40 GHz Monolithic Integrated Mixer in SiGe Bipolar Technology

student paper

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Abstract **Future broadband wireless services will use carrier frequencies in the range of 10 GHz to about 42 GHz. This raises the demand for low-cost components of key RF building blocks like LNAs, mixers, and oscillators for frequencies up to 42 GHz. This work describes an active mixer in a pre-production 0.4 μm SiGe bipolar technology with bandwidth in the range mentioned above. Gain of 25 dB und double-sideband noise figure of 15 dB is achieved at 40 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 converting 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 with 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 25 dB gain in the frequency range between 15 and 40 GHz.

II. 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 1 shows a schematic cross section of the SiGe transistors.

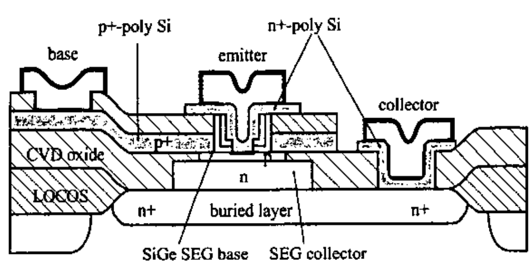

Fig. 1. Schematic cross section of the SiGe transistor (SEG = selective epitaxial growth).

III. Circuit Design

The presented mixer is based on the Gilbert cell concept [10]. Figure 2 shows the 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. The additional capacitance between the emitters of the lower transistor pair improves the conversion gain at the expense of linearity. The capacitance also improves the mixers bandwidth because of creating a resonance together with inductive circuit properties. Matching to 50 Ω output has been done with emitter followers.

Compromises between gain, linearity, low noise and high bandwidth have been made by careful optimization of the transistor sizes. Figure 3 shows the chip micrograph. The chip size is 0.45 mm × 0.55 mm. To avoid additional production steps and save costs the capacitance is realized with four metallisation layers.

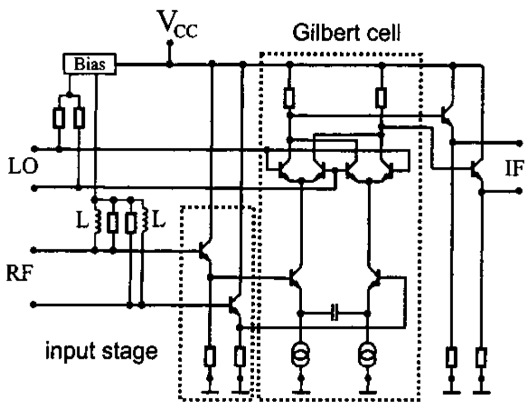

Fig. 2. Simplified circuit diagram of the mixer.

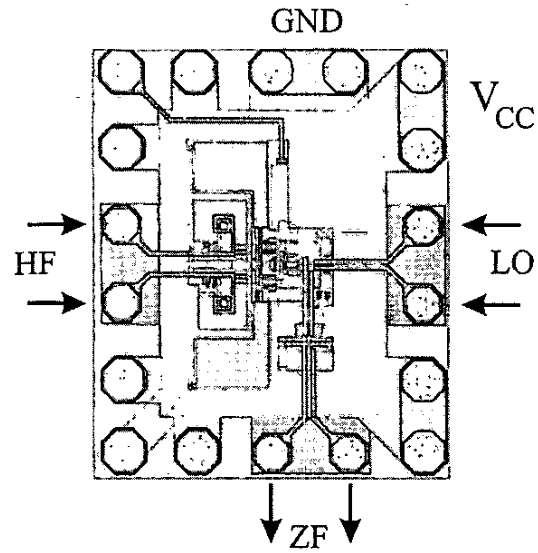

Fig. 3. Chip micrograph (size: 0.45 mm x 0.55 mm).

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. A high 3 dB bandwidth from 12 to 42 GHz is achieved. The conversion gain is 25 dB at 40 GHz. It stays nearly constant in the frequency range mentioned. For frequencies higher than 40 GHz the gain is strongly limited by losses of the ceramic substrate and the connectors. At 50 GHz the loss of the testboard is 17 dB and therefore only 2 dB conversion gain of the mixer is measured.

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 13 dB is achieved at 30 GHz. At 40 GHz the noise figure is 15 dB.

The 1 dB compression point is -20.5 dBm referred to the input and 3.5 dBm referred to the output.

For intermodulation measurements the RF frequencies have been set to 40 and 40.001 GHz. The LO frequency is 40.3 GHz. The 3^{rd} order intercept point is -11.5 dBm referred to the input. Referred to the output the 3^{rd} order intercept point is as high as 13.5 dBm. The intermodulation characteristic of the mixer is shown in figure 6.

Table 1 summarizes the technical data.

Figure 7 gives the state of the art for mixers in different semiconductor technologies at different fre-

TABLE 1. Technical data of mixer.

3 dB bandwidth	12 - 42 GHz
conversion gain (LO=5 dBm)	25 dB at 40 GHz
double-sideband noise figure	15 dB at 40 GHz
1 dB compression point referred to output	3.5 dBm at 40 GHz
3^{rd} order intercept point referred to output	13.5 dBm at 40 GHz
supply current	73 mA (5 V)
power consumption	365 mW (5V)
chip size	0.55 mm x 0.45 mm
technology	85 GHz f_T SiGe bipolar

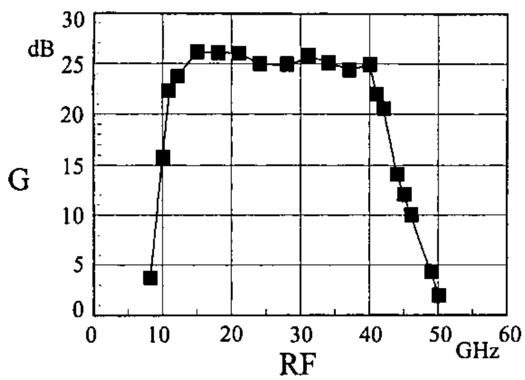

Fig. 4. Measured conversion gain vs. RF. The IF is 300 MHz, P_{LO} is 5 dBm.

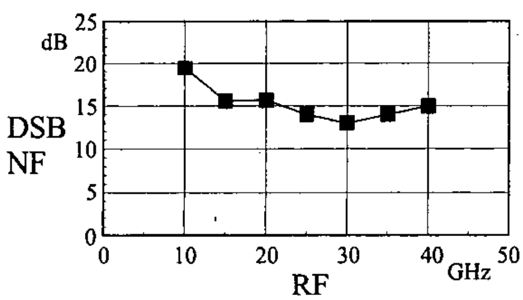

Fig. 5. Measured double-sideband noise figure vs. RF. The IF is 300 MHz, P_{LO} is 5 dBm.

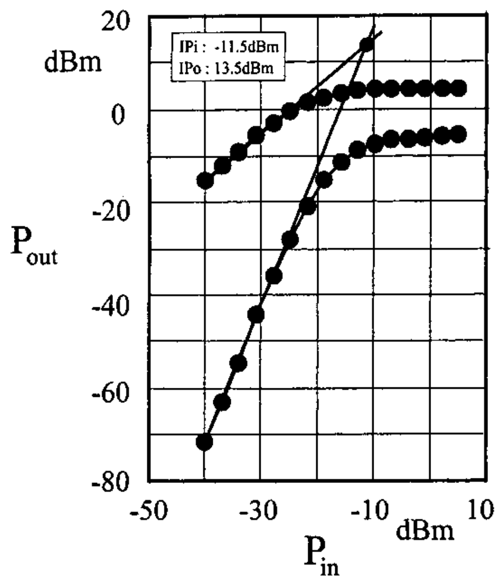

Fig. 6. Measured output power vs. input power. The RF frequencies are 40 and 40.001 GHz, the LO frequency is 40.3 GHz. P_{LO} is 5 dBm.

quencies 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 suited for LMDS and MVDS applications.

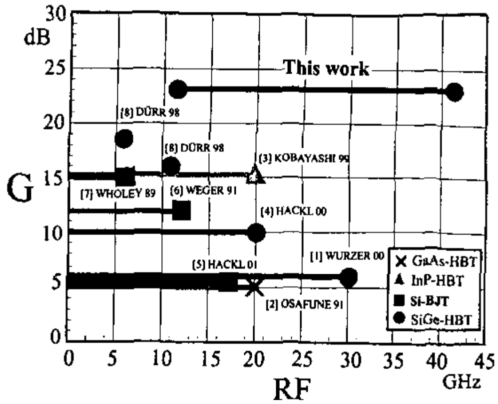

Fig. 7. Comparison of monolithic integrated mixers in bipolar technology.

V. Conclusions

An active mixer in SiGe bipolar technology has been presented. The mixer sets a new state of the art for monolithic integrated mixers realized in bipolar technologies. A high gain of 25 dB is reached between 15 and 40 GHz. The double-sideband noise figure is smaller than 16 dB in the frequency range mentioned above. The circuit may be used for applications like point to multipoint systems between 24 and 28 GHz or LMDS and MVDS systems at 28, 38, and 42 GHz. Due to the fact that for frequencies higher than 40 GHz the gain is strongly reduced by losses of the testboard and that SiGe bipolar technologies still have a high potential for further improvements increasing advantages in gain, noise, and bandwidth for active mixers can be expected.

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