The Development of Quasi-Optical THz Detectors

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***Abstract*—The design and testing of a broadband quasi-optical THz Schottky-diode detector is described. Initial measurements yielded a responsivity of 1000-300 V/W over the frequency range from 150-400 GHz. The effect of the antenna geometry on the performance, and the methods used to calibrate the waveguide and quasi-optical detectors will be described.**

I. Introduction And Background

SCHOTTKY diode detectors have long been used at mm- and submm-wavelengths because of their high sensitivity, their ability to operate at ambient or cryogenic temperature and their fast response time compared with other room temperature detectors, such as Golay cells, pyroelectric detectors, or bolometers[1,2]. Waveguide-based Schottky diode detectors have typical responsivities ranging from 4000-1000 V/W over the frequency range 100 GHz to 1 THz. However, the frequency bandwidth of the waveguide-based detectors is limited by fundamental waveguide operation to approximately 50% fractional bandwidth. For many applications it is desirable to achieve wider operating bandwidth. A series of quasi-optical detectors have been designed using self-complementary broadband antennas mounted on Silicon substrate lens[3]. These antennas have well controlled beam patterns with decade or wider bandwidths. This paper will describe the development and testing of these quasi-optical detectors. Particular focus will be placed on the choice of antenna geometry, and the methods used to calibrate the detector responsivity.

II. Results

Zero-bias planar Schottky diodes fabricated at Virginia Diodes[4] were mounted across the feeds of different self-complementary antenna geometries, such as the log-periodic antenna shown in Figure 1. The antenna was then mounted onto a 10 mm diameter high resistivity Silicon substrate lens (resistivity > 10,000 Ohm-cm), which focuses the antenna pattern to achieve a directivity of up to 30 dB for the antenna+lens combination, depending upon the choice of extension length[5]. There is a trade-off between the directivity and Gaussicity, and so the appropriate choise of extension length depends upon the particular application. The Silicon lens is left uncoated, which causes a reflection loss at the air-dielectric interface of 1.6 dB, thus reducing the responsivity. An anti-reflection coating could be used to reduce this loss, but would affect the broadband performance of the antenna.

The antenna pattern of the various quasi-optical detectors was measured at 195 GHz and 585 GHz. The measured antenna patterns for a log-periodic antenna with an extension length of 2.2 mm are shown in Figure 2. The antenna directivity ranges from 24 dB at 150 GHz to 32 dB at 600 GHz. The directivity in this case is higher than desired for general practical use, and so antennas with shorter extension lengths are also being developed.

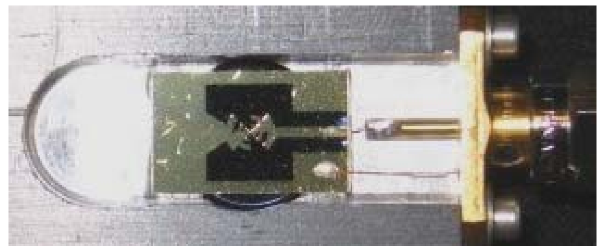

Fig. 1. Photograph of a log-periodic antenna mounted in a housing with SMA output and Silicon substrate lens.

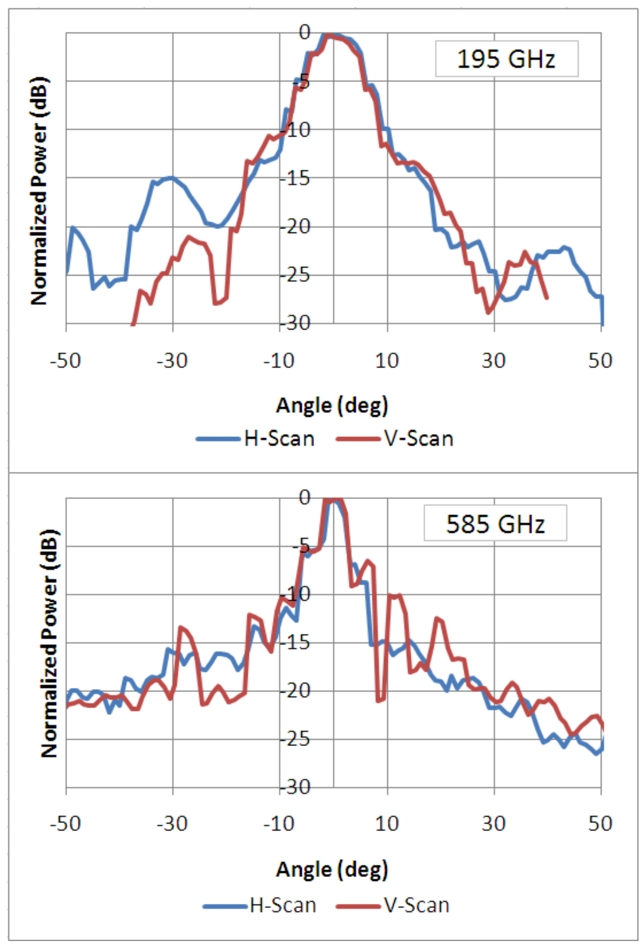

Fig. 2. Measured antenna patterns for a log-periodic antenna at 195 GHz and 585 GHz.

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The frequency dependence of the quasi-optical detectors was then measured by illuminating the detectors in the far field of a broadband frequency multiplier-based source ranging in frequency from 150 GHz up to 600 GHz. The detected video response voltage was measured as a function of frequency.

In order to provide a point of reference, a set of waveguide detectors were also measured at the same location in the source beam. Figure 3 shows the measured voltages for a quasi-optical detector as compared with a series of four separate waveguide detectors. The waveguide detectors had simple diagonal horns with directivity of 22-25 dB to couple the power to free-space.

The responsivity of the waveguide detectors had been determined previously using a waveguide directional coupler and a calorimeter to determine the incident power. By estimating the effective aperture of the quasi-optical and waveguide detectors the responsivity of the quasi-optical detector is estimated to range from 1000-300 V/W over the frequency range from 150-400 GHz, as shown in Figure 4. The decrease in responsivity at the higher frequencies is not expected, since the same diode has been used for waveguide detectors in this same frequency range without a degradation in responsivity. Further measurements are underway to determine the source of the rolloff.

III. Conclusions

The initial characterization of broadband quasi-optical zero-bias detectors has been described. A responsivity of 300-1000 V/W was measured for a quasi-optical detector over a frequency range from 150-400 GHz, with good performance up to 600 GHz. Similar performance is expected up to about 1 THz using flip-chip mounted detector diodes. Extension of these results to 2 THz and higher is possible by integration of the diode with the antenna during fabrication.

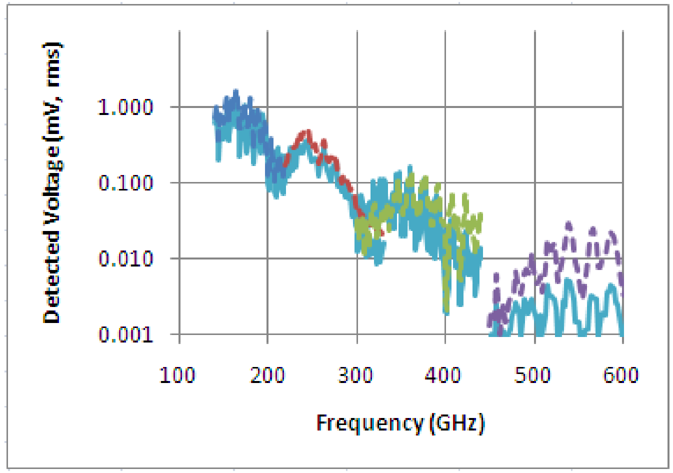

Fig. 3. Measured output voltage of quasi-optical detector (solid lines) compared with a series of four different waveguide detectors (dashed lines).

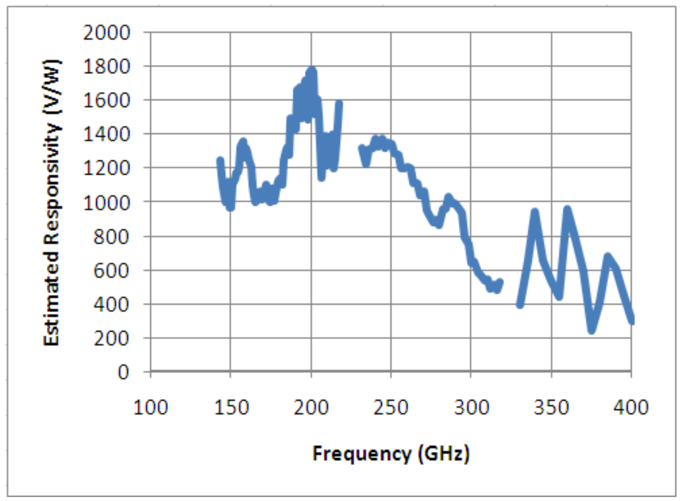

Fig. 4. Measured responsivity of the quasi-optical detector, with responsivity determined by comparing response to that of a calibrated waveguide detectors.

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