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802GHz INTEGRATED HORN ANTENNAS IMAGING ARRAY

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ABSTRACT

This short paper presents the pattern measurements at 802GHz of a single element in a 256-element integrated horn imaging array. The integrated-horn antenna consists of a dipole-antenna suspended on a $1\mu m$ dielectric membrane inside a pyramidal cavity etched in Silicon. The theoretical far-field patterns, calculated using reciprocity and Floquet-modes representation of the free-space field, agree well with the measured far-field patterns at 802GHz. The associated directivity for a 1.40λ horn aperture, calculated from the measured E and H-plane patterns is $12.3dB\pm0.2dB$. This work demonstrates that high-efficiency integrated-horn antennas are easily scalable to terahertz frequencies and could be used for radio-astronomical and plasma-diagnostic applications.

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INTRODUCTION

The integrated horn antennas array has been successfully demonstrated at 94GHz and 240GHz [1-4]. The antenna array is fully monolithic, free of dielectric and surface-wave losses and easily reproducible for array applications. The horn antennas are typically between 1λ and 1.5λ square, and show excellent patterns at 93GHz with a directivity around 10-13dB. The integrated-horn antenna has a measured aperture efficiency of 72% at 93GHz [2], and the design can be easily extended to submillimeter-wave applications. The horn array is composed of two stacked Silicon wafers with a <100> crystal orientation. The opening of the front wafer determines the aperture size, while its thickness determines the position of the dipole feed inside the horn. The horn cavity is made by anisotropic etching of the Silicon wafers. The etching process forms pyramidal holes bounded by the <111> crystal planes, and produces a horn flare-angle of 70.6° [5]. The dipole antennas and detectors are fabricated on membranes which are formed by depositing a 3-layer SiO_2/Si_3N_4 dielectric on the front wafer, and etching the underlying Silicon until the transparent membrane appears. The two wafers are finally aligned and assembled together to form the horn antenna array (Fig. 1).

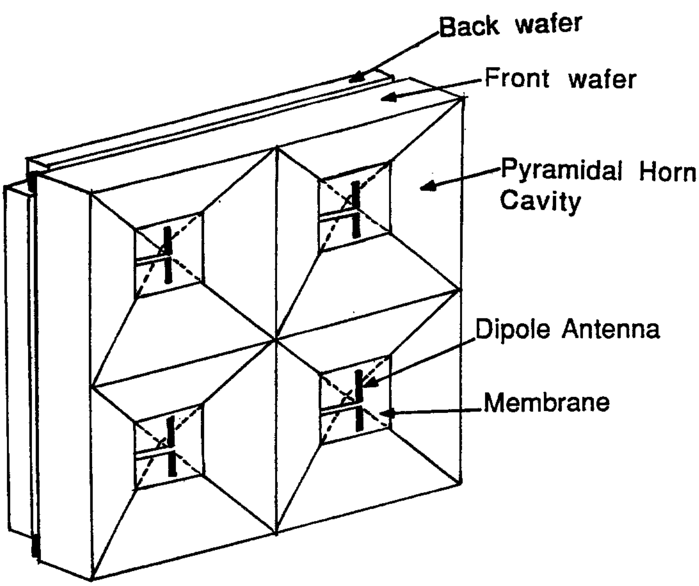

Figure 1: An integrated horn-antennas array with single polarization.

DESIGN AND MEASUREMENTS

The theoretical far-field patterns of a horn antenna in a two-dimensional array is calculated by approximating the horn structure with a cascade of rectangular waveguide sections. The fields in each waveguide section are given by a linear combination of TE/TM waveguide modes and the fields in space are given by a discrete spectrum of Floquet modes. The boundary conditions are matched at each of the waveguide sections and at the aperture of the horn. Reciprocity is then used to relate the fields of a dipole to the dipole in the horn cavity. The reader is referred to [1] for a complete description of the theory. A microwave scale model of the horn antenna was built at 1.1GHz and impedance measurements were done for a 1.40λ square horn. The resonant feed-dipole impedance can be varied between 30Ω and 80Ω for feed positions between 0.3λ and 0.5λ from the apex of the horn and this impedance range is quite suitable for Schottky-diode and SIS receivers [4]. For a feed position of 0.38λ, The resonant length of the feed dipole is 0.4λ and the resulting bandwidth is about 10% (Fig. 2). An array of 16x16 integrated horn antennas was built at 802GHz with 1.40λ horn opening with a feed dipole of length 0.4λ positioned 0.38λ from the apex (Fig. 3).

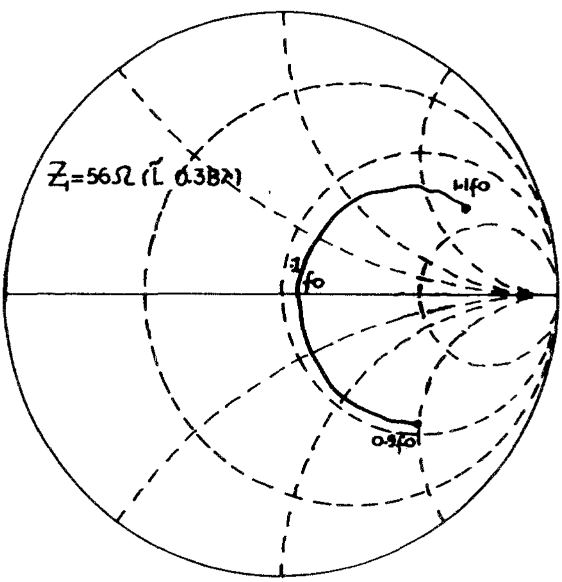

Figure 2: Resonant input impedance for a feed dipole at 0.38λ from the apex, and for a 1.35λ horn opening.

The far-field patterns of a single integrated horn antenna in an array were measured using a far-infrared laser tuned at 802GHz. The detectors are 4μm-square Bismuth microbolometers and are integrated at the center of each dipole antenna. Figure 4 shows the experimental E and H-plane patterns which agree well with the theoretical patterns. The H-plane is smooth due to the TE_{10} tapering of the electric field across the aperture. In the case of the E-plane, the horn sees the array and the spikes and nulls in the patterns are due to specific Floquet-modes. The E and H-plane 10dB-beamwidths are 80° and 90° respectively and the far-field pattern matches well an f/0.8 imaging system. The directivity of a single horn antenna calculated from the measured E and H-plane patterns is 12.3dB$\pm$0.2dB. The pattern is quite symmetrical as is evident from the measured 45°-plane pattern (Fig. 5). The radiated power is well confined to a main central beam, and nearly 88% of the radiated power is within a 100° beamwidth. The resulting spillover loss is around 0.5dB.

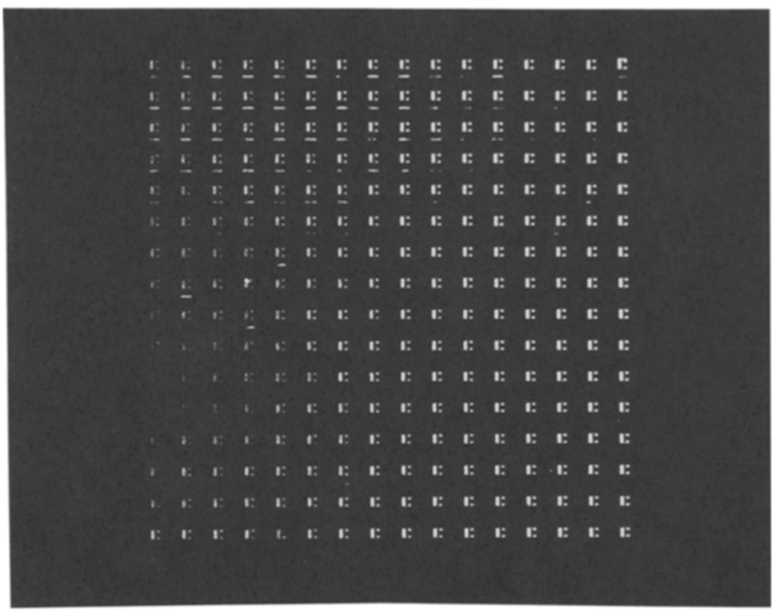

Figure 3: a 16x16 integrated horn-antennas array built at 802GHz.

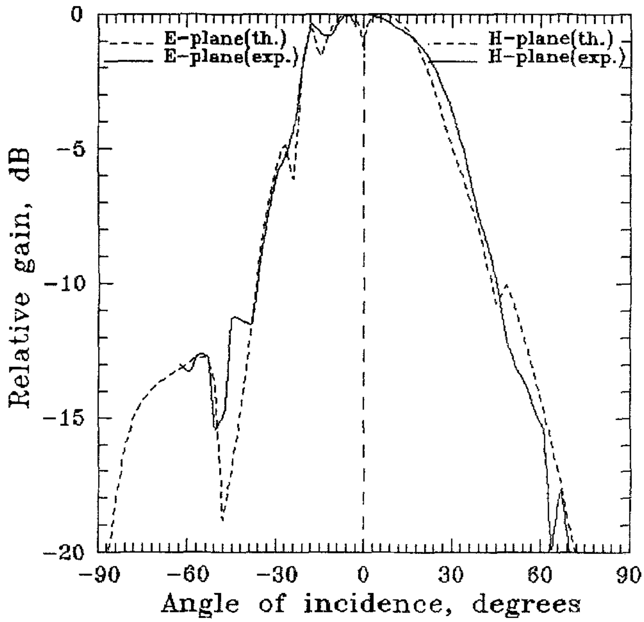

Figure 4: Theoretical and experimental E and H-plane patterns.

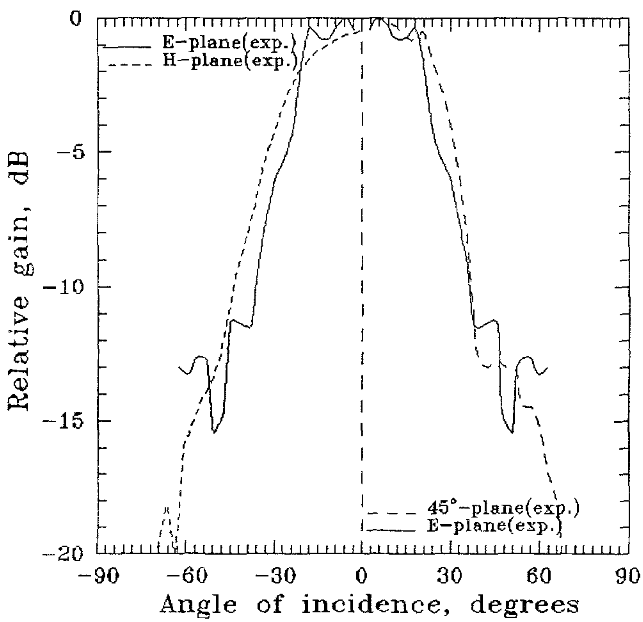

Figure 5: Experimental E, H and 45°-plane patterns.

CONCLUSIONS

An efficient antenna has been built at 802GHz and is suitable for submillimeter-wave receivers. In the future, it should be also possible to integrate SIS detectors on the membranes. The available space on the back of the wafer on which the dipole antennas are integrated allows the integration of the RF, LO and IF circuitry of the receiver.

ACKOWLEDGEMENTS

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