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Evolutionary Design and Characterization of Coaxial Corrugated Horn for Satellite Feeds

Chandan Raj. A[1], Robin Raju[2] and K O Joseph[3]

[1]Final Year Engineering Student Dept. of ECE, GKM College of Engineering and Tech., Chennai, India
[2]Component Engineer, Dept. of ESS, Flextronics, Chennai, India
[3]Professor, Dept. of ECE, GKM College of Engineering and Tech., Chennai, India
achandan009@gmail.com,robinraju@live.com,josephkandath49@gmail.com

Abstract. In this paper the design, fabrication and Field measurements of a concentric Longitudinal Corrugated feed assembly with low design complexity, low cross polarization and wide operating bandwidth is discussed. This would find its main application in the illumination of Offset Parabolic Reflectors. The Radiator and the Auxiliary feed accessories, namely: the Modified Directional Coupler and the Rectangular to Circular Waveguide Transition were optimized using the simulation techniques to operate in the X-Band Frequencies effectively. The Antenna and the feed assembly together has resulted in a Half Power Bandwidth of 20 degrees and a maximum gain of 15 decibels.

Index Terms: Cylindrical Corrugated structure Corrugated matched feed, Modified Directional Coupler, dual-mode Corrugated Horn, Rectangular to Circular Waveguide Transition, Longitudinal Corrugations, Offset Parabolic Reflectors

1. Introduction

1.1. Design of a Corrugated Feed

The Antennas for space-borne applications has several requirements to achieve like the specified accuracies, sensitivity and the desired performance in space. These include high beam efficiency (> 95 %), high gain, low losses, low cross-polarization and low side-lobe levels.

1.2. Existing Technology

The Offset Parabolic Reflector Antenna fulfills most of the above mentioned requirements due to their inherent advantages of reduced aperture blockage, isolation between the Reflector and the feed, lesser spurious radiation and suppressed side-lobes[4]. However, the performance of the Offset Reflector is satisfactory only when a configuration having larger Focal length to Diameter ratio F/D (F/D >1) is selected [6]. Generally, in spacecraft Antennas, the available space for the Antenna structure is limited, and hence the Reflector with a large F/D may not be preferred. Alternatively, the use of an Offset Reflector Antenna with a smaller F/D ratio results into high cross-polarization (when illuminated by linearly polarized feed), and beam squinting (when illuminated by a circularly polarized feed) .This high cross-polarization and beam squinting degrade the overall performance of the system and restricts the use of Offset Reflectors for many practical applications. Thus, to overcome these limitations, an effective cross-polarization suppression technique as well as beam squinting minimization technique are to be explored

The unwanted high cross-polarization can be suppressed either by mounting polarization-selective grids [7] between the Reflector and the feed or by illuminating the Reflector by a Horn with a phase-correcting lens. However, these options add to the complexity of the Antenna structure and may put a mechanical constraint on its use for space-borne Antennas. The more practical solution to reduce the high cross-polarization is to use a conjugate matched feed to illuminate the Offset Reflector [2]. Recently the authors have studied the cross-polarization performance of an Offset Reflector illuminated by matched feed and also compared the results with that of a conventional dual mode. Bahadori and Rahmat-Samii have simulated a gravitationally balanced back-to-back Reflector

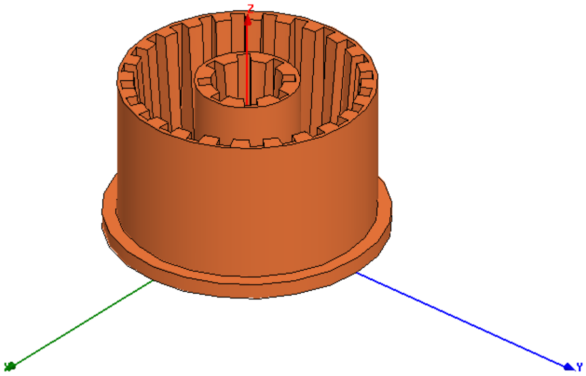

Fig. 1.a. HFSS model of Concentric Corrugated Cylindrical Horn Antenna

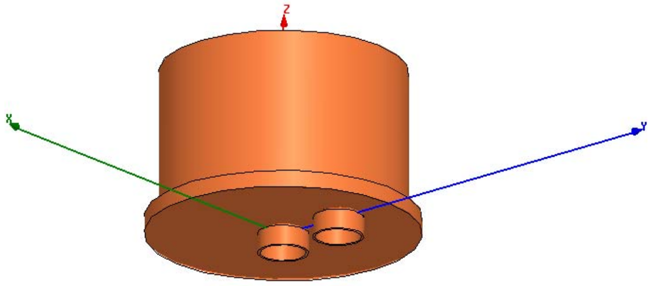

Fig. 1.b. HFSS model of Concentric Corrugated Cylindrical Horn Antenna (port view)

illuminated by a matched feed, and achieved an additional 20 dB improvement in the cross-polarization over the conventional Horn fed Reflector [3]. Prasad and Shafai have also noticed a significant improvement in the cross-polarization performance of an Offset Reflector when illuminated by a matched feed [8].

2. Proposed Design

The concept of matched feed has been implemented only in a smooth-walled cylindrical structure. However, it will be equally interesting to apply the 'matched feed' concept to the cylindrical Corrugated structure. To the best of author's knowledge, no such designs of a Corrugated matched feed and its performance with an Offset Reflector has been reported in open literature.

The basic objective of this paper is to apply the concept of matched feed (conjugate field matching) in a cylindrical Corrugated structure and to present the design of a novel Corrugated matched feed. The designed Corrugated matched feed is then used as a primary feed to illuminate the Offset Parabolic Reflector Antenna and the secondary radiation pattern is estimated. The simulated results are to be compared with the conventional Corrugated Horn fed Offset Parabolic Reflector. The concept of matched feed was implemented in a conical Horn by Rudge and Adatia to suppress the unwanted high cross-polarization introduced by the Offset geometry [1].

Matched feed is basically a multi-mode Horn, in which the tangential electric fields in the aperture of the primary feed are to be matched with the focal region fields of the Reflector to suppress the high cross polarization [5]. This matching condition can be achieved in a cylindrical Corrugated structure by adding HE21 mode with the fundamental HEll mode. Thus, in case of a Corrugated structure, the matched feed is a dual-mode Horn, in which the HE21 mode reduces the cross polarization (in θ =90°) as well as beam squinting. In order to achieve the desired performance of the dual-mode Corrugated Horn the HE21 mode amplitude should be approximately -20 dB relative to the fundamental HEll mode and should be 90° out of phase. Thus the Antenna dimensions and feed should be set as per the required condition in order to obtain optimum results both in case of simulation using the commercially available software HFSS and also in the laboratory measurements.

3. Simulation and Results

As the designed Antenna consists of two ports for excitation, the simulation in HFSS as well as the experimental characterization was done with three different possible variations:

1. Excitation of Inner Channel alone
2. Excitation of Outer Channel alone
3. Excitation of Both Inner Channel and Outer Channel simultaneously as per the above discussed specifications.

The fabricated setup of the structure is shown in fig 5.

Fig. 5. Designed Antenna with the test set up

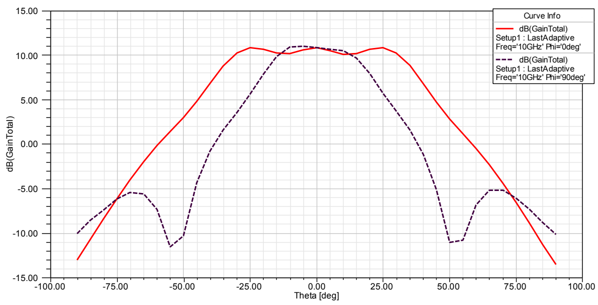

Fig. 2.b. Result Using HFSS: Rectangular Plot of Gain (dB) exciting the main Channel

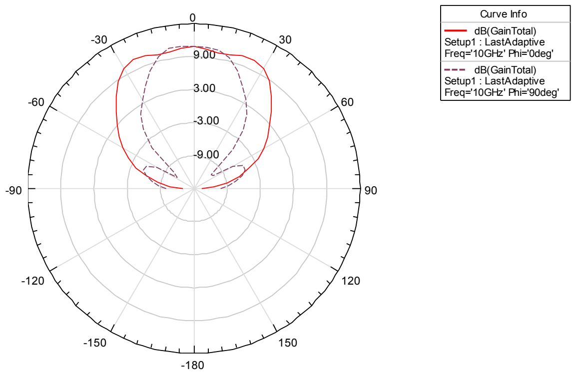

Fig. 2.a Result Using HFSS: Polar Plot of Gain (dB) exciting the main Channel

3.1. Excitation of Main (Inner) Channel Alone

The Excitation of the Main (inner) Channel is done using a Modified Directional Coupler and a Low Loss Rectangular to Circular waveguide transition. The simulation results obtained by exciting the inner Channel are shown in Figure 2.a and the experimental results obtained at 8.5Ghz is shown in figure 2.b.The Auxiliary Channel is kept isolated while the inner Channel is excited.

3.2. Excitation of Auxiliary Channel Alone

The simulation results using HFSS by exciting the Auxiliary is given in figure 3.a The Auxiliary Channel is excited at 8.5 GHz using a Microwave Klystron test bench. The main (inner) Channel is isolated while taking the readings. The results obtained are plotted and shown in figure 3.b

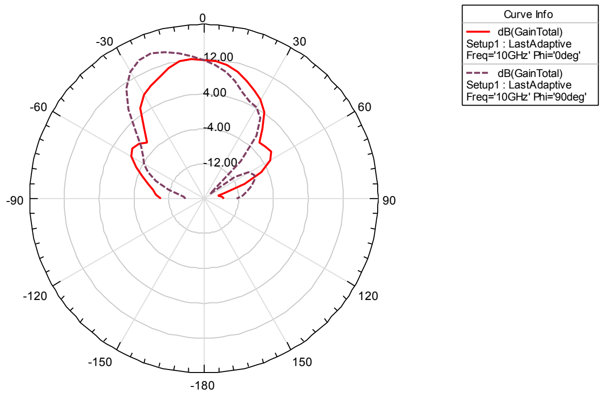

Fig. 3.a. Result Using HFSS: Polar Plot of Gain (dB) exciting the Auxiliary Channel

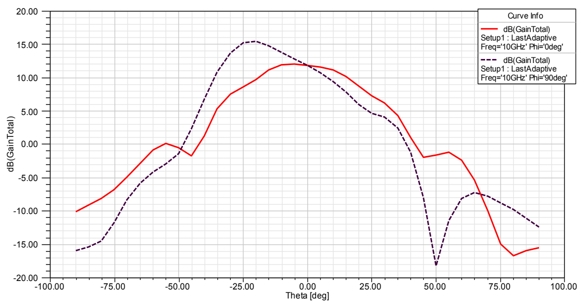

Fig. 3.b. Result Using HFSS: Rectangular Plot of Gain (dB) exciting the Auxiliary Channel

3.3. Simultaneous Excitation of Both the Channels

In this method of Simultaneous Excitation of both the channels, different possibilities of power and phase being fed into them where considered (for example: equal power at both the ports and same phase, equal power at both the ports and phase difference of 90°, unequal powers with both same and 90° phase shifts etc). It was observed our preliminary design considerations when the main Channel was fed with a power 20dB greater than that of the Auxiliary Channel with a phase difference of 90° gave the most desirable characteristics The results thus obtained are shown in figures. 4.a and 4.b.

Inferring from the simulation results, the Coaxial Horn's characteristics was obtained under laboratory condition. The coupling of source power at the desired phase and amplitude from the X-Band Microwave Test Bench was achieved by utilizing a Modified Directional Coupler and a low loss Rectangular to Circular Waveguide Transition.

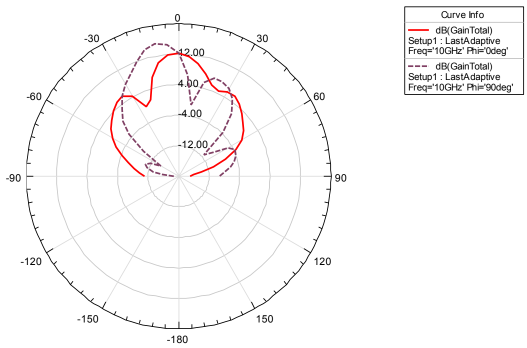

Fig. 4.a. Result Using HFSS: Polar Plot of Gain (dB) exciting the Auxiliary Channel and main Channel simultaneously with 20dB power difference and a phase shift of 90°

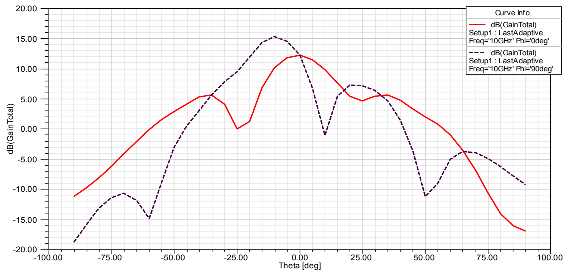

Fig. 4.b. Result Using HFSS: Rectangular Plot of Gain (dB) exciting the Auxiliary Channel and main Channel simultaneously with 20dB power difference and a phase shift of 90°

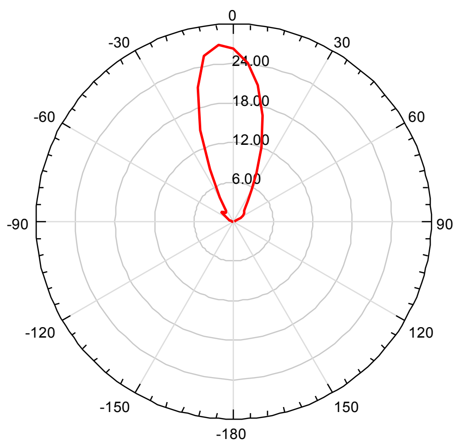

Fig. 6. Polar Plot for Radiation Pattern Using power meter

The readings were taken separately using both the Cathode Ray Oscilloscope and a Power Meter. The observations thus obtained are shown in Fig 6.

4. Conclusion

In this paper a novel design of a Coaxial Horn with Longitudinal Corrugations was presented. The characteristics of the Horn at different power and phase were studied using the HFSS simulation software. The results thus obtained were then verified experimentally by fabricating Longitudinal Corrugated Coaxial Structure. The fabricated Coaxial structure was tested on an X-Band Microwave Test bench. The field measurements were taken using a power meter for covering 180degrees and the same is shown in fig 6. The simulated results and the experimental results where found to be in agreement to a great extent.

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