Design and Analysis of a Linearly Polarized S-band Conical Horn Antenna

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Abstract: **Horn antennas are widely preferred antennas when it comes to satellite communication since they operate at high frequencies and have a large bandwidth. They have no resonating elements and hence produce a high gain. Here we have designed an antenna operating at a S-band range i.e. between 2GHz and 4GHz.The antenna is simulated using the CST studio tool and MATLAB and is fabricated after calculations made using the standard design equations defined to design an antenna. The aim of designing this antenna is to provide a better gain, better directivity appreciable reflection coefficient parameter and a good Voltage to standing wave ratio.**

Index Terms: **Horn antennas, Satellite Communication, S-band, MATLAB, CST studio.**

I. INTRODUCTION

An antenna is a transducer device used to receive or transmit data by converting electrical power into electromagnetic waves or vice versa. An antenna is also called an aerial. An antenna or aerial is a metallic structure that can both be used as a transmitter or receiver. The IEEE definition of an antenna as given by Stutzman and Thiele is, "That part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves". In two-way communication an antenna acts as both transmitter and receiver. In a transmitter antenna, the electrical signals received by the antenna are converted to electromagnetic waves and radiated. In a receiving antenna, the electromagnetic signals received from the incoming beam are converted back to electric signals. In a scenario where a wiring system cannot be laid down from transmission and reception antennas can be widely used. There are many antenna designs available in the market tailored to suit the application for which it is needed.

1.1 Horn antenna

The horn antenna is a widely used simplest form of the microwave antenna. A horn antenna may be regarded as a flared-out waveguide. The horn antenna is widely used as a feed element for large radio astronomy, satellite tracking and communication dishes throughout the world. The function of the horn antenna is to produce a uniform phase front with a larger aperture than that of the waveguide and hence greater directivity. In addition to its utility as a feed for reflectors and lenses, it also serves as a universal standard for calibration and gain measurements of other gain antennas. The important advantages of horn antenna are its simplicity in construction, ease of excitation, versatility, large gain, overall performance or greater directivity. As it is widely used at microwave frequencies, it may be considered as an aperture antenna. The horn antenna can also be considered as a waveguide with hollow pipe of different cross sections which is flared or tapered into a larger opening. Basically, the horn antennas are classified as rectangular horn antennas and circular horn antennas. The rectangular horn antennas are fed with rectangular waveguide, while the circular horn antennas are fed with circular waveguide. Depending upon the direction of flaring, the rectangular horns are further classified as sectoral horn and pyramidal horn. A sectoral horn is further classified as E-plane sectoral horn and H-plane sectoral horn. The circular horn antennas can be obtained by flaring the walls of the circular waveguide. The circular horn antennas are of two types namely conical horn antenna and biconical horn antenna.

1. **Pyramidal Horn Antenna**: When the flaring is done along both the walls of the rectangular waveguide in the direction of both the electric and magnetic fields vectors, the horn obtained is called pyramidal horn. It is most widely used electromagnetic horn which has characteristics as a combination of E-plane and H-plane sectoral horns.
2. Conical Horn Antenna: It is an antenna constructed using cylindrical waveguide and the flaring is done in the horn which is in the shape of a cone which has a circular cross section and hence its name. They are generally used as calibration antennas to measure and check the gain of other antennas.

II. PROPOSED SYSTEM

The idea of the proposed system is to design an antenna having a higher gain, better directivity, a voltage to standing wave ratio value between 1 and 2 and a S11 parameter below -10dB is to be achieved. The first stage of the project is the comparison between two types of horn antennas i.e., the pyramidal horn antenna and the conical horn antenna. The pyramidal horn antenna and the conical horn antenna differ in its physical shape and the type of waveguides used. This comparison is made to study the difference in performance between the two types of antennas to see which outperforms the other at the said frequency (2.756 GHz). This comparative study is carried out using the MATLAB software with the the antenna toolbox.

After the analysis of their performances, we could see that the conical horn antenna performs better at the chosen frequency and hence the simulation of the antenna is to be carried out. Mathematical calculations are made using the formulae to determine the physical structure of the antenna. The slant length is fixed at 17cm and the respective calculations are made to find the parameters like the waveguide height, cone height, flare angle, diameter of the cone and the diameter of the cylindrical waveguide.

After these calculations, the antenna is simulated using the CST software. In the CST software, each of the parameters like height, length and parameters are specified separately for the antenna's waveguide and the antenna's flare cone. After sketching out the antenna, the simulations are carried out. The results of the antenna is noted down and compared to the ideal values that an antenna must possess. When the conditions were approved, the antenna is now fabricated. The fabrication is done using the aluminium sheets available in the market and is to be fed with a coaxial feed and a female SMA connector. The cutting of the antenna sheets is to be done using a CNC machine to cut down metallic sheets and later on welded to get the antenna in shape. The fabricated antenna is to be sent for analysis at the antenna testing facility to check the performance in real time and its results are to be studied.

III. RESULTS

The simulated results of the pyramidal and conical horn antenna are as follows

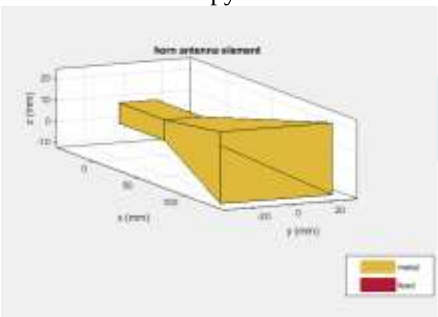

Figure 3.1. Pyramidal Horn Antenna

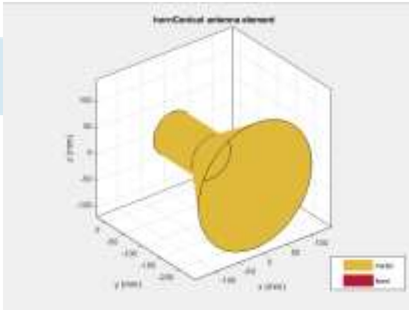

Figure 3.2.Conical Horn Antenna

The above two figures show the simulated pyramidal horn antenna and the conical horn antenna. Their outputs were achieved after the code was verified and run on the MATLAB software. Parameters like directivity at azimuth, directivity at elevation, charge distribution and beam coverage were analysed and the values are compared and tabulated below.

Table 3.1 Outputs of the Simulated Horn Antennas

S.no	Parameter	Pyramidal Horn- Value	Conical Horn- Value
1.	**Directivity at Azimuth**	**5.499 dB**	**12.81 dB**
2.	**Directivity at Elevation**	**3.189 dB**	**14.63 dB**
3.	**Charge distribution**	**Uniform**	**Uniform**
4.	**Beam coverage**	**309° to 348°**	**125° to 235°**

From the above table it is quite clear that the Conical antenna is performing better in the S-band range. Now certain formulae have been used to calculate the dimensions of the Conical horn antenna.The antenna has been simulated with same geometrical dimensions in the CST software and the outputs were achieved.

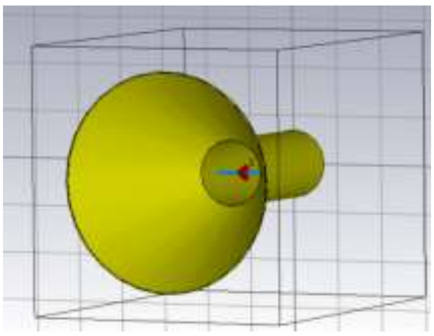

Figure 3.3. Simulated conical horn antenna with discrete port

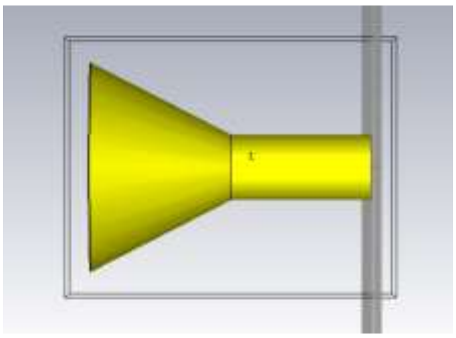

Figure 3.4. Side view of the conical horn antenna

The antenna was simulated using aluminium material and a discrete port was specified to be the feed of the antenna. The discrete port is placed such that it touch the walls of the conical horn antenna. The 3D radiation pattern was achieved and the gain, directivity, S11 parameter and VSWR graphs were noted.

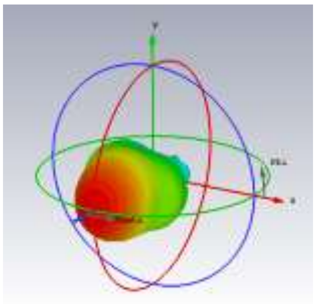
Figure 3.5. 3D pattern

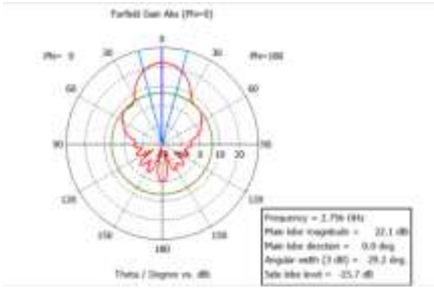
Figure 3.6. Polar plot for gain

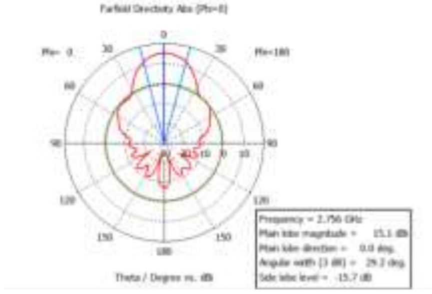
Figure 3.7. Polar plot for directivity

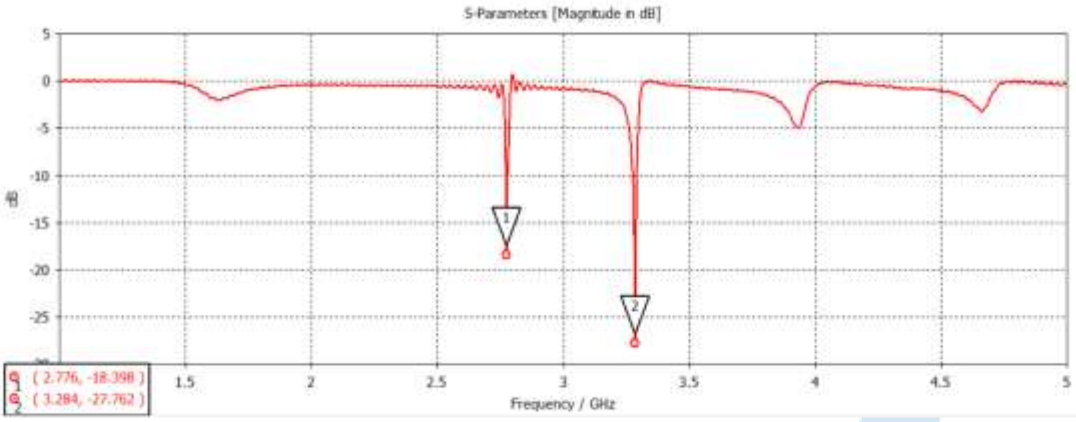

Figure 3.8. S Parameter graph

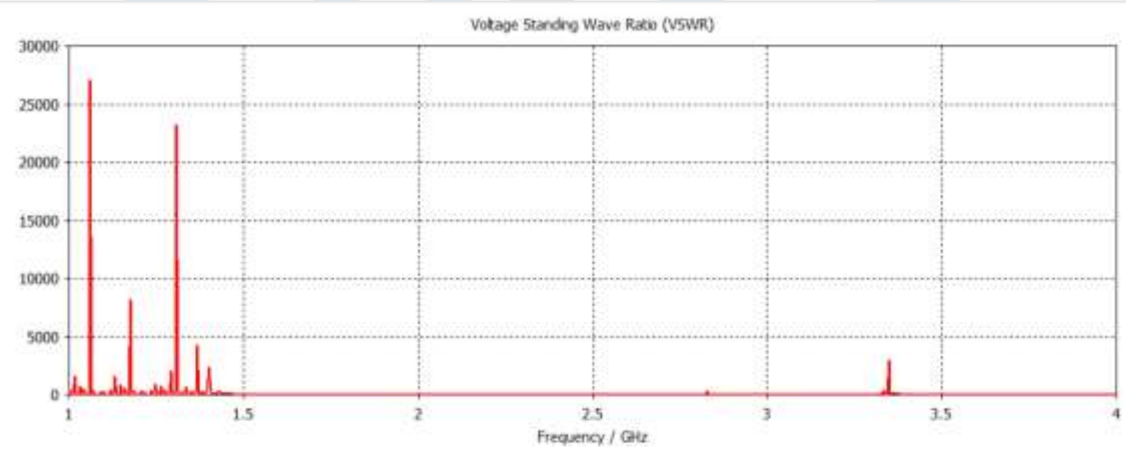

Figure 3.9. VSWR graph

The aluminium conical horn antenna is fabricated now after the simulated outputs were appreciable and in the ideal range. The antenna was fabricated using aluminium sheets and a copper wire is used as a coaxial feed with a female SMA connector. The fabricated antenna is given below.


Figure 3.10. Fabricated Conical Horn Antenna


Figure 3.11. Coaxial feed made of copper

The fabricated antenna was tested using a vector network analyzer. The S11 graph and VSWR graph were obtained.

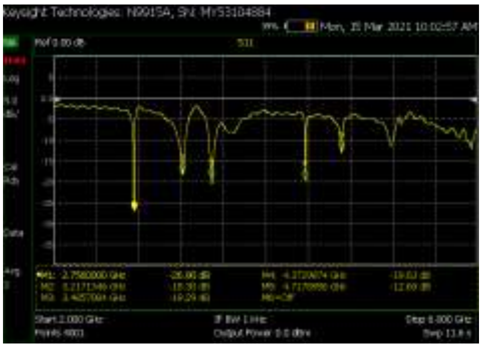

Figure 3.12. S11 graph

Figure 3.13. VSWR

IV. CONCLUSION AND FUTURE SCOPE.

Hence the fabricated antenna is performing good in the S-band range between 2 GHz and 4 GHz. The fabricated antenna had better performance metrics than the simulated outputs. The table 4.1 specifies the values obtained by both the methods.

Table 4.1 Performance metrics of the Conical Horn Antenna

S11 Parameter	-26.90 dB
Voltage to Standing Wave Ratio	1.09
Gain	22.14 dB
Directivity	15.11 dB
Efficiency	65.7%

The bandwidth of the antenna is quite small. Hence in the future the antenna can be designed to enhance a wider operating bandwidth of frequencies.

V. ACKNOWLEDGEMENT

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