MONOLITHIC SINGLE FET MIXERS WITH COPLANAR TECHNOLOGY TO CONVERT BETWEEN V AND C BAND

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ABSTRACT

In this paper the design of single FET coplanar mixers to convert signals between V and C band is presented. A step by step design technique was used, based on harmonic balance simulation. The mixer non-linear device is a PMHFET with a 0.15µm T-gate. Two different topologies were designed, fabricated and tested: cold mixer and drain mixer. The mixers were optimised for minimum conversion losses on the widest possible bandwidth in order to be used on a large number of applications. The experiments show: for the cold mixer, a conversion loss on a 8GHz band in the range of 8 to 10dB both as up and downconverter; and 2.5dB on a 4GHz band for the drain mixer as down converter.

INTRODUCTION

To reduce the cost of the RF front end of the transceivers of the emerging millimetre wave civil systems, such as those related to wireless communications systems for road traffic control, mobile communications and LANs, make extensive use of MMICs with a minimum numbers of fabrication steps and the widest bandwidth and modes of operation, to increase the range of possible applications per chip.

In this paper the design and test of monolithic active mixers to convert signals between V and C band will be described. Two different topologies were studied: cold mixer, able to operate as up and down converter; and drain down converter mixer. Both topologies are single FET circuits and don't need bulky couplers for LO-RF isolation. The drawback are the losses. Accordingly, the specific design goals are conversion losses better than 8dB for the cold mixer and better than 4dB for the drain mixer and return losses better than 10dB for both. These values should be obtained with Plo< 10dBm, f_{LO}=56.8GHz, and at least f_{RF} from 62 to 66GHz, which are in agreement with the specifications of a V band mobile system [1]. Since a wider range of applications is envisaged, the analysis and test of the mixers were performed on a wider f_{RF} bandwidth and for different LO power. To design the mixer an harmonic balance CAD program was used. The transistor model was obtained according to [2]. The design has been realised in 3 main steps based in the technique presented in [3].

The mixers were implemented with coplanar technology. It has been proven [4], that coplanar lines and discontinuities show only marginal dispersion effects compared to microstrip lines. This technique will come up where microstrip technology reaches its limitations. Even lower fabrication costs can be achieved, because processing steps like substrate thinning and via hole etching become unnecessary. A coplanar library, integrated in an user friendly CAD software with an automatic layout tool, has been used to obtain the final design [5].

The experiments are in good agreement with the simulations and some of the measured characteristics are better than the design goals.

MIXER DESIGN AND PERFORMANCE

For both solutions the final layouts were produced (figures 1 and 2) and MMICs were fabricated at Thomson TCS and Daimler Benz foundries on GaAs using 0.15mm PMHFETs technology.

It was not possible to use the same PMHFET model for both topologies because they operate in very different modes. Accordingly, we have used an improved Tajima model for the drain mixer and Materka model for the cold mixer.

For both mixers simple line-stub matching networks and an open λ/4 stub for LO rejection have been used. The optimum bias and LO power for each circuit was obtained by using an iterative method similar to the previously presented by the authors for microstrip circuits [3]. Air bridges are used to connect both ground strips (figure 1, 2) in order to reduce the discontinuities effects of the bends, T junctions and crosses. Based on a previous study, corrected models for the coplanar passive structures were used in the simulations [7].

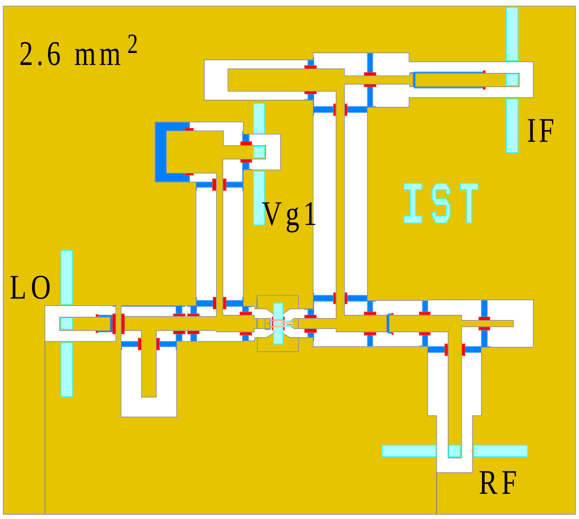

Figure 1 - Cold mixer layout

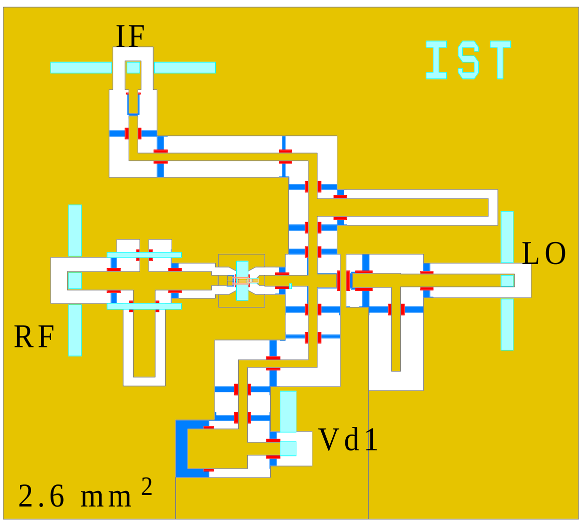

Figure 2 - Drain mixer layout

The cold mixer, as down converter, presents minimum conversion losses of 8dB and a 12% 3dB bandwidth (figure 3) for P_{LO}=7dBm. As up converter, the minimum conversion losses are 9.5dB and the 3dB bandwidth is 15% (figure 4) also for P_{LO}=7dBm. If P_{LO}=-2dBm the conversion losses increases only 2.0dB (figure 5). These measured values as well as the large signal return losses are in close agreement with the simulation. The LO-RF isolation is 7.9dB and the LO-IF is 33dB which are very similar to the simulated results (6.7dB and 34.6dB respectively). For the input -1dB compression point we have measured +7dBm (simulation predicts +8dBm).

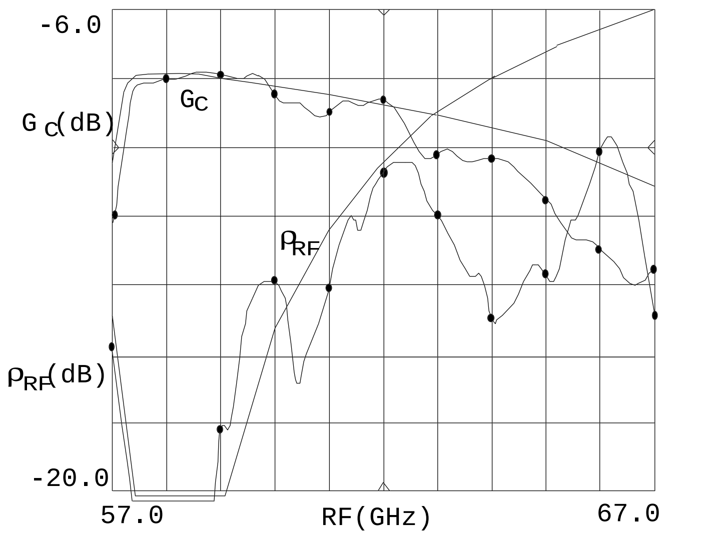

Figure 3 - Cold mixer conversion loss as down converter and RF return loss vs. frequency (simulated (-), measured (•), P_{LO}=7dBm, f_{LO}=56.8GHz)

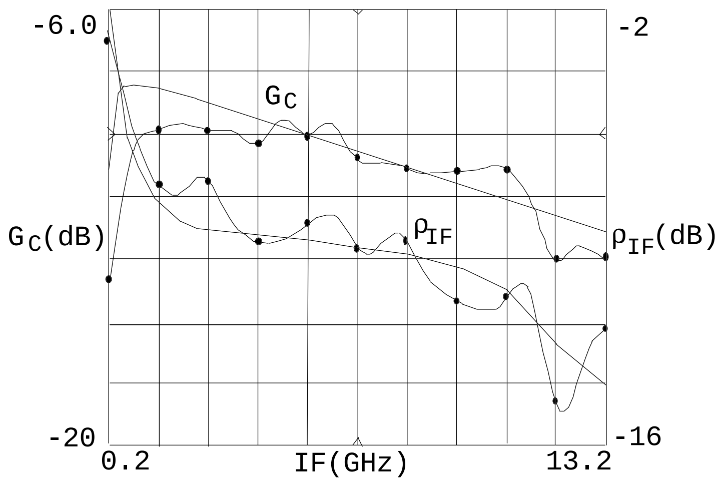

Figure 4 - Cold mixer conversion loss as up converter and IF return losses vs. frequency (simul. (-), measured (•), P_{LO}=7dBm, f_{LO}=56.8GHz).

As far as the authors knowledge the experiments show the best performance concerning an up and down MMIC converter (the cold mixer) for millimeterwave frequencies with such a wide band and small circuit size (single FET) and with coplanar technology (no backside processing is needed). These results are very close with the state of the art of diode mixers on the same frequencies [6].

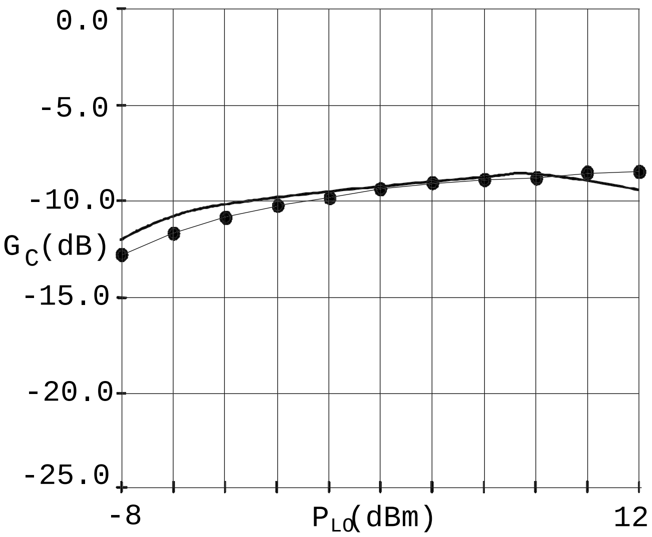

Figure 5 - Cold mixer conversion loss as down converter vs. P_{LO} (simulated (-), measured (•), f_{RF}=62GHz, f_{LO}=56.8GHz)

For the drain mixer a 3dB bandwidth of 7.5% was achieved. The minimum conversion loss for P_{LO}=9dBm, 2.5dB, and the bandwidth are in very close agreement with the simulation (figure 6). The input return losses at the RF port are better then 12dB over the entire band and output return losses at the IF port are better then 10dB in the range of 6GHz-9.2GHz (figure 6 and 7). A conversion gain increase, with P_{LO}≥-10dBm, close to 1dB/dB was measured (figure 8). The LO-RF isolation is 12.5dB and the LO-IF isolation is 32dB which are very similar to the simulated results (11.7dB and 45.8dB respectively).

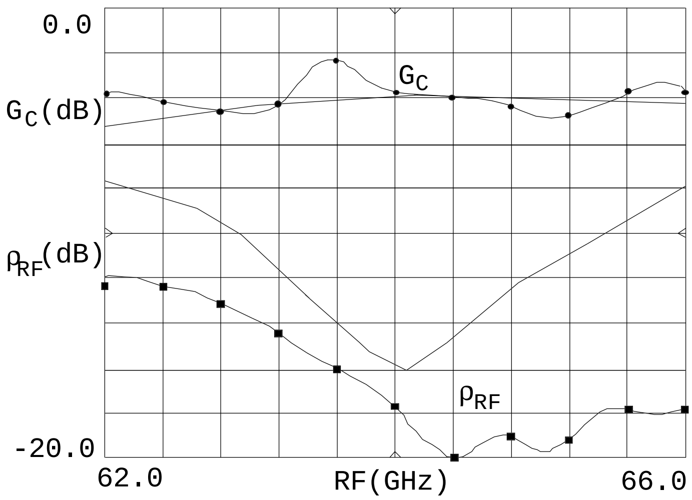

Figure 6 - Drain mixer conversion loss and RF return loss vs. frequency (simulated (-), measured (•), P_{LO}=9dBm, f_{LO}=56.8GHz).

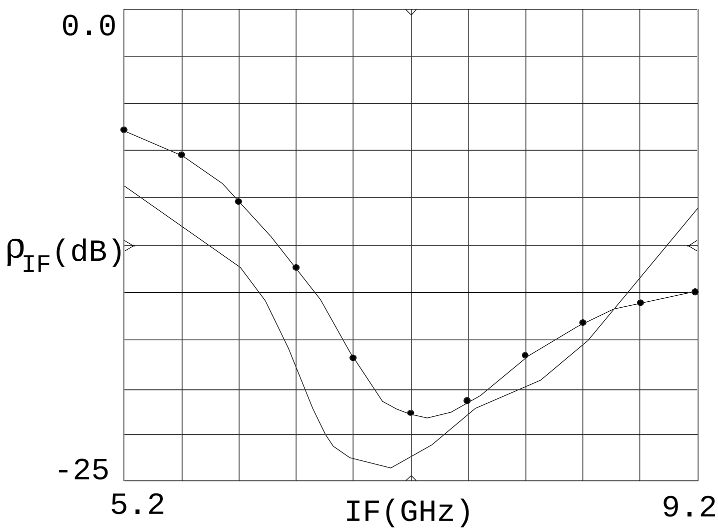

Figure 7 - Drain mixer IF return losses vs. frequency (simulated (-), measured (•), P_{LO}=9dBm, f_{LO}=56.8GHz).

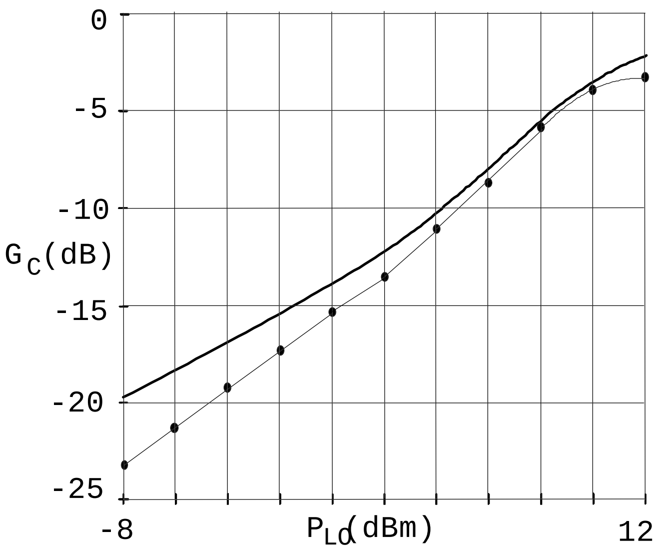

Figure 8 - Drain mixer conversion loss vs. P_{LO} (simulated (-), measured (•), f_{RF}=62GHz, f_{LO}=56.8GHz)

CONCLUSIONS

The design and test of two monolithic single PMHFET mixers with coplanar technology for frequency conversion between V and C band were presented. One of the mixers uses the PMHFET cold biased in order to allow the operation as both up and down converter, with similar parameters as it is shown experimentally (C_{Lup}=9.5dB and C_{Ldown}=8dB). The other topology, a drain mixer, leads to a reduced C_L (C_{Ldown}=2.5dB) together with a high isolation between ports (LO-RF=32dB and LO-RF=12.5dB) and a good conversion linearity (P_{in-1dB}=2dBm) wich is important for mobile communication receivers.

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