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Design and Analysis of Pair of Pyramidal Horn Antenna Using HFSS

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***Abstract:* -- This paper discusses the design, simulation of medium gain, lightweight, wide beamwidth pyramidal horn antenna pair for terrestrial microwave line of sight communication in mobile & wireless applications. This antenna has been designed for K-band frequencies widely used in terrestrial microwave communication for mobile & wireless applications. Simulated horn antenna pair shows wideband characteristics of VSWR < 2 for bandwidth range of minimum 8GHz. Antenna is linearly polarized and show wide beam characteristics in azimuth plane with minimum gain of 16.9dB. E-field & H-field analysis for K-band Applications for pyramidal horn feeds have also been discussed. Absolute gain measurement techniques have been employed for the measurement of antenna gain. Design meets the ruggedness, strength & reliability, durability, weight, corrosion resistance, temperature variation requirements of terrestrial/ line of sight (LOS) communication. Design, Simulation & Optimization for K-band pyramidal horn antenna pair has been done on ANSOFT HFSS 13.**

I. INTRODUCTION

This paper discusses the design & measurement techniques for wide beamwidth, medium gain, wide band and light weight K-band pyramidal horn antenna pair used as reflector feed in terrestrial / line of sight (LOS) communication for mobile & wireless applications. Pyramidal horn antennas have been widely used as standard gain horns in anechoic chamber testing application. However other applications for pyramidal horn antennas include terrestrial communication in satellite links, they are widely used in cellular, banking line of sight (LOS) communication / transmission applications [1]. Pyramidal horns select the polarity of the waves to be received, which helps to attenuate unwanted signals from adjacent channels and transponders, and from other communications satellites at nearby orbital positions. For our designed Pyramidal horn antenna pair the measured peak gain is measured to be approximately 16.9 dB with half power beamwidth of approximately 60 degrees in azimuth plane. This beamwidth is calculated to minimize the spill over losses, illumination losses for reflector dish & to increase the reflector efficiency [2].

A. Advantages and Disadvantages

There are various advantages of using pyramidal horn antennas over other types of antennas which are as follows: (a) It serves as global standard for testing & calibration in anechoic chambers (b) It design & construction is simple as compared to dual & quad ridge horns (c) They are lightweight as compared to many other antennas providing similar gain (d) Capability to provide beam width pattern of user's choice as antenna can be designed accordingly (e)Availability of waveguide dimensions & charts for easy designing & determination of gain for aperture. (f) Most widely used as feed in large radio astronomy, dish antennas & also used in satellite communication & tracking [1]. However disadvantages include their linear polarization characteristics, as circular polarization is useful in satellite communication. However this disadvantage proves to be main advantage in terrestrial (LOS) communication where circular polarization is not required as vertical polarization is the requirement for LOS terrestrial communication [3].

B. Pyramidal Horn Antenna

Pyramidal horns antennas vary widely in size, gain, weight & have the capability of being designed & developed within wide range of frequencies ranging from MHz to THz. Pyramidal horn basically constitutes of rectangular waveguide with pyramidal aperture. These antennas possess good electrical characteristics therefore are ideal to be used as reflector antenna feeds. Pyramidal horns are combination of E-plane & H-plane Sectoral horns as aperture dimensions are greater than the waveguide dimensions. If properly designed pyramidal horn show wideband characteristics along with low side lobes as well.

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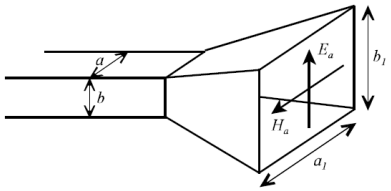

Figure 1: Illustration Diagram for Pyramidal Horn

Antenna

Directivity for pyramidal horn is given by [1]
����2
Dp = aaa1 a1DEDH (1)

DH= Directivity of H-Plane Sectorial Horn

a= larger dimension of rectangular waveguide b= dimension of rectangular waveguide
a1= dimension of rectangular aperture parallel to a b1= dimension of rectangular aperture parallel to b λ= operating frequency
Discussion & theory regarding the radiation pattern for pyramidal horn is not the scope of our application and it can be seen in great detail in the following text [4, 5, 6, 7]

II. PYRAMIDAL HORN ANTENNA PAIR DESIGN & SIMULATION

Modelling of K-Band Pyramidal Horn antenna pair has been performed using advanced EM simulation software 'HFSS 13'. HFSS uses Finite Element Method as analysis & solution to electromagnetic problems by developing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lanczos-Pade Sweep (ALPS) [8].

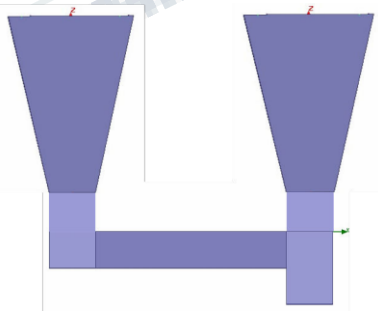

Figure 2: 2D modelling view of simulated K-Band

Pyramidal horn pair.

Mentioned designed pyramidal horn antenna pair easily exceeds the bandwidth requirement practices of wireless telecommunication industry. The main
design goal is to achieve wide beamwidth in

Where

DP= Directivity of Pyramidal Horn

DE= Directivity of E-Plane Sectorial Horn azimuth plane for the pyramidal Horn pair so that the reflector surface is completely utilized and spill over losses can be minimized. Standard waveguide dimensions are selected for waveguide design. Apertures are also carefully designed with ratio of
2:1 i.e. (b1=2a1) such that the design is close towards E-Plane Sectoral Horn in configuration but is categorized as pyramidal horn as (a1>a) however in case of E-plane Sectoral horn (a1=a). Other cases for aperture dimensions are also simulated such that (a1=2b1), (a1=b1) & (b1=a1) but they were rejected as gain patterns generated were not per our application requirement. Antenna is linearly polarized as per the requirement in terrestrial line of sight communication. Impedance testing for developed antenna was conducted through Vector Network Analyser (VNA) & results for linear polarization as well as for gain & beamwidth were conducted in anechoic chamber facility. Simulated Gain for K-Band Pyramidal horn antenna pair comes out to be 16.9dB.

Simulated Antenna results shows wideband characteristics for frequency range of 22GHz for VSWR<2

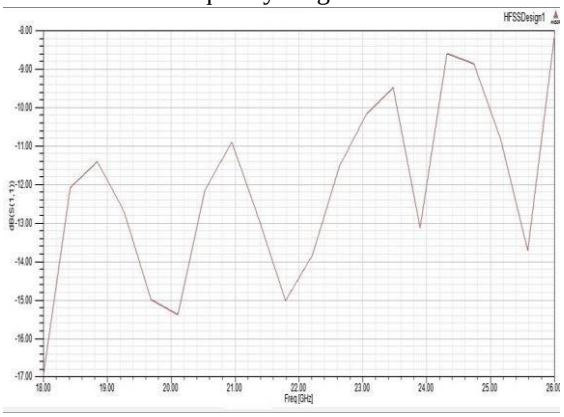

Figure 3: S-11 plot for K-Band Pyramidal horn antenna pair using HFSS

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III. MEASUREMENT RESULTS

Measurements for reflection coefficient were conducted using vector network analyser however gain test was conducted using anechoic chamber facility. S-11 measurements through Vector Network Analyser proved antenna possesses excellent wide bandwidth ranging from 18 - 26GHz. Bandwidth of 22 GHz (33%) was measured for VSWR<2.

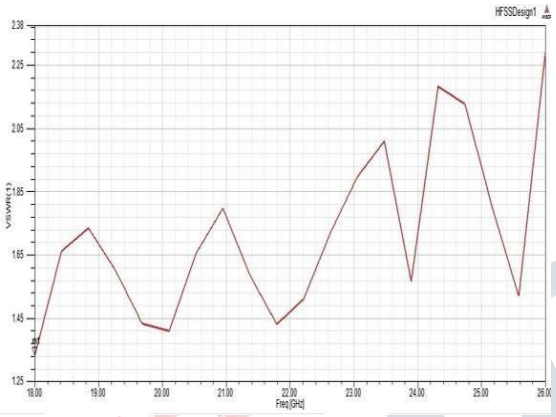

Figure 4: S-11 measurement plot for K-Band pyramidal horn antenna pair

Absolute gain method was used for gain measurements [1]. Directivity & Gain measurements can also accomplished through gain transfer method, phase center location method, extended edge wave diffraction model discussed in following text [10, 11, 12, 13].

Name	Theta	Ang	Mag
m1	0.0000	0.0000	16.6540

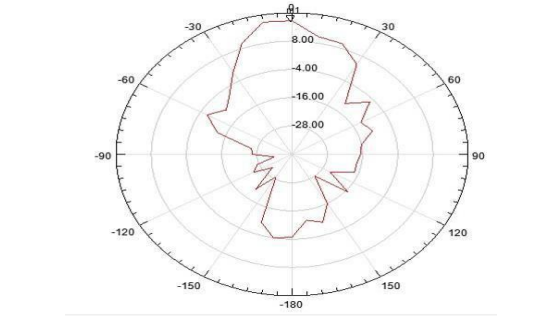

Figure 5: 2D radiation pattern of K-Band horn antenna pair

Measured & tested beamwidth for K-band pyramidal horn antenna pair comes out to be 63° in azimuth plane as per our requirement. Measured gain comes out to be 16.9 dB.

The graphical representation of field variations of an antenna is the radiation pattern. The figure 5 shows the 2D radiation pattern of K- Band pyramidal horn antenna pair, at theta=0 degree and phi=180 degree. We can observe that the peak gain is 16.6 dB at the specified angle of theta and phi.

The figure 6 shows the average gain of the design. The red colour indicates average peak gain achieved. The obtained average peak gain is approximately 17 dB, which shows the high gain performances of the realized antenna.

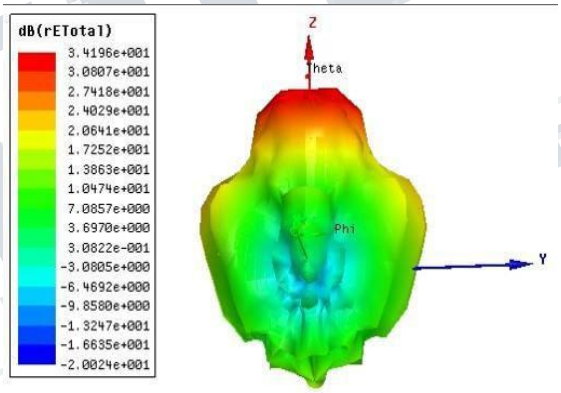

Figure 6: 3D Polar plot for K-Band Pyramidal horn antenna pair

IV. CONCLUSION

This paper discusses design and simulation of wideband, high performance pyramidal horn antenna pair for terrestrial microwave line of sight communication.. Antenna shows excellent electrical characteristics with gain of 16.9 dB & has wide coverage beam of 60°. Antenna is linearly polarized which is the basic requirement for terrestrial microwave communication in mobile & wireless applications. Design meets the ruggedness, strength & reliability, durability, weight, corrosion resistance, temperature variation requirements of terrestrial/ line of sight (LOS) communication. Advantages & Disadvantages of pyramidal horn antennas have also been discussed.

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