AN OSCIPLIER UP TO K-BAND USING DUAL-GATE GaAs MESFET

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ABSTRACT

The feasibility of using a dual-gate GaAs MESFET with Mo-Au gates as a Ku or K-band osciplier has been demonstrated. Two test oscipliers were measured, one osciplier in Ku-band delivered 16.3 dBm at 12 GHz, while the other in K-band offered 9.0 dBm output power at 18.2 GHz and 3.8 dBm at 22 GHz.

INTRODUCTION

Due to pronounced nonlinearities in a dual-gate GaAs MESFET, this device has been used as a mixer, modulator, power limiter, and recently as a frequency multiplier [1] as well as a self oscillating mixer [2]. The purpose of this paper is to demonstrate feasibility of ultilizing the Mo-Au dual-gate GaAs MESFET as an osciplier in Ku or K-band. The osciplier is defined as a circuit combining self-oscillation with inherent multiplication in a single device.

DEVICE FABRICATION AND CHARACTERISTICS

Dual-gate GaAs MESFET's were fabricated on an ion-implanted active layer. The layer was formed by double ion-implanting into semi-insulating GaAs substrate [3]. The source and drain ohmic contacts were alloyed Au-Ge. The Mo-Au gate metals were approximately 1000Å and 7000Å thick respectively and were deposited by electron beam evaporation. Both Mo-Au parallel gates, 2-μm apart, are 1-μm long and 400-μm wide. Figure 1 shows typical Mo-Au dual-gate GaAs MESFET drain current characteristics. Figure 2(a) and (b) plot the first and second gate small transconductance measured at 1 MHz vs. the respective gate bias.

In terms of microwave performance, the device in common source configuration offered 15 dB maximum available gain at 10 GHz, if the second gate was properly terminated with a capacitive load. Furthermore, 19.5 dBm output power at 10 GHz was obtained with an associated gain of 6.5 dB in the same test condition. While the second gate is tuned for maximum gain, this dual-gate MESFET exhibites the f_{max} at 40 GHz. The results of device loadpull measurement indicted good capability in producing second and third order harmonics, if the drain was seperately tuned at each harmonic.

OSCIPLIER TEST CIRCUIT

It was known that a dual-gate GaAs MESFET can be used as a frequency multiplier having good conversion gain, because of its transfer nonlinearity controllable by either gate bias [1]. Recently, a dual-gate MESFET has been reported to act as an oscillator at 9 GHz [2].

It becomes evident that the combination of an oscillator with a frequency doubler in such a dual-gate MESFET can be realized. A dual-gate GaAs MESFET fabricated with Mo-Au gates is particularly suited for this nonlinear operation, because the possible gate metal electromigration resulted from the oscillating gate currents can be certainly alleviated.

The basic principle of operation is explained by the simple test circuit diagram depicted in Figure 3. First, based upon the oscillator design theory [4], a varactor-tuned oscillator was designed using a feedback element L_1 at the first gate and a GaAs varactor of $C_{jo} \doteq 1.1$ pF at the source. While the drain is properly loaded, this oscillator is tuneable from 6 to 11.5 GHz for various L_1's. As for the frequency multiplication, it was found that a capacitive load C_2 at the second gate improved the conversion efficiency [1]. Subsequently, a MIC oscillator indicated by the dotted lines was realized on a 10-mil thick sapphire substrate using microstrip lines.

Based on the device results of loadpull measurement, the drain load impedance necessary for the maximum oscillation differs markedly from the load impedance matched for optimum multiplication of the second harmonic. As far as osciplier is concerned, the device drain is required to match to these two different impedance. Consequently, a frequency-selective tuner [5] is adopted, since it can readily provide at least two distinct impedance at different frequencies.

Once the oscillation builds up at the first gate, the second harmonic of this oscillating signal is generated by two kinds of device nonlinearities, namely, the second gate input nonlinearity and the drain output nonlinearity. Next, the resultant harmonic is amplified and then extracted from the drain through a circulator by the tuner 2 in the frequency -selective tuner.

It was observed that the tuner 1 was, as expected, sensitive to both the fundamental and second harmonics, yet the tuner 2, to a small extent, had an effect on the fundamental. The possible mechanisms responsible for the latter observation are following: (a)poorer matching of tuner 2 to the drain as a result of the considerable losses of bias tee, circulator, and HPF, and (b) the degraded circulator isolation between ports due to its non-ideal loads.

MEASURED RESULTS AND DISCUSSION

Two osciplier circuits having different gate inductance L_1's were tested. In terms of fundamental frequency, the osciplier A with $L_1 \doteq 0.9$ nH oscillated from 6 to 8.9 GHz and the osciplier B with $L_1 \doteq 0.6$ nH was tuneable from 8.5 to 11.5 GHz.

Figure 4 shows the calibrated output power measured from those two oscipliers at various doubling frequencies. The device bias was adjusted at each data point for maximum output power. Also, the frequency-selective tuner was normally adjusted for maximizing both the fundamental and second harmonics. At Ku-band, the corrected output power of 16.3 dBm at 12 GHz was achieved from the osciplier A; with regard to doubling frequency, its DC to RF conversion efficiency was 8.5%. At K-band the corrected output power of 9.0 dBm and 3.8 dBm were obtained at 18.2 GHz and 22 GHz respectively.

A coupler of 20 dB was inserted betwween the device drain and bias tee to monitor the tuning of both the frequencies f_0 and $2f_0$, as shown in Figure 3. The use of a HP 8566A spectrum analyser allows simultanuous display of all harmonics up to 24 GHz. Due to the frequency limitations of coupler, tuner, and circulator, this osciplier test circuit is characterized with higher loss at higher frequencies, i.e. 25 dB loss for less than 10 GHz and 30 dB loss for higher than 12 GHz. Figure 5 gives the osciplier performance at four different frequencies, measured on the HP 8566A spectrum analyser.

In comparison with the two power outputs P_1 and P_2 from the osciplier A as shown in Figure 4, it is quite clear that the higher second harmonic power P_2 can only result from the unique combination of frequency multiplication and amplification in a device. As frequency increases, the power decline of doubling frequency is primarily attributed to the device gain falloff and to poorer matching of the frequency-selective tuner at higher frequencies.

When tuned only at the second harmonic, the test osciplier A has demonstrated excellent capability in generating third and fourth order harmonics, as is evident in Figure 6.

CONCLUSION

Two oscipliers utilizing GaAs Mo-Au dual-gate MESFET's were designed and measured producing resonable output power at Ku and k-band. Therefore, the feasibility of combining three types of operation, namely, oscillation, frequency multiplication, and amplification in a single dual-gate MESFET has been demonstrated.

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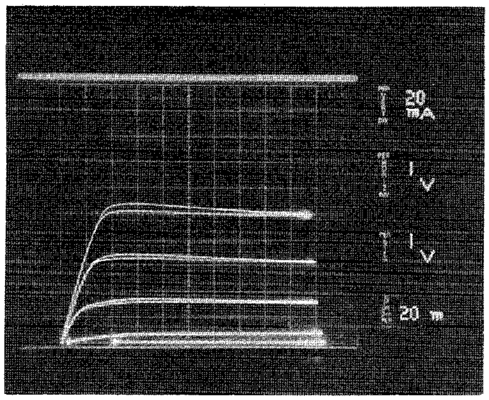

Fig. 1. Typical I-V characteristics of a Mo-Au dual-gate GaAs MESFET in Common-source configuration with V_{G2S}=2.5 V.

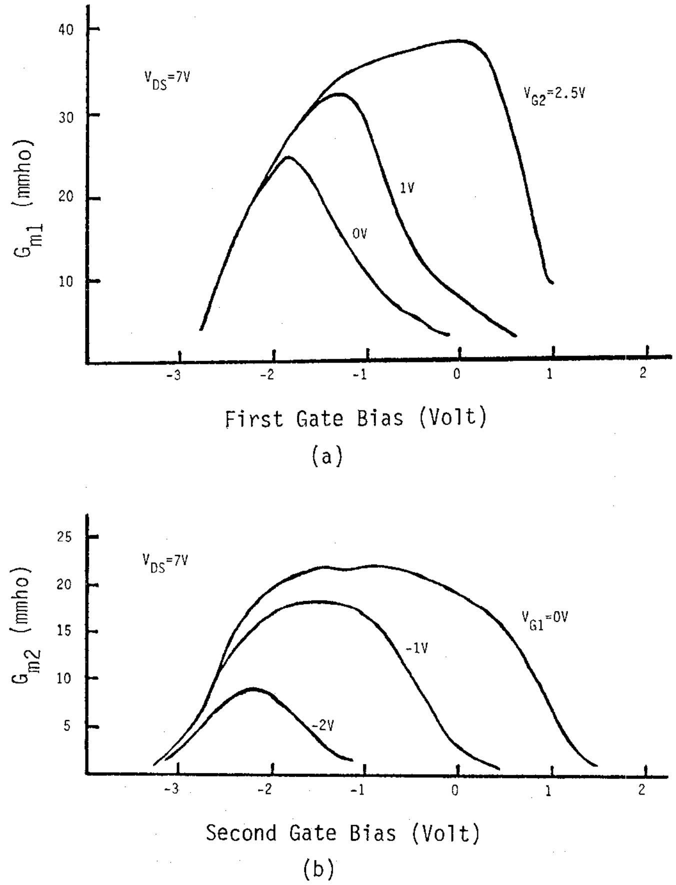

Fig. 2. Typical small transconductance characteristics of a Mo-Au dual-gate GaAs MESFET. (a) first transconductance versus the first gate bias, (b) second transconductance versus the second gate bias.

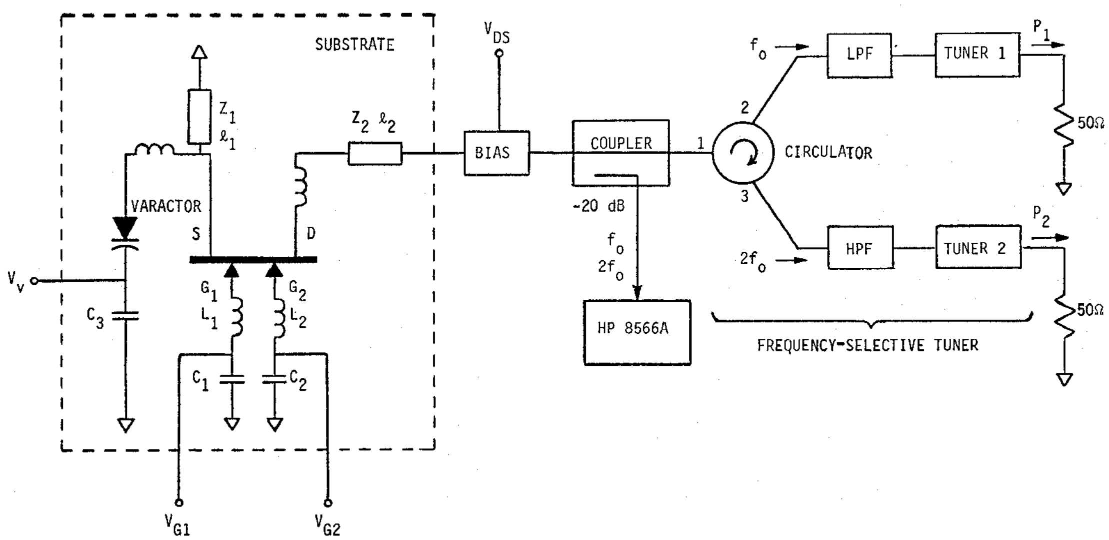

Fig. 3. Dual-gate MESFET osciplier test circuit.

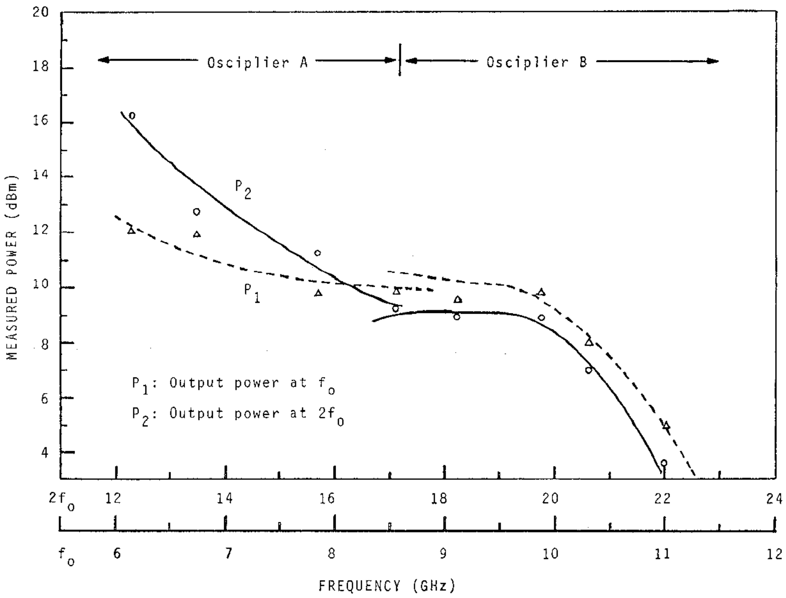

Fig. 4. Power performance of two dual-gate MESFET osciplliers. Device bias is adjusted at each data point.

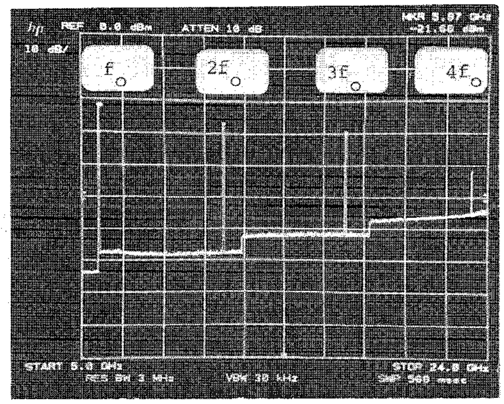

Fig. 6. Higher order harmonics content of the oscipliier A measured on the HP 8566A spectrum analyser.

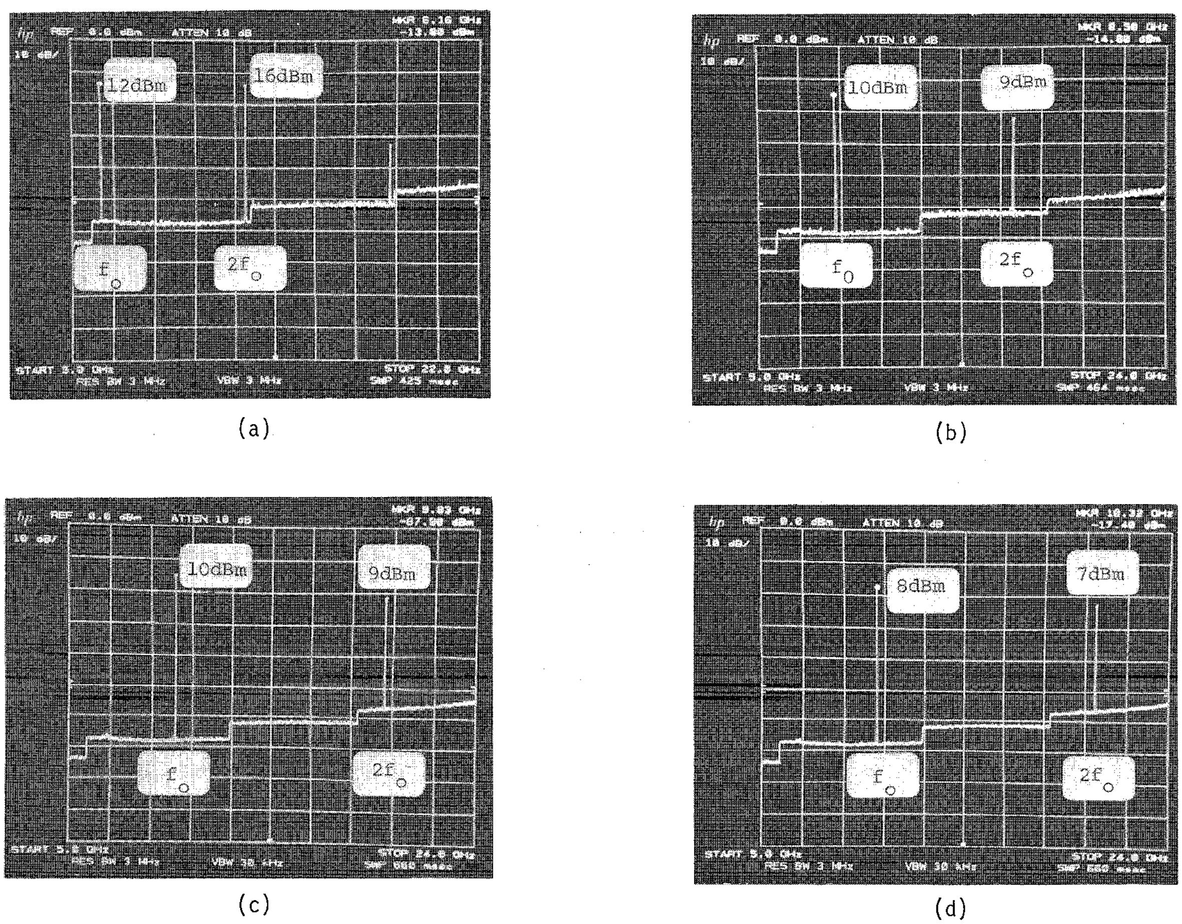

Fig. 5. Oscipliier performance at four different frequencies measured on a HP 8566A spectrum analyser. Reference level at 0 dBm is calibrated to 25 dBm for the fundamental and 30 dBm for doubling frequencies. The labelled power levels have been corrected.