DEVELOPMENTS IN TWO DIMENSIONAL ARRAYS

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Abstract

A two dimensional array of individual millimeter wave antennas with detectors will be described. The array is placed on a substrate lens [1] in the focal plane of a primary lens to form an imaging system (Fig. 1.). Calculations which predict ideal efficiencies of over 90% will be presented. Fabrication of the array and preliminary measurements will also be discussed.

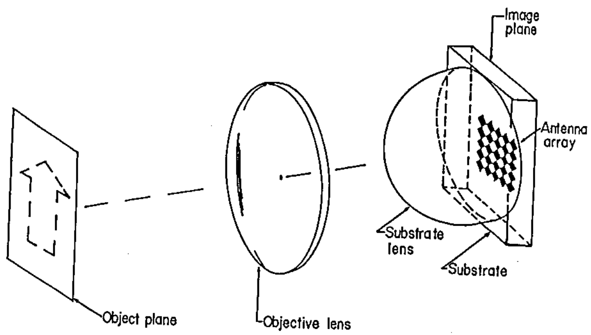

Figure 1. Imaging System.

Introduction

Millimeter wave antennas are becoming important in many scientific and military applications. In these applications there is a need for integrated detector arrays for use as high efficiency imaging systems [1]. Such a system might consist of a two dimensional array of squares (Fig. 2.) joined by bolometers, SIS detectors or Schottky diode detectors, mounted on a substrate lens. In this structure each unit cell looks like a 90^{o} bow tie.

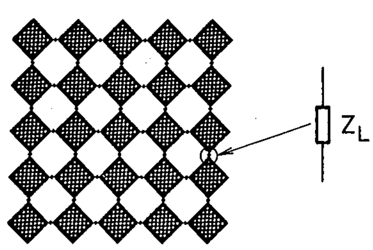

Figure 2. Two Dimensional Array.

Theory

In the design of an efficient array it is important to match the array impedance to the incident wave to get maximum power coupled into the detector. Analysis of the array is simplified by using an equivalent circuit. A plane wave incident on the antenna array is modeled by a traveling wave on a transmission line. The array is represented by a two port network in which one port is shunted across the transmission line and the second port is connected to the detector (Z_d). The impedance matrix $\underline{Z}$ for the two port is calculated by considering the properties of the mesh when the second port is open and closed. These scattering properties are calculated rigorously using the method of moments. The short circuit case consists of a periodic array of square holes in which the aperture field may be expanded in terms of TE/TM waveguide modes. Similarly the open circuit case may be analyzed as an array of metal squares whose currents may be described by modes that are dual to the waveguide modes. The solutions are checked using Conservation of Energy, Reciprocity and Babinet's principle. For the free space array the open and short circuit impedances are related by Babinet's principle. Reciprocity requires that the impedance matrix $\underline{Z}$ be symmetrical. Once the impedance matrix of the array is obtained the absorption efficiency for any given detector impedance may be calculated.

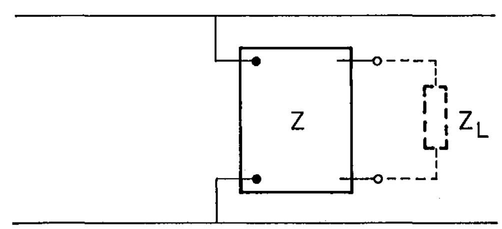

Figure 3. Equivalent Circuit.

The impedance matrix $\underline{Z}$ was calculated for the array sitting on an dielectric substrate with refractive index n. At long wavelengths the two port was found to be equivalent to a transmission line with characteristic impedance equal to the impedance of a bow tie antenna. The

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coupling efficiency is defined as the power absorbed by the detectors divided by the incident power. For radiation incident normally from the dielectric side it can be shown that the maximum efficiency occurs when the impedance looking in at port 1 is purely real and given by 377/(n+1)Ω. For this impedance the efficiency is n/(n+1). For the bow tie array (Fig 1.) the electrical length of the two port is small so the input impedance becomes very nearly equal to Z_d. This predicts that for bolometers with resistance close to the optimal value very high efficiencies should be obtainable (78% for n=3.5).

Fabrication

Several arrays with a period of 44 mils have been built for operation at 94GHz. They are fabricated on a quartz substrate 1/16 inches thick using conventional lithography and liftoff. The square patches are evaporated silver 1000Å thick. The detectors used are bolometers. They are fabricated by making a photoresist bridge at each corner of the square and then evaporating bismuth at an angle on each side of the bridge. The final bismuth thickness was 1000Å and the DC resistance of the bolometers was in the range 100-130Ω.

Measurement

The array was in placed in front of a 94GHz source and the bolometers were biased with a constant current supply. The A voltage across the array is then proportional to the power absorbed by the array. By placing a movable mirror behind the array a tuning curve of power absorbed versus mirror position may be measured. These measurements were compared with the equivalent two port theory (Fig. 4.).

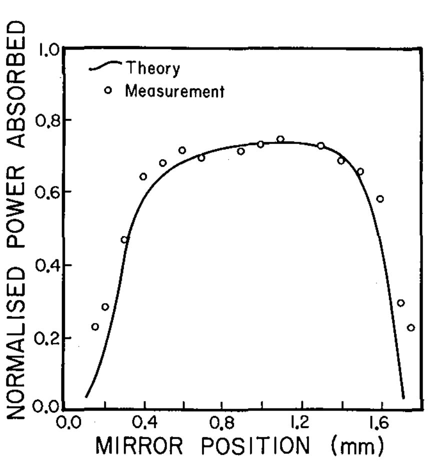

Figure 4. Power absorbed for an array on a quartz substrate.

Imaging Array

By placing the array in the focal plane of an optical system [3] very high efficiencies for the bow tie array can be obtained. In Figure 5 contours of normalized power absorbed for an array on a substrate with n=3.5 are calculated. In these calculations the array is characterized by a uniform sheet resistance and reactance. This impedance depends on the impedance of the detectors and the array geometry. The incident field is decomposed into an angular spectrum and the equivalent mesh impedance is assumed constant for small angles of incidence. The calculations predict very high coupling efficiencies. In future work the imaging properties of the array will be explored by measuring individual signals from each detector.

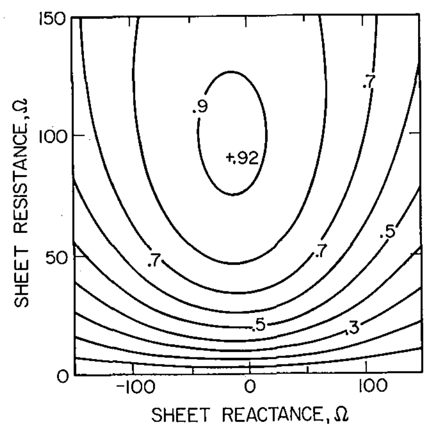

Figure 5. Theoretical Efficiency for Imaging Array.

Acknowledgments

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References

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3. Chung-en Zah, Richard C. Compton and David B. Rutledge, 'Efficiencies of Elementary Integrated-Circuit Feed Antennas', in **Electromagnetics** 3 pp 239-254, 1983.