Ka-band Monolithic GaAs PHEMT Circuits for Transceiver Applications

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This paper presents the development of Ka-band circuits for transceiver applications including a low noise amplifier (LNA), a medium power amplifier (PA), a voltage-controlled oscillator (VCO), and a mixer. These monolithic microwave/millimeter-wave integrated circuits (MMICs) are fabricated with a 0.2-μm pseudomorphic (PM) GaAs-based HEMT technology, carried out by commercially available foundry. The LNA demonstrated a measured small signal gain of from 30 to 40 GHz of 17 dB and flat gain is observed. The PA showed a measured small signal gain 15dB at 31 GHz. The VCO demonstrated a measured output power 11 dBm at 34.3 GHz, and mixer has a measured conversion loss 10.5 dB. Due to fabrication with the commercial foundry process, these MMICs have the potential for mass production.

1 Introduction

Microwave low noise amplifiers (LNAs), power amplifiers (PAs), voltage-controlled oscillators (VCOs), and mixers are very important components for RF front-end receiver applications. As the wireless communications become more popular, the application frequency is moving toward higher frequency range due to the crowdness of low frequency spectrum. Owing to the advancement of GaAs HEMT MMIC technology [1]-[3], it is feasible to develop MMIC wireless applications. These MMIC chips are fabricated using a commercial 0.2-μm pseudomorphic (PM) GaAs-based HEMT technology foundry process [4], therefore they have the potential for mass production. Moreover, these MMIC chips are suitable for front-end low noise receiver applications and can be integrated with other components to form a single-chip RF subsystem.

The LNA has a measured small signal gain of from 30 to 40 GHz is 17 dB and good gain flatness is observed. The medium PA has measured a small signal gain of 15 dB at 31 GHz. The VCO demonstrated a measured output power of 11 dBm at 34.3 GHz. The mixer has a measured conversion loss of 10.5 dB.

2 Device Characteristics and MMIC Process

The GaAs-based pseudormorphic HEMT (PHEMT) MMIC process foundry service is provided by Philips Microwave Limeil, France [4]. The device is a 0.2-μm gate-length low noise PHEMT with a maximum unit current gain frequency (f_T) of 53 GHz. The drain current at peak transconductance under 3-V drain bias is 208 mA/mm. The passive components include GaAs bulk resistor, MIM capacitor, and via hole through 100-μm GaAs substrate. The entire chip is also protected by silicon-nitride passivation for reliability concern.

3 Low Noise Amplifier

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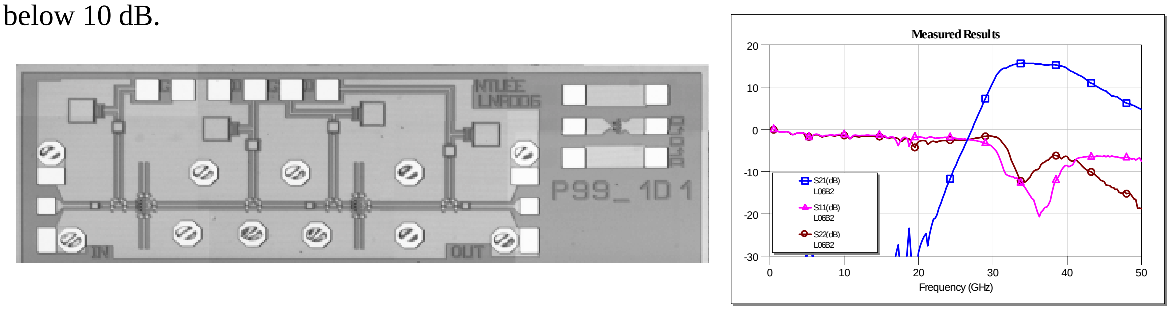
The two-stage grounded CPW low noise amplifier is designed using 120-µm PHEMT devices [5]. Inductive T transformers were used as matching networks. MIM capacitors were used for dc blocking and RF bypassing, while air bridges and via holes were fabricated to prevent the excitation of the slot-line modes. Fig. 1(a) shows the chip photo, while the chip size is 2.25×1 mm^2. The measured results of the two-stage LNA are shown in Fig. 1(b). Small signal gain from 30 to 40 GHz is 17 dB and good gain flatness is observed. In the central frequency, both input and output return loss are below 10 dB.

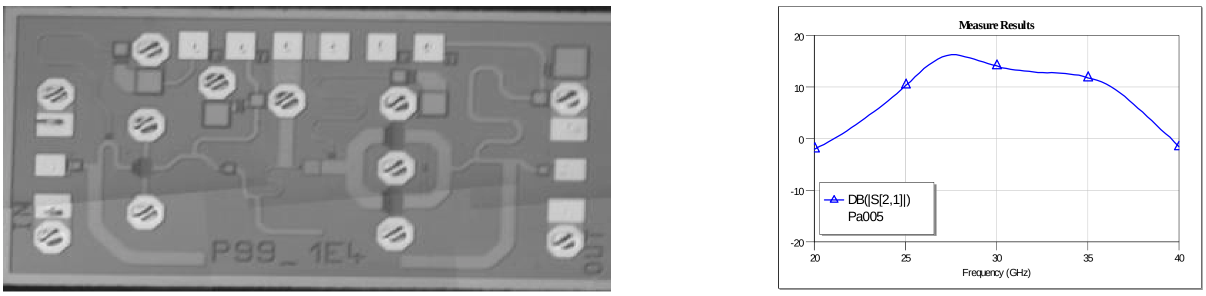


(a) (b)

Fig. 1(a) The chip photo, and (b) the measured results of the two-stage CPW LNA.

4 Medium Power Amplifier

This medium power amplifier is a two-stage single-ended microstrip-line design with output device periphery of 360 µm [6]. Optimum load at 35 GHz was determined from the device nonlinear model using harmonic balance simulation. Two devices were combined at the second stage to provide enough power and the first stage was designed to drive the second stage. Source inductance is added at driver stage for stability concern. Odd mode clamping resistor was inserted between combined devices to suppress odd mode oscillation. Out-of-band stability was improved by the resistively loaded quarter-wave-length stubs. Fig. 2(a) shows the chip photo of the two-stage PA. Small signal measured results are shown in Fig. 2(b). 15-dB small signal gain is achieved at 31 GHz.

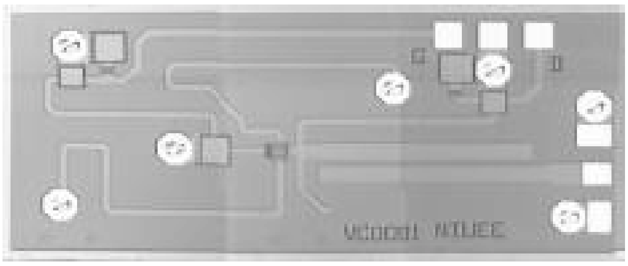


(a) (b)

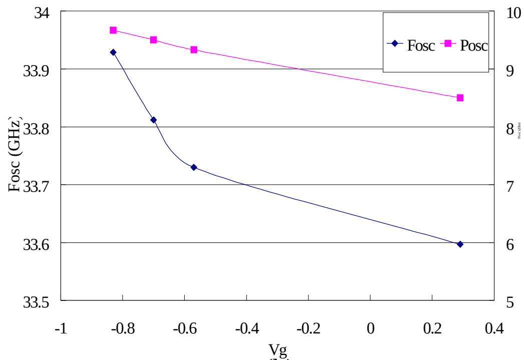
Fig. 2(a) The chip photo. (b) The measured results of the two-stage microstrip-line PA.

5 Voltage-Controlled Oscillator

A four-finger with 120-µm periphery PHEMT was used for the output power consideration. The VCO is a common gate design, and the oscillating frequency is tuned by the gate voltage. A pair of coupled lines were used to couple the output power to the output port and served as a dc blocking. Fig. 3(a) shows the chip photo of the monolithic 35-GHz VCO, with a chip size of 2.25 × 1 mm^2. Fig. 3(b) shows the spectrum plot of the output signal. An 11-dBm output power is measured at 34.3 GHz. The output frequency can be tuned by using the gate bias. The tuning range is 330 MHz.



(a)

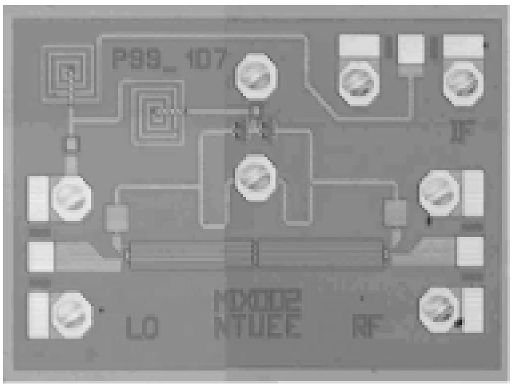


(b)

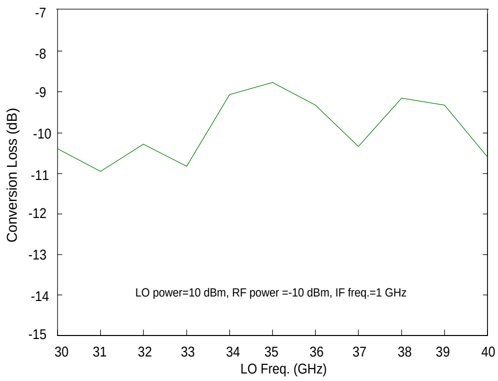
Fig. 3(a) the chip photo, and (b) output power and tuning range as function of bias voltage of the VCO.

6 Mixer

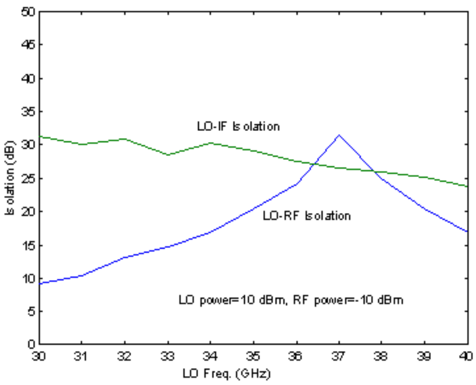
The singly balanced diode mixer was designed using microstrip-lines. The Lange coupler was selected as 90^{o} 3-dB hybrid for bandwidth consideration. A pair of four-finger diode with 80-μm were selected. A low pass filter was designed to achieve both Lo-to-IF and RF-to-IF isolations. Fig. 4(a) shows the chip photo of this mixer, while the chip size is 1.5×1 mm^2. About 10.5 dB conversion loss is achieved as shown in Fig. 4(b). Isolation and return loss measurements are shown in Fig. 4 (c) and Fig. 4(d) receptively. The return loss of LO and RF are both better than 20 dB and isolation are better than 10 dB and 25 dB.



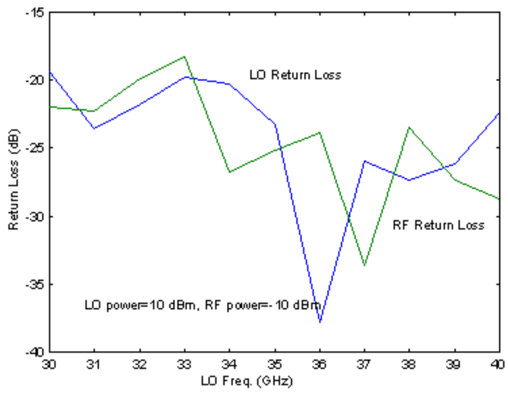
(a)



(b)



(c)



(d)

Fig. 4 The measured results of the singly balanced diode mixer. (a) chip photo (b) conversion loss (c) isolation (d) return loss

7 Summary

Several Ka-band monolithic chips including a CPW LNA, a medium PA, a VCO, and a singly balanced-diode mixer for RF front-end receiver applications were developed with reasonable performance. The MMIC chips are fabricated via commercial GaAs PHEMT foundry process and these chips can be integrated with other RF transceiver components into a multi-functional chip for compact transceiver module applications.

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