An Eight MESFET Periodic Spatial Power Combiner

Arul Balasubramaniyan, John Heinbockel and Amir Mortazawi

Department of Electrical and Computer Engineering
University of Central Florida, Orlando, FL 32816-2450

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ABSTRACT

An X-band eight MESFET two dimensional spatial periodic power combiner is designed and fabricated. This paper describes the theoretical analysis and experimental results obtained. The Effective Radiated Power of this combiner is 8.5 W at 9.73 GHz. This combiner is small, light weight, and suited for monolithic implementation.

INTRODUCTION

The necessity for high power microwave and millimeter wave solid state sources has led to extensive research into various power combining techniques [1]. Recently, a significant amount of research has been done on the use of two and three terminal devices in spatial power combining structures [2,3,4,5].

Design of a four MESFET one dimensional periodic spatial power combiner is described in [6]. A new periodic combiner is presented which doubles the density of devices achieved in earlier work. This paper presents an eight MESFET two dimensional periodic spatial power combiner designed at X-band. Results of large signal analysis of a unit cell containing two GaAs MESFETs are also presented here. The non-linear model for the MESFET used in the large signal analysis is based on Curtice's cubic model [7]. The variation of power and frequency with respect to bias variation are investigated. Other results include a comparison of theoretical and experimental radiation patterns. This combining circuit offers many advantages which include low cost, simplicity and good stability. Due to it's planar structure it is amenable to monolithic implementation and has applications in radar and communication systems.

THEORY AND DESIGN PROCEDURE

The first step in combiner design begins with the design of a single MESFET oscillator as shown in Fig. 1. The oscillator design employs the small signal S-parameters given by the manufacturer and is based on the negative resistance model. A short circuited series inductive stub is used as a feedback element at the source to generate negative resistance. An open ended line attached to the gate resonates the MESFET at the desired frequency. The microstrip patch antenna connected to the drain of the MESFET is designed using the transmission line model [8]. The negative resistance looking into the drain is matched to the radiation resistance of the antenna using a quarter wave transformer. In the next step two of these oscillators are connected together via their gates as shown in Fig. 2. These two oscillators constitute the basic single power combining "cell". Since both the oscillators in the cell are identical, they should oscillate at the design frequency without loading each other. This is verified by large signal analysis.

Using the measured I-V characteristics of the Avantek ATF26884 MESFET along with the S-parameters at a single bias point supplied by the manufacturer, an approximate non linear model based on Curtice's cubic model [7] is determined. Large signal analysis of the cell is performed by employing this model with the Microwave Spice™ program. Fig. 3 shows the build up of the oscillation from noise level. The voltages V(508) and V(608) at the drains of the MESFETs are shown in Fig. 4. It can be seen that the two oscillators are in phase and have the same amplitude. In this analysis 200 ohm resistors are placed at the output of each device to simulate the radiation resistance of the patch antennas. The power dissipated in each resistor is 15.35 dBm at a frequency of 10.438 GHz. Also no other mode of oscillation is excited.

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Fig. 5 shows a general power combining circuit in which several cells are loaded periodically via a transmission line with periodicity λ_g, the guide wavelength. Injection locking of the cells is accomplished via their interaction through this transmission line.

EXPERIMENT

As a first step a unit cell consisting of two MESFET oscillators (Fig. 2) was fabricated on a Duroid substrate with a dielectric constant of 2.33 and thickness of 31mils. In order to measure power generated, the output of each device is matched to a 50 ohm load using a quarter wave transformer. Avantek ATF26884 general purpose GaAs MESFETs were biased at 5.5 V with a nominal drain current of 30 mA. The measured output from each device is 15.73 dBm at a frequency of 10.11 GHz which is close to the results obtained by large signal analysis of the unit cell. No other mode of operation was observed.

Fig. 6 shows an eight MESFET power combiner consisting of four cells connected periodically to a microstripline. The periodicity of the structure is lg, the guide wavelength, to ensure proper phasing of the radiating elements. Injection locking of the cells is accomplished through this microstripline. The Effective Radiated Power [9] for the eight MESFET power combiner is 8.5 W at 9.73 GHz and the isotropic DC to RF conversion gain [9] is 7.67 dB. Fig. 7 shows the frequency spectrum of the eight MESFET combiner. Fig. 8 and Fig. 9 show the theoretical and experimental H-plane and E-plane patterns. It can be seen that there is a close match between the theoretical and experimental radiation patterns. Fig. 10 shows the variation of power and frequency with the drain bias of the eight oscillator power combiner. It can also be seen that the oscillation is stable for a 2 V variation in the drain bias voltage. This combiner has a good cross polarization value of -35.5 dB along the beam maximum.

CONCLUSION

An eight MESFET spatial power combiner was designed and fabricated. This power combiner is not sensitive to bias variations. Large signal analysis of the structure has been done and no other mode of oscillation is excited. The structure presented lends itself easily to integrated circuit fabrication. These types of structures may find application in motion detection, communication and medical applications where radiating structures are desirable.

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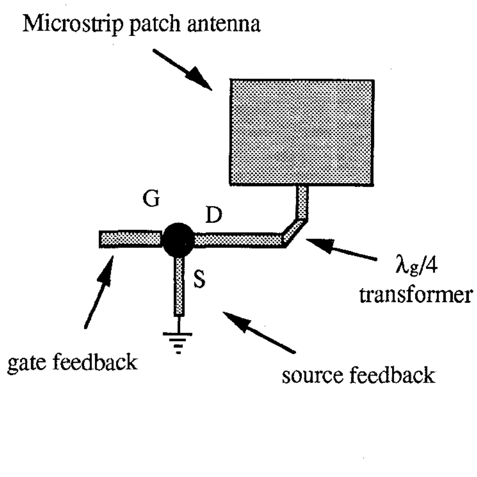

Fig. 1 A single MESFET oscillator

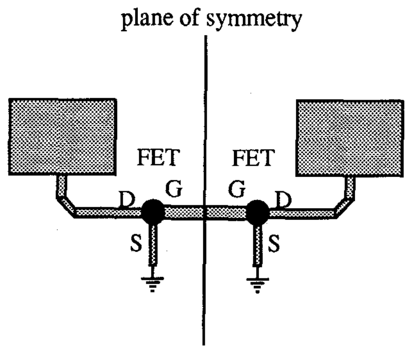

Fig. 2 The basic CELL which consists of two MESFET connected via their Gates

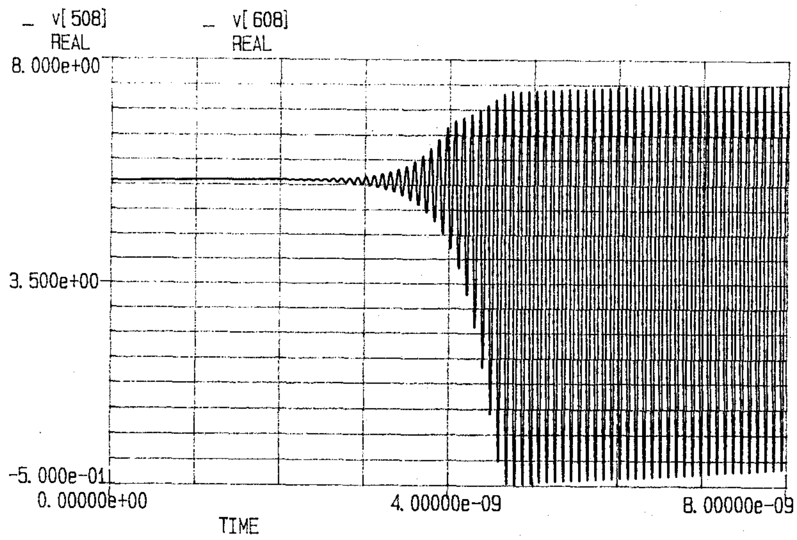

Fig. 3 Build up of oscillation from noise level

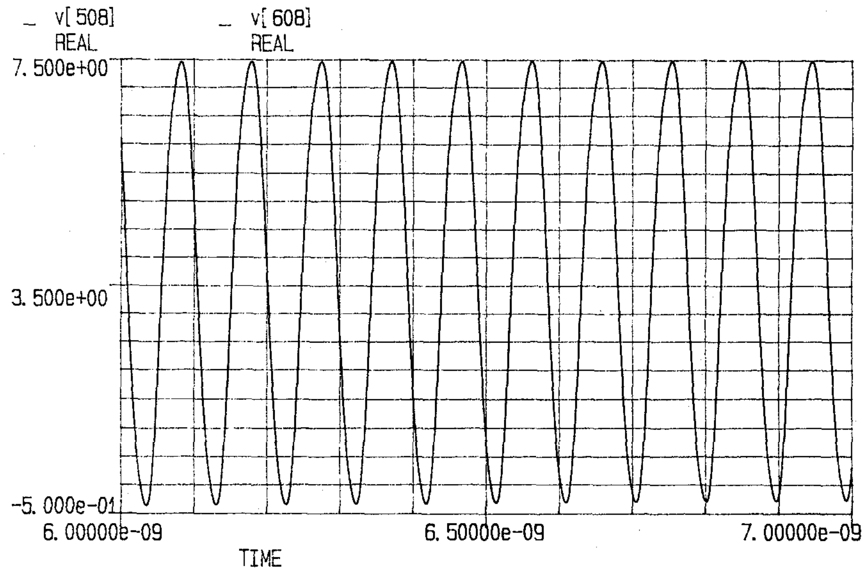

Fig. 4 Voltages at the drains of two MESFET combiner.
They are in Phase and have equal amplitudes.

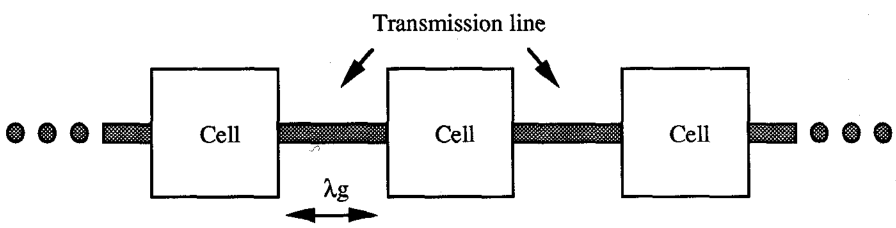

Fig. 5 General power combining configuration
Each cell consists of two MESFETs

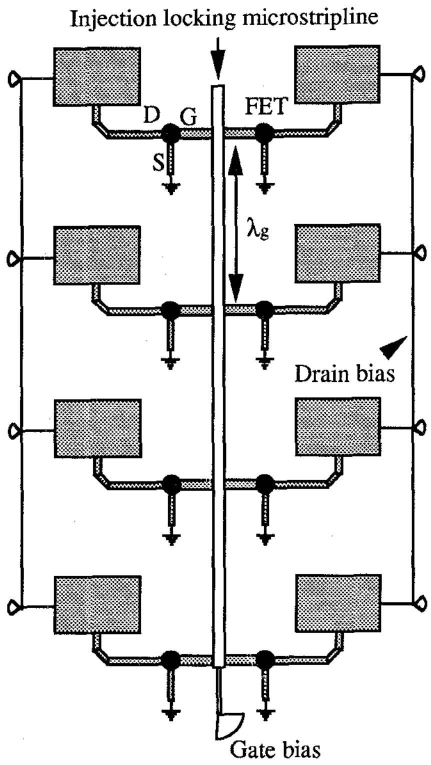

Fig. 6 The Eight MESFET spatial power combiner

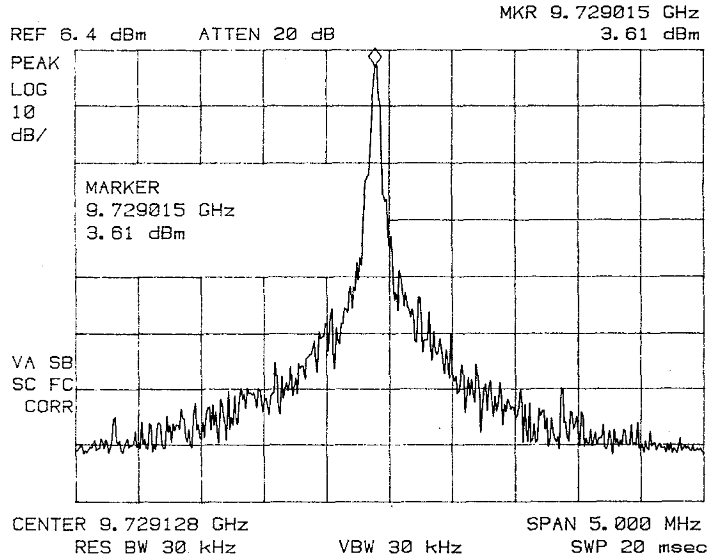

Fig. 7 Frequency spectrum of eight MESFET combiner

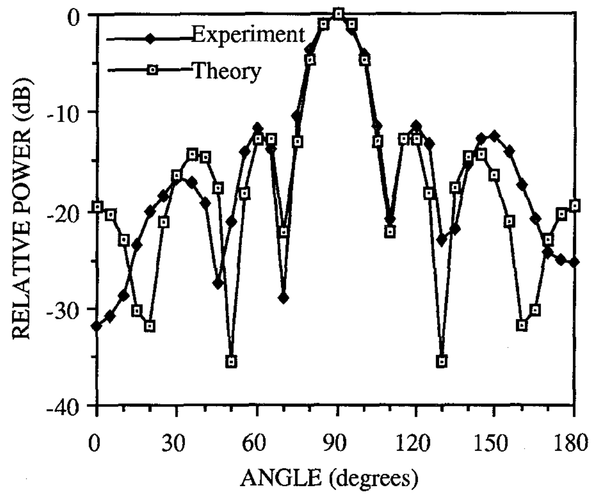

Fig. 9 Theoretical and Experimental E-plane pattern

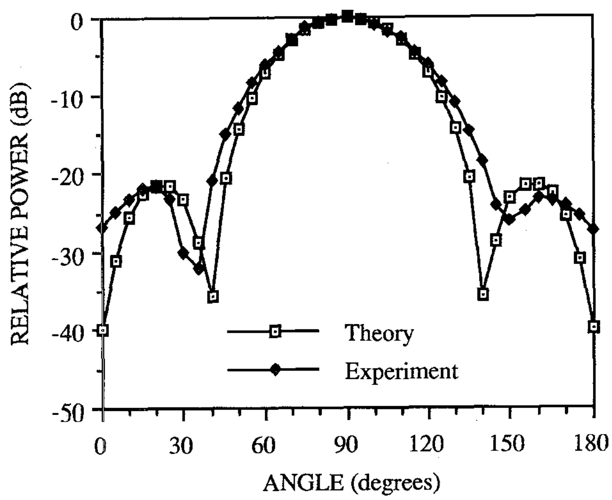

Fig. 8 Theoretical and Experimental H-plane pattern

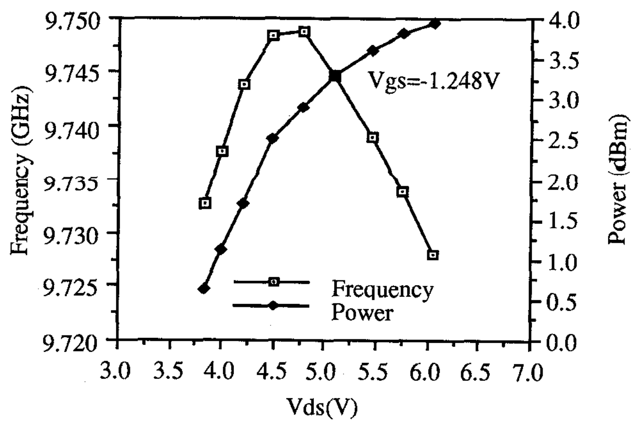

Fig. 10 Vds versus power and frequency