Two-Dimensional Horn Imaging Arrays

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ABSTRACT

A two-dimensional horn imaging array has been demonstrated at 242 GHz. In this configuration, a dipole is suspended in a pyramidal horn on a 1-μm silicon-oxynitride membrane. This approach leaves room for low-frequency lines and processing electronics. Pattern measurements agree well with theory, and show no sidelobes and 3-dB beamwidth of 35° and 46° for the E and H planes respectively. Possible application areas include superconducting tunnel-junction receivers for radio astronomy and imaging arrays for plasma diagnostics and radiometry.

INTRODUCTION

Wideband log-periodic antennas and imaging arrays have been integrated on membranes for millimeter and submillimeter wavelengths applications [1]. However, these imaging arrays were limited to one dimensional designs. This is due to the fact that focal plane antennas needed to be as large as the spot size of the imaging optics to attain good coupling efficiencies, thus limiting the available area for supporting electronics. We have solved this problem by fabricating a two-dimensional horn imaging antenna arrays, with a dipole suspended on a membrane inside the pyramidal horn (Fig. 1). The membrane is so thin compared to a wavelength that the dipole effectively radiates in free space inside the horn. This configuration results in plenty of room for processing electronics and does not suffer from dielectric losses. It should also be possible to scale the design for different wavelengths.

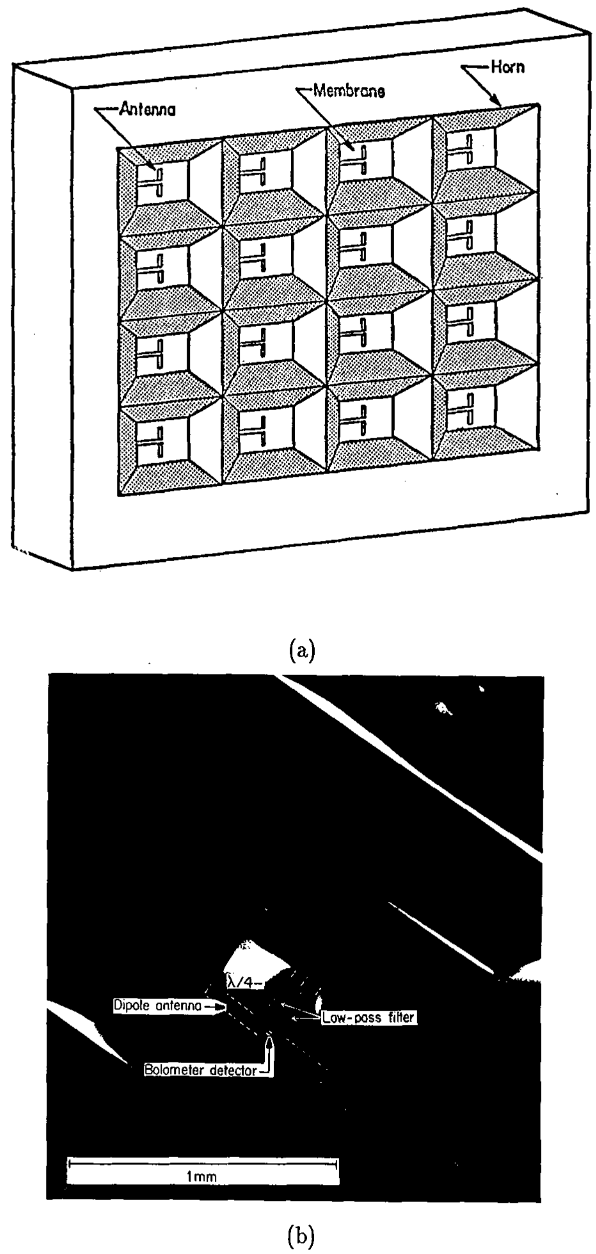

Figure 1. (a) Perspective view of a two-dimensional horn imaging array. (b) SEM photograph of a single horn.

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THEORY

The theoretical pattern is calculated for an infinite two-dimensional array of horns. In this method, the horn is approximated by a structure of multiple rectangular waveguide sections, and the fields in each section are given by a linear combination of waveguide modes. The fields in air are given by two-dimensional Floquet modes. The boundary condition are matched at each of the waveguide discontinuities, and at the aperture of the horn [2]. The pattern is found by reciprocity, by calculating the received fields at the position of an infinitesimal dipole inside the horn, for waves at different incident angles.

FABRICATION

The antenna is a stacked silicon-wafer structure. The back wafer acts as a reflecting cavity, while the front wafer acts as the mouth of the horn. Both wafers are patterned and etched in an ethylenediamine-pyrocatecol solution [3]. The etching process is anisotropic, and forms pyramidal cavities bounded by the <111> crystal planes. These make an angle of 54.7° with the <100> surface plane. The etching is stopped when a closed pyramidal cavity is formed, or in the case of the front wafer, when a transparent membrane appears. The antenna and detector are litographically defined on the membrane. The opening on the front wafer defines the aperture size of the horn, while the thickness determines the position of the antenna inside the horn. The opening on the back wafer is made equal to the membrane size, to result in a horn with smooth walls. The wafers are finally aligned and glued.

MEASUREMENTS

The patterns were measured at 242 GHz, on three single elements in a 9×9 imaging array with a horn aperture of 1.45λ and a membrane dimension of 0.54λ. The patterns are very similar, and agree well with theory (Fig. 2). The measured cross-polarization ratio was 26 dB and was noise limited.

ACKNOWLEDGEMENTS

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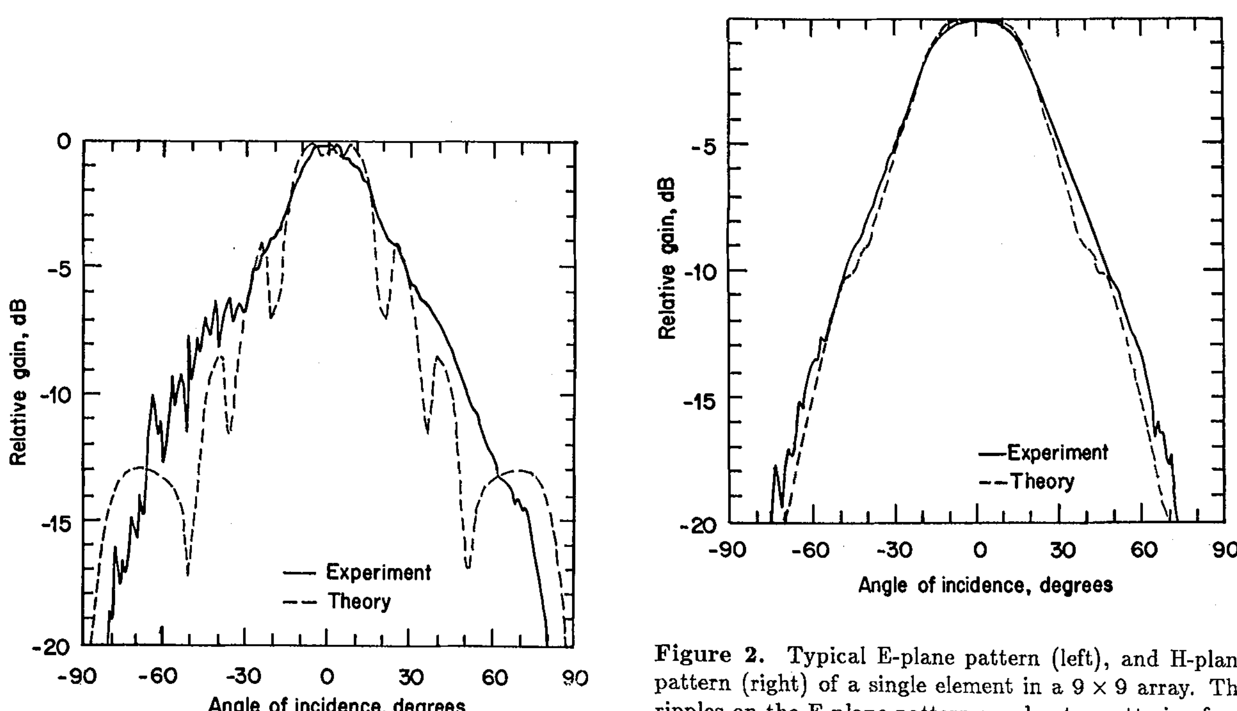

Figure 2. Typical E-plane pattern (left), and H-plane pattern (right) of a single element in a 9×9 array. The ripples on the E-plane pattern are due to scattering from the antenna mount.