A Slab-Based Quasi-Optical Power Combining System

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Abstract A slab-based quasi-optical power combining system with convex and concave lenses is investigated. Experimental results imply that a concave-lens system has less scattering loss and higher system gains than a concave-lens system. An amplifier gain of 15 dB and a system gain of 8 dB were achieved.

1. Introduction

Many types of quasi-optical power combining systems have been investigated. A type which is particularly compatible with MMIC technology and planar fabrication is the quasi-optical slab power combiner [1, 2]. Developments of this system are presented here.

In this paper, both convex-lens and concave-lens quasi-optical slab waveguide systems, shown in Fig. 1, were investigated. The experimental results included scattering loss of lenses, amplifier gain, and passive and active system gains, and showed that the concave-lens system has lower scattering loss and higher system gains. Input power versus output power was also measured, and showed the output power entered saturation as input power was higher than −15 dBm. All the measured data implies that a concave-lens system is more suitable for MMIC as the problem of having dissimilar materials is mitigated.

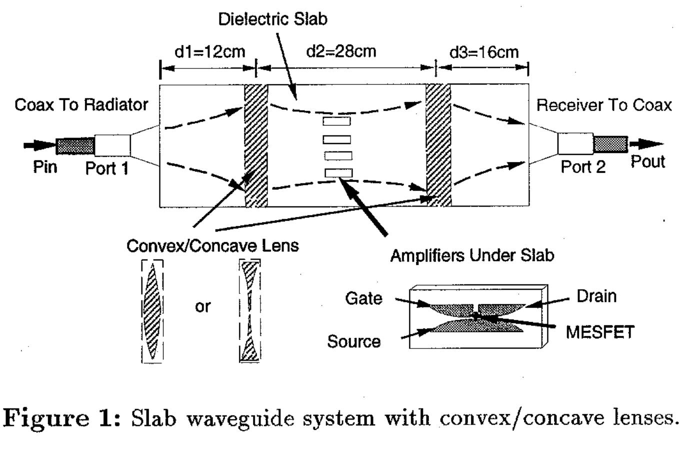

Figure 1: Slab waveguide system with convex/concave lenses.

2. System Description

The complete slab waveguide with convex/concave lenses shown in Fig. 1 consisted of a 4 × 1 MESFET amplifier array built underneath and between the two lenses. The energy radiated from the input port travels in a quasi-optical TE Gaussian mode along the slab waveguide where the lenses are used to focus the waves for optimal field distributions on the amplifier elements. To investigate the effect of reducing scattering on loss, a metallic top was placed over the system. The amplifier unit was derived from the active notch antenna by Leverich [3] and was described in [2]. The slab waveguide was Rexolite ($\epsilon_r = 2.57$, $\tan\delta = 0.0006$) and was 27.94 cm wide, 62 cm long, and 1.27 cm thick. The convex lenses were Macor ($\epsilon_r = 5.9$, $\tan\delta = 0.0006$), and the focal length is 28.54 cm. The concave lenses were just air, and the focal length is 40.4 cm.

3. Experimental Results and Discussions

The passive system gains were measured on the slab system with no amplifiers present, and is shown in Fig. 2. This measured data shows that the concave-lens system has 4 dB to 6 dB lower loss than the convex-lens system. The E-field patterns across the slab measured at 7.28 GHz is shown in Fig. 3. By integrating the area under the E-field curves in Fig. 3, we estimate the scattering loss is about -3.66 dB for a convex lens, and -1.18 dB for a concave lens. Fig. 2 and 3 reveal that the concave-lens slab system has less scattering loss and will be more appropriate for MMIC.

The amplifier gain, computed from the ratio between P_{out}(AMP ON) and P_{out}(AMP OFF), is shown in Fig. 4. This gain is about 16 dB and 14 dB respectively for the concave and convex cases. This implies that the amplified power is less scattered in the concave-lens system. The active system gain (defined as P_{in}/P_{out}) is shown in Fig. 5 for the convex and concave cases with and without a metallic top cover. The metallic cover is 12 cm wide and is located 1.6 cm above the system. For the concave case, the active system gain is about 7.7 dB with and without the cover. For the convex case, this gain is about 6 dB and 4 dB with and without the cover, respectively. The active system gain shows that using a metallic top cover can compensate more scattering loss for the convex case than for the concave case. The input and output powers, P_{in} and P_{out}, at 7.12 GHz for both cases without a metal top are shown in Fig. 6. The highest system gains at this frequency were about 2 dB and 4.5 dB for the convex and concave cases, repectively. This figure shows the 1:1 ratio between P_{out} and P_{in} as $P_{in} < -15$ dBm, and shows that P_{out} reached the saturation condition as $P_{in} > -15$ dBm.

4. Conclusion

Quasi-optical power combining using a 4×1 MESFET amplifier array in a slab waveguide with convex and concave lenses is achieved. The concave lens system has less scattering loss, higher amplifier and system gains than the concave lens system, and is more suitable for MMIC. To achieve higher active system gain, the input power should be limited under the saturation condition of the amplifier array.

References

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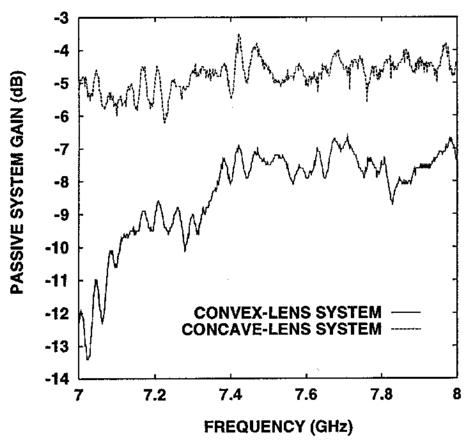

Figure 2: Passive system gains for the convex-lens and concave-lens systems.

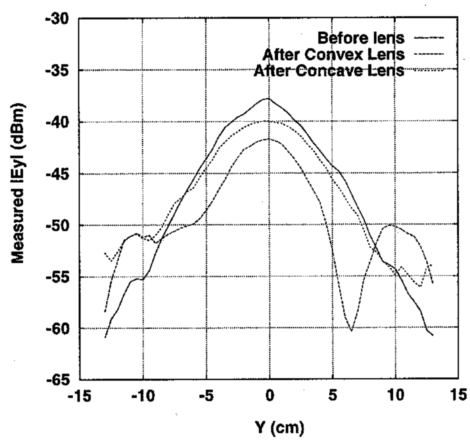

Figure 3: $|E_y|$ distributions across the slab before and after the lenses.

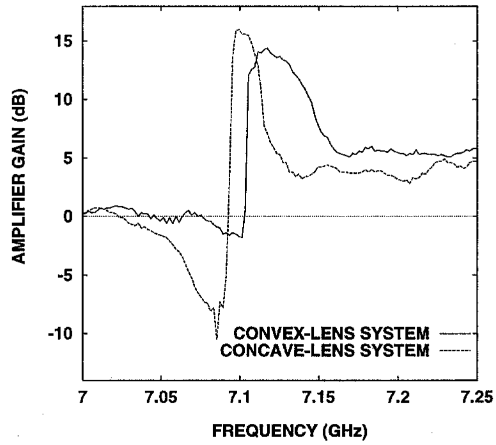

Figure 4: Small signal amplifier gains for the convex-lens and concave-lens systems.

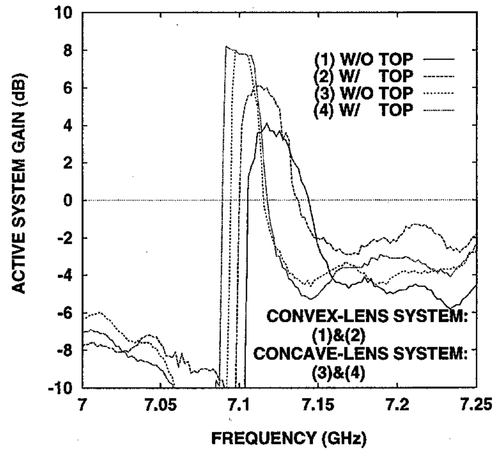

Figure 5: Active system gain for the convex-lens and concave-lens systems.

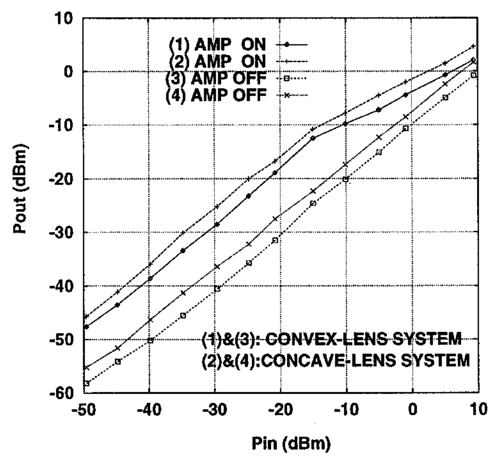

Figure 6: Input and output power of the convex/concave slab system without a metallic top.