A PMHFET BASED MMIC GATE MIXER FOR KA-BAND APPLICATIONS

M. Matthes, J.–M. Dieudonné*, W. Stiebler, L. Klapproth

Technical University of Berlin,
Institute of Radio Frequency Engineering

* Daimler–Benz Aerospace AG, Ulm, Germany

ABSTRACT

A multipurpose MMIC gate mixer has been designed, fabricated and measured.
The mixer exhibits a maximum conversion gain of about 0 dB in the frequency range of 32 GHz – 38 GHz with an intermediate frequency (IF) of 100 MHz and an IF load of 50 Ω. With an external IF matching network a conversion gain up to 5 dB can be achieved.
The mixer which consists of one pseudomorphic HFET represents state of the art performance.

INTRODUCTION

The operation of a gate mixer depends on the nonlinear behaviour of the PMHFET transistor under large signal excitation by a local oscillator (LO) signal. The PMHFET operates in a common source configuration. The LO and the radio frequency (RF) signals are applied to the gate. The fundamental frequency component of the modulated transconductance is the primary contributor to frequency conversion and conversion gain. To maximize the transconductance variation the PMHFET must be biased with a gate–source voltage V_{GS} equal to its threshold voltage V_t and must remain in its saturation region throughout the LO cycle at a constant drain–source voltage V_{DS}. To achieve this and to suppress the effects of harmonically varying the nonlinear capacitances and the drain–source resistance, it is necessary to short–circuit the fundamental LO frequency and all LO harmonics at the drain [1].
The mixer consists of a broadband matching network at the gate and a LO short at the drain of the transistor. Realizations of such gate mixers for the X– and K–band, respectively were published by Matthes, et al. [2, 3]. Similar works on gate mixers with one HEMT device were published by Maas [4] and Kwon, et al. [5].

DESIGN

The mixer chip (fig. 1) was made using a pseudomorphic HFET with a gate length of 0.25 μm and a gate width of 6 x 20 μm.
A nonlinear simulator was used to design the circuit. The large signal behaviour of the PMHFET has been simulated using the modified Materka model [6]. Although this model was not developed specifically for PMHFET devices, it is however common and is available in most nonlinear simulators. The model parameters were extracted by an in–house procedure, which accounts for the analytical derivatives of the current equation [7].
The mixer is designed using microstrip techniques. The LO and RF signals were fed into the mixer using a Lange coupler and gate biasing is realized by means of an on–chip bias network. To achieve a broadband match at the gate, a high impedance microstrip transmission line and a MIM capacitor are used. The LO–short consists of a butterfly radial stub and microstrip transmission line transformers. It short–circuits the LO signal and the first harmonic simultaneously.
The LO bias network and the IF matching network have to be realized off–chip. For low IFs the required inductances and capacitances can not be realized in MMIC technology.
The mixer was fabricated at Daimler–Benz, Ulm, Germany.

MEASUREMENTS

The measurements were performed with an automated on–wafer mixer measurement system for frequencies up to 40 GHz. Two synthesizers and the receiver of a network analyzer were used. Biasing was achieved with two source measure units (SMU) and an external bias–

T at the IF port. Calibration and measurements were computer controlled.

RESULTS

The measured converion gain versus local oscillator power for a signal frequency of 35 GHz and an IF of 100 MHz is given in figure 2. In this case the IF load is 50Ω. A maximum conversion gain of 0.4 dB is obtained at 9 dBm of local oscillator power.
Even at low local oscillator power the mixer exibits good conversion properties. This is illustrated in figure 3 where a conversion gain of about -2 dB has been measured in the frequency range of 32–38 GHz with a constant IF frequency of 100 MHz and an local oscillator (LO) power of only 3 dBm. A Comparison with the simulation is given in figure 3.
When the mixer is terminated by a 400Ω external IF load a conversion gain up to 5 dB has been measured as shown in figure 4.
Table 1 shows additional results of the mixer measurements.

RF bandwidth	32 – 38 GHz
IF frequency	up to 2 GHz
conversion gain	$\approx$ 0 dB
	(P_{LO}=9dBm, $R_{IF} = 50\Omega$)
	5 dB
	(P_{LO}=7dBm, $R_{IF} = 400\Omega$)
RF return loss	> 10 dB
LO to RF isolation	> 15 dB
LO to IF isolation	> 27 dB
chip size	7.6 mm^2

Table 1: Measurement results

CONCLUSION

The design and measurement results of a Ka-band MMIC gate mixer with one PMHFET has been described. A conversion gain of up to 5 dB (7 dBm LO power, 400 Ω IF load, 6 GHz RF bandwidth) has been measured. It has been shown that good conversion gain performance is achieved at relatively low LO power levels. Nonlinear simulations and measurements are in good agreement.

References

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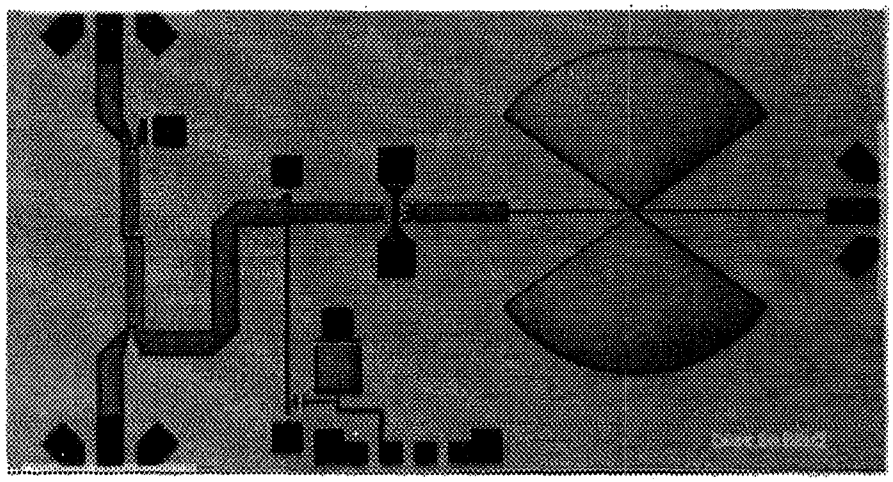

Figure 1: Photograph of the mixer

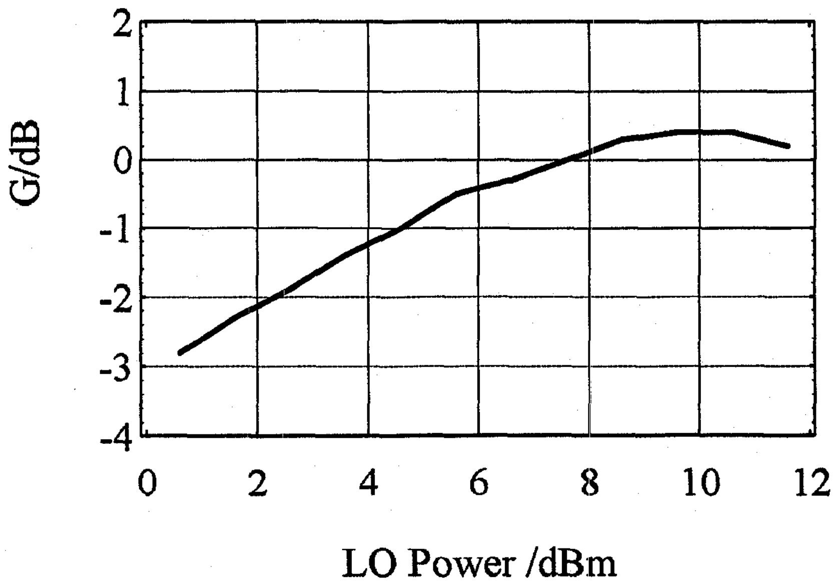

Figure 2: Measured conversion gain G versus LO power ($V_{GS} = V_t$, $V_{DS} = 3$ V, $f_{IF} = 100$ MHz, $R_{IF} = 50\ \Omega$, $f_{RF} = 35$ GHz)

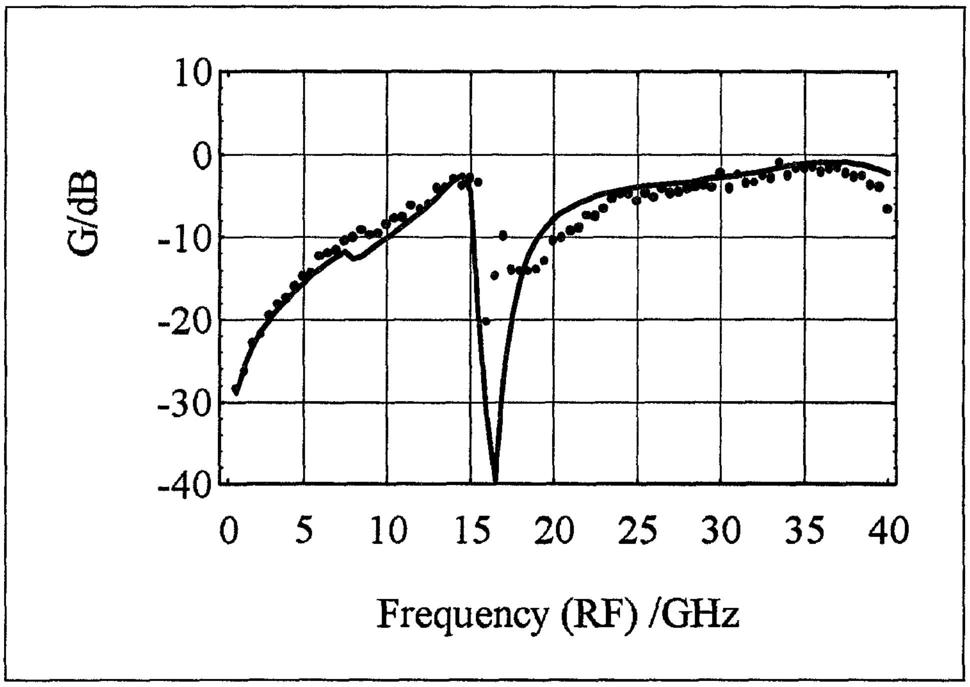

Figure 3: Conversion gain G of the mixer, measured •, nonlinear simulation –, ($V_{GS} = V_t$, $V_{DS} = 3$ V, $P_{LO} = 3$ dBm, $f_{IF} = 100$ MHz, $R_{IF} = 50\ \Omega$)

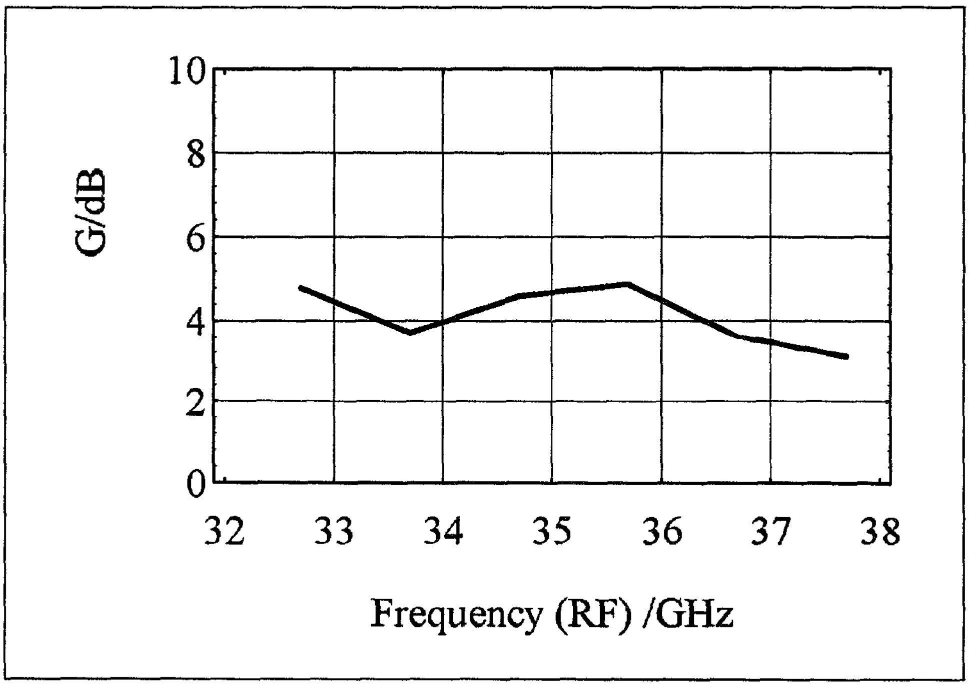

Figure 4: Measured conversion gain G with an external IF load ($P_{LO} = 7$ dBm, $V_{GS} = V_t$, $V_{DS} = 3$ V, $f_{IF} = 100$ MHz, $R_{IF} = 400\ \Omega$)