5.2 GHz SiGe HBT upconverter using active-inductor LC current mirror

T.-H. Wu, C. Meng and T.-H. Wu

A compact 5.2 GHz upconversion micromixer using the 0.35 μm SiGe HBT technology is demonstrated. A bandpass and area-saving LC current mirror using the active inductor is incorporated to increase the conversion gain. The demonstrated upconverter has conversion gain of −3.5 dB, OP_{1dB} of −10 dBm, and OIP_3 of 0 dBm.

Introduction: Recently, the bandpass LC current mirror has been used to increase conversion gain by combining the output differential currents at the high frequency [1, 2]. However, the passive inductors employed in the LC current mirror always occupy large chip area. In this work, the passive inductors in the LC current mirror are replaced by the active inductors consisting of the common-collector transistors and feedback resistors to save die area and still preserve upconverter performance.

Active inductors have been widely used in LC tank circuits, monolithic filters, and matching networks [3, 4]. Compared with the passive counterparts, silicon active inductors have major advantages over spiral inductors in terms of area, inductance tuning capability, and higher quality factor, at the expense of linearity, higher current consumption, and noise performance degradation. In the upconverter application, the noise performance is insignificant and the power amplifier basically dominates the linearity of the whole transmitter chain. The active inductors are incorporated in a current-reused topology in this work. Consequently, the active inductor is adopted in our upconversion mixer design.

Circuit design: The circuit schematic diagram of the 5.2 GHz SiGe upconverter is shown in Fig. 1. The demonstrated upconversion Gilbert mixer consists of a micromixer input (transistors $Q_5 - Q_8$, and resistors $R_1 - R_4$), an LO current-commutation cell (transistors $Q_1 - Q_4$), an LC current mirror (transistors $Q_9 - Q_{10}$, resistors $R_5 - R_6$, and the capacitor C_1), and a Darlington output buffer. The input stage of the upconverter is the single-to-differential micromixer topology [5]. The chip area can be saved because no inductors and capacitors are used at the input port for impedance matching.

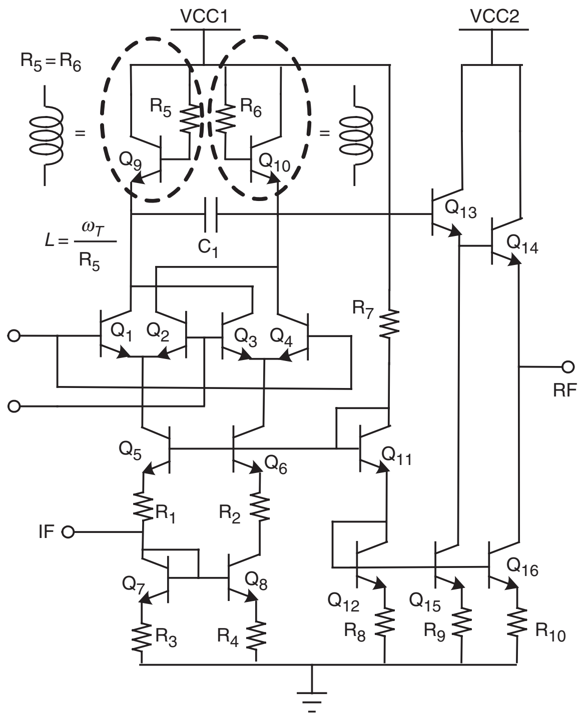

Fig. 1 *Schematic diagram of upconversion micromixer using active-inductor LC current mirror*

The common-collector transistor $Q_9(Q_{10})$, and the resistor $R_5(R_6)$ are designed together to function as an inductor when looking into the emitter terminal. The LC current mirror is able to double the output current at the resonant frequency $f_0 = 1/2\pi\sqrt{(1/2LC_1)}$, which is the designated output RF frequency. The active inductor is valid for the frequency ranging from $f_p = 1/2\pi(R_5//r_{\pi 9})C_{\pi 9}$ to the transistor cutoff frequency, f_T [6]. The $C_{\pi 9}$, $r_{\pi 9}$, R_5 and f_{T9} are 0.3 pF, 700 Ω, 300 Ω and 25 GHz, respectively; therefore the output impedance of the common-collector transistor keeps inductive from 1.8 to 25 GHz in this work.

Measurement results and conclusion: The 0.35 μm SiGe HBT device has BV_{CEO} of 2.5 V, and the maximum f_T of 67 GHz when the current density is 3 mA/μm^2 at $V_{CE} = 1$ V. The photograph of the fabricated circuit is shown in Fig. 2, the total chip area being 0.89 × 0.83 mm^2. Obviously, the pads for the on-wafer measurement dominate the chip area, and the mixer only occupies a small chip area of 200 × 200 μm, as shown in Fig. 2. The supply voltage is 3.3 V, and the current consumption is 9 mA. The peak conversion gain of the demonstrated upconverter is −3.5 dB when the LO power reaches −1 dBm. As shown in Fig. 3, the OP_{1dB} is −10 dBm and the OIP_3 is 0 dBm. Despite using the active inductors, the measured power performance is acceptable. The micromixer input stage is wideband and the measured IF input return loss is better than 10 dB for the frequencies up to 20 GHz. The measured output return loss is better than 30 dB from 3 to 7 GHz. The LO-to-RF isolation of the mixer is 35 dB when the LO input frequency is 4.9 GHz, while the LO-to-IF isolation is 34 dB.

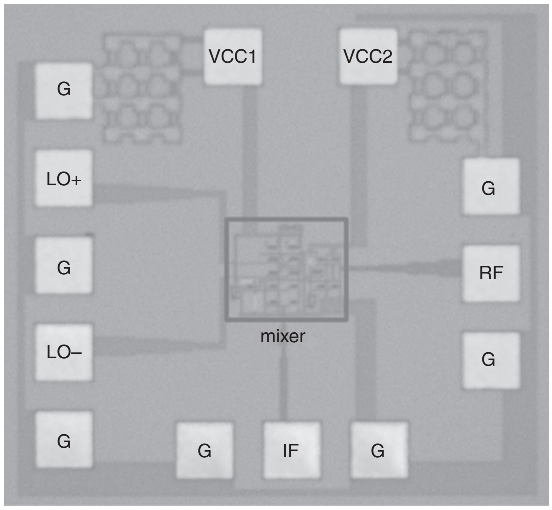

Fig. 2 *Photograph of upconversion micromixer using active-inductor LC current mirror*

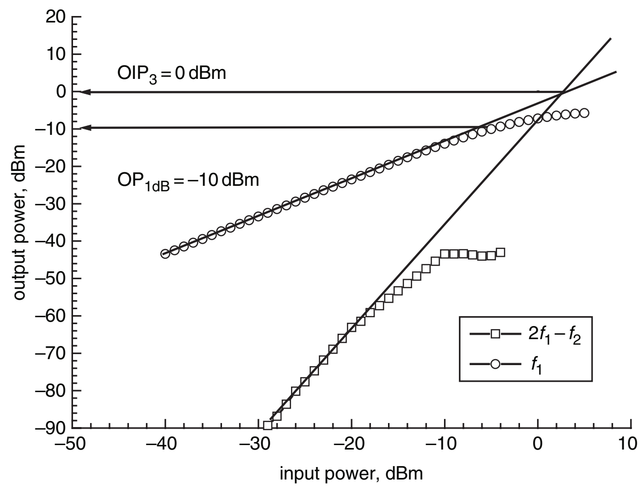

Fig. 3 *Power performances of upconversion micromixer using active-inductor LC current mirror*

The conversion gain against RF frequency shown in Fig. 4 has a bandpass frequency response with the peak at 5.2 GHz. The experimental result of the conversion gain against RF frequency manifests the effectiveness of the bandpass active-inductor LC current mirror.

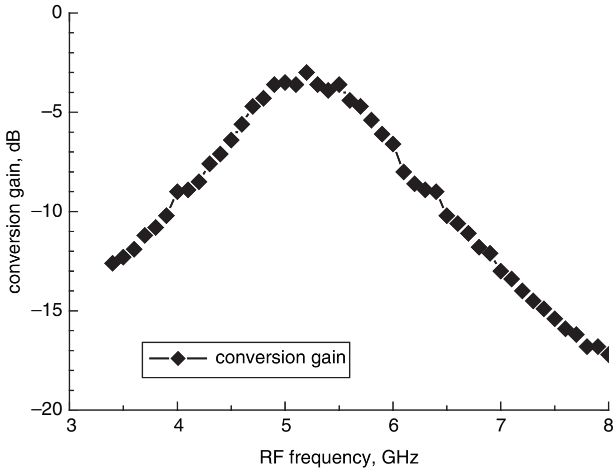

Fig. 4 *Conversion gain against RF frequency of upconversion micromixer using active-inductor LC current mirror*

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