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2.4/5.7-GHz Dual-Band Dual-Conversion Low-IF Downconverter Using 0.35 µm SiGe HBT Technology

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A 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter is demonstrated using 0.35 µm SiGe heterojunction bipolar transistor (HBT) technology. The first image signal is shifted away from the IF band by a complex Weaver architecture while the second image signal is eliminated by a complex Hartley architecture. The downconverter achieves a 45/44-dB image-rejection ratio of the first image (IRR_1) and a 50/48-dB image-rejection ratio of the second image (IRR_2) for 2.4/5.7-GHz modes, respectively, when IF frequency ranges from 20 to 40 MHz.

Introduction

A low-IF receiver is widely used [1]-[3] because this architecture can avoid dc offset and flicker noise problems. Series capacitors can be cascaded at the output to block the dc component in a low-IF receiver while choosing a proper IF band beyond the flicker noise corner can directly escape from the flicker noise problem. In addition, a dual-conversion downconverter alleviates the burden of a high-frequency LO signal generation.

In this paper, a 2.4/5.7-GHz dual-band low-IF downconverter for WLAN 802.11 a/g applications is demonstrated. This work combines the Weaver architecture [4]-[5] and Hartley architecture [6]. The former is a complex dual-conversion system, while the latter consists of a complex mixer and a complex filter, such as a polyphase filter (PPF) [7]-[8] or an active complex band-pass filter [3], [9]-[11].

Circuit Design

Figure 1 shows the block diagram of the 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter consisting of a first-stage single-quadrature complex mixer and a second-stage double-quadrature complex mixer. A single-quadrature complex mixer includes two real mixers with either a quadrature RF or LO input while the other is kept differential. A double-quadrature complex mixer includes four real mixers with both LO and RF signals being quadrature. A Gilbert mixer consists of two current-steering differential amplifiers and thus employing SiGe HBTs in the Gilbert mixer has the advantages of lower LO power and higher conversion gain. A high conversion gain is helpful to suppress the noise contribution of the following stages, especially the cascaded polyphase filter, to reach a better dynamic range. In addition, Gilbert mixers with output in-phase/anti-phase connections are utilized to realize an addition/subtraction function in the current domain for the complex mixing operation in the second downconversion. The IF buffer amplifier is employed to facilitate 50-Ω measurements.

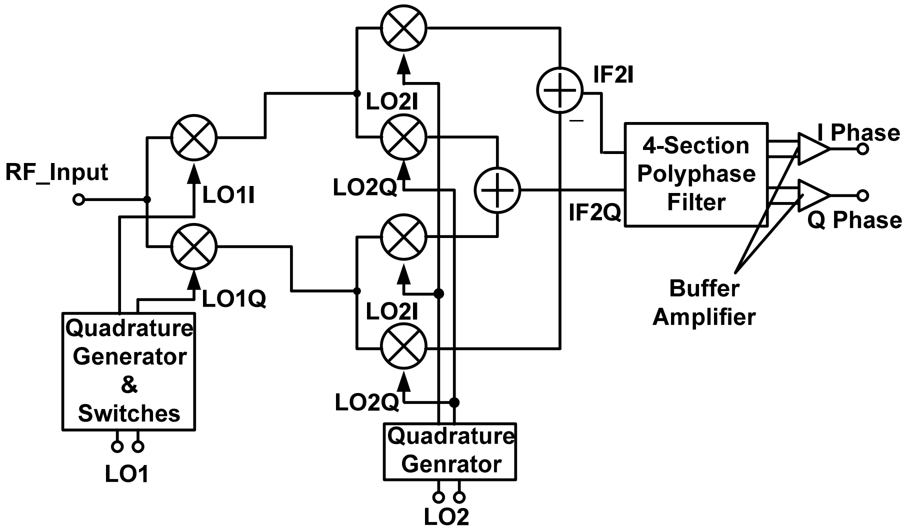


Figure 1. Block diagram of the SiGe HBT 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter.

In this work of a 2.4/5.7-GHz dual-band system, $f_{RFH}=f_{IML}=5.7$ GHz, $f_{RFL}=f_{IMH}=2.4$ GHz. Thus, $f_{LO2}=1.62$ GHz, $f_{LO1}=2.5\times f_{LO2}=4.05$ GHz, and $f_{IF2}=30$ MHz.

Experimental Result

Figure 4 shows the die photo of the 2.4/5.7-GHz dual-band dual-conversion downconverter and the die size is 1.7×1.4 mm^2. Figure 5 shows the conversion gain (CG) and the noise figure (NF) of 2.4/5.7-GHz bands with a supply voltage of 3 V. The CG is 11/10 dB and the NF is 19/18 dB for 2.4/5.7-GHz band, respectively, when the IF frequency is below 100 MHz. The downconverter reaches the peak gain when LO_1 power is 13 dBm and LO_2 power is 5 dBm.

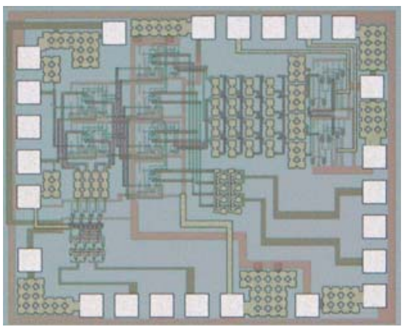


Figure 4. Die photo of the SiGe HBT 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter.

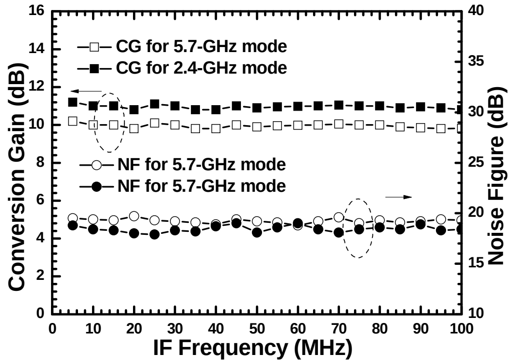
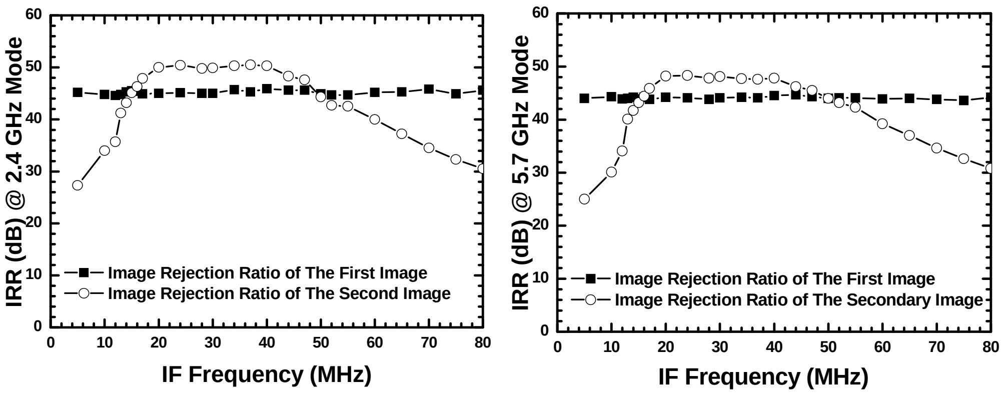


Figure 5. Conversion gain and noise figure of the SiGe HBT 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter.



(a) (b)

Figure 6. Image rejection ratios of the first/second image signals at (a) 2.4-GHz mode (b) 5.7-GHz mode of the SiGe HBT 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter.

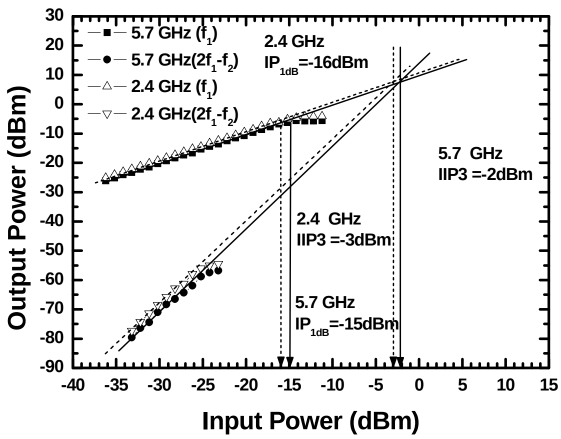


Figure 7. Power performance at 2.4/5.7 GHz mode of the SiGe HBT 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter.

The image-rejection ratios (IRRs) for 2.4/5.7 GHz band are 45/44 dB for the first image and 50/48 dB for the second image as shown in Fig. 6 (a) and (b), respectively. The IRR_1 is flat due to the one-way frequency shifting. Compared with the IRR_1, the IRR_2 response is a narrow band from 20 to 40 MHz due to the frequency response of the four-section poly-phase filter following the second-stage mixers. Figure 7 shows the power performance of both 2.4/5.7-GHz bands. The IP_{1dB} is -16/-15 dBm and the IIP_3 is -3/-2 dBm for 2.4/5.7-GHz band when IF=30 MHz. The output waveforms of both I/Q channels are shown in Fig. 8 and this figure shows a 0.1-dB magnitude mismatch and a 0.7° phase error. Besides, the LO_1/LO_2-to-RF isolation and the RF-to-IF isolation are shown in Fig. 9(a) and (b), respectively. LO_1/LO_2-to-RF isolation is better than 65/36 dB while the RF-to-IF isolation is better than 62 dB for both 2.4/5.7-GHz modes. The performance is summarized in Table I.

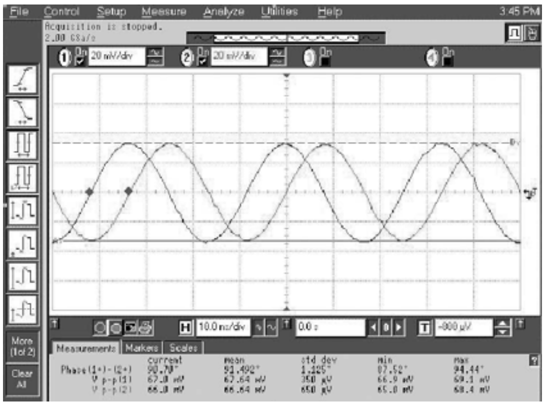
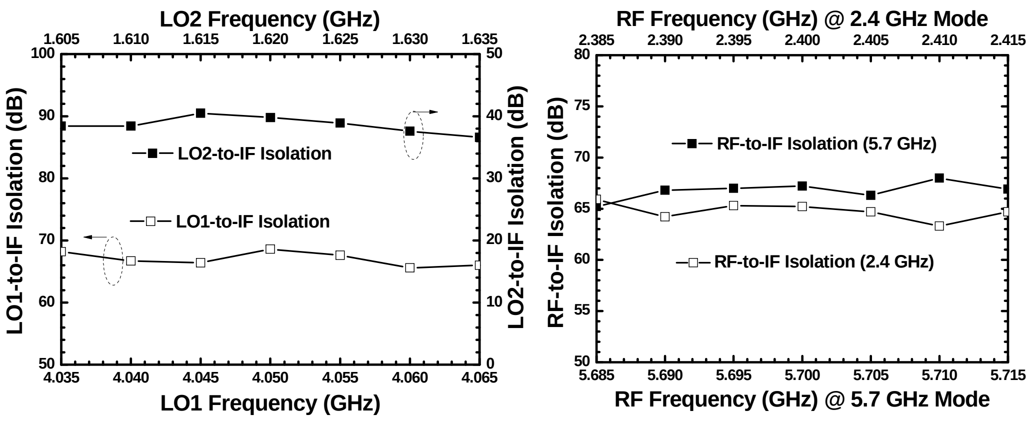


Figure 8. Output I/Q waveforms of the SiGe HBT 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter.



(a) (b)

Figure 9. (a) LO_1/LO_2-to-RF isolation (b) RF-to-IF isolation of the SiGe HBT 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter.

Conclusion

A 2.4/5.7-GHz dual-band dual-conversion low-IF downconverter is demonstrated using 0.35 μm SiGe HBT technology. Both differential-quadrature LO_1 and LO_2 signals are generated by a two-section polyphase filter. An 11/10-dB conversion gain and a

19/18-dB noise figure for 2.4/5.7-GHz mode are achieved in this work. Moreover, the IRR_1/IRR_2 are better than 45/50 dB at 2.4-GHz mode while a 44/48-dB IRR_1/IRR_2 is achieved at 5.7-GHz mode when the designed IF band is 20 to 40 MHz.

TABLE I. Performance Summary.

RF Frequency (GHz)	2.4/5.7
LO Frequency (GHz) [f_{LO1}/f_{LO2}]	4.05/1.62
Conversion Gain (dB)	11/10
Single-Sideband Noise Figure (dB)	19/18
Image-Rejection Ratio of the First Image (dB)	45/44
Image-Rejection Ratio of the Second Image (dB)	50/48
IP_{1dB} (dBm)	-16/-15
IIP_3 (dBm)	-3/-2
IF Bandwidth (MHz)	20-40
Supply Voltage (V)	3
Chip Size (mm^2)	1.7×1.4
Technology	0.35-μm SiGe HBT

Acknowledgments

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