A COMPACT COPLANAR MMIC MIXER FOR 2.4 GHZ TRANSPONDER SYSTEMS

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ABSTRACT

A compact coplanar passive MMIC mixer has been developed, realized and tested successfully as a cost effective part of an I/Q demodulator module for applications in 2.4 GHz transponder systems. Although there are no external elements required, the cold-FET mixer's size is only 1 mm^2 including bias and active matching networks. Operating with 6V/15mA DC bias, required by the active matching FETs, the mixer has a maximum conversion gain of -2 dB at 9.5 dBm LO power and 100 MHz IF frequency. Intermodulation measurements show an IP3 of 6.9 dBm. The small wafer area is due to a consequent use of active elements for matching and biasing purposes.

INTRODUCTION

Today, the market demands for very low cost solutions in the microwave area. MMIC technology plays a significant role in achieving small size, cost effective chips for an increasing spectrum of applications. Especially the coplanar line technique is a favorable technique compared to microstrip design, because of its inherent properties that reduce the costs of the MMICs even further. There is no need for wafer thinning, backside metallization and via-hole etching. This immediately translates into lower cost because of reduced technology steps and improved yield. Coplanar line technique also provides the possibility to develop smaller circuits.

For transponder applications there is a need for compact and very low power consuming devices. The receiver circuitry in such a transponder consists of an stabilized oscillator and an I/Q demodulator. The chosen frequency range of 2.4 GHz allows for the use of a mature and low cost standard 0.5 μm MESFET technology at the Ferdinand Braun Institut, Berlin, Germany. This demodulator, refer to fig.1, contains as a key circuit a mixer, which in our case is configured to be a single-ended cold-FET mixer because of generating possible IF frequencies down to zero and its zero DC power consumption. Nevertheless DC power consuming active matching circuits were necessary to match the small gate width mixing transistor to 50 ohms. The circuit was designed using a coplanar component library which has been developed at the IMST and which is seamlessly integrated into a commercially available circuit design program (HP-EEsof LIBRA™) [1]

COLD-FET MIXER

The key circuit of the transponders I/Q demodulator is the cold-FET mixer. This type of mixer operates at zero drain bias while the gate is pinched off [2]. This eliminates the need for area consuming bias networks and also provides the possibility of a DC output signal because no blocking capacitor is needed. The input signals are applied to the gate (RF) and the drain (LO) of the transistor. Mixing occurs due to the nonlinear behavior of the output resistance. The mixing transistor as well as the transistors in the active matching parts are 40 μm gate width devices. The schematic circuit representation is given in fig. 2.

To achieve a compact layout, the bias and matching networks were carried out in an active way. This means in case of the matching networks to utilize a transistor in common gate configuration. Transistors T1 and T5 in fig. 2 serve this purpose and match the inputs to 50 ohms without any additional reactive elements. A proper choice of the gate width of this MESFETs allows for an inherent matching to 50 ohms. Another benefit is the gain of these transistors which improves the conversion gain and lowers the required LO power. The drain bias for these transistors is provided by the active load transistors T2 and T4. This active load is "integrated", together with a common gate transistor. In fig. 3 an active load FET integrated into a common source FET is shown as an example. The mixing transistor T3 is biased at pinch off and 0 V drain bias.

A chip photography of the realized mixer is depicted in fig. 4. This coplanar design was simulated using IMSTs coplanar library. Because of the nonlinear nature of the circuit, simulation requires the use of a nonlinear model for the incorporated MESFETs. In this case a nonlinear spline based model, developed also at the IMST has been used [3].

RESULTS

The mixer performance was verified by means of linear and nonlinear measurements. The result of the linear S-parameter measurements in fig. 5 shows, that the active matching at the inputs of the mixer works very well. In the required frequency range the matching is better than -12 dB. As can be seen from fig. 6 the maximum conversion gain of the passive mixer is -2 dB for an IF of 100 MHz and a LO power of about 9.5 dBm. Accordingly to the theory, the maximum conversion gain occurs at the mixing transistors pinch off bias point. Usually, passive mixers exhibit a conversion gain in the order of -10 to -6 dB. In our case the active matching transistor in the RF path provides some gain and thus improves the conversion gain of the mixer.

The measured intermodulation properties of the mixer are shown in fig. 7. The 3^{rd} oder intercept point IP3 is extrapolated to be 6.9 dBm with respect to the output power. A LO power of 10 dBm and a frequency offset of 1 MHz was chosen for the measurement. The P_{1dB} conversion gain compression point is in the order of -14 dBm.

CONCLUSIONS

A coplanar MMIC mixer used for a transponder system in the 2.4 GHz range was realized and tested successfully. The circuit is matched at the input ports by means of active matching and utilizes a cold-FET as mixing device. A conversion gain of -2 dB at 100 MHz IF frequency is obtained due to the gain of the matching transistor in the RF path. Although the circuit contains all matching and bias networks and requires no external elements, the size is only 1 mm^2.

REFERENCES

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[2] Maas, S.; "Microwave Mixers", Artech House, Inc.; 1993.

[3] Follmann, R.; Tempel, R.; Sporkmann, Wolff, I.; "A new spline based FET model for MESFETs and HEMTs", accepted for EuMC, September 1997.

ACKNOWLEDGEMENTS

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FIGURES

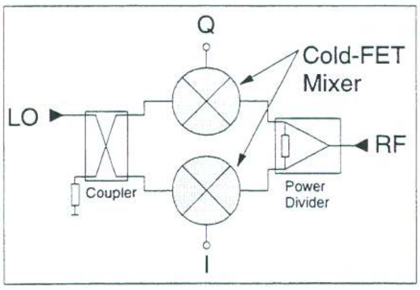

Fig.1: The mixer as key circuit of the I/Q demodulator.

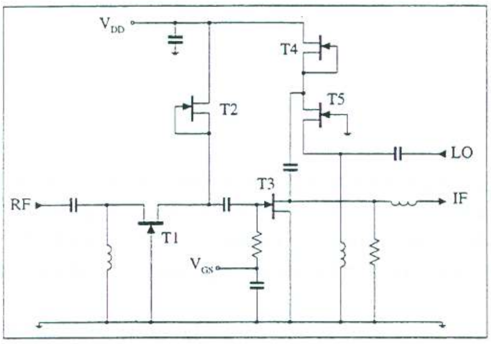

Fig. 2: Simplified circuit representation of the realized cold-FET mixer.

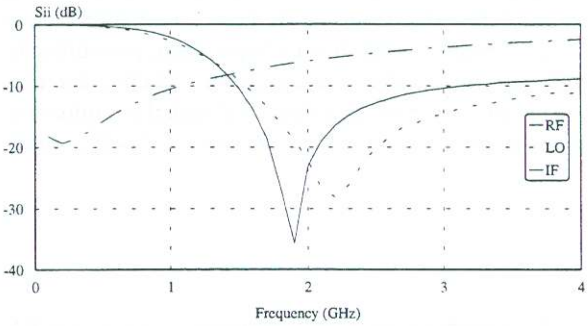

Fig. 5: Measured input and output matching of the cold-FET mixer.

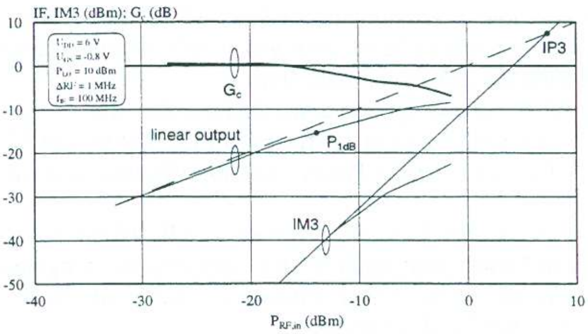

Fig.7: Measured linear and IM3 output power of the IF signal vs. RF-input power (f_{RF}=2.4 GHz).

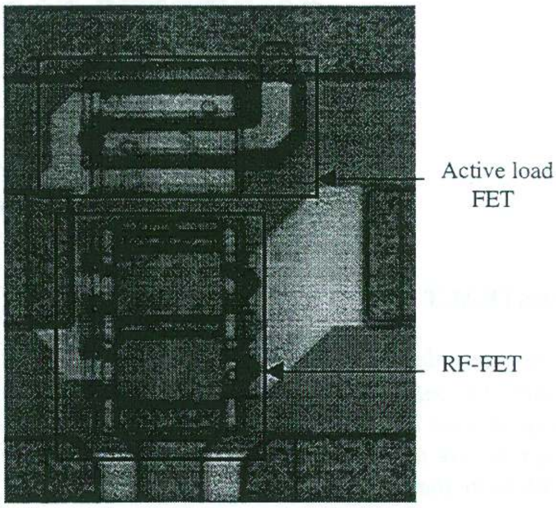

Fig.3: Chip photography of a coplanar transistor with an "integrated" active load transistor.

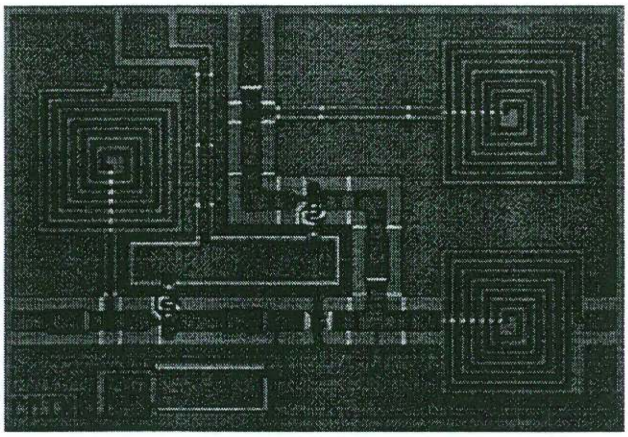

Fig. 4: Chip photography of the coplanar cold-FET mixer. Chip size is 1.25×0.83 mm^2.

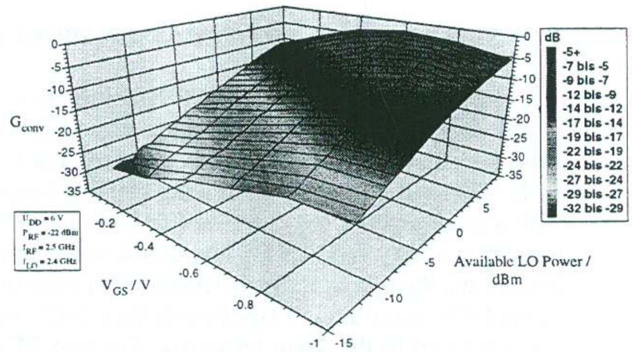

Fig. 6: Measured conversion gain vs. available LO power and gate bias of the mixing transistor.