Ku-band Balanced Resistive FET Mixer with Very Low IMD3

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Abstract— This paper describes a practical realization of a mixer that achieves low 3rd-order intermodulation distortion (IMD3) by using the channel resistance of a GaAs MESFET to provide mixing. The IMD3 of the resistive mixer is 48.5 dBc with −10 dBm RF power at 14 GHz. In additional, the conversion loss and 3rd-order intercept point (IP3) are 7.7 dB and 19.8 dBm with 10 dBm LO power level, respectively. The isolation of LO/RF and LO/IF are 45 dB and 56 dB, respectively. The circuit was realized in microstrip on a Teflon substrate. For improvement of some parameters so as dynamic range, IP3, P1dB and isolation, balanced mixer structure was proposed.

1. INTRODUCTION

The most commonly used mixers in microwave systems employ Schottky-barrier diodes as the mixing elements. The active elements such as FETs which is used for fabrication of microwave mixers, not only can improve the conversion loss but also causes to appear conversion gain. Disadvantages of active mixers in comparison with Schottky-barrier mixers, are instability and more complicated bias circuits. Simplicity of bias circuits, is obtained by using the resistive region of FET, furthermore it decreases probability of instability. On the other hand, because of the very weak nonlinearity of channel resistance, the mixer generates very low intermodulation products and results in high 1-dB compression point.

In this paper, a resistive mixer for Ku-band designed and fabricated. The resistive mixer is one of gate mixer which employs drain-source resistance, which is channel resistance of the FET in order to obtain time-varying resistance in the saturated region. Due to the low nonlinearity, the resistive mixer has very low IMD3 and high output power [3]. In the case of the resistive mixer, the time-varying channel resistance, which is changed by LO cycle, plays as a switch. If the switch is ideal, IMD3 is nonexistent. Therefore, it is known that the resistive mixer has low IMD3. Also, the resistive mixer does not have shot noise due to the DC current, but ohmic noise which is thermal noise due to the channel resistance [2]. Since the shot noise of the mixer is not existence, the resistive mixer has superior noise characteristics comparing with drain mixers and/or gate mixers. The channel resistance of the MESFET is linear over the low drain-source voltage, and then this linear channel resistance can be changed by the depth of depletion layer under the gate. When the gate voltage is smaller than the turn-on voltage, practically, the resistance is infinite. On the other hand, the channel resistance is almost negligible when the gate voltage is reached at the point which causes the gate channel conduction. Typical value of the resistance is just several ohms and the small resistance is sufficient to perform superior conversion characteristics [4].

2. DESIGN AND FABRICATION OF THE ADVANCED MIXER

A block diagram of the mixer is shown in Fig. 1. The LO signal and negative DC bias voltage are applied in the gate, the RF signal is applied in the drain, and IF signal is measured at the drain. A matching network is designed to obtain minimum conversion loss at the drain, and a RF band-pass filter (BPF) is inserted to prevent the RF signal from flowing into the IF terminal. In addition, a $\lambda/4$ open stub is employed to improve the isolation characteristic between LO and RF. Matching circuits are also designed at the drain for LO signal and at the gate for RF signal to be short for IMD3 improvement. Tow filters and a matching circuit are used. A BPF is used at RF terminal for preventing IF and LO signal from flowing into the RF terminal. On the other hand, a low-pass filter (LPF) is used at IF terminal to block signals of high frequency band. Then a matching network is designed at the LO terminal. IMD3 can be measured from two RF input signals which are the same power level. The first RF signal (RF1) is −10 dBm at 14 GHz and the second RF signal (RF2) is $-10\,$dBm at 14.01 GHz. There is 10MHz difference between RF1 and RF2.

The designed resistive mixer was fabricated on the Teflon substrate (RO4003). The dielectric constant is 3.38, height is 0.508 mm and height of copper substrate is 0.017 mm. 50 pF capacitors were used for the DC blocking. Fig. 2 shows a picture of the fabricated resistive mixer.

3. MEASUREMENT AND RESULTS

The RF an LO frequencies used for the measurement are $13 \sim 15\,$GHz and 12 GHz, respectively. IF output power at band-center is $-17.7\,$dBm with $-10\,$dBm RF input power and $+10\,$dBm LO power. Fig. 3 shows the measured IF output power at $12.5 \sim 15.2\,$GHz RF frequency. The IMD3 characteristic of 48.5 dBc is measured with 10 dBm LO and $-10\,$dBm RF input powers. Fig. 4 presents the characteristics of IF and IMD3 powers as a function of RF input power and shows the IP3 of 19.8 dBm at band-center and 10 dBm LO level. The LO to RF isolation is more than 30 dB in the full frequency band and it is 45 dB in band-center. Table 1 compare the difference between designed specifications and measurements of the resistive mixer.

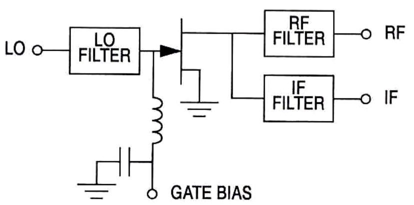

Figure 1: Block diagram of single mixer.

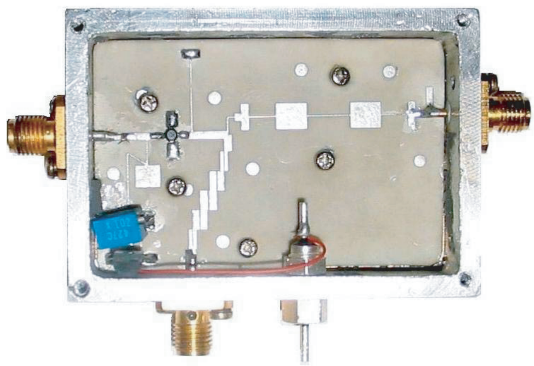

Figure 2: Picture of fabricated single mixer.

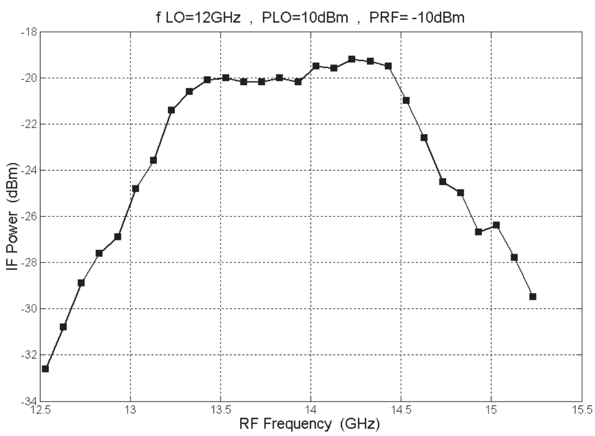

Figure 3: Measured IF output power.

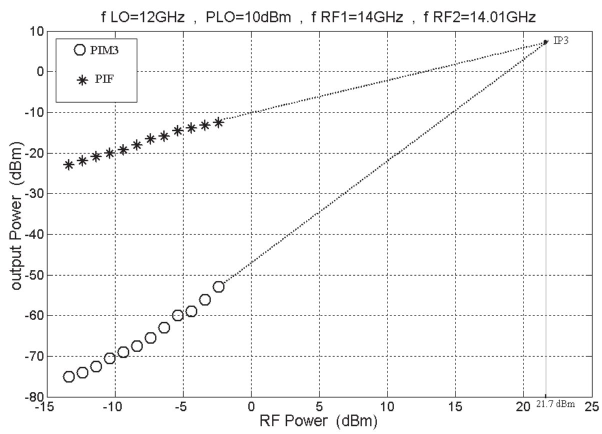

Figure 4: Measured IF power and IMD3 power and showing IP3.

Table 1: (fRF=14 GHz, fLO=12 GHz, PLO=10 dBm).

	Simulation	**Measurement**
conversion loss	6.3 dB	7.8 dB
IMD3	43 dBc	48.5 dBc
LO/RF isolation	20.3 dB	45 dB
IP3	16.7 dBm	19.8 dBm

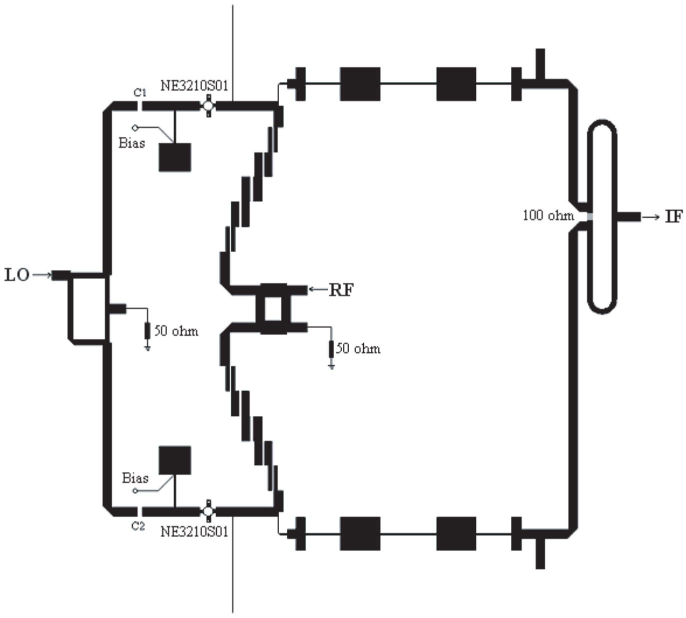

Figure 5: Layout of balanced mixer.

4. BALANCED MIXER

For improvement of some parameters so as dynamic range, IP3, P1dB and isolation balanced mixer structure was proposed and it was accomplished with design of suitable hybrids and combination them with single mixer. Fig. 5 present the layout of balanced mixer. The LO to RF isolation is plotted in Fig. 6.

5. CONCLUSION

In this paper, a resistive mixer for Ku-band was designed and fabricated. Good agreement between mixer's simulation and experimental results was demonstrated. The IMD3 characteristic of the fabricated resistive mixer is 48.5 dBc with −10 dBm RF power. The measured conversion loss is 7.8 dB with 10 dBm LO power. 45 dB isolation is measured for LO/RF isolation and 19.8 dBm IP3 is obtained. This mixer based on the resistance of a GaAs MESFET channel has significant advantages in noise, intermodulation, and power output capability over those based on a pumped Schottky-barrier diode junction. Such a mixer is easy to design and adjust and has characteristics which make it practical for use in low-noise receiver. Parameters of proposed balanced mixer so as dynamic range, IP3 and P1dB are improved.

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