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Investigations and Enhancement of Aperture Solid Dielectric Pyramidal and Cone Horn Antenna in X band Applications

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Abstract: For even better performance, several different types of aperture can be introduced forming additional radiators. However, the bandwidth obtained with dielectric rectangular pyramidal antenna remains moderate because of the high degree of frequency sensitivity of the structure. Still it can be further improved by using different loading techniques. Other forms of matching such as asymmetric taper and use of various tuning structures are being currently investigated. Efforts are on to improve directivity by using different materials as also additional aperture forming in the form of arrays. The dielectric cone may be used both as an antenna on its own and as a guiding structure between antenna elements, such as the feed and the sub reflector. With a more sophisticated (and expensive) launcher such as a corrugated horn the side-lobe level could have been significantly reduced.
Keywords: Dielectric Slab Antenna, Pyramidal, Cone horn antenna, Radiating Slab, X band.

Introduction

Dielectric antennas have proved their utility in higher frequency ranges due to low loss and high performance. Characteristics of dielectric antennas in the form of waveguide, horn, cylinder, cone etc have been investigated analytically [1].

Different methods of theoretical treatment vary in initial assumptions. The problem of radiation from dielectric horn and cone antennas is so complex, that a full understanding is yet to be achieved. The analysis of a hollow metal wave guide supporting a pure TE or TM mode is much simpler compared to the intricacies of the hybrid HE or EH mode characteristics of dielectric rods with circular cross section when they are exited asymmetrically. But with rectangular cross section, dielectric rods exhibit dominant TE modes of propagation leading to ease of analysis.

Here we chose a rectangular dielectric pyramidal horn antenna supporting TE_{10} dominant mode for investigation. A pyramidal dielectric horn antenna fed by a metallic waveguide was investigated, with emphasis on the improvement of impedance matching by insertion of a pyramidal matching section between the dielectric rectangular horn and the metallic waveguide launcher. This is performed simply by inserting a portion of the rectangular horn into the waveguide [2 and 3].

The dielectric conical horn antenna is an antenna that is widely used in the field of communications [4 - 6]. Solid dielectric cone is inserted into the metallic circular waveguide with a conical matching section gives the structure of solid conical dielectric antenna. However during World War -II it was widely used as a means of communications. Traditionally, conical horn antennas have been used for terrestrial microwave communication. They are mainly found in line-of-sight radio towers but they also have many other applications. These other applications include satellite communications and collision avoidance system in vehicles.

It has been observed (from simulation study) that as expected when length of both the radiating horn and cone is increased, the directivity is improved at the cost of size and weight. Antenna directivity can be further increased by enhancing the flaring angle of the dielectric pyramidal horn or cone without adding to its length. Experimental results are presented for rectangular dielectric horn antennas on Teflon (DK =2.4) substrate at deep microwave frequency range (X band). The results indicate its suitability to practical applications like wireless and satellite links.

Antenna Design

Solid rectangular dielectric pyramidal horn fed by standard metallic rectangular waveguide operating in TE_{10} mode is one of the simplest dielectric antennas. Dielectric waveguide antennas have been studied analytically in [1]. Computer simulation results using full wave solver HFSS (Ansoft) [7] for the radiation characteristics of a rectangular dielectric waveguide antenna as a function of its length has been presented in [2]. However, to use such radiators as practical antennas, matching of the waveguide radiator to the launcher is of prime importance. In addition, to achieve improved directivity pyramidal dielectric horns have been investigated.

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Extensive studies on the impedance matching characteristics along with radiation characteristics of dielectric waveguide antennas with tapered matching section used inside the launcher, computed as functions of different physical parameters have been reported in [2 and 3]. Here we present the experimentally measured characteristics of a pyramidal dielectric horn antenna with tapered matching section which show distinct improvement in directivity over rectangular dielectric slab and good impedance matching.

Optimal design was carried out using Ansoft HFSS electromagnetic simulation software [7]. Thereafter, the designed antenna was fabricated in house and tested for radiation and impedance characteristics.

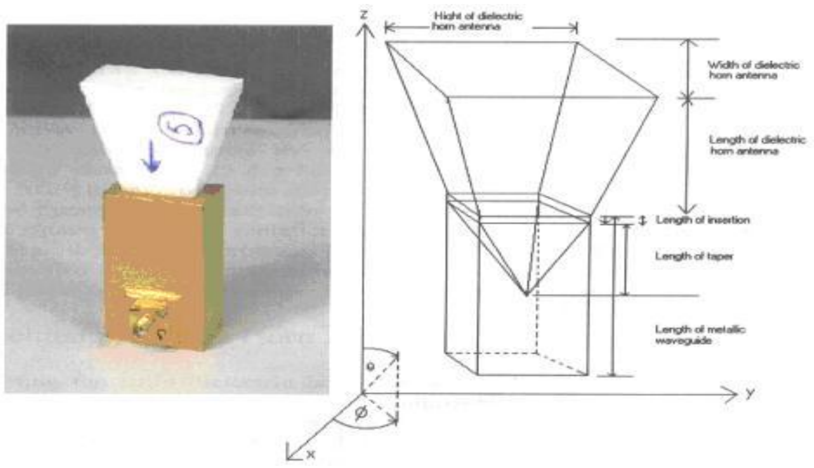

Figure 1: Dielectric horn fed by a WR 90 X band metallic rectangular waveguide

Experimental Results:

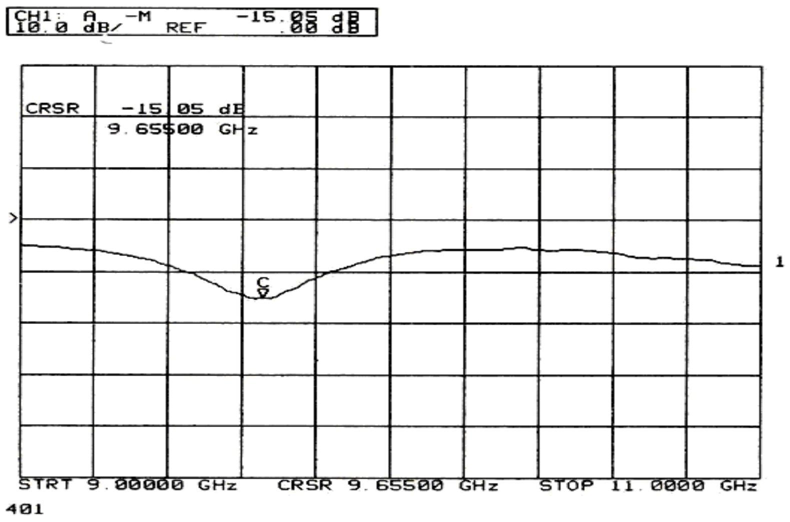

Figure 2: Frequency vs. return loss pattern

The antenna investigated is a pyramidal dielectric horn fed by a WR 90, X band metallic rectangular waveguide, as shown in figure 1. The material used is Teflon with dielectric constant 2.4, with a pyramidal matching section of length 29.2 mm and made of same material. Height of the free end aperture of the dielectric pyramidal horn is 39.8 mm and width of the free end aperture of the dielectric pyramidal horn is 20.4 mm.

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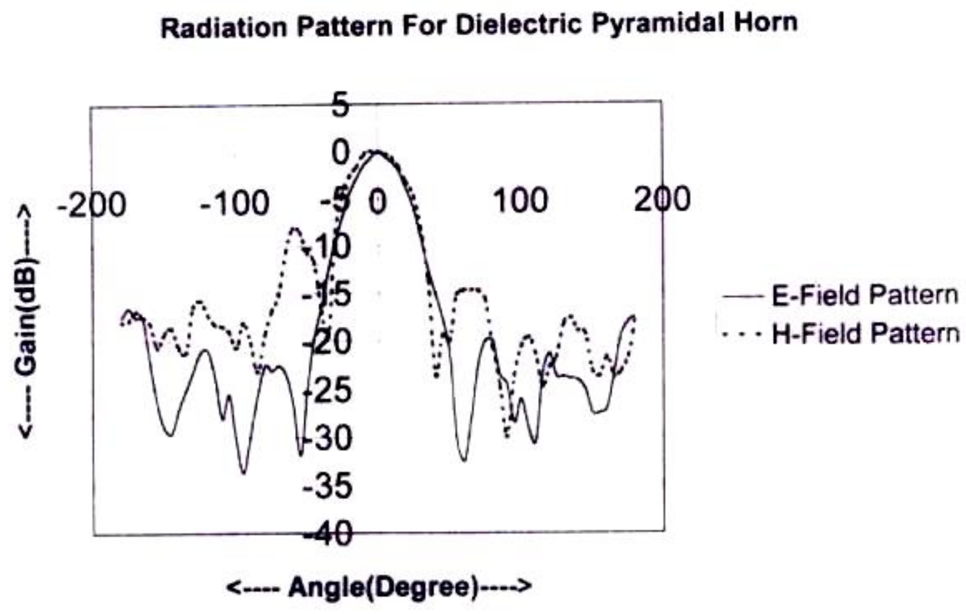

Figure 3: Radiation pattern

The length of pyramidal horn is 40.3 mm and the length of the inserted portion is 3 mm. The antenna shows a return loss of about -15.05 dB at 9.655 GHz and the 2:1 V.S.W.R. band width is about 400 MHz, as shown in figure 2. -3 dB beam width is 25^0 in the E plane & 24^0 in the H plane, as shown in the radiation patterns (Figure.3). The on axis cross polar discrimination level has been found to be approximately 20 dB, as depicted in figure 4.

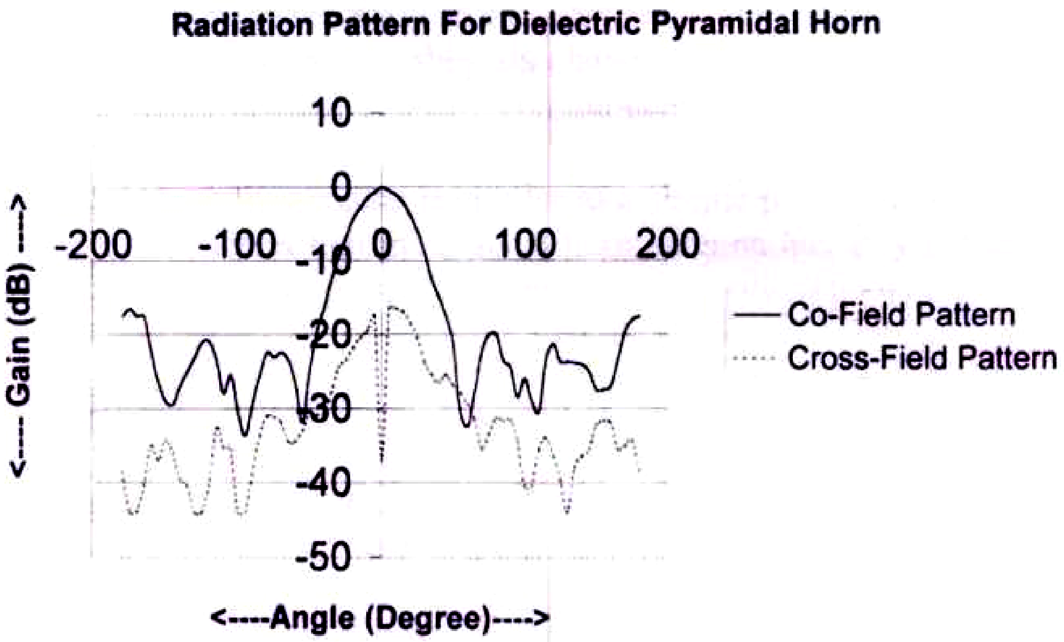

Figure 4: Radiation pattern

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Solid Dielectric Cone Antenna Design

The conical horn antenna is similar to a simple pyramidal horn antenna. The only difference is that the conical horn antenna has a cylindrical shape and not a rectangular or pyramid shape. A conical horn shaped dielectric antenna has been designed optimally through expensive FEM based simulation and studied experimentally, as represented in this section.

The structure of dielectric conical horn antenna is investigated is shown in the figure 5. Here a metallic cylindrical waveguide is used as launcher where,
The diameter of the metallic cylindrical waveguide is = 40.04 mm.
Length of the metallic cylindrical waveguide is = 41.4 mm.
Diameter of the dielectric cone =80 mm.
Length of the dielectric cone = 40.4 mm.
Length of the matching section =28.1 mm.
Length of insertion portion = 3.5mm.

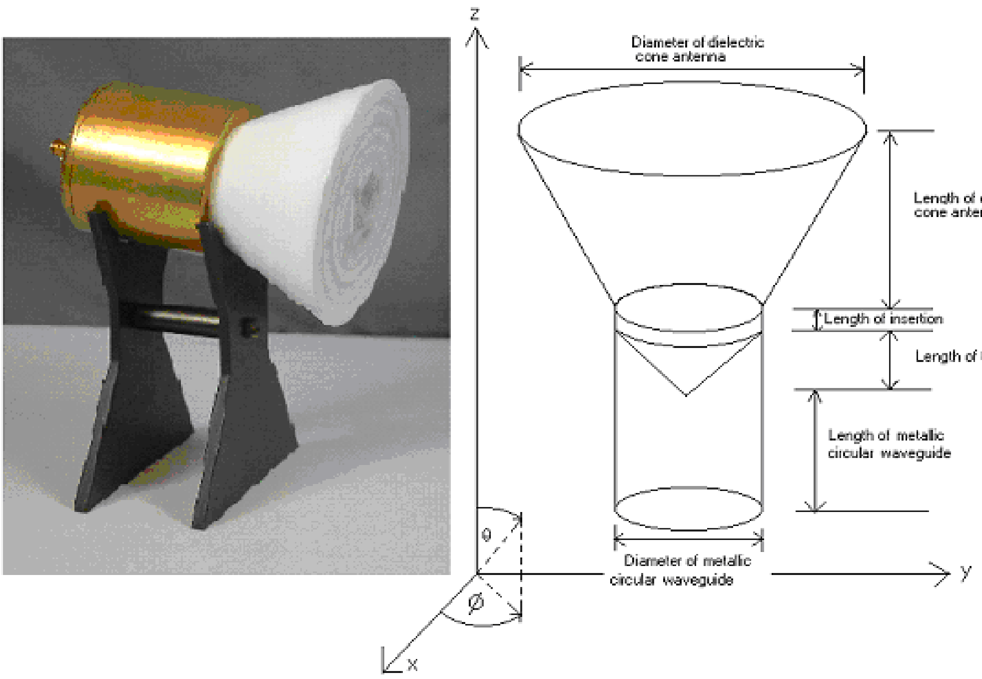

Figure .5: Dielectric cone fed by a metallic circular waveguide

There are theoretical and mathematical relationships of the conical horn antenna which relates the gain, beam width, beam area, aperture efficiency and directivity. Formulas are shown in the following:

Gain:G= $Gain: G = \frac{4\pi\eta A}{\lambda^2}$ Beam Area: $\Omega A = BW_{\varphi\,(a\,z)}\, BW_{\theta\,(el)}$

Beamwidth: $BW = \frac{70\lambda}{d}$ Aperture Efficiency: $A_e = \eta$ and $A = \frac{\lambda^2 G}{4\pi}$

Results:

Solid dielectric cone is fabricated and experimental results of both return loss and radiation pattern are given bellow. Return losses are studied from 1GHz to 27 GHz in figure 6. A low permittivity (2.4), low flare-angle dielectric cone, excited in the TE_{10} mode by a metallic conical horn (Figure 5), is shown to provide a highly symmetrical pattern (shown in Figure 7 and.8), with a side-lobe level about 15 to 20 dB down.

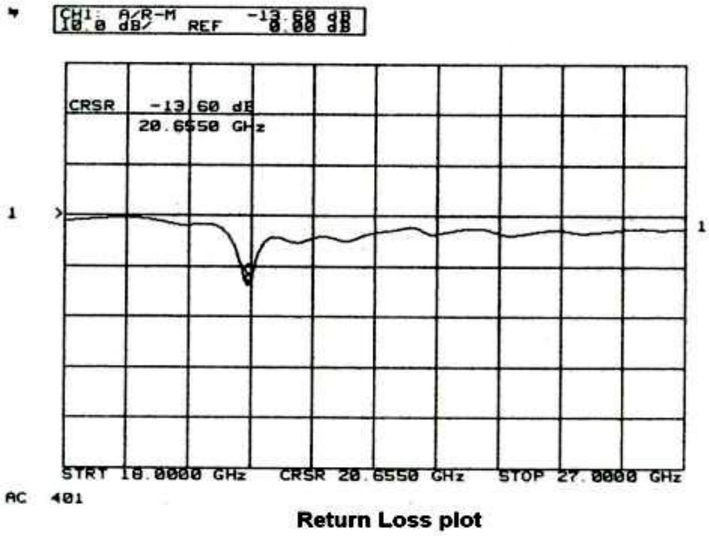

Figure 6: Minimum return loss of about-13.6dB occurs at 20.655 GHz of less bandwidth

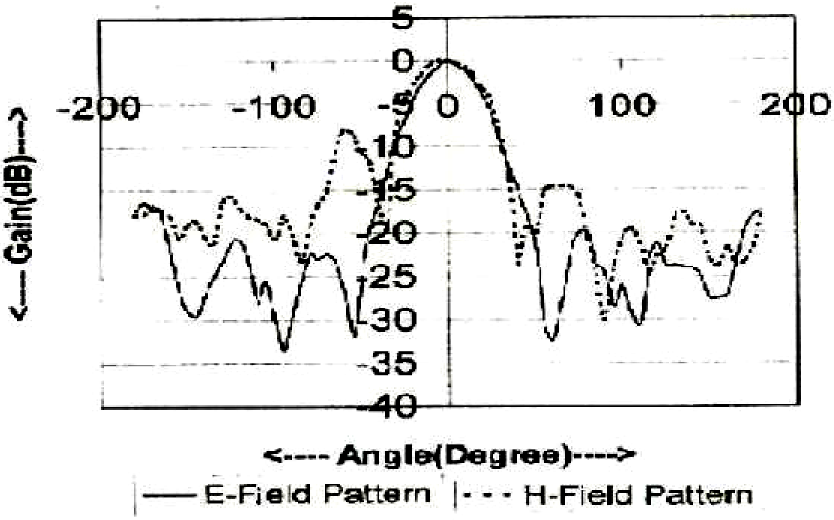

Figure 7: Radiation Pattern for dielectric cone antenna at 20.655 GHz

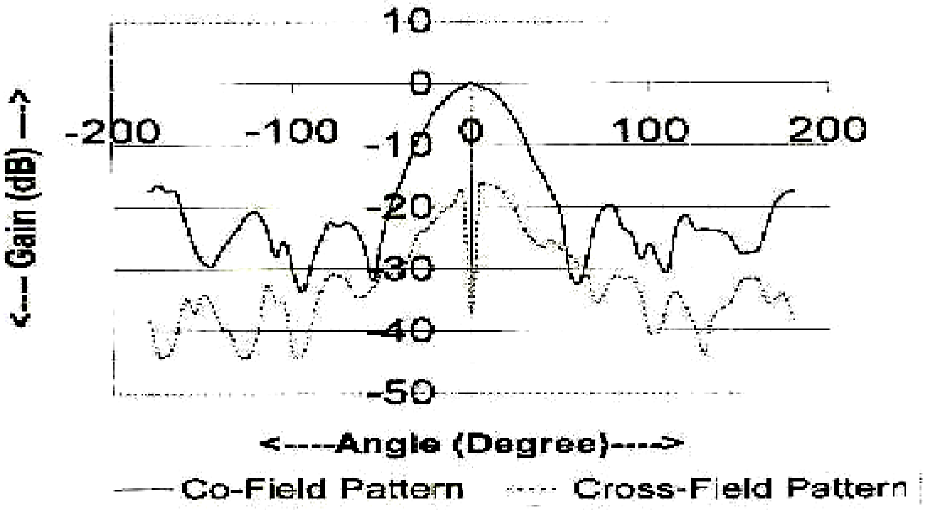

Figure 8: Radiation Pattern for dielectric cone antenna at 20.655 GHz

Conclusion

From the simulation studies it is observed that the directivity increases by increasing the flaring angle of the pyramid. After simulation one of the optimized structures is experimentally observed. The enhanced flaring angle can provide a larger radiating aperture and hence improvement in directivity. This property makes the antenna very well suited for application in wireless base stations.The dielectric cone may be used both as an antenna on its own and as a guiding structure between antenna elements, such as the feed and the sub reflector. With a more sophisticated (and expensive) launcher such as a corrugated horn the side-lobe level could have been significantly reduced.

The dielectric cone may be used to provide fairly large values of directivity with law side-lobe levels and low cross-polarization. For this large aperture, long and heavy launcher is to be required. To reduce the cone and launcher size we may increase the dielectric cone flare angle at the cost of large aperture phase error and a correspondingly lower directivity.

In summary, optimally designed (The antenna parameters chosen were obtained as outcome of an optimal design carried out through exhaustive search using FEM simulation (HFSS [7]) dielectric pyramidal horn and dielectric cone antennas have been investigated and the experimentally measured characteristics have been presented which indicates that they can serve as a useful antenna for base station applications in mobile and wireless communication links.

References

[1] Salema,C., Fernandes, C., and Jha, R.K., "Solid Dielectric Horn Antennas," Artech House, Boston, 1998.

[2] Bhattacharjee R., Gupta B., Poddar D. R. & Chowdhury S. K., **"**Some Results on Dielectric Waveguide Antenna", Proceedings of APSYM, Dept. of Electronics, CUSAT, Cochin, INDIA, Dec. 9-11,2002, pp. 315-318.

[3] Kidney, Brain. Horn Antennas, Engineering 9816- Antennas, Nov.2001.

[4] Clarricoats, P.J.B., and Salema, C.E.R.C., "Propagation and Radiation Characteristics of low Permitivity Dielectric Cones", Electronic Letters, vol.7,No.17 , 1971, pp.483-485.

[5] Clarricoats, P.J.B., and Salema, C.E.R.C., "Radiation Charecteristic of Dielectric Cones", Electronic Letters, Vol.8, No.16, 1972.

[6] Salema, C.E.R.C., "Theory and Design of Dielectric Cone Antennas", Ph.D. Thesis. University of London, 1972.

[7] HFSS, Maxwell^{R} Software, Ansoft Corporation, Four Station Square, Suit 660, Pittsburg, PA 15219, USA