A HIGH-PERFORMANCE BROADBAND MMIC PHEMT RESISTIVE DRAIN MIXER FOR 28-40 GHZ BAND PCN APPLICATIONS

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ABSTRACT

A high performance broadband millimeterwave MMIC upconvertor is reported in this paper. The MMIC mixer has a singly balanced configuration and uses two 0.18 µm PHEMT transistors working at resistive drain mixing mode, in which the LO signal is injected to drains, IF to gate via DC bias circuits, and RF signal output from gates. The mixer presents 1-6 dB conversion loss including all losses in the test board (made of 10 mil Duroid substrate) for 27.5-41 GHz LO band and 0.1-1.2 GHz IF band. The P_{1dB} of IF input power is 0 dBm, and good LO-RF suppression with 50 dB at 37.5 GHz. The mixer has been successfully integrated into a 38 GHz PCN demonstrative system in which 64 QAM modulation-demodulation was realized.

INTRODUCTION

With the explosive growth of emerging applications in wireless communications, great efforts have been focused on the R&D of millimeter wave PCNs and WLANs, particularly at 26, 28, 38, 42, and 55 GHz. The maturing millimetric MMIC technology plays a unique role for cost-effective and high performance systems in these applications [1, 2].

The performance of a millimeter wave transceiver is largely dependant on the behavior of the mixers used. Great effort has been given to the MMIC mixer design recently. For examples, a doubly balanced MMIC mixer using HBT Schottky diodes and a Marchand balun with 8-12 dB conversion loss and 23-40 dB LO to RF isolation has been reported in 28-40 GHz band [3], and a single-ended PMHFET transistor gate active mixer with a conversion gain up to 5 dB for 100 MHz IF and 32.5-37.5 GHz LO band with a relatively poor LO to RF isolation has been described in [4]. No P_{1dB} data have been reported in this LO band yet. In this paper, for the first time, we present the measurement results of a MMIC mixer which has a singly balanced configuration and uses two 0.18 µm PHEMT transistors working at pinch-off resistive mode with LO injected to the drains and IF to the gates, and taken the RF signal from gates. A conversion loss of 1-6 dB is obtained for 27.5-41 GHz LO band and 0.1-1.2 GHz IF band. The LO to RF isolation of 50 dB and IF P_{1dB} input power of 0 dBm at 37.5 GHz are achieved with the test board.

DESIGN AND MEASUREMENT

Figure 1 shows the schematic of the singly balanced mixer. Two PHEMT devices are used, which have a gate length of 0.18 µm and gate width of 300 µm. The IF signal is injected into the gates of the transistors with a 180° phase difference, while the LO is provided to the drains and the RF output is taken from the gates. Good LO suppression can be achieved with the two hybrid couplers and inherent LO rejection of the transistors at pinch-off bias, which simplifies the overall filtering requirement for the system. The gate matching networks and branch coupler were designed at 38 GHz and the drain matching circuits and hybrid for 37 GHz. The performance of the mixer was optimized for the 36-39 GHz PCN band. Figure 2 shows the layout of the MMIC mixer, which has a dimension of 3×5 mm^2. The IF signal is injected via the gate bias circuits which behave as RF/LO bandstop filters. The chip was fabricated by MiSig (Microwave Signal. Inc.) using their 0.18 µm PHEMT foundry on a 3 inch wafer.

To test the MMIC mixer chip and to evaluate the performance of integration with cost-effective MIC technology, a test board with 10 mil Duroid substrate (ε_r=2.2) was fabricated to provide the LO, RF, IF signal paths and DC supply, as shown in Figure 3. The overall dimension is 1×2 inch^2. The mixer chip was wire bonded on the substrate with via holes to provide the ground. A 1:4 IF transmission line transformer and two low pass filters are used to provide the anti-phase IF signals to the gates of the MMIC chip. During the measurement, the test board was placed in a Wiltron test fixture with LO and RF connected to the K-connectors and IF to a SMA connector. The measurement results in this paper are all referenced to these connector interface.

Figure 4 shows the measurement results of conversion loss versus IF frequency (0.1-1.2 GHz) of the chip mixer on the test board with LO driving power of 18 dBm at 37.5 GHz. The drains of the PHEMTs are self-biased and the gates (Vgs) are biased at pinch-off at point of -0.3 V. The solid line is measured with 50 ohm IF impedance, which demonstrates a conversion loss of 6-10 dB for the 0.2-1.2 GHz IF band. By providing conjugated match at the IF port, a conversion loss of 1-3 dB for 200-650 MHz IF and 4-6 dB for 800-1200 MHz IF (solid line), respectively. These measurement results include all the LO, RF, and IF paths losses and connector losses of the Duroid test board, as well as the loss of the 1:4 IF balun which gives 1 dB insertion loss at 1 GHz. By excluding all these losses, the MMIC chip itself would have 0-4 dB conversion loss for the full IF measured band.

The conversion loss as a function of LO power at 37.5 GHz under the condition of 1 GHz and -10 dBm IF power and 50 ohm IF impedance is illustrated in Figure 5, solid line for self drain bias and dashed line for 0 drain bias with gate at pinch-off bias. A conversion loss of 6 dB is obtained for both cases at 18 dBm LO power. Figure 6 gives the performance of conversion loss versus IF input power for both 50 ohm IF impedance (solid line) and conjugated impedance (dashed line) and 1 GHz IF frequency under 37.5 GHz LO with 18 dBm driving power. The input IF P_{1dB} power is 0 dBm, a good performance for this LO frequency.

Figure 7 shows the measured conversion loss in the LO band of 26-41 GHz for LO power of 18 dBm, IF frequency of 1 GHz, IF power of -10 dBm, self-bias at drains and pinch-off at gates of the PHEMTs. Again, results for 50 ohm (solid) and conjugated matching impedance (dashed line) are given. 1-6 dB conversion loss is achieved between 27.5-41 GHz including all losses in the test board, demonstrating an excellent broadband behavior. The LO to RF isolation, as shown in Figure 8, is greater than 17 dB between 26-41 GHz, and better than 40 dB within 35-39 GHz and a maximum of 50 dB at 37.5 GHz.

CONCLUSIONS

A high performance broadband millimeterwave MMIC mixer working as upconvertor is reported in this paper. The MMIC chip provides 0-4 dB conversion loss between 27.5 - 41 GHz, which covers the 28 and 38 GHz PCN bands. Very good LO-RF suppression with maximum of 50 dB at 37.5 GHz was obtained due to the singly balanced configuration and 0.18 μm PHEMT transistors with pinch-off gate bias and drain self-bias. The unique feature of this mixer is that the excellent performance is achieved by pumping LO at the drains and obtaining RF at the gates of the PHEMTs. The mixer has been successfully integrated in a 38 GHz PCN demonstrative system in which 64 QAM modulation-demodulation was realized.

REFERENCES

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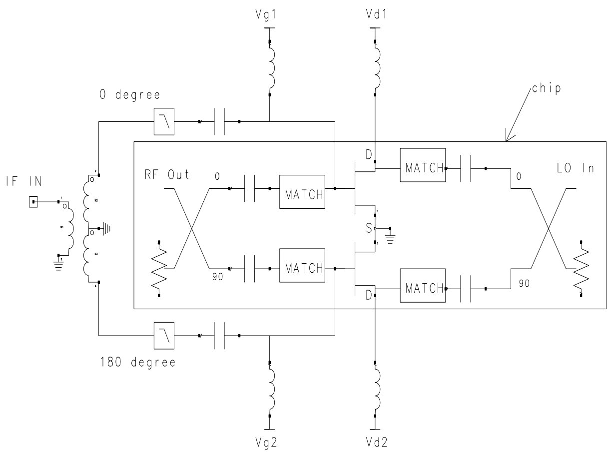


Fig. 1. Circuit schematic of the singly balanced millimeter wave mixer.

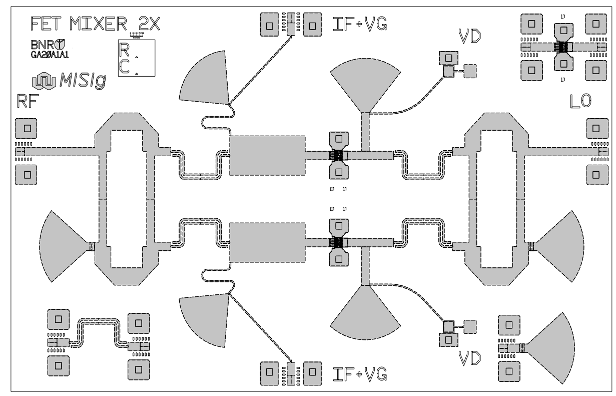


Fig. 2. Layout of the MMIC mixer chip (3×5 mm^2) with balanced configuration and PHEMT transistors. The chip is fabricated by MiSig 0.18 μm process.

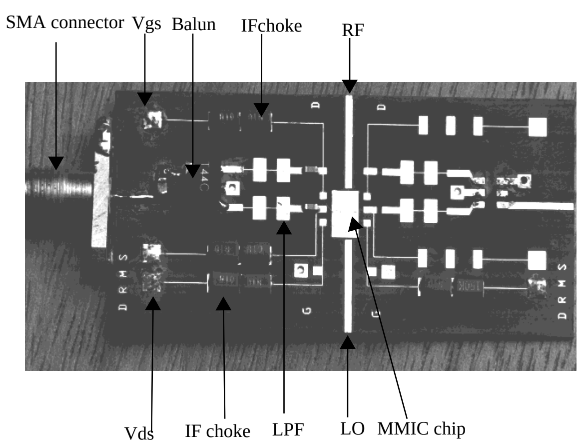


Fig. 3. Photograph of the test board (1×2 $inch^2$) with 10 mil Duroid substrate (ε_r=2.2) to provide LO, RF and IF signal paths and DC supply. The MMIC mixer is wire bonded on the substrate with via holes providing the ground. A 1:4 transformer is used to provide the anti-phase IF signals to the gates of the mixer chips. All measured performance in this paper is obtained at the ports of this test board.

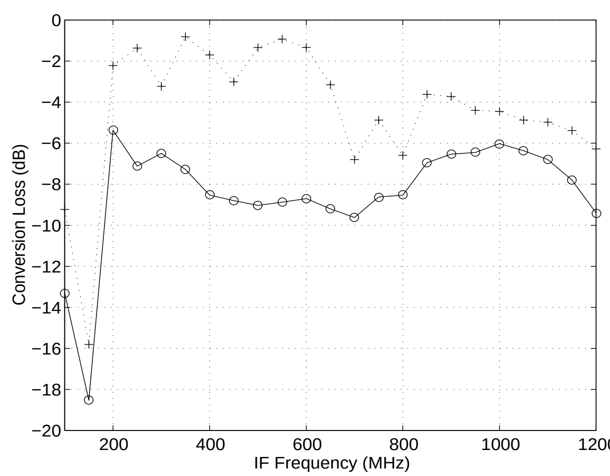
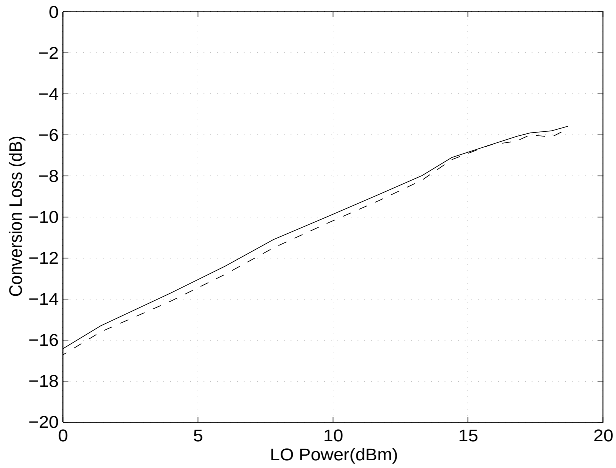


Fig. 4. Measured conversion loss as a function of IF frequency of the chip mixer on the test board with LO pumping power of 18 dBm at 37.5 GHz. The drains of the PHEMTs are self-biased and the gates-source (Vgs) are biased at pinch-off point of -0.3 V. All losses in the test board are included.
--o--o--: 50 Ohm IF impedance
...+...+...: matched IF impedance



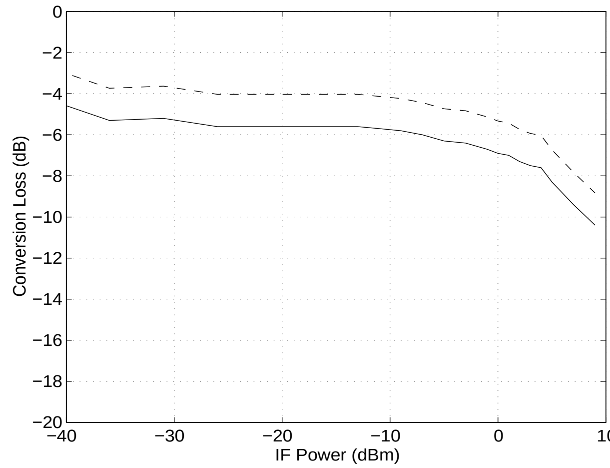
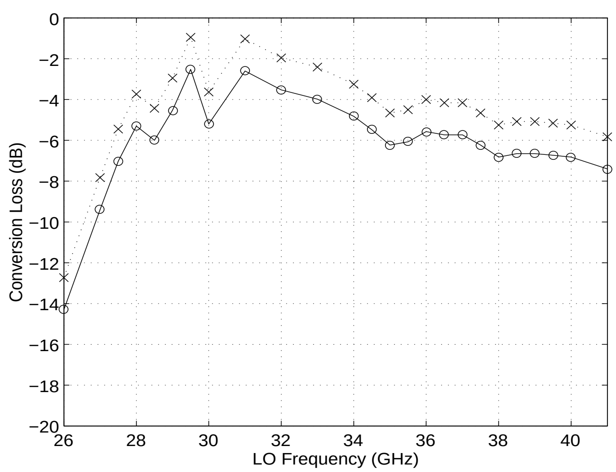


Fig. 5. Measured conversion loss as a function of LO power at 37.5 GHz under the condition of 1 GHz and -10 dBm IF power and 50 ohm IF impedance.The gates of the PHEMT (Vgs) are biased at pinch-off point of -0.3 V. All losses in the test board are included.
-----: drains self-biased
- - -: drains 0 biased

Fig. 6. Measured conversion loss versus IF input power for both 50 ohm IF impedance (solid line) and matched impedance (dashed line) and 1 GHz IF frequency and 37.5 GHz LO with 18 dBm driving power. Bias as stated in Fig. 4. All losses in the test board are included.
-----: 50 Ohm IF impedance
- - -: matched IF impedance



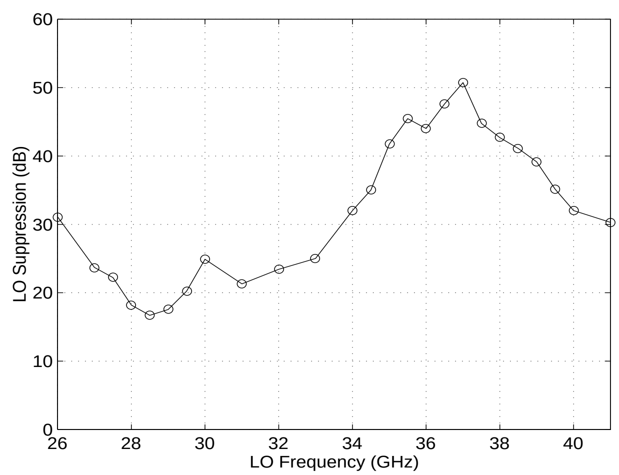


Fig. 7. Measured conversion loss versus LO frequency for 18 dBm LO power, 1 GHz IF frequency of 1, -10 dBm IF power, self-bias at drains and pinch-off at gates of the PHEMTs.
--o--o--: 50 Ohm IF impedance
....×...×...: matched IF impedance

Fig. 8. Measured LO to RF isolation versus LO frequency for -10 dBm IF input power, 1 GHz IF frequency and 18 dBm LO power. Bias is same as for Fig. 4.