A Fully Integrated 5.2 GHz Double Quadrature Image Rejection Gilbert Downconverter Using 0.35 μm SiGe HBT Technology

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***Abstract* — A 5.2 GHz 1 dB conversion gain, IP_{1dB}= -19 dBm and IIP_3= -9 dBm double quadrature Gilbert downconversion mixer with polyphase filters is demonstrated by using 0.35 μm SiGe HBT technology. The image rejection ratio is better than 47 dB when LO=5.17 GHz and IF is in the range of 15 MHz to 45 MHz. The Gilbert downconverter has four- stage RC-CR IF polyphase filters for image rejection. Polyphase filters are also used to generate LO and RF quadarture signals around 5 GHz in the double quadrature downconverter.**

I. INTRODUCTION

Recently, integrated polyphase filters and the double quadrature configuration have been used in the low IF topology in CMOS technology [1], [2], [3], [4]. A low-IF receiver topology consists of RF IQ paths and the integrated polyphase filters to eliminate the off–chip noise filters and IF filters for image rejection. When a large image rejection is required such as in a low-IF topology, a double quadrature downconversion arrangement is better than a single quadrature downconversion arrangement because the double quadrature downconversion has less quadrature accuracy requirement. The LO and RF quadrature signal generation can be implemented by the polyphase filters in a double quadrature downconverter. An HBT transistor has better device matching property than a MOS device. Thus, it is desirable to have a high image rejection double quadrature Gilbert downconverter with polyphase filters in the SiGe HBT technology. The fabricated SiGe HBT double quadrature Gilbert downconversion mixer with polyphase filters has 1 dB conversion gain, IP_{1dB}= -19 dBm and IIP_3= -9 dBm at 5.2 GHz. The image rejection ratio is better than 47 dB when LO=5.17 GHz and IF is in the range of 15 MHz to 45 MHz. The supply voltage is 2.7 V and current consumption is 10 mA.

II. CIRCUIT DESIGN

Figure 1 illustrates the system block diagram of a double quadrature downconverter with polyphase filters. Differential RF and differential LO signals are fed externally and two polyphase filters are used to generate LO and RF differential quadrature signals.

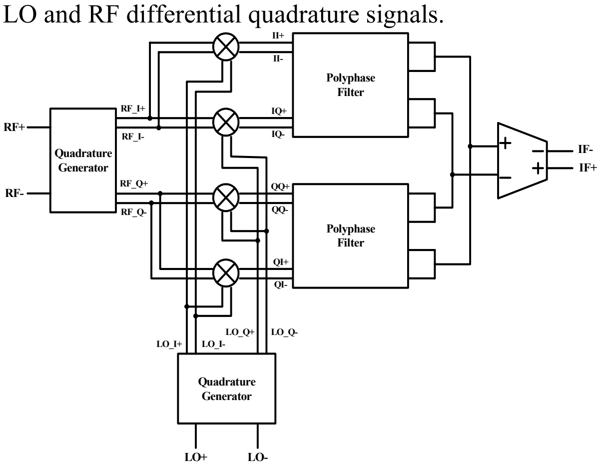


Figure 1 Block diagram of a double quadrature downconversion mixer with polyphase filters.

Four Gilbert multipliers are used in figure 1 to form a complex mixer. Thus, the desired signal and the image signal will appear in different rotational sequences at the output of the complex mixer as explained in reference [1]. Then the image signal will be filtered away by the IF polyphase filters and the desired signal will pass directly through the IF stage. The differential quadrature IF signals following the IF polyphase filter are combined into differential signals by properly shorting the differential quadrature IF signals.

Figure 2 illustrates the detailed schematic of the image rejection downconverter. Two-stage polyphase filters are used to generate both LO and RF differential quadrature signals from their differential counterparts. A conventional Gilbert cell with a differential common collector output buffer is used as the multiplier. The image rejection is performed by using two four-stage RC-CR polyphase filters. The differential quadrature IF signals are combined into differential signals by properly shorting the differential quadrature IF signals and a differential buffer amplifier is also included in the IF final stage as illustrated in figure 2.

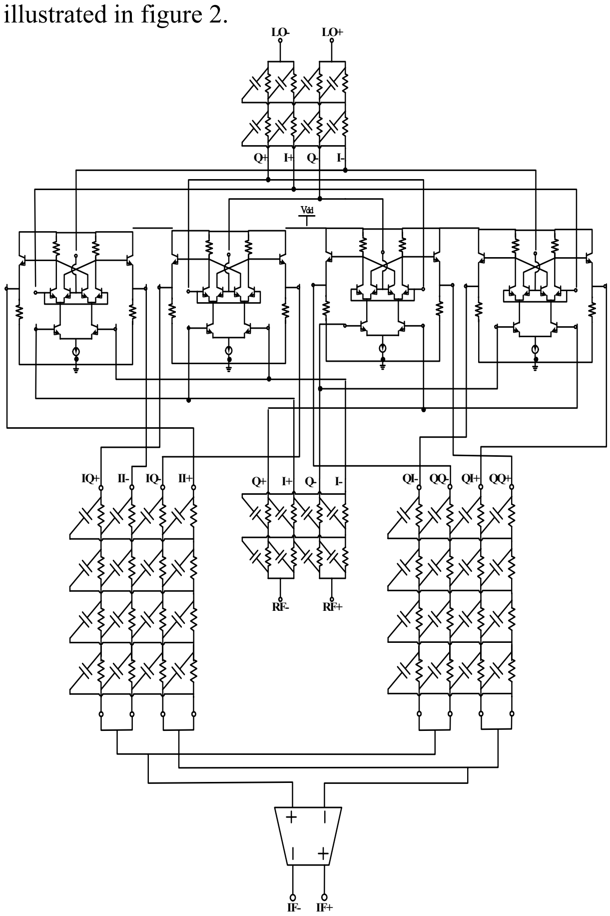


Figure 2 Circuit schematic of a SiGe HBT double quadrature downconversion mixer with polyphase filters.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

The die photograph of a SiGe HBT double quadrature downconverter mixer with polyphase filters is shown in figure 3. The die size is 1x1 mm^2. The SiGe HBT device used in this work has BV_{CEO}=3.8 V and peak f_t around 49 GHz. On-wafer RF measurements are performed because the fabricated circuit in figure 3 has a balanced GSGSG RF input on the left side of the chip, a GSGSG IF output on the right side and a balanced GSGSG LO input on the bottom side. Two ratrace couplers are used to convert the single-ended signals to differential signals. One ratrace for RF signals is centered at 5.2 GHz and the other ratrace for LO signals is center at 5.17 GHz. The phase imbalance is less than 1^o and the magnitude imbalance of the ratrace is less than 0.03 dB in 0.1 GHz bandwidth. Bias tees are inserted between the retrace and the signal generator to provide dc bias for transistors at RF and LO ports.

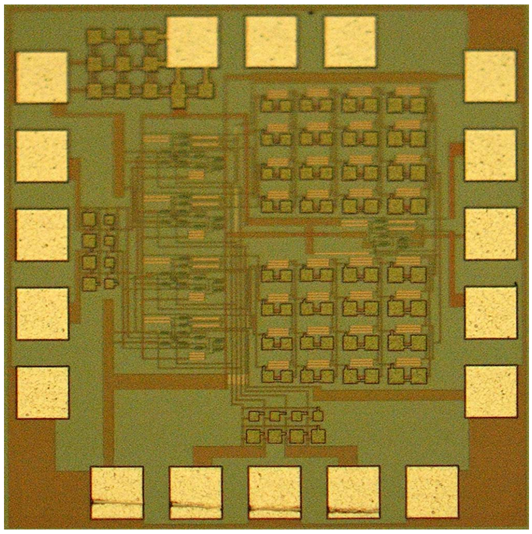


Figure 3 Photograph of a SiGe HBT double quadrature downconverter with poly phase filters

The conversion gain is 1 dB for 0 dBm LO pumping power when LO=5.17 GHz and RF=5.2 GHz. The conversion gain varies within 1 dB while LO power changes from 0 dBm to 10 dBm as shown in figure 4. In other words, the required LO power is small and there exists a wide range of LO power for optimum conversion gain. A Gilbert mixer core implemented with bipolar type technology needs a small local oscillator power and has a wide range of LO power for optimum conversion gain. When LO power equals to 0 dBm, the LO-to-IF isolation measurement results are illustrated in figure 5. 48 dB LO-IF isolations are achieved in the downconverter when LO frequency is around 5.2 GHz. The circuit has more than 49 dB RF-IF isolation as shown in the figure 6 when LO frequency is at 5.17 GHz and power equals to 0 dBm.

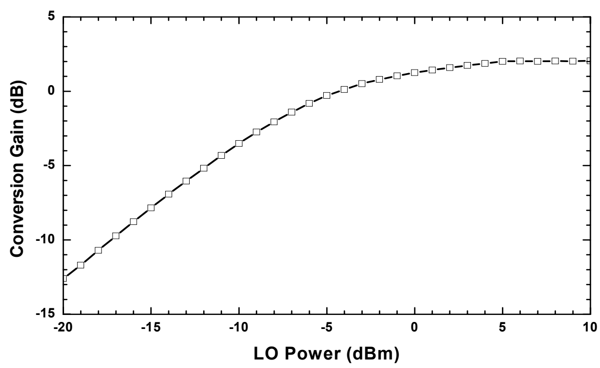


Figure 4 Conversion gain as a function of LO power of the SiGe HBT double quadrature downconverter with poly phase filters.

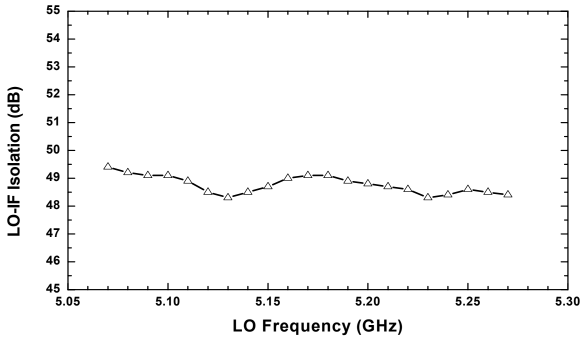


Figure 5 Measured LO-IF isolation of the SiGe HBT double quadrature downconverter with poly phase filters.

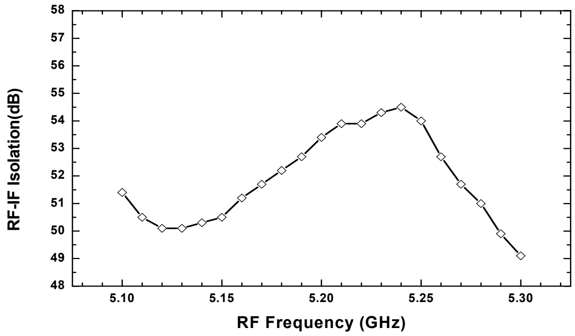


Figure 6 Measured RF-IF isolation of the SiGe HBT double quadrature downconverter with poly phase filters.

The one-tone and two-tone power performance is shown in figure 7 and figure 8, respectively. The fabricated SiGe HBT double quadrature Gilbert downconversion mixer with polyphase filters has 1 dB conversion gain, IP_{1dB}= -19 dBm and IIP_3= -9 dBm. All the power measurements are performed when RF=5.2 GHz and LO=5.17 GHz at 0 dBm.

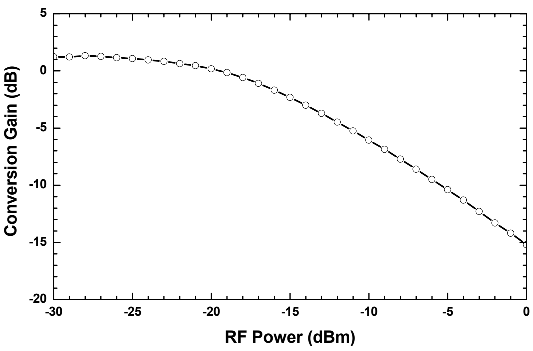
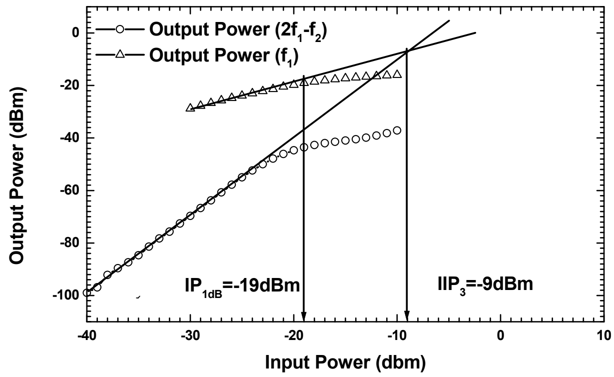


Figure 7 One tone power measurements of the SiGe HBT double quadrature downconverter with poly phase filters.



Figuire 8 One tone and two tone power measurements of the SiGe HBT double quadrature downconverter with poly phase filters.

Figure 9 illustrates the conversion gain as a function of positive IF frequency and negative IF frequency when LO=5.17 GHz and 0 dBm. The IF frequency is positive if the RF frequency is larger than the LO frequency. Otherwise, the IF frequency is negative. The axis for negative IF frequency is folded back to highlight the comparison with positive frequency in figure 9. The conversion gain is about 1 dB for 15 to 45 MHz positive IF frequency and is -46 dB for 15 to 45 MHz negative IF frequency. The image rejection ratio defined as the ratio between positive IF conversion gain and negative IF conversion gain is plotted in figure 10. Image rejection ratios are better than 47 dB for 15 to 45 MHz IF frequencies.

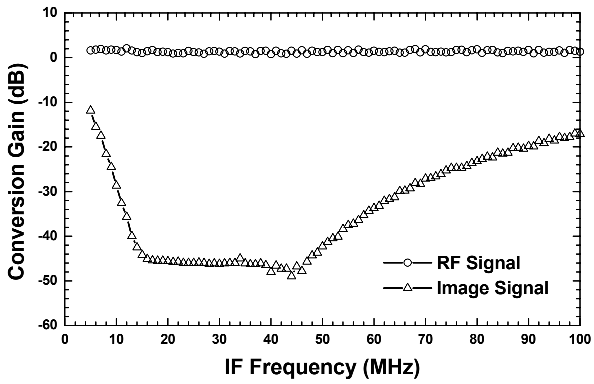


Figure 9 Conversion gain as a function of IF frequency for the SiGe HBT double quadrature downconverter with poly phase filters.

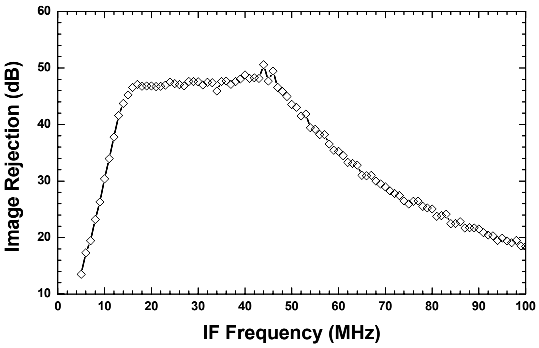


Figure 10 Image rejection ratios as a function of IF frequency for the SiGe HBT double quadrature downconverter with poly phase filters.

IV. CONCLUSION

A fully integrated SiGe double quadrature Gilbert downconversion mixer with polyphase filters has been demonstrated for the first time in this paper to the best of our knowledge. A high image rejection double quadrature Gilbert downconverter with polyphase filters in the SiGe HBT technology has been achieved because GaAs has accurate thin film resistors and the low parasitic semi-insulating substrate. The fabricated SiGe HBT double quadrature Gilbert downconversion mixer with polyphase filters has 1 dB conversion gain, IP_{1dB}= -19 dBm and IIP_3= -9 dBm at 5.2 GHz. The image rejection ratio is better than 47 dB when LO=5.17 GHz and IF is in the range of 15 MHz to 45 MHz.

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