TABLE II
CHARACTERISTICS OF THE HIGH-POWER FET AMPLIFIER

Frequency	6.2 GHz
Output Power	30.2 dBm
Gain	26.2 dB
3 dB Bandwidth	200 MHz
DC Input Power	4.74 watt
Efficiency	22 %
AM-PM at P=+30 dBm	1.2 deg/dB
Noise Figure	8 dB
3rd order IM Distortion at P=+30 dBm	31.5 dB

IV. CONCLUSION

A four-stage GaAs MESFET power amplifier capable of delivering 1-W output power with 26-dB gain has been discussed. This amplifier was developed for a microwave FM radio relay. The third-order intermodulation product of this amplifier chain was 31.5 dB below the fundamental and the power efficiency was 22 percent.

ACKNOWLEDGMENT

The authors wish to thank Dr. K. Kurokawa for supporting this work, and T. Sekizawa for his kind guidance in the development of the microwave high-power FET amplifier. They also appreciate stimulating advice and cooperation recieved from H. Ishikawa, M. Fukuta, H. Suzuki, and K. Suyama.

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Letters

Feedback Effects in the GaAs MESFET Model

GEORGE D. VENDELIN

Abstract—**GaAs MESFET models correctly predict a positive feedback conductance. The effect of common-lead inductance on y_{12} using computer modeling techniques is examined. Experimental data are also included which indicate that the common-lead inductance of about 0.06 nH cannot be omitted from the model in order to accurately predict the feedback conductance.**

Several authors [1]–[3] have reported the existence of a positive feedback conductance term in both MOSFET and MESFET devices. This result is usually observed by calculating $g_{12} = \mathrm{Re}(y_{12})$, which is positive for a negative resistance between gate and drain. Both Johnson [1] and Dawson [3] have shown that a positive g_{12} may be explained by an internal capacitance between drain and channel interacting with input capacitance and common-lead resistance, which produces a positive g_{12} proportional to f^2.

Manuscript received October 2, 1975; revised December 11, 1975. This work was sponsored by the Fairchild Semiconductor, Transistor Division, Microwave Group, Mountain View, CA 94042.
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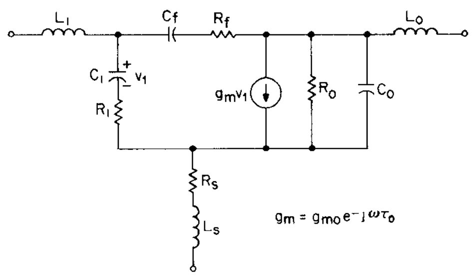

Fig. 1. GaAs MESFET Model (1-μm gate length). Fairchild element values: $R_i = 11\ \Omega$, $R_0 = 400\ \Omega$, $R_f = 237\ \Omega$, $R_s = 7.28\ \Omega$, $C_i = 0.25$ pF, $C_0 = 0.04$ pF, $C_f = 0.007$ pF, $L_s = 0.059$ nH, $L_i = L_0 = 0.3$ nH, $g_{m0} = 20$ mS, $\tau_0 = 5$ ps.

In this letter a slightly different chip model [4], which includes inductances at all three terminals, will be used to calculate feedback effects. The importance of including common-lead inductance will become apparent since g_{12} increases significantly due to this element. Experimental data for GaAs MESFET chips are also included in order to verify the validity of the model.

The circuit model [4] used for the GaAs MESFET is given in Fig. 1. This model is slightly different from Dawson's because the drain capacitance C_0 is returned to the common-source

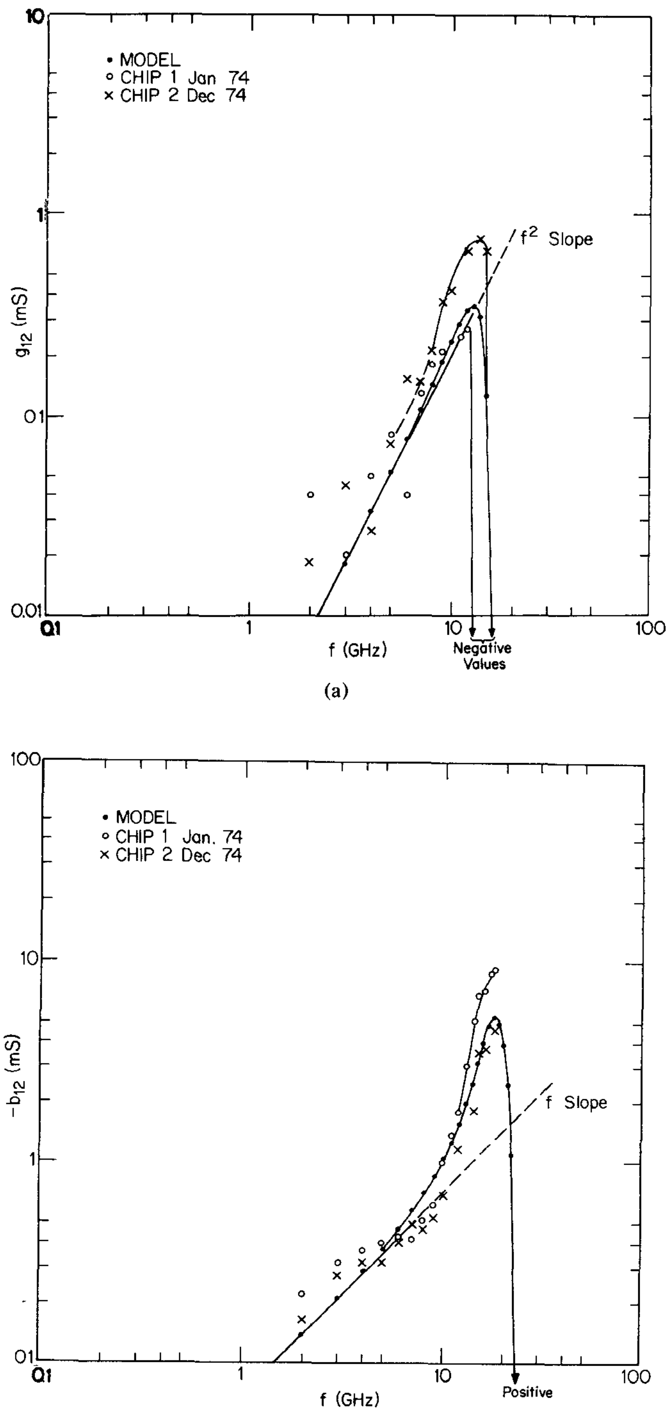

Fig. 2. y_{12} versus frequency for 1-μm gate GaAs MESFET. (a) g_{12} versus frequency. (b) b_{12} versus frequency.

resistor R_s rather than directly to the input capacitance C_i. Also, R_f, τ_0, and the three terminal inductances are included in this model. This equivalent circuit has been modeled on a computer terminal [5] using both COMPACT and SPEEDY2 to determine the feedback effects in the GaAs MESFET model.

The feedback elements in Fig. 1 are R_s, L_s, R_f, and C_f. From computer studies of this model, the terms which increase g_{12} are R_s, L_s, C_i, and C_0. All other elements in the model decrease the positive g_{12}.

Sigg [6] has derived a formula for y_{12} including both inductance and resistance terms in the common-lead branch. For the normal GaAs MESFET model, this formula reduces to Dawson's result when $Z_s = R_s$:

$$g_{12} \cong \omega^2 R_s C_i C_0$$

$$b_{12} \cong -\omega C_f.$$

A typical plot of y_{12} versus frequency is given in Fig. 2 for an experimental 1-μm gate GaAs MESFET chip from Fairchild. Both experimental and equivalent circuit data are plotted, which

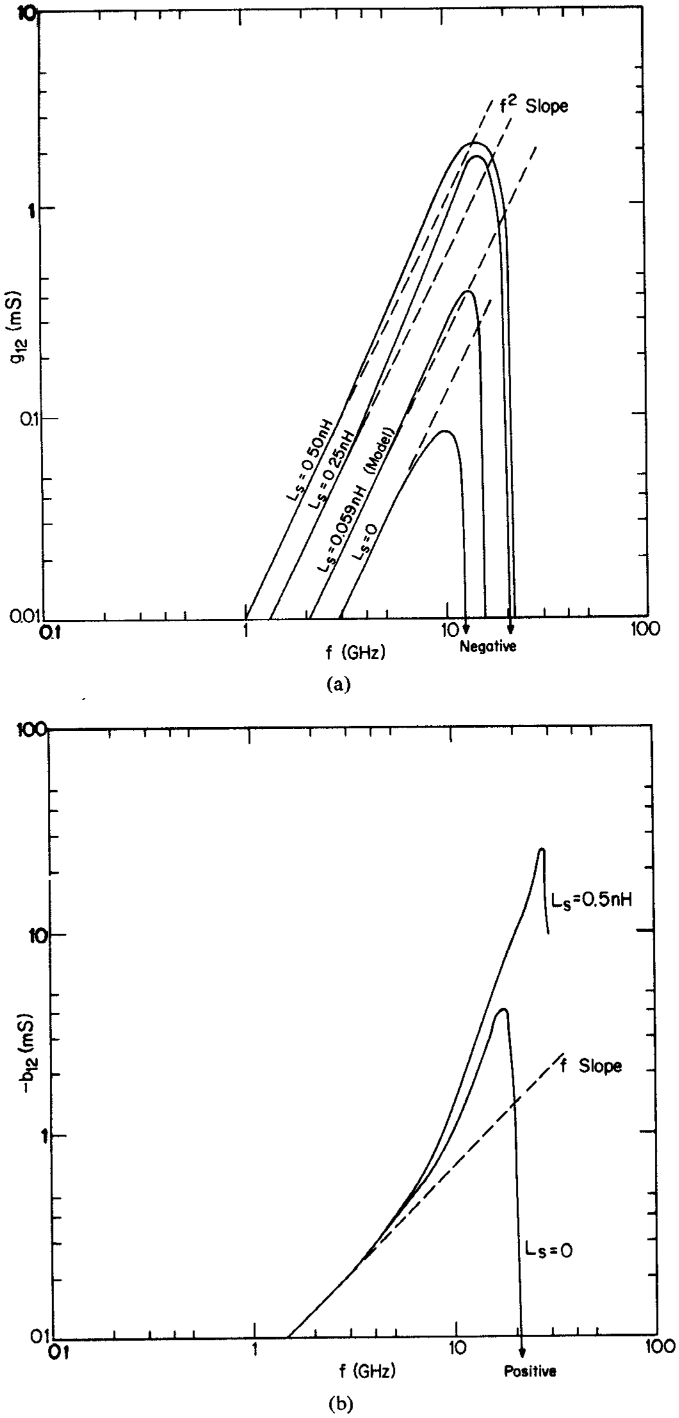

Fig. 3. y_{12} versus frequency with variable common-lead inductance. (a) g_{12} versus frequency. (b) b_{12} versus frequency.

indicate that g_{12} turns negative in *Ku* band. The effect of common-lead inductance on y_{12} can be seen clearly in Fig. 3, which gives the model data for the Fairchild chip as a function of common-lead inductance. By comparing Figs. 2 and 3, the L_s term is needed to fit the measured g_{12}.

The effect of device geometry has also been computed from experimental data. Increasing either gate length or gate width increases the g_{12}, but b_{12} appears to be essentially independent of geometry.

The data reported by Liechti [7] for both single- and dual-gate MESFET's at 10 GHz have also been converted to y parameters with the following feedback result:

	Single Gate	Dual Gate
g_{12}	0.382 mS	0.204 mS
b_{12}	−0.694 mS	−0.151 mS

The feedback is considerably reduced for the dual-gate device.

A positive g_{12} has been clearly demonstrated for GaAs MESFET's up to *Ku* band. This result is unique for FET's since microwave bipolar transistors normally have a negative g_{12}. From computer studies of the present GaAs MESFET model, the feedback inductance can be shown to increase stability (k) below about 8 GHz but decrease stability above 8 GHz. In addition, the maximum available gain or maximum stable gain is reduced by all of the feedback elements. Since the gain is usually reduced, it is confusing to refer to the feedback inductance or resistance as "regenerative" [3]. These results depend upon the particular model parameters of the GaAs MESFET. In addition, packaged MESFET's will behave quite differently due to additional feedback elements. In general, all feedback elements should be avoided since they normally lead to a reduction in gain over a broad frequency range regardless of the effect on g_{12}.

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The GaAs MESFET as a Pulse Regenerator in the Gigabit per Second Range

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***Abstract*—Regeneration and amplification of fast pulses in the 50-ps range have been established using GaAs MESFET's under switching conditions. Sharpening factors, $t_{r_{in}}/t_{r_{out}}$, of 3 and voltage amplification factors of 2 at 50 Ω have been achieved for output pulses up to 100 mA. The sharpening effect is caused mainly by the voltage-dependent gate capacitance which varies with the input pulse amplitude.**

Using a GaAs MESFET under pinch-off conditions, any input pulse high enough may drive the FET into the active region. The turn-on time of the drain current is dependent on 1) the input time constant, 2) the voltage-dependent transconductance, and 3) the slope of the input pulse.

Because of the voltage-dependent gate capacitance the input time constant varies with the input signal. The simplified

Manuscript received October 1, 1975; revised December 17, 1975. This work was supported by the German Research Council, Sonderforschungsbereich 56.
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