A 7 to 14GHz Wideband GaAs Double-Balanced mixer chip

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***Abstract*—A wideband GaAs MMIC double-balanced mixer working at 7-14GHz is designed in this paper on the 0.25μm GaAs pHEMT process. The range of radio frequency (RF) / local oscillator (LO) is from 7 to 14GHz and the intermediate frequency (IF) is from DC to 3GHz. The ring diode is used in the mixer, and the new type of Marchand balun is applied to the RF and LO ports of the designed mixer respectively to diminish the chip area. In order to ensure the performance of the double-balanced mixer, a power driven amplifier is designed to drive the LO signal. Simulated results shows that when the power of LO port is 13dBm, the conversion loss of the double-balanced mixer is less than 10dB, the isolation of LO to RF is over 30dB, and VSWR of LO port and RF port is less than 2 and 2.8 respectively. The total area of the proposed mixer is 1.5 mm × 1.0 mm.**

Keywords*—Wideband; MMIC; GaAs; Double-balanced mixer; Amplifier

I. Introduction

Mixer is an essential circuit in the wireless system. Whether in microwave communication system, or radar, remote control, remote sensing, electronic reconnaissance and other microwave measurement systems, mixer is indispensable because it can reduce microwave signal to be handled in intermediate frequency (IF) or low frequency (LF). As an on-chip system, monolithic microwave integrated circuit (MMIC) has many advantages such as small size, high stability, high consistency and low effects of parasitic parameters. Thus, it achieves broad applications both in military and civil electronic systems. Meanwhile, in order to adapt to the requirements of communication development, wide band, low conversion loss and high isolation MMIC mixer becomes one of the most important devices.

Double balanced mixer has many advantages, such as multiple frequency in working band, pure frequency spectrum, good isolation and large dynamic range. The key of the mixer design is a 180° planar microstrip balun, which determines the performance of the mixer. A well designed balun can achieve multiple frequency band, high isolation and good characteristic of standing wave. What's more, among different structures of baluns, the Marchand balun plays a great important role in impedance transformation and balance to unbalance conversion. However, when the frequency is low, the area of balun will be too large to be accepted in chip design.

In this paper, to solve the size problems mentioned above, a new type of Marchand balun with additional capacitors is proposed. Thanks for this new structure, a double-balanced mixer using 0.25μm pHEMT process on GaAs offered by WIN semiconductor is achieved. To meet the application requirements of the oscillator power of the proposed mixer, a power driven amplifier is designed to supply a linear drive power of 13dBm for LO signal. Finally, the proposed wideband double balanced mixer is designed successfully. RF/LO signal works from 7GHz to 14GHz. IF signal works from DC to 3GHz. The isolation of LO to RF is over 30dB. The total area of the chip is 1.5 mm × 1.0 mm.

II. Circuit Design

A. The Double-Balanced Mixer Design

The schematic diagram of the proposed double-balanced mixer is shown in Fig. 1. The designed mixer is mainly composed of two converted baluns and a ring diode. Considering the LO signal is stronger than the RF signal and the isolation between two signals, RF balun is selected to output IF signal [1].

Because of the symmetry of the circuit structure and the consistency of the semiconductor process, the proposed balun with good balance and good isolation between the RF signal end and the local oscillator can be obtained. The diode ring provides a DC circuit for the diode without other redundant structures, which can achieve multiple frequency range.

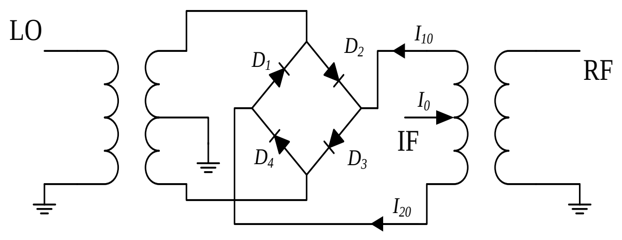

Fig. 1. The schematic diagram of the proposed double-balanced mixer.

As shown in Fig. 1, the RF end and the LO end are added to the voltage 2 V_S and 2 V_L respectively. The diode characteristic is:

$$i = f(v) \tag{1}$$

Thus, the diode current is:

$$i = f(v) = f(V_S + V_L) \quad (2)$$

Generally, $V_S << V_L$; According to the nonlinear analyze, the output IF current is:

$$I_0(t) = \sum_{n=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \dot{I}_{n,m} e^{[j(n\omega_L + m\omega_s)t]}.(1 - e^{jn\pi})(1 - e^{jm\pi}) \quad (3)$$

When m and n are even number, $I_0(t) = 0$. It means that the double balanced mixer can restrain all the even harmonics, and the current only includes the odd times resultant frequency for RF and LO. Thus, the mixer has a pure frequency spectrum.

The analysis above shows that the performance of the mixer, especially the phased balance and the insertion loss, is quite sensitive to the balun design. Therefore, the design of the balun with high performance is the key point of the double balanced mixer design [2].

The function of the balun is to provide the differential signals to the mixer and achieve the resistance transform. In various designs of MMIC double-balanced mixer, Marchand balun is in common used [3]-[4].

The Marchand balun is composed of two annular inductors coupling with each other, as shown in Fig. 2. The vortex generated by the spiral microstrip line can increase the coupling of the microstrip line, and reduces the area of balun effectively. In addition, using the method of capacitive loading can also increases the coupling between the coils, and shorten the length of coupling lines of the balun. which can achieve multiple frequency range [5]-[6].

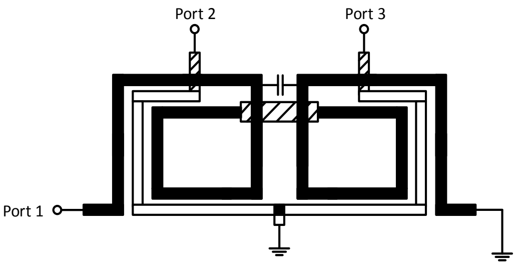

Fig. 2. The proposed structure of the proposed Marchand balun.

B. *The Power Driven Amplifer Design*

The power driven amplifier is designed by 0.25μm pHEMT process on GaAs, which is offered by WIN semiconductor. The schematic diagram of the double-balanced mixer is shown in the Fig. 3.

The function of the power driven amplifier is to supply a linear drive power of 13dBm for the LO signal. According to the simulated results, the power of LO signal has a direct influence on the conversion loss and noise factor of the double balanced mixer. When the LO signal reach the power of 13dBm, the mixer can have good performance.

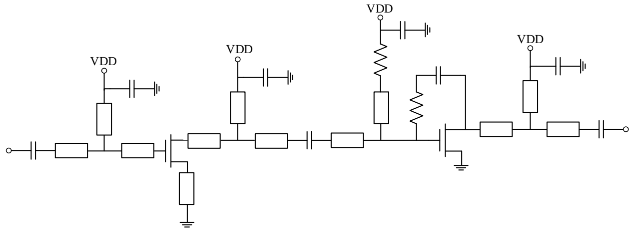

Fig. 3. The schematic diagram of the proposed power driven amplifier.

As shown in Fig. 3, Negative feedback is used in the second stage circuit to realize broad band from 7 to 14 GHz. Source decoupling is used in the first stage to give consideration to noise and gain. The linearity and the gain flatness of the power driven amplifier are achieved by adjusting the impedance matching between two stages.

III. Simulation Results

In this paper, all the layouts were designed by using the WIN PP25-21PDK on the ADS (Advanced Design System).

The layout of the proposed power driven amplifier is shown in Fig. 4.

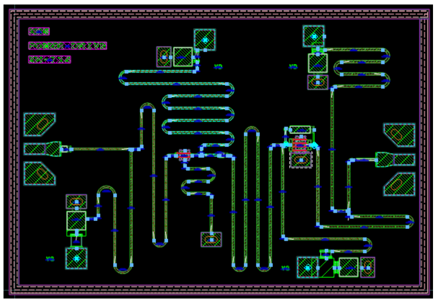

Fig. 4. The layout of the proposed power driven amplifier.

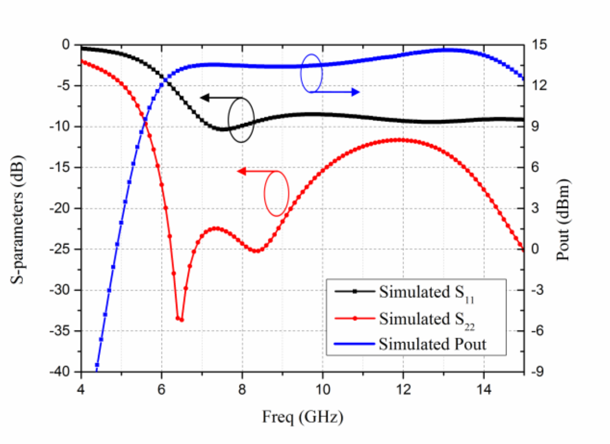

Fig. 5. The S-parameters and the Pout(dBm) of the power driven amplifier

Fig. 5 shows that the S-parameters of the power driven amplifier are about -10 dB, and the linear power is 13.5 dBm in band. It means that the designed power driven amplifier successfully meets the needs.

The simulated conditions is set as follows:

① The power of RF port is -30 dBm;

② The power of LO port is 13 dBm;

③ The intermediate frequency (IF) is 0.1 GHz.

IF is used to scan the frequency of RF. The layout of the proposed double-balanced mixer is shown in Fig. 6.

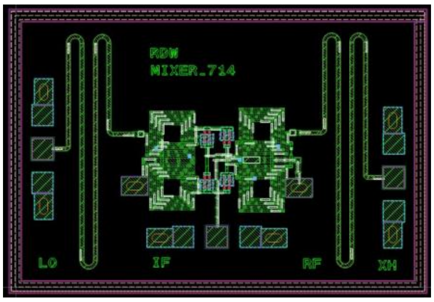

Fig. 6. The layout of the porposed double-balanced mixer.

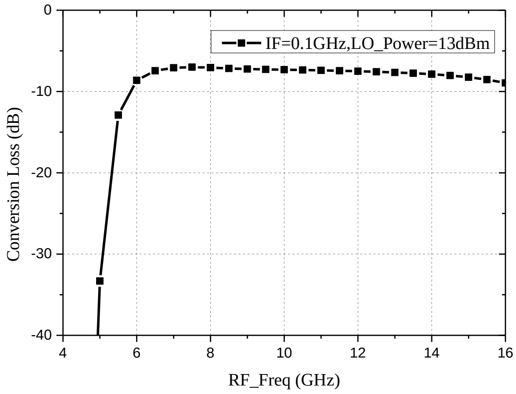

Fig. 7. The frequency conversion loss of the proposed double-balanced mixer.

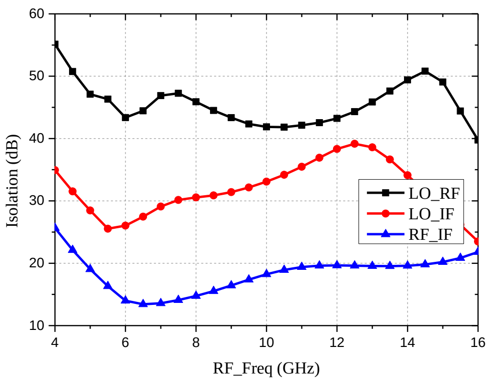

Fig. 8. The isolation between LO and RF ports of the proposed double-balanced mixer.

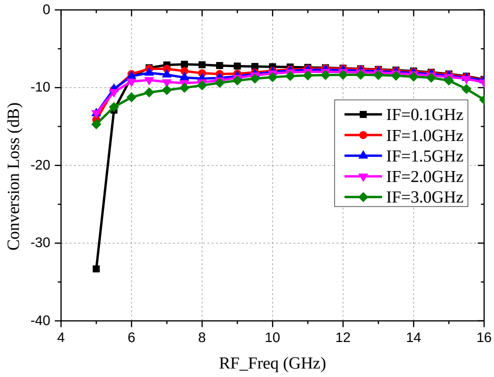

Fig. 9. The down conversion loss of IF band.

Fig. 7 shows that when the power of LO port is 13 dBm and IF is 0.1 GHz, the conversion loss is about 7~9 dB between 6-16 GHz. Fig.8 shows that in this frequency band, the isolation between LO and RF ports is over 40 dB, up to 50 dB. Fig. 9 shows that when IF is in DC-3GHz, the conversion loss is about 7-10 dB.

IV. Conclusion

A broadband GaAs MMIC double balanced mixer working at frequency 7-14GHz is designed in this paper on the 0.25μm GaAs pHEMT process. The new structure was used, which simplifies the impedance matching and diminishes the chip area. The RF/LO frequency range is 7 to 14GHz and the IF is DC to 3GHz. The down conversion loss is in 7-10dB, and the LO to RF isolation is above 30dB across the band. According to the simulation results, all the performance indexes meet the requirements in the broadband across the band.

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