DC-8 GHz 11 dB Gain GaInP/GaAs HBT Double Balanced Gilbert Micromixer

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ABSTRACT: A wideband GaInP/GaAs HBT micromixer is demonstrated from DC to 8 GHz with 11 dB single-ended conversion gain. The input return loss is better than 10 dB for frequencies up to 9 GHz. The single-to-differential input stage in Gilbert micromixer renders good wideband frequency response and eliminates the need for common mode rejection. P_{1dB} = -7 dBm and IIP_3 = -7 dBm are achieved for a small local oscillator power of –2 dBm when LO=5.35 GHz and RF=5.7 GHz.

INTRODUCTION: Micromixer proposed by Gilbert [1] is the ideal circuit for an RF high frequency wideband mixer. A GaInP/GaAs HBT Gilbert micromixer is demonstrated from DC to 8 GHz in this paper. The circuit schematic of the designed micromixer is illustrated in figure 1. The biased current source in a conventional Gilbert mixer contributes noise and deteriorates rapidly the common mode rejection ratio at high frequency. However, the single-to-differential input stage in Gilbert micromixer renders good wideband frequency response and eliminates the need for common mode rejection needed in a conventional Gilbert mixer. A single-to-differential stage is constructed with Q_5, Q_6, Q_7 and two resistors. The common-base-biased Q_5 and common-emitter-biased Q_7 provide equal but out of phase transconductance gain when Q_6 and Q_7 are connected as a current mirror. The common base configuration possesses good frequency response while the speed of common-emitter-configured Q_7 is improved drastically by adding the low impedance diode-connected Q_6 at the input of common-emitter-configured Q_7. Thus, the single-to-differential stage in figure 1 is suitable for wideband high frequency operation.

CIRCUIT DESIGN: The single-to-differential method is not only used to turn an unbalanced signal into balanced signals but also facilitates the wideband input RF impedance matching [1][2]. The resistance seeing into point A in figure 1 is equal to the parallel combination of the resistance seen into the up branch and the resistance seen into the down branch. For the up branch, the resistance is equal to 60 Ω resistance, the resistance series connected with the emitter of Q_5, plus the inverse of G_{m5}, the transconductance of Q_5. For the down branch, the resistance is equal to 60 Ω resistance, the resistance series connected with the collector of Q_6, plus the inverse of G_{m6}, the transconductance of Q_6. We can make the resistance seen into point A be 50 Ω by biasing the Q_5, Q_6 and Q_7 under the condition that the three transistors all have a transconductance value close to 25 mS.

A simple method called current-injection-bias is applied to enhance the conversion gain of the mixer. A current source which is also a diode-connected transistor Q_{cj1} (Q_{cj2}) as illustrated in figure 1 is added as another branch current, which can supply part of the DC current of the drain current of the single-to-differential stage. In other words, the tail current of differential pair in the LO stage joining with the current flowing in the added branch is the dc current of the collector current of the single-to-differential stage. By turning the current of the added branch larger, we can lower the DC current of the LO differential pair and further make the load resistor of the LO stage larger. Because the load resistor is related with the conversion gain of the mixer, we can make the conversion gain higher [3] by raising the value of the load resistor. Another single-to-differential stage with load resistors not shown in figure 1 is also used as LO buffer amplifier in the fabricated circuit.

EXPERIMENTAL RESULTS AND DISCUSSIONS: The micromixer is implemented with 1.4 μm emitter width GaInP/GaAs HBT process. The photo of the fabricated HBT micromixer is shown in figure 2. On-wafer measurement is performed and a single-ended IF output is used in the measurement. The supply voltage is 5 V. Figure 3 to figure 5 illustrate the high frequency experimental results when LO=5.35 GHz and RF=5.7 GHz. Conversion gain as a function of LO power is shown in figure 3. The maximum conversion gain is 11 dB for the single-ended output when the LO power is about –2 dBm. It is expected that a higher conversion gain can be achieved if the IF output is taken differentially. The conversion gain as a function of RF input power when LO power is –2 dBm is illustrated in figure 4. P_{1dB} is –7 dBm from figure 4. Finally, two tone intermodulation measurement is performed and results are shown in figure 5. IIP_3 = -7 dBm is obtained from figure 5.

The single-to-differential stage in a micromixer has intrinsically very wideband frequency response. Figure 6 illustrates the conversion gain as a function of RF frequency of the InGaP/GaAs HBT micromixer when IF is fixed at 350 MHz and RF power is –30 dBm. LO power has gradually increased from –5 dBm at 1 GHz to –2 dBm at 10 GHz to compensate the loss in the cable feeding mixer LO port and to obtain better conversion gain flatness. The RF-IF and LO-IF isolation are also shown in figure 6. LO-IF isolation is beneath –15 dB and RF-IF isolation is beneath –10 dB for all the frequencies. The LO-IF isolation of the Gilbert cell core is much better than –15 dB when the effect of LO buffer amplifier is taken away. RF-IF isolation can be further improved if the IF output signal is taken differentially [4]. The input return loss when IF signal is fixed at 350 MHz, LO power is –2 dBm and RF power is –30 dBm is illustrated in figure 7. The return loss is better than 10 dB for frequencies up to 9 GHz. It is obvious that the micromixer has 8 GHz RF 3-dB bandwidth. Figure 8 illustrates the conversion gain as a function of IF frequency when LO is fixed at 5.35 GHz. The results show that the InGaP/GaAs HBT micromixer has 850 MHz IF 3-dB bandwidth. The LO-IF and RF-IF isolation are better than 20 dB and are also illustrated in figure 8.

CONCLUSION: Gilbert cell variant topology is demonstrated in the double balanced mixer. The single-to-differential input stage in Gilbert micromixer renders good frequency response and eliminates the need for common mode rejection. It is found that the single-ended conversion gain of 11 dB is achieved from DC to 8 GHz. The linearity of this mixer is very good. The P_{1dB} is -7 dBm and IIP_3 is -7 dBm.

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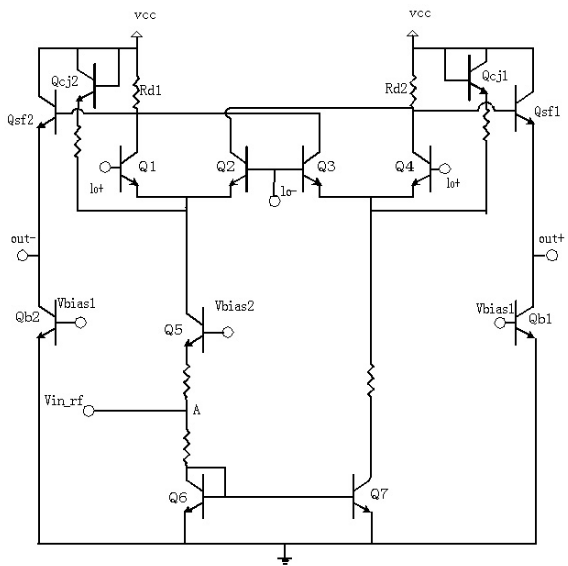


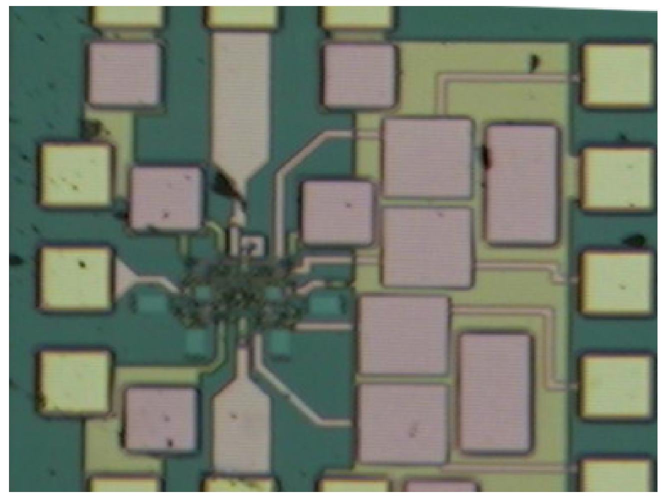
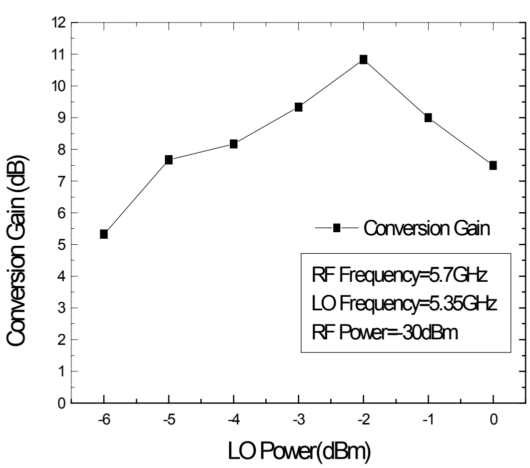


Fig. 1 Schematic of the GaInP/GaAs HBT balanced double balanced Gilbert micromixer

Fig. 2 Photo of GaInP/GaAs HBT double balanced Gilbert micromixer



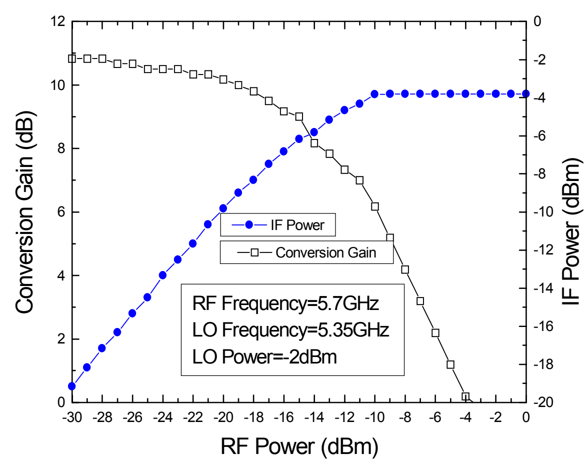


Fig. 3 Conversion gain of the GaInP/GaAs HBT double balanced Gilbert micromixer as a function of LO power.

Fig. 4 Conversion gain of the GaInP/GaAs HBT double balanced Gilbert micromixer as a function of RF power.

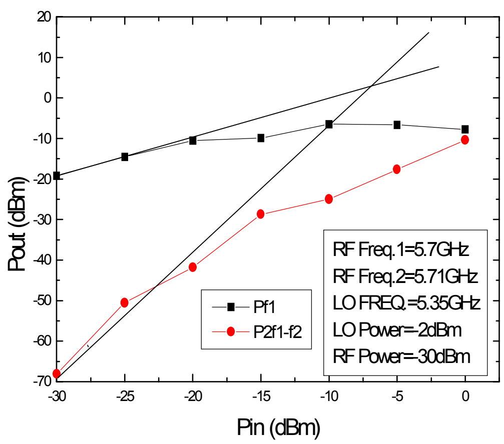


Fig. 5 Measurement of IIP3 of GaInP/GaAs double balanced Gilbert micromixer.

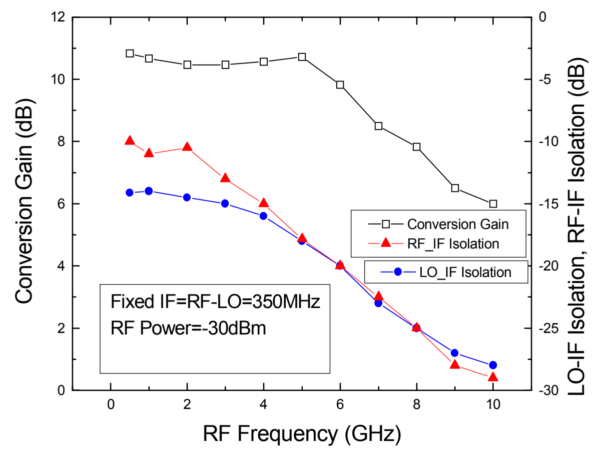


Fig. 6 Measured wide-band down-conversion HBT GaInP/GaAs HBT micromixer performance when IF frequency is fixed

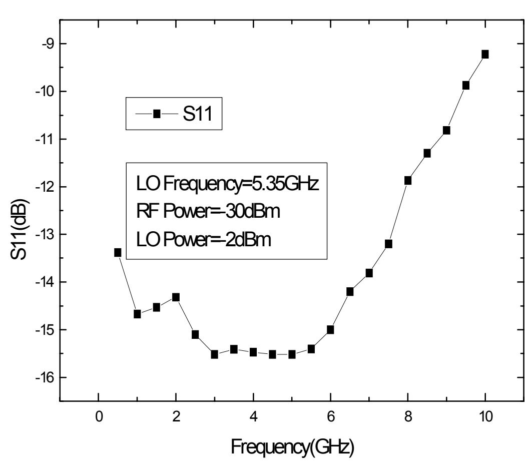


Fig. 7 Input matching characteristics of GaInP/GaAs HBT micromixer.

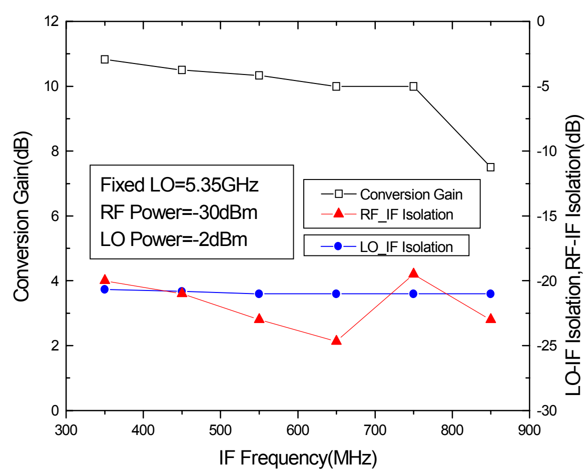


Fig. 8 Measured wide-band down-conversion micromixer GaInP/GaAs HBT performance when LO frequency is fixed.