A 100-Transistor Quadruple Grid Oscillator

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***Abstract*— A three-dimensional power combiner consisting of four oscillator grids stacked in parallel is presented. The 5-GHz quadruple grid oscillator delivers an effective radiated power 6.5 dB greater than that of a single grid, with a corresponding frequency shift of less than 5%. Comparisons are made between a single, double, and quadruple grid oscillator.**

I. Introduction

GRID POWER combiners consisting of an array of solid-state devices loading a two-dimensional printed grating have been demonstrated by a number of authors [1], [2]. Recently, the concept of free-space power combining was extended to three dimensions, in which two grids were stacked in parallel to achieve higher power levels [3]. The advantage of this approach is that the output power is distributed over several surfaces, which facilitates heat-sinking requirements and overcomes limitations on the power-handling capability of the individual device.

In this letter, we expand the technique of three-dimensional power combining by demonstrating a 5-GHz quadruple grid oscillator containing 100 transistors. Comparisons between a single, double, and quadruple grid oscillator are presented.

II. Design

The metallic pattern for a single grid was designed using the induced EMF method as described in [1]. The period of the grid is 8 mm with 1-mm-wide leads. The grids are printed on 2.5-mm-thick Rogers *Duroid* substrates with $\varepsilon_r = 10.8$ and separated by *Stycast HiK* dielectric slabs (Emerson and Cumming) with $\varepsilon_r = 10$ (Fig. 1). These spacers enhance the coupling between the grids, and the optimum thicknesses were determined experimentally. Although it is not yet understood, the highest output power was obtained when the outermost spacers were 25 mm thick and the innermost spacer was 13 mm thick. Conducting plates are placed on the top and bottom surfaces to enforce the TEM mode. These plates also provide mechanical support and have the potential to serve as convenient heat sinks. Twenty-five transistors (Hewlett-Packard ATF-35576 PHEMTs) are loaded on each grid, and all 100 devices are biased in parallel with a common power supply. The structure fits in a compact package measuring 8 cm (4/3 of the free-space wavelength) in all three dimensions.

Manuscript received June 10, 1994. This work was supported by the U.S. Army Research Office through an AASERT grant and by the National Science Foundation through the Research Experience for Undergraduates Program.

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IEEE Log Number 9405077.

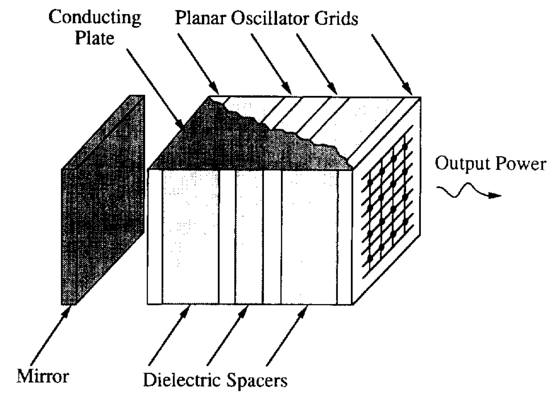


Fig. 1. A quadruple grid oscillator, consisting of four planar oscillator grids stacked in parallel separated by dielectric spacers. An external mirror provides passive cavity feedback, while the grids mutually injection-lock each other through active feedback.

III. Experimental Results

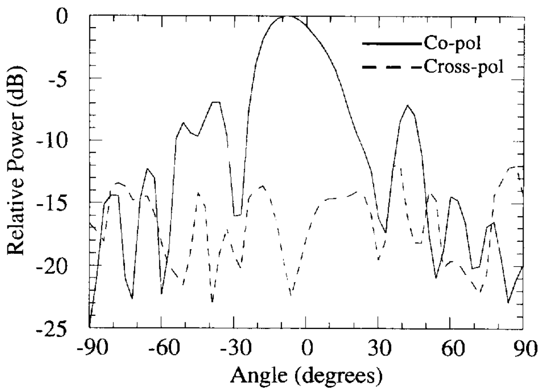
A single grid oscillates at 4.94 GHz, in close agreement with the design presented in [1]. In the quadruple grid configuration, the frequency shifts to 5.15 GHz, which is less than a 5% change.

Fig. 2 shows the far-field radiation pattern of the quadruple grid oscillator. Main lobes occur in the broadside direction, indicating that the grids lock to each other and that the unit cell boundary conditions [1] are preserved.

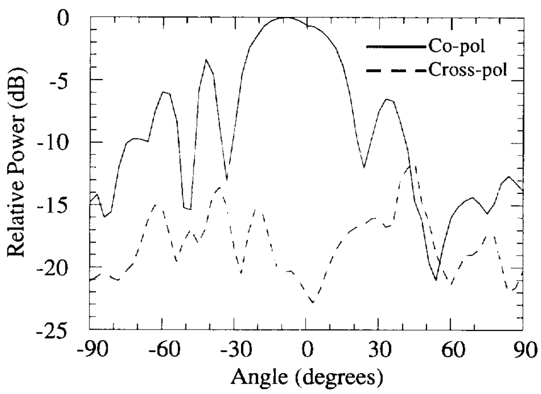
The quadruple grid oscillator demonstrates an effective radiated power of 8 W, which is 6.5 dB more than that of a single grid. The output power and dc-to-rf conversion efficiency were computed based on an estimate of the directivity from the half-power beamwidths of the two principal patterns. Admittedly, this approximation neglects the rather large sidelobes, so the directivity is overestimated while the output power and efficiency are underestimated. Fig. 3 indicates that a single grid delivers nearly 100 mW, while a quadruple grid delivers 265 mW. The total bias current increases by approximately the same factor in going from one to four grids, so the efficiency remains relatively constant.

Since the single, double, and quadruple combiners lock at approximately the same frequency and have similar patterns, a combining efficiency for multiple grid oscillators can be defined as

$$\eta_c = \frac{\textit{output power of an N-grid combiner}}{N \times \textit{output power of 1 grid}}.$$



(a)



(b)

Fig. 2. Measured far-field radiation patterns in the (a) H-plane and (b) E-plane. The estimated directivity is 14.8 dB.

As Fig. 4 shows, the combining efficiency gradually declines as the number of grids increases, due to ohmic, radiation, and substrate losses.

IV. CONCLUSION

A quadruple grid oscillator containing 100 transistors has been shown to deliver nearly three times more output power than a single grid at approximately the same frequency. Three-dimensional power combiners offer the advantage of higher power levels while simultaneously relaxing heat-sinking requirements and power-handling limitations since the power is distributed over several surfaces.

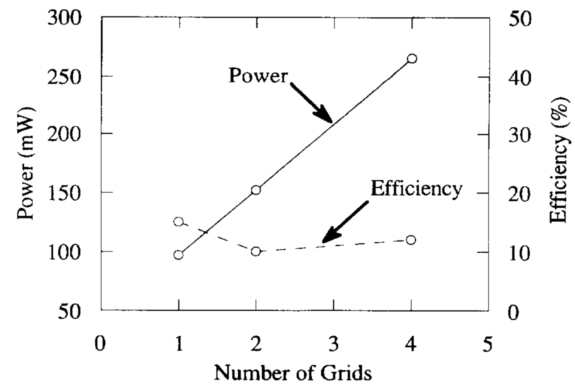


Fig. 3. Output power and dc-to-rf conversion efficiency for a multi-grid oscillator.

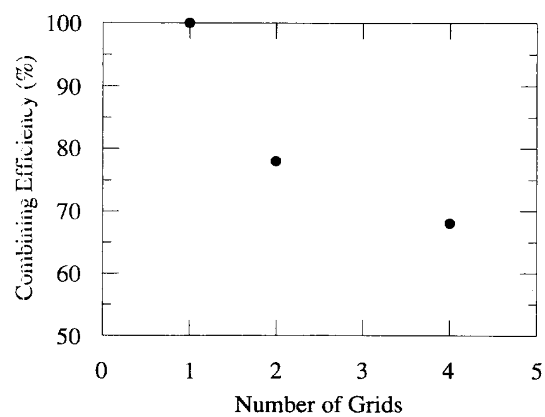


Fig. 4. Combining efficiency as a function of the number of grids.

ACKNOWLEDGMENT

The authors are grateful to Hewlett-Packard and Rogers Corporation for their generous equipment and substrate donations.

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