A MILLIMETER WAVE MONOLITHIC LOAD SWITCHING TWIST REFLECTOR FOR COMPACT IMAGING CAMERAS

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ABSTRACT

A monolithic load comparison twist reflector (LSTR) has been built and tested for use in 94 GHz passive imaging cameras. Radiometric and quasioptical tests show that the array has an insertion loss of 0.25 dB. This active array of PIN diodes replaces the mechanical choppers often used in load comparison.

INTRODUCTION

Millimeter wave imaging systems are being developed for detecting metallic or non-metallic contraband concealed under people's clothing [1]. The cameras under development are passive systems and detect the difference in emissivity between the human and the contraband. The object shows up in the 94 GHz picture as a shadow against the brighter body. Most research radiometers use a waveguide switch or a large mechanical chopper for load comparison, which is necessary but too cumbersome for commercial applications. In this paper we describe a compact monolithic array which replaces the chopper. This design is the next generation of that described by Stephan [2] and by Stephan et.al. [3].

DESIGN AND PERFORMANCE

The complete LSTR comprises a quarter wave plate, the monolithic array, a dielectric absorber with an antireflection layer, and a metal back plate for structure and temperature control. The main requirements of the LSTR are (1) a difference of ≥ 17 dB in reflected power between the diode on and off states, (2) all power reflected without loss when the array is biased off, and (3) a low excess radiometric noise level. A cross section of the LSTR is shown in Figure 1.

In addition to performing the load comparison function, the LSTR with the quarter wave plate are the essential components in the camera's compact optics configuration. This layout, shown in Figure 2, shortens the distance between the feed and lens by about a factor of 3 compared with the unfolded version. The beam originates from the feed and is incident on the transreflector. The electric field component parallel to the conductors in the transreflector is reflected to the twist reflector, a device that transforms the incident polarization to the orthogonal sense on reflection. The reflected beam thus has the orthogonal polarization sense and transmits through the transreflector. The lens focuses the beam.

The building blocks of the wave processing monolithic array are 12.7×12.7 mm tiles comprising a GaAs substrate, a passive mesh on one side, and an active mesh on the other side. The active mesh has a PIN diode between each node in both dimensions, while the passive mesh does not. A 2-D mesh is a quasioptical high pass filter. When the diodes are forward biased, current flows through the mesh and it performs like a high pass filter. The passive mesh on the back side is at the correct distance from the active mesh to form a Fabry-Perot resonator, which is a bandpass filter. When the bias is off, the diodes form an open circuit between each of the nodes. The result is effectively an array of crossed dipoles, which is a notch filter. During the

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unbiased state the array reflects the incident power and with the quarter wave plate, performs as the twist reflector in the compact optics. When the diodes are biased, the beam transmits through the array where it is absorbed by a matched dielectric. In this capacity the mesh is part of the load. Individual tiles were tested in a quasioptical test set-up for transmitted and reflected power, for both the biased and unbiased states of the diodes. Actual 94 GHz data in Figures 3a and 3b show the maximum change in reflected power between the biased and unbiased states to be 24 dB. This switching ratio exceeds the requirement of 17 dB. In the off state, all but 0.25 dB of the power is reflected.

A rectangular array (6×5) of tiles with a quarter wave plate and a matched dielectric load was tested radiometrically using a Y-factor measurement. The test radiometer and the passive optics belonging to this test set-up were all characterized prior to the LSTR measurements. The hot (room temp) and cold (LN_2) temperatures for the Y-factor measurements were assumed to be 295K and 80 K, respectively. The test set-up was calibrated to determine the radiometer sensitivity in Kelvins per volt using an aluminum reflector in place of the 6×5 array in the twist reflector. The amplitude of the switched signal was measured as a function of bias current. The results are shown in Table 1.

Table 1
Bias current vs. Relative Noise Temperature, LSTR Array

I, amps	Rel. Noise Temp, K
0.0	177
0.5	174
1.0	186
1.5	193
2.0	199
2.5	203
3.0	203

A lossless LSTR would yield 215K, the same as the aluminum reflector in the calibration. The loss of the array is given as 10log(203/215), or -0.25 dB. This is in excellent agreement with the reflected power measurements shown in Figure 3.

Figure 4 shows a section of the LSTR tile array.

CONCLUSIONS

We have described the design and test results of a 6×5 element monolithic array of PIN diodes used for load comparison at millimeter waves. The insertion loss under operating conditions is about 0.25 dB and the maximum switching ratio is 24 dB, as measured by quasioptical and radiometric techniques. A much larger array of 204 elements, each 12.7×12.7 mm, has been implemented into a 94 GHz imaging camera.

We anticipate that given the interest in millimeter wave imaging, more of these arrays will be developed and continually improved upon.

ACKNOWLEDGMENTS

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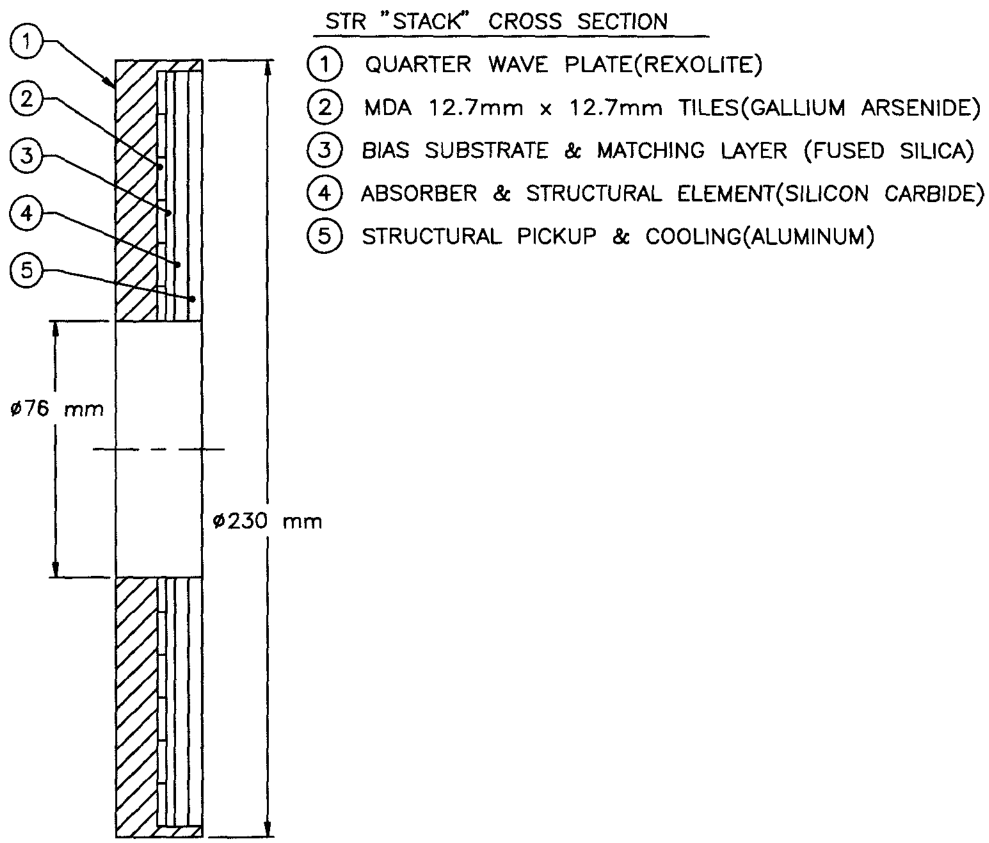

FIGURE 1. Load Switching Twist Reflector Cross Section

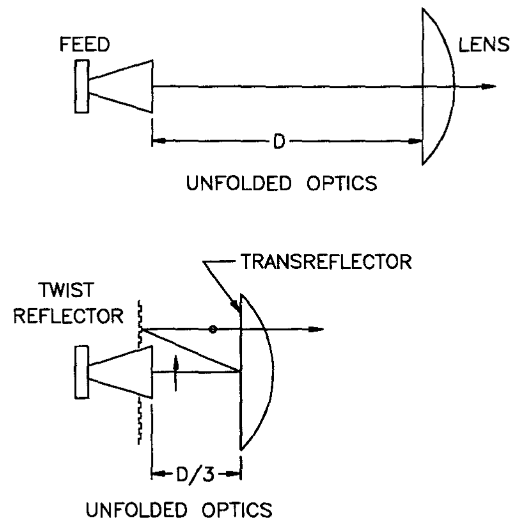

FIGURE 2. Unfolded and Folded Optics

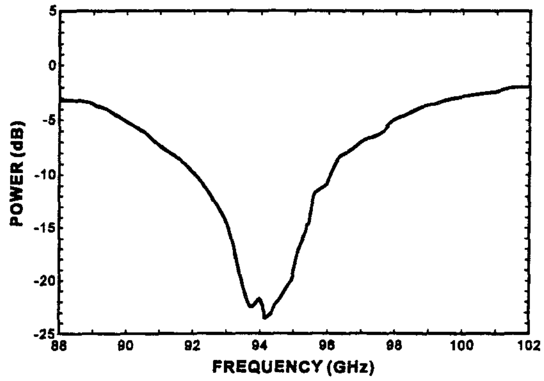

FIGURE 3a. Reflected Power Under Pulsed Bias Condition.

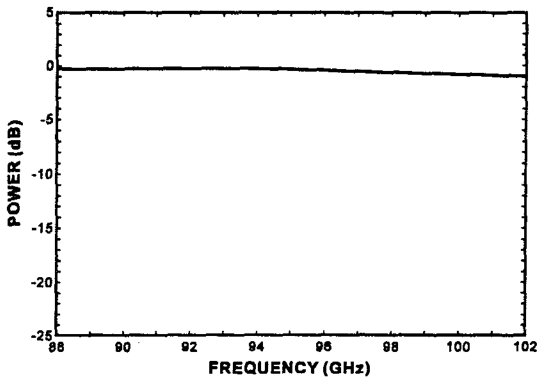

FIGURE 3b. Reflected Power Under No Bias Condition.

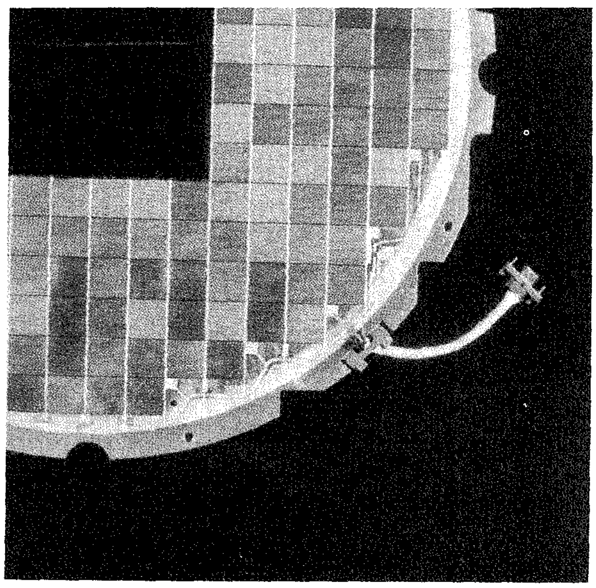

FIGURE 4. LSTR Tile Array Section.