{2}\right)^2} \tag{6.11}$$

Where,

L_1 = Median of horn in E plane and

L_2 = Median length of horn in H plane.

The conditions that one must follow while designing the pyramidal horn antenna for the practical implementation is that, the pyramidal horn design is not possible if $P_E \neq P_H$. In other words we can say that it is not a practical design if it doesn't follow $P_E = P_H$. Hence, it is a necessary condition for the designing of pyramidal horn antenna. Another condition that must be taken under consideration is that the value of A is always greater than B. If $A = B$ then the pyramidal horn takes the shape of square resembling to the ideal shape of pyramid structure. Once all the conditions are satisfied and all the values are calculated the pyramidal horn can be easily designed.

6.1.1 FLARE ANGLE FOR PYRAMIDAL HORN ANTENNA

Other horn antennas such as the sectoral electric plane horn and magnetic plane horn antennas have only one flare angle. Whereas, in the pyramidal horn antenna there are two flare angles one in the E plane and other in the H plane. Calculation for optimum flare angles for the E-plane and H- plane are given by

$$\psi_e = \tan^{-1}\left(\frac{B1}{2L_E}\right) \tag{6.12}$$

$$\psi_h = \tan^{-1}\left(\frac{A1}{2L_H}\right) \tag{6.13}$$

Where, ψ_e = Flare angle for E plane of the funnel.

ψ_h = Flare angle for H plane of the funnel.

In case ψ_e and ψ_h are found to be equal the horn took the shape of perfect pyramid horn antenna. The pyramidal horn antenna do presents the variations in the operation if the values of the flare angles are varied significantly. According to [3], [19] there is significant change in impedance bandwidth and VSWR for the variation of 2.5^o change in flare angles. If the flare variation is set in the range between 7.5^o to 20^o provides significant change in bandwidth in average of 50MHz. However, to obtain higher directivity, gain and higher bandwidth of the pyramidal horn antenna the flare variation should be in the range of 35 ± 2^o. The whole idea of using an electromagnetic horn is that it produces uniform phase front as it has a large aperture area than the aperture area of the waveguide used. This increases the directivity and hence the gain. Principle of equality also applies in the horn funnel design but in not the same way. We assume that the phase deviates but by the small amount then the actual amount. We don't stuck with the wave near the funnel opening is in phase exactly. The calculated flare angle for the horn are $\psi_e = 14.5736^o$ and $\psi_h = 11.0630^o$.

6.1.2 GAIN AND DIRECTIVITY OF ANTENNA

The gain and directivity for the designed pyramidal horn antenna can be calculated in the sense that it should be dependent on the design dimensions. Thus for the design the calculated gain should be close to the assumed gain and the directivity must be close to the simulated value of directivity. The value of gain and directivity can me give by

$$G_c = \frac{2\pi A_1 B_1}{\lambda^2} \tag{6.14}$$

$$D_c = \frac{7.5 A_p}{\lambda^2} \tag{6.15}$$

Where,

G_c = Calculated gain.

D_c = Calculated directivity.

6.2 DESIGNING

The designed horn antenna is a Ku-band pyramidal horn antenna working for whole Ku band frequencies. Before we start with designing we need to evaluate the dimensions of the pyramidal horn antenna. And for this, we must satisfy equation (6.1) for the approximate value of ξ. After we satisfy the Approximation method the dimensions can be calculated using equations (6.4) to equation (6.11).

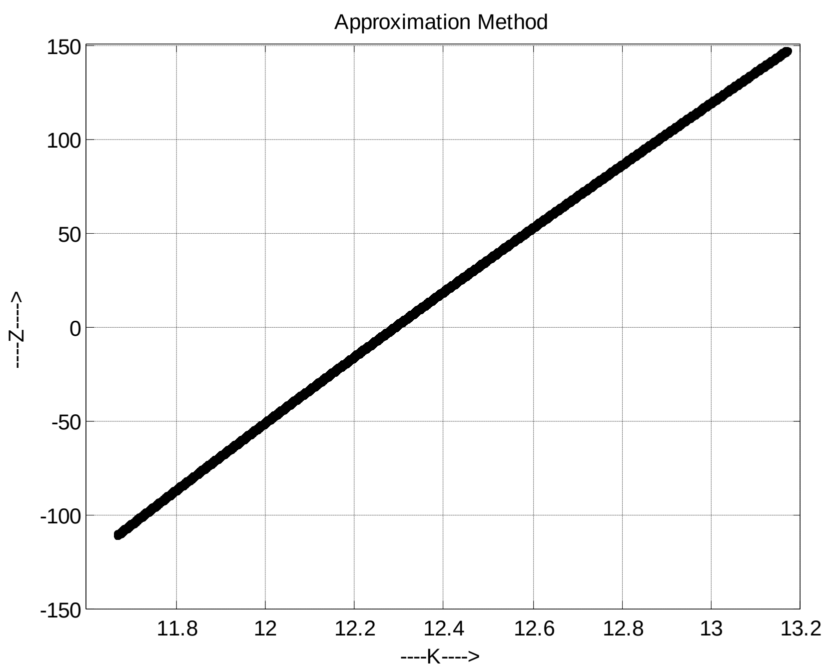


Figure 6.3 Validation of Approximation using MATLAB 2010b.

The calculated dimensions for the Ku band pyramidal horn antenna are given in Table 6.1. The waveguide used for the design is WR-62 with A = 15.7988 mm and B = 7.8994 mm. The value of ξ calculated by using equation (6.2) is 12.6686. After, applying the iterative process to find the value that satisfies the equation (6.1) the value of ξ is found to be 12.2899.

Table 6.1 Dimensions of designed Ku band Pyramidal Horn Antenna.

A (mm)	**B** (mm)	**A1** (mm)	**B1** (mm)	**P_E=P_H** (mm)	**L_E** (mm)	**L_H** (mm)	**L_1** (mm)	**L_2** (mm)
15.7988	7.8994	125.2	99.2	221.6	245.8	261.2	240.7	253.6

As the calculated value of $P_E = P_H$ = 221.6 mm and can be validated from the Table 6.1. Hence, as earlier stated the design is valid if it satisfies this condition. The design can have realistic model. The thickness of the horn wall is considered to be 0.5 mm. We have each and every dimension required. Now, we can represent our model in a 2D representation on a graph sheet. For this, DigiGraph V.2 which is a professional tool for graph work has been used. The graph is shown below

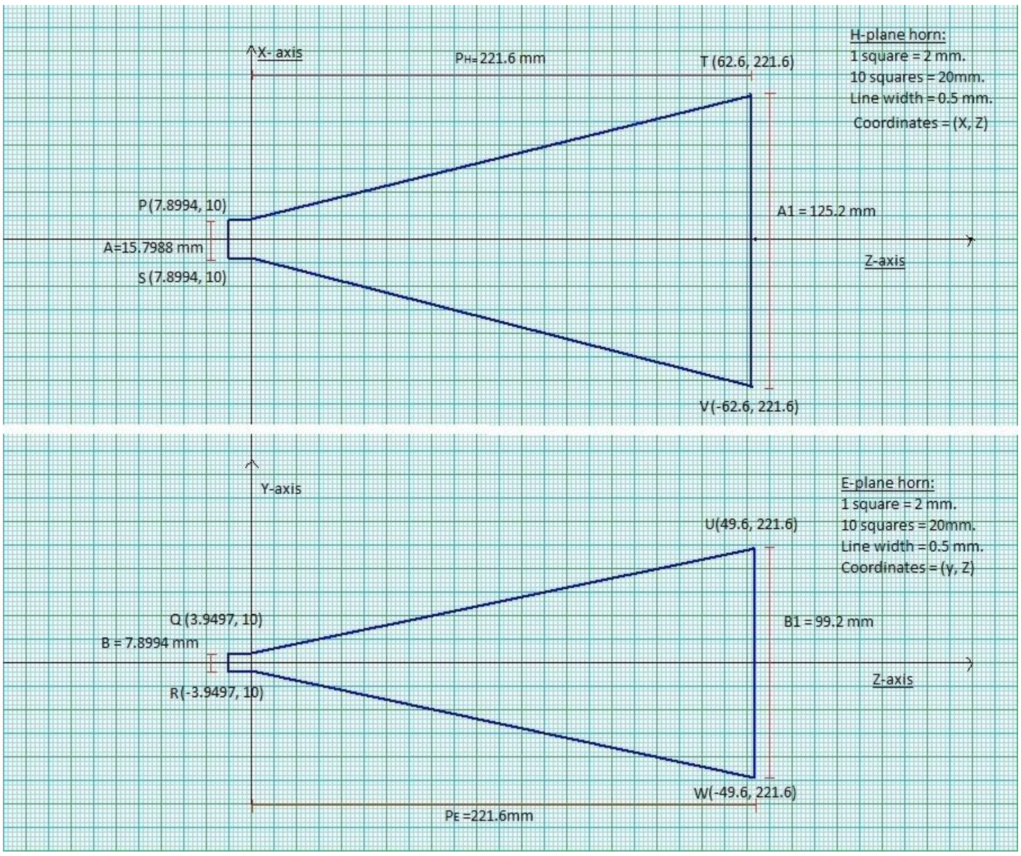


Figure 6.4 2D Representation of design using DigiGraph V.2

We have coordinates for the design now we can move on to the HFSS to design a 3D model of the pyramidal horn antenna.

6.2 DESIGN OF PYRAMIDAL HORN ANTENNA ON HFSS

HFSS, it stands for High Frequency Structure Simulator. It is a high performance electromagnetic field simulator for arbitrary three dimensional volumetric inactive device modeling and simulation. It takes advantage of the Graphical User Interface (GUI). Solutions to your EM problems are quickly and accurately obtained as HFSS integrates design modeling, visualization, simulation and automation in a very flexible work environment. It is a complete software tool for the modeling and simulation of different antenna systems and wide ranging radiating structures. It can also be used to learn more about antennas to get imminent into the conduct of the particular antennas. HFSS is very user friendly software that can advantage user to foresee antenna performance and achieving better results before building the realistic model. HFSS makes it easy to analyze each and every parameter very accurately. But this software requires a good knowledge of coordinate system. The method it employs is the Finite Element Method also known as FEM on the model for solution. Other advantages of HFSS that make it a preferable choice are adaptive meshing, easy user interface and brilliant graphics to give you unparalleled performance and insight to all of the three dimensional Electromagnetic problems. Now we will go through the steps for the designing on HFSS will be discussed. First run the HFSS by left clicking on HFSS icon in the installed directory, the software will open and then insert new HFSS design for creating new 3D model.

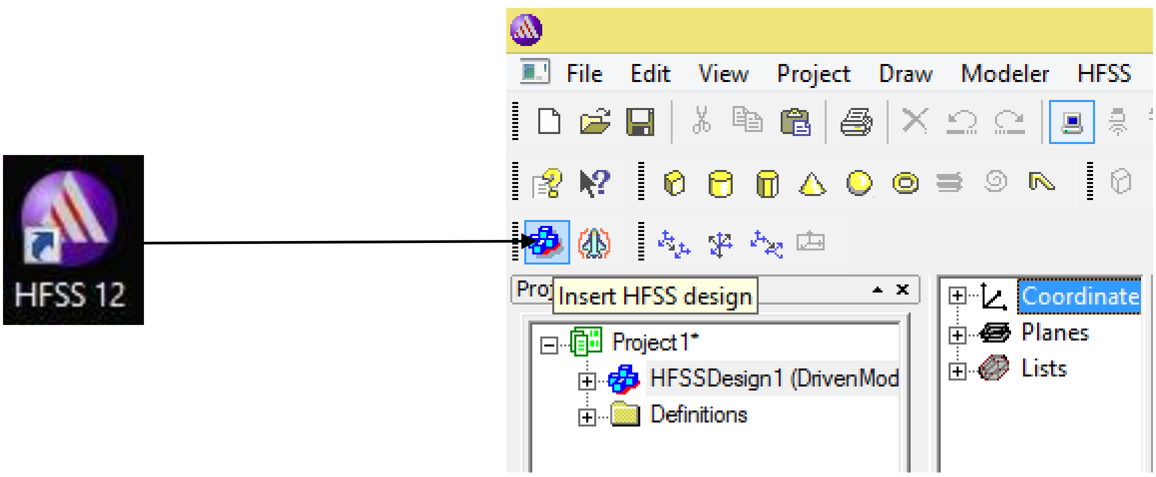


Figure 6.5 How to open new project in HFSS

HFSS includes seven basic windows given below

i. Menu window

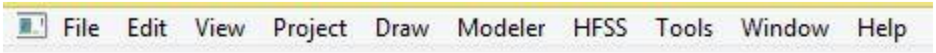


Figure 6.6 Menu Window.

ii. Tools window

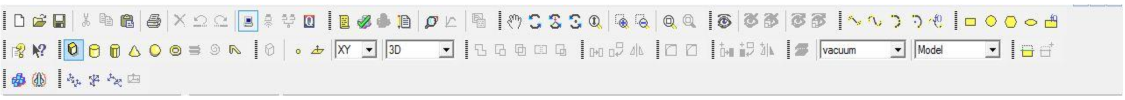


Figure 6.7 Tools Window.

iii. Message window

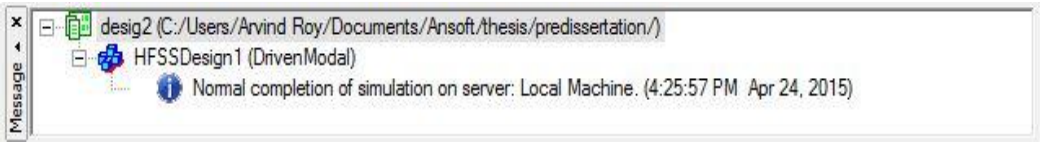


Figure 6.8 Message Window.

Progress window

Figure 6.9 Progress Window.

iv. Modeler window

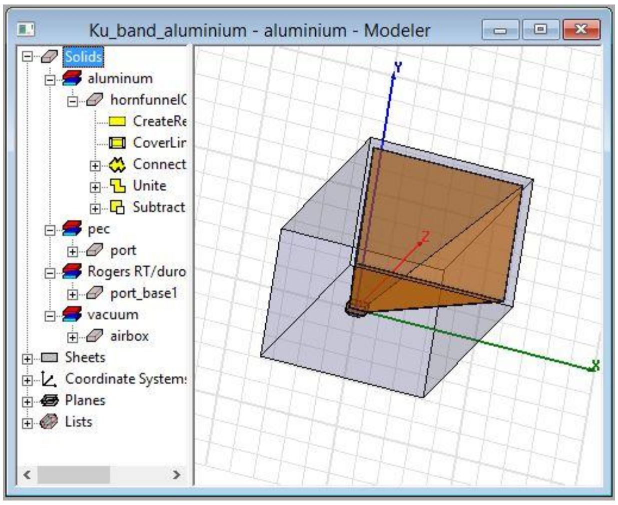


Figure 6.10 Modeler Window.

v. Project window

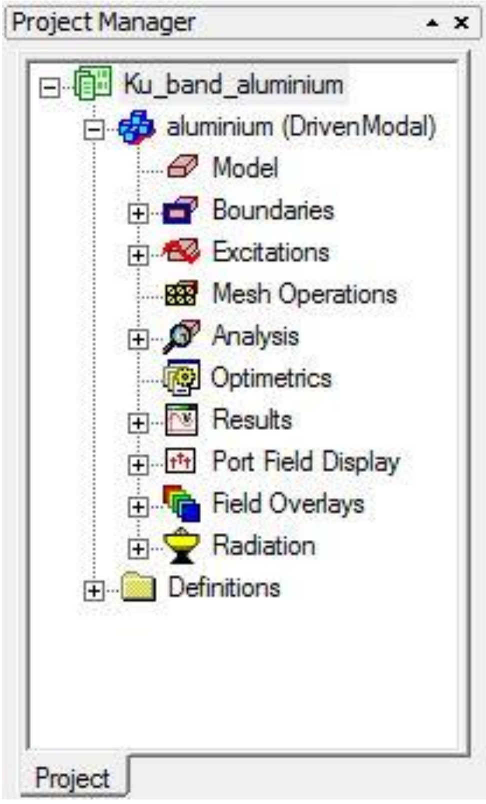


Figure 6.11 Project Window.

vi. Property window

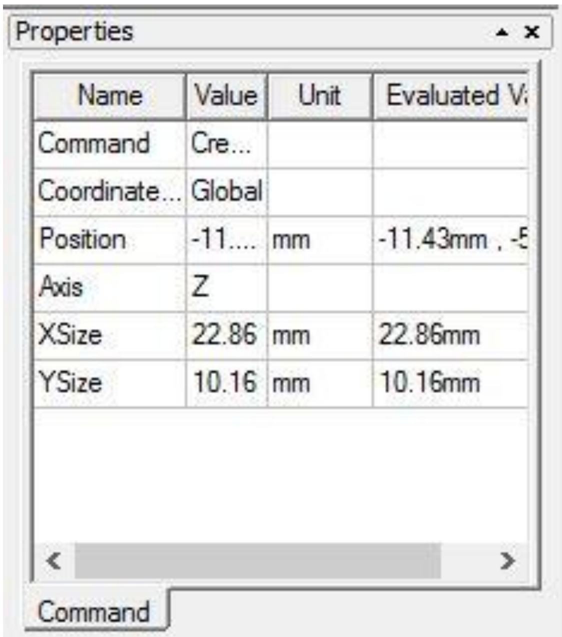


Figure 6.12 Property Window

6.2.1 MODELING WAVEGUIDE AND FUNNEL

To creat the waveguide creat two boxes one with the exact dimentions of the waveguide and other 0.5 mm less than the other one. Now select the outer box and then inner box respectively and apply substraction. The waveguide with wall thickness of 0.5 mm will be formed.

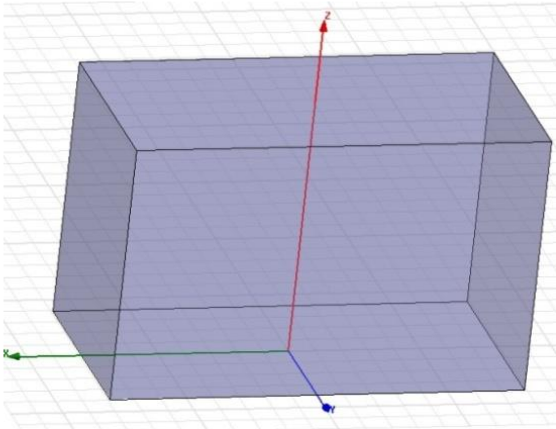


Figure 6.13 Waveguide Box 1.

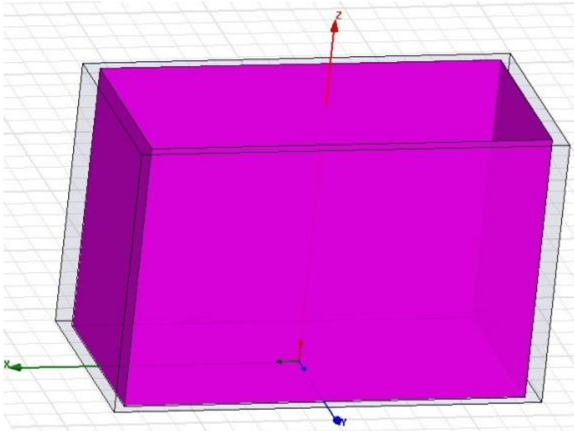


Figure 6.14 Waveguide Box 2.

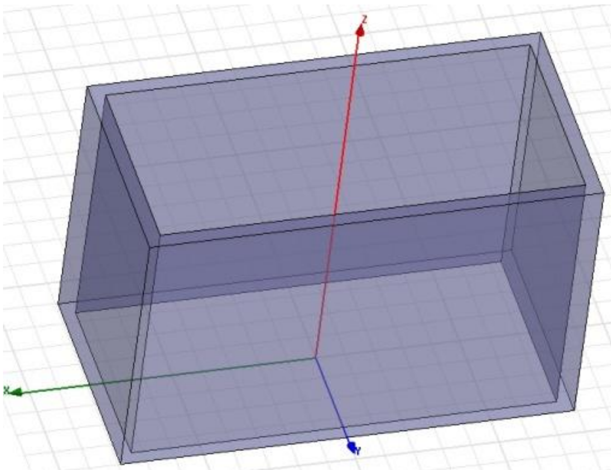


Figure 6.15 Waveguide WR-62.

It should be taken into consideration that the material selected for the waveguide should be aluminium. For the funnel of the pyramidal horn the same procedure is applied as shown in the figures below. When the funnel is created the two parts can be joined together from the modeler tre present in the modeler window. For uniting the two parts the waveguide and the funnel select waveguide and pyramidal horn antenna in the window and select unite option fron the tool bar. The two elements will be united.

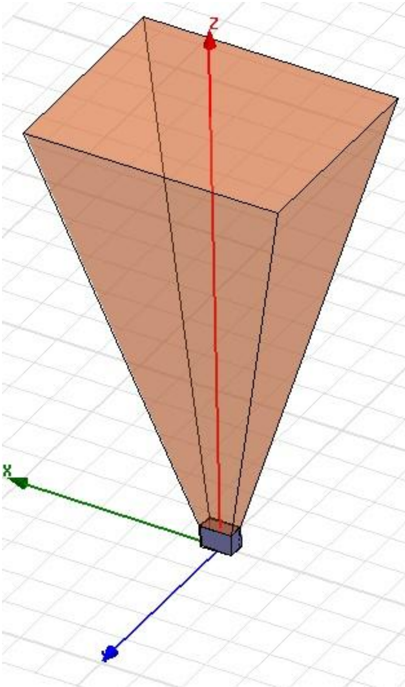


Figure 6.16 Outer Funnel

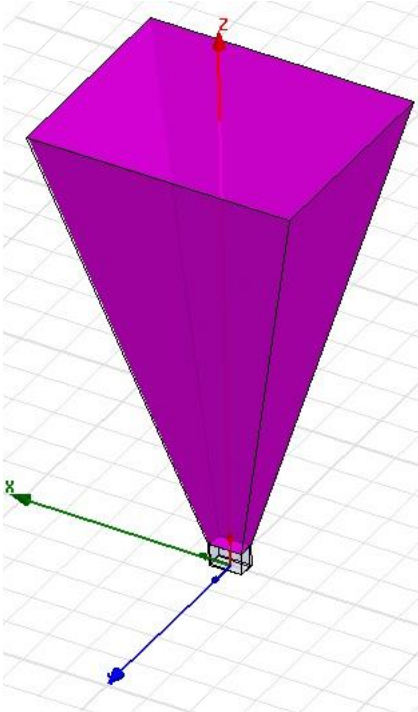


Figure 6.17 Inner Funnel

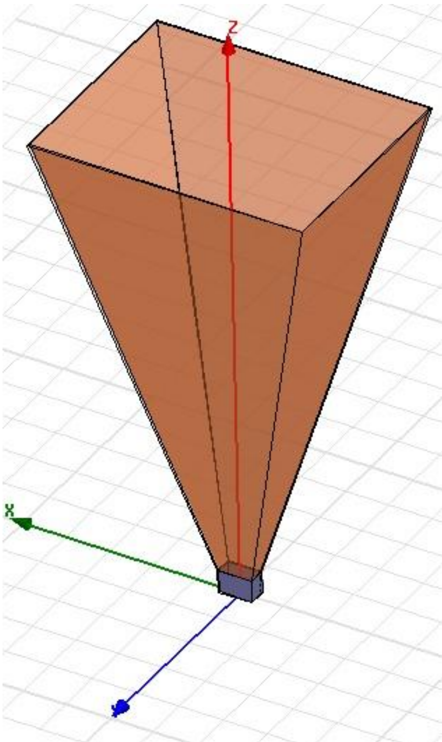


Figure 6.18 Pyramidal Horn Funnel

We can see that the 2D representatioon of the pryamidal horn antenna designed on the DigiGraph V.2 given in Figure 5.4 is similar to that of the 2D representation of the Horn design in HFSS given in figure .

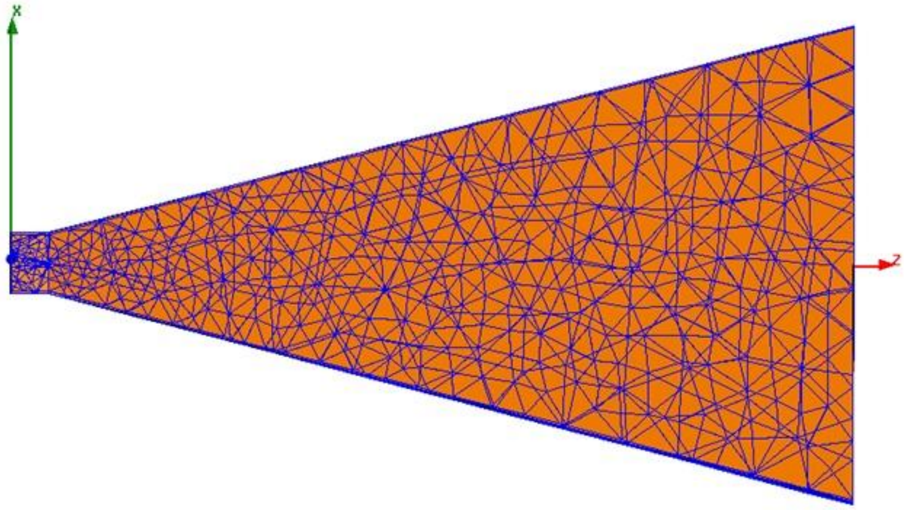


Figure 6.19 2D H plane view in HFSS.

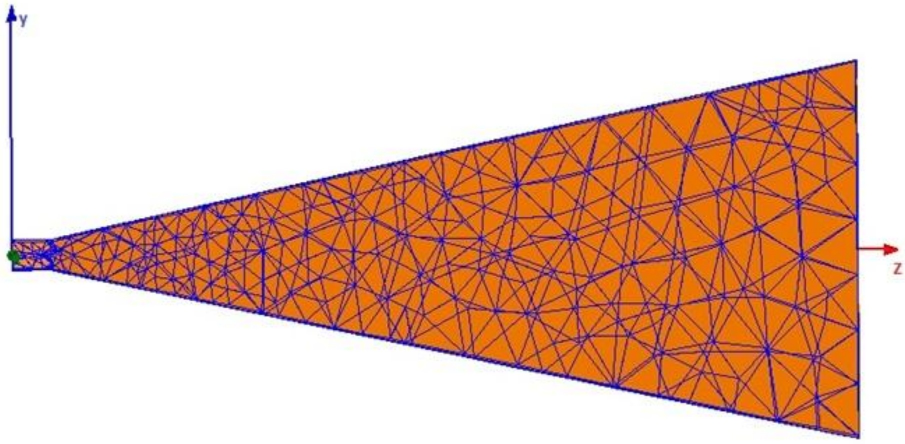


Figure 6.20 2D E plane view in HFSS.

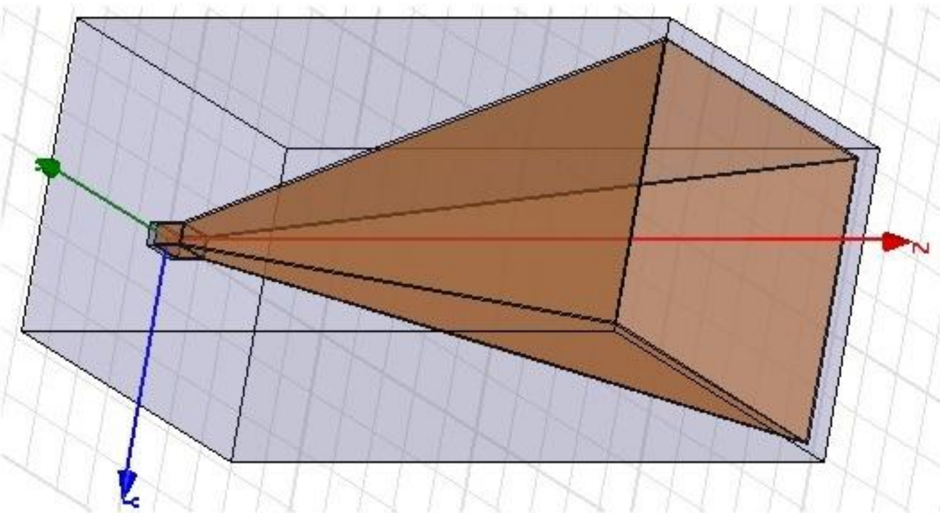


Figure 6.21 Designed Pyramidal Horn in HFSS.

6.3 ENHANCEMENT OF PYRAMIDAL HORN ANTENNA

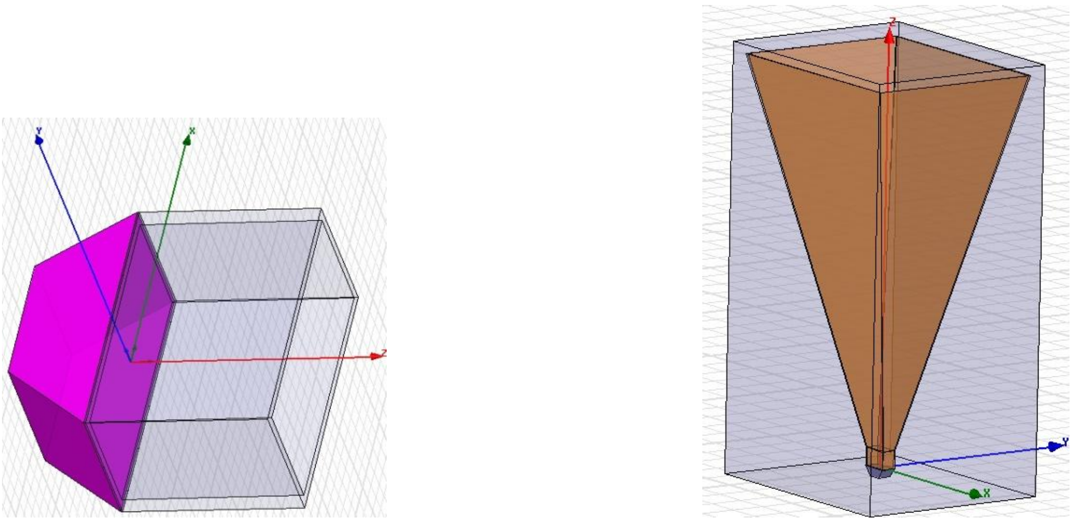
For the enhancement of the design we will use a dielectric microwave cavity attached behind the wave port. Hence from here the question arise what is a cavity. Cavity can be referred to as an enclosure that can store or absorb electromagnetic energy. Alternative names for microwave cavity exist such as cavity resonator. There are commonly three types of microwave cavity resonators which have their usefulness in microwave applications, namely,

a. Rectangular cavity resonator.
b. Circular cavity resonator and
c. Reentrant cavity resonator.

A resonator can have infinite number of resonant modes theoretically, such that each mode for a definite resonant frequency. The maximum amplitude of the standing wave occurs when both signal and resonant frequencies are equal. Also at such condition electric and magnetic energies stored in cavity are equal. The resonant mode with the lowest resonant frequency for the application is called as dominant mode. It is necessary that inside the cavity the electromagnetic field must satisfy Maxwell Equations and the magnetic and electric field at the walls of cavity approaches null.

What a dielectric cavity does is that it absorbs some of the radiations that is radiated in the back and side lobe and also reflects some of the radiation that increases the reflection loss. Hence using this better reflection loss is obtained and simultaneously the side lobes are suppressed. For the dielectric the material used is Rogers RT/duroid 6010/6010 LM. This dielectric have a relative permittivity of 10.2 and dielectric loss of about 0.0023.

Insertion of cavity in the design is shown below



(a) (b)

Figure 6.22 (a) Cavity inserter behind the wave port. (b) Horn antenna with cavity

CHAPTER 7

RESULT AND ANALYSIS

7.1 ANALYSIS OF PYRAMIDAL HORN ANTENNA

Since the optimum design for the Ku band pyramidal horn is ready. It is now turn to simulate the 3D EM model using appropriate setup and boundaries. Now to analyze the pyramidal horn antenna, the radiation boundaries are created. The boundaries are show in the Figure 6.1 and Figure 6.2 respectively.

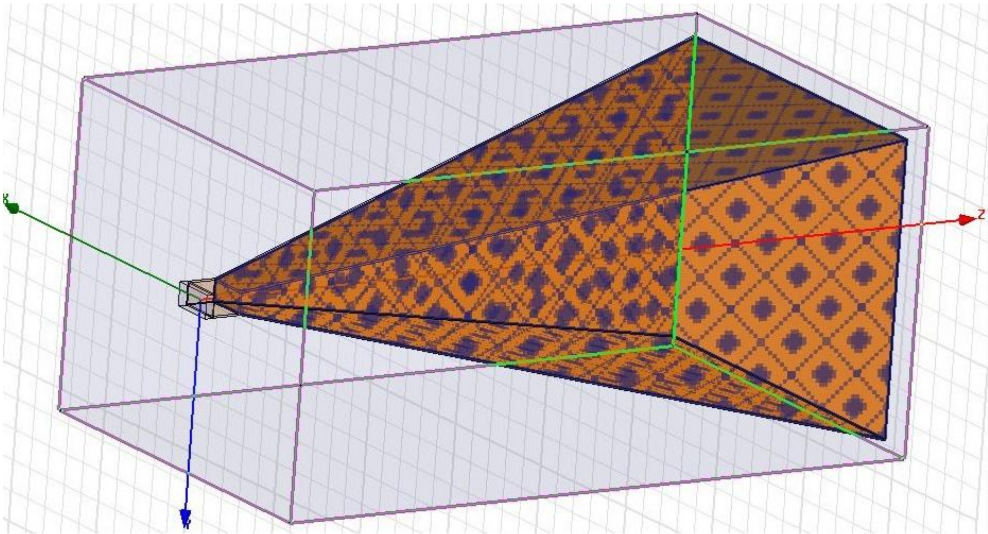


Figure 7.1 Inner Radiation Boundary.

This boundary includes the Perfect E and Perfect H boundary. These boundaries provides better estimate to the emission of the antenna radiations from its surface.

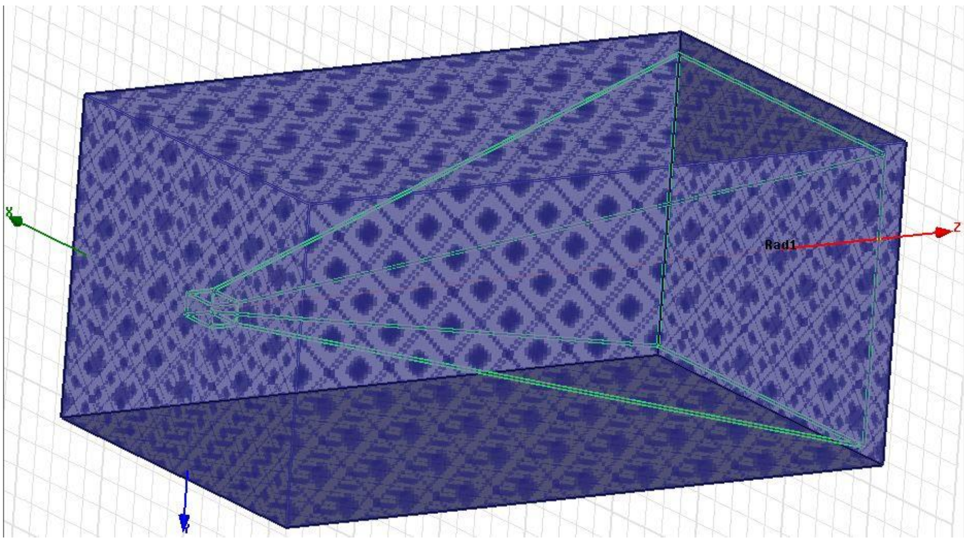


Figure 7.2 Virtual Anechoic Chamber.

As we all know the anechoic chambers are the best setup for studying the antenna transmission/reception and radiation. The walls are pyramidal shaped and are carbon impregnated polyurathene foam which is basically manufactured for absorbing electromagnetic radiations. HFSS provides a virtual environment to create an anechoic chamber so as to analyze the working of the antenna. One of the biggest advantages of using HFSS is that it provides automatic as well as manual mesh operations on the structure. What mesh operation does is that it enhances the exactness of the solution. However, if too much mesh operations are applied it may slow down the simulation by a big factor and may lead to memory overload problem. If fast computer with large memory storage is there then it is useful to apply mesh operations.

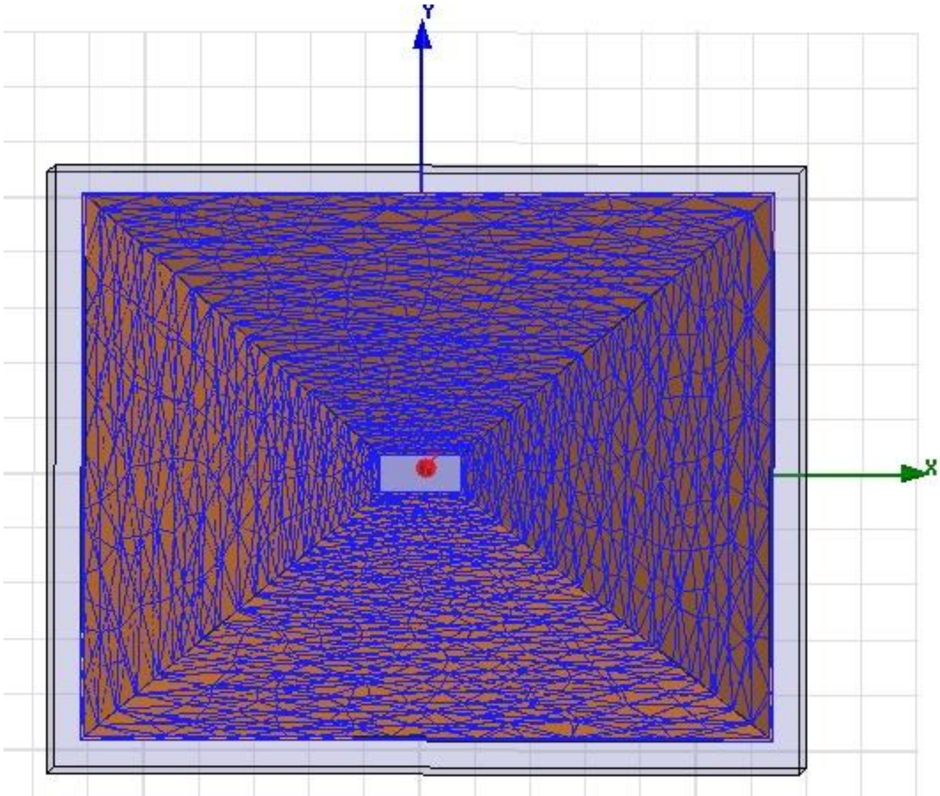


Figure 7.3 Mesh operations on Pyramidal horn antenna.

The antenna is studied under these boundaries and all the results are according to the boundary extremes the temperature of the antenna is initially set to 22^{o}C with an impedance matching of 50 ohm. Designed antenna is excited by defining a wave port to the waveguide as shown in Figure 7.4. HFSS provides different types of excitation procedures namely Lumped port, Wave port and Terminal excitations. Different excitation procedures are used at different situations. For instance if coaxial cable or the power source resides outside the anechoic chamber for the purpose we have to provide terminal excitation. In case the exciting source resides inside the anechoic chamber we have to use lumped port for exciting the structure. In case a wave mode is used the wave port excitation procedure is used. One important point to be remembered while providing wave port excitation is that the declared port must me enclosed with the metal cover.

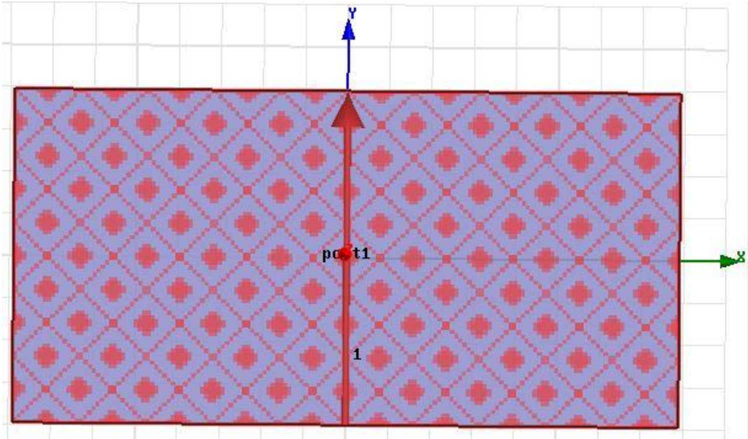
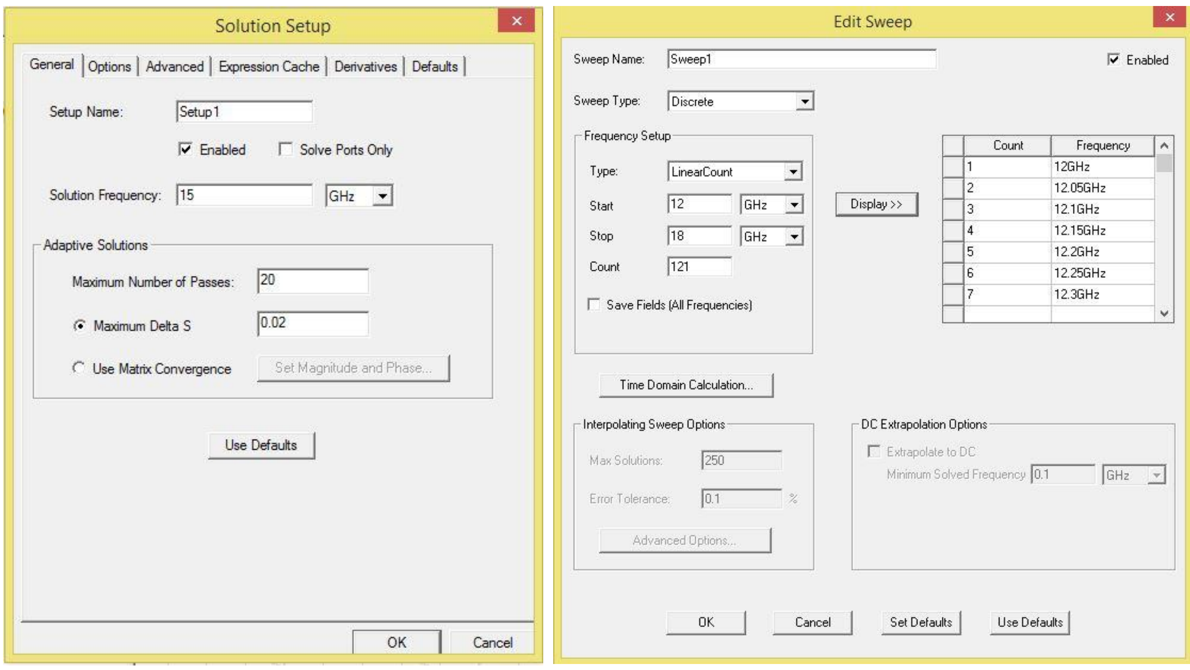


Figure 7.4 Wave port.

The same procedure of initializing boundaries, excitation and setup is done on the enhanced design. Both of the designed are simulated with the same setup and same frequency sweep such that an appropriate comparison of both the design can be made. The setup and frequency sweep setup is shown below in Figure 7.5.



(a) (b)

Figure 7.5 (a) Setup Window (b) Frequency Sweep.

The designed pyramidal horn has a simulation frequency of 15 GHz with the maximum number of passes of 20. The setup for the frequency sweep is selected to be discrete in nature with the start frequency of 12 GHz and 15 GHz. The total numbers of steps to be processed are selected to be 121.

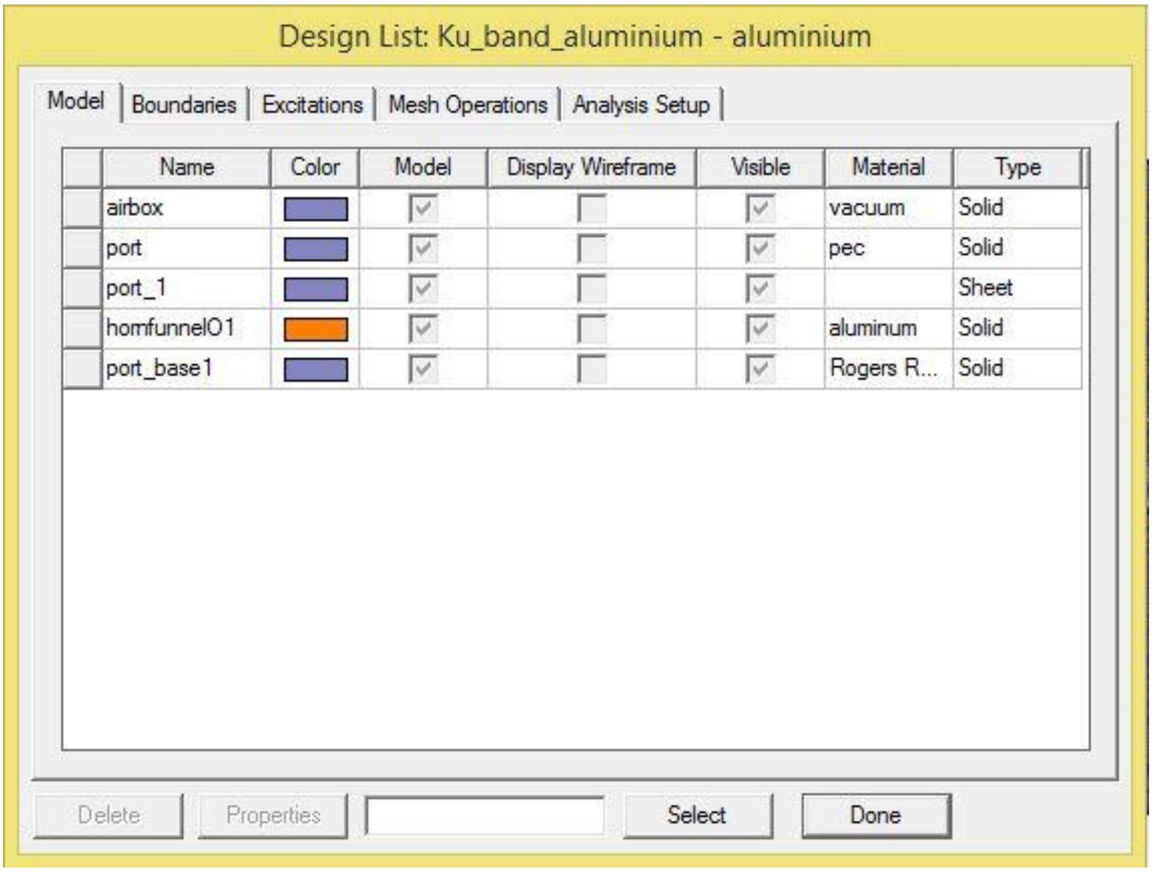


Figure 7.6 Analysis Setup.

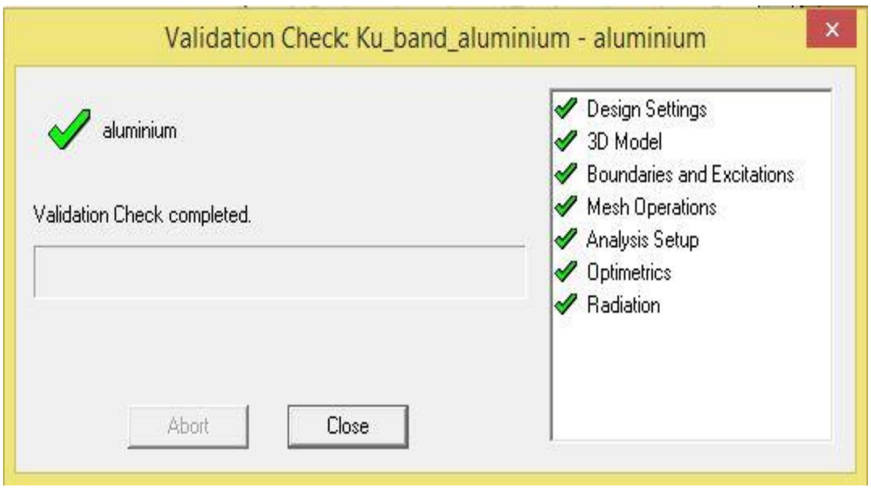
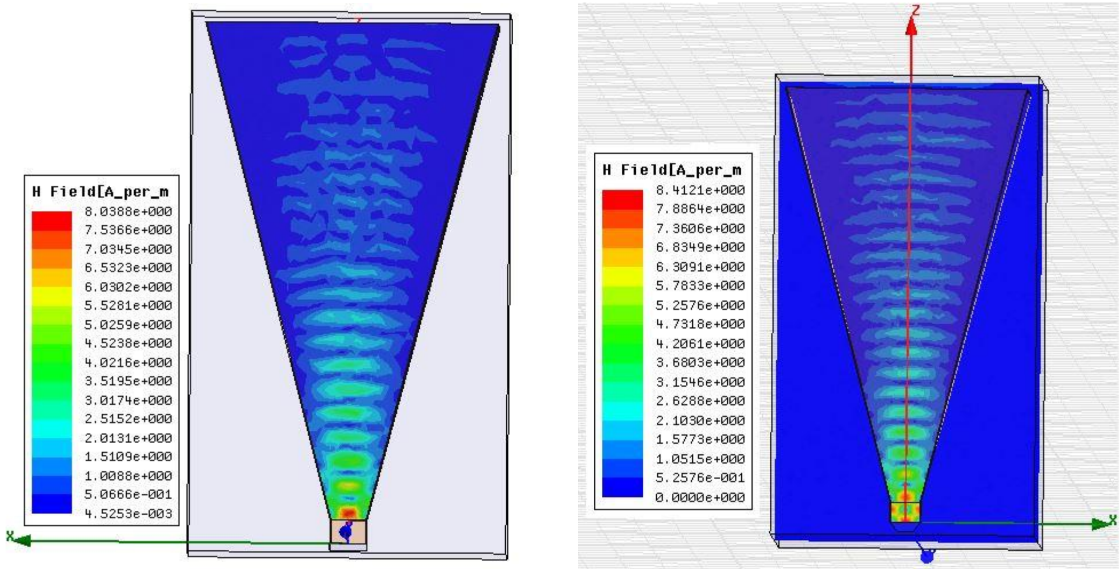


Figure 7.7 Validation of Model.



(a) (b)

Figure 7.8 Emission of radiation form Horn (a) Without cavity (b) With cavity.

7.2 RESULTS FOR BASIC PYRAMIDAL HORN ANTENNA

The results shown below are significant figures obtained after the simulation and are considered important graphs in the study of antenna analysis.

7.2.1 SCATTERING PARAMETER

S-parameters are complex scattering parameters because both the magnitude and phase of the input signal changes. The analysis for scattering parameter is done shown in Figure 7.9 .The reflected energy caused due to impedance mismatch in the system is called the returnloss. The return loss is a numerical value that indicates how much of signal that is reflected back into the waveguide or the cable from the terminating equipment. Hence for the reason it plays an important role in antenna analysis for the satellite based communication. Return loss is generally calculated in dB. Larger values for this parameter are better as they indicated less reflection. The value of 35 to 40 dB and higher are considered acceptable for a proper communication system. The value of 40 dB of returnloss indicated the total of 1% of signal reflecting back and 99% of signal is passed.

$$RL = 10\log_{10}\frac{P^{ref}}{P^{inc}} \qquad (7.1)$$

Where , RL = Return loss measured in dB.

P^{ref} = Reflected power.

P^{inc} =Incident power.

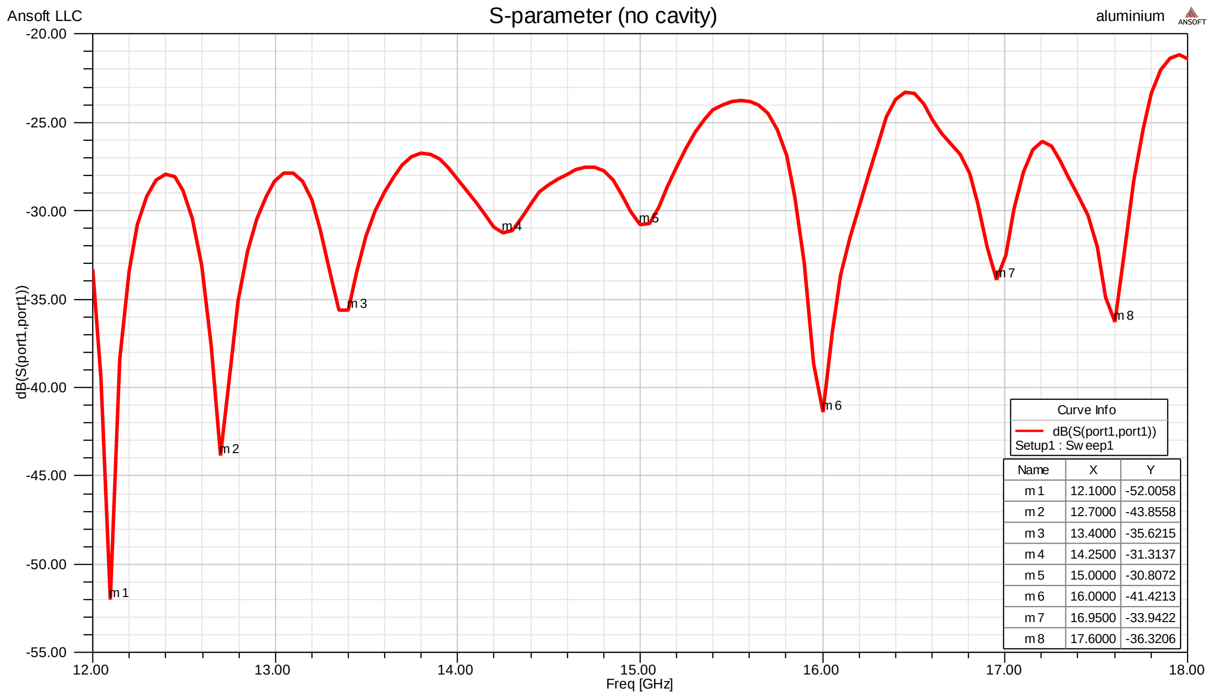


Figure 7.9 S-parameter Vs. Frequency.

7.2.2 VOLTAGE STANDING WAVE RATIO (VSWR)

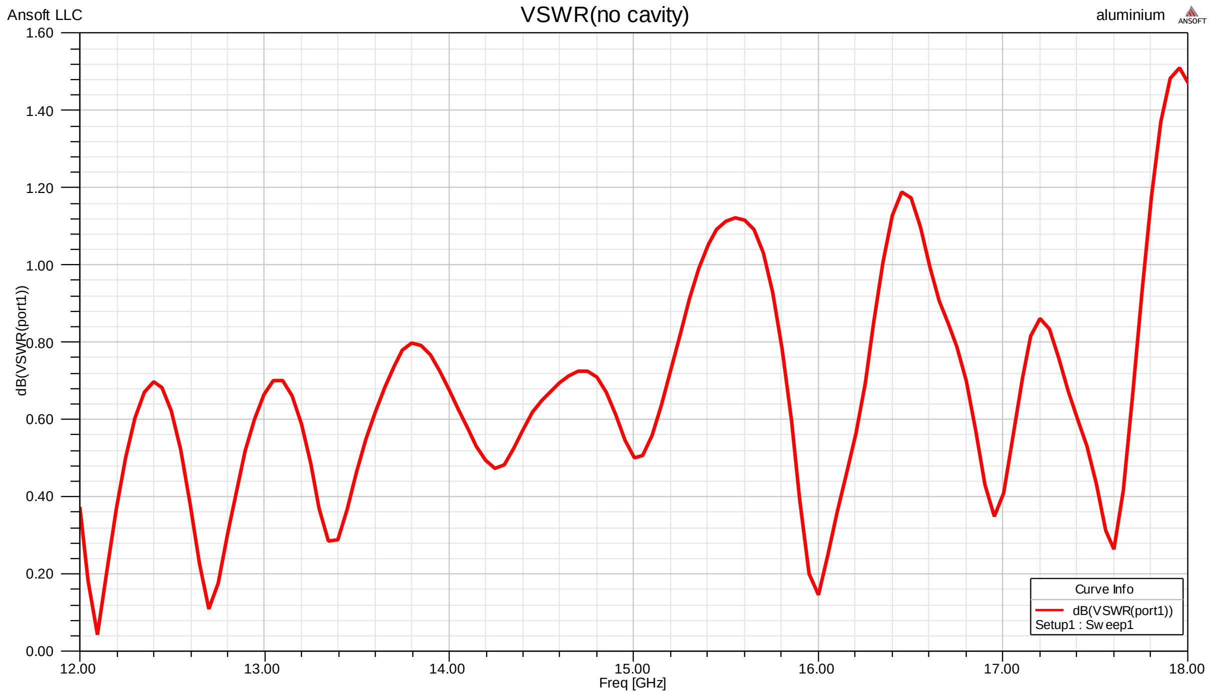


Figure 7.10 VSWR Vs. Frequency.

Voltage Standing Wave Ratio gives us the value that how our antenna is matched with the load resistance or with transmission line impedance. For RL >10 dB, VSWR < 2 is suitable for microwave devices and wireless systems. We can see from the plot that the value of

VSWR is < 2 which shows our antenna is matched and it can be considered fair for signal transmission when there is low attenuation present. The graph for VSWR is presented in the Figure 7.10.

7.2.3 RADIATED EMMISSION

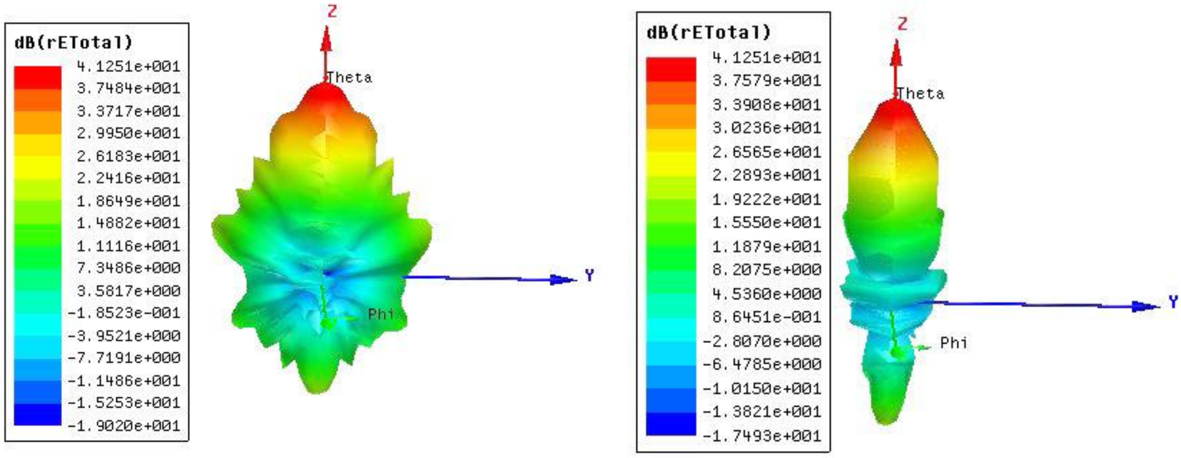


Figure 7.11 3D Power radiation pattern at 30^o and 60^o phi.

The 3D power radiation plots are represented at phi 30^o and 60^o in Figure 7.11. With the maximum value of 41.1251 dB for the designed pyramidal horn antenna.

7.2.4 GAIN AND DIRECTIVITY

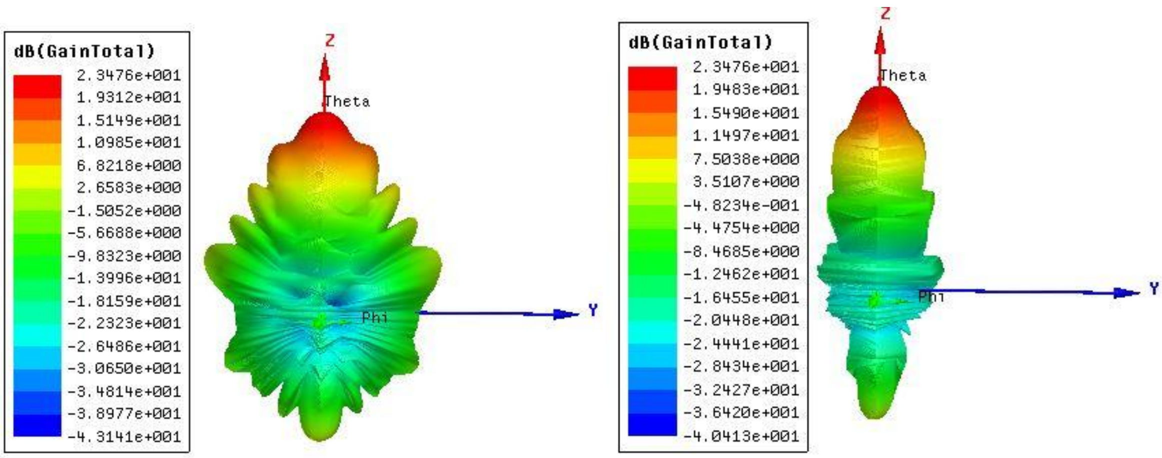


Figure 7.12 3D Gain pattern at 30^o Phi and 60^o Phi.

The gain assumed for the design is 23 dB and after simulation the design is providing a gain of 23.476 dB which is very close to the assumed value. Hence the design is optimum in respect to the gain and directivity. The obtained value of directivity is 22.909 dB and the calculated value of the directivity is 23.6687 dB which are very close to each other. The directivity plots are shown in Figure 7.13. The light increase in the gain may be due to the high performance of the software. However, the obtained results provide great agreement with the calculated values.

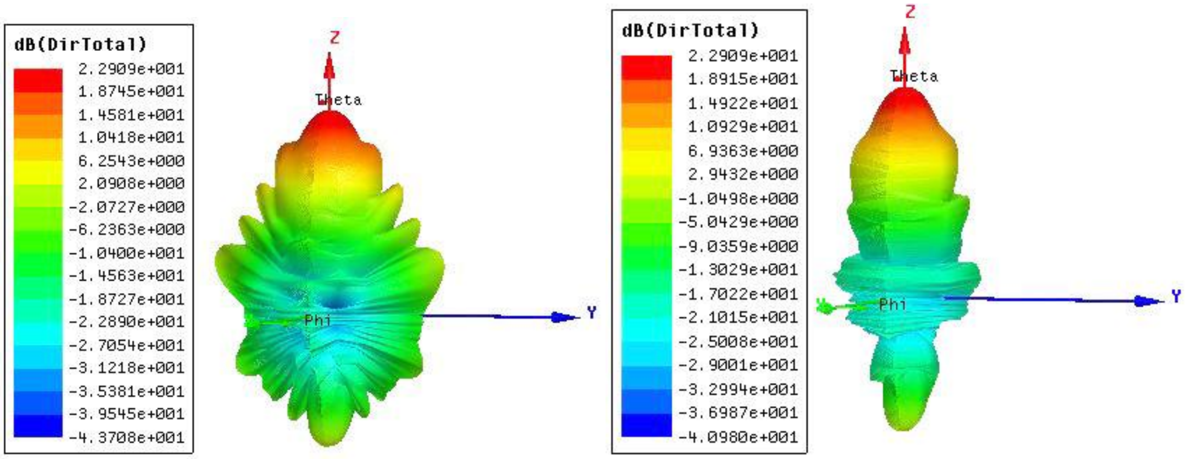


Figure 7.13 3D Directivity pattern at 30^{o} Phi and 60^{o} Phi.

```
Calculated Gain :
   22.8999

Calculated Directivity :
   23.6687
```

Figure 7.14 Calculated Gain and Directivity using MATLAB

.

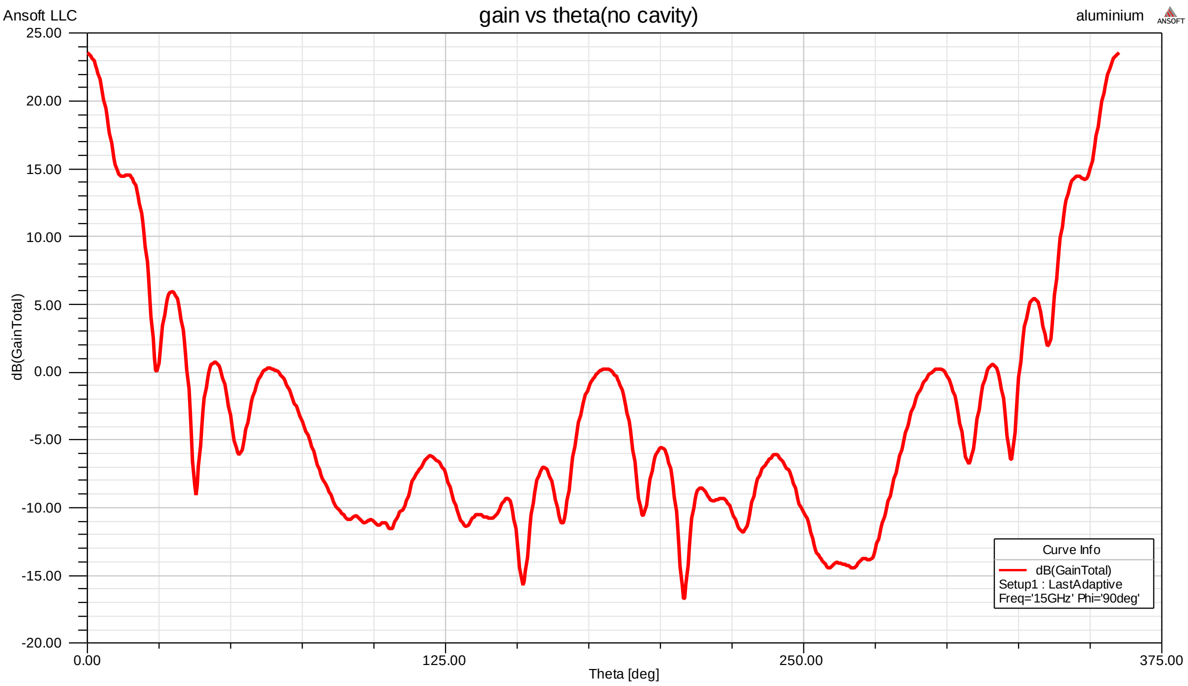


Figure 7.15 Gain Vs. Theta.

7.2.5 2D RADIATION PATTERNS

The 2D power pattern for the pyramidal horn antenna at 15GHz at Phi = 90 deg in Figure 7.16. The power plot is plotted in the dB and maximum value is found to be 41.251 dB. The diagram below shows the directive pattern with respect to Theta = 0^0 and Phi = 90 deg. Form the figure it is clear that the maximum emission is in the direction of Theta = 0^0.

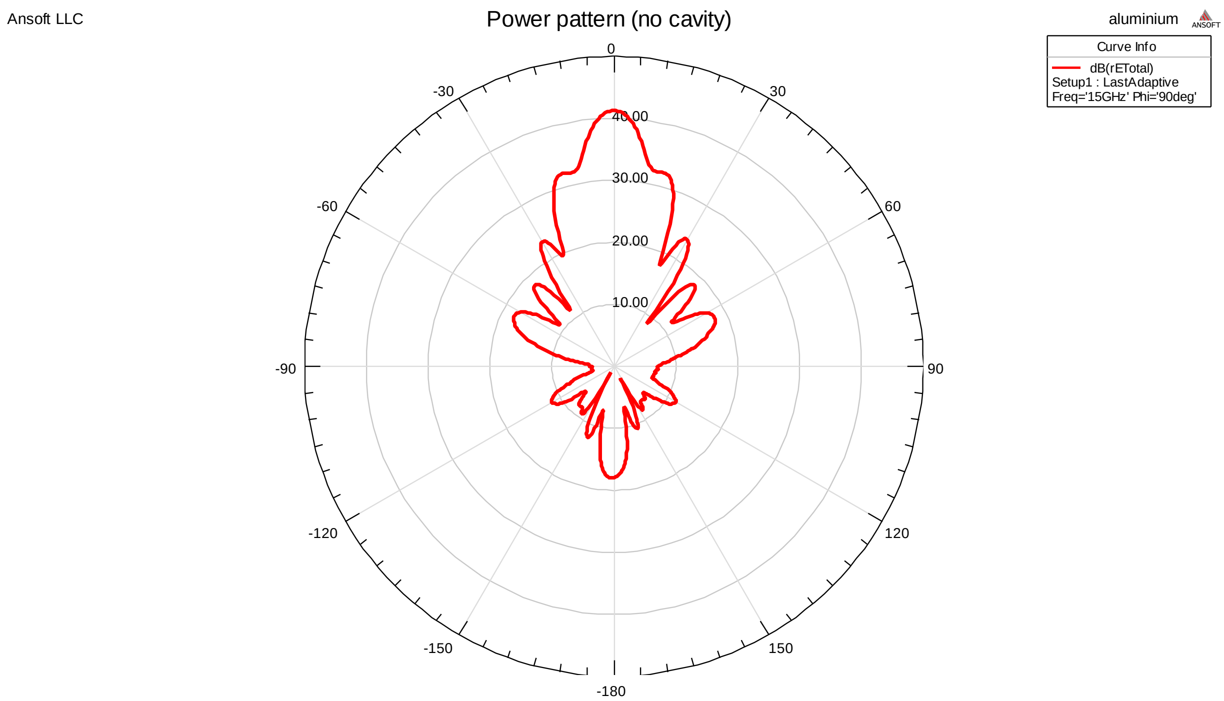


Figure 7.16 2D Power Pattern at Phi of 90^o.

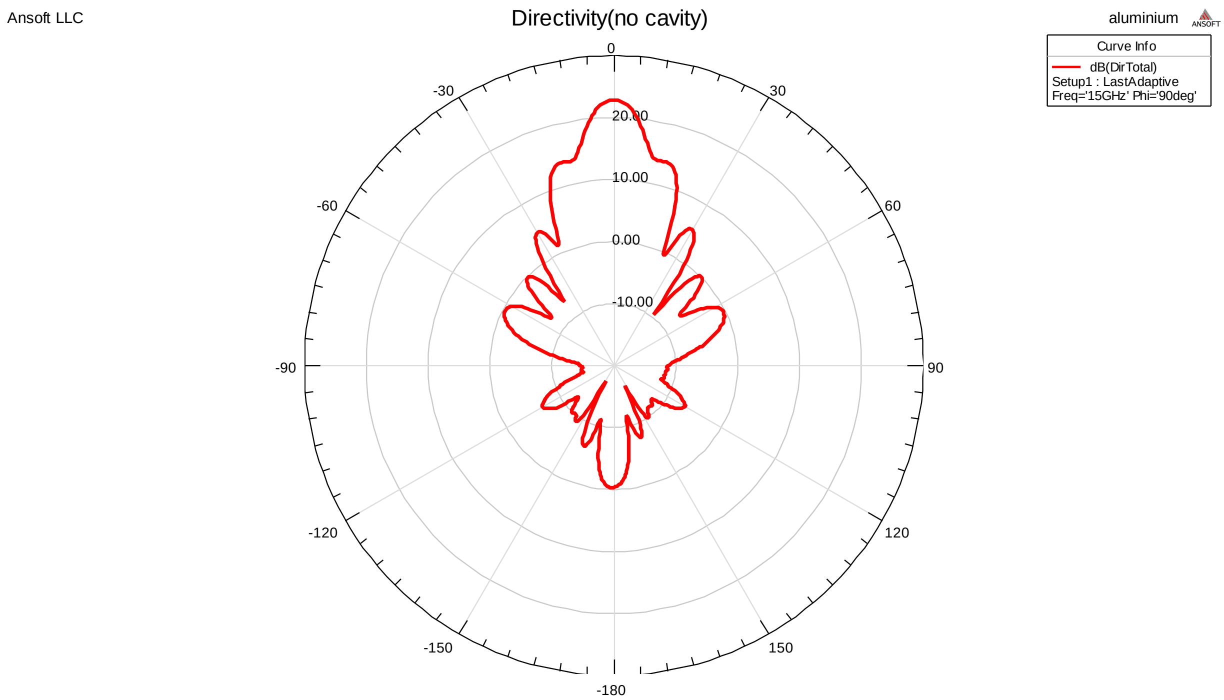


Figure 7.17 2D Directivity Pattern at Phi of 90^o.

7.2.6 IMPEDANCE MATCHING AND WAVELENGTH

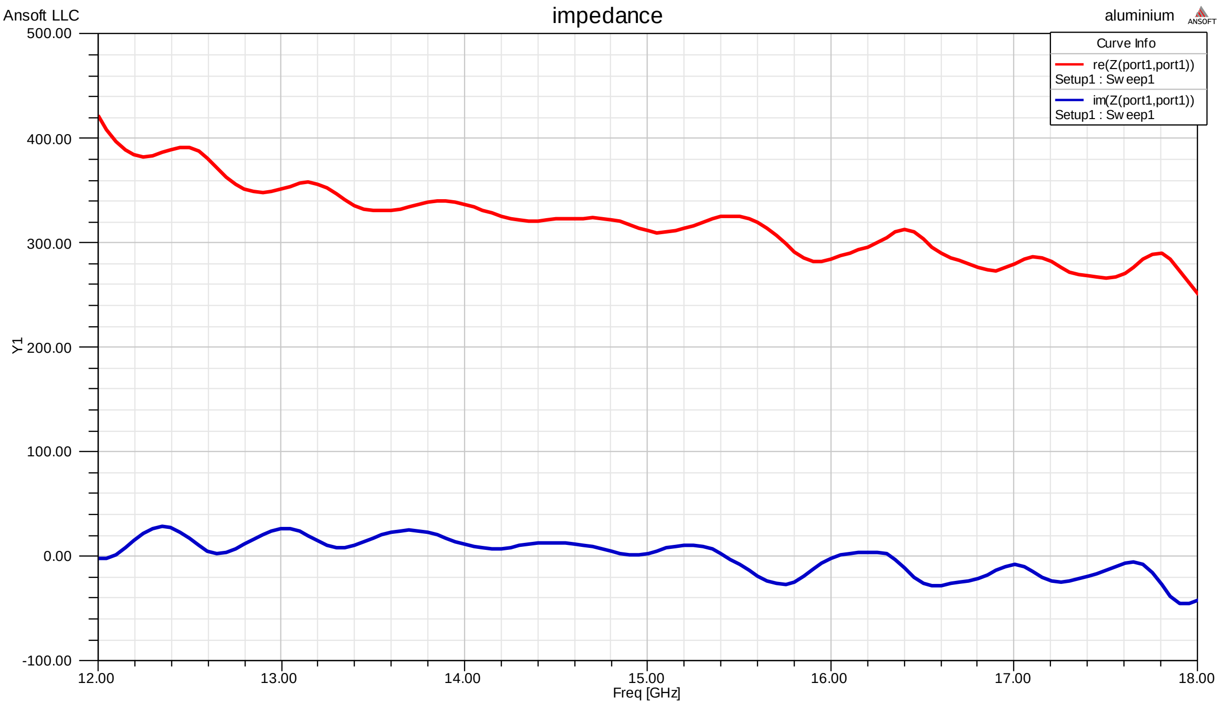


Figure 7.18 Impedance Plot.

Figure 7.18 represents the real and imaginary values of impedance for the designed pyramidal horn antenna for the frequency sweep shown in Figure 7.5(b).

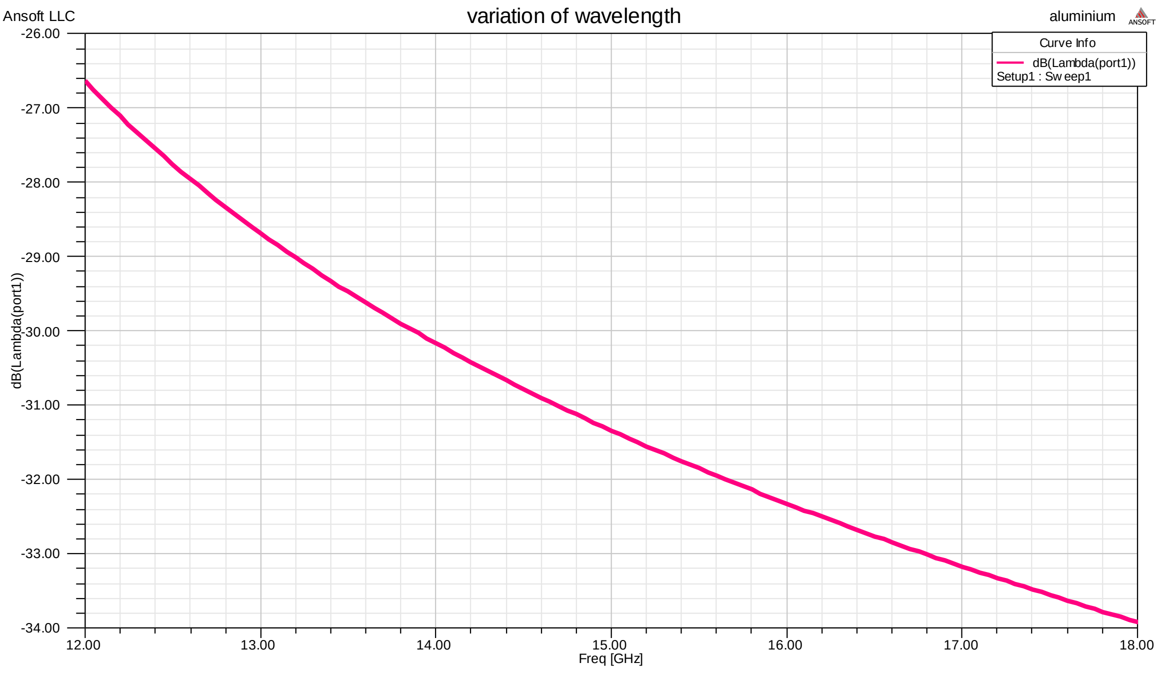


Figure 7.19 Wavelength vs. frequency.

The variation of wavelength with respect to frequency is plotted for the same sweep over which antenna is analysed. However, lambda is represented over dB scale.

7.3 RESULTS FOR ENHANCED PYRAMIDAL HORN ANTENNA

7.3.1 SCATTERING PARAMETER

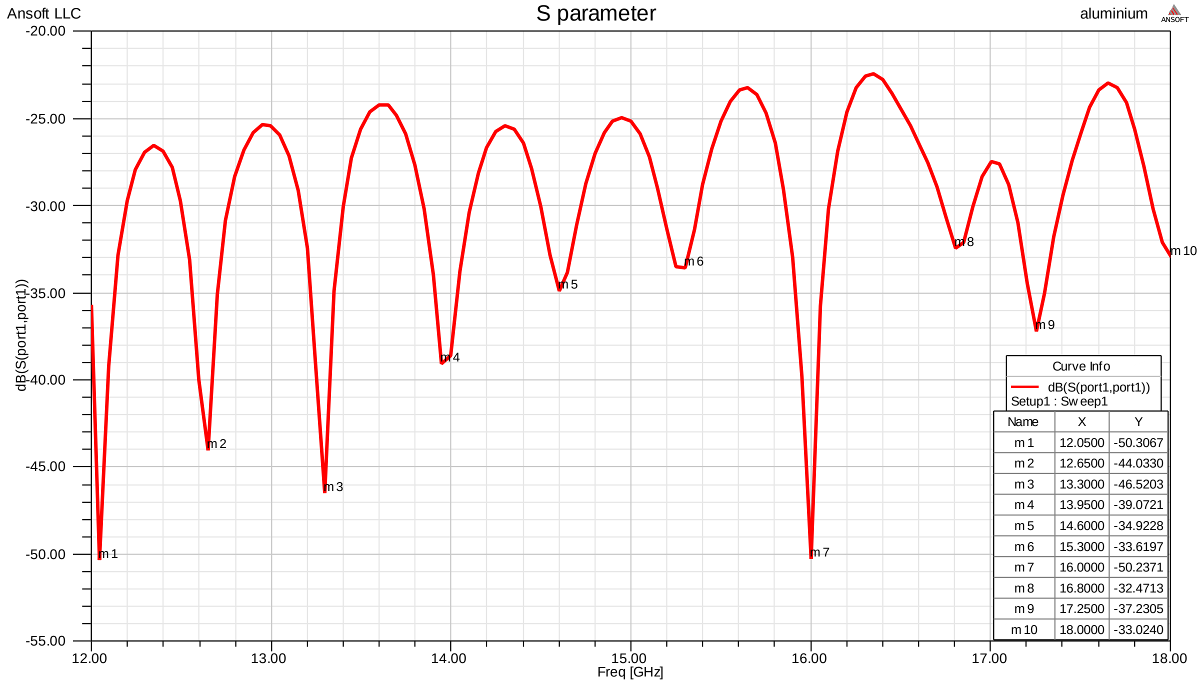


Figure 7.20 S-parameter vs. Frequency (Cavity Model).

7.3.2 VOLTAGE STANDING WAVE RATIO (VSWR)

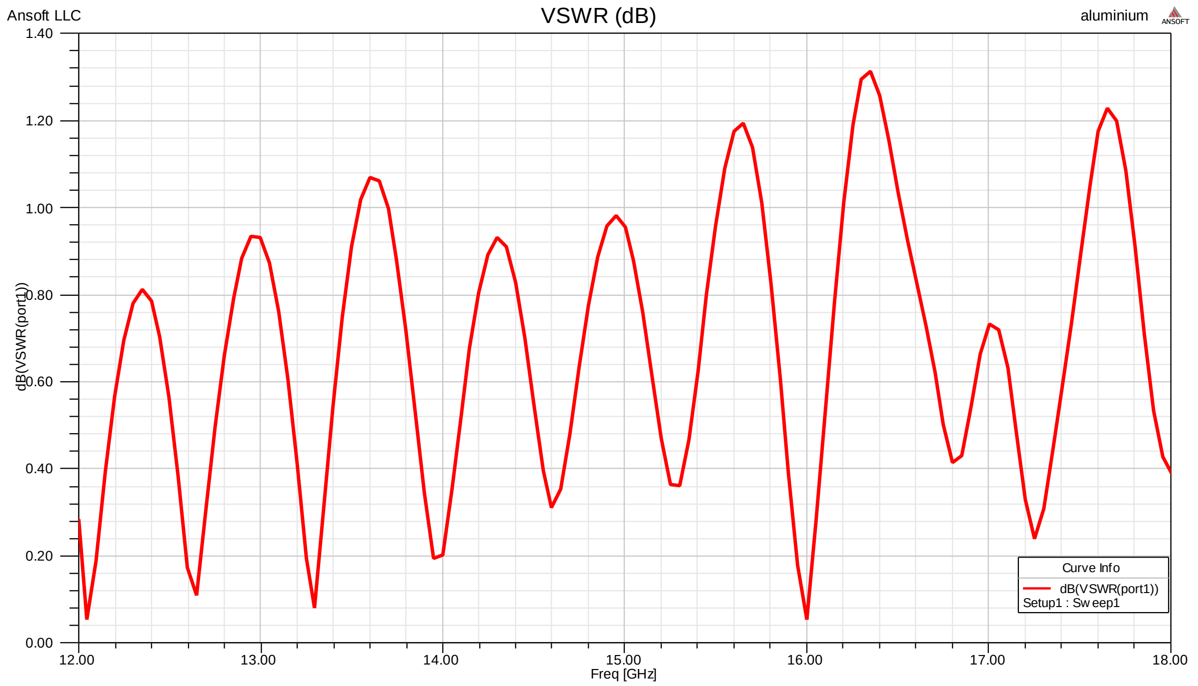


Figure 7.21 VSWR Vs. Frequency (Cavity Model).

The simulated results for enhanced pyramidal horn antenna are represented below. The value of reflection loss is way better than the basic design of the pyramidal horn antenna and the value of VSWR is < 2 which shows our antenna is matched and it can be considered fair for signal transmission with low attenuation.

7.3.3 RADIATION EMISSION

3D power patterns are shown at 30^{o} and 60^{o} are represented with a maximum emission of 41.548 dB. As from the legend it is clear that the radiation emission of the design with the cavity has increased as for the basic design shown in Figure 7.11 the value is 41.251 dB.

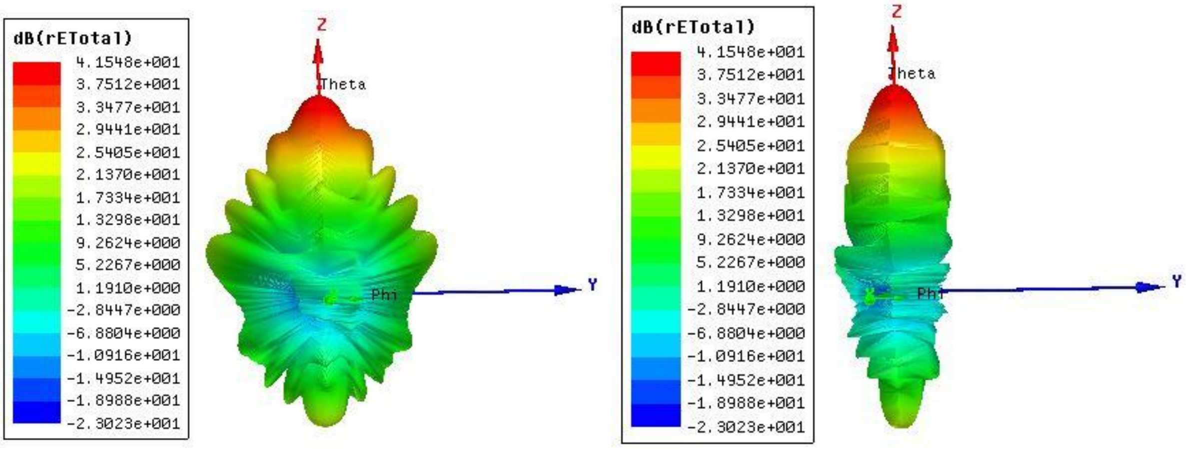


Figure 7.22 3D Power radiation pattern at 30^{o} and 60^{o} phi.

7.3.4 GAIN AND DIRECTIVITY

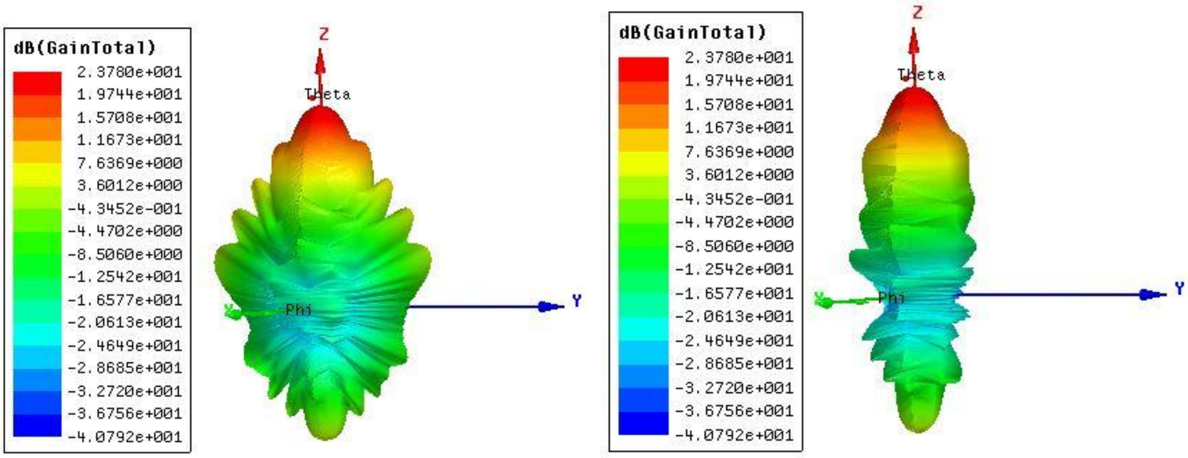


Figure 7.23 3D Power radiation pattern at 30^{o} and 60^{o} phi.

The gain of the basic pyramidal horn antenna design obtained was 23.476 dB. For comparing the legends shown in of Figure 7.12 can be observed. After the enhancement of the pyramidal horn the gain obtained is 23.780 dB. Thus a significant gain enhancement is obtained by the insertion of the microwave dielectric cavity.

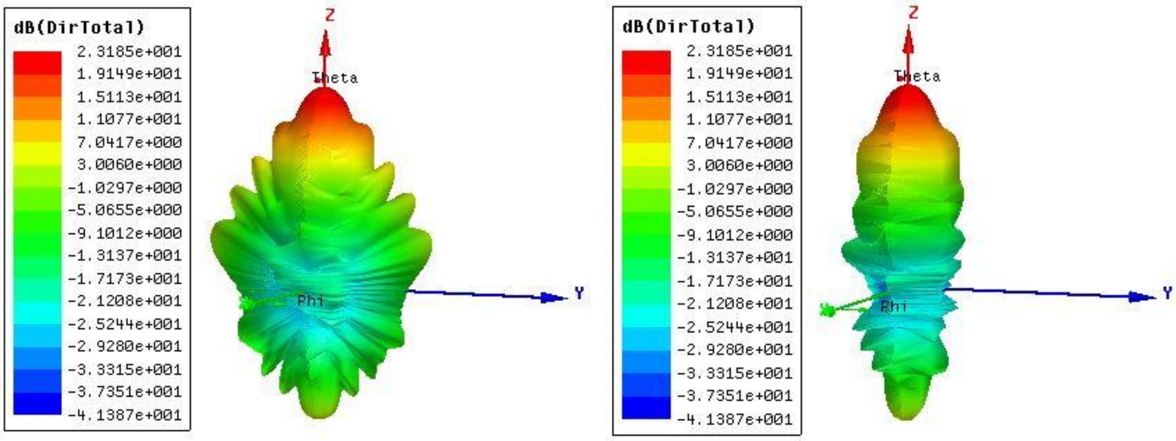


Figure 7.24 3D Power radiation pattern at 30° and 60° phi.

The directivity of the basic pyramidal horn antenna design obtained was 22.909 dB but after the enhancement of the pyramidal horn the directivity obtained is 23.185 dB. It can be noticed that the gain has increased. For comparing the viewer can check the legends of Figure 7.13.

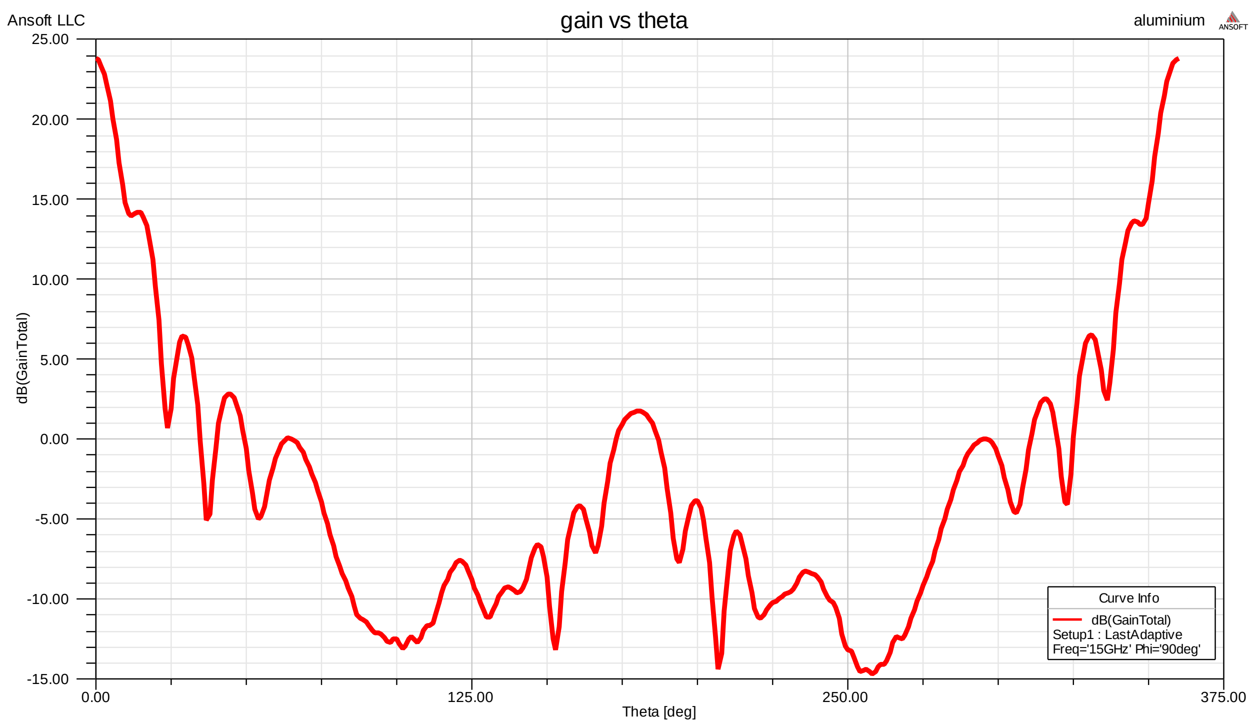


Figure 7.25 Gain vs. Theta.

The Figure 7.23 represents the variation of gain with theta angle. We can observed that the side lobes are suppressed and the power in the side lobe is mainly concentrated in the major lobe radiated from the pyramidal horn antenna.

7.3.5 RADIATION PATTERN

The 2D power pattern for the pyramidal horn antenna at 15GHz at Phi = 90 deg in Figure 7.16. The power plot is plotted in the dB and maximum value is found to be 41.548 dB. The diagram below shows the directive pattern with respect to Theta = 0^0 and Phi = 90 deg. Form the figure it is clear that the maximum emission is in the direction of Theta = 0^0.

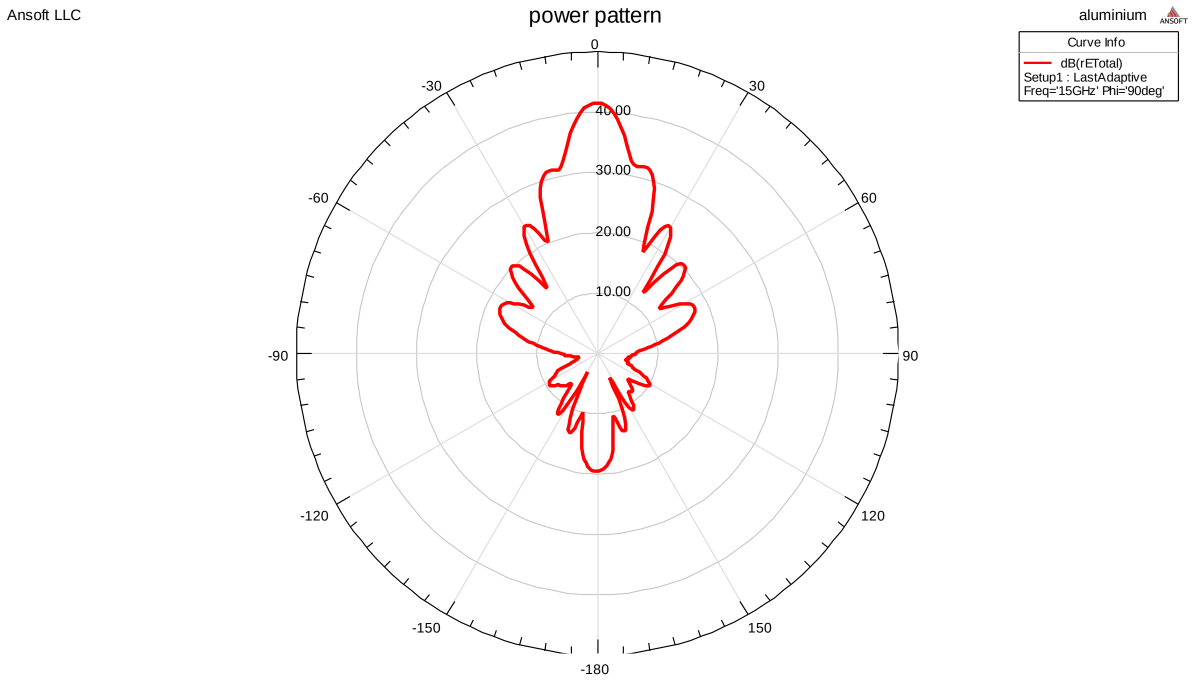


Figure 7.26 2D Power Pattern of Enhanced Design.

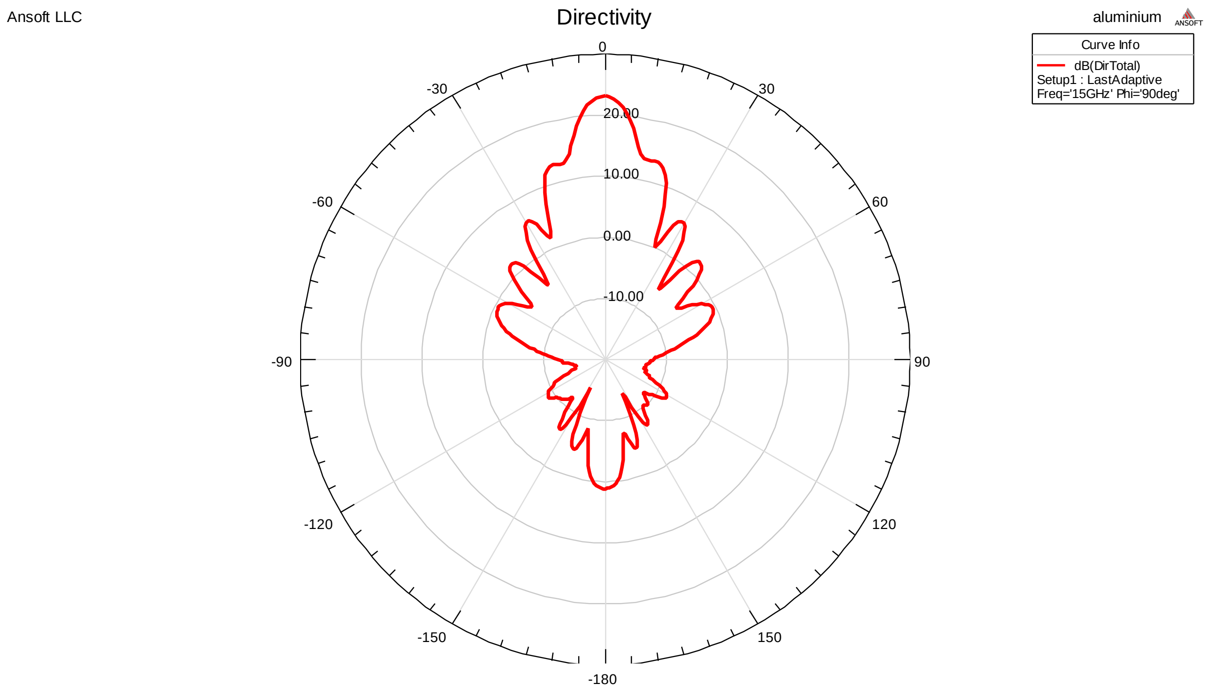


Figure 7.27 2D Directivity Pattern of Enhanced Design.

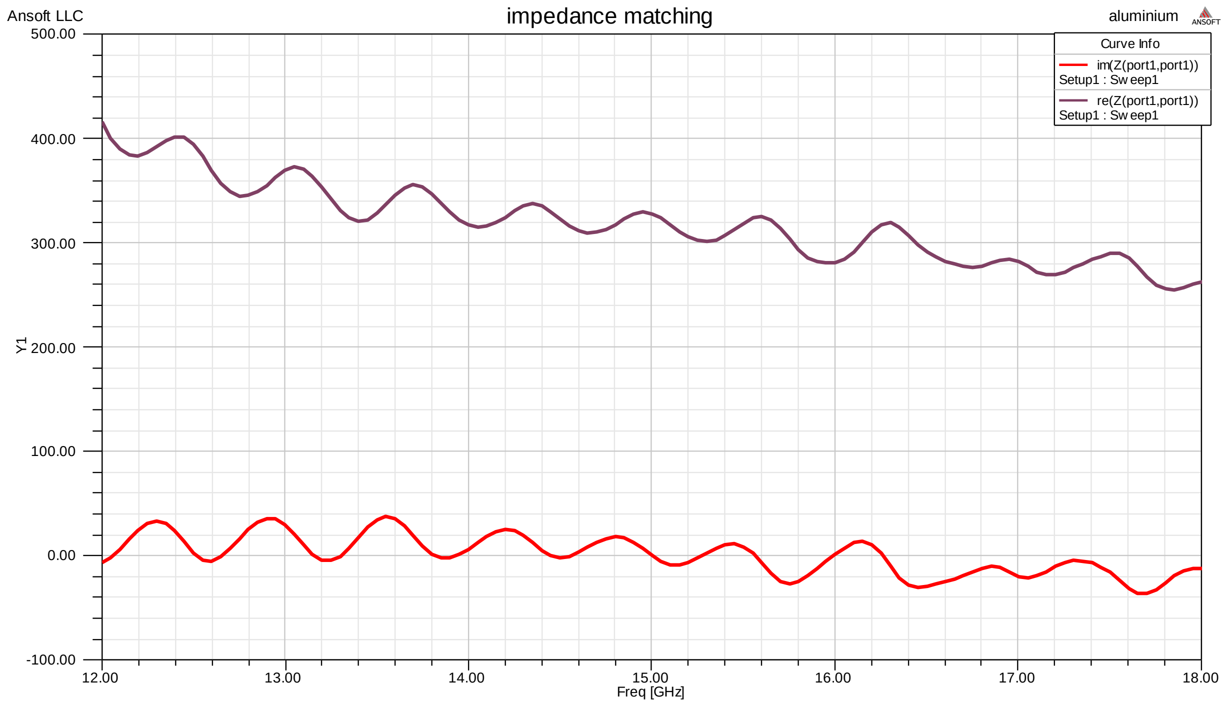


Figure 7.28 Impedance Matching for Enhanced Design.

The Figure 7.28 represents the impedance plot for the enhanced pyramidal horn the real and the imaginary values of the impedance are shown in the plot.

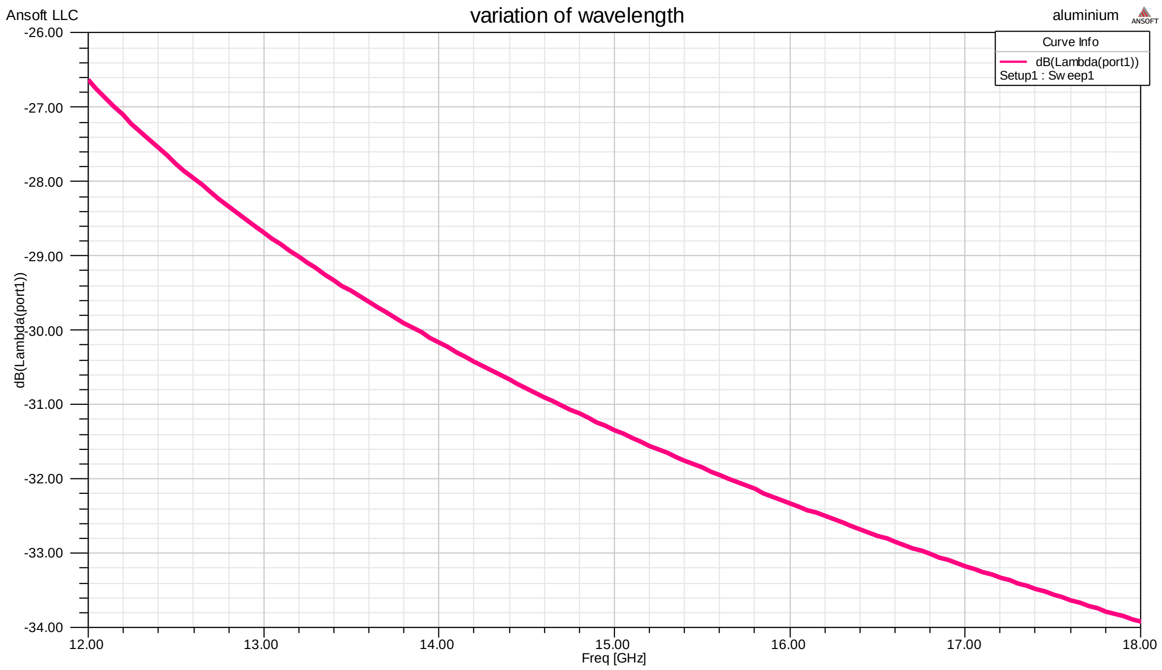


Figure 7.29 Wavelengths Vs. Frequency (GHz).

The variation of the wavelength in the Ku-band frequencies is represented in Figure 7.29.

7.4 PERFORMANCE EVALVATION

In this section, we will compare the simulated results obtained from both basic and enhanced pyramidal horn antenna. The comparison is performed using MATLAB 2010b by exporting the required values of in an .csv file from both the designs, such that a proper comparison can be created.

From the results is is clear that the results obtained by the enhanced design are way better than the base design. The plots for the comparison are given below

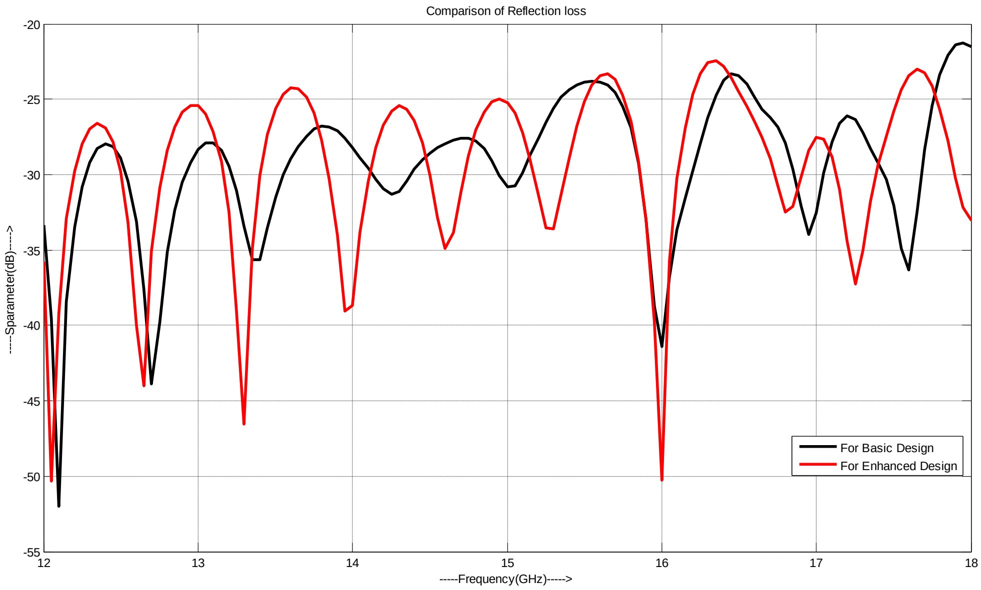


Figure 7.30 Comparison of Reflection Loss.

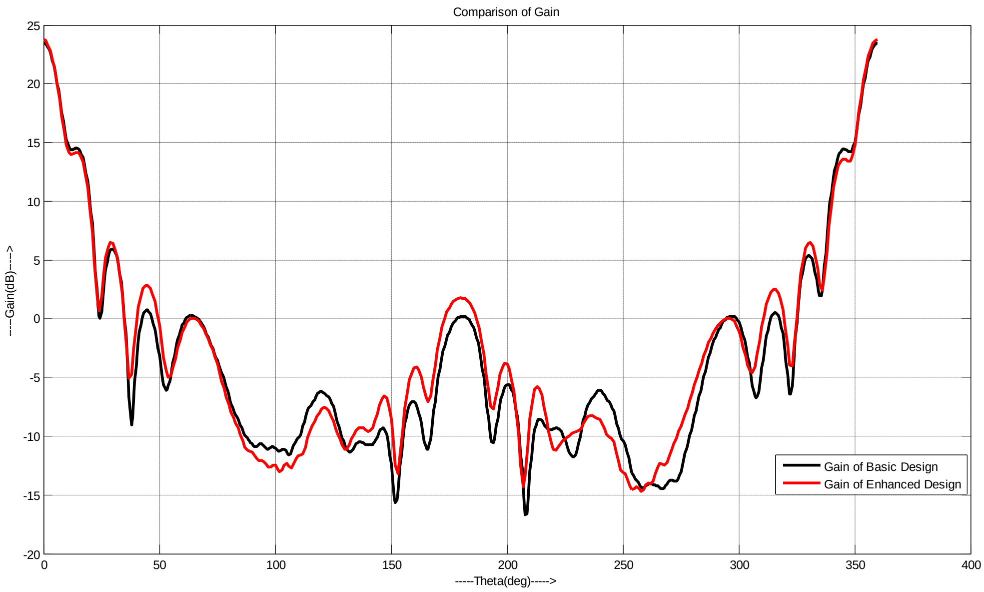


Figure 7.31 Comparison of Gain.

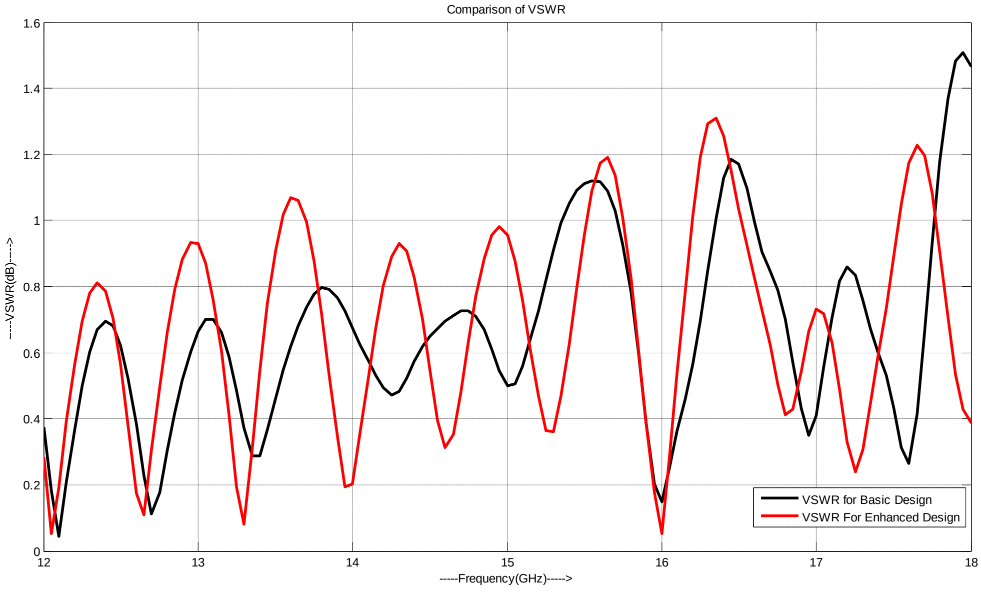


Figure 7.32 Comparison of VSWR.

The return loss has improved drastically it is due to the fact that the radiations emitted by the pyramidal horn antenna which increasing the back lobes are relfected back into the main lobe. The side lobe levels are compressed while the impedance matching is maintained. There are no abrupt changes in the VSWR and its variation with respect to frequency is smooth. Other important factors are also compared in the Table 7.1 given below

TABLE 7.1 Comparison of Antenna Parameters.

Antenna Parameter	Basic Pyramidal Horn Antenna	Enhanced Pyramidal Horn Antenna
Radiation Intensity (W/sr)	17.689	18.943
Peak Directivity	195.23	208.19
Peak Gain	222.48	238.77
Radiated Power (W)	1.1386	1.1434
Incident Power (W)	1	1
Accepted Power (W)	0.99917	0.99698
Radiation Efficiency	1.1396	1.1469

From the comparison of the antenna parameters presented in section 7.4, it is clear that the objectives for the enhancement in the design of pyramidal horn antenna are justified.

CHAPTER 8
CONCLUSION AND FUTURE SCOPE

8.1 CONCLUSION

Design presented is an Optimum Pyramidal horn antenna, operating in the complete Ku band i.e 12-18 GHz. The research on the enhancement of the Ku band pyramidal horn in this report has been done. The results obtained after simulation shows that the designed antenna is working properly in the range of frequency of Ku band. The objectives are fulfilled. The main advantage for designed pyramidal horn antenna is the small size hence, light weight, increased gain and directivity. The emission of radiation is more directed in direction of the major lobe. Also the enhanced performance of the antenna is compared with the basic configuration of the pyramidal horn antenna designed using approximation method. The performance is much better than the basic design. The designed dielectric cavity used for the enhancement is half the length of waveguide. However, on increasing the cavity length the value of reflection loss decreases and on decreasing the cavity length the performance of antenna reaches almost same for the basic design.

The main limitation in the ever increasing applications of these antennas is their size. The size of the antenna varied with the change in frequency. Also the horn antennas have to be designed as per the selected waveguide. Hence, selecting a proper waveguide is important. In today’s technology we need compact antenna size that could serve better performance for the application. However, from communication point of view pyramidal horn antenna are playing important role. This antenna can be used for applications in satellite beaconing, telemetry, wireless communications, detection and targeting using drones, or for astrophysical research. The designed antenna can be used significantly in the systems where directivity of the signal or information is of main concern.

8.2 FUTURE SCOPE

This type of enhancement in the pyramidal horn can be a great advantage to the modern upcoming technologies in telemetry and targeting. However, these antennas are under development and further more changes may require for their better performances. These antennas can be enhanced using ridges, better conductive materials and dielectric lens. The tapered horns are also being used as an enhancement of pyramidal horn antenna.

REFRENCES

[1] C.A. Balanis, "Antenna Theory; a Review", 3rd edition, Wiley Publications, Volume 80, No.1, 2005.

[2] Samuel Y.Liao, "Microwave Devices and Circuits", 3rd Edition, Pearson Publications, 2011.

[3] Mathew N.O. Sadiku, "Principles of Elecromagnetics",4th Edition, International Version, Oxford University Press, 2011.

[4] Samuel Silver, "Microwave Theory and Design", 1st Edition, New York Toronto, McGraw Hill Company.

[5] S. J. Orfandis, "Electromagnetic Waves and Antenna", Rutgers University, New Jersey, November, 2002.

[6] M. A. Othman, M. Z. A. A. Aziz, N. Saysoo, A. R. Othman, "Development of Ultra-Wideband (UWB) Horn Antenna Using Approximation Method" , 2012 IEEE, symposium on wireless technology and application (ISWATA),September, 2012.

[7] Christian Bruns, Pascal Leuchtmann, and Ruediager Vahldieck, "Analysis And Simulation Of A 1–18-Ghz Broadband Double-Ridged Horn Antenna", Electromagnetic Compatibility, IEEE Transactions on Electromagnetic compatibility,Volume:45 , Feb, 2003 ,pages 55-60.

[8] SohaibIkram, Ghulam Ahmad, "Design & Implementation Of A Standard Gain Horn Antenna For Optimized Gain And Radiation Pattern Using Mathcad & HFSS", Second International Conference on Electrical Engineering: Lahore, Pakistan ,2008.

[9] E. Palantei, L. Ramos Emakarim, A. Nugraha, and N.K. Subaer, "Optimized Wideband Horn Antennas Of High Gain And Directivity", (ICEAA), International Conference, 2010.

[10] D. U. NAIR1 & CHETAN ZELE, "Design Of Substrate Integrated Waveguide H-Plane Horn Antenna on a PTFE Substrate", Electronics Department, IJEEE, Volume 2, 2007.

[11] Shao Jinjin, Liu Guochang, JiYicai, Fang Guangyou, Yin Hejun, “UWB TEM Horn Antenna For The Asphalt Pavement Investigation”, Journal of Electronics, china, Volume 61, No 1, Feb 2014

[12] Kerim Guney, “Design of Pyramidal Horn Antennas”, Journal of Marmara for Pure and Applied Science, 2002.

[13] Sadia Khandaker, Monika Mousume Haque ,“Design And Implementation Of A Pair of Horn Antenna For UIU Microwave Test Setup”, EEE, Bangladesh, 2010.

[14] Konstantinos B. Baltzis, “Polynomial-Based Evaluation of The Impact Of Aperture Phase Taper On The Gain Of Rectangular Horns”, J. Electromagnetic Analysis & Applications, 2010.

[15] Yahya Najjar, Mohammad Moneer, Nihad Dib, “Design Of Optimum Gain Pyramidal Horn With Improved Formulas Using Particle Swarm Optimization”, Irbid, Jordan, 29 August, 2006.

[16] Leandro de Paula Santos Pereira, Marco Antonio Brasil Terada ,“New Method For Optimum Design Of Pyramidal Horn Antennas”, Journal of Microwaves, Optoelectronics and Electromagnet Applications, Vol. 10, June 2011.

[17] Daniyan O.L, Opara F.E, Okere B.I, Aliyu N, Ezechi N,Wali J., Eze K., Chapi J., Justus C. and Adeshina K.O, “Horn Antenna Design : Concept and Considerations ”,International Journal of Emerging Technology and Advanced Engineering”, Volume 4, Issue 5, May 2014.

[18] Shubhendu Sharma, “Design and Analysis of Pyramidal Horn Antenna at 8GHz Frequency”, International Journal of Research in Electronics and Communication Engineering, Volume 3, Issue 2, February 2014.

[19] Arvind Roy, Isha Puri, “Design and Analysis of X-band Pyramidal Horn Antenna using HFSS”. International Journal of Advanced Research in Electronics and Communication, Volume 4, Issue 3, March 2015, pp.0488.-.0493.

BIBLOGRAPHY

NAME : Arvind Roy

QUALIFICATION : B.Tech in Electronics and Communication Engineering.

ADDRESS : H.No-42, Main Market Khellani, NH-3,

Near New Standard High School Khellani.

Post Office Khellani, District Doda, (J&K).

PIN-182201.

CONTACT NUMBER : +91-9779728871.

CONTACT EMAIL : arvind19roy@rediffmail.com

PUBLICATIONS

"*Design and Analysis of X band Pyramidal Horn Antenna Using HFSS*", in International Journal of Advanced Research in Electronics and Communication Engineering, Volume.4.Issue.3, March-2015, pp.0488.-.0493.

APPENDIX A

A.1 GENERATION OF RADIATION

The first question arises about antenna is how they radiate and what are the factors that are required? Regardless of antenna type different antennas involve the same basic principle that radiation hence, for an antenna to radiate necessary certain conditions that should be known and satisfied:

a) If a charge is not moving, current is not generated and there is no radiation.
b) If charge is moving with a uniform velocity, there will be no radiation if the wire is straight.
c) Radiations will be generated by the element if it is curved, bent, discontinuous, terminated or truncated.
d) If the charge is oscillating in a time motion then it will radiate even if the wire is straight.

Antennas can be planned to transmit/receive radio waves in all directions equally such antennas are known as omnidirectional antennas or transmit them in a beam in a particular direction and they receive from that one direction only such antennas are often called directional or high gain antennas. According to [1], if the pulses are of shorter and more compact duration along with continuous harmonic oscillations charge produces a stronger radiation with a more broad frequency spectrum.

A.2 KU-BAND SPECIFICATION

As we know all radio systems require frequency spectrum and also delivery of high speed data require wide bandwidth. Firstly, the satellite communication started in C-band with 500 MHz of frequency allocation along with terrestrial microwave links. With period this frequency band was occupied with satellites working at C-band. Therefore new satellites were required and therefore designed for next available frequency that is, for the Ku-band frequencies. The IEEE has delivered different set of frequency range for different wireless applications so that, there is no overlapping in operational frequency of appliances. From the table, it is clear that the Ku band is the 12 to 18 GHz section of the electromagnetic frequency spectrum in the microwave range of frequency. Ku band is dedicated to satellite communications, generally for fixed and broadcast services. Ku signifies K-under which indicated the band just below the K-band. This band is further segmented into small frequency bands by International Telecommunication Union (ITU).

TABLE A.1 IEEE Microwave Frequency Range.

Nomenclature	Frequency range in Giga hertz
HF	0.003 to 0.030
VHF	0.030 to 0.300
UHF	0.300 to 1.000
L band	1.000 to 2.000
S band	2.000 to 4.000
C band	4.000 to 8.000
X band	8.000 to 12.000
Ku band	12.000 to 18.000
K band	18.000 to 27.000
Ka band	27.000 to 40.000
Millimeter	40.000 to 300.000
Sub-millimeter	>300.000

Satellites used in this band may also be used for backhauls. Some of the advantages of Ku band are it is not regulated in power to avoid interference with terrestrial microwave systems the power of its uplink and downlink can be increased. Thus the size of the antenna can be decreased. Nowadays, the beamwidth has become much more serious than gain. The Ku band provides much focused beams. This band also provides less susceptibility to rain fades. However, with such advantages this band possesses some disadvantages too. Ku band satellites require more power than C-band satellites. Also, the snow fades may occur during winter precipitation. Rain fade and snow fade can be mitigated by using an appropriate link budget strategy while designing satellite network system.

A.3 WAVEGUIDE DATA SHEET

Frequency Range (Ghz)	Waveguide Designation			Internal Dimensions (mm)	Flann 'Standard' flange details Please see page 110-115 for outline dimensions	
	British WG	IEC R	EIA WR		Flange Designation	Description
1.14 - 1.73	6	14	650	165.100 x 82.550	UG-417B/U Type (but without groove)	Rectangular, Ten hole fixing + 2 dowel holes
1.72 - 2.61	8	22	430	109.220 x 54.610	UG-435B/U Type (but without groove)	Rectangular, Ten hole fixing + 2 dowel holes
2.60 - 3.95	10	32	284	72.140 x 34.040	5985-99-083-1560 also drilled for the 5985-99-083-0010	Circular, Six/Eight hole fixing
3.30 - 4.90	11A	40	229	58.170 x 29.083	UDR 40	Rectangular, Ten hole fixing
3.94 - 5.99	12	48	187	47.550 x 22.149	UAR 48	Circular, Eight hole fixing
4.64 - 7.05	13	58	159	40.390 x 20.193	UAR 58	Circular, Six hole fixing
5.38 - 8.18	14	70	137	34.850 x 15.799	UAR 70	Circular, Six hole fixing
6.58 - 10.0	15	84	112	28.449 x 12.624	UBR 84	Square, Four hole fixing
8.20 - 12.5	16	100	90	22.860 x 10.160	UBR 100	Square, Four hole fixing
9.84 - 15.0	17	120	75	19.050 x 9.525	UBR 120	Square, Four hole fixing
11.9 - 18.0	18	140	62	15.799 x 7.899	UBR 140	Square, Four hole fixing
14.5 - 22.0	19	180	51	12.954 x 6.477	UBR 180	Square, Four hole fixing
17.6 - 26.7	20	220	42	10.668 x 4.318	UBR 220 Type	Square, Four hole fixing
21.7 - 33.0	21	260	34	8.636 x 4.318	UBR 260 Type	Square, Four hole fixing
26.4 - 40.1	22	320	28	7.112 x 3.556	UG-599/U	Square, Four hole fixing
33.0 - 50.1	23	400	22	5.690 x 2.845	*UG-383/U	Circular, Four hole fixing/doweled
39.3 - 59.7	24	500	19	4.775 x 2.388	*UG-383/U (Modified)	Circular, Four hole fixing/doweled
49.9 - 75.8	25	620	15	3.759 x 1.880	*UG-385/U	Circular, Four hole fixing/doweled
60.5 - 92.0	26	740	12	3.099 x 1.549	*UG-387/U	Circular, Four hole fixing/doweled
73.8 - 112	27	900	10	2.540 x 1.270	*UG-387/U (Modified)	Circular, Four hole fixing/doweled
92.3 - 140.0	28	1200	8	2.032 x 1.016	*UG-387/U (Modified)	Circular, Four hole fixing/doweled
114.0 - 173.0	29	1400	6	1.651 x 0.826	*UG-387/U (Modified)	Circular, Four hole fixing/doweled
145.0 - 220.0	30	1800	5	1.295 x 0.648	*UG-387/U (Modified)	Circular, Four hole fixing/doweled
172.0 - 261.0	31	2200	4	1.092 x 0.546	*UG-387/U (Modified)	Circular, Four hole fixing/doweled
217.0 - 330.0	32	2600	3	0.864 x 0.432	*UG-387/U (Modified)	Circular, Four hole fixing/doweled

Figure A.1 Data sheet for Waveguides.

A.4 PYRAMIDAL HORN CONNECTOR

To connect the Pyramidal horn antenna a connector that provides the azimuthal and elivational rotation mechanism for adjusting the the horn is required. However, if we are focussed on the line of sight (LOS) communication then the pyramidal horn antenna can be fixed permanently in the prticular direction of intrest.

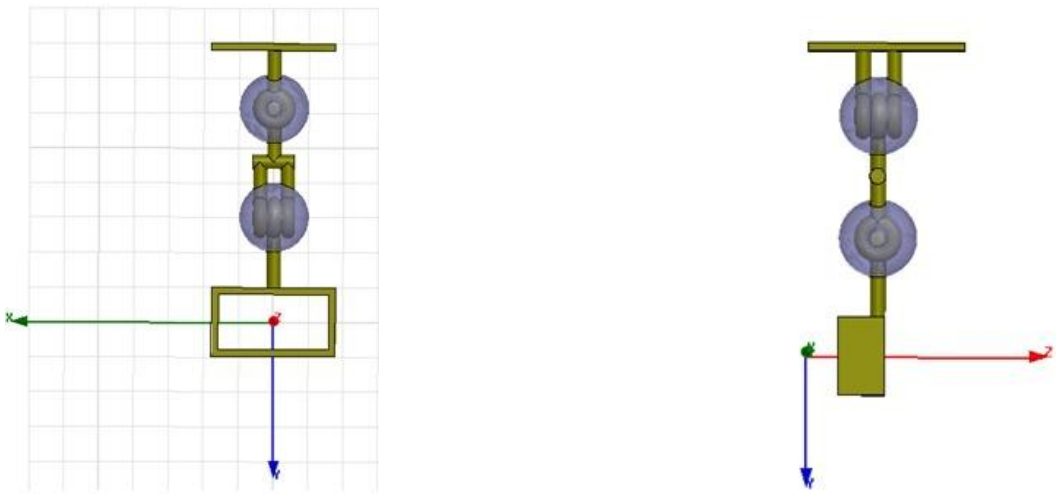


Figure A.2 Pyramidal Horn Connector, Front view and Side view.

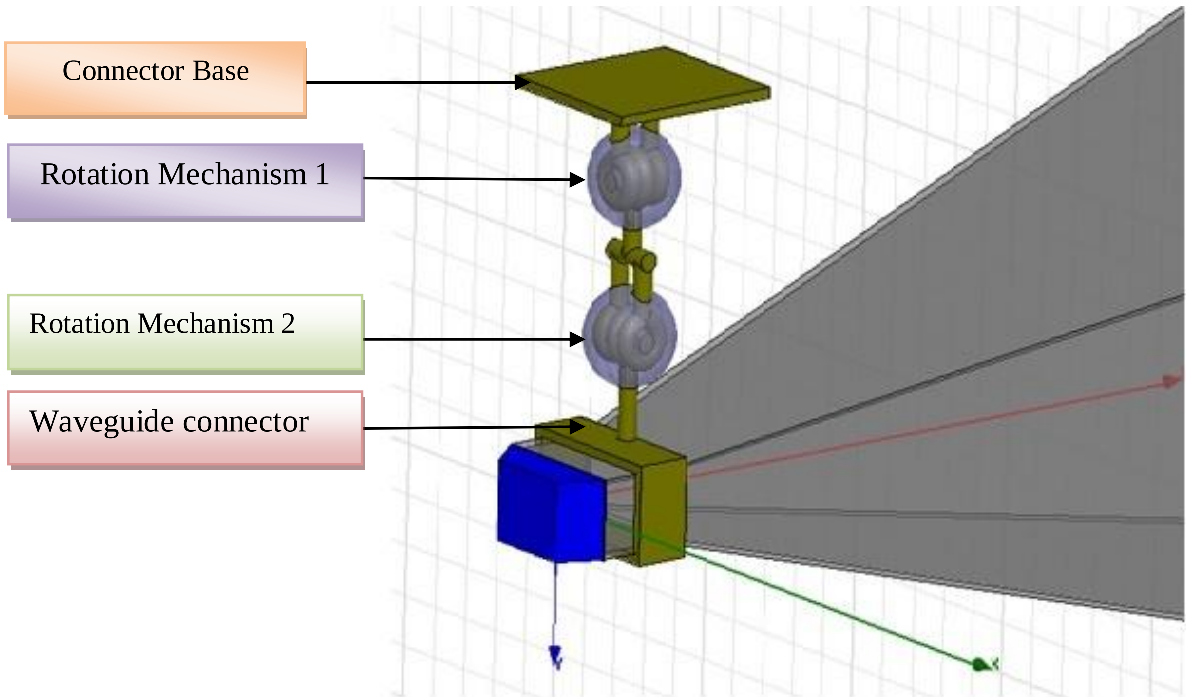
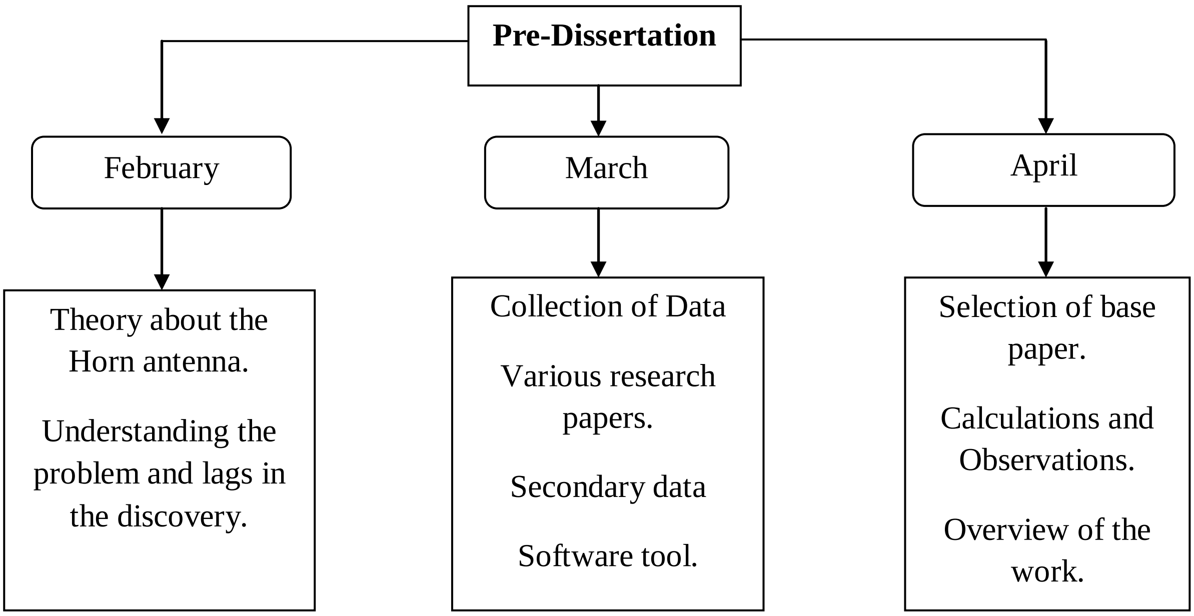


Figure A.3 Connector for Pyramidal Horn Antenna.

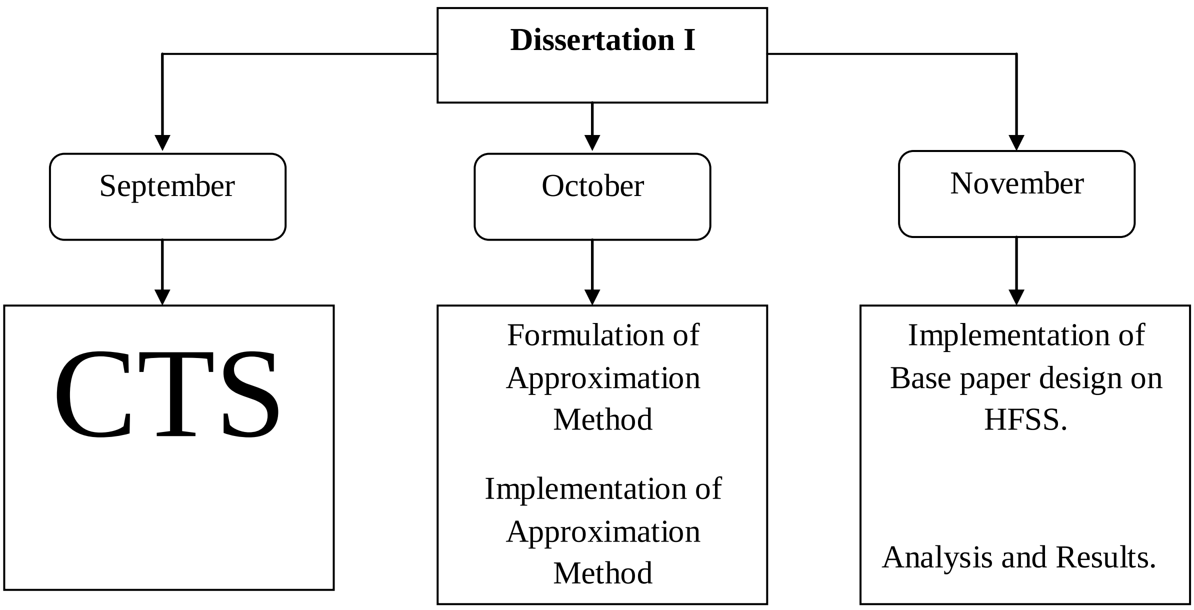
APPENDIX B

B.1 WORK PLAN WITH TIMELINES

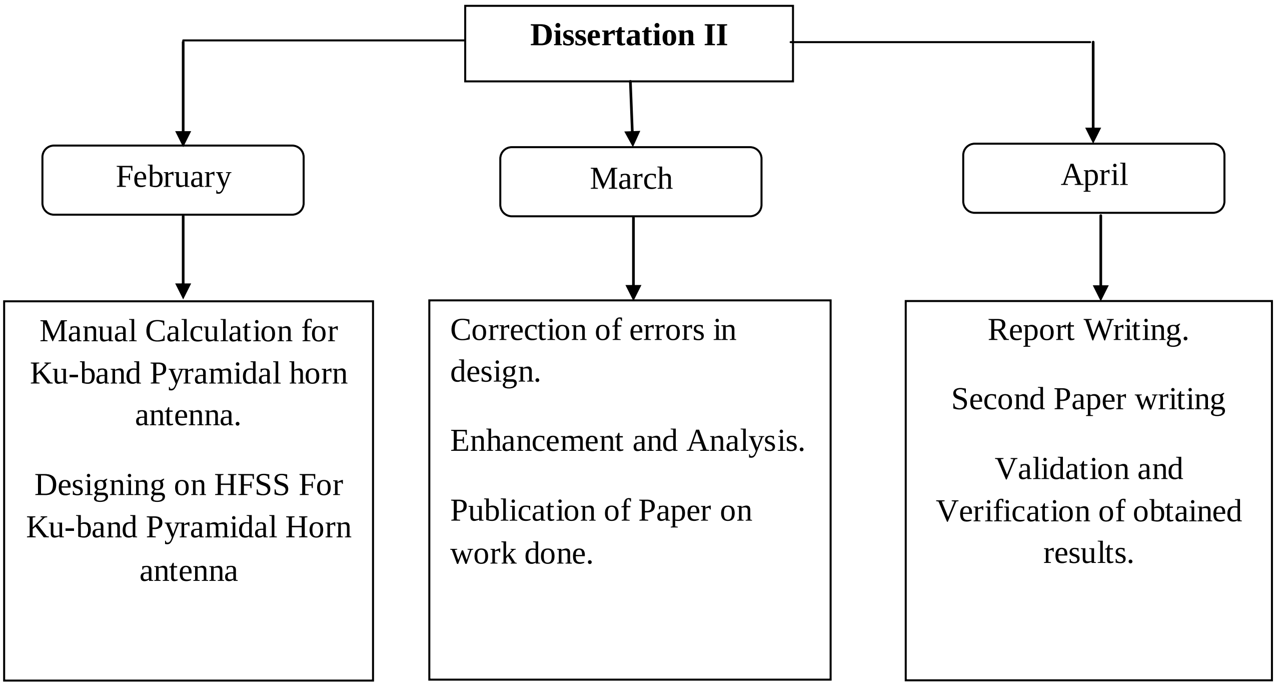
The work plan is briefed below the thesis is divided into 3 parts the work is fragmented on the monthly bases.



Flowchart B.1 Monthly work plan for Pre-Dissertation .



Flowchart B.2 Monthly work plan for Dissertation I.



Flowchart B.3 Monthly work plan for Dissertation II.