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DESIGN AND DEVELOPMENT OF A DUAL-MODE CORRUGATED HORN FOR AN OFFSET REFLECTOR ANTENNA

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ABSTRACT: *This article presents the design and radiation characteristics of a dual-mode corrugated matched feed horn. This type of feed eliminates the unwanted high cross-polarization of an offset parabolic reflector antenna and improves the overall performance of the antenna sub-system. In a cylindrical corrugated structure, higher order* HE_{21} *mode is added with the fundamental* HE_{11} *mode to configure a dual-mode corrugated horn. For the proposed horn, the return-loss characteristics and the far-field radiation patterns were measured and the results are compared with the simulated results. The horn has been used as a primary feed device to illuminate a linearly polarized offset parabolic reflector antenna and the improvement in the cross-polarization has been estimated.* © 2009 Wiley Periodicals, Inc. Microwave Opt Technol Lett 52: 113–116, 2010; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.24852

Key words: *corrugated horn; cross polarization; offset reflector antenna*

1. INTRODUCTION

The present day demand of very high spatial resolution has made the antenna design for remote-sensing microwave radiometers very challenging. To achieve the desired performance of the microwave radiometer in the space, the antenna system should have high gain, low losses, very high beam efficiency (of the order of 95–97%), high polarization purity (very low cross-polarization), low side-lobe levels, high aperture efficiency and light weight [1]. For applications demanding such stringent specifications, the parabolic reflector antenna can be considered as one of the most suitable candidates because of its high gain, high bandwidth, and design maturity. However, structurally symmetrical prime-focal parabolic reflectors may not be preferred due to its serious drawback of aperture blocking, which leads to decrease in the aperture efficiency and increase in the side-lobe levels. The offset reflector configuration overcomes these limitations of a prime-focal reflector, as the fields radiated by the reflector are not blocked by the primary feed. Also, the offset reflector possesses several additional advantages, such as isolation between the reflector and the feed, lesser spurious radiation and suppressed side-lobes as compared to a symmetrical parabolic reflector antenna [2]. However, the performance of an offset reflector is satisfactory only when the larger F/D ($F/D > 1$) configuration is selected. Alternatively, the use of an offset reflector antenna with a smaller F/D ratio results into high cross-polarization when illuminated by a linearly polarized feed and beam-squinting in case of a circularly polarized feed [2]. The high cross-polarization and beam-squinting restricts the use of offset reflectors where the frequency reuse is necessary for the effective utilization of the available bandwidth. Also, in case of remote sensing applications, the high cross-polarization reduces the beam efficiency, which may results into poor spatial resolution [3].

Detailed study on the cross-polarization properties of an offset parabolic reflector antenna has been carried out by many authors [4–7]. From these studies, it reveals that, in an offset reflector, the cross-polarization strongly depends on the offset geometry, i.e., the offset angle (θ_0) and the F/D ratio. As reported in Ref. [7], the cross-polar performance of an offset reflector can be improved by selecting a reflector configuration with large F/D ratio and small offset angle. But, usually for remote sensing satellite systems, the available space for the antenna structure is limited, and hence the reflector with a large F/D ratio may not be preferred. Thus, for a low F/D offset reflector, effective cross-pol suppression techniques are to be explored.

The other source of cross-polarization is the cross-polarization of the feed that illuminates the offset reflector antenna [6]. Hence, to reduce the overall cross-polarization, an improved feed with symmetrical patterns and low cross-polarization is essential. It is well known that a fundamental HE_{11} guided corrugated horn produces symmetric E-and H-plane patterns with a very low cross-polarization over a wide bandwidth [8]. However, it has been observed that a conventional corrugated feed (with fundamental HE_{11} mode) cannot suppress the cross-polarization introduced by the asymmetry of the offset geometry. This fact is evident from, Figure 1, which shows a high cross-polarization of the order of -24.7 dB in secondary radiation patterns of an offset reflector illuminated by a conventional corrugated horn. These results, further confirm that, a pure HE_{11} mode guided cylindrical corrugated feed is not an ideal choice for an offset reflector with low F/D ratio.

As suggested by Rudge and Adatia [2, 9–11], by adding a suitable proportion of higher order HE_{21} mode to the fundamental HE_{11} mode, a dual-mode corrugated matched feed can be designed. This type of feed when illuminates an offset reflector antenna, the undesirable cross-polarization will be cancelled-out.

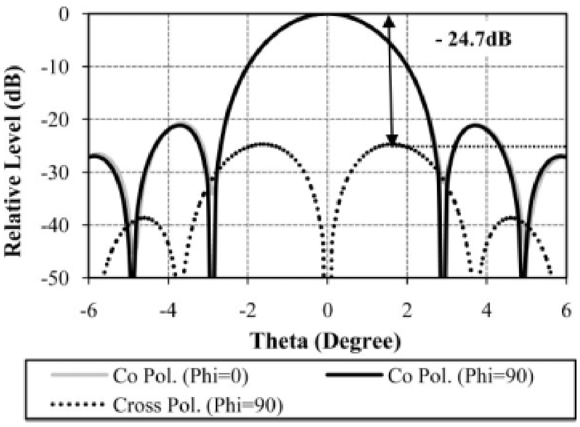
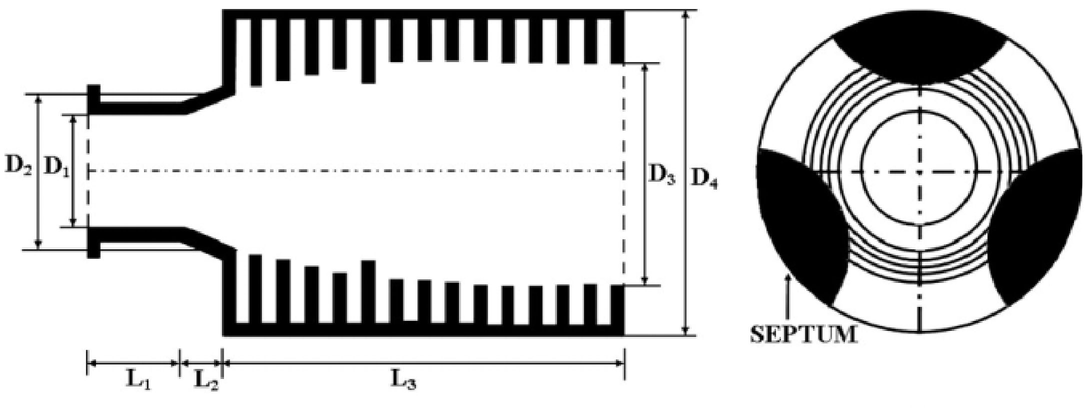


Figure 1 Simulated secondary radiation pattern of an offset reflector illuminated by a conventional (HE_{11} mode guided) corrugated horn. (For $F/D = 0.82$, $\theta_0 = 34.8°$)



(a) (b)

Figure 2 HFSS simulated design of a proposed dual-mode corrugated horn (a) Front view (b) Side View ($D1 = 34$ mm, $D2 = 50$ mm, $D3 = 68$ mm, $D4 = 102$ mm, $L1 = 30$ mm, $L2 = 15$ mm, $L3 = 98$ mm)

To the best of authors' knowledge, such a dual-mode corrugated matched feed design has not been reported in the open literature. Therefore, the primary objective of this article is to present the design of a dual-mode corrugated horn. The measured return-loss characteristics and the primary radiation patterns of the prototype horn are also included. The feed has been used to illuminate the offset reflector antenna and the effectiveness of the same has been validated by showing the improvement of the cross-polarization in the secondary radiation pattern.

2. DUAL-MODE CORRUGATED FEED

For the dual-mode corrugated matched feed, the θ and ϕ components of the far-field radiation pattern can be expressed as,

$$E_\theta = E_\theta^{\mathrm{HE11}} + j.\alpha.E_\theta^{\mathrm{HE21}} \tag{1}$$

$$E_\phi = E_\phi^{\mathrm{HE11}} + j.\alpha.E_\phi^{\mathrm{HE21}} \tag{2}$$

where, α is the arbitrary constant defining the relative power in HE_{21} mode with respect to the fundamental HE_{11} mode. For a suitable value of α, (1) and (2) represent the polar and the azimuthal radiation pattern components of a dual-mode corrugated horn. The expressions for $E_\theta^{\mathrm{HE}_{11}}$, $E_\theta^{\mathrm{HE}_{21}}$, $E_\theta^{\mathrm{HE}_{11}}$ and $E_\theta^{\mathrm{HE}_{21}}$ can be obtained using the general expressions for E_θ and E_ϕ from [12]. Once the final expressions for a dual-mode corrugated feed are obtained, physical optics (PO) based mathematical model proposed by Rudge [13] can be used to estimate the cross-polarization of an offset reflector antenna.

2.1. Feed Design

The geometry of the prototype dual-mode corrugated horn is shown in Figure 2. The horn dimensions were finalized after extensive simulations performed by HFSS software. The input waveguide of the horn was excited by a pure TE_{11} mode. The input diameter of the feed was decided by satisfying a condition, $D_1 = (x_{\mathrm{np}} \times \lambda)/\pi$, where, x_{np} is the cut-off wave number of the TE_{11} mode ($= 1.84118$), and λ is the operating wavelength. Following this, a mode converter was introduced to convert TE_{11} mode into a hybrid HE_{11} mode. The required HE_{21} mode was generated, by inserting three ''arc shaped'' symmetrical septums. The amplitude of the HE_{21} mode largely depends on the dimensions of the septums. As the improper septum dimensions may degrade the overall performance of the reflector, proper care should be taken while deciding the size of the septums. The corrugation pitch and the pitch-to-width ratio were decided based on the guidelines provided in a standard corrugated horn design primer [14]. The required phase relationship (−90°) amongst the HE_{11} mode and the HE_{21} mode was established by properly adjusting the horn length. The horn aperture diameter was selected based on the beam width requirement for the application under consideration. The proposed dual-mode corrugated horn was fabricated with utmost care, as a single error in the

(a) (b)

Figure 3 The hardware of a proposed dual-mode corrugated horn (with transition) (a) Front view (b) Side view. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

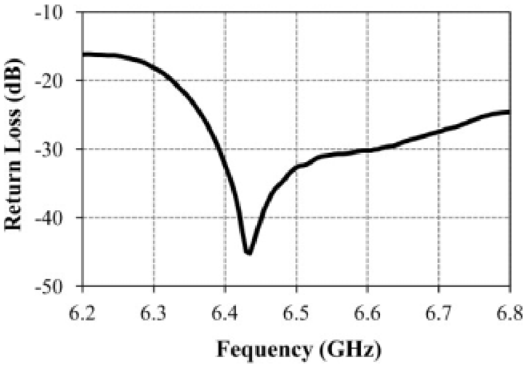


Figure 4 The measured return-loss characteristics of a proposed dual-mode corrugated horn

dimension may acts as a discontinuity and degrades the radiation performance of the horn. The photograph of the prototype horn is shown in Figure 3.

The measured return-loss characteristic of the designed dual-mode horn is shown in Figure 4. The return-loss was found better than 20 dB over a wide frequency band. The predicted and the measured radiation characteristics (primary radiation patterns) of the feed were found in close agreement and are shown in Figure 5. The high cross-polarization observed in the primary radiation pattern [see Fig. 5(b)] will ultimately cancel out the unwanted cross-polarization in the secondary radiation pattern of an offset reflector.

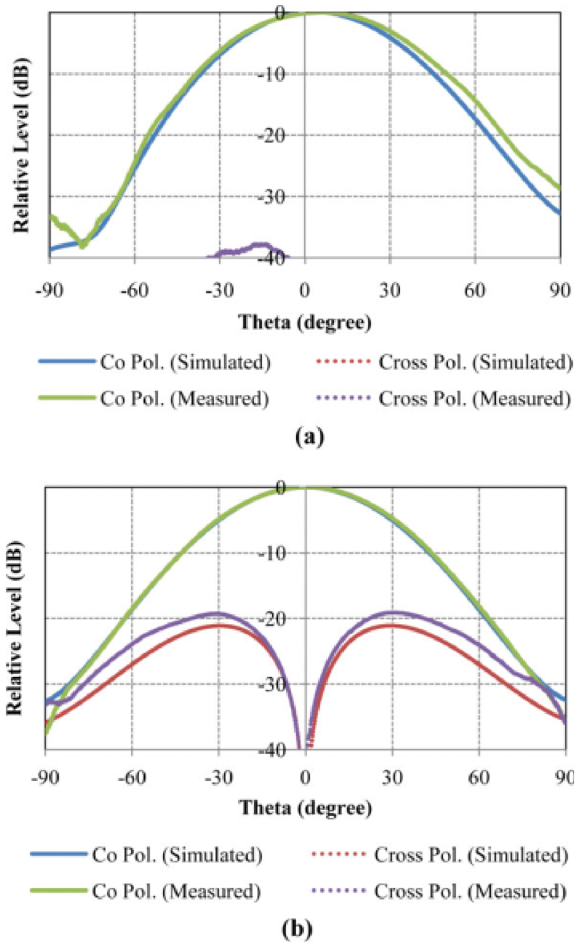


Figure 5 The normalized simulated and measured primary radiation patterns of a dual-mode corrugated horn (a) For Phi = 0° and (b) For Phi = 90°. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

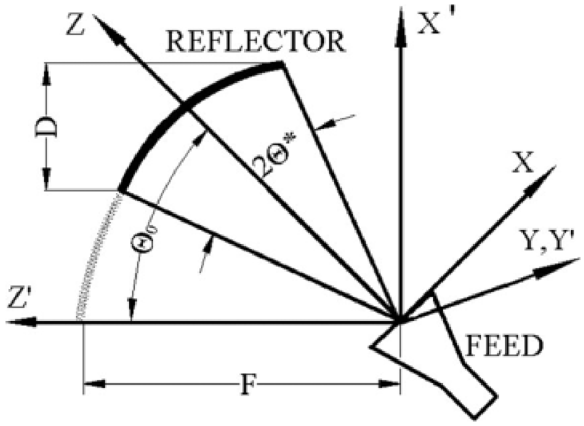


Figure 6 The offset reflector geometry under consideration

3. RESULTS AND DISCUSSION

The offset reflector geometry under investigation is shown in Figure. 6. In Figure 6, x', y', z' represent the symmetrical cartesian coordinates and x, y, z represent associated offset coordinates. The relation between the primed (x', y', z') and the unprimed (x, y, z) coordinates can be found from [2]. For the present offset reflector geometry, the projected aperture diameter was chosen to be 1.242 m, with $F/D = 0.82$. The offset angle (θ_0) was kept 34.8 degree. The offset reflector was illuminated by a linearly polarized dual-mode corrugated horn and the far-field measurements were carried out at the Compact Antenna Test Range—CATR (CCR-75/60). The entire antenna measurement set-up is shown in Figure 7. The measured far-field radiation patterns for the two principle planes, i.e. $\phi = 0°$ and $\phi = 90°$ are shown in Figure 8. As in an offset reflector antenna, the worst cross-polarization occurs is an asymmetrical ($\phi = 90°$) plane [1], the same is chosen for estimating the actual improvement in the cross-polarization. Comparison of far-field patterns in Figure 1 (conventional corrugated feed) and Figure 8(b) (dual-mode corrugated feed) shows, ~7 dB improvement in the cross-polarization when a dual-mode corrugated horn is used as a primary feed. Thus, the

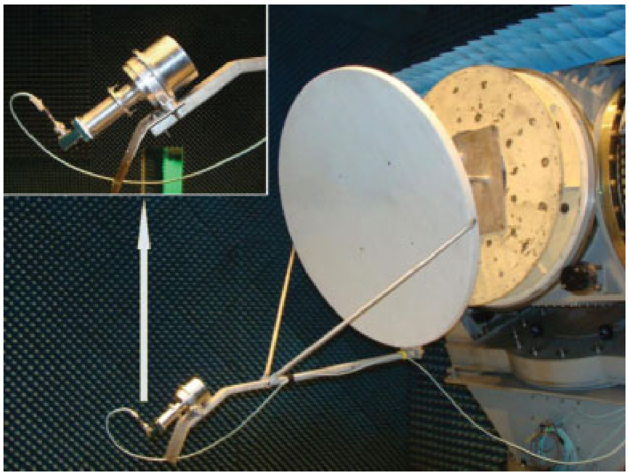
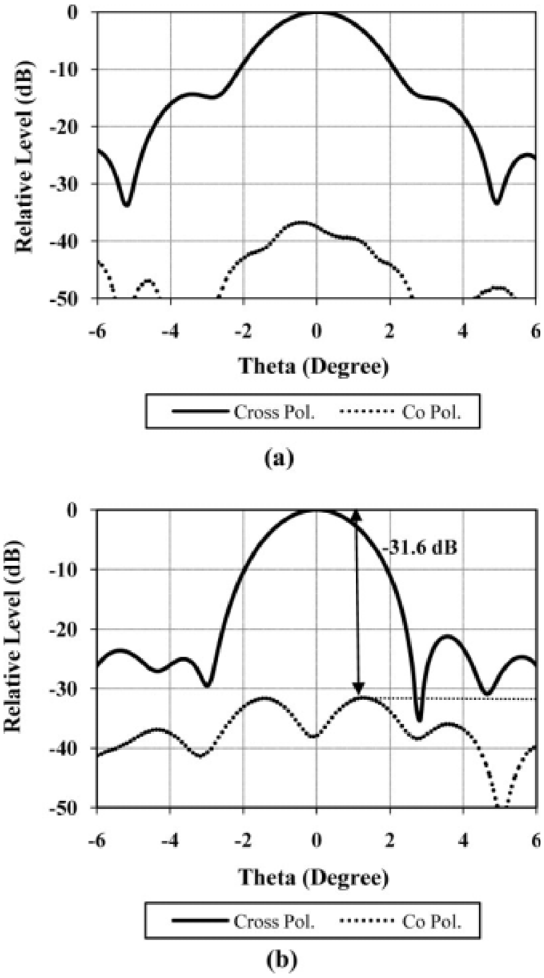


Figure 7 The offset reflector and a dual-mode corrugated horn under test at CATR. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]



(a)

(b)

Figure 8 Measured secondary radiation pattern of an offset reflector illuminated by a dual-mode corrugated horn (a) For Phi = 0° and (b) For Phi = 90°

results validate the effectiveness of the dual-mode corrugated horn as a primary feed device for an offset reflector antenna.

4. CONCLUSION

In this article, the design of a novel dual-mode corrugated horn has been presented. Some remarks on the design and the results are in order:

1. The dual-mode corrugated horn, can effectively suppress the unwanted high cross-polarization introduced by the offset geometry in an offset parabolic reflector antenna.
2. The amplitude proportion of the HE_{21} mode largely depends on the offset geometry. Generally, it is of the order from −15 dB to −30 dB with respect to the fundamental HE_{11} mode.
3. The HE_{21} mode should satisfy a quadrature phase (−90°) relationship with the fundamental (HE_{11}) hybrid mode.
4. Utmost care should be taken while deciding the horn dimensions, and also during the fabrication process to ensure the desired improvement in the cross-polarization of the offset reflector.

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A 0.6-V LOW-POWER ARMSTRONG VCO IN 0.18 μM CMOS

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ABSTRACT: *A low-power differential voltage-controlled oscillator (VCO) is proposed and implemented in a 0.18 μm CMOS 1P6M process. It consists of two single-ended Armstrong oscillators via cross-coupled transistors to obtain a differential output. At the supply voltage of 0.6 V, the output phase noise of the differential VCO is −120.02 dBc/Hz at 1 MHz offset frequency from the carrier frequency of 3.85 GHz and the figure of merit is −188.5 dBc/Hz. Total VCO core*