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Gain Enhancement of Pyramidal Horn Antenna for X Band using Improved Geometry

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ABSTRACT: An improvement of the gain of the rectangular pyramidal horn antenna is proposed in this paper. The design is obtained by varying the size of the flare and the length of the horn antenna. The radiation pattern has been improved. By improving the design, the reflection coefficient obtained at -17dB, gain of 18 dB, VSWR of less than 1.2 has achieved. The reflection coefficient of optimal design is at -17.9dB and a gain of 18 dB and VSWR less than 1.25 has achieved. The simulations have been done using HFSS tool. The results obtained are compared with other design of horn antenna. The proposed design has better gain calculated even at reduced dimensions.

KEYWORDS: Horn Antenna, Gain, Rectangular rings, .

I. INTRODUCTION

Horn antenna is just a flaring of the waveguide in E & H plane to direct radio waves in a beam. Horn antenna finds wide applications in microwave range because of low VSWR, moderate bandwidth and high gain. Horn antenna is widely used as to capture RF power, to radiate RF power, as Feeder for reflector, as a standard calibration antenna in laboratory, directive antenna for devices as radar gun, automatic door opener, microwave radiometer.

Yingranhe et al. in [1] proposed the horn antenna filled with bulk metamaterial which increases the gain and aperture efficiency. The reflection coefficient below -20 dB was achieved and gain of 15dB is obtained. To obtain these parameters the bulk metamaterial with permeability anisotropy & permittivity anisotropy was employed to shorten the length upto 3mm. E-plane directivity of material can be enhanced by changing the permitivity while H plane directivity can be enhanced by changing permeability of a material. The dielectric lens is used to reduce the horn length and gain was enhanced, but due to lens, the antenna weight is increased significantly.

Meng et al. in [2] poposed zero index metamaterial lens (ZIML) of modified split ring resonators for gain enhancement Z1ML was designed to approach effective permeability permittivity to zero, which leads to have wave impendence matching with air to zero. The lens was not attached with which makes it difficult to carry ZIML for some kind of applications where placement of antenna is not fixed. Another design of horn antenna in [3] whose gain was 20 dB as initially 15dB gain was obtained and then by increasing the dimensions of the horn the gain was increased to 20 dB. The length of the horn was increased upto 10 inches, which is not feasible for handy applications.

A shortened length pyramidal horn antenna has been proposed in this paper without using metamaterial which aims at improving the gain and reduces the size of horn antenna. The gain of the antenna can be increased easily by just increasing the dimensions of the antenna, but a long horn cannot meet requirements in engineering applications so it was strongly recommended to obtain short length & high gain at the same time. In this paper, rectangular rings are inserted into the horn antenna to enhance the gain. The five rectangular rings are inserted into the horn at different locations. These locations are varied to obtain the gain as high as possible. This paper has 4 sections as first section

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explains about the introduction part of horn antenna and 2nd section give idea about the proposed design of horn antenna while the section 3rd and 4th give details about the result and conclusion.

II. DESIGN OF PYRAMIDAL HORN

A. WAVEGUIDE

A waveguide is a structure which guides the waves, like sound waves or EM waves. The signal in waveguide propagate with a minimum loss [4]. There are different types of waveguides for different waves. The most common used waveguide is a hollow metal conductive pipe used to propagate the high frequency signal. The frequency which is used to transmit the signal through waveguide itself defines the shape of the waveguide like optical fiber will guide the high frequency light but not transmit microwave. The propagation of the wave occurs in spherical waves in open space, but the waveguide confines the wave to propagate in one dimension [5]. Due to the metal boundaries the wave confines in the interior of the waveguide and propagation of wave described as zig zag between the walls.

There are a number of waveguides types are used for transmitting power or signal between the components of a system such as radar or optical devices. Waveguides are also used to measure acoustic, optical, elastic properties of material and objects. The dimensions of X-band rectangular waveguide are a=2.286cm and b=1.016cm. The length of the waveguide in this design is l=2.54cm. These dimensions are taken from the common standard rectangular feed waveguide. The waveguide standard used in this design is WR90.

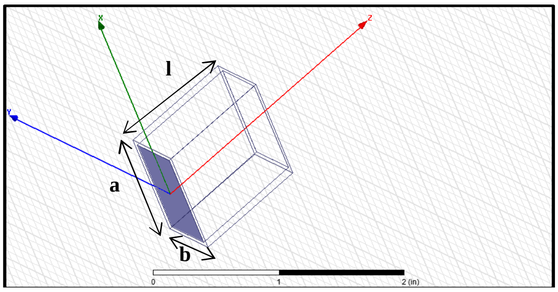

Fig (1) Dimensions of waveguide

B. RECTANGULAR WAVEGUIDE STANDARDS

The standard notation for rectangular waveguide WR is described as below

Table 2: Standard for Rectangular Wave Guide

Frequency band	**Waveguide standard**	**Frequency limit(GHz)**	**Inside dimension**
C band	WR-137	5.85-8.20	1.372x0.622
X band	WR-90	8.2-12.4	0.90x0.40
Ku band	WR-62	12.4-18	0.622x0.311
Ka band	WR-28	26.5-40	0.280x0.140

In this design waveguide with WR90 specifications have been used, which is a=0.9’’ and b=0.4’’.

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*C. **PYRAMIDAL HORN***

Figure (2) shows the basic horn antenna. In this figure dimension A shows the broad wall of the horn antenna and dimension B shows the narrow wall of horn antenna. The flare length is shown by dimension L.

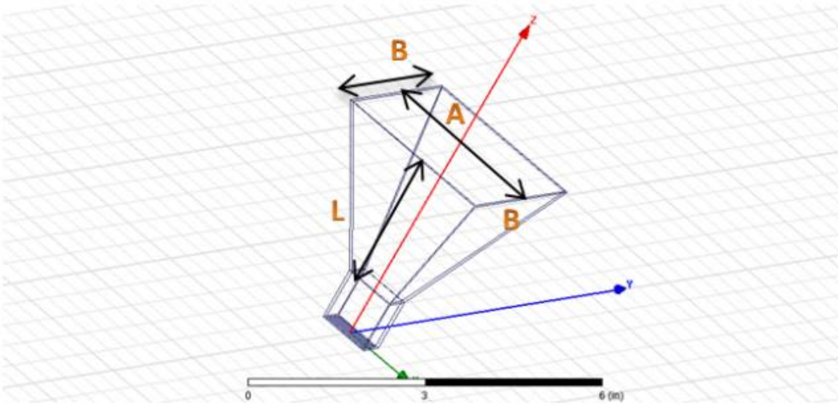
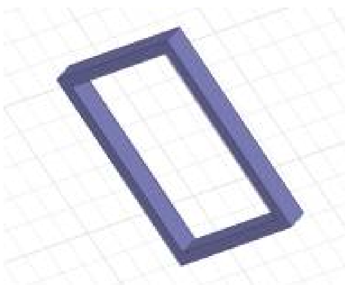


Fig (2) basic dimensions of horn antenna

The horn antenna has been designed using rectangular rings fixed in an aperture of the horn antenna. By insertion of rectangular rings in the aperture of horn antenna reflection coefficient has been improved and bandwidth can be changed by varying the positions of these rings.



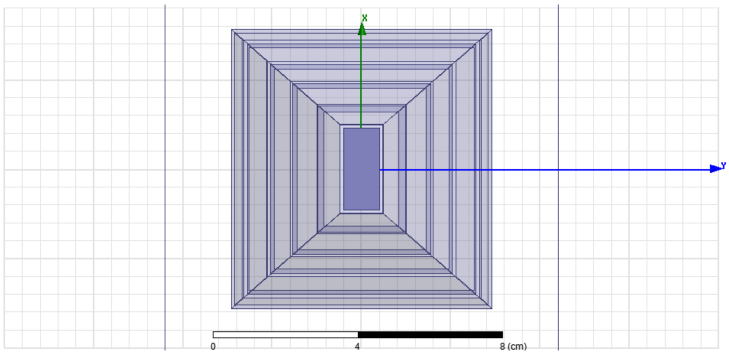


Fig (3) Rectangular ring(left), Fig (4) Top view of Horn Antenna(right)

Figure (3) shows the picture of one rectangular ring. The length and width of the ring are adjusted according to the position of the ring in aperture. The thickness and height of the ring is h=0.4 cm. Figure (4) shows the top view of the antenna with rectangular rings. In this design five rings are being used to optimize. The dimensions of the rectangular rings in flare of horn are given in table (1).

The pyramidal horn is excited by a wave port through a waveguide. The material of the antenna is taken as Aluminium. The geometry of the pyramidal horn antenna with dimensions of aperture broad wall A=7. 6 cm and narrow wall B=7. 1 cm.

Table 1: Dimensions of rectangular rings in flare

Ring	X axis (cm)	Y axis (cm)	Z axis (cm)	Thickness (cm)
1	2.5	1.2	2.4	0.4
2	3.6	2.5	4.3	0.4
3	4.9	4	6	0.4
4	6	5.3	7.5	0.4
5	7.2	6.7	9.1	0.4

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The length of the aperture is L=7. 4 cm. The thickness of the Aluminium sheet is taken as t=0.2 cm. The rectangular rings have been introduced in the flare part of the horn to optimize the gain as shown in the figure (5).

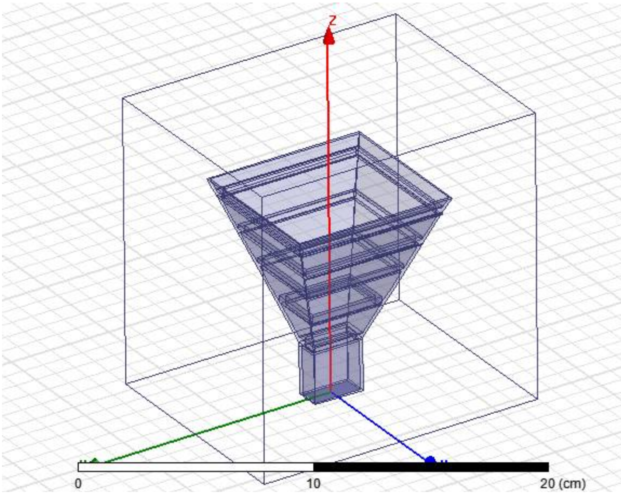

Fig (5) Pyramidal horn antenna

The dimensions of this flare are calculated using an optimization process which was executed in HFSS . The optimized dimensions are then used to optimize the gain and bandwidth. The radiation pattern, VSWR and smith chart were observed and obtained a gain of 18.1dB.

III.RESULTS

The HFSS is used for simulation. Figure (6) shows the 3D polar plot for the far field gain. The gain calculated is 18dB. Figure (7) shows the 17.8dB of directivity with pyramidal horn antenna was achieved using equation 1.

$$D = \frac{32*A*B}{\lambda^2 \pi} \quad (1)$$

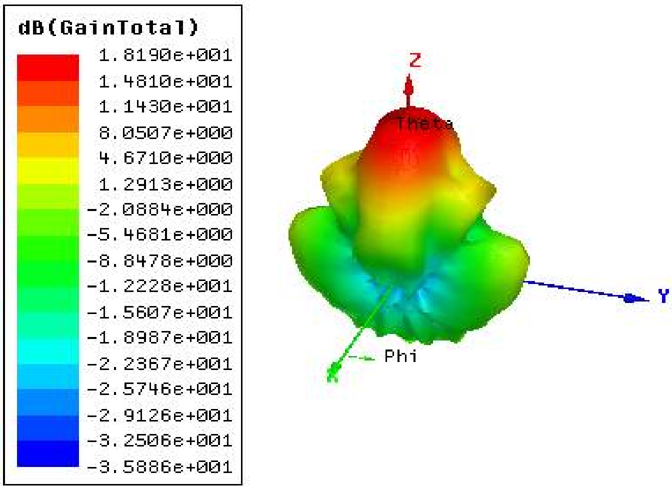

Fig (6) 3D Polar plot of Gain

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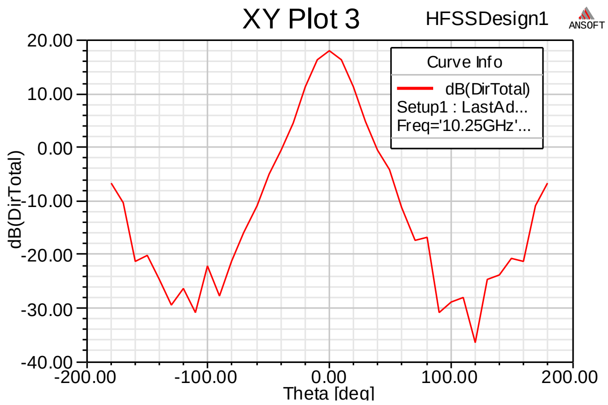

Fig (7) Plot of Directivity

Figure (8) shows the VSWR plot, the VSWR calculated is 1.25

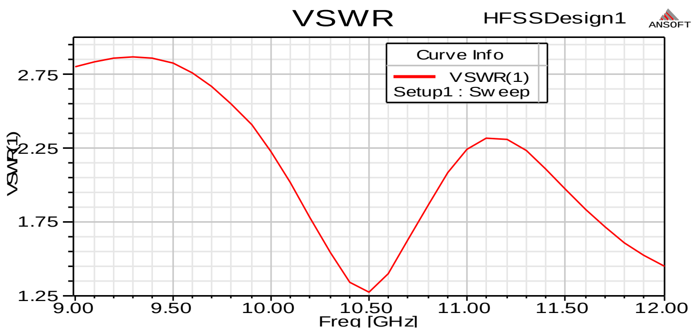

Fig (8) VSWR plot at 10.4GHz

Figure 9 the rectangular plot of gain.

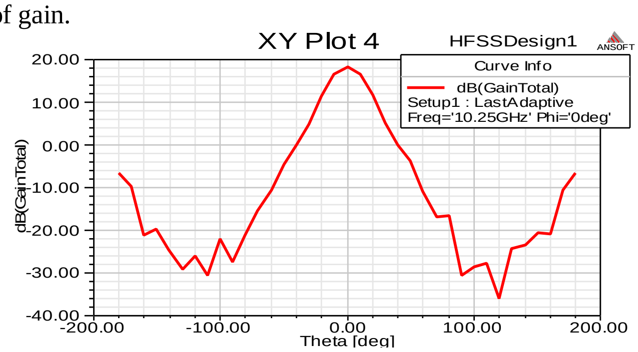

Fig (9) Gain plot

Figure (10) shows the reflection coefficient of horn antenna operating at 10.5GHz. The reflection coefficient -17.9dB is measured.

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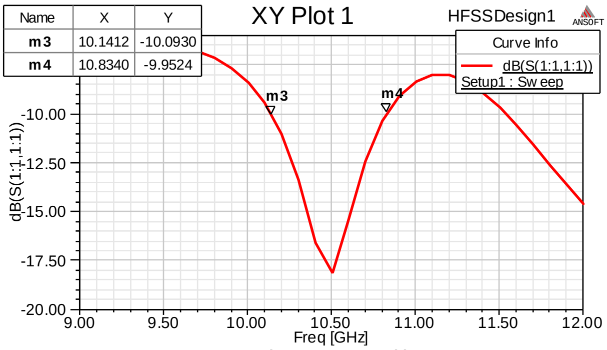

Fig (11) Reflection coefficient

Comparison

Table 2 shows the comparison of the proposed design with the existing design in [4]. In table A and B shows the broad wall of the aperture and narrow wall of aperture respectively.

Table 2: Comparison of proposed design with design in [4]

Parameter	Design in [1]	Design in [4]	Proposed design
A and B (inches)	2.36'' and 2.36''	4.87'' and 3.62''	2.99'' and 2.79''
Flare length (inches)	1.18''	10''	2.91''
Gain (dB)	15	20	18.1

IV. CONCLUSION

A horn antenna has been designed to operate at 10.4GHz using rectangular rings inserted in the flare of a horn at a specific distance. The comparison of the proposed design and existing designs have been shown and optimization of existing designs have been done to achieve the improved radiation pattern, reflection coefficient and VSWR. The optimum gain obtained in this design is 18dB, VSWR is 1.25 and reflection coefficient of -17.9 dB is achieved.

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