A 20-dB Quasi-Integrated Horn Antenna

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Abstract— **A multimode quasi-integrated dipole-fed horn antenna is presented with a performance comparable to that of waveguide-fed corrugated horn antennas. The antenna has been designed using fullwave analysis and has been fabricated and tested at 91 GHz. The horn has a gain of 20 dB with very symmetric patterns, a Gaussian coupling efficiency of 97%, and a cross-polarization level of –22.7 dB. This antenna provides a significant improvement in integrated antenna designs and is suitable for millimeter-wave communication and radar systems and as a Gaussian-beam launcher in quasi-optical receiver systems.**

I. Introduction

INTEGRATED-CIRCUIT antennas typically suffer from poor coupling efficiencies to quasi-optical receiver systems and thus are not competitive with corrugated horn antennas [1]–[3]. This has limited the widespread use of integrated-circuit antennas at millimeter-wave frequencies. Currently some radio-astronomical receivers use planar spiral or log-periodic antennas for quasi-optical coupling at 300–500 GHz where corrugated horns are very hard to fabricate [2], [3]. Of the family of planar antennas, the integrated horn antenna proved to be a very good candidate for millimeter and submillimeter-wave applications with a Gaussian coupling efficiency of 75–80% [4]–[7]. The main limitation of the standard integrated horn stems from its large flare-angle of 70° which is inherent in the anisotropic etching of silicon. This limits the gain to 13 dB and restricts its 10-dB beamwidth to 90°. In this letter, a quasi-integrated horn antenna is proposed with improved pattern-symmetry, high Gaussian coupling efficiency and higher gain. The quasi-integrated horn antenna consists of a flared machined section attached to a standard integrated horn antenna to form a multimode horn (Fig. 1) [9]. The minimum dimension of the machined section is about 1.4 λ, which permits the fabrication of the quasi-integrated horn up to 1.5 THz. Any processing electronics can be integrated using the silicon portion of the horn. Alternatively, a thin GaAs wafer could be sandwiched between the silicon wafers for integration of high speed devices.

II. Theory and Measurements

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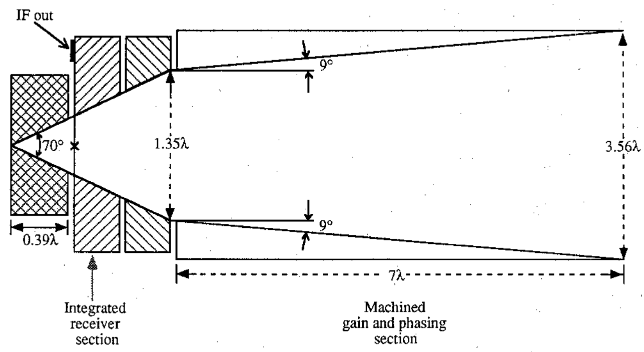

Fig. 1. 20-dB quasi-integrated horn antenna.

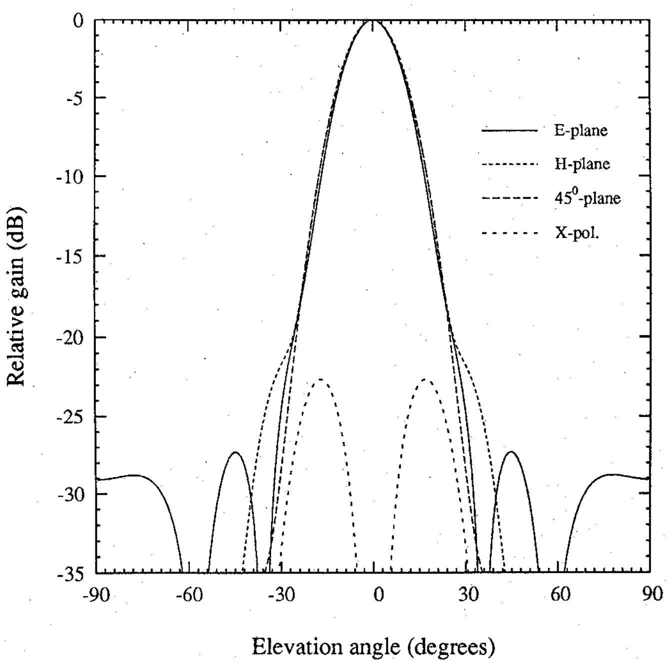

Fig. 2. Calculated far-field patterns.

The abrupt change of flare-angle at the junction of the integrated and the machined section of the horn (Fig. 1) acts as a mode-converter that excites mainly the TE_{10}, TE_{12}/TM_{12} and TE_{30} modes. These modes are subsequently properly phased on the radiating aperture by selecting the length and the flare-angle of the machined section. This results in symmetric patterns with low sidelobe-level and low cross-polarization. Also, the machined section transforms the 1.35 λ-square aperture of the standard integrated horn to a larger 3.56 λ-square radiating aperture yielding a gain of 20 dB. The design was performed using a fullwave analysis procedure

TABLE I
THE MAIN RADIATION CHARACTERISTICS OF THE QUASI-INTEGRATED HORN ANTENNA

Gain	20 dB
Aperture efficiency	62.8%
10-dB beamwidth	34°
Sidelobe-level (E-plane)	–27 dB
Cross-pol. (45°)	–22.7 dB
Beam-efficiency (to –10 dB)	86%
Gaussian coupling	97.3%

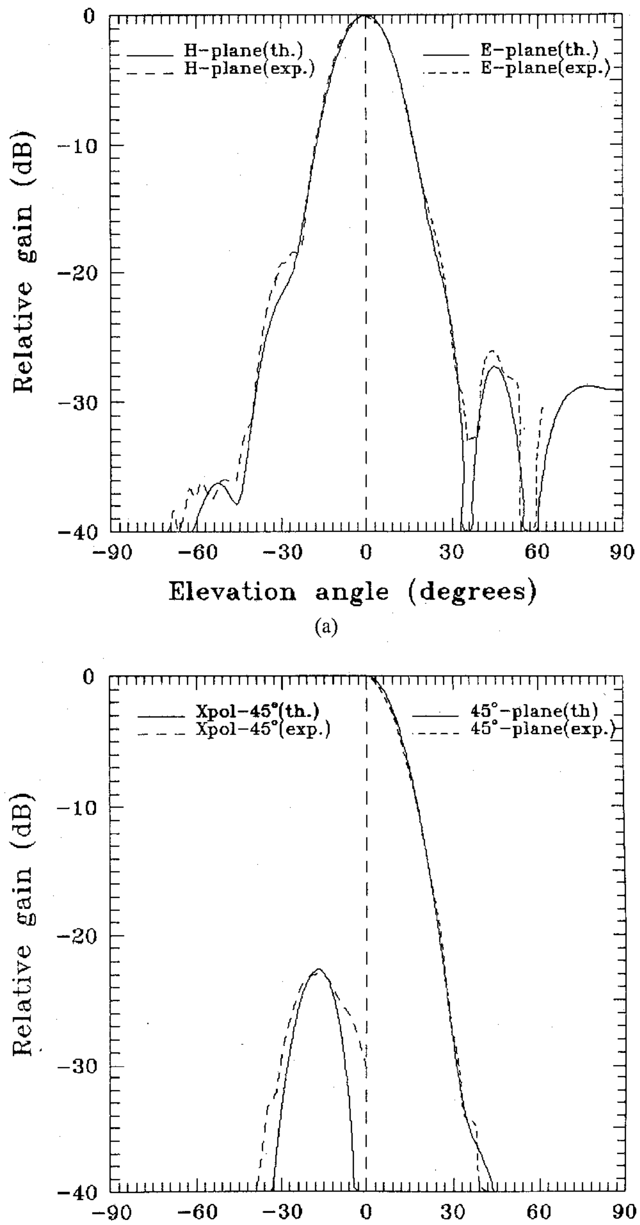

Fig. 3. Predicted and measured patterns at 91 GHz. (a) *E*/*H*-planes. (b) 45°-plane.

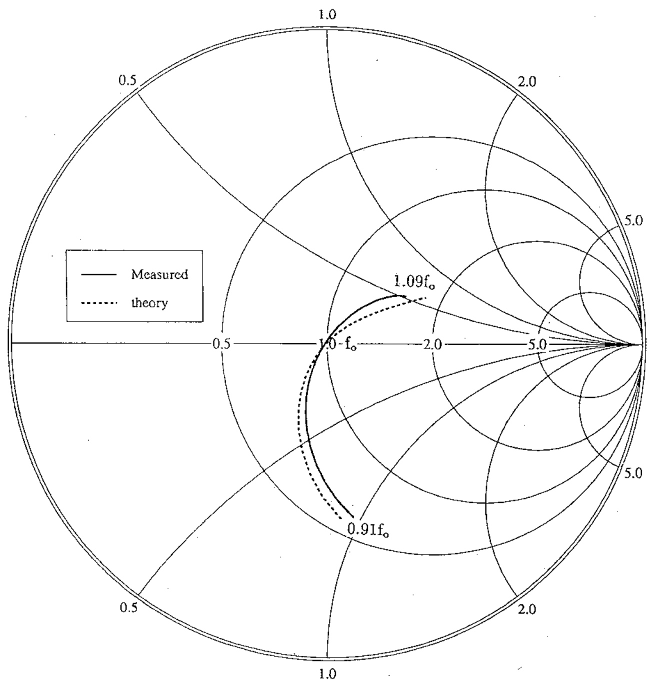

Fig. 4. Predicted and measured input impedance vs. frequency for a feed position of 0.39 λ from the apex of the horn (microwave scale model at f_o = 6 GHz).

that has been developed for dipole-fed horn antennas [8]. The calculated patterns are presented in Fig. 2, where it is observed that the pattern symmetry is excellent down to –20 dB. The main radiation characteristics of the quasi-integrated horn are presented in Table I.

The fundamental Gaussian coupling was calculated by the standard technique of expanding the aperture field into Hermite–Gaussian modes [10]. It is also found that for a bandwidth of ±5%, the 10-dB beamwidth does not vary more than 3° and the Gaussian beam coupling efficiency remains always above 96.5%. The high Gaussian coupling along with the high gain of the quasi-integrated horn indicate that the antenna is well suited for Gaussian-beam launching at millimeter wavelengths.

The quasi-integrated horn has been fabricated and tested at 91 GHz. A planar Schottky diode was soldered to the feeding-dipole on the dielectric membrane to serve as the video detector. The comparison between theory and experiment for the E/H and 45°-plane patterns is excellent as it is shown in Fig. 3. The input impedance of the feeding dipole was measured on a 6-GHz scale-model. The feeding dipole was located at a distance of 0.39 λ from the apex of the horn resulting in a resonant resistance of 50 Ω with a bandwidth of about 10% (Fig. 4). This enables the integration of the quasi-integrated horn with Schottky diodes for receiver applications.

III. CONCLUSION

A new multimode quasi-integrated horn antenna has been introduced as an improvement to the standard integrated horn antenna. The quasi-integrated horn has a gain of 20 dB with highly symmetric patterns and low cross-polarization. For narrowband applications (±5%), the quasi-integrated horn antenna has characteristics which are comparable to those of a waveguide-fed corrugated horn antenna. Currently, receivers based on this antenna are being developed at 90 and 250 GHz at the University of Michigan. Furthermore, a 23-dB quasi-integrated antenna is currently under design and testing.

Acknowledgment

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