INTEGRATED TERAHERTZ CORNER-CUBE ANTENNAS AND RECEIVERS

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SUMMARY

This paper summarizes work completed and under progress on integrated corner-cube antennas and receivers at the University of Michigan. An integrated corner-cube antenna has been developed for use at millimeter-wave and terahertz frequencies. The antenna is high gain and has low cross-polarization levels (<-17dB at 222GHz and <-15dB at 119μm) in the principal planes. The monolithic approach allows the integration of a matching network and a Schottky diode at the base of the antenna to yield a low-noise monolithic 600GHz receiver.

The standard corner-cube antenna, which consists of a traveling-wave antenna backed by a 90° corner reflector, has been a favorite antenna for submillimeter-wave receivers. The standard design is a 4λ-long traveling-wave antenna placed 1.2λ from the apex of the machined corner reflector. 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 1μm dielectric membrane in a longitudinal pyramidal cavity (Fig. 1). The membrane electrical thickness is 0.02λ at 3THz, so the traveling-wave antenna effectively radiates in free space at 119μm. The cavity is etched in silicon wafers, and the reflector flare angle is fixed by the orientation of the crystal planes at 70.6° [4]. 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.

A millimeter-wave linear corner-cube array was fabricated for use at 222GHz. The traveling-wave antenna is 1560μm long (1.15λ at 222GHz) and is 60μm wide with a 20μm bend portion. These dimensions were optimized using microwave scale model measurements. A 6μm-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 were measured at from 180GHz to 270GHz using millimeter-wave doublers and triplers fed by appropriate Gunn sources. Over the 180-270GHz bandwidth, the patterns are well-behaved with a narrow mainbeam and no off-axis sidelobes. At 222GHz, an increase in the extention of the ground planes was shown to narrow the quasi-H plane resulting in a rotationally symmetric mainbeam with a 10dB beamwidth of approximately 40° (Fig. 2) and cross-polarization levels of less than -17dB in the E and quasi-H planes. A co-polarized directivity of 19dB at 222GHz was calculated from the full two-dimensional patterns [1,2].

A 16-element 119μm array was built at the University of Michigan and tested at NASA Goddard. The traveling-wave antenna is 137μm long (1.15λ at 119μm), and is 8μm wide with a 5μm bend portion. A 4μm-square microbolometer was integrated at the bottom tip of the traveling-wave antenna. The far-field patterns of a single integrated corner-cube antenna in a linear array were measured using a far-infrared laser tuned at 119μm (Fig 2). The mainbeam is circularly symmetric with a 10dB beamwidth of approximately 40°. The higher sidelobes in the E-plane may be due to scattering from the test mount. This will be examined in detail later. A directivity of 18±0.5dB was calculated from measured 119μm E- and quasi-H plane patterns, and the cross-polarization in the E- and quasi-H planes was lower than the noise level of -15dB [3].

600GHz INTEGRATED CORNER-CUBE RECEIVER DESIGN

A 600GHz integrated corner-cube receiver is currently under development at the University of Michigan (Fig. 3). A University of Virginia membrane-type diode with a 1μm anode diameter will be mounted in hybrid fashion to the silicon wafer containing the antenna, RF matching network, and low-pass IF filter. The estimated diode parameters are R_s=20Ω,C_{jo}=1fF, C_p=2fF, n=1.2, and ϕ_{bi}=0.8V. These parameters yield a figure of merit cutoff frequency of $f_T=1/(2\pi C_T R_s)$=2.7THz. The RF and LO signals will be injected quasi-optically through the antenna which is matched to the diode through a simple RF matching network. The RF matching newtork is a single 0.38λ length of 40Ω CPW transmission yielding an RF imbedding impedance of 52+j29Ω at the diode. Using the harmonic balance technique of Held and Kerr [5] with the above diode and RF matching network, the RF diode impedance is 51-j53Ω, and the conversion loss is 7.6dB.

ACKOWLEDGEMENTS

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REFERENCES

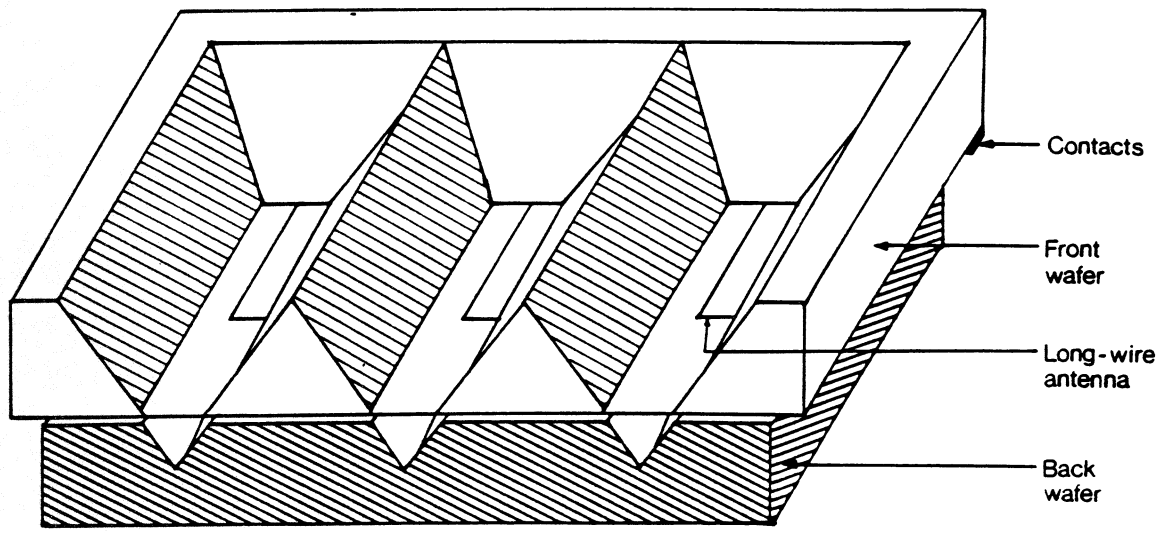
[1] S.S. Gearhart, C.C. Ling and G.M. Rebeiz, "Integrated 222GHz Corner-Reflector Antennas," *Microwave and Optical Technology Letters*, vol.4, No.1, pp.12-15, Jan. 5, 1991.

[2] S.S. Gearhart, C.C. Ling and G.M. Rebeiz, "Integrated Millimeter-Wave Corner-Cube Antennas," To be published by *IEEE Transactions on Antennas and Propagation*, July, 1991.

[3] S.S. Gearhart, C.C. Ling, G.M. Rebeiz, G. Chin and H. Davé "Integrated 119μm Linear Corner-Cube Array," Accepted for publication by *IEEE Microwave and Guided Wave Letters*, Mar. 1991.

[4] K.E. Peterson, "Silicon as a mechanical material," *Proc. IEEE*, vol.70, pp.420-457, 1982.

[5] A.R. Kerr, "A technique for determining the local oscillator waveforms in a microwave mixer," *IEEE Transactions on Microwave Theory and Techniques*, vol. MTT-23, pp.828-831, Oct. 1975.



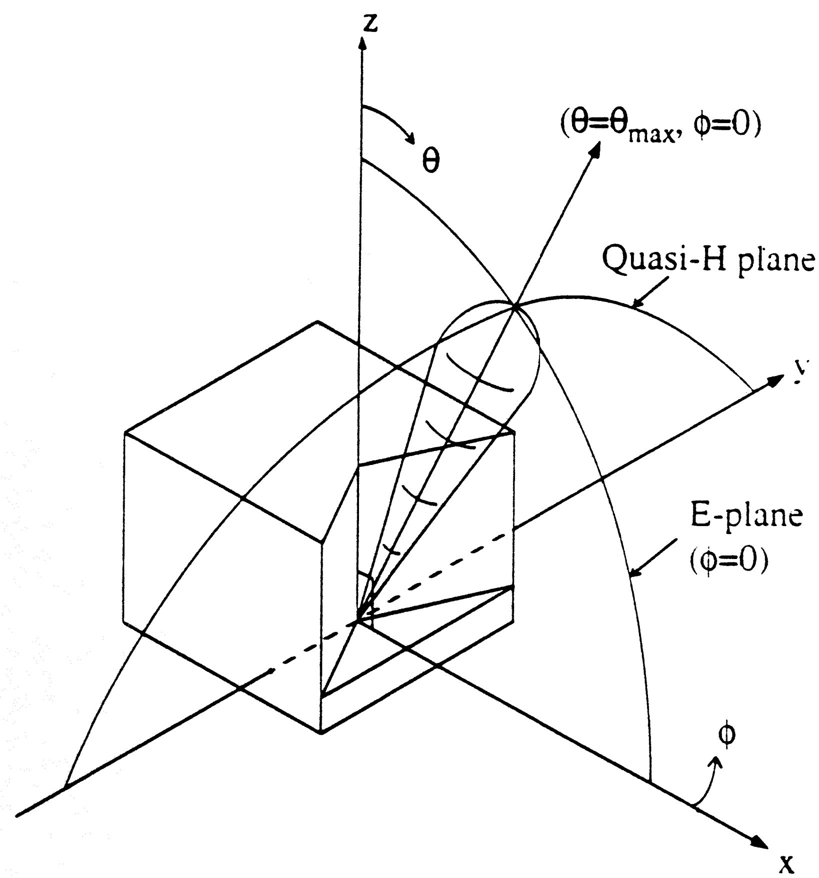
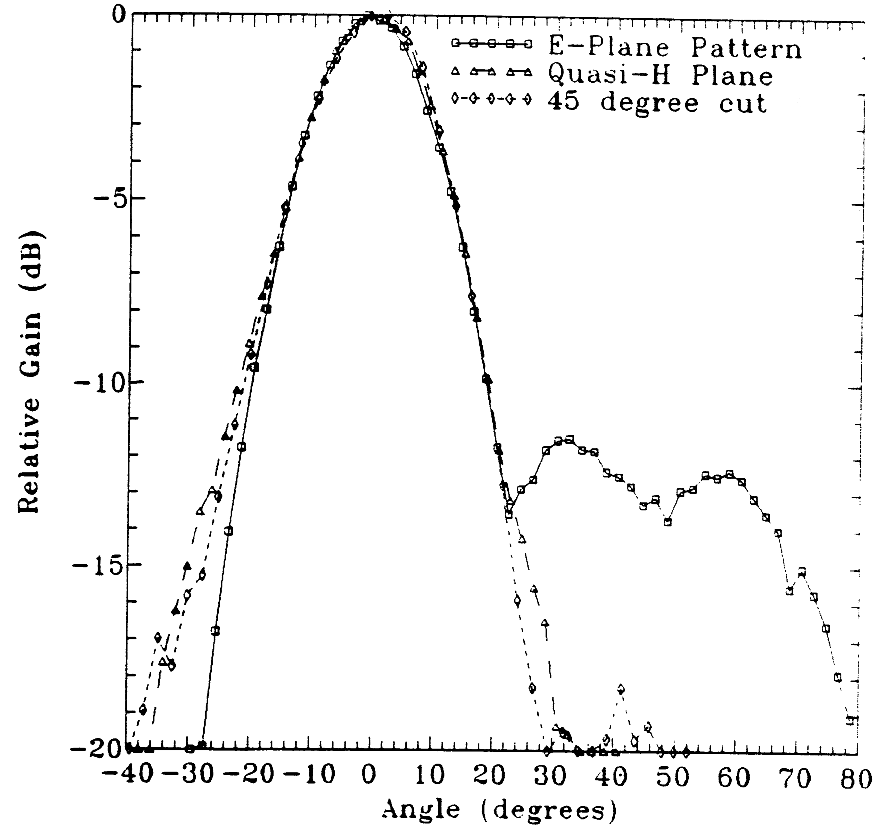
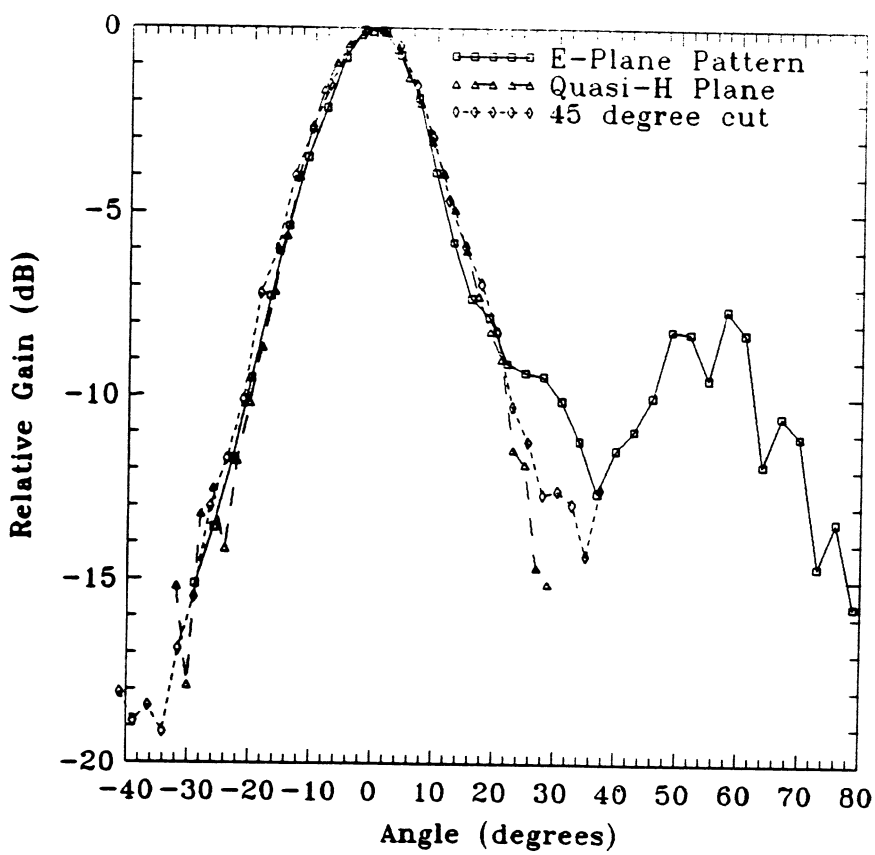


Figure 1: A monolithic corner-reflector imaging array: (a) perspective view. (b) the coordinate system used.

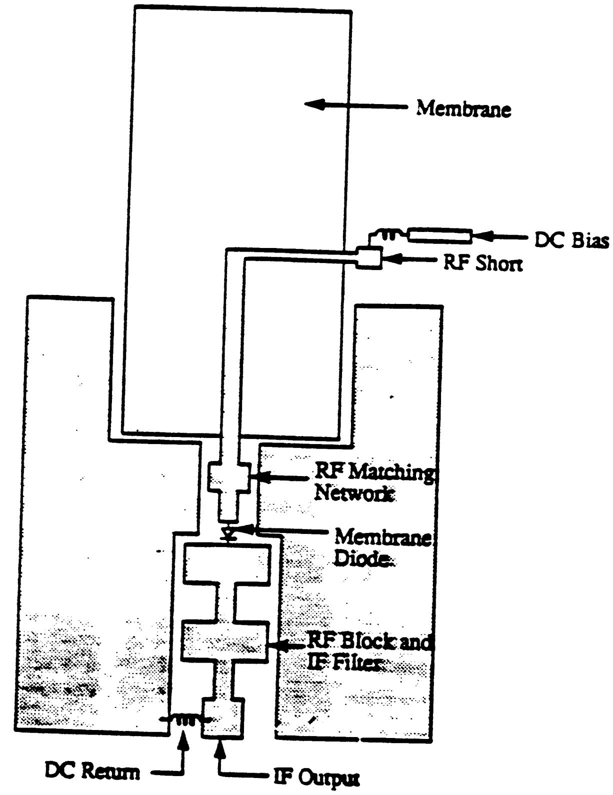


(a)

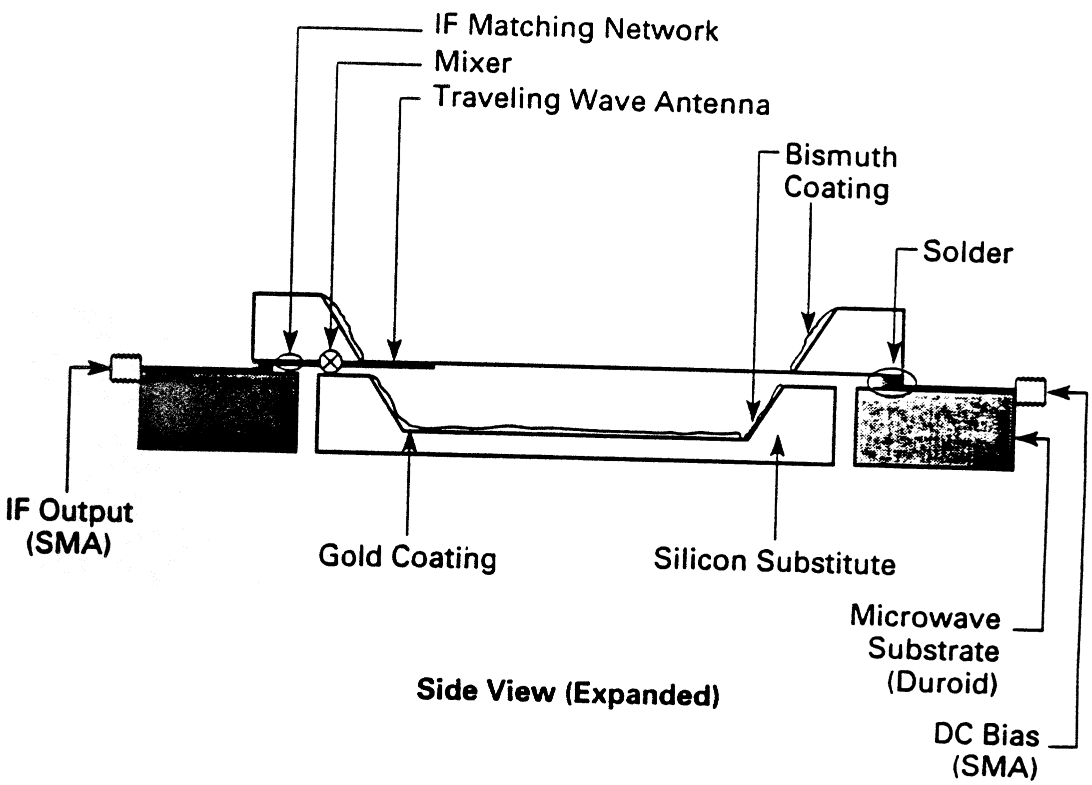


(b)

Figure 2: Measured patterns with (L,d)=(1.15λ,0.92λ): (a) 222GHz. (b) 119μm.



(a)



(b)

Figure 3: 600GHz integrated corner-cube receiver: (a) back of membrane wafer. (b) side view.