A Performance Consideration on Conversion Loss in the Integrated Single Balanced Diode Mixer

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Abstract—In this paper, we consider the factors that affect a conversion loss performance in designing a single balanced diode mixer integrated with IRF(Image Reject Filter), based on the embedded electrical wavelength placed between the IRF and mixer, diode matching and LO drive amplifier. To evaluate the conversion loss performance, we suggest two types of a single balanced mixer using 90 degree branch line coupler, microstrip line and schottky diode. One is only mixer and the other is integrated with IRF and LO drive amplifier. The measured results of a single balance diode mixer integrated IRF show the conversion loss of 8.5 dB and the flatness of 1 dB p-p from 21.2 GHz to 22.6 GHz with 10 dBm LO. The measured input P1dB and IIP3 are 7 dBm and 15 dBm respectively under the nominal LO power level of 10dBm. The LO/RF and LO/IF isolation are 22 dB and 50 dB, respectively.

Index Terms—conversion loss, single balance diode mixer.

I. INTRODUCTION

A typical RF receiver front end architecture is shown in Fig .1. The down-conversion mixer is used to convert the RF signal down to an intermediate frequency (IF) by mixing the RF signal from the low-noise amplifier (LNA) with the local oscillator (LO) signal. The RF and image-rejection filter (IRF) are used to reject undesired out-of-band signals. The down conversion mixer is very important building block because its performance affects the system performance and performance requirements of its adjacent building block which include the LNA, LO, RF filter, IRF, and IF stage.

An image rejection filter is essential component in heterodyne receiver since noise figure is strongly influenced by its image band rejection performance and the image degrade the sensitivity of receiver[1][2]. The common approach to suppressing an image is through the use of an image reject filter placed before mixer, but one of the problems in designing the mixer being integrated with an image rejection filter would be a conversion loss performance.

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In this paper, based on the embedded line length placed the IRF and mixer, matching condition and LO drive amplifier that affect mixer's conversion loss performance, we consider a conversion loss variation occurred when designing a single balance mixer integrated with image rejection filter. To verify it, two single balance diode mixer are designed and compared, one is mixer only and the other is integrated mixer with IRF.

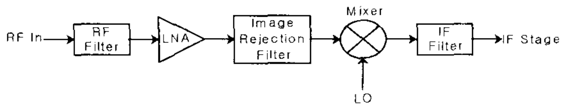

Fig. 1 RF front-end

Table 1 Specifications of integrated mixer

Parameters	Specification
RF freq	21.2-22.4 GHz
LO freq	22.4-23.6 GHz
IF freq	1.2GHz±50MHz
LO power	10±2 dBm
Conversion loss	10 dB nom.
Flatness	±1dB
IIP3	12 dBm min.
P1dB (input)	5 dBm min.
N.F.	10 dB nom.
Image rejection	15 dB nom.
LO/RF isolation	20 dB

II. DESIGN APPROACH

In this section, two types of a single balanced diode mixer using a microstrip line and two schottky barrier beam lead diodes are designed to consider a conversion loss performance. One consists of 90 degree branch line coupler, matching circuit and IF LPF. The other is integrated with dc-block capacitor of LO amplifier and IRF. The passive circuits and mixer performances are simulated for accuracy by moment method and harmonic balance technique, respectively. Table.1 is the summarized specification for balanced mixer in a receiver module.

Designing mixer here is focused on having a good performances of conversion loss when the IRF is integrated with mixer. A degradation of conversion loss, especially its variation in mixer with IRF, could be an impedance termination condition in RF port with respect to LO impedance. This is because filter's impedance in RF frequency is far from the LO frequency band and can not be maintained to its characteristic impedance. Consequently, the reflected LO power reflected from the RF port makes conversion loss worse[3][4]. Therefore, we choose the proper electrical wavelength which is placed between the filter and mixer to produce a better conversion loss performance.

A very common mixer topology is the 90 degree branch line hybrid as shown in Fig. 2. The hybrid is a 4 port device with the LO and RF being fed into two adjacent ports, and the two mixer diodes which are connected in series are connected to the remaining two ports. Each section of square is 90 degree in length. The IF is extracted from junction of the two diodes. Proper filtering of the RF and LO is needed at the IF port. this mixer provided good input match at the LO and RF port but has limited bandwidth and port to port isolation. Another mixer configuration is the hybrid ring mixer which is sometimes called a rat race mixer. It shows inherent high isolation characteristic and a wider bandwidth as compared to other mixer types but port return loss is strongly dependent on matching between hybrid and diode[5].

For balancing the diode mixer in this paper, the 90 branch line coupler is adopted to obtain a better return loss at output of LNA and LO amplifier, considering together with phase balance, VSWR and isolation over both RF and LO frequency band. A parallel-coupled dc block circuit in LO port of mixer is utilized to consider the impedance of LO amplifier with IRF simultaneously.

The diode parameters for matching diodes, a DMK 2790 is used with spice model provided from Alpha. The matching network is completed after plotting large signal s-parameter simulation results on the smith chart as shown in Fig. 3 The LO power required to drive mixer diodes is also chosen by harmonic balance technique, satisfying input P1dB specification enough. When designing matching network, diode pumping power is simulated with 7 dBm which is lower than 3 dB injected into LO port, and dc bypass induced by pumping power should be considered because of impedance change in matching network. In the design of matching network, diodes should be optimally matched to the LO band rather than RF band to minimize reflected power which influence the conversion loss and its variation, considering the embedding phase between IRF and mixer. but in the case of matching for RF band, it was found that a embedding phase is critical factor in determining the overall flatness in mixer.

A RF choke for biasing induced dc power is composed of high impedance microstrip line of quarter-wave length at RF and LO frequency band with via hole so as to keep open circuited characteristic on intersection. A radial stub at the junction of diode pair rejects LO power and enhance its isolation to IF. A LPF in output port is designed as a type of high-Low-high step impedance and also suppresses LO fundamental additionally.

III. SIMULATED RESULTS

Fig. 2 shows that the power balance of 90 degree branch line coupler at LO and RF port is about 3 dB, the phase balance of LO and RF phase is about 90 degree, and the return and isolation are under 20 dB over RF and LO band, respectively.

Under the same specifications, two types of mixer are designed. Fig. 4 shows the simulated results for the performance of conversion comparing the mixer only and the integrated mixer. The presented results are extracted from where embedding length between IRF and RF port of mixer is 50mil. Other lines in length show that levels of LO pumping power fluctuate and consequently degrade the conversion loss performance.

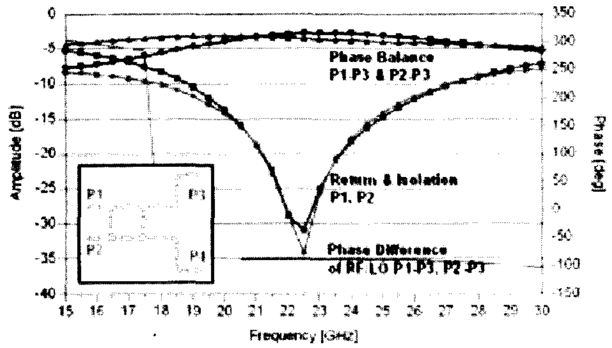

Fig. 2 Simulated results of coupler

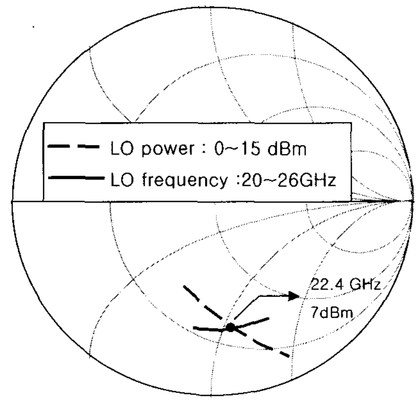

Fig. 3 Diode impedance

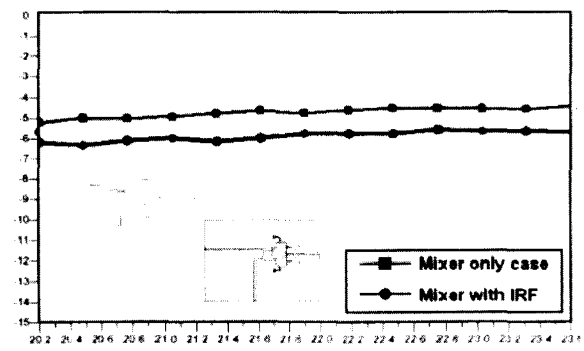

Fig. 4 Simulated conversion loss

IV. EXPERIMENTAL RESULTS

Fig. 5 shows a test bench for measuring the fabricated mixer. HP83650A is utilized as a RF sweeping source and HP83630B is used as a LO sweeping source. A loss of cable and connector is compensated with a power meter. Since a IF is fixed at 1.26 GHz, output power is measured with calibrated HP 8565E spectrum analyzer.

The measured results on conversion loss variation compared with mixer only and integrated mixer are presented in Fig. 6 The variation of overall RF band is under 1 dB and the shape of conversion loss is same if an insertion loss of IRF is considered. The measured conversion loss versus LO power shown in Fig. 7 show LO power level required to get a minimum conversion loss is about 5 dBm and the conversion loss is saturated at 8 dBm.

Fig. 8 represents the IIP3 of integrated mixer is about 18 dBm. Frequency variation of IIP3 is under 2 dB, and minimum IIP3 is measured at the frequency of 21.2 GHz with a value of 15.42 dBm. Input 1-dB compression point is dependent on LO pumping power. In the configuration of LO path, LO amplifier can drive nearby 10 dBm nominally. Noise figure is measured about 10 dB as shown in Fig. 9 The Implemented single balance mixer and integrated mixer with IRF is shown in Fig. 10, respectively.

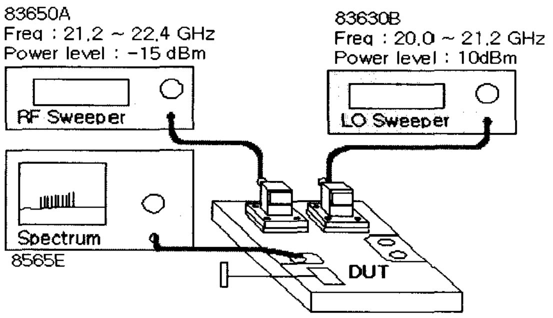

Fig. 5 Test bench

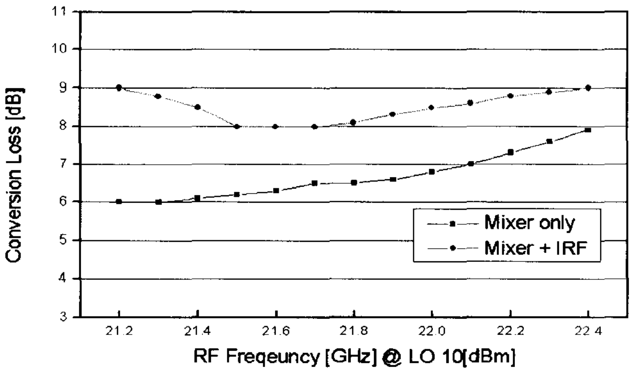

Fig. 6 Measured conversion loss VS RF freq.

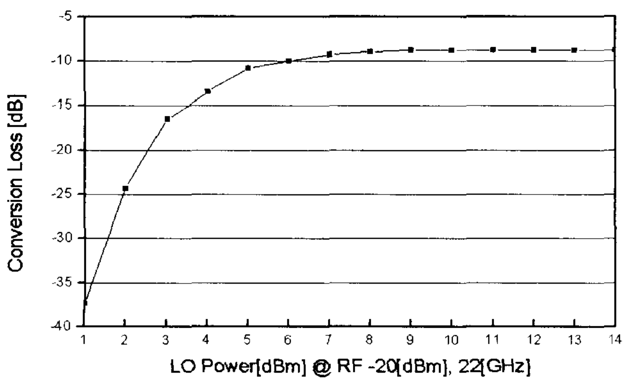

Fig. 7 Measured conversion loss VS LO power

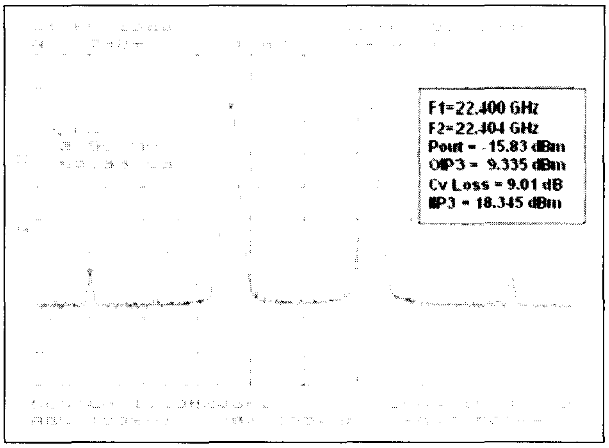

Fig. 8 Measured IIP3

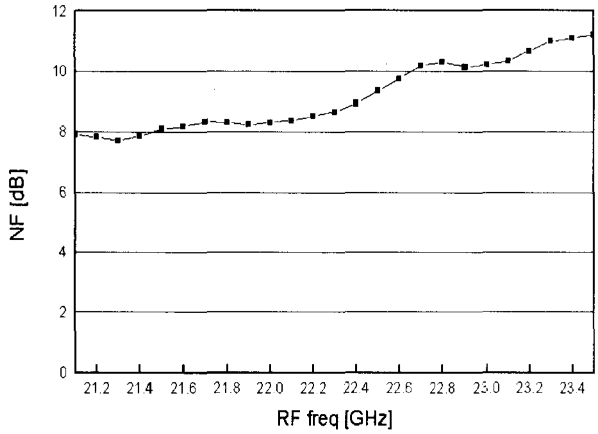

Fig. 9 Measured noise figure

V. CONCLUSIONS

To investigate the factors that affect conversion loss performance in designing a single balance diode mixer integrated with IRF, we fabricated two type of a single balanced diode mixer comparing the performance. It was found that a degradation of conversion variation primarily depends on the electrical wavelength between the IRF and mixer when LO power for matching diode is optimized. Additionally, dc block capacitor in LO drive amplifier is also considered. This paper would be helpful for designing single balance diode mixer with IRF.

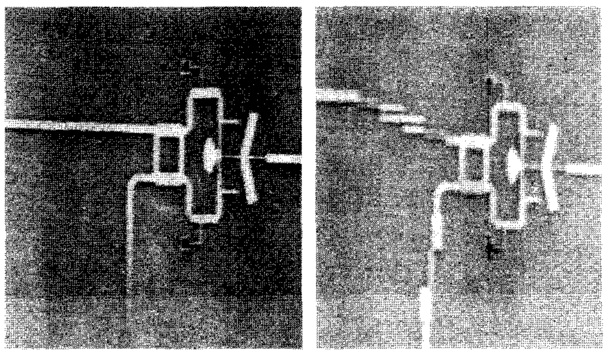

Fig. 10 Picture of fabricated mixer

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