14 - 38 GHz 14 dB Monolithic Integrated Mixer in SiGe Bipolar Technology

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Abstract - This work describes a monolithic integrated active mixer in a pre-production 0.4 µm SiGe bipolar technology. The 3 dB bandwidth is in the frequency range between 14 and 38 GHz with gain higher than 14 dB. At 38 GHz the circuit has a 3rd order intercept point of 19.3 dBm referred to the output. The mixer may be used for future broadband wireless services like LMDS at 28 and 38 GHz.

I. Introduction

Future broadband wireless services like point to multipoint systems between 10 and 28 GHz or LMDS and MVDS systems at 28, 38, and 42 GHz raise the demand for components for high carrier frequencies. This is the reason for investigating realizations in different technologies. Recent advances in the SiGe bipolar technology and improvements of the circuit design allow cost-effective mixer realizations.

Mixers are important components for frequency conversion in all transmitter and receiver systems. In [1] - [8] published papers of mixer realizations are listed for frequencies in the range mentioned above. The highest frequency published for active mixers realized in bipolar technology is 30 GHz. The circuit uses SiGe offering gain of 5.9 dB at 30 GHz [1]. Mixers published in GaAs and InP offer maximum bandwidth of 20 GHz with gain of 5 and 15 dB [2], [3]. This work describes a mixer in SiGe bipolar technology with more than 14 dB gain in the frequency range between 14 and 38 GHz.

II. Circuit Design

The presented mixer is based on the Gilbert cell concept [10]. Figure 1 shows the simplified circuit diagram of the mixer.

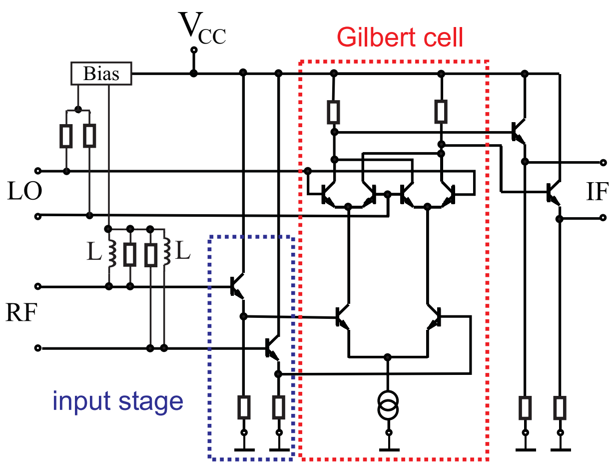

Fig. 1. Simplified circuit diagram of the mixer.

It has a double-balanced structure and connects the LO signal to the mixer core and the RF signal to the RF input stage. To achieve maximum gain at frequencies higher than 20 GHz an additional input stage with emitter followers is used to increase the mixers bandwidth. Biasing the RF input stage with an additional inductor a resonance to higher frequencies is created together with parasitic capacitances. Matching to 50 Ω output has been done with emitter followers. Figure 2 shows the chip micrograph. The chip size is 0.45 mm × 0.55 mm.

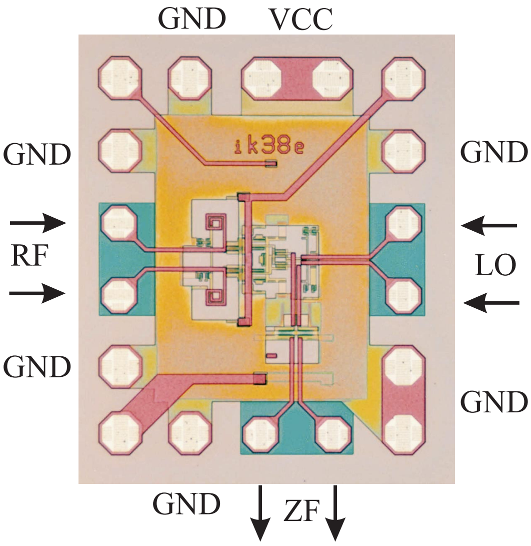

Fig. 2. Chip micrograph (size: 0.45 mm × 0.55 mm).

III. Technology

SiGe bipolar technology is one of the most attractive candidates for the emerging field of broadband wireless services. It combines the potential to fulfill the technical specifications with the cost advantages, integration, and manufacturing capabilities of standard silicon technologies. The circuit is fabricated in a pre-production 0.4 μm SiGe bipolar technology [9], using a double- polysilicon self-aligned emitter-base configuration. The transistors manufactured in this technology offer cut-off frequency of 85 GHz, maximum oscillation frequency of 128 GHz, and CML gate delay time of 6.8 ps. Four available metallisation layers enable low parasitic wiring capacitances. Figure 3 shows a schematic cross section of the SiGe transistors.

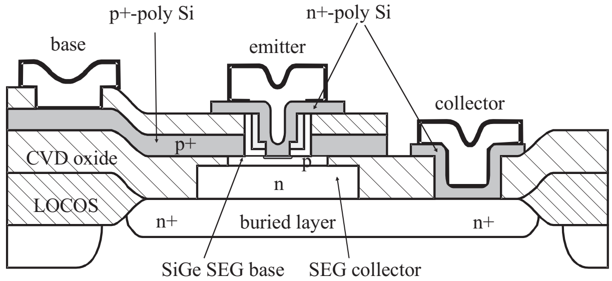

Fig. 3. Schematic cross section of the SiGe transistor (SEG = selective epitaxial growth).

IV. Experimental Results

For electrical characterization the chips are bonded on ceramic substrates ($\epsilon_r = 9.9$). The size of the testboard is 30 mm × 30 mm. For the following measurements an intermediate frequency of 300 MHz is chosen. The local oscillator power is 5 dBm.

At a voltage supply of -5 V, the circuit draws a current of 73 mA.

Figure 4 shows the measured conversion gain vs. frequency of the mixer. Because of the inductors and the additional input stage, the circuit provides maximum gain at frequencies higher than 20 GHz. A 3 dB bandwidth from 14 to 38 GHz is achieved with maximum conversion gain of 17.1 dB at 25 GHz. It stays nearly constant in the frequency range mentioned.

Noise measurements have been done between 10 and 40 GHz. Figure 5 shows the double-sideband noise figure vs. RF frequency. A low double-sideband noise figure of 16.3 dB is achieved at 30 GHz.

At 38 GHz the 1 dB compression point is -5.8 dBm referred to the input and 7.3 dBm referred to the output.

For intermodulation measurements the RF frequencies have been set to 38 and 38.001 GHz. The LO frequency is 38.3 GHz. The 3^{rd} order intercept point is 5.2 dBm referred to the input. Referred to the output the 3^{rd} order intercept point is as high as 19.3 dBm. The intermodulation characteristic of the mixer is shown in figure 6.

Table 1 summarizes the technical data.

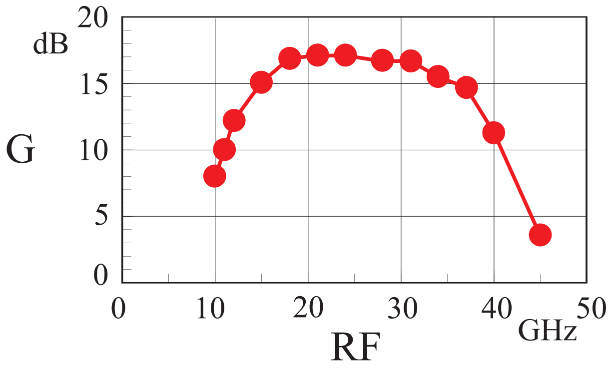

Fig. 4. Measured conversion gain vs. RF. The IF is 300 MHz, P_{LO} is 5 dBm.

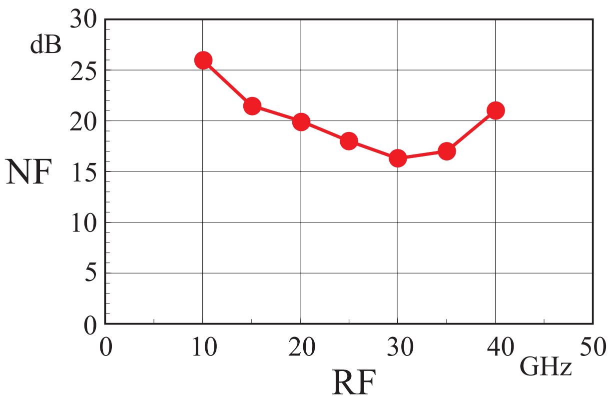

Fig. 5. Measured double-sideband noise figure vs. RF. The IF is 300 MHz, P_{LO} is 5 dBm.

Figure 7 gives the state of the art for mixers in different semiconductor technologies at different frequencies including the data presented above. Improvements of the circuit design and recent advances in the SiGe bipolar technology allow cost-effective realization of mixers for frequencies up to 38 GHz.

V. Conclusions

An active mixer in SiGe bipolar technology has been presented. The 3 dB bandwidth is 14 to 38 GHz with maximum gain of 17.1 dB at 25 GHz. The 3^{rd} order intercept point is 19.3 dBm referred to the output. The circuit may be used for applications like point to multipoint systems between 14 and 38 GHz or LMDS systems at 28 and 38 GHz.

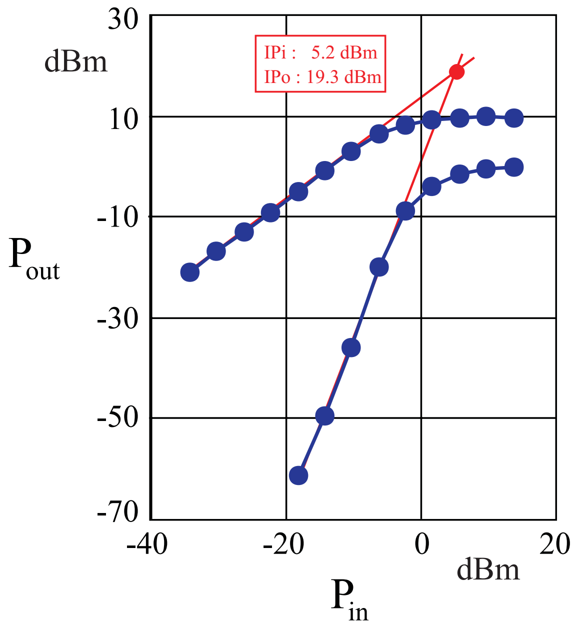

Fig. 6. Measured output power vs. input power. The RF frequencies are 38 and 38.001 GHz, the LO frequency is 38.3 GHz. P_{LO} is 5 dBm.

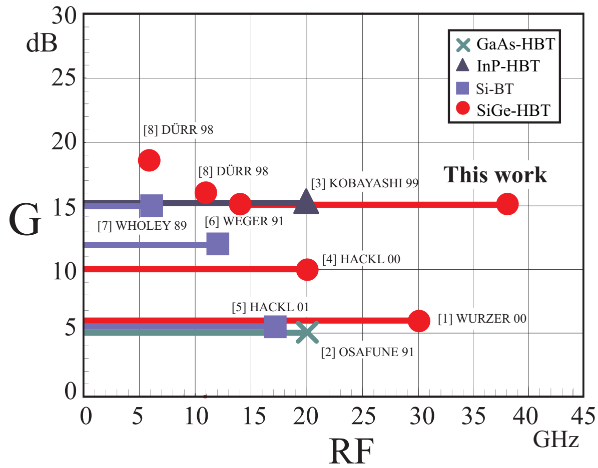

Fig. 7. Comparison of monolithic integrated mixers in bipolar technology.

TABLE 1. Technical data of mixer.

3 dB bandwidth	14 - 38 GHz
max. conversion gain (LO=5 dBm)	17.1 dB at 25 GHz
min. double-sideband noise figure	16.3 dB at 30 GHz
1 dB compression point referred to output	7.3 dBm at 38 GHz
3^{rd} order intercept point referred to output	19.3 dBm at 38 GHz
supply current	73 mA (-5 V)
power consumption	365 mW (-5V)
chip size	0.45 mm × 0.55 mm
technology	85 GHz f_T SiGe bipolar

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