A 3-33 GHz PHEMT MMIC Distributed Drain Mixer

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ABSTRACT — **A compact wide-band GaAs PHEMT MMIC distributed drain mixer covering the RF frequency from 3 to 33 GHz is reported in this paper. The measured results show that the conversion loss of the distributed drain mixer is better than 4 dB over the frequency range at LO power 13 dBm without IF amplification. Using the matching circuit in the output of the FETs, the LO-to-IF and LO-to-RF isolations are better than 19 dB from 3 to 33 GHz. This mixer utilized a simple distributed topology with single-gate HEMTs and achieved a very broad band performance comparable to the cascode or dual-gate distributed mixers. The overall chip size of this MMIC is only 1.7 x 1 mm^2.**

I. INTRODUCTION

The distributed mixer is a promising technique to realize MMIC mixers with ultra-wideband performance. Similar to the distributed amplifiers [1]-[3], the distributed topology can be used to design MMIC mixers with decade bandwidths that are insensitive to MMIC process variations.

The distributed mixers can be implemented using either single FETs [5]-[7], [13], or dual-gate or cascode FETs [4], [8]-[12]. The use of dual-gate or cascode FETs as the mixing devices in distributed mixer circuits provides inherently good isolation between LO and RF signals when they are applied to the separate gates. However, one may need special FET device layout and models in the dual gate or cascode FET mixer designs.

In this paper, a compact, simple MMIC distributed drain mixer using single-gate HEMT devices is presented. The measurement results show that the conversion loss of the mixer is better than 4 dB from the RF frequency 3 to 33 GHz at LO power 13 dBm without IF amplification. Using the matching circuit in the output of the FETs, the measured LO to IF and LO to RF isolations are better than 19 dB from 3 to 33 GHz. Without using dual-gate or cascode FETs, this MMIC mixer still achieves a broadband and high isolation performance, which rivals the previously published results [4]-[13].

II. DEVICE CHRACTERISTICS AND MMIC FABRICATION

The MMIC mixers were fabricated using GaAs-based pseudormorphic HEMT (PHEMT) MMIC foundry process provided by TRW [14]. The device is a 0.15-μm gate-length PHEMT with a unit current gain frequency (f_T) of 81 GHz. The passive components include GaAs thin film resistor, MIM capacitor, and via hole through 100-μm GaAs substrate. The entire chip is also protected by silicon-nitride passivation for reliability concern.

III. CIRCUIT DESIGN

The circuit schematic diagram of the four-section distributed drain mixer is shown in Fig. 1. There are four 0.15-μm PHEMTs with a gate periphery of 200 μm. The PHEMTs are biased near the knee region, where the nonlinear characteristics of drain-to-source current versus drain-to-source voltage are used for frequency mixing. Microstrip lines are used to form the artificial gate and drain transmission lines, and for phase equalization of the signal on the drain transmission line. A matching circuit is designed in the output of the PHEMTs to maximize the IF output power and offer the LO-to-IF isolation. The mixer performance is simulated via the harmonic balance technique implemented in the commercial CAD software (LIBRA™ from HP-EESOF). The nonlinear HEMT model used in the simulation is Curtice cubic model provided by the foundry. Fig. 2 shows the photo of the MMIC chip, with die size of 1.7 x 1 mm^2.

IV. CIRCUIT PERFORMANCE

The mixer was measured via on wafer probing. The PHEMTs are biased near the knee region of the DC-IV curve, with V_{DS} = 1.1 V and V_{GS} = -0.7 V. The conversion loss and LO-to-IF, LO-to-RF isolations were evaluated for the mixer. The measured conversion loss results versus local oscillator power level from 2 to 18.5 dBm at frequencies at 5, 15, 25 GHz with IF is fixed at 1 GHz and RF is at 6, 16, 26 GHz are plotted in Fig. 3. It is observed that for LO drive level above 13 dBm, the conversion performance becomes saturated. The simulated and measured conversion loss versus LO frequencies from 2 to

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32 GHz with RF input power of -10 dBm and LO drive of 13 dBm with V_{DS} = 1.1 V, V_{GS} = -0.7 V and Ids = 70 mA were plotted in Fig. 4. The measured conversion loss is between 1 and 4 dB across the band and demonstrated a broadband performance. The simulation and measurement results agree to each other reasonably. The measured isolations versus LO frequency were illustrated in Fig. 5. The LO-to-RF and LO-to-IF isolations are greater than 19 dB covering the RF frequencies from 3 to 33 GHz. The simulation and measurement broad bandwidth RF and LO input matched characteristics of the distributed circuit topology are shown in Figure 6. Both ports have better than 5-dB return loss over most of the 5 to 31 GHz bandwidth.

Fig. 7-9 show the RF input power at 6, 16 and 26 GHz versus IF output and the third order intermodulation products for LO power level of 13 dBm at 5, 15 and 25 GHz, respectively. The measured two-tone input third-order intercept points are 10, 12, and 12 dBm. Table I summarized the features and performances of the previously published distributed mixers and this work. Compared with the previously published results [4]-[13], this MMIC mixer demonstrated the widest RF bandwidth performance. It is noted that the measured results in [6] only showed LO frequency to 25 GHz.

V. CONCLUSION

A compact and wide-band drain mixer using a simple single-gate HEMTs distributed topology is described in this paper. Using the matching circuit in the output of the HEMTs, the conversion loss is less than 4 dB and the LO-to-RF and LO-to-IF isolations are better than 19 dB at RF frequency from 3 to 33 GHz, which are comparable to those of the cascode or dual-gate distributed mixers. It demonstrated the widest RF bandwidth compared with the previously published distributed mixers.

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Table I

Summary of the previously published distributed mixers and this work

Ref.	Frequency (GHz)			Performance					P_{LO} (dBm)	Design features	
	RF	LO	IF	Conversion Gain (dB)	LO-RF Isolation (dB)	LO-IF Isolation (dB)	P_{1dB} (Input) (dBm)	IP3 (Input) (dBm)		Process	Number of sections
[4]	5-17	6-18	1	-1~-6					17	GaAs 0.25 μm HEMT MMIC	4
[5]	2-10		0.01	1					9	Hybrid (alumina)	2
[6]		10-50	4.6	0~-4					5	GaAs 0.2 μm HEMT MMIC	4
[7]	2-14		0.07	0~-1		20			16	Hybrid (Duroide)	3
[8]	2-26		0.5	5~11	20		5	11-15	12	GaAs 0.7 μm HEMT MMIC Contain filter and amplifier	4
[9]	1-12		0.4	0~-3			8		11	Hybrid (0.38-mm thick alumina) GaAs 0.5 μm dual-gate HEMT	4
[10]	2-20		1	2~4					10	GaAs PHEMT MMIC	4
[11]	3-15		0.5	3~0	20				12.5	GaAs PHEMT MMIC	2
[12]	14-20	12	2-8	-6	30	20			12.6	GaAs 0.7 μm dual-gate FET MMIC	4
This work	3-33	2-32	1	-1~-4	20	19	0	10-12	13	GaAs 0.15 μm PHEMT MMIC	4

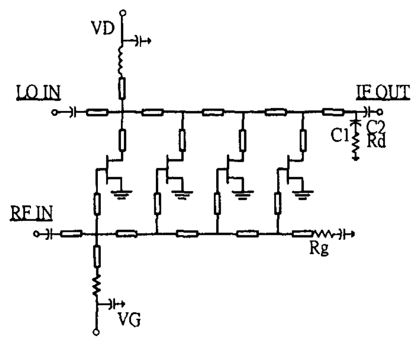

Fig. 1. The circuit schematic diagram of the MMIC distributed drain mixer.

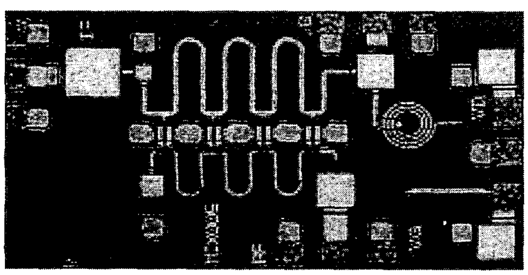

Fig. 2. The chip photo of the MMIC distributed drain mixer with chip size of 1.7 x 1 mm^2.

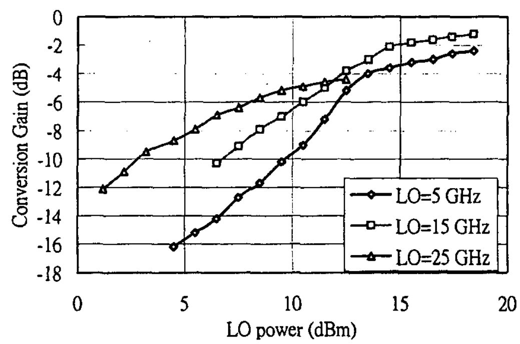

Fig. 3. Measured mixer conversion gain as a function of applied LO power with IF fixed at 1 GHz for LO frequencies at 5, 15 and 25 GHz with V_{DS} = 1.1 V, V_{GS} = -0.7 V.

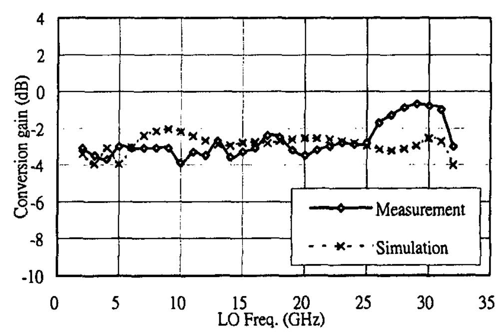

Fig. 4. Simulated and measured conversion gain versus LO frequency of the MMIC distributed drain mixer. IF frequency is fixed at 1 GHz and RF and LO input power level are -10 and 13 dBm for frequency down conversion with V_{DS} = 1.1 V, V_{GS} = -0.7 V.

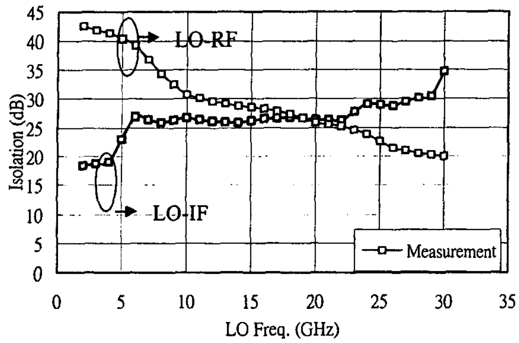

Fig. 5. Measured isolation versus LO frequency of the MMIC distributed drain mixer. LO input power level is 13 dBm with V_{DS} = 1.1 V, V_{GS} = -0.7 V.

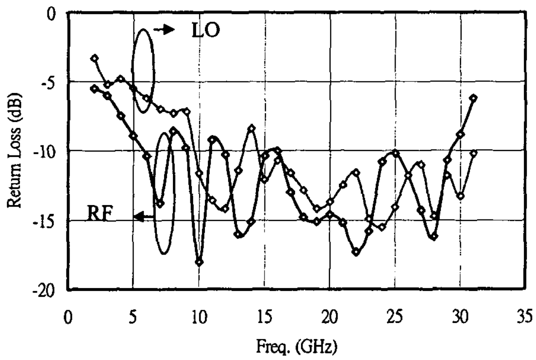

Fig. 6. Simulated and measured LO and RF return loss versus frequency of the MMIC distributed drain mixer. LO and RF input power level is 13 and -10 dBm.

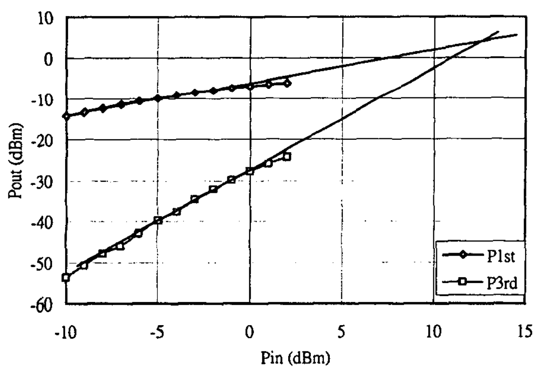

Fig. 7. Measured IF output and the third order intermodulation products versus RF input power of the MMIC distributed drain mixer. LO input power level and frequency are 13 dBm and 5 GHz. f_{RF1} = 6.1 GHz, f_{RF2} = 6 GHz, V_{DS} = 1.1 V, V_{GS} = -0.7 V.

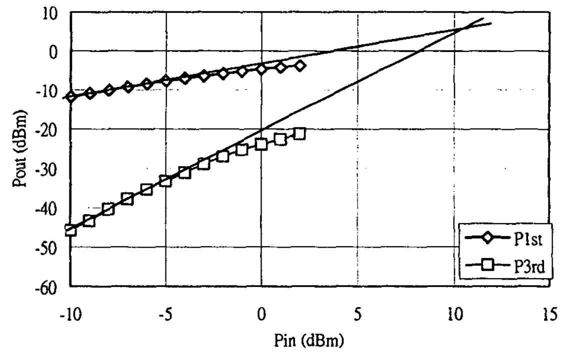

Fig. 8. Measure IF output and the third order intermodulation products versus RF input power of the MMIC distributed drain mixer. LO input power level and frequency are 13 dBm and 15 GHz. f_{RF1} = 16.1 GHz, f_{RF2} = 16 GHz, V_{DS} = 1.1 V, V_{GS} = -0.7 V.

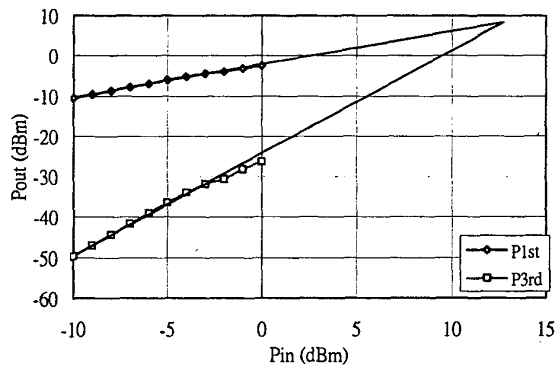

Fig. 9. Measured IF output and the third order intermodulation products versus RF input power of the MMIC distributed drain mixer. LO input power level and frequency are 13 dBm and 25 GHz. f_{RF1} = 26.1 GHz, f_{RF2} = 26 GHz, V_{DS} = 1.1 V, V_{GS} = -0.7 V.