5.7 GHz GaInP/GaAs HBT sub-harmonic Gilbert downconverter with octet-phase LO generator

T.-H. Wu, C. Meng and T.-H. Wu

A 5.7 GHz GaInP/GaAs heterojunction bipolar transistor (HBT) sub-harmonic Gilbert downconversion mixer with octet-phase LO generator is demonstrated. The conversion gain is 15 dB, IP_{1dB} is −13 dBm, IIP_3 is 0 dBm, and IIP_2 is 24 dBm when the LO power equals 3 dBm. The measured IF quadrature output waveforms indicate that the phase difference between the in-phase and quadrature-phase output channels is only 1.3°.

Introduction: Two sub-harmonic mixer topologies with I/Q outputs are employed to eliminate the DC offset problem caused by self-mixing in a direct conversion system. One method is to generate quadrature signals in the RF and LO paths [1]. The other approach is to generate octet-phase signals in the LO path and keep the simple real signal in the RF path [2]. The latter topology eliminates the lossy polyphase RF quadrature generator employed in the first topology. Although the second architecture has better performance in terms of noise figure and conversion gain, it is difficult to generate accurate higher frequency octet-phase signals, especially in silicon technologies. The demonstrated CMOS sub-harmonic mixers have the octet-phase LO signal generators less than 2 GHz possibly because of the process variation and the substrate effect [2]. The SiGe HBT sub-harmonic mixer has been demonstrated at 5–6 GHz with the extra electronic tuning in the octet-phase LO signal generator [3].

The GaInP/GaAs HBT technology provides precision thin-film resistors with 50 Ω per square sheet resistance and Si_3N_4 MIM capacitors with 0.36 fF/μm^2. Compared with 0.18 μm CMOS technology, the sheet resistance is about 300 Ω per square and the unit capacitance is 1 fF/μm^2. The passive elements provided by the GaInP/GaAs HBT technology can tolerate more process variations because larger dimensional passive elements are employed in the circuit. Furthermore, the problematic parasitic substrate effect in silicon is totally absent because of the semi-insulating GaAs substrate. Hence, accurate octet-phase LO signals without any extra electronic tuning can be achieved in the high frequency regime using GaInP/GaAs HBT technology.

Circuit design: The circuit topology is shown in Fig. 1. There are two sub-harmonic mixers for I-Q downconversion paths. As shown in Fig. 1, the LO stage consists of a two-section passive polyphase filter and buffer amplifiers to generate the required octet-phase LO signals for I and Q mixers [1]. The levelled LO cell consists of several emitter-coupled pairs, as in Fig. 1. If differential input signals are injected into the emitter-coupled pair, only the even harmonics appear at the common collector nodes. Thus, this structure can be used for the sub-harmonic mixer.

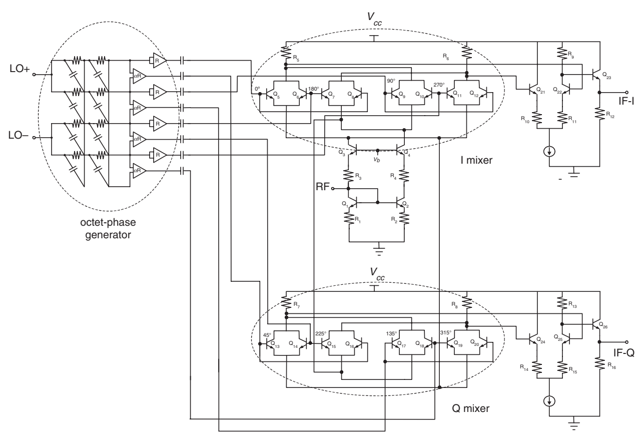

Fig. 1 *Schematic of 5.7 GHz sub-harmonic GaInP/GaAs HBT Gilbert downconversion mixer*

The micromixer [4] is a suitable topology for high frequency mixer designs. As shown in Fig. 1, the micomixer has a high-speed single-to-differential input RF stage consisting of transistors Q_1–Q_4 to generate the differential RF signals required by the LO current commutation stage. An output stage is employed at the IF output port to combine the output signal and to perform the output impedance matching in the RF measurement environment.

Results and conclusions: The die photo is shown in Fig. 2 and the total size is 2 × 1 mm, including probing pads. The DC power supply is 5 V and the current consumption of mixer cores excluding buffer amplifiers is 12 mA. The measured conversion gain is 15 dB when the IF frequency is 400 kHz and the LO power equals 3 dBm. The measured P_{1dB} is −13 dBm, the IIP_3 is 0 dBm and the IIP_2 is 24 dBm, as shown in Fig. 3. The measured double sideband noise figure of the mixer is 28 dB. The measured LO-to-IF isolation is better than −39 dB from 2.55 GHz and 3.15, while the measured LO-to-RF isolation is better than −36 dB. The measured 2LO-to-RF isolation is better than −51 dB, while the 2LO-to-IF isolation is better than −60 dB.

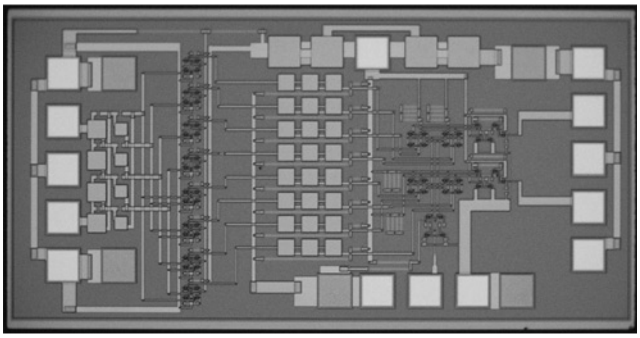

Fig. 2 *Die photo of fabricated 5.7 GHz sub-harmonic GaInP/GaAs HBT Gilbert downconversion mixer*

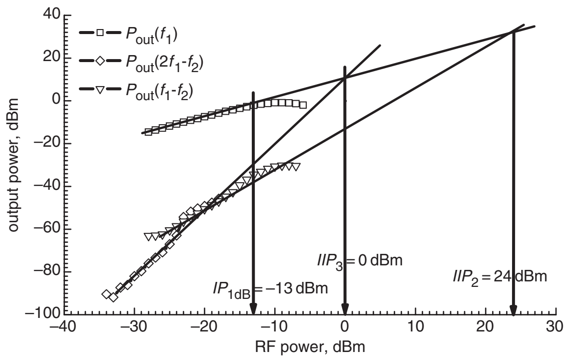

Fig. 3 *Measured P_{1dB}, IIP_2 and IIP_3 of 5.7 GHz sub-harmonic GaInP/GaAs HBT Gilbert downconversion mixer*

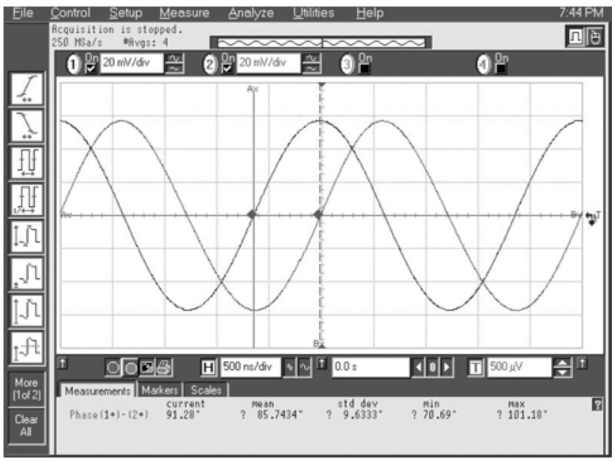

Fig. 4 *Measured IF waveform at I-channel and Q-channel of 5.7 GHz sub-harmonic GaInP/GaAs HBT Gilbert downconversion mixer*

The measured RF S_{11} is better than −12 dB from DC to 6 GHz. Fig. 4 shows the measured I-Q IF output waveforms and the experimental results indicate that the phase difference between the I channel and the Q channel is only about 1.3°. The I-Q output of the mixer is also highly quadrature without any tuning resulting from the careful chip layout, the accurate passive circuit elements being provided by the GaInP/GaAs HBT technology and the fully-balanced structure.

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T.-H. Wu, C. Meng and T.-H. Wu (*Department of Communication Engineering, National Chiao Tung University, Hsinchu 300, Taiwan, Republic of China*)

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