A MICROSTRIP-BASED QUASI-OPTICAL POLARIZATION ROTATOR ARRAY

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ABSTRACT

A low-loss quasi-optical Ka-band polarization rotator array with 18% bandwidth has been designed and tested. Each cell of the array consists of a pair of input probe antennas connected via microstrip lines to orthogonally oriented output probe antennas. The design shows promise for use as an active array, as multistage MMIC amplifiers can be inserted in a straightforward manner into each cell.

INTRODUCTION

Millimeter wave quasi-optical/beam-waveguide systems have the advantage of offering very low loss over extremely broad bandwidths [1]. Recently, researchers have demonstrated active components such as amplifiers, frequency multipliers, and switches for insertion into the beams of these systems [2-8]. In these designs, the limited power handling capabilities of semiconductor active devices at millimeter wave frequencies are overcome by distributing the incident power across an array of devices. In quasi-optical amplifier designs, the outputs from the arrays are often cross-polarized with respect to the inputs to provide input-output isolation. In this paper results are presented for a quasi-optical component which, when inserted into a beam-waveguide system, effectively couples the beam power into and out from a 2-D array of microstrip-based cells and rotates the polarization of the incident beam to produce a cross-polarized output.

ARRAY DESIGN

The array design, which is pictured in Figure 1a, evolved from earlier work published by the authors for a design of a quasi-optical amplifier array unit cell [9]. But unlike this earlier work which required square waveguide inputs/outputs, the current design is planar. As shown in Figure 1a, the array utilizes an inductive mesh (a square metal grid) on one side of a substrate. The microstrip lines and probe antennas are patterned on the opposite side of the substrate from the mesh, allowing the mesh to serve as the ground plane for the microstrip lines. The grid period was chosen to get optimal coupling through the array at the frequency of operation.

As vertically polarized incident waves strike the mesh, electric fields are excited in the mesh apertures. These aperture fields, which are in large part similar to the TE_{10} waveguide fields of a square waveguide, are coupled into $50\,\Omega$ microstrip lines through the use of vertically oriented probe antennas. The microstrip lines pass through three 90° bends and then feed the orthogonally oriented output probe antennas. These probe antennas are similar to those used in waveguide-to-coax transitions. In such transitions, a probe antenna is positioned at an electric field maximum, approxi-

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mately $\lambda/4$ from a short circuit, to maximize coupling from the TE_{10} mode into the coax. In the case of this design, wire grid polarizers are used on either side of the array at a short distance from the probe antennas to act as the short circuits and maximize the coupling (see Figure 1b).

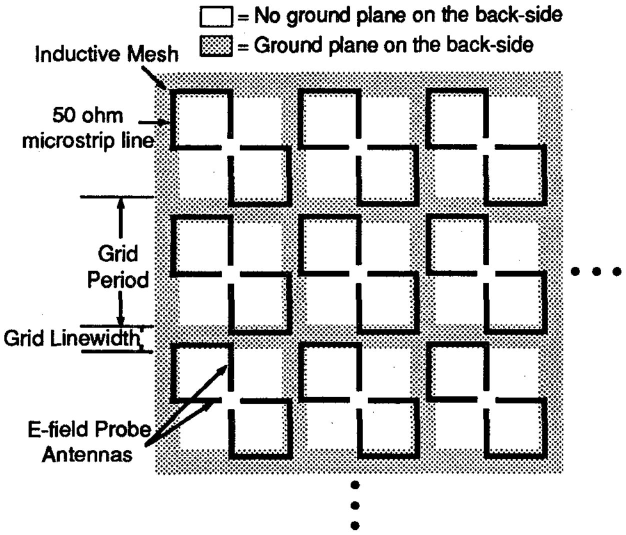

Figure 1a: Rotator array design. The substrate is 5 mil thick duroid of dielectric constant 10.8. The grid period is 2100 microns, the grid linewidth is 420 microns, and the microstrip width is 100 microns. Each probe antenna is 100 microns wide and 690 microns long.

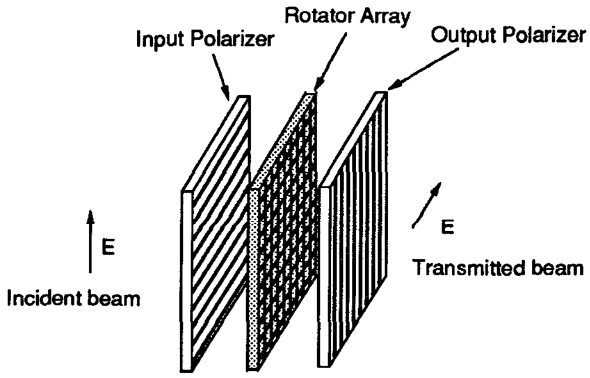

Figure 1b: Rotator array with polarizers.

The array was fabricated on a 3 inch square copper-clad piece of high dielectric constant ($\epsilon_r = 10.8$, thickness = 5 mil) RT/Duroid substrate. This high dielectric constant material was chosen for compatibility with eventual GaAs implementation. The microstrip aspect of the array allows the design to be used in future monolithic active arrays. For example, a monolithic GaAs amplifier array can be made by placing a matched multi-stage MMIC amplifier into each microstrip path.

MEASUREMENTS

The rotator array was tested using a Ka-band focused Gaussian beam test set-up as shown in Figure 2. The Gaussian beam is produced by a pyramidal Ka-band horn antenna (this horn antenna has a calculated 88% Gaussian coupling efficiency with a Gaussian beam radius of 15.3 mm at the horn aperture). The first lens focuses this diverging Gaussian beam down to a beam-waist. Upon reaching the beam-waist, the beam starts diverging again until it meets the second lens where it is re-focused into the second pyramidal Ka-band horn antenna. In this set-up the beam-waist location is used as the measurement plane because at this location the beam has a constant phase front and a minimum beam radius.

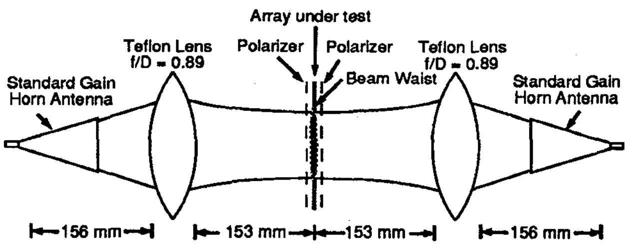

Figure 2: The focused beam test set-up used to make measurements over the band 26.5 to 40 GHz.

The lenses in this set-up are Teflon bi-convex hyperboloidal surfaces. The hyperboloidal surfaces are necessary to prevent spherical aberrations. Teflon was chosen because of its low loss tangent and its low dielectric constant ($\epsilon_r = 2.06$). The lenses each have a diameter of 3.75 inches and a focal length of 85.15 mm. In the current set-up, the spacing between each horn and lens is equal to 156 mm, and this leads to a beam-waist of measured radius 15 mm at a location 153 mm from the center of each lens. This beam-waist radius ensures that a 3 inch diameter array will receive greater than 99.9% of the incident beam. Three dimensional scans across the system were performed to confirm Gaussian beam operation.

To measure the array, the test set-up was first calibrated to the measurement plane by connecting the input and output horn antennas to ports 1 and 2 respectively of a network analyzer, and then performing a two-port LRM (line-reflect-match) calibration. In doing this calibration, a straight sheet of metal was inserted at the measurement plane to act as the reflect standard, and then the sheet was rotated 45° (so that all the incident power was reflected away) to act as the match standard. A dielectric slab was used as a verification standard to check the calibration. After calibration the rotator array was measured by inserting the array and polarizers at the measurement plane and rotating the output horn by 90°. The results of this measurement are shown in Figure 3. The origin of the ripples in this data is not well understood.

As can be seen the array has good rotation over a 3-dB bandwidth of approximately 18%. The array has a peak insertion loss of approximately 1 dB and has a reflection loss of less than 10 dB over most of its pass-band. This bandwidth is comparable to that attained with quasi-optical ferrite rotators at this frequency band [10]. In addition, this rotator array is tunable over most of the band by translating the position of the polarizers.

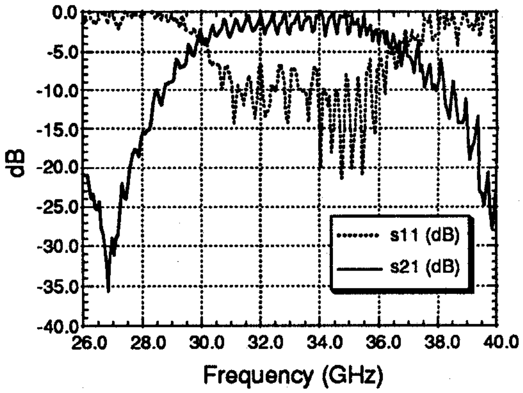

Figure 3: Transmission and reflection characteristics for the rotator array of Figure 1.

CONCLUSIONS

A Ka-band quasi-optical polarization rotator array with 18% bandwidth has been designed. The design has the advantage of being compatible with monolithic fabrication technology. In addition, because the design is microstrip-based, active elements can be inserted into the array.

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