Characterization of a Dual-Mode Horn for Submillimeter Wavelengths

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***Abstract*—A simple dual-mode conical horn has been developed and tested at 0.5, 1.4, 3.1, and 34.2 mm. The horn has nearly equal beam shape in the E and H plane far field patterns with a 3-dB half angle of 6°. At 34.2 mm, the waveguide reflection loss and the phase center have been determined.**

I. Introduction

At short wavelengths, scalar feed horns [1] are difficult to make. There are, nonetheless, many applications where the near symmetry of the E and H patterns and the low sidelobe levels of a scalar horn are desirable properties. A dual-mode horn of the type developed by Potter [2] has many of the desirable properties of a scalar horn, but is simpler to construct. The purpose of this paper is to describe a simplification in the Potter design which has been tested in the submillimeter and near-millimeter spectral region.

II. Theory

The dual-mode horn described by Potter has a tapered section, connecting two circular waveguides, with a matching iris, a step transition to a larger circular waveguide (called the "phasing section"), and a canonical horn section. The step transition generates a small fraction of TM_{11} mode, as well as the propagating TE_{11} mode. The phasing section and the conical horn combine to create a phase difference for the two modes at the aperture relative to the phase generated at the step. The effect of the TM_{11} mode is to make the E plane aperture distribution more tapered than it would be for a standard single-mode conical horn. The phase difference between the step transition and the aperture is

$$\Delta\phi = 2\pi\left(\int dz/\lambda_g\mathrm{TE} - \int dz/\lambda_g\mathrm{TM}\right) \qquad (1)$$

in which z is the distance along the axis of the horn and λ_g is the guide wavelength. The integrals in (1) can be determined analytically if it is assumed that λ_g follows the formula for a cylindrical waveguide. For the original design by potter, $\Delta\phi = 3.6\pi$.

In principle, addition or subtraction of multiples of 2π to $\Delta\phi$ will not change the performance at the phase center, but will change the bandwidth. In our design, $\Delta\phi$ has been changed to 1.6π so that the bandwidth will be increased. This change concurrently reduces the precision required to manufacture the phase-sensitive dimensions of the horn. For ease of fabrication, we have eliminated the phasing section and selected a flare angle so that the condition of $\Delta\phi = 1.6\pi$ can be obtained while maintaining the dimensions of the aperture and step transition. We have also eliminated the matching iris. The dimensions of the resulting design are shown in Fig. 1. All dimensions are in units of the designed center wavelength, λ_0.

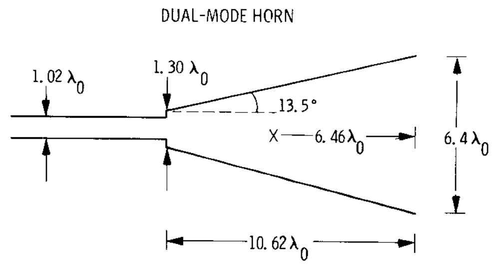

Fig. 1. Design parameters of a dual-mode horn. Lengths are in units of the center wavelength. The flare angle is 13.5° and the phase center is marked by ×.

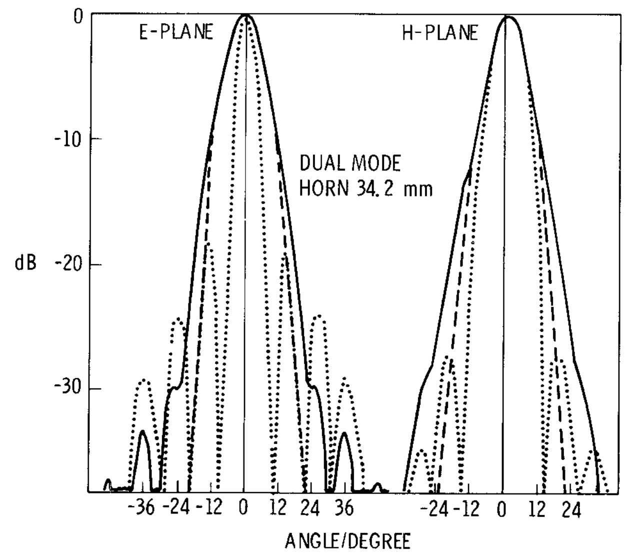

Fig 2. Far-field patterns at 34.2 mm (8.725 GHz). Dashed lines are Gaussian profiles. Dotted lines are theoretical single-mode horn patterns.

III. Measurements

We have constructed models of the dual-mode horn at 0.5, 1.4, 3.1, and 34.2 mm. The two shorter wavelength horns were made by electroforming copper over an aluminum mandrel, while the longer wavelength horns were turned directly on a lathe. The far-field patterns for each horn were measured in the E and H planes. In each case, the patterns were equal (within 1 dB) in the E and H planes down to the -10-dB level. The average half power beamwidth half angle was 6°. The measurements were made most accurately at 1.4 and 34.2 mm, and the results obtained are summarized in Figs. 2 and 3. Cross-polarized far-field patterns were measured at 1.45 mm. The maximum level of cross-polarized signal observed over a 20-percent bandwidth was -28 dB, relative to the main beam. The measurements of the horns built for 0.5 and 3.1 mm agreed with those in Fig. 3 within the 0.3° measurement accuracy. The Gaussian beam parameters of the horn were estimated by matching a Gaussian beam at the -3 and -10-dB points on both E and H plane patterns. The mean estimate is $w_0 = 1.78\lambda_0$. The higher sidelobe level observed in comparison with the Gaussian is the result to be expected for a finite aperture distribution. It should be noted that the sidelobe

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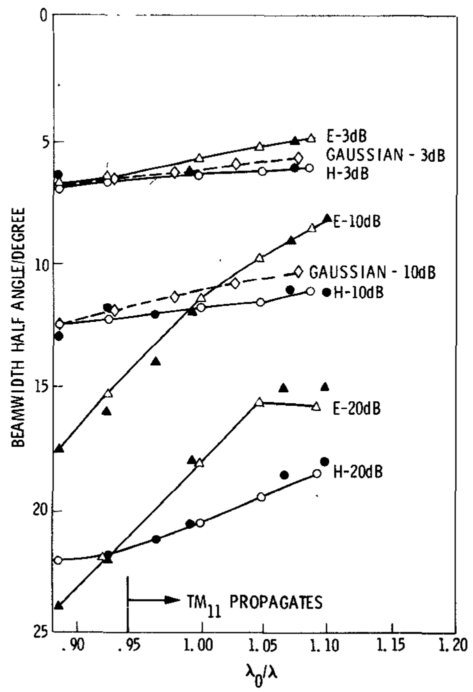

Fig. 3. Frequency variation of 3, 10, and 20-dB points on the far-field patterns. Frequency is in units of the center frequency, and angles are in degrees. Solid figures represent data measured near $\lambda_0 = 34.2$ mm and open figures represent data measured near $\lambda_0 = 1.4$ mm.

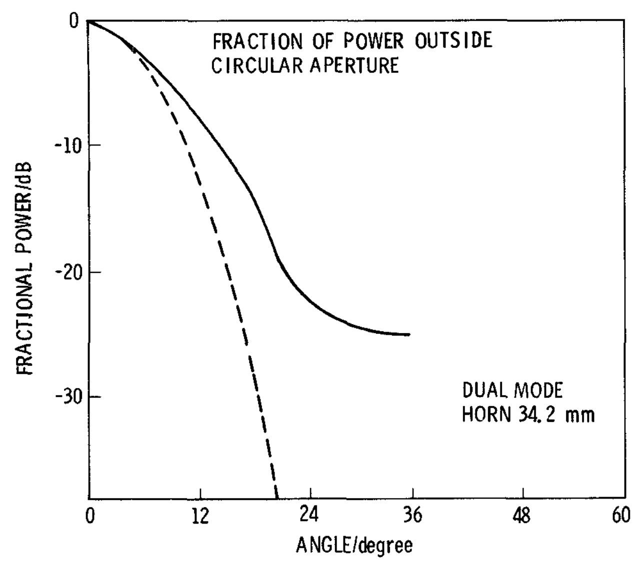

Fig. 4. Fractional power outside a cone of a given polar angle.

levels are considerably reduced in comparison with single-mode radiation patterns for a cylindrical waveguide [3].

The beam efficiency was obtained by integrating the 34.2-mm patterns over all solid angles. Fig. 4 shows the fractional power outside a cone of a given polar angle.

For the 34.2-mm horn, far-field phase measurements were performed. The phase center was found to be 6.46 λ_0 back from the aperture. The far-field phase deviation relative to a spherical wave centered at this point are summarized in Fig. 5.

Waveguide reflection loss was measured over a 30-percent bandwidth centered at 34.2 mm. The reflected power was less

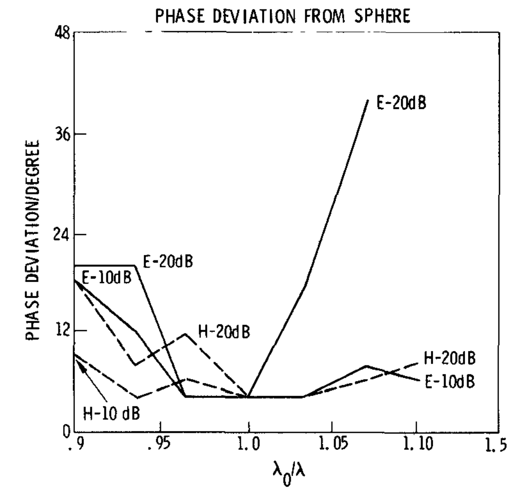

Fig. 5. Far-field phase deviation in degrees from a sphere centered at the phase center measured near $\lambda_0 = 34.2$ mm.

than −23 dB over the whole band, corresponding to a VSWR of 1.15.

IV. Conclusions

We have designed and tested a dual-mode horn at four different wavelengths. The horn has low sidelobe levels and nearly equal E and H plane patterns. The patterns provide a good match to a Gaussian beam. The far-infrared patterns have a single well-defined phase center which is independent of polarization and frequency. The VSWR is quite low, and adequate for near-millimeter applications. The bandwidth of the horn is between 10 and 20 percent, depending on the level of acceptable performance required.

Acknowledgment

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An Analytical Method for the Capacitance of the Rectangular Inhomogeneous Coaxial Line Having Anisotropic Dielectrics

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***Abstract* — An analytical technique for the capacitance of a rectangular inhomogeneous coaxial line with zero thickness offset inner conductor and**

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