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DESIGNING OF THE CONICAL CORRUGATED HORN ANTENNA

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Abstract— The objective of the paper is to provide the overview of the principle of operation and designing approach that is used to design the conical corrugated horn antenna. This paper deals with the designing of the conical corrugated horn with large aperture and narrow flare angle of 15 degree using brass plates that would produce symmetric radiation patterns, good impedance match and low crosspolarisation which would be used as feed horn for the Cassegrain antenna working at 35.6 GHz for cloud radar. The final design using High Frequency Simulator System (HFSS), shows successful simulated results with symmetrical E and H radiation patterns with good impedance match and low cross polar levels.

Index Terms— Corrugated horn, Conical corrugated horn, Feed horn

1 INTRODUCTION

THERE are three main reasons for the existence of corrugated horn antennas. Firstly, they exhibit radiation pattern symmetry, which offers the potential for producing reflector antennas with high gain and low spillover; secondly, they radiate with very low crosspolarisation, which is essential in dual polarisation systems and finally, they offer a wide bandwidth response.

Now-a-days, in the age of the communications, horn antennas take a very important role in the development of the actual and future communications systems with high requirements in their radiations patterns. In fact, corrugated feeds are the best feeds ever developed.

Ten to twenty years ago, corrugated horn antennas were restricted to be used in high performance applications, like being on board of satellites, earth station radio telescope horns, antenna measurement chambers and very few more applications. They were restricted to those applications for two main reasons: difficulties in the design and difficulties in the manufacture process of a corrugated feed.

Now-a-days, likely global market applications for corrugated feeds are: compact parabola feeds, covert surveillance, secure communications, base station power saving, reduced interference.

2 PRINCIPLES OF OPERATION OF CORRUGATED HORN

The corrugated wall that alters the field pattern in a corrugated waveguide describes the principle of operation of corrugated horns. The corrugations of the walls will change the fields to achieve desirable properties such **as** symmetrical radiation pattern, low sidelobes, low crosspolarisation and a resulting good return loss**.** In order to obtain these properties, in particular the symmetrical radiation pattern and low crosspolar level, the aperture field must be almost linear as shown in figure 1 below.

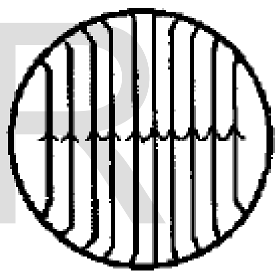

Fig 1. Ideal aperture electric field in corrugated horn

Looking at figure 1, a small amount of field curvature is present and the fields are not precisely linear. This particular aperture electric field is required to cancel all the crosspolar components, thus yielding very low crosspolarisation. By examining the aperture fields of an 'open-ended corrugated waveguide, the dominant mode in a hybrid mode waveguide that produces the aperture electric fields is [1]

$$\left.\begin{aligned} E_x &= A_1 J_0(Kr) - \frac{(X-Y)}{kr_1} A_2 J_2(Kr)\cos 2\phi \\ E_y &= \frac{(X-Y)}{kr_1} A_2 J_2(Kr)\sin 2\phi \end{aligned}\right\} \quad (1)$$

Where A_1 and A_2 are amplitude coefficients, $J_0(Kr)$ and $J_2(Kr)$ are the Bessels function of the first kind . K and k are the transverse and the free-space wavenumbers and X and Y are the impedance and the admittance at the boundary r = r1 given by

$$\left.\begin{aligned} X &= -j\frac{E_\phi}{H_z}y_0 \\ Y &= +j\frac{H_\phi}{E_z}y_0 \end{aligned}\right\} \quad (2)$$

And y_0 is the admittance of free space.
From equation 1, no crosspolarised field exists when the term (X-Y) vanishes. This is because the angular variable ϕ will not affect the aperture field with Ey = 0. For (X - Y) term to approach zero, both X and Y will have the same value. Due to the corrugations, both X and Y value will be zero. With these properties, the electric and magnetic fields are exactly balanced to produce radiation pattern symmetrical copolar patterns and low crosspolarisation. This is described as a 'balanced hybrid' mode. Low crosspolarisation can be achieved by designing the corrugation geometry in such a way that no current flows axially along the corrugated ridges. With quarter of wavelength deep corrugations, the corrugations will behave as short transmission lines. This is to ensure that the axial current will not flow. This condition is based on assuming that the corrugated wall is a flat plane surface.

3 DESIGN METHODOLOGY

For most applications the horn is fed from a smooth-wall circular waveguide supporting the fundamental TE_{11}mode. We therefore require a mode converter, which transforms the TE_{11} to the HE_{11} mode. This conversion must be carried out with negligible mismatch and excitation of higher order modes, particularly the highly cross-polarized EH_{11} slow (surface) wave and the EH_{12}mode.
For optimum performance it is essential to optimize the parameters of the mode converter independently of the input waveguide diameter and the horn output flare. Two additional sections are therefore required to complete the horn; an input taper between the input waveguide and the mode converter, and a corrugated transition section between the mode converter and the output flare. The transition section accommodates any necessary changes in flare angle, slot depth, and pitch between the mode converter and output flare. Slot widths are varied between 0.1λ and 0.3λ. Ridge width to slot width ratios are taken between 0.1 to 1[3].

4 DESIGN STEPS

4.1 Choosing the waveguide feed

Normally, conical corrugated horn is fed from a smooth-wall circular waveguide supporting the TE_{11}fundamental mode. A circular waveguide of diameter 6.35 mm is selected circular waveguide standards, whose operating band is 33.0 – 38.5 GHz as we are working for Ka band and our operating frequency is 35.6GHz and mode cutoff frequency is 27.27 GHz for TE_{11} mode.

4.2 Dimensions of the corrugated horn

Usually, for a normal corrugated horn antenna, the input mode at the throat region will be the TE_{11} smooth circular waveguide mode; this mode defines approximately the input radius of the corrugated horn antenna profile. For minimum return loss of this mode, corrugation depth at the throat region must be around $\lambda/2$.
So, the corrugated horn antenna is designed using HFSS(High Frequency Structure Simulation)with slot width s=1mm,ridgewidth w=0.5mm as width-to-pitch ratio δ is usually taken to be 0.7≤ δ≤ 0.9 [2] and the pitch p,is usually chosen to be such that $\frac{\lambda}{10} \le p \le \frac{\lambda}{5}$. [4].

For 1 ≤ j ≤ N_{MC}+1, then the slot depth of the jth slot is

$$d_j = \left\{\sigma - \frac{j-1}{N_{MC}}\left(\sigma - \frac{1}{4}\exp\left[\frac{1}{2.114(k_c a_j)^{1.134}}\right]\right)\right\}\lambda \qquad (3)$$

where σ ($0.4 \le \sigma \le 0.5$) is a percentage factor for the first slot depth of the mode converter.
N_{MC} is the number of slots in the mode converter.

5 RESULTS

All simulated results are obtained using HFSS(High Frequency Simulator System).
Figure 2, shows the return loss plot of the designed conical corrugated horn antenna. And

for a chosen operating frequency of 35.6GHz the return loss is -23.606GHz. The return loss measured from the corrugated horn exhibits an excellent impedance match at the throat region of the horn with a design operating frequency of 35.6GHz

Figure 3a and figure 3b shows the rectangular plot of the E and H plane of the radiation pattern respectively. From fig. 3a and fig. 3b, the obtained gain of the designed conical corrugated horn antenna is 20.1416dB.This figure shows the copolar plot of the radiation pattern

Figure 4 shows the copolar and crosspolar level of the designed conical corrugated horn antenna. From Fig4, at boresight, gain (copolar) in dB is 20.1416dB and the cross-polarization to this in dB is -39.5512 dB. So, the cross-polarization level at boresight is -59.6922dB.

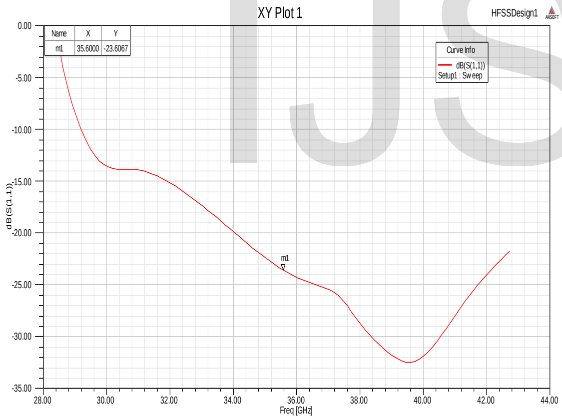

Fig 2 . Return Loss Plot

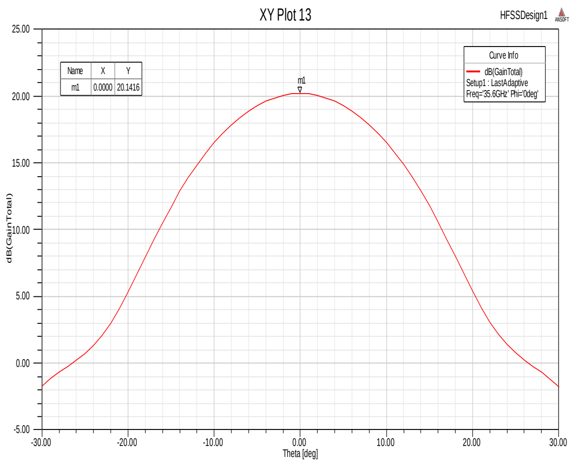

Fig 3a Rectangular Plot of E Radiation Pattern

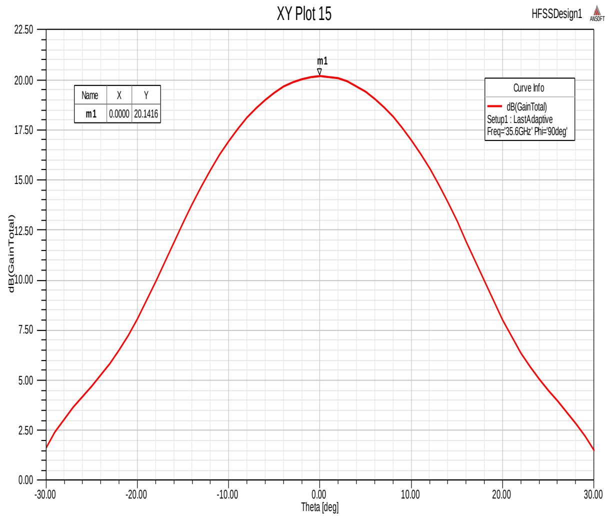

Fig 3b Rectangular Plot of H Plane Radiation **Pattern**

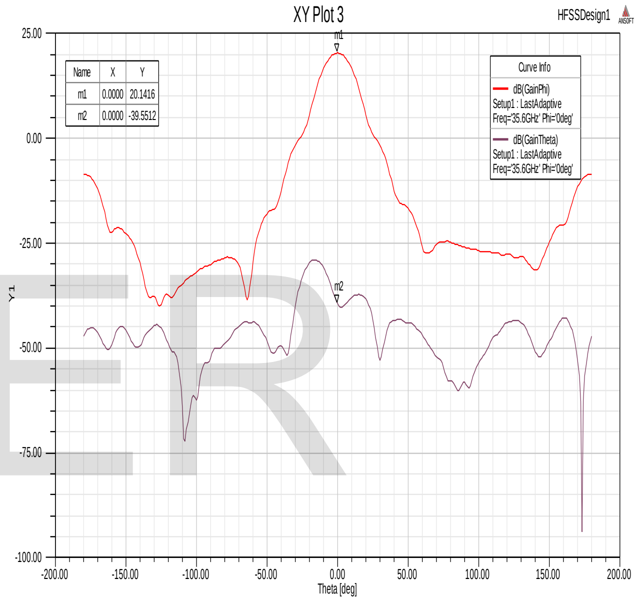

Fig 4 Rectangular plot of Copolar and Crosspolar Level of Radiation Pattern

6. CONCLUSION

The conical corrugated horn antenna is designed with the stimulated results showing good return loss at operating frequency of 35.6GHz and the excellent pattern symmetry i.e. both E-plane and H-plane radiation pattern are almost similar. The crosspolar level obtained is also excellent

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