concluded that the proposed antenna works properly with an acceptable receiving level in wide bandwidth.

4. CONCLUSION

In this study, the frequency tuning circuit is applied to an electrically small antenna for wideband applications in low frequencies. The T-DMB service allocated to the 200-MHz band and composed of seven service channels with 6 MHz bandwidth each is selected for testing this proposed concept. The used radiator size was chosen as $10 \times 30 \times 3$ mm^3 and the input impedance was measured as almost zero in the band of target range even with the matching circuit. To match the low impedance to 50 Ω and provide the frequency tuning ability to the antenna concurrently, the tuning circuit is designed. It makes the antenna not only to be matched to about 50 Ω with properly narrow bandwidth, but also satisfy the required 42 MHz bandwidth by moving its resonant frequency. The validity of the proposed antenna is proved by the measured result, and it shows the frequency bands' shifting with appropriate signal reception level.

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GaInP/GaAs HBT BROADBAND INDUCTORLESS RECEIVER

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ABSTRACT: *A GaInP/GaAs HBT broadband RF front-end consisting of a low-noise wideband amplifier and a micromixer is demonstrated in this article. The major advantage of this work is the elimination of inductors and thus the chip area can be greatly saved. The bandwidth of the RF front-end is up to 7 GHz. The measured conversion gain is higher than 25 dB from 1 to 7 GHz and the noise figure of the RF front-end is less than 8 dB within the bandwidth.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 247–250, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23048

Key words: *GaInP/GaAs HBT; wideband amplifier; micromixer; Gilbert mixer*

1. INTRODUCTION

Recently, there is a trend to merge many RF front-ends into a multiband multimode system [1–5]. The conventional receivers for multiband and multimode applications are often implemented by integrating many low noise amplifiers (LNAs) and mixers directly [1, 2]. In this kind of implementation [1, 2], each LNA is designed for one specific RF band and excellent performances can be achieved, because each LNA simply takes care of one particular band. However, this type of multiband receiver suffers from large chip area. For instance, the circuit in [1] contains so many inductors that the on-chip inductors occupy 80% chip area of the RF circuit. In addition, the circuit in [2] contains two LNAs and thus the on-chip inductors also occupy more chip area.

In this article, an inductor-less RF front-end is demonstrated using 2 μm GaInP/GaAs HBT technology. As shown in Figure 1, the RF front-end consists of a dual-feedback wideband LNA using the Kukielka topology [6] and a wideband Gilbert micromixer [7, 8]. The wideband amplifier has excellent RF bandwidth due to the feedback circuit technique. In addition, the heavily doped base of the GaInP/GaAs HBT has the low-base resistance, and good noise performance can be achieved because the thermal noise is low. As a result, the wideband LNA is possible by using the Kukielka topology.

To reduce the cost by saving chip area, more and more multiband LNA are demonstrated using the feedback amplifier [3–5]. The first-stage double-feedback wideband amplifier contains no inductors in this work and the active area of the wideband amplifier only occupies 300×150 μm^2. The second-stage micromixer is also very compact and no inductor is necessary to perform impedance matching. The active area of the micromixer is only about 250×300 μm^2. Consequently, a multiband and compact RF front-end is demonstrated in this article with acceptable wideband low-noise performance. The measured conversion gain is larger than 25 dB from 1 to 7 GHz and the noise figure is less than 8 dB within the bandwidth.

2. CIRCUIT DESIGN

The wideband amplifier contains two stages. The first stage amplifier is a common-emitter amplifier (transistor Q_1) with emitter capacitive peaking [9]. The second stage amplifier is a Darlington pair (transistors Q_2 and Q_3) with emitter capacitive peaking. This

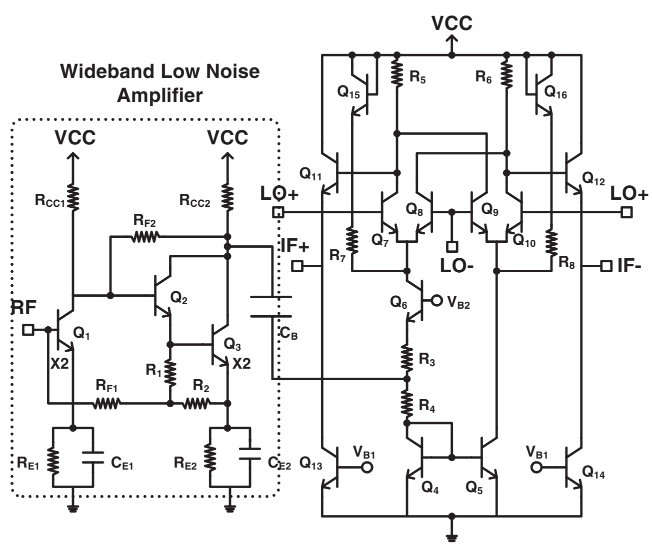

Figure 1 The circuit schematic of the GaInP/GaAs HBT broadband RF front-end

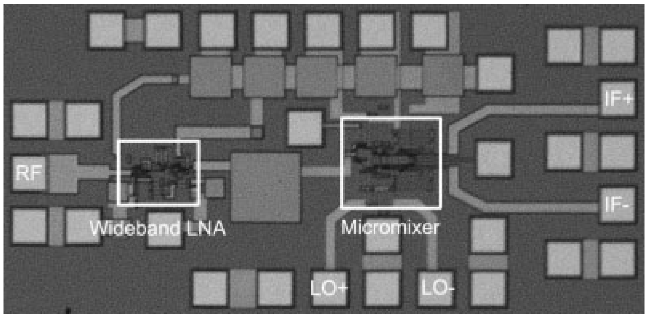

Figure 2 The die photo of the GaInP/GaAs HBT broadband receiver

two-stage wideband amplifier actually is a Cherry–Hooper amplifier [10] if the feedback loop resistor, RF_1, is absent. The Cherry–Hooper topology is a high-speed amplifier because the shunt–shunt feedback (resistor RF_2) lowers the impedance seen by the output of the common emitter first stage.

Moreover, the gain-bandwidth as well as the input/output matching bandwidth is further improved by the emitter capacitive peaking tank (RE_1 with CE_1 and RE_2 with CE_2) and the global shunt-series feedback loop RF_1 [6]. Therefore, the two-stage amplifier is suitable for multiband application. The noise figure of this wideband amplifier can be small if the feedback resistors of the amplifier are proper designed [11]. In addition to the circuit design, the GaInP/GaAs HBT has very small base resistance (R_B). In our design, there are two transistors in parallel for the HBT Q_1 as shown in Figure 1. Each HBT has emitter area of $2 \times 6\ \mu m^2$ and its base resistance provided by the foundry model is 82 Ω. Similarly, the base resistances of other HBTs are also very small. As a result, the thermal noise of the wideband amplifier can be minimized.

The micromixer topology is an excellent high-speed mixer. The diode-connected transistor Q_4 effectively lowers the input impedance of the transistor Q_6; therefore, the speed of the micromixer input stage (transistors Q_4–Q_6) can be improved. In addition to the high-speed performance, the active area of the micromixer can be very compact. Because the input impedance matching is achieved by the resistive matching (resistors R_3 and R_4), no inductor is required. Common collector output buffers consisting of transistors Q_{11}–Q_{14} are used in the IF output stage to perform RF measurement.

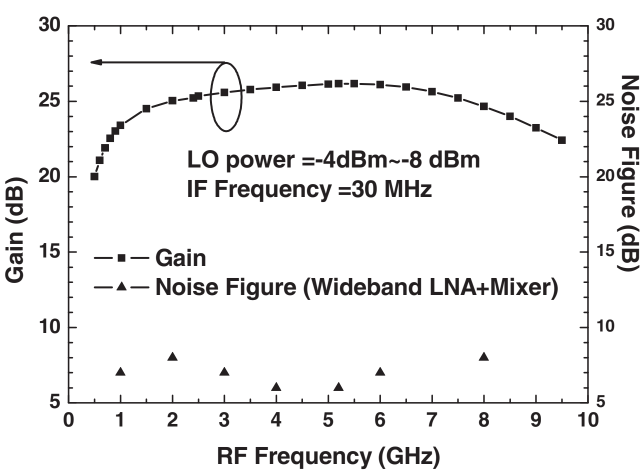

Figure 3 The measured gain and noise figure as a function of RF input frequency of the GaInP/GaAs HBT broadband receiver

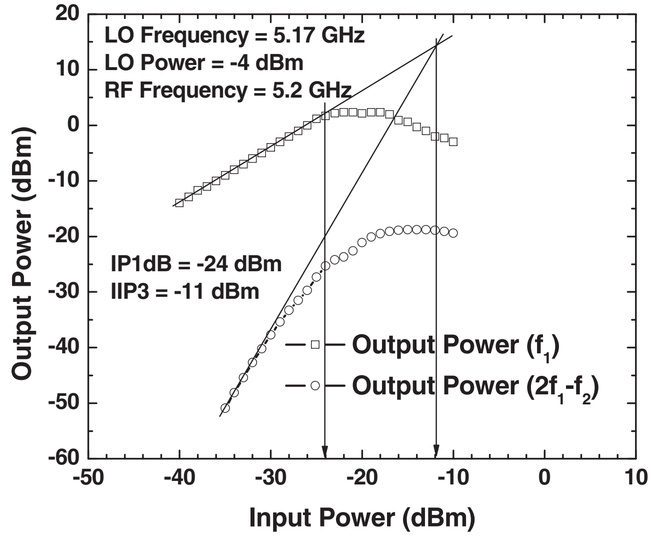

Figure 4 The measured IP_{1dB} and IIP_3 of the GaInP/GaAs HBT broadband receiver when the RF frequency is 5.2 GHz

Figure 2 shows the die photo of the wideband RF front-end. The total chip area is $2 \times 1\ mm^2$. The chip area of the wideband amplifier and the micromixer is only about $300 \times 150\ \mu m^2$ and $250 \times 300\ \mu m^2$, respectively. As shown in the photo, the RF on-wafer probing pads, by-pass capacitors, and the DC blocking capacitor (CB) limit the most of the chip area. There is a 2.3-pF DC blocking capacitor to maintain the bias point of input transistors in the micromixer.

3. MEASUREMENT RESULTS

The V_{CC} of the wideband amplifier is 3.3 V and it draws 10 mA. The V_{CC} of the micromixer is 4 V and its current consumption is 6 mA excluding the output buffer. Figure 3 shows the conversion gain and the double sideband noise figure as a function of the RF input frequency. As shown in Figure 3, the conversion gain is about 25 dB from 1 to 7 GHz. The measured noise figure is less than 8 dB as shown in Figure 3 and there is a local minimum about 6 dB when the RF frequency is around 4–5 GHz. The experimental

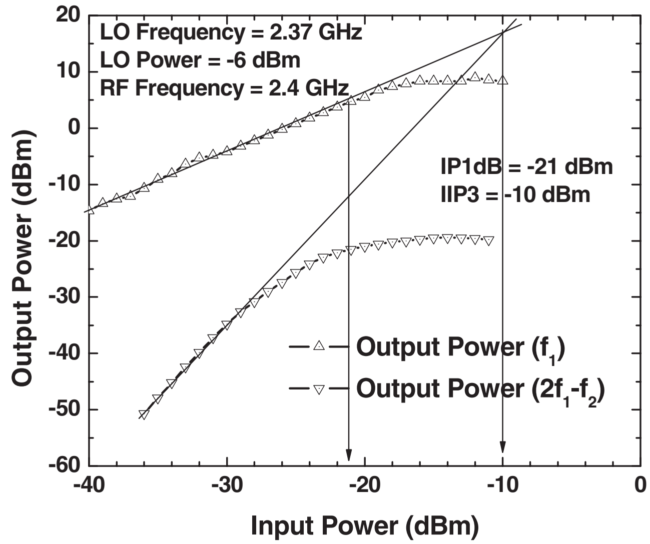

Figure 5 The measured IP_{1dB} and IIP_3 of the GaInP/GaAs HBT broadband receiver when the RF frequency is 2.4 GHz

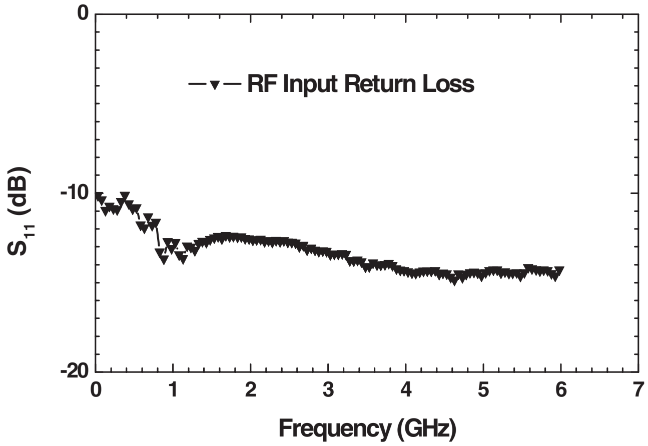

Figure 6 The measured input return loss of the GaInP/GaAs HBT broadband receiver

results shown in Figure 3 is measured when the IF frequency is 30 MHz and the LO power is −4 to −8 dBm.

The IP_{1dB} and IIP_3 when the RF frequencies are 5.2 and 2.4 GHz are shown in Figures 4 and 5, respectively. As shown in Figure 4, the IP_{1dB} of the wideband RF front-end is −24 dBm and the IIP_3 is −11 dBm when the RF frequency is 5.2 GHz and the LO power is −4 dBm.

As shown in Figure 5, the IP_{1dB} of the wideband RF front-end is −21 dBm and the IIP_3 is −10 dBm when the RF frequency is 2.4 GHz and the LO power is −6 dBm. Figure 6 shows the measured S_{11} of the wideband RF front-end. The receiver has broadband input matching.

Figure 7 shows the IF bandwidth of the wideband RF front-end when the RF frequency is 5.2 GHz. The measured 3-dB IF bandwidth is about 150 MHz. The noise figure as a function of IF bandwidth is also plotted in Figure 7. The double sideband noise figure is less than 6 dB when the RF frequency is 5.2 GHz and is less than 8 dB when the RF frequency is 2.4 GHz.

Figure 8 shows the LO-to-IF and LO-to-RF isolations of the demonstrated wideband RF front-end when the RF and LO frequencies are around 5.2 GHz. The measured LO-to-IF and LO-to-RF isolations are −25 and −75 dB, respectively.

Figure 9 shows the LO-to-IF and LO-to-RF isolations of the demonstrated wideband RF front-end when the RF and LO frequencies are around 5.2 GHz. The measured LO-to-IF and LO-to-RF isolations are −26, −85, and 8 dB, respectively.

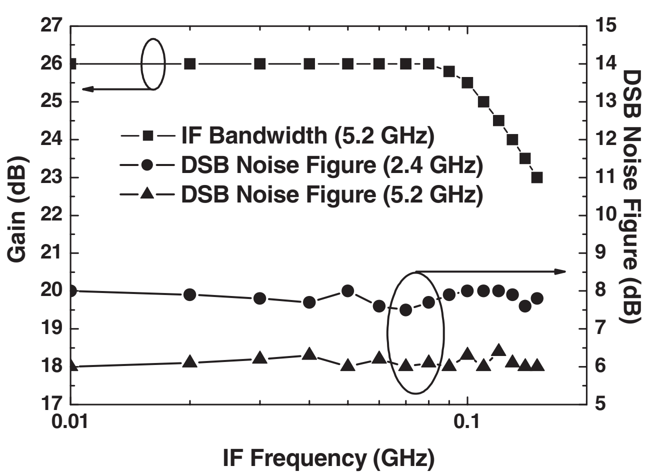

Figure 7 The measured conversion and double sideband noise figure as a function of the IF frequency

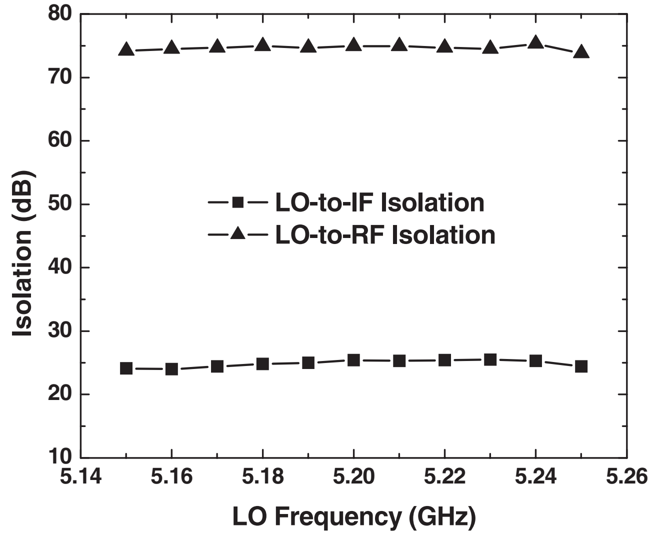

Figure 8 The measured port-to-port isolation of the GaInP/GaAs HBT broadband receiver when the LO and RF frequencies are around 5.2 GHz

4. CONCLUSION

A compact GaInP/GaAs RF front-end for multiband applications is demonstrated in this article. Instead of using multiple LNAs for multi RF-band, a feedback wideband LNA is employed. The die size of the demonstrated circuit is very compact, because no inductor is used in this work. The chip area of the wideband amplifier and the micromixer is only about 300 × 150 μm^2 and 250 × 300 μm^2, respectively. The measured conversion gain is larger than 25 dB from 1 to 7 GHz and the noise figure is less than 8 dB in the bandwidth.

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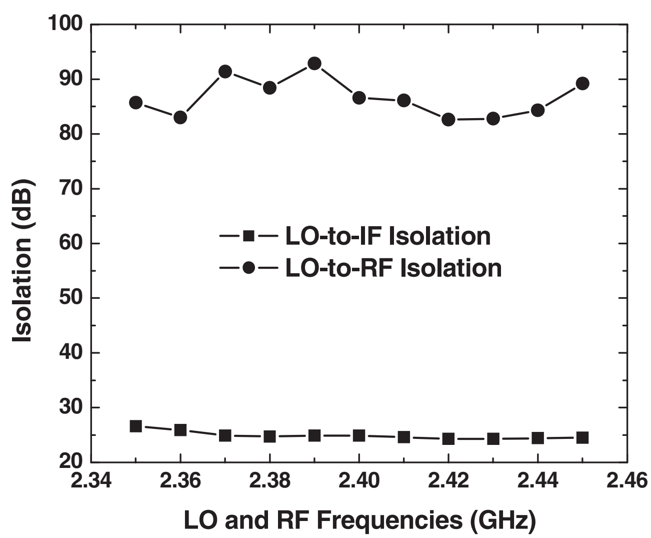

Figure 9 The measured port-to-port isolation of the GaInP/GaAs HBT broadband receiver when the LO frequencies are around 2.4 GHz

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A COMPACT SPIRAL STRIPLINE-LOADED MONOPOLE ANTENNA WITH A VERTICAL GROUND PLANE

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ABSTRACT: *In this letter, we propose a compact spiral stripline-loaded monopole antenna on a vertical ground plane. The measured results show that the antenna has a fractional bandwidth of 12.1% for a voltage standing wave ratio (VSWR) less than 2 at the center frequency of 1.10 GHz, as well as a good omni-directional radiation pattern. The small size of 0.04 $\lambda_o \times 0.04\ \lambda_o \times 0.04\ \lambda_o$ makes it promising for use as an internal antenna in mobile handsets.* © 2007 Wiley Periodicals, Inc.

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Key words: *small antenna; spiral stripline-loaded monopole antenna; disk-loaded monopole antenna; electromagnetically coupled feed*

1. INTRODUCTION

Increasing consumer demand for small handheld transceiver units has spurred the rapid development of compact and broadband antennas [1]. Many antenna structures have been proposed for this application, such as a compact helical antenna using the normal-mode of two helix wires [2], a disk-loaded monopole antenna

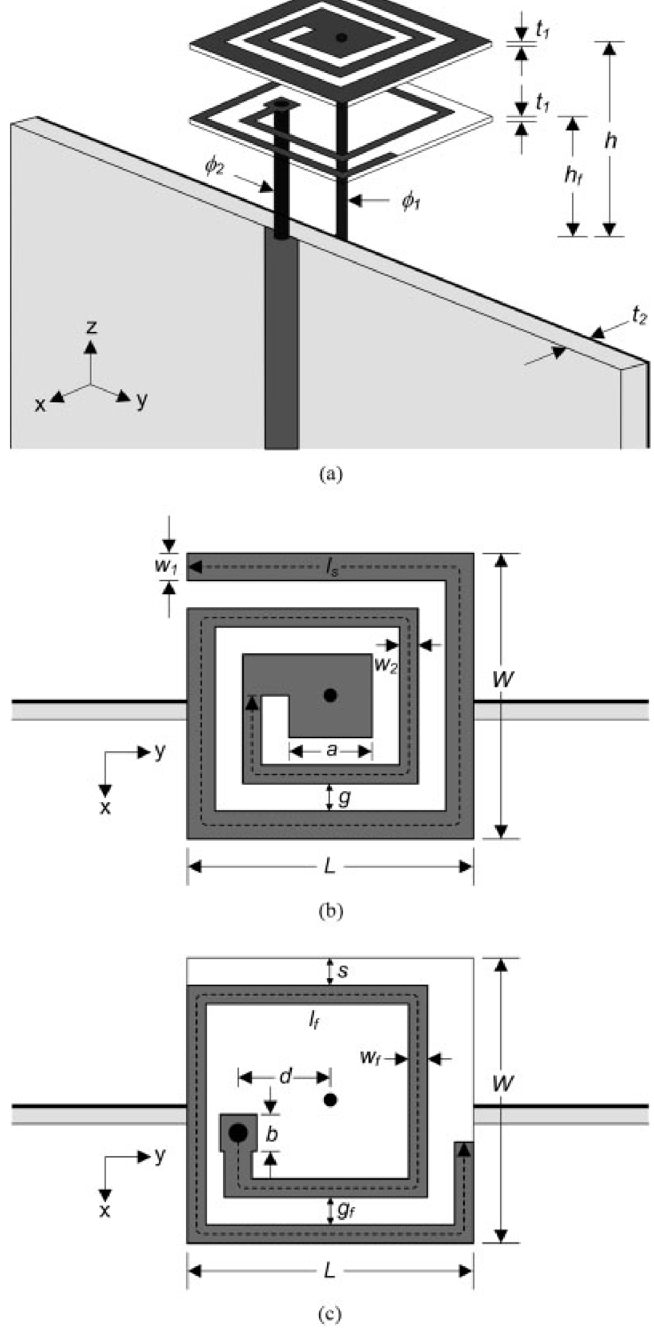

Figure 1 Antenna structure: (a) 3-dimensional view, (b) top view of the upper spiral stripline, (c) top view of the lower spiral stripline