Integrated 119-μm Linear Corner-Cube Array

Steven S. Gearhart, Curtis C. Ling, Gabriel M. Rebeiz, Hemant Davée, and Gordon Chin

Abstract—**An integrated corner-cube antenna has been designed, fabricated, and measured at 119 μm. The structure consists of a traveling-wave antenna integrated on a 1-μm dielectric membrane and suspended in a longitudinal cavity etched in silicon wafers. The patterns at 119 μm agree well with millimeter-wave patterns measured on a scaled antenna at 222 GHz. A directivity of 18 ± 0.5 dB is calculated from *E*- and *H*-plane measurements. This work demonstrates that high-efficiency integrated corner-cube antennas are easily scalable to terahertz frequencies and could be used for radio-astronomical and plasma-diagnostic applications.**

I. Introduction

The standard corner-cube antenna, which consists of a traveling-wave antenna backed by a 90° corner reflector, has been the favorite antenna for submillimeter-wave receivers [1]–[6]. The standard design is a traveling-wave antenna of length $L = 4\ \lambda$ placed $d = 1.2\ \lambda$ from the apex of the machined corner reflector. The antenna has a mainbeam tilted at an angle θ_{max} from the axis containing the corner of the reflector. The E-plane is the $\phi = 0$-plane, and the quasi-H-plane is defined as the plane cutting perpendicularly through the mainbeam at its peak (Fig. 1(a)). The antenna also acts as a whisker contact to a Schottky diode mounted at its base.

The integrated corner-cube antenna consists of a traveling-wave antenna suspended on a 1-μm dielectric membrane in a longitudinal pyramidal cavity (Fig. 1(b)). The membrane electrical thickness is 0.02 λ at 3 THz, so the traveling-wave antenna effectively radiates in free space at 119 μm. The cavity is etched in silicon wafers, and the reflector flare angle is fixed by the orientation of the crystal planes at 70.6° [8]. This angle does not result in degradation of performance when the appropriate antenna design parameters (L, d) are used. The integrated antenna has a number of advantages over the standard machined corner-cube antenna. The integrated antenna is fully monolithic and easily reproducible for array applications. An RF matching network can be included between the antenna and Schottky diode, thus increasing coupling efficiency and reducing the receiver noise temperature. Also, the integrated antenna is fabricated using standard photolithographic processes, so the antenna can be produced with great precision.

The corner-cube array is composed of two stacked Silicon wafers with a ⟨100⟩ crystal orientation. The 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 reflector flare angle of 70.6° [8]. The membranes 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. After etching, the cavity walls are coated with gold using an angle evaporation technique, and the antennas, detectors, and low-frequency lines are deposited on the backside of the front wafer using standard lithography. The two wafers are finally aligned and assembled together to form the corner-cube array.

II. Design and Measurements

A detailed discussion of the design and properties of the integrated corner-cube antenna is given in reference [7] and will not be discussed here. The design of $(L, d) = (1.15\ \lambda, 0.92\ \lambda)$ was tested with a scale microwave model. The far-field patterns had nearly equal E- and quasi-H 10-dB-beamwidths of 44° and a sidelobe level of −16 dB. The cross-polarization level is −16 dB in the E-plane and −15 dB in the quasi-H-plane. The measured input impedance at microwave frequencies is broadband with a radiation resistance centered at 140Ω and a reactance lower than 60Ω [7].

A 16-element 119-μm array (Fig. 2) was built at the University of Michigan and tested at NASA Goddard. The traveling-wave antenna is 137-μm long (1.15 λ at 119 μm), and is 8-μm wide with a 3.5-μm bend portion. A 4-μm-square microbolometer was integrated at the bottom tip of the traveling-wave antenna. This is the same position that one would integrate a matching network and a Schottky-diode or SIS detector in a receiver application. The far-field patterns of a single integrated corner-cube antenna in a linear array were measured using a far-infrared laser tuned at 119 μm. The resulting patterns are shown (Fig. 3(a)) with the patterns from an identically scaled antenna measured at 222 GHz (Fig. 3(b)). The mainbeam is circularly symmetric at both frequencies. A directivity of 18 ± 0.5 dB was calculated from measured 119-μm E- and quasi-H-plane patterns, and the cross-polarization in the E- and quasi-H-planes was lower than the noise level of −15 dB. The 222-GHz antenna has a directivity of 19.5 ± 0.5 dB with cross-polarization levels of less than −16 dB [7].

Conclusion

An integrated corner-cube antenna has been developed for use at 119 μm. The antenna is high gain and has cross-polari-

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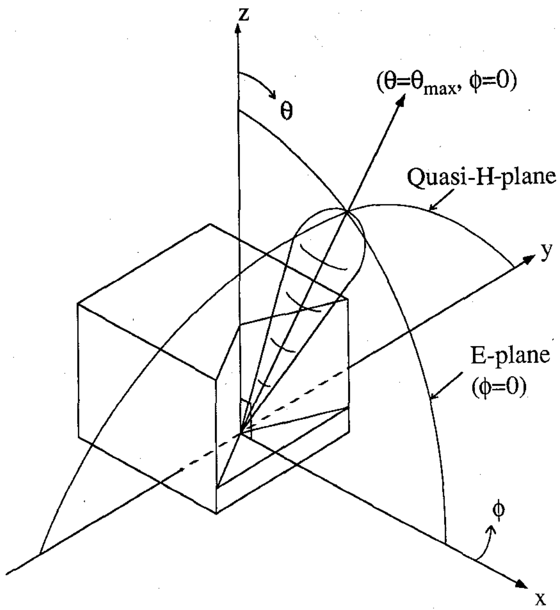
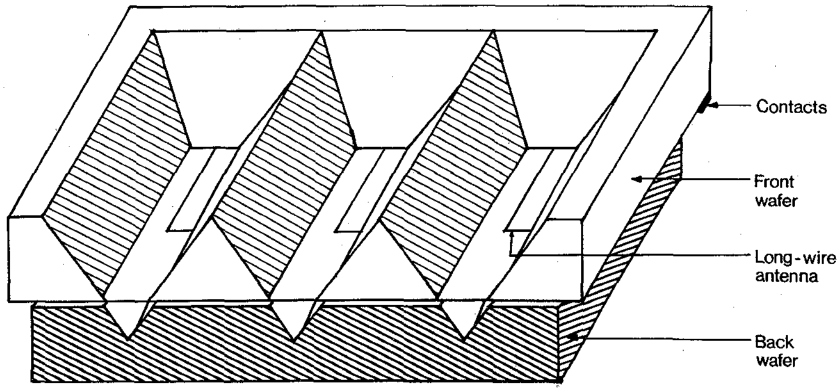
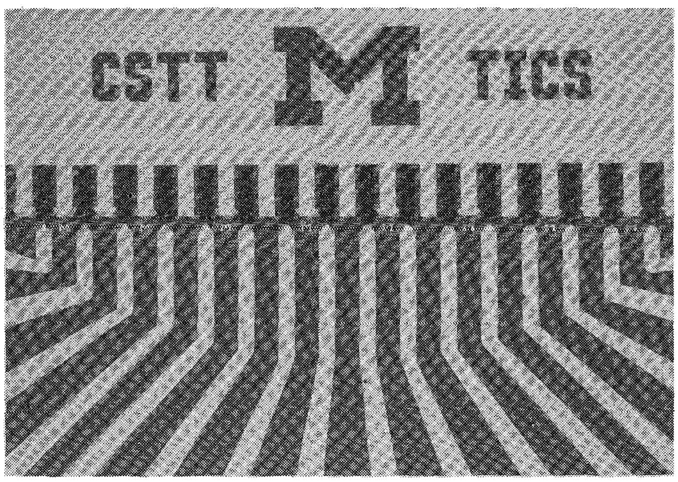


(a)

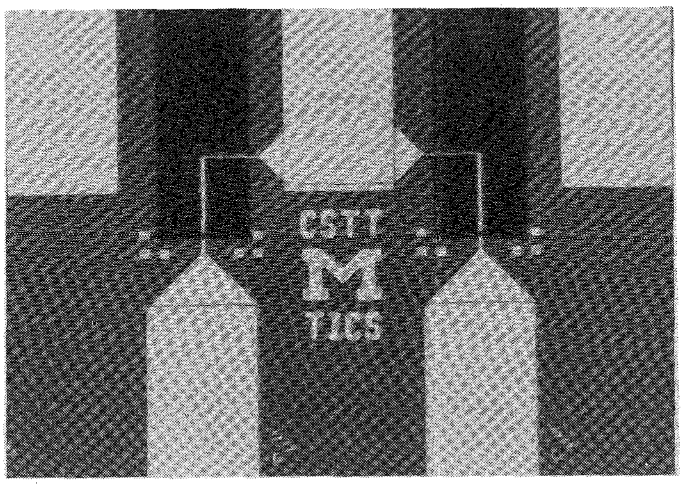


(b)

Fig. 1. Monolithic corner-reflector imaging array. (a) Coordinate system used. (b) Perspective view.



(a)



(b)

Fig. 2. 119-μm corner-cube array, back side of front wafer. (a) 16-element array. (b) Close-up view of two antennas. Note that dielectric membranes appear as dark rectangles, and bismuth bolometers are at the base of the antennas.

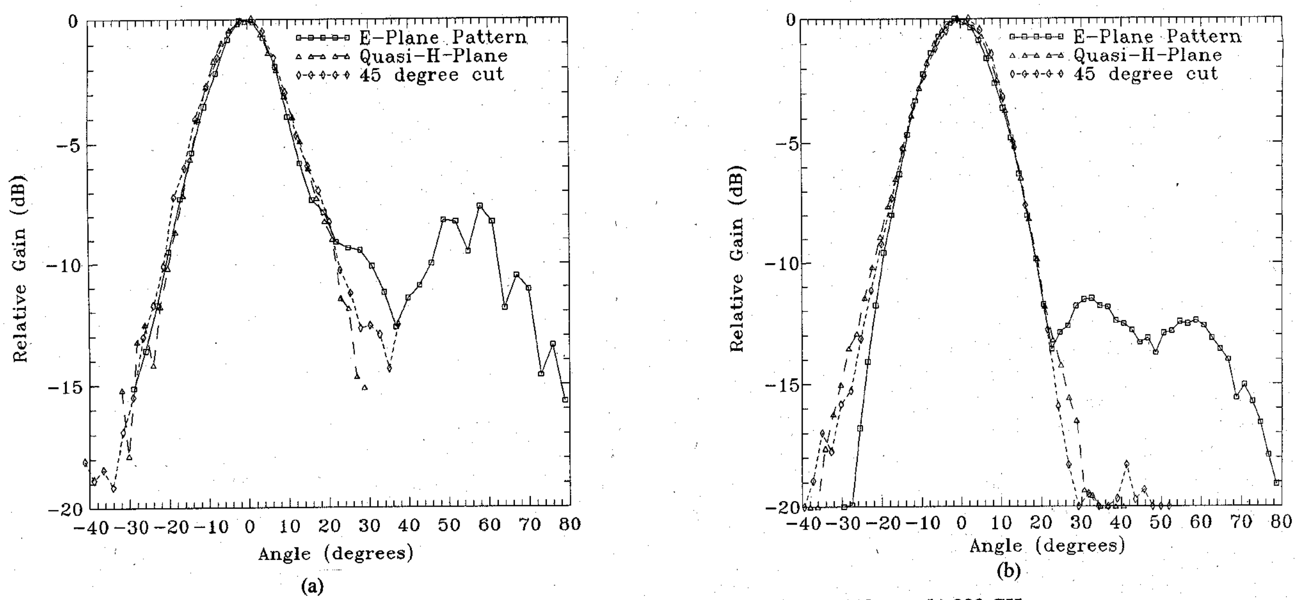


Fig. 3. Measured patterns with $(L, d) = (1.15\ \lambda, 0.92\ \lambda)$. (a) 119 μm. (b) 222 GHz.

zation levels of less than -15 dB in the principal planes. The monolithic approach allows the integration of a matching network and a Schottky-diode or SIS detector at the base of the antenna to yield a low-noise monolithic 119-μm receiver.

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