

On the other hand, several MIMO configurations have been considered to compare performances in terms of channel capacity including electromagnetic parameters of the antenna, such as radiation patterns and mutual coupling. The Spatial Channel Model from 3 GPP has been used for the simulations. Higher capacity has been obtained in the configuration where the two antennas has been placed in parallel with a spacing of 0.4 wavelengths within a PDA, mainly due to the lower mutual coupling and thus to uncorrelation between MIMO subchannels. Moreover, the radiation pattern for both antennas has been measured and MIMO channel measurement have been carried out in an indoor environment, obtaining in average higher capacity in the case of the designed PIFAs.

#### ACKNOWLEDGMENT

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## A FULLY SINGLE-ENDED GaInP/GaAs HBT MICROMIXER USING AN INTEGRATED ACTIVE LO BALUN

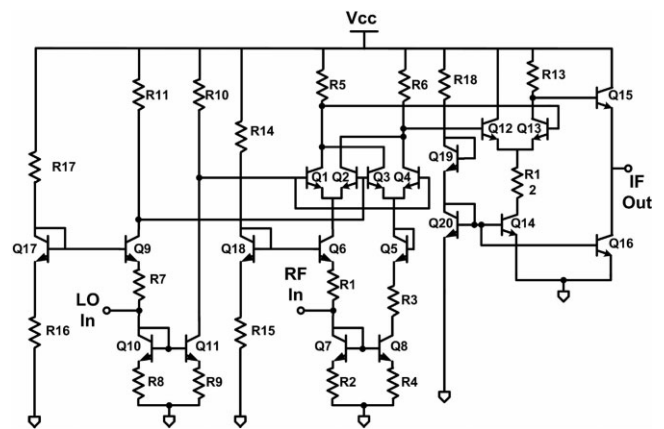
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**ABSTRACT:** A Gilbert micromixer is demonstrated in this paper using GaInP/GaAs HBT technology. By using an on-chip active LO balun, the



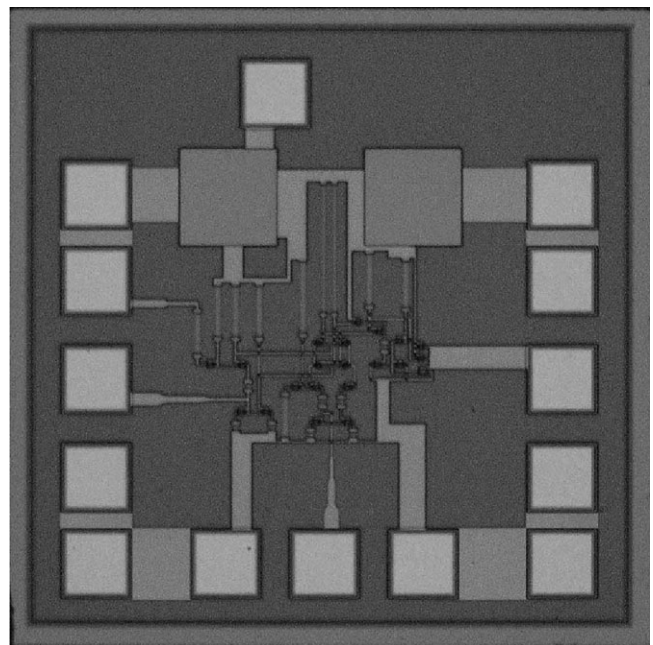
**Figure 1** The circuit schematics of single-ended GaInP/GaAs HBT micromixers with an LO active balun

*micromixer with the single-ended RF, LO, and IF ports is suitable for hybrid RF system applications. The port-to-port isolation has its best performance when the LO signal is balanced. The fully matched high-linearity micromixer has the conversion gain of 12 dB,  $IP_{1dB}$  of  $-9$  dBm,  $IIP_3$  of 1 dBm when  $f_{IF(input)} = 300$  MHz,  $f_{LO} = 3.5$  GHz, and  $f_{RF(output)} = 3.8$  GHz. © 2008 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 50: 1918–1921, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23549*

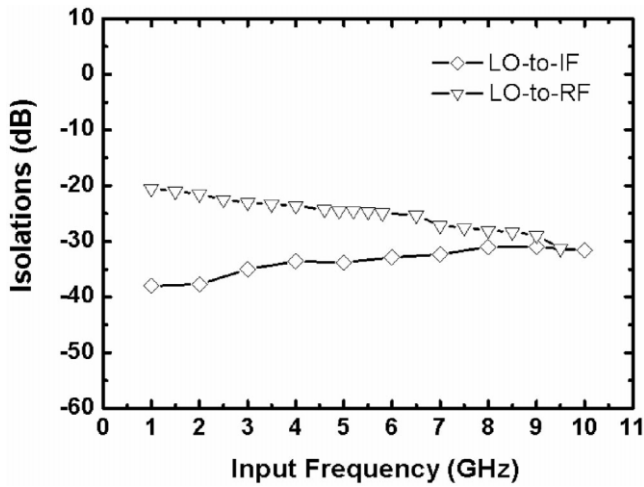
**Key words:** GaInP/GaAs HBT; micromixer; single-ended; active balun

#### 1. INTRODUCTION

The mixer is a circuit with two high-speed ports and one low-speed port. The speed of the RF input port in a down-conversion mixer must be fast enough to response the RF input signal. Thus, the emitter degeneration and the micromixer topology are used to increase the input RF bandwidth of the mixer [1–4]. A Gilbert mixer needs balanced IF, LO, and RF signals for higher conversion gain, better dynamic range, and good isolation [5]. The RF stage of micromixer can generate truly balanced RF signal and increase the



**Figure 2** The die photo of the micromixer using the active LO balun

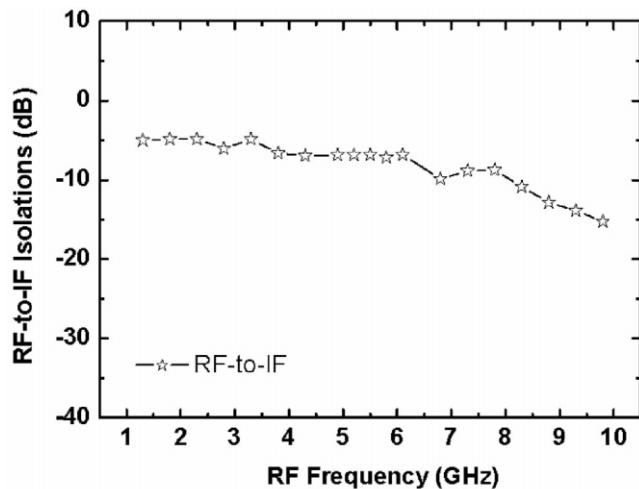


**Figure 3** The measured LO-to-IF and LO-to-RF isolations of the GaInP/GaAs HBT micromixer with the active balun

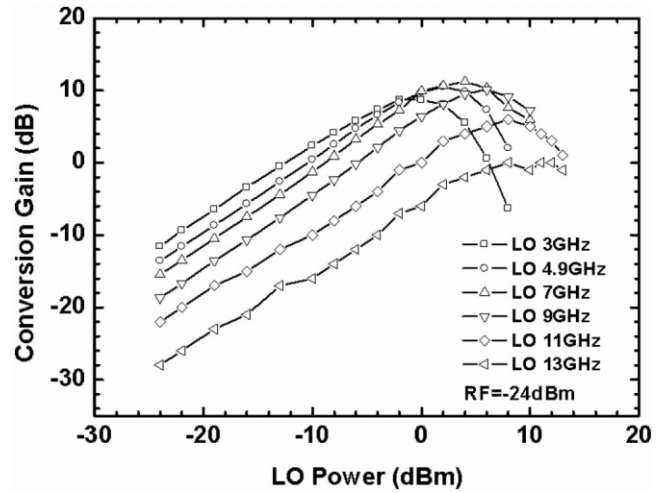
RF bandwidth simultaneously. On the contrary, the speed of the mixer Gilbert cell is usually faster than that of the RF stage, and the challenge of the LO stage is to supply a pair of truly differential LO signals.

A micromixer using LO on-chip baluns is demonstrated in this paper. The RF, LO, and IF ports of the micromixer are single-ended; therefore, they are suitable for the stand-alone board-level applications. A micromixer with an LO active balun is demonstrated as shown in Figure 1. Generally speaking, the active balun has advantages in terms of the smaller chip area by the active balun when compared with the passive baluns [6, 7]. A new experimental observation method is developed in this paper to indicate the LO signal balance. The maximum port-to-port isolation occurs when the LO and RF signals are truly differential.

The best LO-to-IF and LO-to-RF isolations can be achieved when the LO signal is truly balanced. Thus, the observation on the port-to-port isolations can effectively indicate the LO signal balance. In this paper, the mixer using the active balun keeps the same when varying the frequency of the LO signal. It is because the active balun has a wideband response. The mixer using the active balun has 12 dB gain and smaller chip area. The RF-to-IF, LO-



**Figure 4** The measured RF-to-IF isolation of the GaInP/GaAs HBT micromixer with the active balun



**Figure 5** The measured conversion gain as a function of the LO power of the micromixer with the active balun

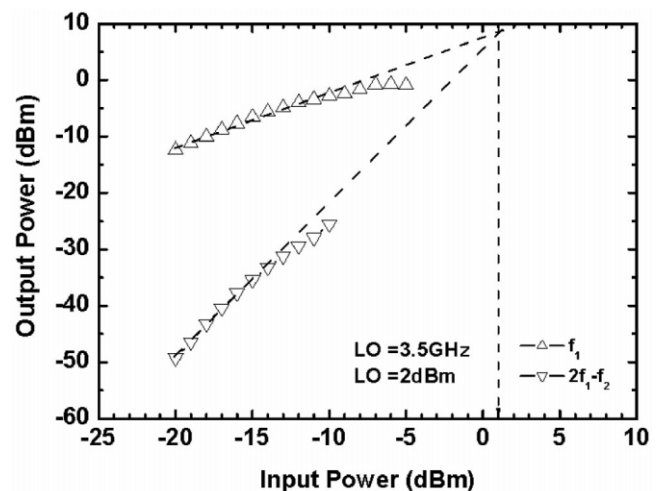
to-IF, and the LO-to-RF isolations of the mixer with the active balun are about  $-5$ ,  $-20$ , and  $-30$  dB, respectively.

## 2. CIRCUIT DESIGN

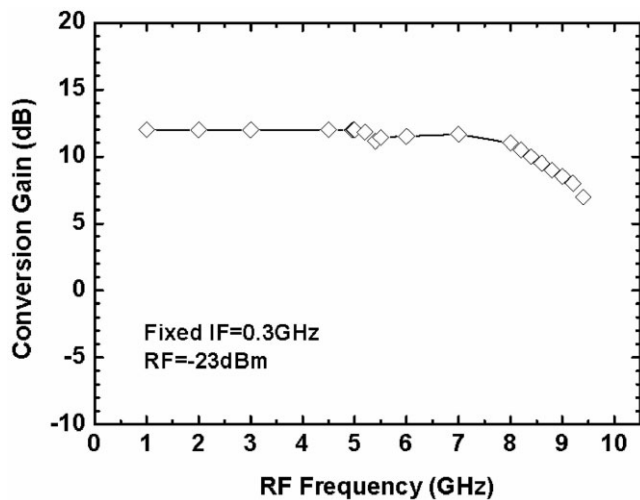
The down-conversion mixer in Figure 1 consists of a LO Gilbert mixer core (Q1, Q2, Q3, and Q4) with an on-chip LO balun (Q9 to Q11, and R17 to R10), an active RF single-to-differential transconductance stage (Q5, Q6, Q7, and Q8), and an IF output differential amplifier (Q12 and Q13) with a common-collector output buffer, Q15.

The Gilbert mixer with the RF input stage in Figure 1 is known as the micromixer. The single-to-differential transconductor replaces the conventional emitter-coupled-pair transconductor in the Gilbert down-conversion mixer and does not consume extra power [1, 2]. The diode-connected transistor Q7 lowers the impedance of the common-emitter transistor Q8 and thus improves the frequency response of the RF input port.

The active balun requires extra biasing current and the dynamic range is usually worse than that of the passive lumped rat-race hybrid [6, 7]. However, the active balun consumes only very small chip area and provides some gain for the LO signal. Figure 2



**Figure 6** The measured  $IP_{1dB}$  and  $IIP_3$  of the GaInP/GaAs HBT micromixer with the active balun



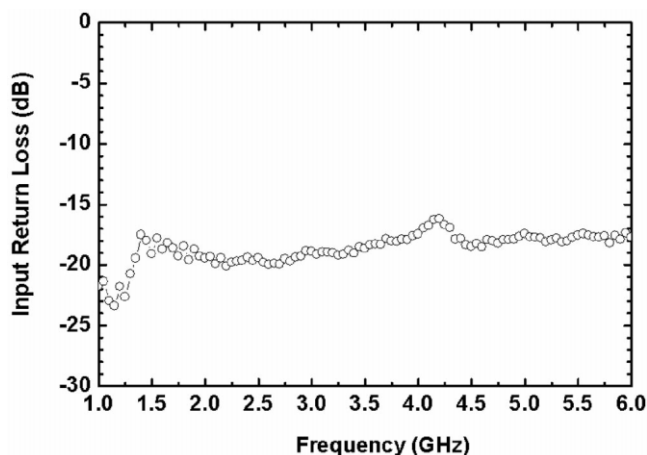
**Figure 7** The measured RF bandwidth of the GaInP/GaAs HBT mixer with the active LO balun

shows the die photo of the micromixer using active LO balun. This all single-in and single-out mixer consumes very small IC area of  $350 \times 200 \mu\text{m}^2$  including the active balun. The micromixer with passive balun consumes biasing current of 20 mA, whereas the current consumption of the mixer with active balun is 25.4 mA. The DC supply voltages of both mixers are 4.5 V.

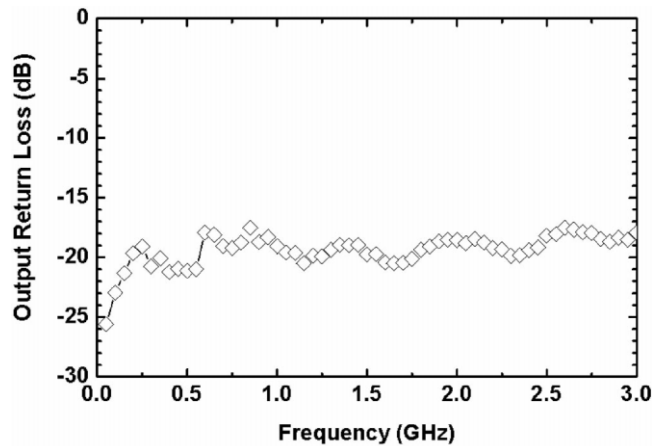
### 3. EXPERIMENTAL RESULTS

Figure 3 shows the LO-to-IF and LO-to-RF isolations of the mixer using the active balun. The LO-to-IF isolation and the LO-to-RF isolation are better than  $-20$  and  $-30$  dB, respectively. Because the active LO balun has broadband frequency response, the measured port-to-port isolations do not vary significantly as the LO frequency sweeps. Figure 4 shows the RF-to-IF isolation and it is better than  $-5$  dB.

In general, the BJT-type Gilbert cell requires only small LO power; therefore, the conversion gain as a function of the LO power should have a flat response. It is because when the LO voltage is larger than 100 mV (four times of the thermal voltage,  $V_T$ ), the LO Gilbert cell begins to commute the RF current as long as the LO signal is truly differential. Figure 5 shows the conversion gain as a function of the LO power of the micromixer



**Figure 8** The measured input return loss of the GaInP/GaAs HBT mixer with the active LO balun

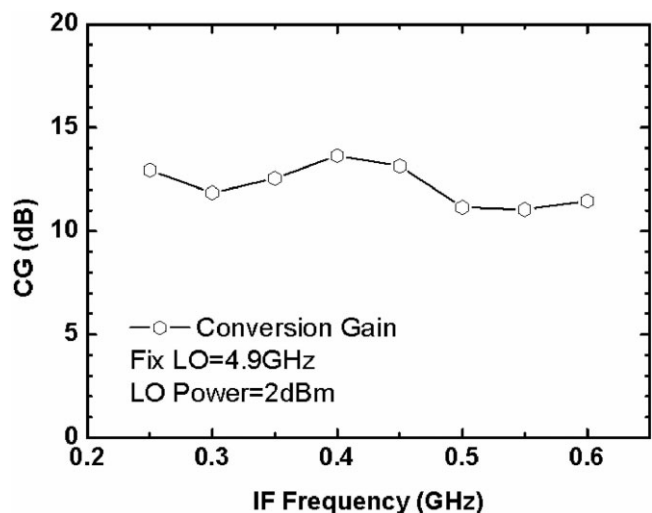


**Figure 9** The measured output return loss of the GaInP/GaAs HBT mixer with the active LO balun

using the active balun. When the LO frequency increases, the conversion gain degrades because the active balun has a low-pass frequency response.

Figure 6 shows the measured  $IP_{1\text{dB}}$  and the  $IIP_3$  of the mixer with the active balun when the RF frequency is 3.8 GHz and the LO frequency is 3.5 GHz. Under the LO power of 2 dBm, the  $IP_{1\text{dB}}$  and  $IIP_3$  are  $-9$  and 1 dBm, respectively. Figure 7 shows the RF frequency response of the mixer using active balun. The RF bandwidth is about 9 GHz because of the micromixer input stage. Because of the micromixer, the response of the input stage is improved and is up to 9 GHz.

Figure 8 shows the input return loss of the micromixer using the active LO balun. The measured input  $S_{11}$ , which is better than  $-15$  dB, shows that the micromixer has wideband input impedance matching. On the other hand, the output return loss is shown in Figure 9. The measured  $S_{22}$  is better than  $-17$  dB from 50 MHz to 3 GHz. The output stage of the demonstrated micromixer is a common collector stage, and thus the output impedance matching is also wideband. Figure 10 shows the measured IF bandwidth of the GaInP/GaAs HBT mixer.



**Figure 10** The measured IF bandwidth of the GaInP/GaAs HBT mixer with the active LO balun

### 3. DISCUSSIONS AND CONCLUSIONS

A Gilbert micromixer is demonstrated in this paper using GaInP/GaAs HBT technology, and the stand-alone micromixer is suitable for hybrid RF system applications. The fully matched and high-linearity micromixer has a conversion gain of 12 dB,  $IP_{1dB}$  of  $-9$  dBm,  $IIP_3$  of 1 dBm when  $f_{IF(input)} = 300$  MHz,  $f_{LO} = 3.5$  GHz, and  $f_{RF(output)} = 3.8$  GHz.

### ACKNOWLEDGMENTS

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## A NOVEL RECONFIGURABLE CIRCULAR POLARIZATION PATCH ANTENNA

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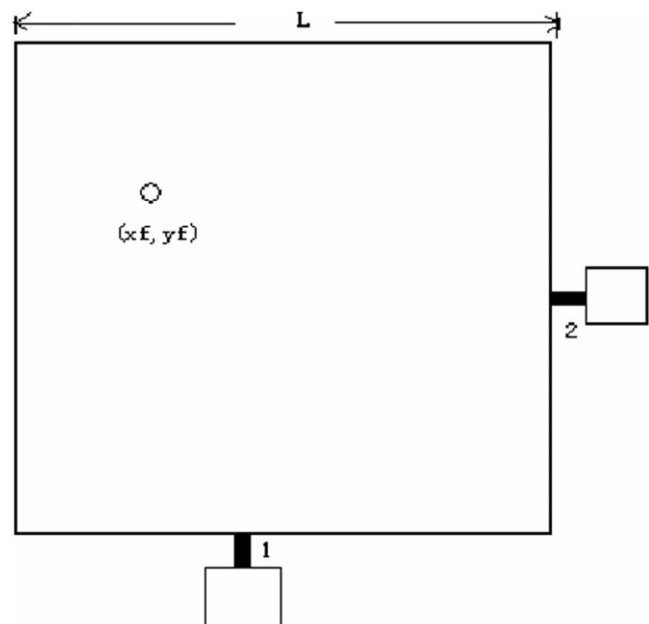
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**ABSTRACT:** A novel design of a microstrip patch antenna with switchable branches is proposed to achieve circular polarization diversity. Two branches are incorporated into the patch and two switches are utilized to switch the branches on and off. By turning the switches on or off, this antenna can radiate with either right-handed circular polarization or left-handed circular polarization using the same feeding probe. Experimental results validate this concept. This design demonstrates useful features for wireless communication applications and future planetary missions. © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 1921–1923, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23537

**Key words:** diversity method; microstrip antennas; polarization

### 1. INTRODUCTION

Antenna systems that utilize polarization diversity are gaining popularity because of the development of wireless communication in recent years. Polarization diversity antennas provide a powerful modulation scheme [1]. In [2] and [3], a reconfigurable antenna was built from a dual-polarized aperture-coupled antenna, which used a 3-dB hybrid branch-line coupler as a polarizer to obtain circular polarization (CP). Boti et al. [1] proposed a compact single-feed switchable antenna with four-beam lead pin diodes inserted directly on coupling slots, but with three metallization levels. To switch the polarization sense, Yang and Rahmat-Samii [4] used only two diodes directly mounted on two orthogonal slots incorporated on the probe-fed patch antenna. In [5], the switching between right-handed circular polarization (RHCP) and left-handed circular polarization (LHCP) is obtained by turning ON/OFF two pairs of beam-lead pin diodes soldered near an annular slot ring. With the same radiating structure, Ho et al. [6] used two pin diodes on a uniplanar antenna where both the radiating element and feed-line circuit were on the same layer. In a recent project to build a Mars rover, a patch antenna with dual-frequency and dual-polarization capabilities is required [7]. In light of these applications, we present a novel antenna for polarization diversity: a patch antenna with switchable branches that can achieve RHCP and LHCP with a single feeding port. The patch antenna is selected because of the desirable features it possesses, such as low profile, light weight, and conformability with RF circuitry. Two branches are incorporated into the square patch and two switches are positioned to control their status. By turning the switches on or off, either RHCP or LHCP be obtained with the same feeding probe which is located on the diagonal line of the patch. Compared with previous designs, this antenna is simple and attractive in that it involves only one patch and a single feed. It is also worthwhile to point out that the RHCP and LHCP are time separated so that there is no coupling between these two polarizations. The validity of this concept is demonstrated by experimental results with good axial ratios (ARs) achieved in both RHCP and LHCP operations.



**Figure 1** Geometry of a patch antenna with switchable branches for RHCP/LHCP diversity