A Low Distortion GaAs Quadrature Modulator IC

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Abstract

A low distortion GaAs Quadrature Modulator IC with on-chip active 90° phase-shifter was fabricated by using high linearity GaAs MESFET technology for wide-band wireless applications. The IC showed OIP3 of +16dBm, CLR of -40dBc, and IRR of -40dBc at supply voltage of 5.0V, dissipation current of 70mA and carrier frequency of 600MHz. Excellent EVM smaller than 1.0% and ACPR of 60dBc were also obtained for 4Mbps QPSK signal with Pout of -10dBm.

Introduction

In a wide-band wireless communications, a high dynamic range and high modulation accuracy of the device are indispensable for high capacity and high communication quality of the systems. A Quadrature MODulator (QMOD) IC is one of the key devices to this system because the modulator dominates the quality of modulated signal. Several types of QMOD ICs were reported with excellent RF performance by using Si bipolar or GaAs FET technologies [1-3], but their performance was not appropriate to the use for a wide-band system. The purpose of this work is to develop a low EVM and low distortion QMOD IC with on-chip 90° phase-shifter using GaAs MESFET for wide-band wireless applications.

Design of the IC

In order to attain the objective, the following techniques have been introduced to the design of the QMOD IC;

(1)High linearity mixer and high gain phase-shifter by the best combination of FETs of different gate lengths.

(2)High uniformity and high performance FETs by self-aligned asymmetric LDD MESFET process.

(3)High accuracy active phase-shifter by using high-ε_r capacitors as a DC de-coupler.

Intermodulation distortion in the QMOD originates mainly from a non-linearity in the FETs that handle base-band signals. Reducing non-linearity in drain conductance by extending gate length can lower the non-linearity in the FETs, but on the other hand, this approach may result in smaller gain and higher power consumption. In order to satisfy the objectives at the same time, two types of FETs were individually designed. High linearity and high dynamic range FETs were designed for base-band signal and high gain and low dissipation current FETs for active phase-shifter by using individual process techniques.

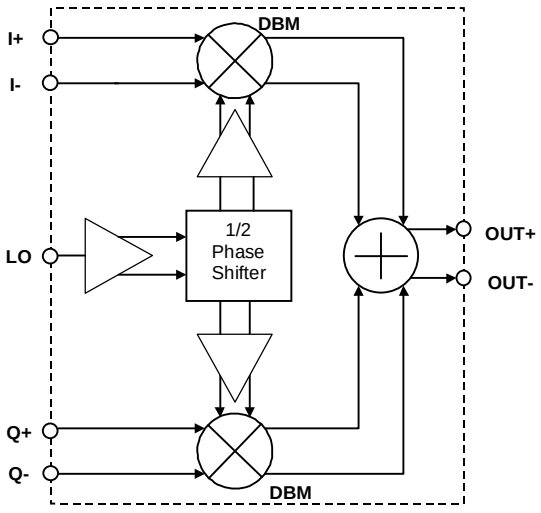

Fig. 1 Block diagram of the quadrature modulator.

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Figure 1 shows a block diagram of the QMOD IC. An active phase shifter using master-slave flip-flop frequency divider and Double Balanced Mixer (DBM) compose this QMOD IC. Each circuit of these blocks is shown in Figure 2 and 3 respectively.

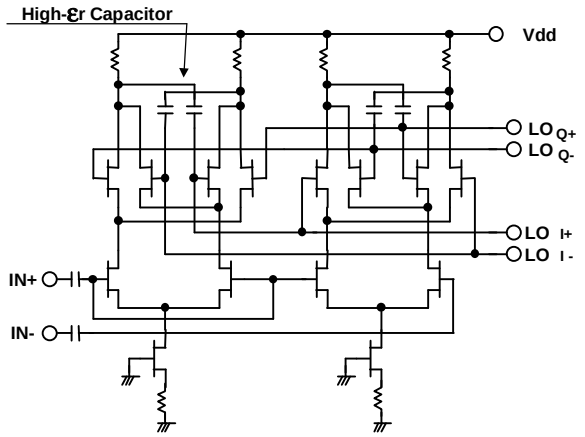

Fig. 2 Circuit schematic of the master-slave flip-flop phase shifter using STO high-εr capacitors.

The active phase-shifter was composed of a flip-flops (F/F) 1/2-frequency divider, buffer amplifier and differential amplifiers. Figure 2 shows a circuit schematic of master-slave F/F 1/2-frequency divider. Each circuit block was connected by using high-ε_r capacitor [4], therefore each blocks were free from a bias fluctuation of other circuit blocks. This DC de-coupling circuits lead the circuit to high accuracy and high stability operation. Furthermore, it offers flexibility for circuit design without increasing the chip size because small size capacitor was realized by using high-ε_r MIM capacitor.

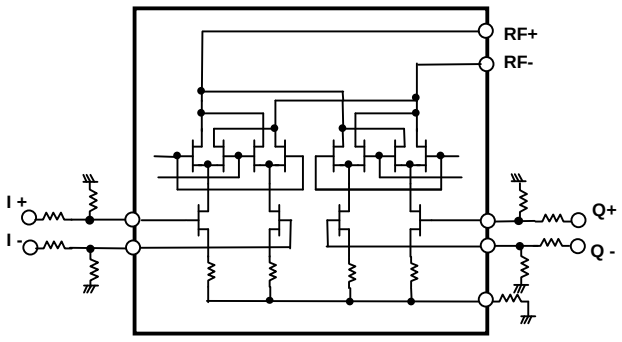

Fig. 3 Circuit schematic of the double-balanced mixer

Figure 3 shows the circuit schematics of the DBM. The DBM was composed of the Gilbert cell FET mixer. A base-band signal input to the gate of a first stage FET. An offset voltage of the base-band signal controlled gate voltage of the FET. To obtain a low distortion mixer, we designed the FET to have a large Wg and long Lg as compared with the phase shifter. Wg of the FET was 1.0mm and Lg was 1.0μm.

IC Process

Figure 4 shows a schematic cross sectional view of the LDD BP-MESFET and high-ε_r capacitor. The GaAs MESFET was fabricated by using self-aligned asymmetric LDD process using a refractory metal gate. We designed the FET of the mixer as 1.0μm-gate and threshold voltage (Vth) of –1.0V to achieve a high linearity mixing operation. On the other hands, the FET of the phase shifter was designed as 0.5μm-gate and Vth of –0.7V with buried p-layer FET to achieve a high gain and to prevent a short channel effect. Furthermore, for low drain conductance, high K-value and high breakdown voltage on the asymmetric LDD FET, the distance between the gate and the drain was optimized as 1.0μm for 0.5μm-gate and 1.5μm for 1.0μm-gate, respectively. The K-value and drain conductance of the fabricated FET was 300mA/V^{2}mm and 0.30mS for the 0.5μm-gate FET, and 170mA/V^{2}mm and 0.18mS for the 1.0μm-gate FET.

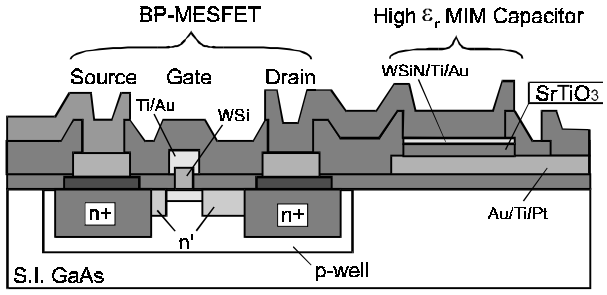

Fig.4 Schematic cross-sectional view of the LDD BP-MESFET and high-εr capacitor

The high-ε_r MIM capacitor was fabricated by using $SrTiO_3$ thin film. It was deposited on the Pt electrodes

by the low temperature RF sputtered process technique [4]. Film deposition temperature was set at under 300ºC. ε_r of the 120, leakage current density of less than 10^{-6} A/cm^2, the break-down voltage of 30 V at film thickness of 300 nm and 1MV/cm were obtained. This capacitor offers 10 pF by only 50 $\times$50 μm^2 that was 1/14 of the SiN MIM capacitor.

As a result, the chip was minimized to size of 1.2 x 1.4mm^2 (Fig. 5) and molded in a SSOF16 plastic package (Fig. 6).

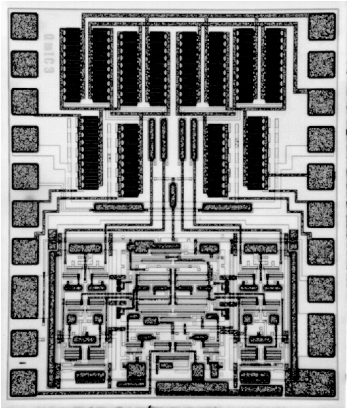

Fig. 5 Chip photomicrograph
Chip size:1.2 X1.4mm^2

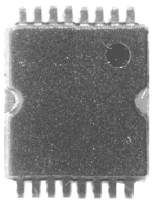

Fig. 6 External view of QMOD IC (SSOF16)

IC Performance

Excellent RF characteristics of the GaAs QMOD IC were obtained at carrier frequency of 600MHz using new techniques as mentioned above.

Figure 6 shows an output spectrum of the fabricated QMOD IC. The power-supply voltage was 5.0V. The base band frequency was 2MHz. The image rejection ratio and carrier rejection ratio is about –40dBc, and other spurious level are smaller than -65dBc.

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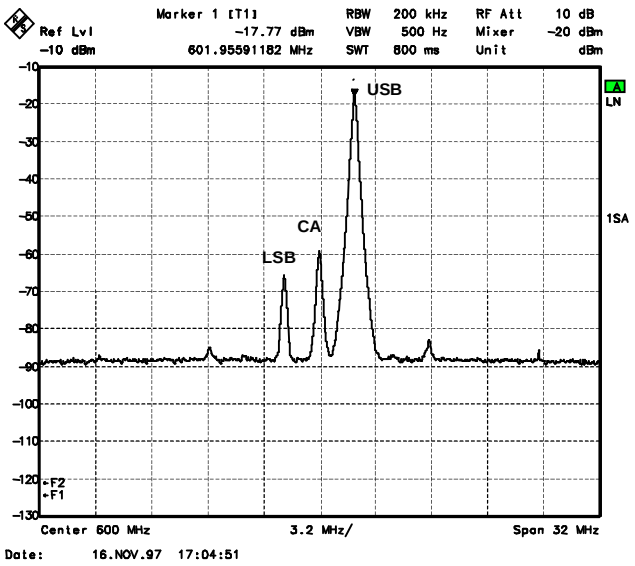

Fig. 7 Output spectrum at local frequency of 600MHz.

Figure 8 shows the dependence of the output products on the LO input level at the local signal frequency of 1.2GHz. This IC realized a modulation with lower input power of LO signal such as -40dBm by using high RF performance 0.5µm-gate FET.

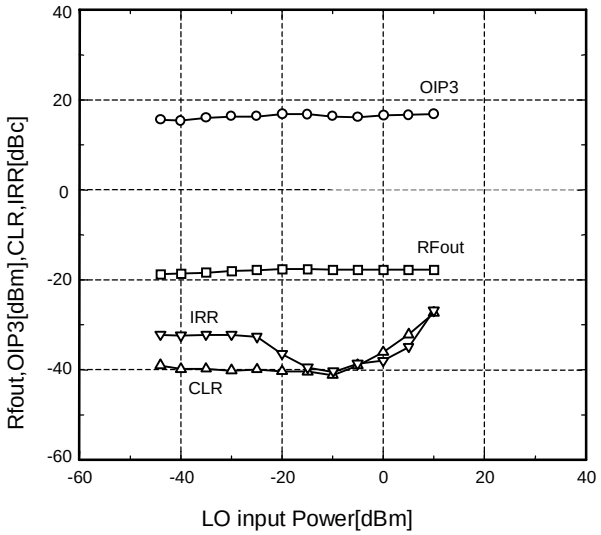

Fig. 8 RF performances as a function of the LO input power

Figure 9 shows IMD characteristics of the IC. We applied a conventional 3-tone IMD method for the QMOD IC. Two frequency base-band signals and a LO

signal were input to the IC. Owing to the low distortion design, an excellent OIP3 of +16dBm are obtained.

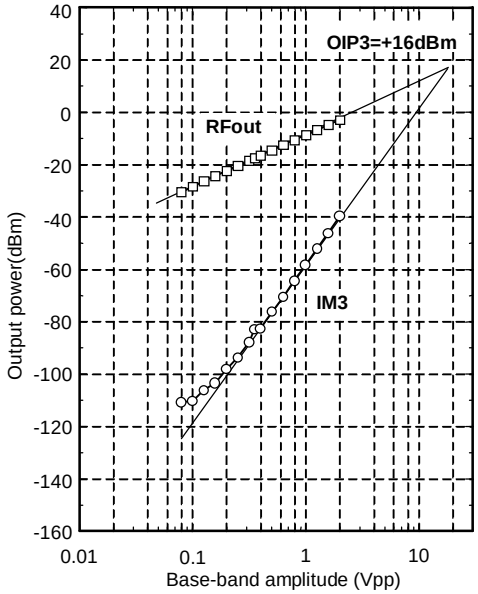

Fig.9 Pin-Pout linearity at local frequency of 600MHz.

Figure 10 shows an output spectrum of the 4/πQPSK modulation signal (bit rate = 4.0Mb/s). ACPR (Adjacent Channel Power Ratio) are less than –60dBc at channel width of 5MHz. The vector error is less than 1.0% rms which is a limit of our measurement system.

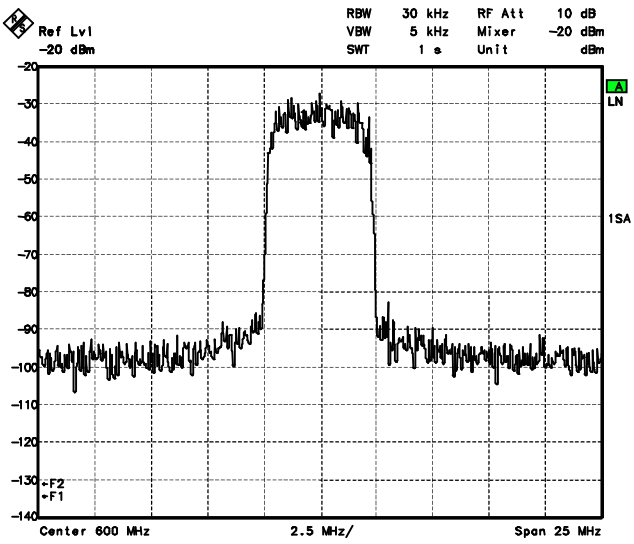

Fig. 10 Output spectrum of QPSK modulation with 4Mbps

Table 1summerizes the measured performance. The power dissipation current is 70mA at 5V.

Table 1 Summary of the fabricated GaAs QMOD IC

Carrier frequency	600MHz
OIP3	+16dBm
Image ratio	<-40dBc
Carrier leakage	<-40dBc
Vector error(QPSK)	<1.0%rms
Power supply voltage	5.0V
Dissipation current	70mA
Chip size	1.2 x 1.4mm^2

Conclusions

The low distortion GaAs Quadrature Modulator (QMOD) IC with on-chip 90° phase-shifter has been successfully developed. The IC will contribute to realize low distortion wide-band wireless communication systems.

Acknowledgment

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