Wideband Impedance Matched GaInP/GaAs HBT Gilbert Micromixer with 12 dB Gain

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ABSTRACT

A wide band GaInP/GaAs HBT micromixer with 12 dB conversion gain is demonstrated from DC to 9GHz. Input P_{1dB} of -4 dBm and IIP_3 of 2 dBm are also achieved. The supply voltage is 5 V and the total quiescent current of the circuit is 5mA including the bias circuit. The single-to-differential input stage in Gilbert micromixer renders good frequency response and eliminates the need for common mode rejection.

Keywords

micromixer、mixer、conversion gain、RF-to-IF isolation、LO-to-IF isolation、IIP3、S11、bandwidth.

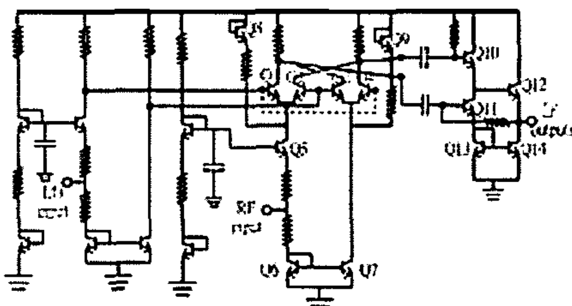

Figure 1: Schematic of the GaInP/GaAs HBT double balanced Gilbert micromixer.

1. INTRODUCTION

The biased current source in a conventional Gilbert mixer contributes noise and deteriorates rapidly the common mode rejection ration at high frequency. Micromixer proposed by Gilbert [1] is the ideal circuit for RF high frequency mixer. The circuit schematic of the designed micromixer is shown in figure 1. The single-to-differential input stage in Gilbert micromixer renders good frequency response and eliminates the need for common mode rejection needed in a conventional Gilbert mixer. A single-to-differential stage is constructed with Q5, Q6, Q7 and two resistors. The common-base-biased Q5 and common-emitter-biased Q7 provide equal but out of phase transconductance gain when Q6 and Q7 are connected as a current mirror. The common base configuration possesses good frequency response while the speed of common-emitter-configured Q7 is improved drastically by adding the low impedance diode-connected Q6 at the input of common-emitter-configured Q7. Thus, the single-to-differential stage in figure 1 is suitable for high frequency operation. In this paper, a GaInP/GaAs micromixer is demonstrated from DC to 9 GHz with a conversion gain of 12 dB.

2. CIRCUIT DESIGN

The single-to-differential method is not only used to turn a single signal into two balanced signals but also facilitate the input RF impedance matching [1][2]. The resistance looking into RF port in figure 1 is equal to the parallel combination of the resistance seen into the up branch and the resistance looking into the down branch. For the up branch, the total resistance is designed to be 100 Ω, which the sum of the resistance connected seriesly with the emitter of Q5 and the inverse of Gm5, the transconductance of Q5. For the down branch, the resistance is also designed to be 100 Ω, which is the sum of the resistance connected seriesly with the collector of Q6 and the inverse of Gm6, the transconductance of Q6. The resistance looking into RF port can be designed to be 50 ohm by biasing the Q5, Q6 and Q7 to have a transconductance value close to 20 mS.

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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 Q8 (Q9) as shown 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, by raising the value of the load resistor we can make the conversion gain higher [3]. Another single-to-differential stage with load resistors shown in figure 1 is also used as LO buffer amplifier in the circuit. Output buffer circuit shown in figure 1 is a push-pull type balun which is composed of a common emitter Q10 with degeneration and a common collector Q11. The output balun is used to cancel the LO and RF leakage at the output of the balun. The common-collector transistor Q12 is used to match output port to 50 Ω.

3. MEASUREMENT RESULT

The micromixer is implemented with 1.4 μm emitter width GaInP/GaAs HBT process. The photo of the fabricated HBT micromixer is shown in Fig. 2.

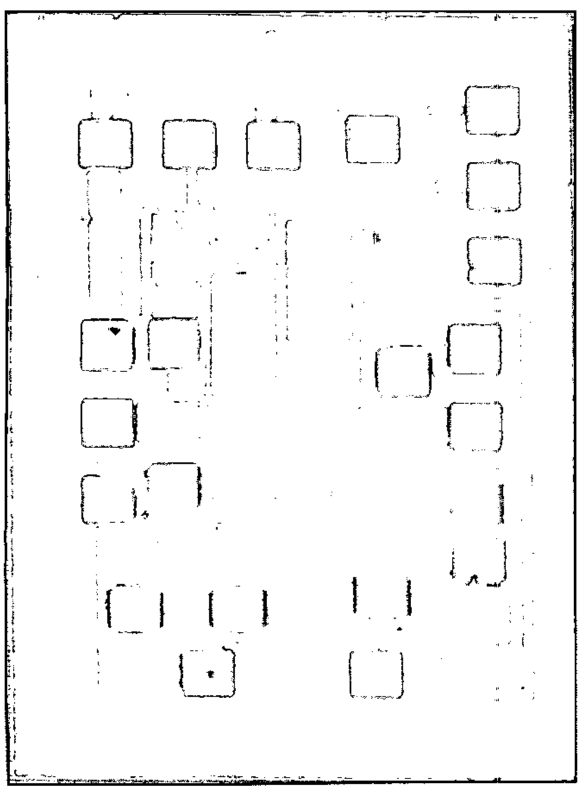

Figure 2: photo of GaInP/GaAs HBT double balanced Gilbert micromixer

On-wafer measurement is performed and a single-ended IF output is used in the measurements. The supply voltage is 5 V and the total quiescent current of the circuit is 5mA including the bias circuit. Figure 3 illustrates the conversion gain as a function of LO power when LO=5 GHz and RF=5.15 GHz. The conversion gain is 12 dB for single-ended output when the LO power is about –8 dBm. The LO-IF isolation is 34 dB and the LO-RF isolation is above 50dB when LO=5 GHz. The conversion gain as a function of RF input power when LO power is –8 dBm are illustrated in figure 4. P1dB is –4 dBm.

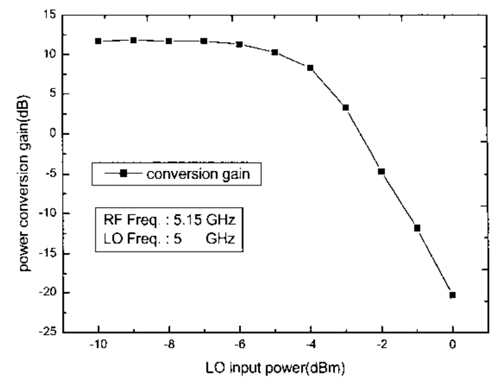

Figure 3: Conversion gain of the GaInP/GaAs HBT double balanced Gilbert micromixer as a function of LO power

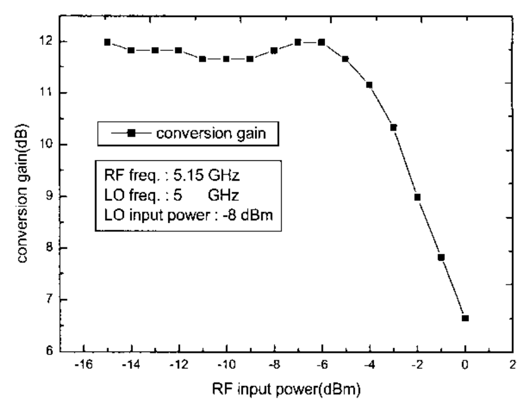

Figure 4: Conversion gain of the GaInP/GaAs HBT double balanced Gilbert micromixer as a function of RF power

Finally, two tone intermodulation measurement is performed and results are shown in figure 5. IIP_3 = 2 dBm is obtained from figure 5 and table 1. The single-to-differential stage in a micromixer has intrinsically very wide band frequency response.

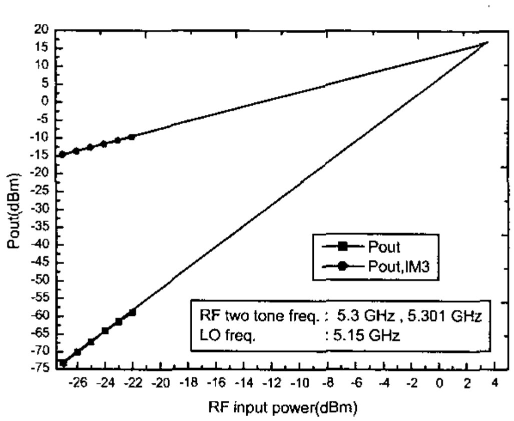

Figure 5: Measurement of OIP3 of GaInP/GaAs HBT double balanced Gilbert micromixer

Table 1: Calculated IIP3 of GaInP/GaAs HBT double balanced Gilbert micromixer

Pin (dBm)	Output power at 150MHz (dBm)	IM3 output power at 149MHz (dBm)	Calculated IIP3 (dBm)
27	-14.67	-73.33	2.33
-26	-13.67	-70.17	2.25
-25	-12.67	-67.33	2.33
-24	-11.67	-64.17	2.25
-23	-10.67	-61.5	2.41
-22	-9.67	-58.83	2.58
			Average: 2.36

Figure 6 illustrates the conversion gain as a function of RF frequency of the InGaP/GaAs HBT micromixer when IF is fixed at 150 MHz, LO power is –8dBm. The conversion gain is saturated for a –8 dBm LO power at all the LO frequencies. The RF-IF and LO-IF isolation is also shown in figure 6. LO-IF isolation is above 20 dB and RF-IF isolation is above 10 dB for all the frequencies. The input return loss when IF is fixed at 150 MHz, which LO power is –8 dBm, is illustrated in figure 7. The return loss is better than 25 dB for frequency up to 10 GHz. It is obvious that the micromixer has 9 GHz RF 3-dB bandwidth.

4. 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 a conversion gain of 12 dB are achieved from DC to 9 GHz for a small local oscillator power of –8 dBm. The linearity of this mixer is very good: the input P_{1dB} is -4 dBm and IIP_3 is 2 dBm.

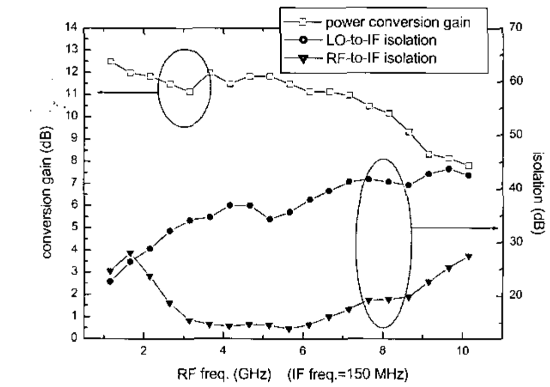

Figure 6: Measured wide-band down-converter GaInP/GaAs HBT micromixer performance when IF frequency is fixed

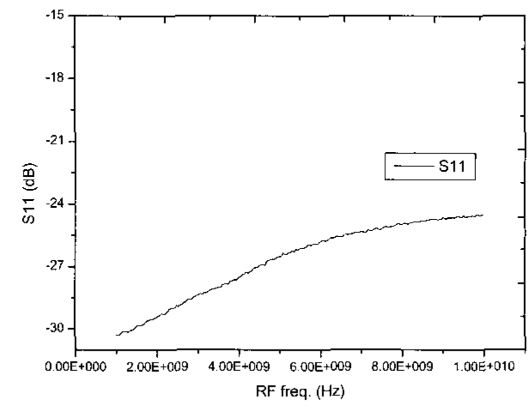

Figure 7: Measured input matching characteristics of GaInP/GaAs micromixer

5. ACKNOWLEDGMENTS

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