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A BI-DIRECTIONAL ACTIVE LENS ANTENNA ARRAY

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I. Introduction

IN THIS PAPER we present a passive and an active 2-D lens antenna array fed from a focal point in the near field, eliminating a corporate feed structure at the plane of the array. The active circuits in each element of the active array perform transmit and receive functions. In transmission, a source illuminates the array from a focal point [1], and in reception the signal is received at the same focal point [2]. Used as a front end in a communication system, the array can reduce the effects of multipath fading. A lens array can also add angular diversity to a receiver [3], by placing several receivers along the focal surface. In transmission, the array offers increased ERP. Because the noise in each element is uncorrelated and the power is combined in free-space, the array offers increased dynamic range in reception. Here we present 10-element passive and active lens amplifier arrays designed for *X*-band and operating in both transmitting and receiving modes.

II. Design of passive and active lens array

A passive array consisting of 24 elements in a triangular lattice, Fig. 1, was designed and fabricated on a 0.507-mm-thick $\epsilon_r = 2.2$ Duroid substrate. Orthogonally polarized antiresonant slot antennas are used at input and output. The input and output antennas are connected by microstrip lines of different lengths to provide focusing. The delay line lengths are calculated using the equation for a one degree of freedom lens [4]. The focal distance is 27.5 cm for this design.

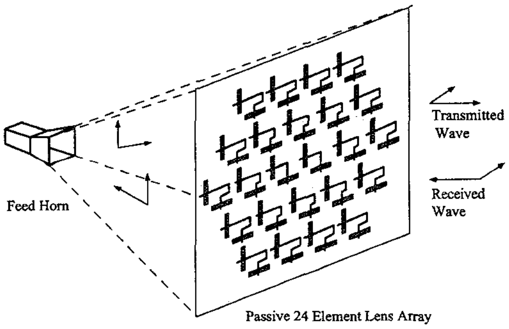

Fig. 1. A 24 element passive lens array consisting of orthogonally polarized slot antennas connected by lensing delay lines. Only the center 10 elements are connected.

Anti-resonant slot antennas were chosen for their relatively wide bandwidth and ease of fabrication with microstrip feed lines. The slots are 2.5 cm long and 2 mm wide for a 65 Ω input impedance at 10 GHz. Both the characteristic impedance of the microstrip lines and the antenna input impedance are 65 Ω to avoid additional matching sections

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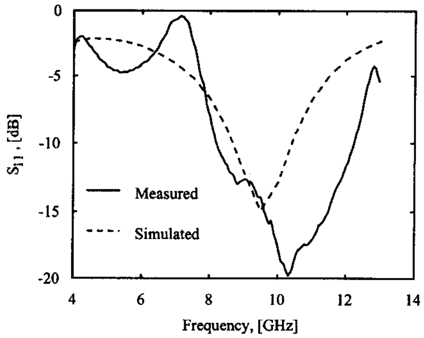


Fig. 2. Measured (–) and simulated (- -) return loss of a single slot antenna. The simulations were performed with the CAD package *Ensemble.*

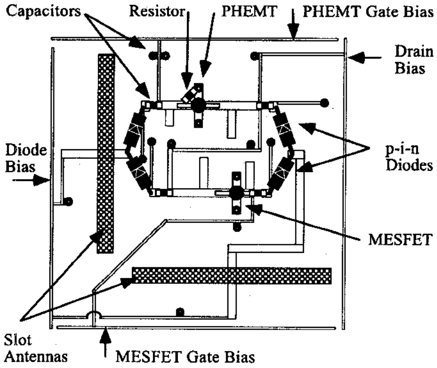


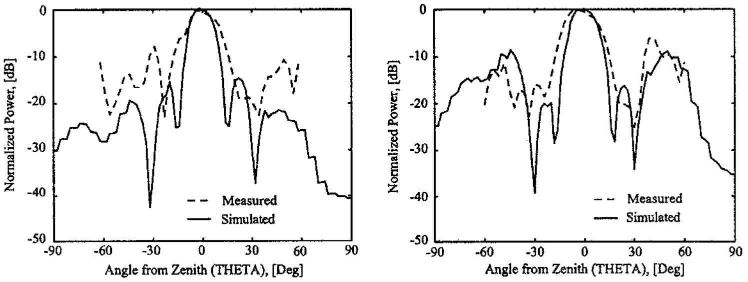
Fig. 3. A bi-directional quasi-optical array amplifier element. The slot antennas are 2.5 cm long and 2 mm wide, and the unit cell dimensions are 3.5 by 3.7 cm [5].

for the antennas. The measured and simulated return loss for a slot antenna is shown in Fig. 2. The simulations were performed with the CAD package *Ensemble.*

In the active array, transmit and receive amplifiers are connected between the two slots in each of the center 10 elements as shown in Fig. 3. The element dimensions are 3.5x3.7 cm. Two SPDT switches are used to switch between a general purpose MESFET amplifier stage for transmit mode and a PHEMT amplifier stage for receive mode. Both amplifiers are matched for gain. The measured gain for the transmit and receive amplifiers are 7 and 8 dB, respectively [5]. The DC bias for the *p-i-n* diodes in each switch are supplied through the slot antenna feed-lines.

III. EXPERIMENTAL RESULTS

A horizontally polarized horn located in the far field of the array, provides an incident plane wave to the passive lens array located at the plane of an absorbing apperture. The plane wave is received by the horizontally polarized slots and reradiated from the



(a)

(b)

Fig. 4. (a) Measured (–) and simulated (- -) E-plane radiation pattern for the receive amplifier at 9.4 GHz. (b) Measured (–) and simulated (- -) H-plane radiation pattern for the receive amplifier at 9.45 GHz. The theotetical patterns were calculated using the measured antenna pattern of a single slot antenna.

vertically polarized slots towards a vertically polarized horn located at the focal distance. Two polarizers are inserted at a half wavelength on each side of the array to improve the gain. The passive lens antenna array, has a loss of about 10 dB at 10 GHz relative to a through measurement. To overcome this loss, the active antenna array was designed. In receive mode, a maximum power gain of about 10 dB relative to the passive array is measured at 9.4 GHz. In transmit mode, the measured power gain is about 5 dB at 10.2 GHz. A description of the active circuits and details on the gain measurements are given in [5]. The E-plane and H-plane radiation patterns are measured at 9.4 GHz in receive mode as shown in Fig. 4 a) and b). The theoretical patterns were calculated using the measured antenna pattern of a single slot antenna. The active lens amplifier has a measured 3 dB-beamwidth of about 20 degrees in both planes.

In wireless communication systems multipath fading can lead to a dramatic increase in bit error rates [6]. A measurement is performed to show how a lens amplifier array can reduce the effects of multipath fading. The experimental set-up is shown in Fig 5. A 45×30 cm metallic mirror located parallel to the optical axis in front of the array is translated in 3-mm steps from the axis. For each step, the mirror is rotated through a set of angles. The received power is measured for all mirror positions with and without the lens amplifier. The measured maximum fades of a 9.5 GHz carrier signal with and without the lens amplifier and normalized to the received signal without the mirror inserted are shown in Fig. 6 a) and b). Fading nulls of about -10 dB and more than -25 dB were measured with and without the lens amplifier, respectively. This simple measurement show that a lens amplifier can provide a significant improvement of multipath fading effects in addition to improved dynamic range and increased ERP.

IV. ACKNOWLEDGMENT

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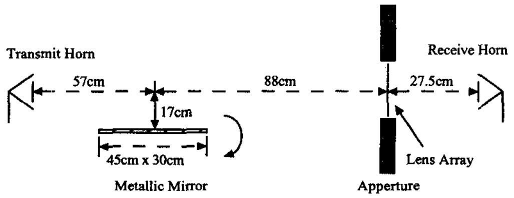

Fig. 5. Experimental set-up of the multipath experiment. A 45×30 cm metallic mirror located parallel to the optical axis of the lens in front of the lens amplifier is translated in 3 mm steps from the axis.

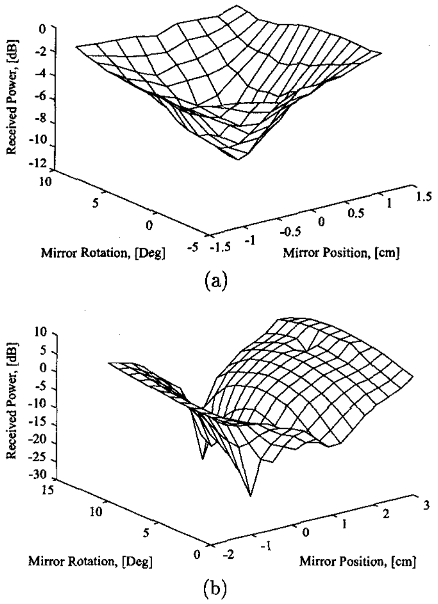

Fig. 6. Measured maximum multipath fading nulls of a 9.5 GHz carrier signal. The received power is normalized to a measurement without the mirror inserted. With (a) and without (b) the active lens array inserted. Note the different scales.

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