A 17 to 26 GHz Micromixer in SiGe BiCMOS Technology

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Abstract—**We report, for the first time, our experimental results of a high frequency Micromixer operating from 17 to 26 GHz in SiGe technology. Good linearity performance is achieved: typically 0 dBm input-referred P_{-1dB} and 8 dBm IIP3. The conversion gain and double side band noise figure at 23 GHz RF input are –3.6 dB and 18.2 dB, respectively. The local oscillator power required for proper operation is below 0 dBm and the DC power consumption is 86 mW for a 3.3 V supply. For purpose of comparison, a Gilbert mixer is also implanted on the same wafer. The experimental results are compared for the two active mixers.**

I. INTRODUCTION

Active mixers are popularly used nowadays in construction of RF and microwave transceivers. One design challenge of this kind of mixers comes from linearity requirement in the transceiver application. Normally speaking, Micromixer [1]-[3] has advantage of better linearity performance than standard Gilbert mixers [8]-[11]. It also has high port-to-port isolation and wideband input impedance match (e.g. from DC to 9GHz) [4]-[7]. The main drawback is its high noise figure. Micromixers published so far have been designed for RF frequencies below 9 GHz [1]-[7], and it is doubted whether Micromixer topology can be useful in high frequency (>20 GHz) applications.

With the aggressive development of low cost semiconductor technologies in recent years, such as advanced RF CMOS and SiGe BiCMOS, the transistors deliver better and better noise and gain performances at frequencies well beyond deep millimeter waves. It is therefore interesting to explore the possibility of improving the linearity of high-frequency mixers via deploying linearity-favored circuitry, such as Micromixer, rather than applying large bias current that is normally used in Gilbert mixer for linearity improvement [10].

In this paper, we report, for the first time, our experimental results of a high frequency Micromixer operating from 17 to 26 GHz. It converts the RF input to an IF output of 1 Ghz and is manufactured in STMicroelectronics' SiGe BiCMOS technology. The performance of the mixer will be discussed in terms of its conversion gain, noise figure, DC power consumption and, especially, the input-referred third-order intercept point (IIP3). A Gilbert mixer operating at the same frequency range is manufactured on the same wafer as well. The performance of the two mixers will be compared experimentally.

II. MICROMIXER CIRCUIT

The circuit schematic of the Micromixer is shown in Fig. 1. The mixer core consisting of (Q5-Q8) is identical to a Gilbert mixer. The differences lie in the trans-conductance stage [1]-[3]. During a positive excursion of the RF input voltage, a current mirror consisting of Q1 and Q2 delivers output I_1 to the mixer core; while during the negative excursion, the common-base-biased Q3 provides equal but anti-phase current I_2. In principle, such trans-conductance stage can handle large signal amplitudes. This is why Micromixer is generally more linear than standard Gilbert mixer [1]. Unlike Gilbert mixer, large bias current is not required to improve the linearity. Thus, Micromixer consumes less DC power. Q4 is added to equalizer the *Vce* of Q1 and Q2, as well as to reduce the LO to RF leakage [1]. Inductors *L1, L2* and *L3* as well as Re_1 and Re_2 are used for input impedance match and controlling the conversion gain. The drawback with this topology is that its noise figure is relatively high. One obvious reason is that more transistors are used in the trans-conductance stage as compared with Gilbert mixer.

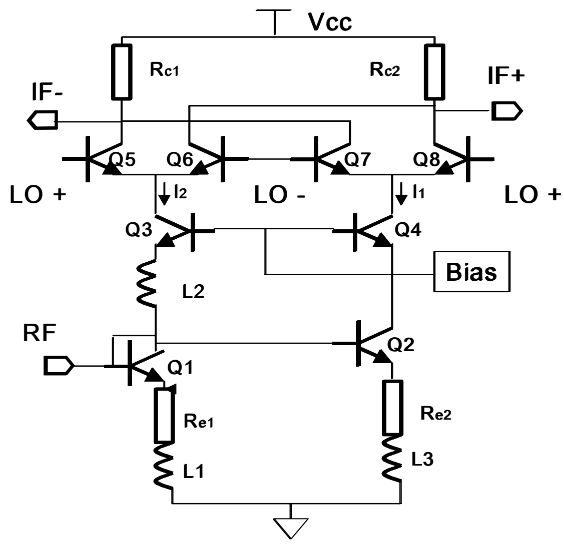

Fig. 1. Circuit schematic of Micromixer

This Micromixer is fabricated in STMicroelectronics' 0.25μm SiGe BiCMOS process. The SiGe HBT in use has an emitter width of 0.4μm (drawn size), featuring 70GHz f_T and 90GHz f_{max} [12]. The technology offers 5 metal layers for interconnect, MIM capacitors of 2fF/μm^2, various kinds of resistors and inductors, all scalable. The physical dimension of circuit including pads is 0.70x0.69 mm^2.

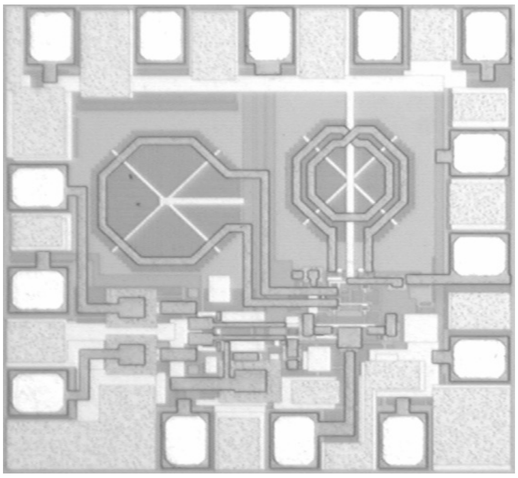

Fig. 2. Chip photo of Micromixer

III. MIXER PERFORMANCE

Simulations are carried out in ADS using Harmonic Balance analysis. Long RF paths are represented in the simulation by using ADS built-in transmission line models. The simulated mixer performance is presented below and will be compared with measured results.

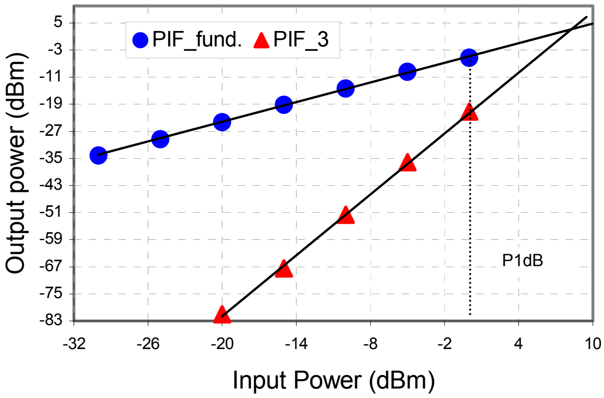

Fig. 3. Fundamental and IM3 power versus RF input power at 23GHz

Mixer IIP3 performance is determined by two-tone measurement. The frequency spacing between the two tones is 100 KHz. Fig.3 show the measured two-tone inter-modulation performance of the mixer versus RF input power at 23GHz. Here, the LO power is -0.7 dBm. The input referred 1 dB compression point P_{1dB} and IIP3 are found to be 0 dBm and 8 dBm, respectively. In Fig.4, IIP3 as a function of LO power is plotted. The simulated curve shows a feature similar to the measured one, thought it underestimates the IIP3.

Conversion gain is measured using spectrum analyzer and the double side band (DSB) noise figure is measured using noise figure meter. The gain is also monitored during noise figure measurement and the results obtained are consistent with measurement using spectrum analyzer. The simulated and measured conversion gain and DSB noise figure as a function of LO power is plotted in Fig. 5. The maximum measured gain is about –3 dB and this is about 4 dB less than the prediction from simulation. Related to this, the measured DSB noise figure is also about 4 dB higher than simulated one. Fig. 5 shows that the gain and noise figure are quite flat for LO power from -2 dBm to 6 dBm. Thus, considering IIP3, gain and noise figure performance together, LO power around 0 dBm should be optimal for this Micromixer.

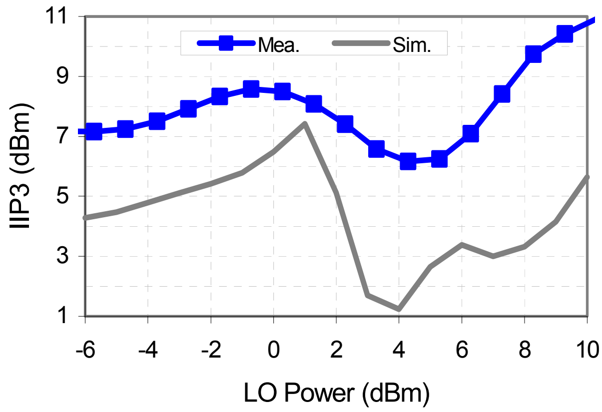

Fig. 4. Measured and simulated IIP3 vs. LO power. RF frequency is 23 GHz

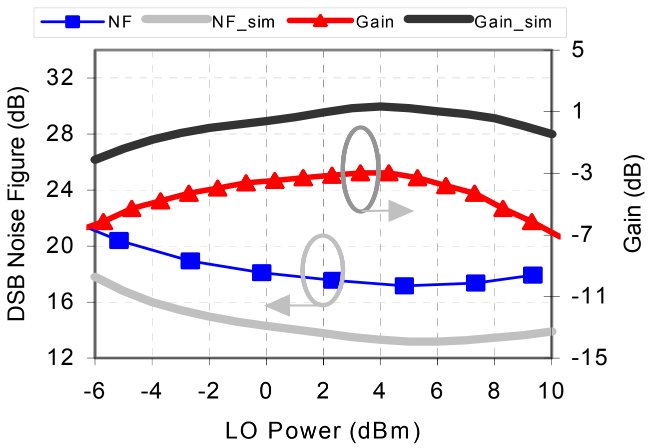

Fig. 5. Measured and simulated Gain and noise figure vs. LO power. RF frequency is 23 GHz

The Micromixer demonstrates wideband characteristic. Measurement shows that it operates normally for RF input frequencies from 17 GHz up to 26 GHz. Fig. 6 plots the conversion gain over input RF frequency. The corresponding DSB noise figure and IIP3 are plotted in Fig. 7. The measured noise figure increases 5 dB over the frequency range. These data are obtained at a LO power of –0.7 dBm. The conversion gain, noise figure and IIP3 all vary smoothly and monotonically over this frequency range (Fig. 6 and Fig. 7).

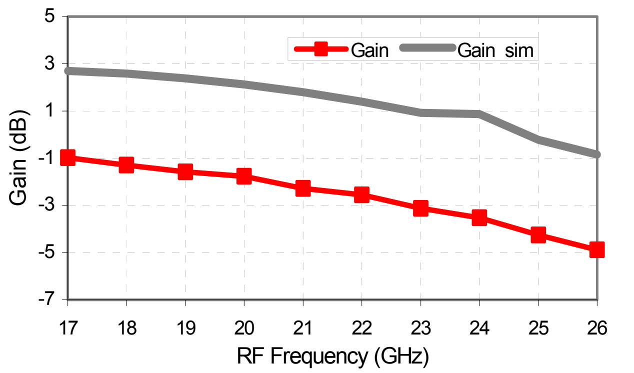

Fig. 6. Conversion gain versus RF frequency, data obtained at –0.7 dBm LO power.

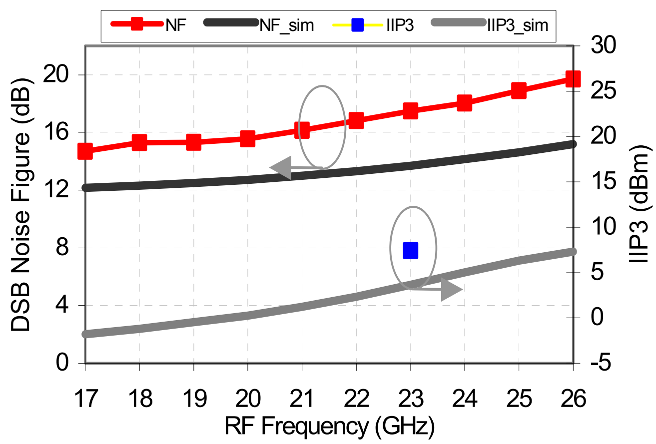

Fig. 7. DSB noise figure and IIP3 versus RF frequency, data obtained at –0.7 dBm LO power.

IV. COMPARISON WITH GILBERT MIXER

Gilbert mixers are active mixers more commonly used than Micromixers. Such a mixer is fabricated on the same wafer as the Micromixer and is designed for the same frequency range [11]. In Table I we list the experimental performance of the two mixers at 23 GHz RF input. An exclusive comparison is not justified here, because the two mixers are measured under their optimal bias conditions that differ for the two mixers. Nevertheless, we hope that Table I could give a crude feeling on how the two types of mixers behave at high frequencies. The Micromixer consumes much less DC power, demonstrates better IIP3, and at the same time has higher noise figure and lower conversion gain.

V. ONCLUSION

A Micromixer have been designed and manufactured in SiGe BiCMOS technology. Its performance over 17-26 GHz is presented in terms of conversion gain, noise figure and linearity. As compared with Gilbert mixer, the Micromixer requires much less DC current to achieve a certain level of linearity. But its noise figure is relatively high and, therefore, can be recommended only when noise figure is not a paramount design requirement.

TABLE I
PERFORMANCE OF MICROMIXER AND GILBERT MIXER

	Micromixer	Gilbert Mixer
IIP3 (dBm)	8.6	3.5
P_{1dB} (dBm)	0	-6
Gain (dB)	-3.6	5.8
Noise Figure (dB)	18.2	8.2
DC power (mW)	86	140
LO power (dBm)	-0.7	2.0

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