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SIGE BICMOS SUBHARMONIC GILBERT MIXER USING LUMPED-ELEMENT RAT-RACE COUPLERS

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ABSTRACT: A single-ended down-conversion subharmonic mixer is implemented using 0.35- μm SiGe BiCMOS technology. Two lumped-element rat-race couplers are applied to generate differential LO and RF signals. This single-ended rat-race mixer has the conversion gain of 25 dB, -90-dB $2\times\text{LO}$ -to-RF isolation and -78-dB $2\times\text{LO}$ -to-IF isolation at the RF frequency of 10 GHz. The input return loss is about -10 dB. © 2007 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 49: 2018–2020, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22563

Key words: direct-conversion; lumped-element; rat-race; SiGe subharmonic

1. INTRODUCTION

Direct-conversion is the main stream in the transceiver architecture design. Because of no demand of image rejection in a direct-conversion transceiver, many bulky and expensive off-chip components are eliminated [1–3]. Therefore, the direct-conversion structure can be utilized not only for the manufacturing cost reduction but also for the high integration. In a direct-conversion structure, the LO frequency of the fundamental mixer is too close to the RF one so that the LO radiation and self-mixing caused by the LO leakage can influence the transceiver performance. However, a harmonic mixer conquers these problems because of the large difference between the RF and LO frequencies. The subharmonic mixer works with the second harmonic of the LO signal, so that the LO frequency is set to be half of the RF frequency. Then, the mixer is free of LO self-mixing and the LO leakage radiation is easily lowered by a well-designed antenna.

There are three distinct subharmonic active mixers based on the double-balanced structure. The first one is a two-level stacked-lo structure. The two-level stacked-lo structure performs twice mixing with quadrature LO signals and had been implemented in the SiGe HBT technology [4]. The other two types, top-lo-configuration and bottom-lo-configuration mixers, are one-level structures

and their operation is based on the second harmonic generated by the transistor nonlinearity [5–7].

Subharmonic active mixers need balanced differential input signals and balanced quadrature LO signals to perform harmonic mixing perfectly. External baluns or hybrids are commonly used to generate the desired signals. However, those components should be integrated in chips to reduce the magnitude and phase mismatches of cables or baluns for high frequency applications. The most commonly used 180° hybrid is a rat-race coupler. For integration, the lumped-element techniques are applied in rat-race couplers for size reduction [8]. In this letter, a 10-GHz subharmonic mixer with rat-race couplers is demonstrated using 0.35- μm SiGe BiCMOS process.

2. CIRCUIT DESIGN

When an emitter-coupled pair with collectors tightening together is fed with a differential sinusoidal signal, this emitter-coupled pair doubles input signal frequency and also eliminates the fundamental tone. Thus, it can be used to effectively double the LO frequency. The mixer core in this letter is designed based on this principle.

Figure 1 depicts the bottom-lo-configuration subharmonic mixer. The LO emitter-coupled pairs are under the RF input stage. These emitter-coupled pairs can effectively double the LO frequency as well as the phase. Here, the differential quadrature LO signals generated by a two-section poly-phase circuit and a 5-GHz rat-race coupler are employed to pump the mixer LO port. The LO differential quadrature signals hence function as the $2\times\text{LO}$ differential signals.

Two rat-race couplers are employed at RF and LO stages. For size reduction, the lumped-element technique is utilized. Simplified lumped-element rat-race is designed based on quarter-wavelength and three-quarter-wavelength “pi” networks [8]. The adjacent shunt capacitor and inductor can cancel each other while two neighboring shunt capacitors are combined in order to reduce the number of lumped elements.

Differential active PMOS loads replace resistive loads in order to improve the conversion gain without reducing the voltage swing headroom. The drawback is the bias stability between PMOS and NMOS transistors. Therefore, the common mode feedback (CMFB) technique is adopted to adjust the current of active PMOS

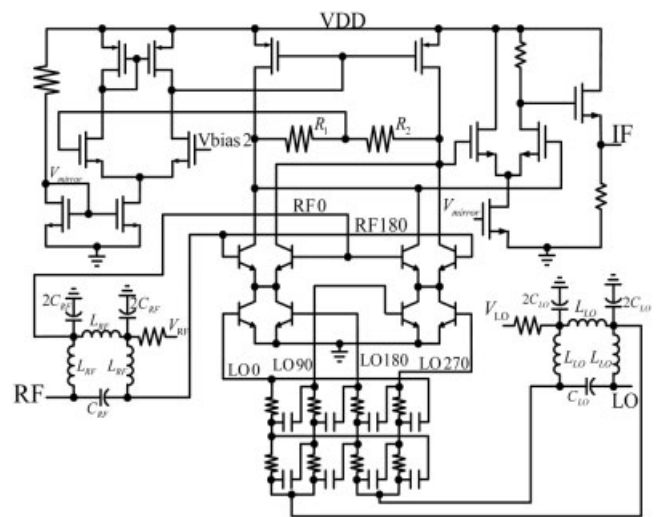


Figure 1 Schematic representation of the subharmonic mixer with lumped-element LO and RF rat-race couplers

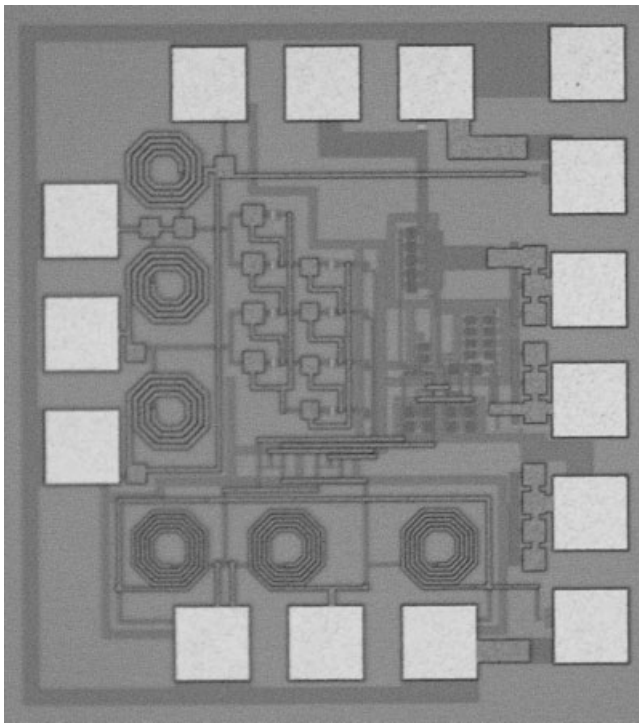


Figure 2 Die photo of the rat-race subharmonic mixer

loads and to guarantee NMOS and PMOS in saturation region. Here, the resistors, R_1 and R_2 , serve as the CMFB sensing resistors with high resistance to preserve high gain performance.

3. EXPERIMENTAL RESULTS

A high frequency subharmonic mixer is fabricated on the $0.35\text{-}\mu\text{m}$ SiGe BiCMOS technology and its die photo is shown in Figure 2. The chip size is only about $0.8 \times 0.9 \text{ mm}^2$. The input return loss is about -10 dB and the total current consumption is about 16 mA at 3.3 V supply. The wideband property of the subharmonic mixer is measured with RF frequency from 9.8 to 10.4 GHz . The conversion gain is about 25 dB with the fixed IF frequency of 50 MHz .

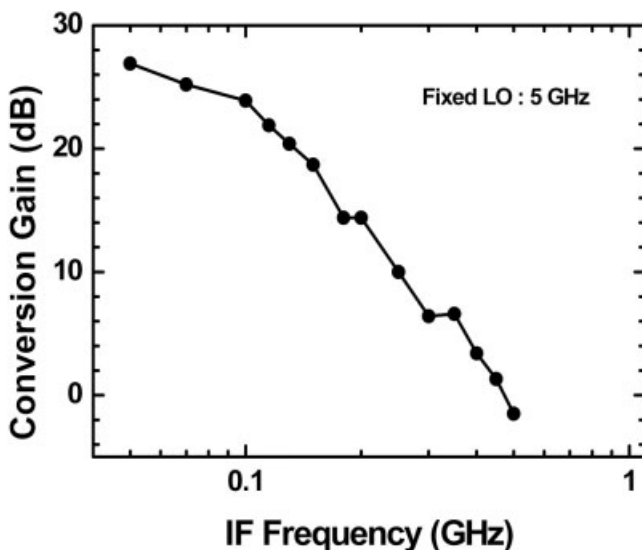


Figure 3 Conversion gain of the rat-race subharmonic mixer with respect to IF frequencies

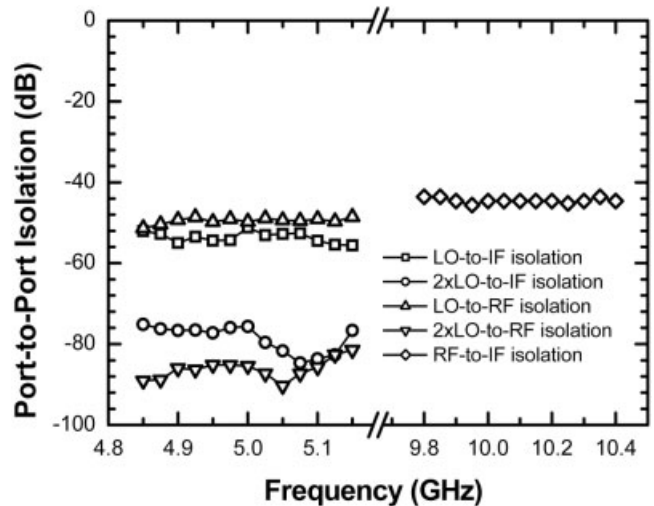


Figure 4 Port-to-port isolations of the rat-race subharmonic mixer

This rat-race mixer is measured with a fixed 5 GHz LO signal, as shown in Figure 3. Because of high impedance of PMOS loads, the frequency response is slow. The input 1-dB compression point, $IP1\text{dB}$, is -30 dBm and the input third-order intercept point, $IIP3$, is -22 dBm because of the high gain of the output buffer. This rat-race subharmonic mixer has the -49-dB LO-to-RF isolation, -90-dB $2\times\text{LO}$ -to-RF isolation, -53-dB LO-to-IF isolation, -78-dB $2\times\text{LO}$ -to-IF isolation, and -44-dB RF-to-IF isolation, as shown in Figure 4. High port-to-port isolations are achieved, thanks to the truly balanced quadrature LO and differential RF signals.

4. DISCUSSIONS AND CONCLUSIONS

This letter demonstrates a single-ended rat-race down conversion subharmonic mixer using standard $0.35\text{-}\mu\text{m}$ SiGe BiCMOS technology. Differential LO and RF signals are generated by integrated lumped-element rat-race couplers. This rat-race mixer operates at 10 GHz and has 25-dB conversion gain with the IF frequency of 50 MHz . Besides, high port-to-port isolations are archived thanks to the truly balanced quadrature LO and differential RF signals. The input return loss is about -10 dB and the chip size is $0.8 \times 0.9 \text{ mm}^2$. The total power consumption is about 52.8 mW .

ACKNOWLEDGMENTS

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A MICROSTRIP BANDGAP FILTER WITH THE PHOTONIC BAND GAP RESONATORS

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ABSTRACT: A microstrip bandstop filter using four square air hole resonator at frequencies above 10 GHz has been investigated. The square air holes resonator generate a bandgap, and its operation mechanism is made clearly through the Finite Differential Time-Domain method. The measured frequency response of the filter is in good agreement with the simulation, and the center frequency of stopband of the microstrip filter shifted to higher frequency along with the dimension of the square air holes increased. © 2007 Wiley Periodicals, Inc.

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Key words: microstrip filter; Photonic Band Gap; bandstop; Finite Differential Time-domain (FDTD)

1. INTRODUCTION

In microstrip technology, a Photonic Band Gap (PBG) structure is obtained by introducing an adequate periodic pattern drilled in the substrate [1, 2], etched in the ground plane [3, 4] and etched in the microstrip [5–7]. The shortcoming of the previous two methods is the fabricated method and interference problem for the other electronics in the same substrate: the drilled substrate can affect the other designed microwave elements in the same substrate; the etched ground plane must be far from any metal plate to keep etched patterns in the function. The third method has conquered the shortcoming of previous methods, and the majority of the structure has higher order bandgap.

In this study, a microstrip bandgap filter with four square air holes etched in strip is investigated. The structure contains periodic cells of square patterns (Fig. 1).

The structures were both measured and simulated with Finite Different Time-Domain (FDTD). The measured results are good agreement with the simulation.

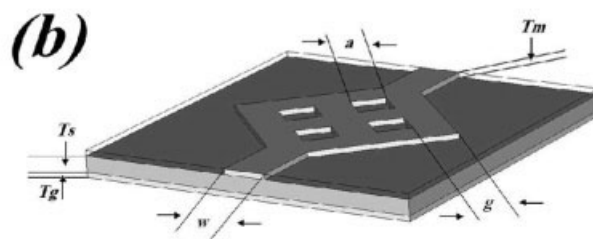
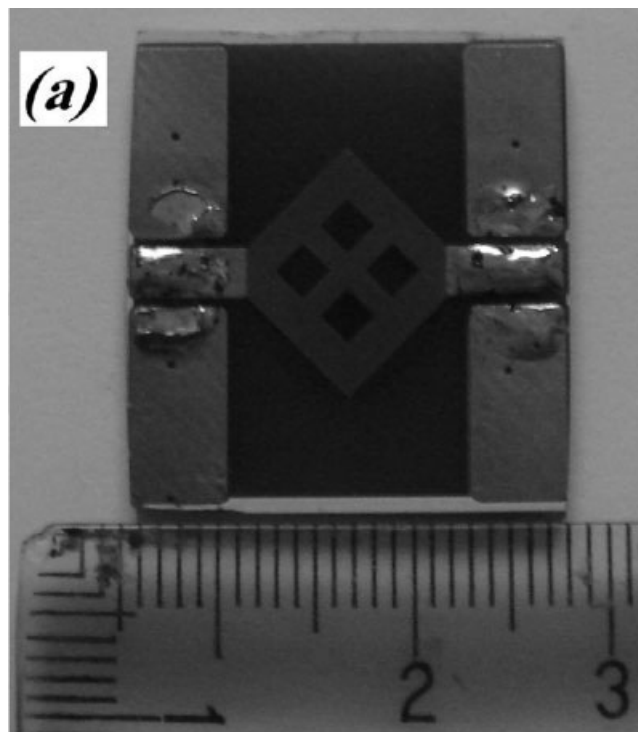


Figure 1 (a) The photograph of microstrip bandstop filter; (b) the schematic diagram of microstrip bandstop filter

2. FILTER DESIGN AND FABRICATION

The design and subsequent analysis of the filter was carried out by means of FDTD simulation method, which is a popular computational electrodynamics modeling technique. The targeted cutoff frequency was around 11 GHz, with potential application for the microwave communication, radar target identification, and wireless communication device. The microstrip filter is fabricated by the etching of PCB, which has been printed on circuit boards [Fig. 1 (a)]. The substrate of our microstrip filter is made of the microwave materials FR-4. The dielectric constant of FR-4 and the thickness is 4.5 mm and is 1.4, respectively. The thickness of the microstrip and the ground are both 0.1 mm. The width of the microstrip line is 2.5 mm, corresponding to a 50 Ω characteristic impedance.

The microstrip consists of a square patch, and four square air holes in the patch. The detailed dimension information of the microstrip filter is as following [Fig. 1 (b)]. The square patch is 9.2 mm \times 9.2 mm, the square air hole a is 2 mm \times 2 mm, and the distance g is 1.9 mm between the edge of square air hole and square patch. The feedline is connected with corner of the square patch. The length and width of feedline are 6 and 2.5 mm, respectively.