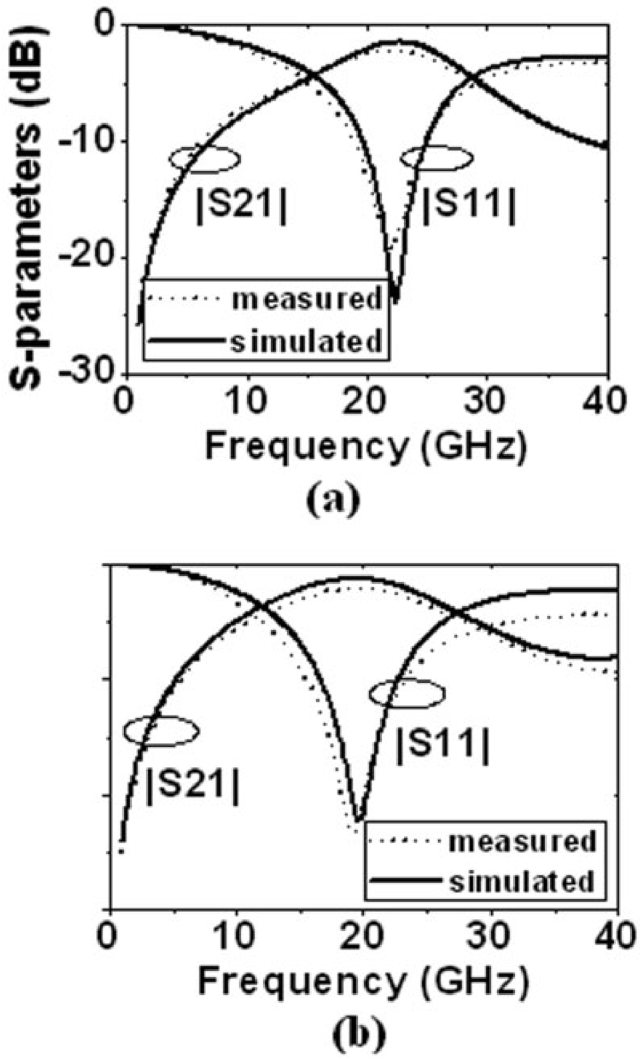

Figure 9 Simulated and measured frequency responses of the designed one-stage broadside-coupled filters. (a) Filter with solid ground; (b) filter with UC-PBG ground

ACKNOWLEDGMENTS

The authors would like to acknowledge SMIC (Shanghai) RF group for the IC implementation. This work is supported by Shanghai (China) Natural Science Foundation under grant 06ZR14103.

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COMPARISON OF WIDEBAND GILBERT MICROMIXERS USING SIGE HBT AND GAINP/GAAS HBT TECHNOLOGIES

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Received 7 January 2008

ABSTRACT: *Wideband downconversion mixers are demonstrated by using both 0.35-μm SiGe heterojunction bipolar transistor (HBT) and 2-μm GaInP/GaAs HBT technologies. A micromixer topology is implemented in the RF port while a differential type shunt–shunt feedback amplifier and a differential-to-single CE-CC output buffer are used in the IF stage. The frequency response analysis and systematic measurement approach for a wideband Gilbert mixer are proposed in this article for each individual stage of local frequency (LO), radio frequency (RF), and intermediate frequency (IF). The differential LO signals are generated by several off-chip 180° hybrids to cover more than 8:1 bandwidth. The SiGe HBT Micromixer achieves the conversion gain of 6 dB, IP_{1dB} of −17.5 dBm, and IIP_3 of −7 dBm with the 3.3-V supply voltage and the power consumption of 37.5 mW. On the other hand, the GaInP/GaAs HBT Micromixer achieves the conversion gain of 25 dB, IP_{1dB} of −25 dBm, and IIP_3 of −15 dBm with the 5-V supply voltage and the power consumption of 50 mW.* © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 2254–2257, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23642

Key words: *SiGe; GaInP/GaAs; heterojunction bipolar transistor (HBT); micromixer; shunt-shunt feedback; CE-CC*

1. INTRODUCTION

A Gilbert mixer topology is widely used in the RF mixer design [1, 2] when compared with the passive mixer design [3], because the local frequency (LO) pumping power is not large especially for the bipolar transistors employed in the mixer core. Both RF and IF bandwidths of active mixers were measured in [4, 5]. In this article, a measurement approach to determine the frequency response for each LO, RF, and IF stage is proposed. To separate the effects of each frequency response of these three stages, the schematic of the wideband Gilbert downconversion micromixer is shown in Figure 1.

2. CIRCUIT DESIGN

The photographs of the downconversion mixers using 0.35-μm SiGe HBT and 2-μm GaInP/GaAs HBT technologies are illustrated in Figures 2(a) and 2(b). The die sizes are 0.75 mm × 0.75 mm and 1 mm × 1 mm, respectively. The downconverter is

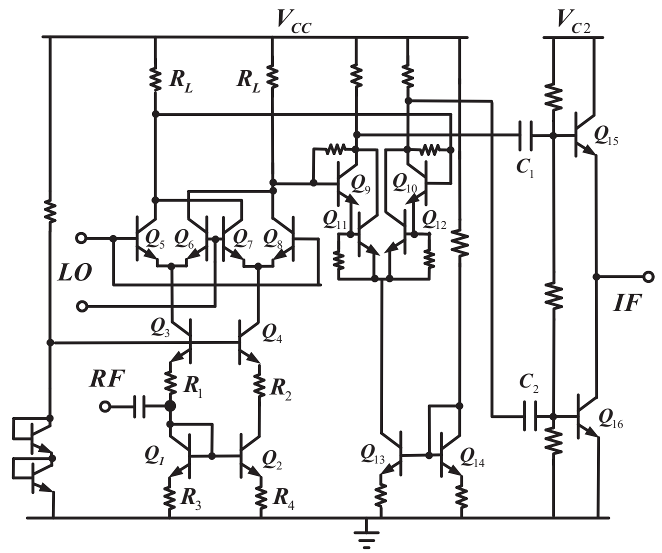


Figure 1 The schematic of the downconversion Gilbert micromixer

constructed by a well-known micromixer [6–8], shunt–shunt feedback amplifiers and a differential-to-single CE-CC output buffer. The micromixer is formed by a common-emitter-configured transistor Q_2 with emitter degeneration resistor, and common-base-configured transistor Q_3 to generate differential ac currents. Larger dc current leads to higher frequency response, more voltage drop from the resistors (R_1–R_4), which are used for resistive matching of the input stage, and thus higher supply voltage. Two differential pairs with crossed output connection of Q_5–Q_8 are employed in the LO stage and operate in the large signal switching mechanism. The output stage is formed of a differential shunt–shunt feedback transimpedance amplifier, Q_9–Q_{12}, a differential-to-single CE-CC output buffer, Q_{15}–Q_{16}, and blocking capacitors, C_1 and C_2.

3. FREQUENCY RESPONSE ANALYSIS

The analysis of the Gilbert mixer frequency response in this work can be separated into the RF input stage, the LO switching stage, and the IF output stage. The frequency responses of these three stages are described as follows:

3.1. RF Input Stage

The micromixer topology employed in the RF stage can be decomposed of two single balanced mixers with a common-emitter (CE) with emitter degeneration resistor stage and a common-base (CB) input stage, as illustrated in Figures 3(a) and 3(b), respectively. The transconductance gains are the same for both single balanced mixers except for the signs as shown in Figure 3.

3.2. LO Switching Stage

Bipolar transistors used in a Gilbert cell, shown in Figure 4, have the advantage that only several times of the thermal voltage (V_T) is needed for the LO input voltage swing to achieve the large signal switching mechanism [9–11] as shown in Figure 5. At high frequencies, the LO switching stage can be treated as charging and discharging the capacitors of the bipolar transistors. Consequently, the higher frequency is, the more pumping power is needed to make the LO stage operate properly, as shown in our measurement of Figure 6. However, as LO pumping power is too large, the transistors in the Gilbert cell are driven into the saturation region and then the conversion gain degrades.

3.3. IF Output Stage

The IF output buffer consists of a differential shunt–shunt feedback amplifier and a CE-CC buffer to realize a differential-to-single output stage [8]. The shunt–shunt feedback amplifier is employed to extend the IF bandwidth. Two dc blocking capacitors are used before the CE-CC buffer.

4. MEASUREMENT APPROACH

For the measurement of Gilbert mixers, we can just increase the LO pumping power to make the mixer core commutate RF currents with LO frequency perfectly, and thus LO stage is irrelevant to the conversion gain in general cases.

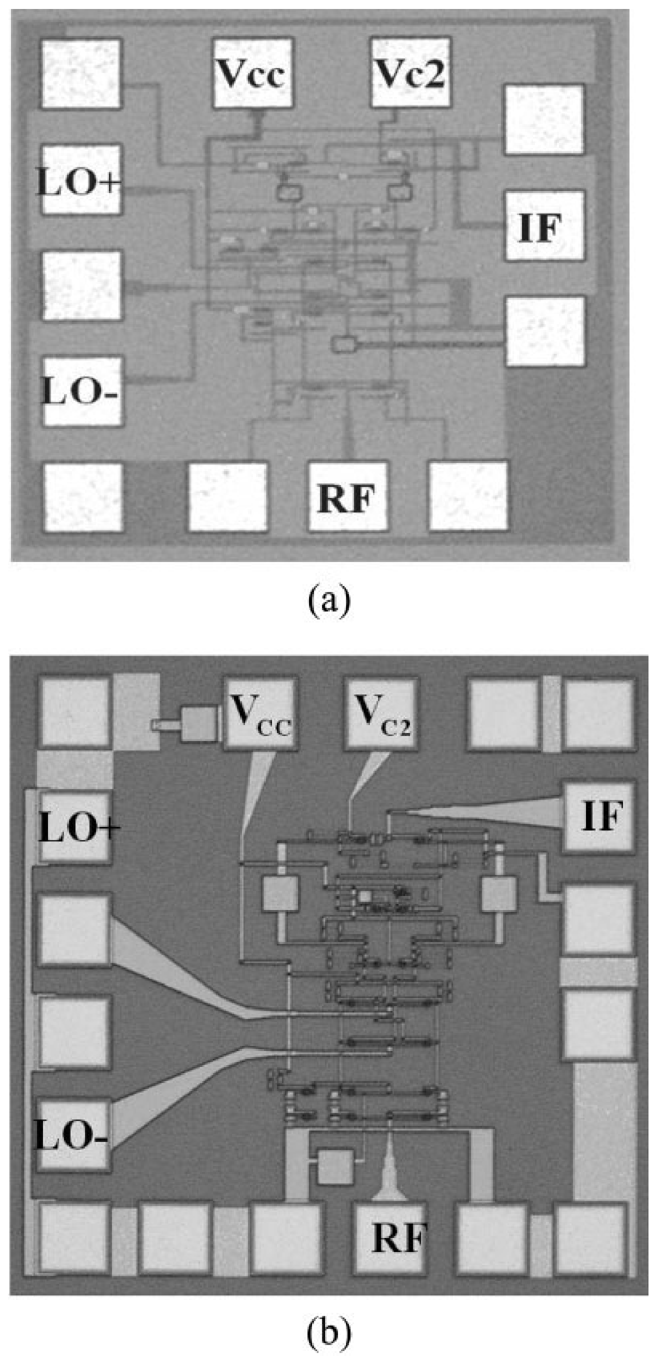
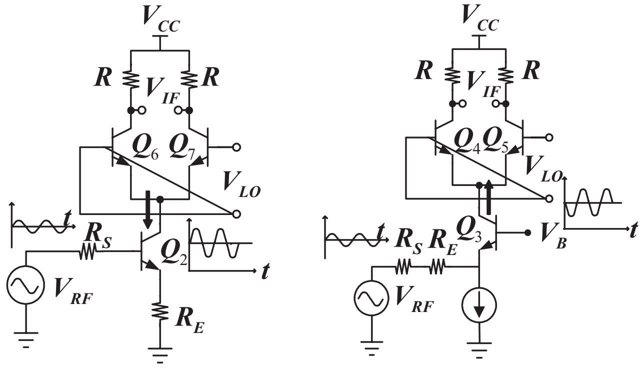


Figure 2 The photographs of the downconversion Gilbert micromixer (a) using 0.35-μm SiGe HBT technology (b) using 2-μm GaInP/GaAs HBT technology



(a) (b)

Figure 3 (a) A single balanced mixer with CE with emitter degeneration resistor input stage. (b) A single balanced mixer with CB input stage

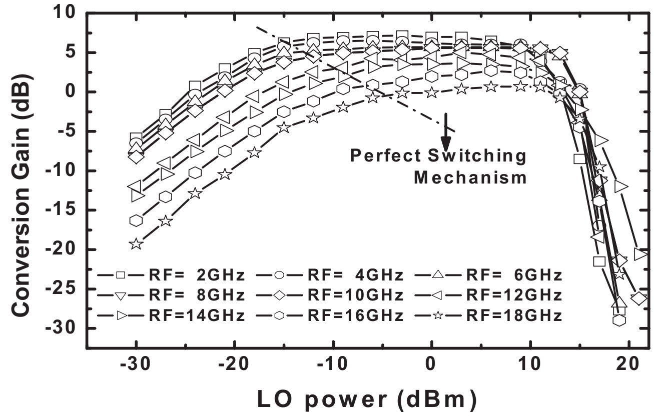


Figure 6 The conversion gain of the SiGe HBT downconversion mixer with respect to LO power

Therefore, finding proper LO pumping power is the first step in all the frequency response measurements. As shown in Figures 6 and 7, the gain response for the fixed IF frequency is obtained by sweeping RF frequencies while keeping the difference between RF and LO constant. Thus the perfect large signal switching mechanism region can be defined.

Secondly, an appropriate LO power, in the common flat gain region, is chosen so that the same LO large signal switching response at different LO frequencies is maintained. As a result, the effect of both LO and IF stages can be eliminated in the process of determining the RF frequency response.

Finally, because the frequency responses of the RF and LO stages are much higher than that of the IF output stage. Therefore, the IF bandwidth is obtained by sweeping RF frequencies when LO frequency is fixed.

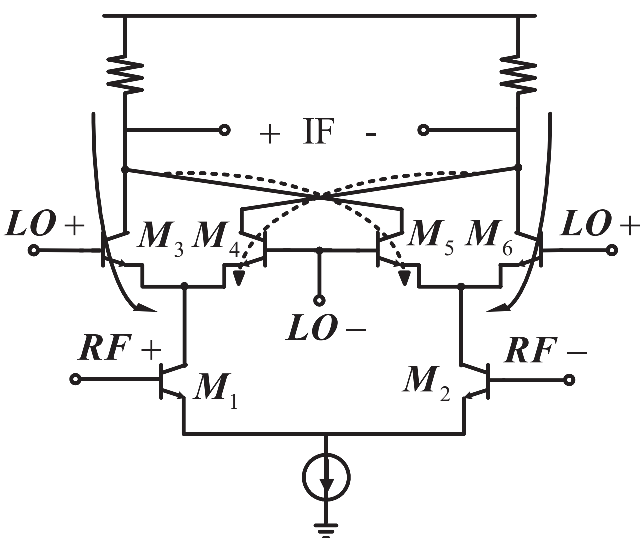
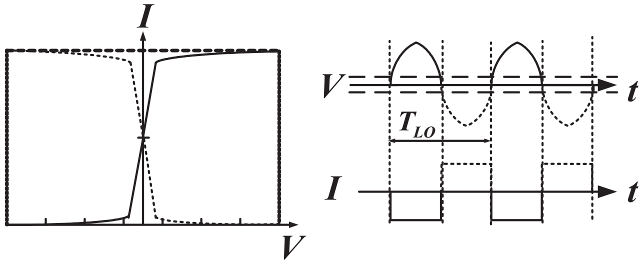


Figure 4 The switching mechanism of a Gilbert mixer



(a) (b)

Figure 5 (a) I–V characteristics of emitter-coupled pair used in LO stage. (b) The timing diagram of the input voltage and output current

5. MEASUREMENT RESULTS

Both IF and RF ports are single-ended and convenient for the on-wafer measurement. The differential LO signals are generated by several external passive 180° hybrids for suitable frequency bands instead of an on-chip balun because a very wideband, more than 8:1 bandwidth ratio, passive balun is difficult to design. Therefore, the allowable frequency band of measurement is limited by the external passive hybrids.

The conversion gain as a function of LO power of the SiGe and GaInP/GaAs downconverters for RF ranging from 2 GHz to 18 GHz are shown in Figures 6 and 7, respectively. There is a flat conversion gain region for each frequency. The higher the LO frequency is, the narrower the flat gain region is.

Next, for the RF bandwidth determination, we choose IF = 950 MHz and LO power = 0 dBm to make sure that the mixer core commutates RF current perfectly for the LO frequencies ranging from 1.05 to 17.05 GHz. As a result, the RF 3-dB bandwidth of the SiGe HBT downconverter is around 14 GHz as shown in Figure 8 while the GaInP/GaAs HBT downconverter has the bandwidth of

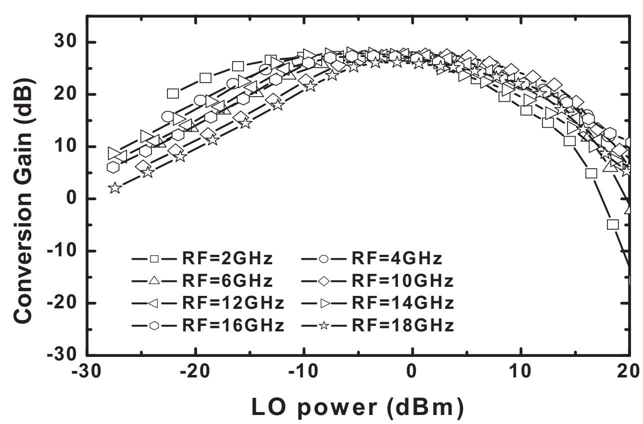


Figure 7 The conversion gain of the GaInP/GaAs HBT downconversion mixer with respect to LO power

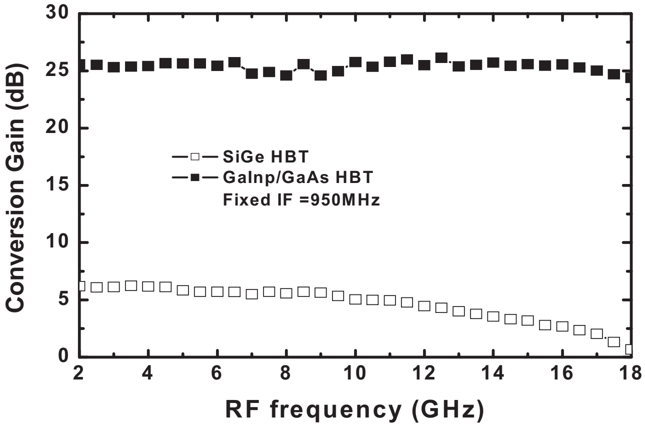


Figure 8 The conversion gain of the downconversion mixers with respect to RF frequency with LO power = 0 dBm

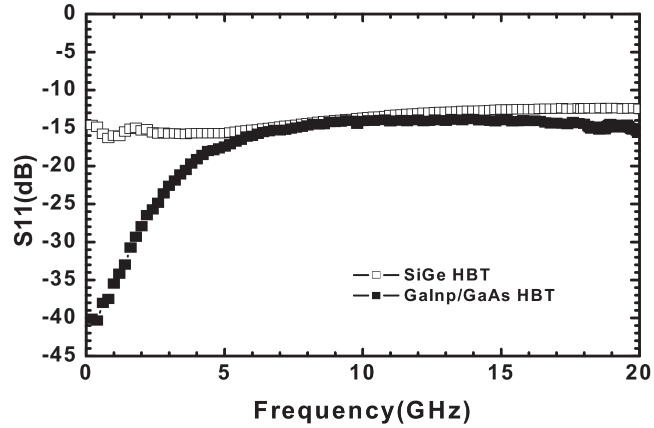


Figure 10 Input and output return loss of the downconversion mixer using 0.35-μm SiGe HBT and 2-μm GaInP/GaAs technologies

more than 18 GHz but the measurement is limited by the external baluns used in the LO stage. The IF 3-dB bandwidth is from 0.2 to 1.5 GHz and almost the same for different LO frequencies. The low frequency response falls off because of the blocking capacitors, C_1–C_2, in the output buffer. The IP_{1dB}, OP_{1dB} and IIP_3 of the downconversion mixers are measured as shown in Figure 9. Figure 10 shows that RF input return loss for both SiGe and GaInP/GaAs downconverters is better than 12 dB over 20 GHz

6. CONCLUSION

Wideband downconversion mixers are demonstrated using 0.35-μm SiGe HBT and 2-μm GaInP/GaAs technologies. This article presents a systematic measurement procedure to determine the frequency responses of LO, RF, and IF stages of wideband Gilbert mixers. First of all, by sweeping LO power at different LO frequencies the suitable LO power for the flat gain region can be obtained. Secondly, sweeping the RF frequency while keeping the IF frequency constant can find the RF frequency response. Finally, the IF bandwidth can be obtained by fixing the LO frequency while sweeping the RF frequency.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance and support of the Chip Implementation Center (CIC) and NDL RF Group. This work is supported by National Science Council of Taiwan, Republic of China under contract numbers NSC 96–2752-E-009–001-PAE, NSC 95–2221-E-009–043-MY3, by the Ministry of Economic Affairs of Taiwan under contract number 95-EC-17-A-05-S1–020, and by MoE ATU Program under contract number 95W803.

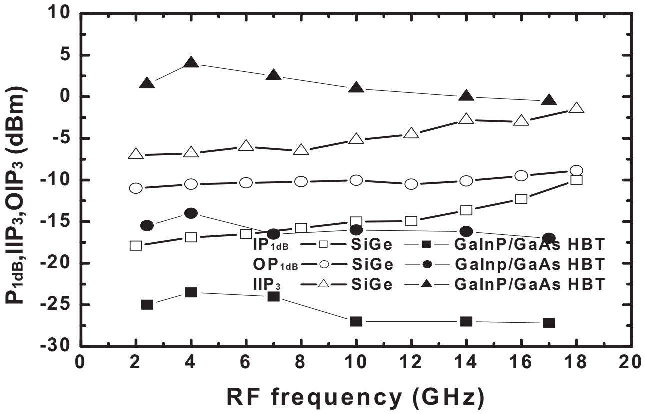


Figure 9 P_{1dB} and IIP_3 and OIP_3 of the downconversion mixers using 0.35-μm SiGe HBT and 2-μm GaInP/GaAs technologies

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