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A 236–311-GHz SiGe BiCMOS Receiver for High Data Rate Communication

Frida Strömbeck, *Member, IEEE*, Yu Yan, *Member, IEEE*, and Herbert Zirath, *Life Fellow, IEEE*

***Abstract*—An H-band (220–325 GHz) 90-nm silicon–germanium (SiGe) BiCMOS receiver (Rx) for high data rate communication is presented. It consists of an ×8 local oscillator (LO) multiplier chain and a Gilbert cell-based downconverter mixer. The 3-dB RF bandwidth is 75 GHz, using an IF of 1 GHz. At 288 GHz, the 3-dB IF bandwidth is 24 GHz. It supports data rates up to 100 Gb/s using 32-QAM modulation, with a signal-to-noise ratio (SNR) of 17.6 dB and error vector magnitude (EVM) of 8.4%. The DC power consumption for the Rx is 237 mW.**

***Index Terms*—Energy efficient, H-band, high data rate, J-band, receiver, Rx, silicon–germanium (SiGe) BiCMOS, subterahertz (sub-THz).**

I. Introduction

THE rapid growth in data traffic driven by applications, such as wireless backhaul, data centers, and emerging 6G systems, has created a need for ultrahigh data rate communication links. Frequencies in the subterahertz (sub-THz) range, particularly the H-band (220–325 GHz), offer large unused bandwidths that enable data rates beyond 100 Gb/s. However, the implementation of efficient and compact transceivers at these frequencies remains challenging due to device limitations, signal losses, and power consumption constraints [1].

Indium phosphide (InP) technologies (HBT/HEMT) have been the leading candidate for such RF front ends for many years, reaching data rates above 150 Gb/s at 300 GHz [2]. Although InP processes offer outstanding high-frequency performance, they have several important drawbacks. The main drawbacks are high cost, low yield, and low scalability. The material is fragile and faces challenges in thermal management. Consequently, it is a bad candidate for commercial systems [3].

Silicon–germanium (SiGe) BiCMOS technology has emerged as a promising platform for sub-THz systems, combining high-speed heterojunction bipolar transistors (HBTs) with mature integration capabilities. Recent advances have demonstrated high-speed transmitters and receivers operating above 200 GHz, but achieving wide bandwidth, high modulation order, and good energy efficiency simultaneously is still an open challenge [4], [5], [6], [7].

In this work, we present a 236–311-GHz receiver implemented in a 90-nm SiGe BiCMOS technology. The receiver incorporates a broadband ×8 local oscillator (LO) multiplier chain and a Gilbert-cell-based downconversion mixer optimized for wideband operation. The proposed design achieves a 75-GHz RF bandwidth and supports data rates up to 100 Gb/s using higher-order modulation schemes, such as 32-QAM while maintaining competitive energy efficiency.

TABLE I
Comparison With Other Receivers Above 200 GHz

Reference	[2]	[4]	[5]	[6]	[this]
Tech.	60 nm InP HEMT	130 nm BiCMOS	130 nm BiCMOS	130 nm BiCMOS	**90 nm BiCMOS**
Modul.	16-QAM	16-QAM	16-QAM	16-QAM	**32-QAM**
Freq. (GHz)	297	230	240	220	**290**
3-dB RF BW (GHz)	50	40	NA	60	**75**
Data Rate (GHz)	160	90	100	50	**100**
Energy Eff. (pJ/bit)	5.6	10.4	8.5	NA	**2.4**
Chip area (mm^2)	4.00	1.64	5.10	3.92	**1.00**
EVM %	14.8	14.6	18.6	13.8	**8.4**

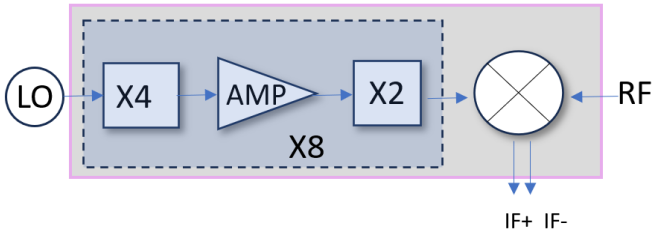

Fig. 1. Block diagram of the receiver.

II. Circuit Design

The receiver (Rx) was designed and fabricated in Infineon Technologies' 90-nm SiGe BiCMOS process (B12HFC), taking advantage of the high-speed npn HBTs with f_t/f_{max} of

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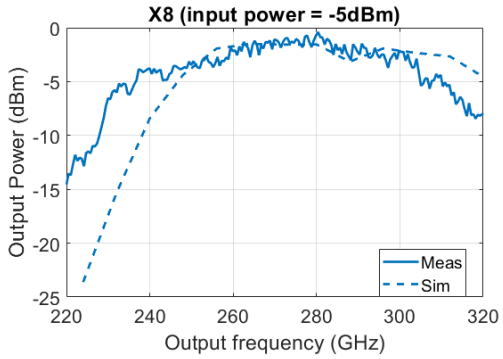

Fig. 2. Measured and simulated output power for the ×8 LO multiplier.

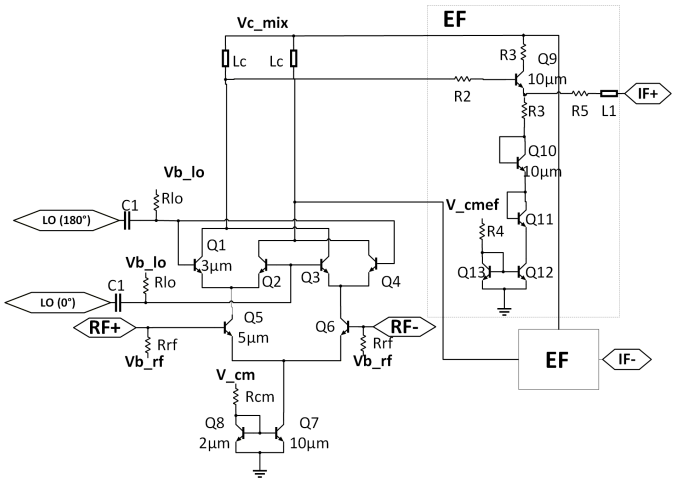

Fig. 3. Simplified schematic of the Gilbert cell-based downconverter mixer.

300/500 GHz [8]. It consists of a ×8 LO multiplier chain and a Gilbert cell-based downconverter mixer. The block diagram can be seen in Fig. 1. The multiplier chain has two cascaded doublers, followed by a D-band (110–170 GHz) buffer amplifier and a last-stage H-band doubler.

A breakout version of the frequency multiplier [9] was characterized. The output power can be seen in Fig. 2.

The downconverter mixer (Fig. 3) uses differential RF and LO signals. To convert the single-ended RF input signal and the single-ended signal from the LO multiplier chain, Marchand baluns are used for their broadband performance. The mixer core has transistors that are stacked on three levels. The bottom pair is a current mirror that generates and controls the current through the transistor stack. In a SiGe HBT Gilbert mixer, the current mirror at the bottom is added mainly to provide a well-controlled tail current and to improve the robustness of the mixer's operation. The middle pair of transistors (Q5 and Q6) is a transconductance stage, where the RF voltage is converted to current. The top pairs (Q1–Q4) are switching pairs. The downconverted differential IF signal is then fed to emitter followers. The resistors in the emitter followers are used to achieve broadband IF matching. The mixer uses two DC biases, Vc_mix = 3.5 V and V_cmef = 1.3 V. The rest of the voltages (Vb_lo, Vb_rf, V_cm) are

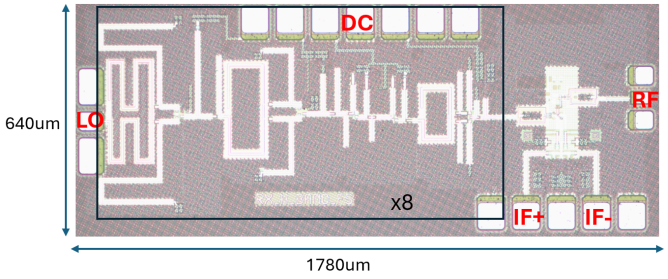

Fig. 4. Photo of the fabricated receiver. The size is 1590 by 630 μm.

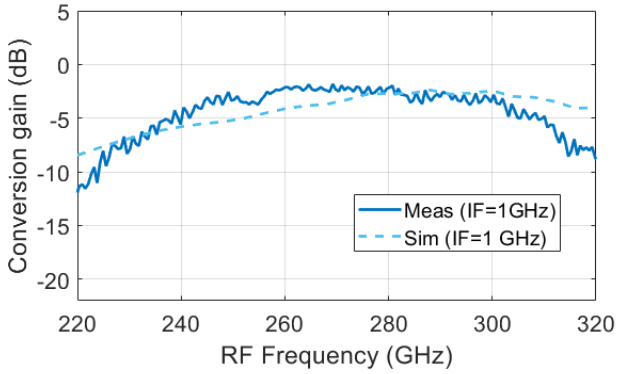

Fig. 5. Measured and simulated conversion gain for the receiver sweeping the RF frequency. The IF frequency was 1 GHz.

generated through stacked transistors (configured as diodes) and resistors.

A photograph of the fabricated Rx can be seen in Fig. 4. The total area (including pads) is 1 mm^2.

III. Measurement Results

The Rx was characterized on-wafer in both the frequency and time domains.

A. Frequency Domain

For the frequency domain measurements, a Keysight PNA-X (67-GHz N5247A) was used together with a VDI H-band extender WR 3.4 at the input. The differential IF output signal was connected to a Mariki balun (BAL-0050) to convert it to a single-ended signal. The conversion gain for the receiver was measured first by sweeping the RF frequency (Fig. 5). The 3-dB RF bandwidth, using a 1-GHz IF signal, is between 236 and 311 GHz, resulting in 75 GHz. The peak conversion gain is −2 dB.

To evaluate the IF bandwidth, the IF frequency was swept while keeping the LO signal at 288 GHz. In Fig. 6, the conversion gain can be seen, and the 3-dB IF bandwidth is 24 GHz.

B. Time Domain

The setup used during the time domain measurement is shown in Fig. 7. A WR 3.4 VDI compact converter (CC) was used as transmitter. The CC operates with a single-ended input, so generating an I/Q-modulated signal requires the use

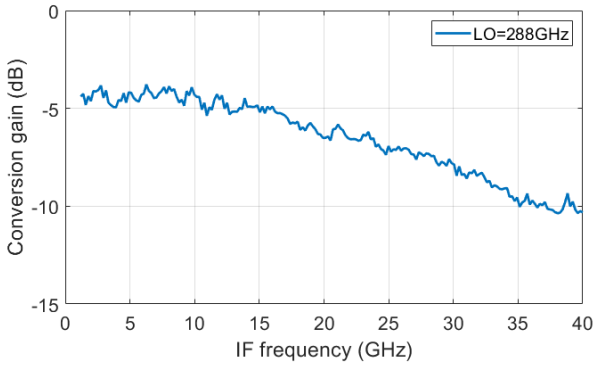

Fig. 6. Measured conversion gain of the receiver sweeping the IF signal. The LO frequency was 288 GHz.

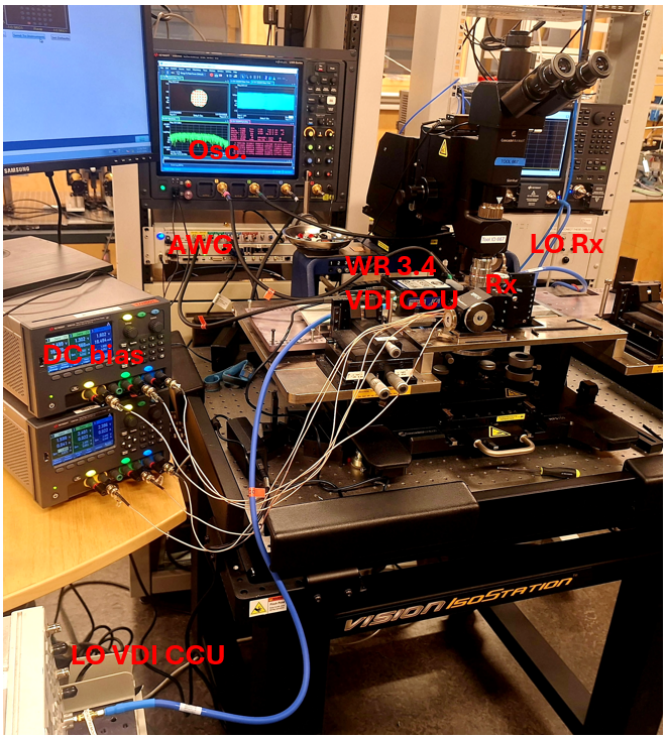

Fig. 7. Measurement setup used during the time domain measurements.

of an IF carrier, which in turn restricts the achievable data rate. The data input (using an IF carrier) was provided by a Keysight M8195A arbitrary waveform generator (AWG), which generated a pseudorandom binary sequence (PRBS-11) using root-raised cosine pulse shaping with a roll-off of 0.85. The transmitted signal was connected through an infinity WR3.4 probe to the receiver. The downconverted signal was captured by a Keysight UXR1104A Infiniium Real-time oscilloscope for evaluation. The error vector magnitude (EVM) and the signal-to-noise ratio (SNR) were measured.

16- and 32-QAM modulation were tested at a baud rate (GBd) of 15 and 20 GBd. For 16-QAM, this corresponds to 60 and 80 Gb/s, and for 32-QAM it corresponds to 75 and 100 Gb/s. The received I/Q constellations can be seen in Figs. 8 and 9.

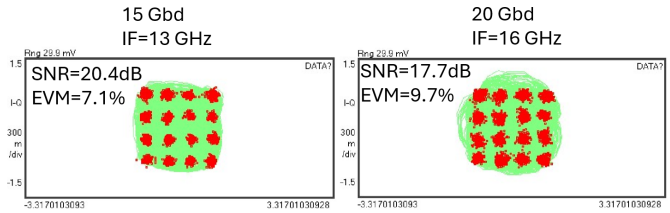

Fig. 8. Received I/Q constellation for 15 and 20 GBd QAM16.

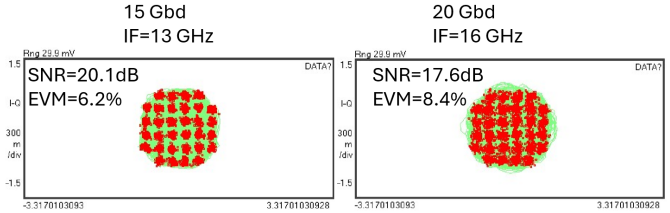

Fig. 9. Received I/Q constellation for 15 and 20 GBd QAM32.

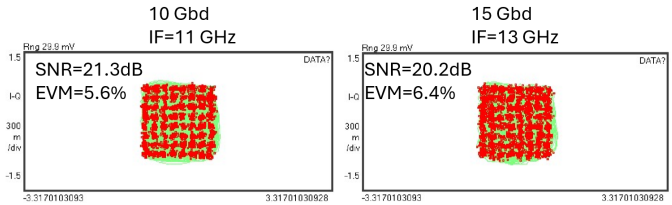

Fig. 10. Received I/Q constellation for 10 and 15 GBd QAM64.

In Fig. 10, higher modulation (64-QAM) was tested, but at a lower baud rate (10 and 15 GBd).

The total DC energy consumption for the receiver is 237 mW, which corresponds to 2.37 pJ/bit for 100 Gb/s transmission. Limitations in the setup include the SNR and bandwidth of the AWG, and the sensitivity of the oscilloscope.

IV. Conclusion

In this work, a 236–311-GHz receiver implemented in 90-nm SiGe BiCMOS technology has been demonstrated for ultrahigh data rate communication. The proposed architecture achieves a wide 3-dB RF bandwidth of 75 GHz and an IF bandwidth of 24 GHz, enabling operation across a large portion of the H-band. Measurement results confirm support for data rates up to 100 Gb/s using 32-QAM modulation while maintaining a low EVM of 8.4% and an SNR of 17.6 dB.

The receiver further exhibits a competitive energy efficiency of 2.37 pJ/bit at 100 Gb/s with a total power consumption of 237 mW, outperforming previously reported receivers in this frequency range in terms of both efficiency and modulation capability Table I. These results highlight the strong potential of SiGe BiCMOS technology for compact, energy-efficient sub-THz transceivers. Overall, the presented receiver represents a significant step toward practical high-capacity wireless links for future applications, such as 6G networks, data center interconnects, and short-range backhaul systems.

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