A 10-ELEMENT ACTIVE LENS AMPLIFIER ON A DIELECTRIC SLAB

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ABSTRACT

This paper presents an active lens amplifier on a dielectric slab. An amplifier gain of 11 dB at 8.25 GHz, measured from input to output connector, with a 3-dB bandwidth of 0.65 GHz has been demonstrated. Measurements of output power versus input power are also presented.

INTRODUCTION

Quasi-optical power combiners have the potential for efficient power combining of large numbers of solid-state devices. Most previous work has focused on three-dimensional approaches, such as the wave beam type [1], grid type [2], microstrip coupling type [3], and lens type [4]. A quasi-optical structure based on the dielectric slab-beam waveguide (DSBW) [5] is two-dimensional and therefore more amenable to planar fabrication technologies. An oscillator [6] and two amplifiers [7], [8] based on the DSBW have been reported. These structures excited an electric field parallel to the slab ground plane. Such a mode has very low loss but is difficult to excite cleanly with no perturbation or scattering loss. Dielectric lenses were used to focus and constrain the quided waves. In this work, Yagi-Uda slot antenna arrays, fed by microstrip lines, are used to efficiently excite the dominant DSBW mode with the electric field normal to the slab ground plane. Microstrip delay lines are used to focus the quided waves in a manner similar to that reported in [4]. Delay line length is analogous to thickness of a conventional dielectric lens. Commercial gain blocks are used to amplify the RF signals. Measurements of amplifier gain and output power versus input power are presented. At 8.25 GHz, an amplifier gain of 11 dB, measured from input to output connector, has been achieved. The amplifier 3-dB bandwidth is 0.65 GHz.

SLAB-BEAM LENS AMPLIFIER

The slab-beam lens amplifier is shown in fig. 1. Microstrip lines, and gain blocks are on the top side of a thin substrate on top of a thick dielectric slab. Microstrip fed Yagi-Uda slot antenna arrays on the common ground plane are used to either receive or transmit slab-beam modes. A feed element illuminates a 10-element slab-beam active lens which both amplifies and focuses the signal onto a collector element. Microstrip delay line lengths are such that the total phase delay from feed to collector element is identical for each lens element. The dielectric slab and thin substrate on top of it are RT/Duroid 6010 (ε_r = 10.2, tanδ = 0.002). Hewlett Packard MGA-64135 GaAs MMIC amplifiers are used as the cascadable gain blocks shown in fig. 1. Two gain blocks cascaded together produce 18 dB of gain at 8.25 GHz.

Directive excitation of the DSBW was achieved with a microstrip fed Yagi-Uda slot array with one reflector and one director. The slots were etched in a common ground plane separating the DSBW and microstrip substrates. Truly planar excitation, compatible with planar fabrication technology, of the DSBW has been achieved. Coupling into the DSBW substrate was maximized by choosing the thickness to be such that the center operating frequency corresponds to 90% of the cutoff frequency of the second order TM mode; slot excitation of the first order TE mode is negligible. Initial dimensions for the Yagi-Uda slot array antenna were selected using guidelines available in the literature [9]. Experimental optimization of the antenna dimensions resulted in a design with a SWR<2.0 and front-to-back ratio greater than 10 dB over a 5% bandwidth.

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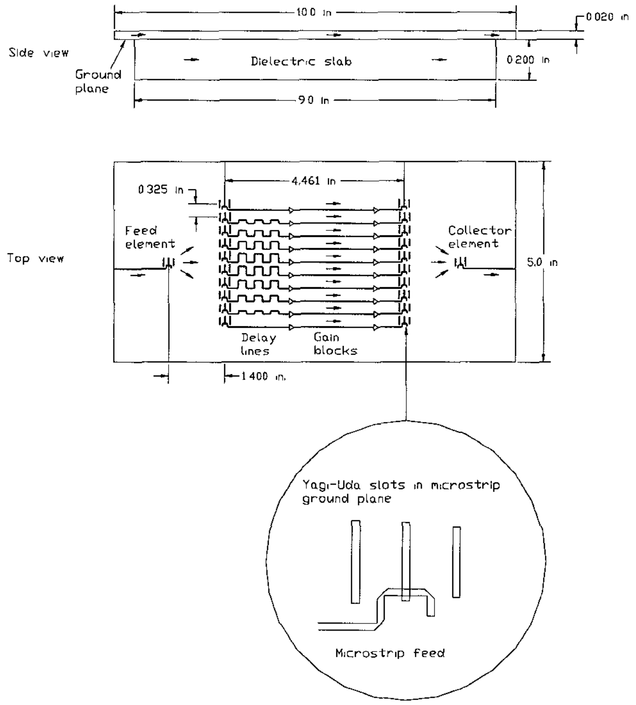

Fig. 1. Slab-beam lens amplifier. Gain blocks and microstrip lines are on top side of thin substrate on top of dielectric slab. Yagi-Uda slot arrays are on the common ground plane.

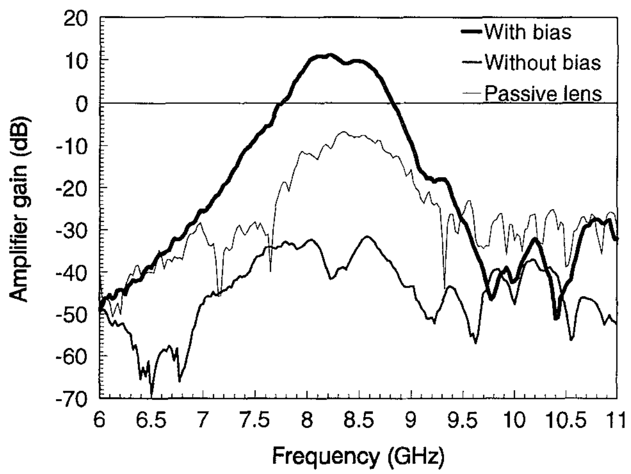

Fig. 2 Slab-beam lens amplifier gain versus frequency. The peak is 11 dB at 8.25 GHz. The 3-dB gain bandwidth is 0.65 GHz. Insertion loss of a passive lens is included for reference.

EXPERIMENTAL RESULTS AND DISCUSSION

Gain of the slab-beam lens amplifier was measured from the feed element microstrip line to the collector element microstrip line. Microstrip-to-coaxial SMA connectors were used to interface with a network analyzer. Measured peak gain was 11 dB at 8.25 GHz with a 3-dB bandwidth of 0.65 GHz (fig. 2). With no bias, the gain dropped below -30 dB over the entire frequency range measured. Peak response of a passive lens was -6.7 dB. The passive lens has through lines instead of gain blocks. Difference in peak response between the active lens and passive lens is 17.7 dB, close to the 18 dB gain of two cascaded gain blocks. Gain of the slab-beam lens amplifier closely matches the Yagi-Uda slot array return loss response (fig. 3). Output power at 8.25 GHz plotted against input power is shown in fig. 4. Output power at 1 dB gain compression is 16 dBm.

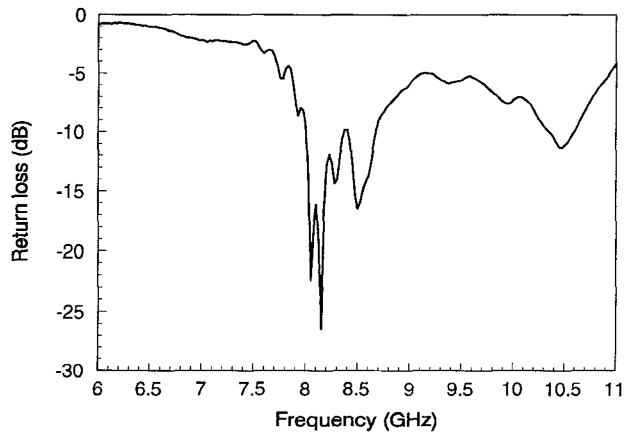

Fig. 3. Yagi-Uda slot array input return loss versus frequency. Return loss is better than -10 dB over a 0.68 GHz bandwidth centered at 8.3 GHz. The antenna element pass-band matches that of the slab-beam lens amplifier (Fig. 2.).

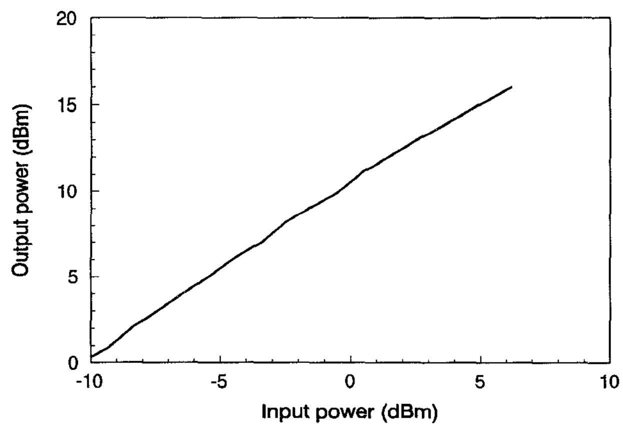

Fig. 4 Output power at 8.25 GHz plotted against input power. Output power at 1 dB gain compression is 16 dBm.

A loss budget for the passive lens is presented in table 1. Direct measurement or calculation of each of the deduced losses in table 1 is difficult. Slots spaced end to end should not couple strongly. Radiation from both the passive and active lenses is estimated to be low based on the fact that the measured results were not affected by the presence of objects placed in proximity to the circuits. Therefore, the lens spillover losses are estimated to be 1.6 dB. The one-way spillover loss is 0.8 dB. A waveguide to DBSW transition should have very low losses. If waveguide transitions were used to collect the lens output power the combining efficiency would be 68%. This combining efficiency corresponds to the one-way spillover loss plus the loss due to a single Yagi-Uda antenna.

Recall that the slab-beam lens output power at 8.25 GHz was 16 dBm at 1 dB gain compression. To compute the power output by the ten output gain blocks, we should add the one-way spillover loss, loss due to two Yagi-Uda antennas, and loss due to the 1.4 in. long microstrip line feeding the collector element. Therefore, the output gain blocks are producing 18.8 dBm. Typical output power of the Hewlett Packard MGA-64135 gain blocks is quoted as 12 dBm at 1 dB gain compression. Ten of these amplifiers should yield 22 dBm. Amplitude taper on the lens causes the power to be lower. Elements in the lens center put out more power than those on the edges.

Table 1. Passive lens losses.

Total measured loss (minimum)	6.7 dB
Yagi-Uda slot array antenna losses (measured) Input return loss = 10 dB Mismatch loss = 0.46 dB Front-to-back ratio = 10 dB Back lobe loss = 0.41 dB Total antenna element loss 4(0.46 + 0.41) = 3.5 dB	-3.5 dB
Microstrip line losses (0.2 dB/in) (measured)	-1.6 dB
Deduced losses (spillover, radiation, and mutual coupling)	1.6 dB

CONCLUSION

A two-dimensional slab-beam lens amplifier has been developed for efficient quasi-optical power combining of large numbers of solid-state devices. An uncommonly high peak system gain of 11 dB at 8.25 GHz has been demonstrated. The amplifier 3-dB bandwidth is 0.65 GHz or 7.9%. Fabrication of the slab-beam lens amplifier is compatible with planar fabrication techniques.

ACKNOWLEDGMENT

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