A Monolithic Even Harmonic Quadrature Mixer Using a Balance Type 90 Degree Phase shifter for Direct Conversion Receivers

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Abstract

This paper proposes a novel circuit configuration of an even harmonic quadrature mixer (EHQMIX) for direct conversion receivers. In this EHQMIX, a 90 degree phase shifter consists of balance type high pass and low pass filters, and it does not require any circuits connecting to the ground plane. So this configuration is suitable for low cost monolithic IC without any via-holes, because amplitude and phase imbalance can be reduced caused by inductance included in wires and leads of a package for circuits to the ground plane. A developed L-band MMIC achieves good quadrature detecting characteristics.

Introduction

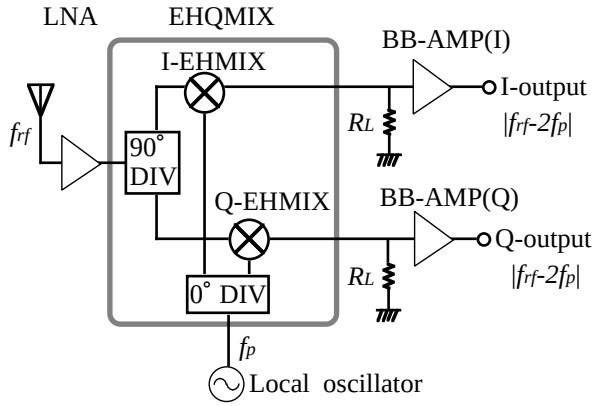
Direct conversion receivers, that convert RF signal to baseband signal directly, are suitable for small sized terminals[1]-[4]. In the direct conversion receivers, detection is performed in a RF band quadrature mixer. So dynamic range of receivers are not so much as that of heterodyne receivers because of second order mixing products, such as second order intermodulation(IM2) and self detected LO noise. Furthermore, Amplitude and phase imbalance causes degradation of receiving characteristics.

We had proposed an even harmonic direct conversion receiver(EH-DCR) using EHQMIX[5]. This direct conversion receiver can suppress even harmonic products caused in the quadrature mixer, and achieve as much performance as that of the heterodyne receivers. Also we had developed monolithic integrated EHQMIX that suppress amplitude and phase imbalance caused by interference between I and Q mixer, and insufficient matching between a mixer and a 90 degree phase shifter[6].

To get more accuracy, this paper proposes a circuit configuration of an EHQMIX using a balance type 90 degree phase shifter for direct conversion receivers. In this EHQMIX, a 90 degree phase shifter consists of balance type high pass and low pass filters, and it does not require any circuits connecting to the ground plane. So amplitude and phase imbalance can be reduced caused by inductance included in wires and leads of package used for circuits connecting to the ground plane, and this circuit topology is suitable for low cost monolithic IC without any via-holes. A developed L-band MMIC size is 2.6 mm x 2.2 mm, and good characteristics are achieved in 1.4 - 1.7 GHz.

Configuration

Figure 1 shows a configuration of the direct conversion receiver with an EHQMIX[5][6]. This mixer consists of two even harmonic mixer(EHMIX)s, 90 degree power divider (90˚ DIV) for RF signal (f_{rf}) and in-



LNA : Low noise amplifier
EHQMIX : Even-harmonic quadrature mixer
90˚ DIV : 90 degree power divider
EHMIX : Even-harmonic mixer
0˚ DIV : In-phase divider
BB-AMP : Baseband amplifier

Fig.1 The configuration of even harmonic direct conversion receiver (EH-DCR).

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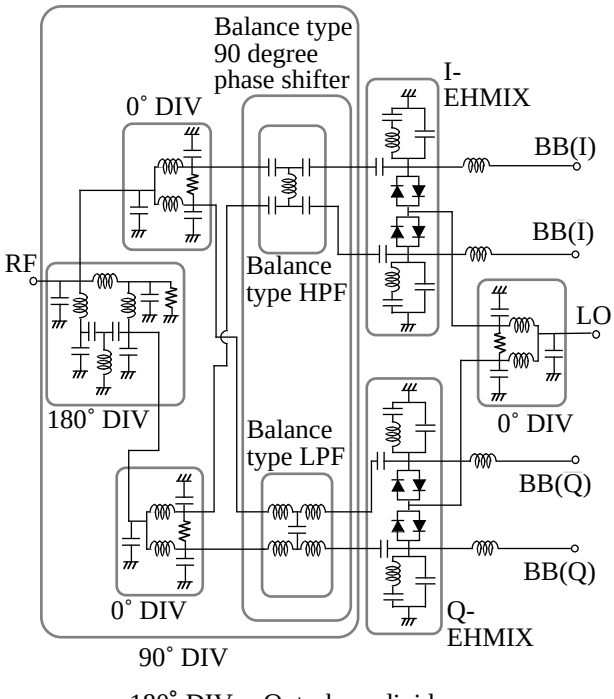
phase power divider (0˚ DIV) for LO (f_P). RF signal received at antenna is amplified in the low noise amplifier (LNA), and mixed with a second harmonic component of LO by the EHQMIX. I and Q baseband signals ($|f_{rf}-2f_P|$) produced at load resistance R_Ls are amplified by baseband amplifies (BB-AMP). This circuit configuration with the EHQMIX has the advantages of low second order distortion and self detected LO noise.

Figure 2 shows a configuration of the proposed EHQMIX. In the EHQMIX, 90˚ DIV consists of a out-phase power divider (180˚ DIV) and two 0˚ DIVs, and the 90 degree phase shifter. This phase shifter is composed of balance type high pass filter (HPF) and low pass filter (LPF). This mixer has features as follows:

(1)wires and leads of package for circuits connecting to the ground plane are not needed. So amplitude and phase imbalance caused by inductance included in wires and leads of package can be reduced.

(2)To isolate RF signal and LO, a balance mode mixer topology and lumped elements stub circuits are used.

(3)Passive elements are used except diodes, so d.c. power supply is not needed.



180˚ DIV : Out-phase divider

Fig.2 The configuration of the EHQMIX using a balance type 90 degree phase shifter.

Figure 3 shows a relative phase of RF signal in the 90˚ DIV using a balance type phase shifter. The input RF signal is divided into two out-phase signals in the 180˚ DIV, and both signals are divided into two in-phase signals in the two 0˚ DIV. So balance mode signals are added to the HPF and LPF. These signals are varied +45 degree in the HPF and -45 degree in the LPF respectively, so relative phase of RF signals added to I-EHMIX are 0 and 180 degree, Q-EHMIX are 90 and 270 degree.

In the I- and Q-EHMIXs employing antiparallel diode pairs[7], RF signals and second harmonic component of LO are mixed. As shown in figure 4, stub

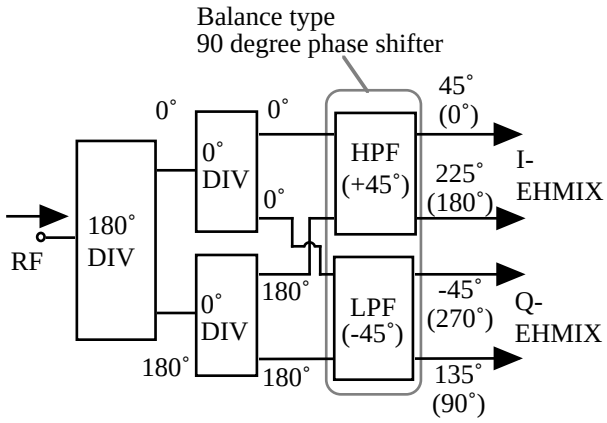


Fig.3 A relative phase of RF signal in the 90˚ DIV using a balance type 90 degree phase shifter.

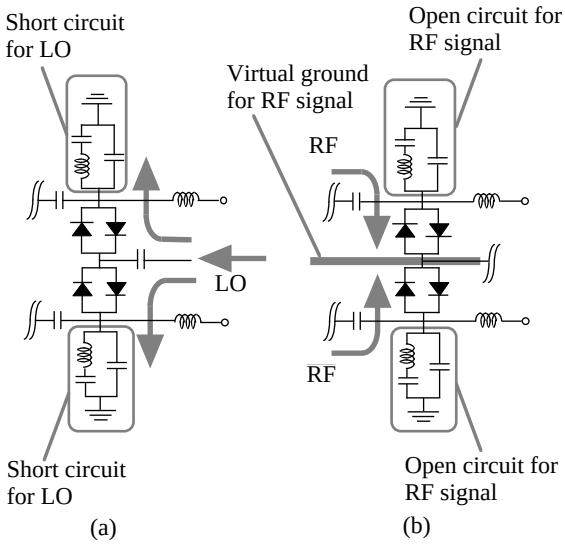


Fig.4 Signal propagation in the EHMIX. (a) LO and (b) RF signal.

circuits using lumped elements operate as short circuit for LO, and open circuit for RF signals relatively. Balance mode RF signals added to EHMIXs and these stub circuits realize isolation between RF signal and LO. I and Ī baseband signals are outputted from I-EHMIX, and Q and Q baseband signals are outputted from Q-EHMIX.

Experimental results

Figure 5 indicates a photograph of the developed L-band monolithic EHQMIX. The size of the chip is 2.6 mm x 2.2 mm. To reduce a chip cost, via-holes are not employed, and pads on the MMIC are connected to the ground plane with wires. Finger width of diodes is 60 um x 3 = 180 um.

For following measurements, high load

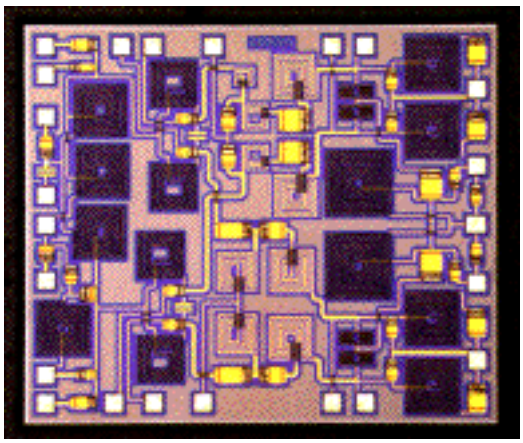


Fig.5 A photograph of the developed L-band monolithic EHQMIX. The chip size is 2.6 mm x 2.2 mm.

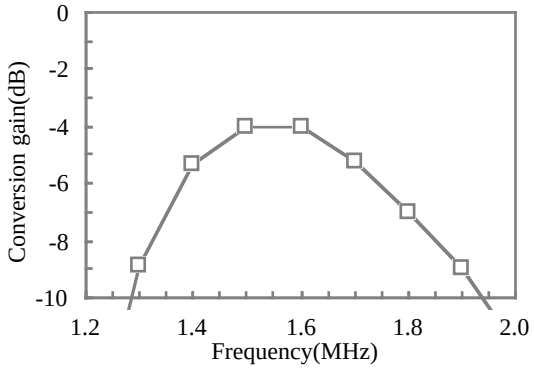


Fig.6 Voltage conversion gain of the developed EHQMIX (LO power:P_p =9 dBm, R_L =510 Ω).

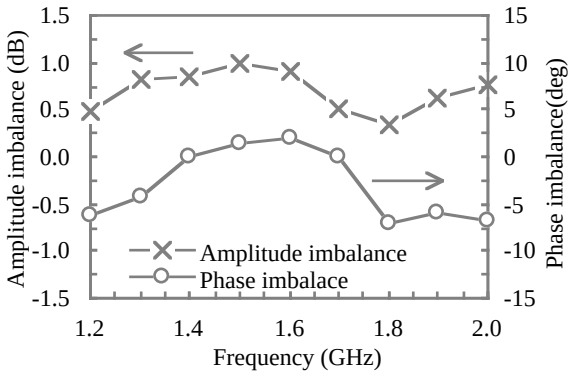
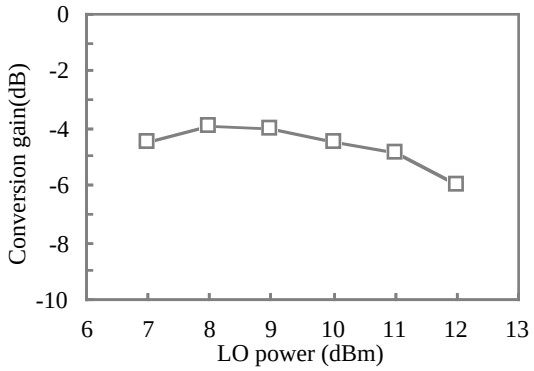
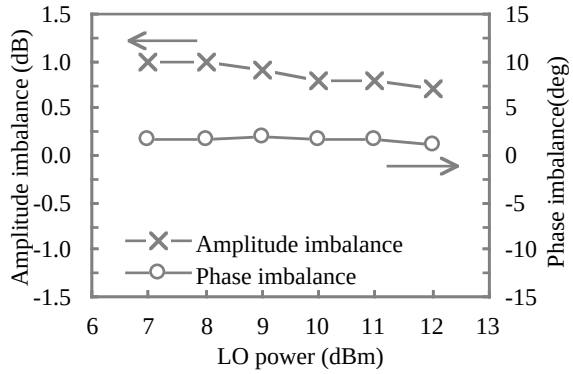


Fig.7 Amplitude and phase imbalance of the developed EHQMIX (LO power:P_p =9 dBm, R_L =510 Ω).



(a)



(b)

Fig. 8 Voltage conversion gain, amplitude and phase imbalance versus LO power of the developed EHQMIX (f_{rf} =1.6 GHz, R_L =510 Ω).

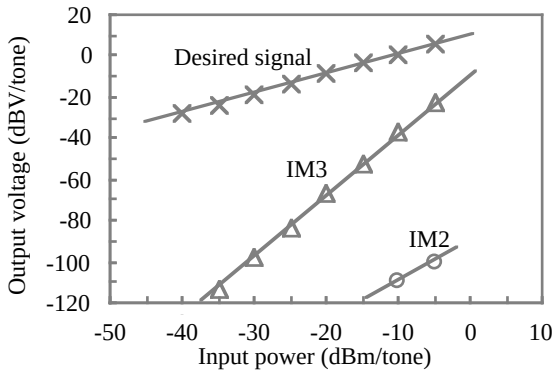


Fig. 9 Intermodulation characteristics of the developed EHQMIX (f_{rf} =1.6 GHz, LO power:P_p = 9 dBm, R_L =510Ω).

resistance is employed to improve voltage conversion gain[5].

Figure 6 shows the voltage conversion gain of the developed EHQMIX. The conversion gain is -4 dB at 1.6 GHz, and less than -7 dB from 1.4 GHz to 1.7 GHz, including dividing loss of the 90˚ DIV. Figure 7 shows amplitude and phase imbalance of the developed EHQMIX. The amplitude imbalance is from +0.3 dB to +1.0 dB, and the phase imbalance is within ±5 degree in the above frequency range. This amplitude imbalance can be corrected with BB-AMP easily. Figure 8 shows the voltage conversion gain, amplitude and phase imbalance versus LO power of the developed EHQMIX. The voltage conversion gain is below -6 dB, amplitude imbalance is +0.4 dB to +1.0 dB, and phase imbalance is below +2 degree for LO power range of 7 to 12 dBm.

Figure 9 shows intermodulation characteristics of the developed EHQMIX. The intercept point of the third order intermodulation at the input port (IIP3) is 9 dBm at f_{rf}=1.6 GHz and LO power P_p=9 dBm. IM2 is extremely low in the actual input power region. 23 dB of noise figure is achieved at 100 kHz of baseband frequency with BB-AMP.

Conclusion

In this paper, a novel configuration of the even harmonic quadrature mixer using a balance type phase shifter was proposed. In the mixer, a 90 degree phase shifter consists of balance type high pass and low pass filters, so the mixer can suppress amplitude and phase imbalance caused by inductance included in the wires and leads of package used for circuits connecting to the ground plane, and it is suitable for low cost monolithic IC without any via-holes. A developed L-band monolithic EHQMIX achieved good quadrature detecting characteristics.

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