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An X-Band MESFET Grid Oscillator with Gate Feedback

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Abstract — **In this work we present a design for a quasi-optical MESFET power-combining array that utilizes gate feedback. This circuit is different from previous MESFET grids that utilized packaged devices and source feedback to produce an oscillator at 5 GHz. The present configuration allows the drain and source leads to couple directly to the radiated field. Simulations indicate that this configuration can be used to build a high-frequency oscillator. A transmission-line model for the grid is presented and used to design a 25-element grid for operation at 10 GHz. Measurements show that the grid delivers an effective radiated power (ERP) of 2.4 W at 10.9 GHz.**

Introduction

Power combining of solid-state devices using quasi-optical techniques has received much attention the past few years. Quasi-optical power-combining structures typically include a resonator cavity and a two- dimensional array in which active devices are embedded. The structure is reminiscent of a laser oscillator with the grid of active devices providing gain and the resonator cavity providing feedback. A variety of quasi-optical configurations have been explored including grids [1,2], patch antennas [3], and bow-tie arrays [4,5]. Effective radiated powers of over 20 W have been achieved with a 100-element MESFET grid operating at 5 GHz [2] and a 16-element Gunn diode patch array operating at 10 GHz [3]. The paper presented here describes a 25-element MESFET grid that utilizes chip-form transistors and is an extension of the earlier work by Popović, et. al. on transistor grid oscillators [2]. This planar design is suitable for monolithic integration and should provide an attractive means of obtaining high power from solid-state sources.

Theory

A diagram of the MESFET grid is shown in Figure 1. The MESFET lies in the center of a unit cell which is defined by the grid symmetry. The drain and source leads of the transistor lie vertically while the gate lead runs horizontally across the grid and is orthogonal to the radiated field. If the MESFET's are assumed to be identical, then a grid of infinite extent would consist of an array of unit cells with electric walls on the top and bottom and magnetic walls on each side.

Since the unit cell is a fraction of a wavelength across, the induced EMF method can be used to analyze this structure. Such an EMF analysis leads to the transmission-line

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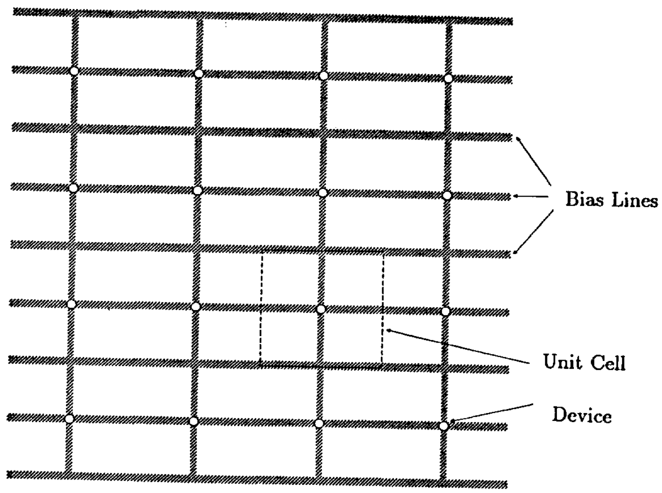
model in Figure 2. Radiation is represented by a 377 Ω transmission line. A center-tapped transformer describes the coupling of the drain and source currents to the radiation. The coupling of the currents to evanescent TM and TE modes are included in the model with reactive elements. Simulation of the grid is done by calculating the reflection coefficient the grid presents to a normally incident plane wave. The MESFET is included in the model as a two port network using its small signal s-parameters.



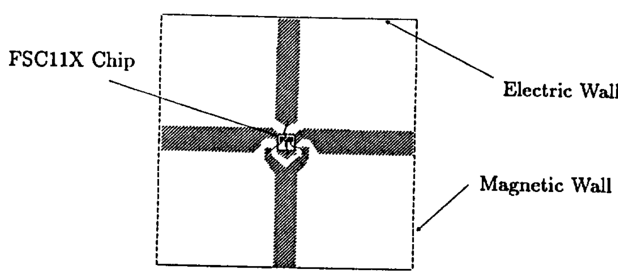


Figure 1. Schematic of the MESFET Grid oscillator. Boundary conditions at planes of symmetry reduce the grid to an equivalent waveguide as shown. Adjacent leads share bias lines. The solid lines represent electric walls and the dashed lines represent magnetic walls.

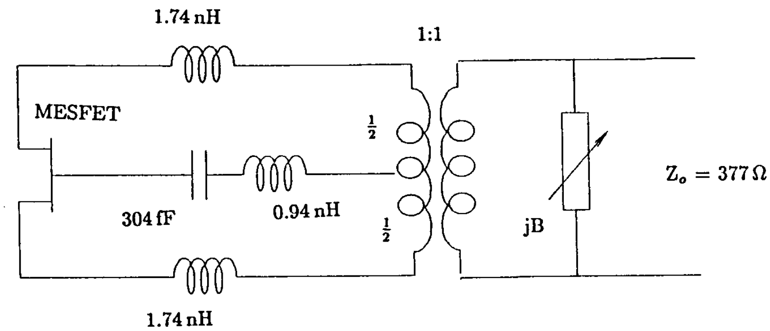


Figure 2. Transmission-line model for the MESFET grid. The values for the grid parameters are calculated from an EMF analysis on the unit cell.

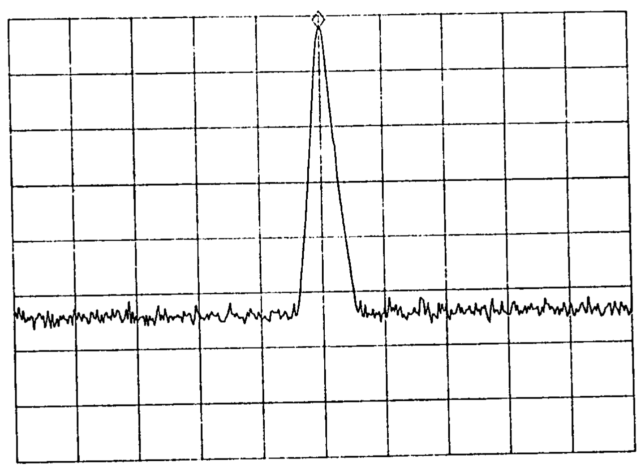


Figure 3. Measured spectrum of the grid showing an oscillation at 10.94 GHz. The horizontal scale is 10 MHz per division and the resolution bandwidth is 1 MHz. The vertical scale is 10 dB per division with the reference level being 5 dBm.

Design and Measurement

The devices used in the grid are Fujitsu FSC11X MESFET's which are chip-form transistors. The grid pattern was fabricated on a Duroid substrate having a dielectric constant of 2.2. The substrate is 2.54 mm thick and is placed 3 mm in front of a planar mirror. The unit cell is 9 mm × 9 mm and the bias lines are 1 mm across, running horizontally across the grid. Drain and source bias leads extend down from the bias lines and are tapered at the ends to reduce the edge capacitance. The MESFET's are soldered to the gate bias lead which serves as a heat sink. Gold bond wires are then used to make the electrical connections from the transistors to the bias leads.

Simulations using the transmission-line model indicate that the grid should oscillate near 10 GHz. Measurements performed on the grid showed that at a bias of $V_{DS} = 2.5$ V and $I_D = 1$ A, the devices locked to a single frequency at 10.9 GHz. The grid spectrum is shown in Figure 3. The effective radiated power of the grid was measured to be 2.4 W.

Conclusions

In this paper we have presented a 25-element planar grid for quasi-optical power combining. The grid oscillates at 10.9 GHz and is amenable to monolithic integration. In addition, the grid can be modelled with a relatively simple transmission-line circuit. By appropriate scaling and using modern IC fabrication technology, it should be possible to produce a grid which can produce significant power at millimeter-wave frequencies.

Acknowledgments

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