WIDE-BAND VARACTOR-TUNED GaAs MESFET OSCILLATORS AT X- AND Ku-BANDS*

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ABSTRACT

Performance results of wide-band (4-5GHz) varactor-tuned GaAs MESFET oscillators at X- and Ku-bands are presented. It it shown that output powers up to 210 mW can be achieved.

Introduction

The microwave GaAs MESFET has been shown to be an efficient solid-state device for use either as a linear amplifier or as a free-running oscillator. In either mode, significant progress has been made with respect to the output power and the upper operating frequency limit. Advancement of GaAs material growth, device fabrication and circuit implementation techniques has made available both power and small-signal GaAs MESFETs for microwave system applications. In the case of free-running oscillators, output powers as high as 500 mW and efficiencies as high as 45% have already been achieved at X-band.[1] The tunability of the GaAs MESFET oscillator was reported by Heyboer and Emery[2] in a 6-10 GHz YIG-tuned oscillator. In their work, a 1μm gate small-signal GaAs MESFET was used as the active element. With a buffer amplifier output stage, output powers of between 20 and 5 mW were reported across the 6-10 GHz band. This paper further describes the most recent advances in the performance of wide-band varactor-tuned GaAs MESFET oscillators at X- and Ku-bands.

Circuit Development and Microwave Performance

For the X-band tunable oscillators, GaAs MESFETs with 1μm electron-beam defined gates and 1200μm gate width were used. When used as an amplifier, this device can provide up to 500 mW of output power with 5-6 dB gain at 9 GHz.[3] Small signal GaAs MESFETs with 0.5μm electron-beam defined gates (300μm gate width) were used for the Ku-band oscillator design. Both the X- and Ku-band oscillators were operated in a common-gate configuration, with the inductance from gate to ground used as the feedback element. The FET chips were mounted on small gold-plated copper blocks for attachment to the microstrip circuits.

The wideband negative resistance property of the common-gate GaAs MESFET oscillator has been measured with a network analyzer in a 50 ohm microstrip circuit. The small-signal negative resistance characteristics of a 1μm gate FET with 1200μm gate width is shown in Figure 1. A compressed Smith chart is used to show the output impedance as a function of frequency with the drain voltage as a parameter. It is seen that, for drain voltages greater than 5V, the FET possesses negative resistance within the measuring frequency range (7 to 12 GHz) shown. The negative resistance value increases with increasing drain voltage and seems to be relatively constant across the frequency range shown. For maximum output power, the optimum load resistance will be from one-third to one-half of the small-signal value. It should be noted that, in all the oscillators described here, the negative gate bias is provided by the voltage drop across a bias resistor connected between source and ground. The voltage drop is caused by the flow of the drain current through this resistor. By adjusting the value of this resistor, optimum gate bias can be achieved. An inductance in series with an MOS by-pass capacitor to ground was connected to the source for the oscillator operation. By varying the value of the feedback inductance, the frequency coverage of the oscillator can be changed as desired. The negative resistance plot such as that shown in Figure 1 has provided valuable information for an optimum GaAs MESFET VCO design.

The electronic tuning of the common-gate GaAs MESFET oscillators has been accomplished by the use of a GaAs tuning varactor in series with either the output matching circuit or with the gate feedback inductance. Figure 2 shows the tuning curve for an X-band GaAs MESFET VCO with series varactor tuning in the output circuit. A tuning range of 3.5 GHz (8 to 11.5 GHz) is shown. At the highest frequency of 11.5 GHz, 210 mW of output power can be obtained with 17.5% efficiency (excluding the loss in the bias resistor). It is noted that output powers in excess of 100 mW are obtainable for frequencies above 10 GHz. For even wider tuning bandwidth of the common-gate oscillator, the tuning varactor was connected in series with the gate feedback inductance. A tuning range of 5 GHz (8.2 to 13.2 GHz) was achieved. Figure 3 shows the tuning curve for this oscillator. It is worth noting that a 4.2 GHz tuning range (8.2 to 12.4 GHz) covering all the X-band frequencies can be obtained with a varactor voltage swing of approximately 25 volts. The output power variation across the X-band remains less than 3 dB (50 to 100 mW). To minimize the output power variation across the tuning frequency range, the load resistance must be properly tailored as a function of frequency for a given feedback inductance.

Similar feedback and tuning schemes (varactor in series with the feedback inductance) as those used for the X-band oscillators have been used for the design of a Ku-band GaAs MESFET VCO. The results are shown in Figure 4. A small-signal 0.5μm gate FET was used for this oscillator. A tuning range of 4 GHz (12.8 to 16.8 GHz) is shown. The nominal output power is 20 mW. An exceptionally leveled output power was achieved. With further optimization of the circuit parameters, a tuning range covering the full Ku-band will be possible.

Conclusions

It has been shown that wideband (4-5 GHz) varactor-tuned GaAs MESFET oscillators can be achieved at X- and Ku-bands. An output power of 210 mW with 17.5% efficiency at 11.5 GHz has been obtained for an X-band, varactor-tuned oscillator. Output power levels such as those reported in this paper for the GaAs MESFET VCOs can only previously be obtained from VCOs using two-terminal negative resistance devices such as Gunn or IMPATT diodes at X- and Ku-bands. Although comparable tuning bandwidth can be achieved with either the Gunn or IMPATT diodes, the diodes have either lower efficiency (Gunn) or higher noise (IMPATT). The GaAs MESFET VCOs have been shown to possess the desirable characteristics of having respectable output power, high efficiency, low operating voltage, and wide tuning

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bandwidth. The noise performance of the GaAs MESFETs is also expected to be far superior to that of the IMPATT diodes. The position of the Gunn and IMPATT diode VCOs will certainly be challenged by the newly emerged GaAs MESFET VCOs, at least for frequencies up to 30 GHz, in such important microwave system applications as ECM, solid-state sweepers, and mixers.

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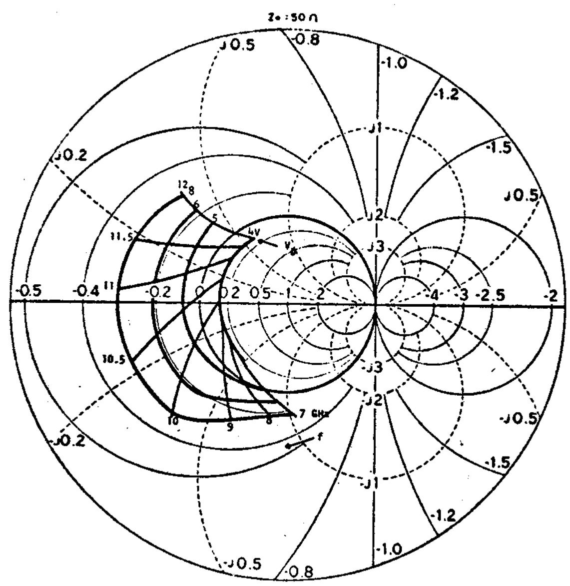

Figure 1. Output impedance of a common-gate GaAs MESFET oscillator as a function of frequency and with the drain voltage as a parameter.

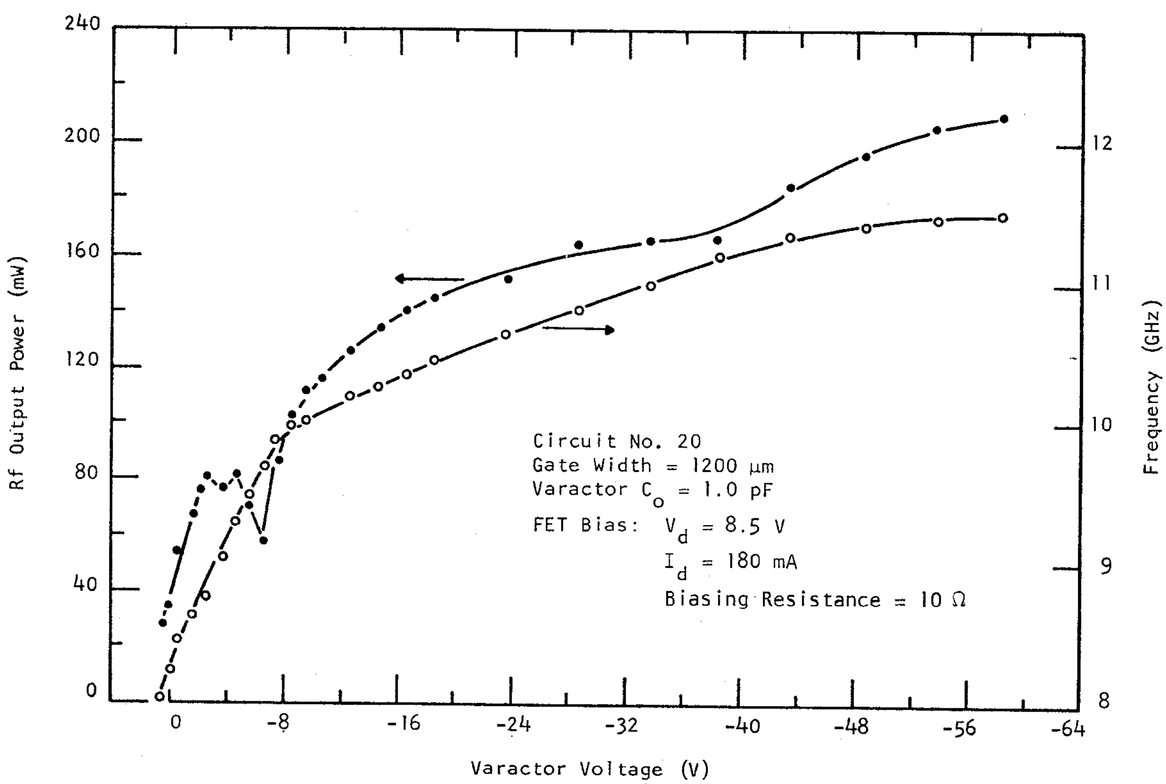

Figure 2. Microwave performance of a GaAs MESFET VCO with series varactor tuning in the output circuit.

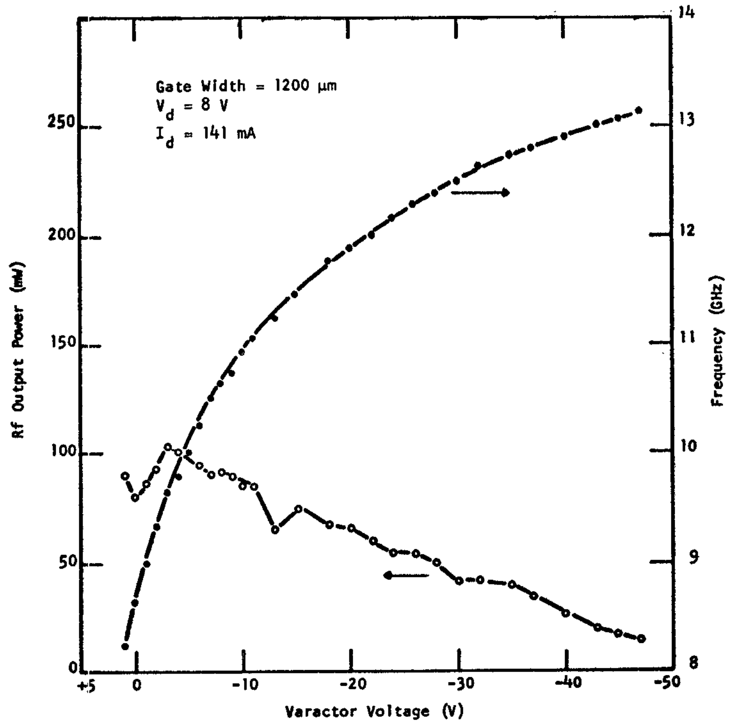

Figure 3. Microwave performance of an X-band GaAs MESFET VCO with varactor tuning in the gate circuit.

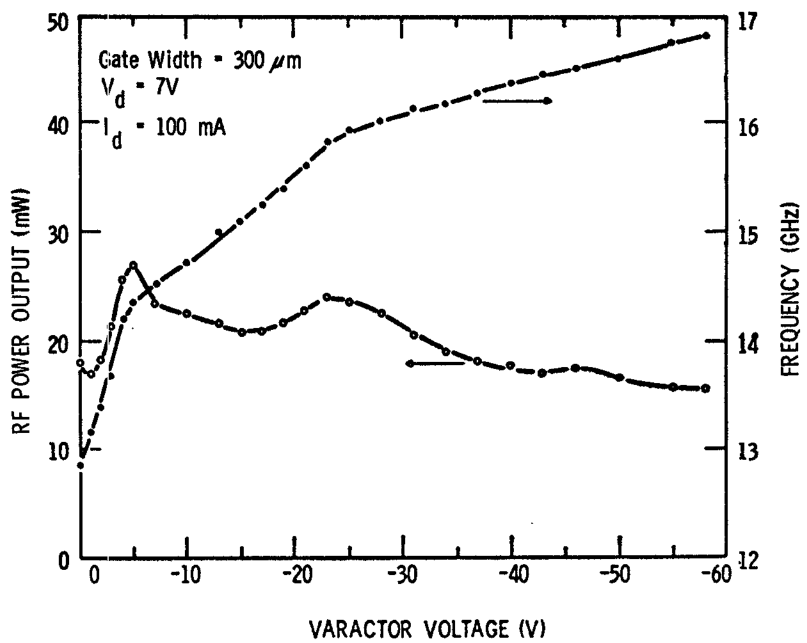

Figure 4. A Ku-band GaAs MESFET VCO.