A Novel Common-Gate Mixer for Wireless Applications

B. M. Frank, A. P. Freundorfer, and Y. M. M. Antar

***Abstract*—In this paper, a balanced 27-GHz common-gate downconvert mixer is presented. The common-gate configuration allows 0.8-μm MESFETs to be used at frequencies in excess of those practical for the common-source configuration. Measurements indicate a conversion loss of 10.7 dB at an input RF frequency of 27 GHz and local-oscillator power of 7.4 dBm, with a third-order intercept at −5.3-dBm output power. This performance is in the range of reported mixers at this frequency, even though most use higher tolerance and more expensive processes.**

***Index Terms*—Common gate, MESFET, mixer, MMIC.**

I. Introduction

The demand for high-bandwidth wireless systems has led to significant research on low-cost high-speed millimeter-wave systems. This paper presents a downconvert mixer that was designed using a simple low-cost 0.8-μm MESFET process, working at an input RF frequency of 27 GHz, and a 25.5-GHz local oscillator (LO).

Microwave FET mixers generally employ one of three mixing schemes: drain LO injection [1], [2], gate mixing [3], [4], or source mixing [5]. These schemes bias the transistor in the common source (CS) configuration, which is suitable when the mixing frequencies lie below the CS f_T. However, the CS configuration suffers a large conversion loss at high frequencies due to the Miller effect, whereby the parasitic capacitance $C_{\rm dg}$ between the drain and gate produces feedback at high frequencies.

However, if the transistor is biased in the common-gate configuration, the transistor may be used at higher frequencies due to the elimination of the Miller effect. It does, however, suffer from instability. The transistor may be stabilized either using feedback or a balanced structure. For this design, the second option was chosen, as the balanced structure also provides LO–RF isolation.

The process used has a CS $f_t = 20$ GHz, which is significantly less than the frequency of operation of this circuit. More importantly, the $G_{\rm MAX}$ of the CS configuration is very small at the 27-GHz RF frequency; Fig. 1 shows measured $G_{\rm MAX}$ data for the CS and common-gate configurations of a 0.8-μm MESFET, with a gatewidth of 280 μm. As can be seen, the common-gate configuration may be used at much higher frequencies than the CS. Despite the fact that this process is not intended for millimeter-wave circuits, it has already been demonstrated that the common-gate configuration may be used at frequencies up to 30 GHz in an amplifier [6], [7].

Previous work on common-gate mixers used a CS/common-gate combination to implement balun and mixing functions [8]. To the authors' knowledge, this is the first presentation of a mixer composed exclusively of common-gate MESFETs.

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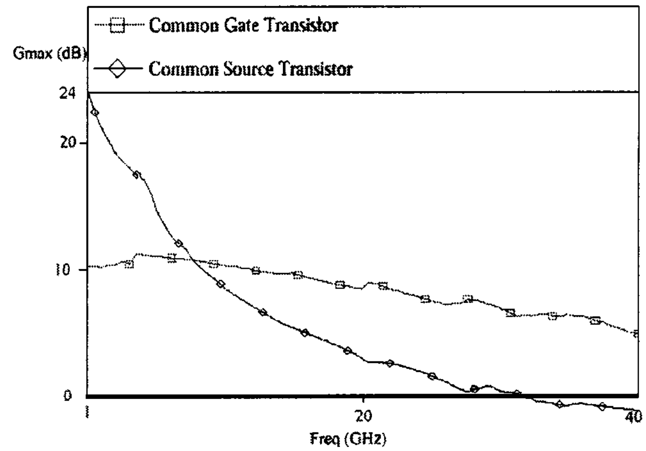

Fig. 1. $G_{\rm MAX}$ of 0.8-μm MESFET, $W = 280$ μm (from [6]).

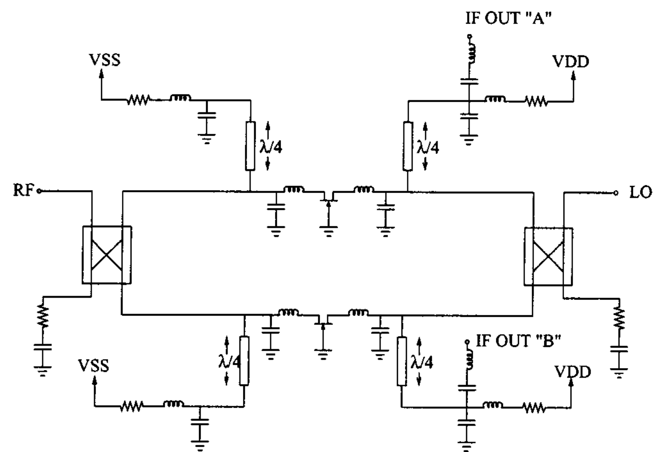

Fig. 2. Schematic of mixer.

II. Mixer Design

The mixer was designed using a standard computer-aided circuit design tool. A schematic of the mixer is shown in Fig. 2. The process used for this mixer utilized unthinned 625-μm GaAs with a thick metal sub-process for making spiral inductors.

The common-gate configuration was used in a balanced structure, providing isolation between the LO and RF ports, and also maintaining stability. Double-connected gates were used to reduce the parasitic gate resistance and maximize the high-frequency performance. Lange couplers were used for the hybrids because of their very precise phase shift and good power split performance.

Coplanar waveguide (CPW) transmission lines were used throughout the circuit, due to their simplicity, and the presence of a ground plane on the substrate surface, thus eliminating the need for highly inductive and costly vias.

The bias networks at the sources of the MESFETs each consist of a $\lambda/4$ high-impedance CPW line and a lumped capacitor, followed by a spiral inductor and resistor. This configuration was chosen because the spiral inductors self-resonate at frequencies below 20 GHz and, thus, cannot be connected directly to the high-frequency sections of the circuit.

The bias networks at the drains of the MESFETs are slightly more complicated; a lumped-element *LC* filter is placed after the $\lambda/4$ transmission line to filter out the LO and RF signals at the IF port. The drain

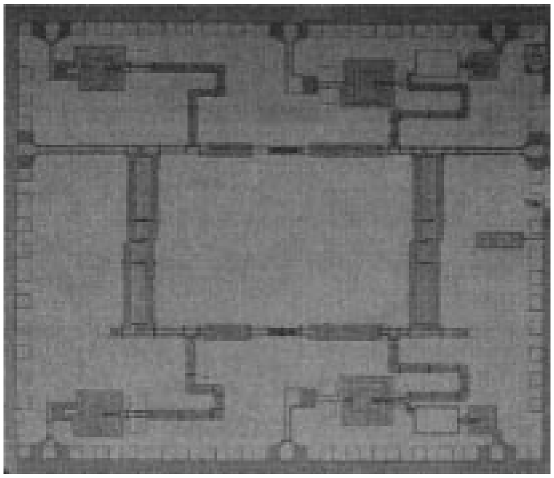

Fig. 3. Mixer layout.

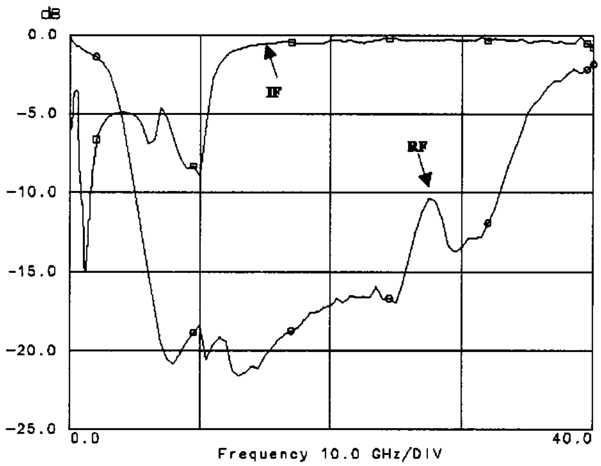

Fig. 4. Measured return loss at RF and IF ports.

bias is provided through a resistor and spiral inductor at the end of the $\lambda/4$ CPW.

Two in-phase IF signals are produced as output (labeled "IF OUT A" and "IF OUT B" in Fig. 2) after the $\lambda/4$ CPW lines. Decoupling capacitors and small inductors were used to isolate the IF from the LO/RF signals.

The matching networks use high-impedance CPW lines and lumped capacitors.

III. Measured Results

The circuit was laid out as shown in Fig. 3; its size is approximately 2 mm $\times$ 2 mm.

After fabrication, the mixer was characterized by its conversion gain, third-order intercept, isolation, and match at the three ports. Further information on the measurement of this circuit is available in [9]. All measurements were made using only a single output port; combining the outputs of both IF ports should give a slightly superior conversion loss (by approximately 3 dB).

The conversion gain was measured by applying appropriate bias voltages to the drain and source networks, and a large-signal LO signal and a small-signal RF to the respective inputs. The minimum conversion loss for a single output was measured to be 10.7 dB with a 27-GHz RF and a 25.5-GHz LO with 7.4-dBm LO power. The bias on the transistors was approximately $V_{\rm ds} = 1.1$ V, $V_{\rm gs} = 0.26$ V, with $I_{\rm ds} = 39$ mA.

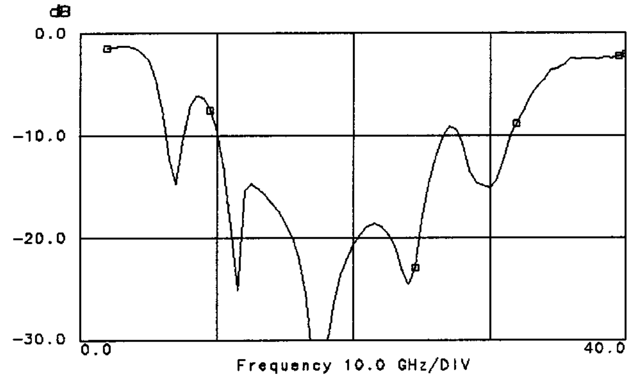

Fig. 5. Measured return loss at LO port.

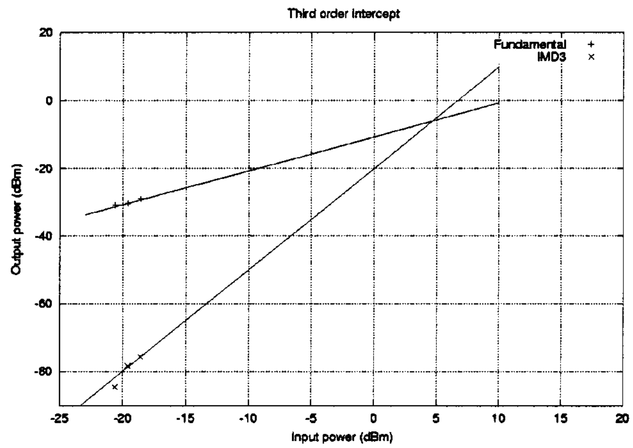

Fig. 6. Measured IP3.

TABLE I
PERFORMANCE COMPARISON WITH OTHER REPORTED MIXERS

Author(s)	Frequency Range	Process	Conversion Gain (dB)
This work	27 GHz RF	0.8 μm MESFET	-10.7
Cardinal *et al* [10]	38 GHz RF	0.18 μm PHEMT	-1 to 6
Chang *et al* [11]	93 GHz RF	0.1 μm PHEMT	-12.8
Chen *et al* [12]	42-46 GHz RF	0.25 μm HEMT	-8
Freundorfer *et al* [13]	27-30 GHz IF	3x6.5 μm HBT	1
Kobayashi *et al* [14]	31-39 GHz IF	0.2μm PHEMT, 2μm HBT	-6 to -9
Madihian *et al* [5]	23 GHz RF	0.15 μm HEMT	-6
Nam *et al* [15]	36.5-40 GHz RF	0.25 μm PHEMT	-10
Schefer *et al* [16]	61-71 GHz	0.2 μm InP HEMT	5
Wenger *et al* [17]	32-38 GHz	0.25 μm PHEMT	3
Yhland *et al* [18]	17.5-20 GHz RF	0.15 μm, 0.25 μm HEMT	-6 to 8

Measurements of the return loss at the input and output ports indicated a slight mismatch at the design frequencies, partially due to extrapolating the transistor model from 18 to 30 GHz. However, processing factors that were unknown when the circuit was designed resulted in a suboptimal Lange coupler, and an inferior match at the RF and LO ports.

The return loss is shown in Figs. 4 and 5. As can be seen, at the frequencies of minimum conversion loss, the return loss was approximately -15, -10, and -15 dB at the LO, RF, and IF ports, respectively.

The third-order intercept was measured at an output power of approximately -6.2 dBm, corresponding to an input power of 4.5 dBm, under the conditions that provided maximum conversion gain. Fig. 6 shows the third-order intercept. Note that closely spaced measurements were made at low power levels due to power limitations of the sources used.

The LO–RF isolation was measured to be 49 dB, the RF–IF isolation was 52 dB, and the LO–IF isolation was 33 dB at the frequency of minimum conversion loss.

This mixer's performance is similar to the published performance of other mixers; this is significant because the 0.8-μm MESFET process used for this mixer is much less expensive than most of the processes usually used at this frequency. Table I shows a comparison of this work with other reported mixers. Note that the data for this work are measured using only a single output.

IV. Conclusions

This paper has presented a MESFET downconvert mixer that uses the common-gate configuration. The common-gate configuration allows a simpler process to be used than would be possible with a CS configuration. Measurements on the mixer indicate a conversion loss of 10.7 dB, with a third-order intercept at -6.2-dBm output power.

A survey of published mixer results showed that the performance of this mixer is similar to that of other mixers in this frequency band. However, most mixers designed in the Ka-band use more expensive higher performance processes. This paper suggests that circuits may be designed using common-gate transistors to achieve performance comparable to circuits designed using more expensive processes.

Acknowledgment

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Analytical Evaluation of the MoM Matrix Elements for the Capacitance of a Charged Plate

Jen-Tsai Kuo and Ke-Ying Su

***Abstract*—Closed-form expression is derived for the fourfold integral involved in the evaluation of the capacitance of a charged plate using the Galerkin's procedure in the method of moments. The dimensions of each rectangular subsection for discretizing the conducting plate can be arbitrary. The calculated solutions converge faster than the point-matching results, as expected.**

***Index Terms*—Galerkin's procedure, method of moments.**

I. Introduction

The capacitance of a charged conducting plate can be evaluated by the method of moments (MoM). Thus far, in the MoM, the

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