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Design and Implementation of Two Single-Balanced Mixers for a Bluetooth Transceiver

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ABSTRACT

In this study, two different types of 90-degree hybrid mixers were designed and analyzed in an ISM (industrial, scientific, and medical) 2.4 GHz band. The first is a general type; the other, a low-distortion type. For the low-distortion type, the 1-dB compression point and the third interception point are increased about 3-dB. The proposed mixers have a major shortcoming with a significant penalty in board space on the 2.4 GHz frequency band. Both mixers have their own features and characteristics; hence, they can be chosen for Bluetooth applications.

Key Words: mixer, 1-dB compression point, third intercept point, Bluetooth

可應用於藍芽收發機之單平衡混頻器之設計與製作

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摘　要

本篇論文主要是設計與分析兩種可應用於 2.4 GHz ISM（industrial, scientific, and medical）頻帶之 90 度合成混頻器，分別為一般型與低失真型。其中低失真型 90 度合成混頻器的 1-dB 壓縮點與第三階截斷點均增加約 3-dB。90 度合成混頻器主要的缺點是在 2.4 GHz 頻帶時具有過大的面積，因此我們利用電容補償的方法設計了一個小面積的 90 度單平衡混頻器。兩種混頻器均具有各自的特色與特性，因此可被應用於藍芽收發機。

關鍵詞：混頻器，1-dB 壓縮點，第三階截斷點，藍芽

I. INTRODUCTION

Mixer is one of the most important parts in the RF (radio frequency) front-end in modern telecommunication systems. A mixer uses the non-linearity of a diode to generate an output spectrum consisting of the sum and difference frequencies of two input signals [5]. In a receiver application, an RF signal and an LO (local oscillator) signal mixed together to produce an intermediate frequency. This is called a heterodyne receiver which is useful because it has much better sensitivity and noise characteristics. Heterodyne system also has the advantage of being able to tune over a band by simply changing the LO frequency, without needing for a high-gain, wideband RF amplifier [6]. There are many types of mixer circuits, which can be classified into two main parts: active and passive. Passive type mixer is adopted in our single-balanced mixer design and it is simple and efficient. A balanced mixer combines two or more identical single-ended mixers with a 3-dB hybrid junction (90° or 180°) to give either better input SWR (standing wave ratio) or better RF/LO isolation [4].

In this paper, two different types of 90-degree hybrid mixers such as the general type and the low-distortion type, were designed and analyzed for Bluetooth applications. For low-distortion type, the 1-dB compression point and 3rd intercept point are increased about 3-dB. The 90-degree single balanced mixer has a major shortcoming at 2.4 GHz frequency band with a significant penalty in board space, hence another application for a small size 90-degree single balanced mixer was designed by using capacitor compensated method. We will analyze the design concepts of these mixers and discuss the performances of both mixers.

II. ANALYSIS FOR THE SINGLE BALANCED MIXER

For these two different type mixers we implement them by using the Schottky-barrier diode which has high switching rate, low turn on voltage and low LO power requirements. The circuit of balanced mixer is shown in Fig. 1. It consists of two single-ended mixers with matched characteristic, driven with a 3-dB coupler. Fig. 2 shows the general type of single balanced mixer. The mixer consists of a single pair of diodes, a branch-line coupler for 2.4 GHz, a DC (direct current) return path and an IF (intermediate frequency) filter. This mixer operates in 2.45 GHz for RF signal and 2.38 GHz for LO signal. Therefore it achieves 70 MHz signal for IF signal. This type of 90-deg single balanced mixer is a symmetrical structure so that the performances will not be affected by changing RF signal input port and LO signal input port. Furthermore, we also use a short-stub to bypass DC signal and utilize an open-stub to reject the LO and RF signal appear in IF port [6]. As a result of the frequency is load, which is far away from the SUM (SUMmation) signal (RF+LO), therefore the SUM signal will attenuate and we can neglect it. The photograph of general type 90-deg single balanced mixer is shown in Fig. 3. The second type of 90-deg single balanced mixer is low distortion type. In this application, we use double pair diode instead of single pair diode. Therefore, the 1-dB compression point and 3rd intercept point increase about 3-dB because it needs more LO power than single pair to drive the mixer to nonlinear area, i.e. 3-dB. Theoretically, if we series 3 diodes, then the LO power requirements is 5-dB. However, we need to use larger LO signal to pump the mixer to achieve the same efficiency [1-3]. At the IF port, in order to increase the isolation of larger LO power, we use the radial-line structure as a band-stop filter to reject the LO signal. The circuit diagram and photograph of this mixer are illustrated in Fig. 4 and Fig. 5, respectively.

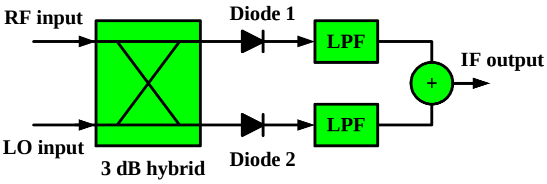

Fig. 1. Configuration of the balanced mixer

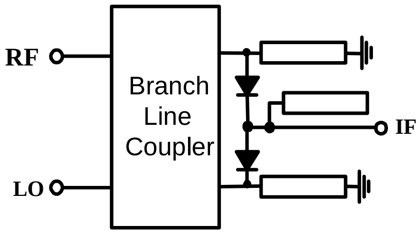

Fig. 2. General type of 90-deg single balanced mixer circuit

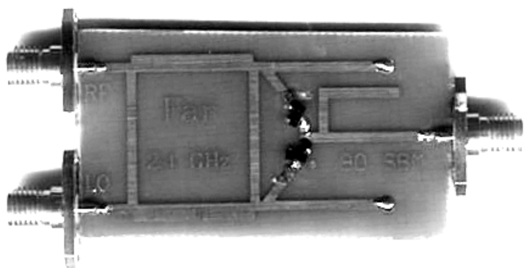

Fig. 3. Photograph of general type 90-deg single balanced mixer

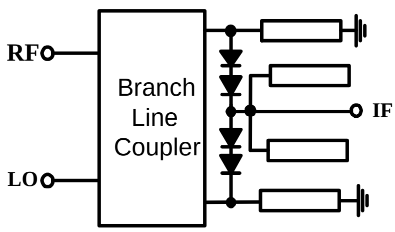

Fig. 4. Low distortion type of 90-deg single balanced mixer circuit

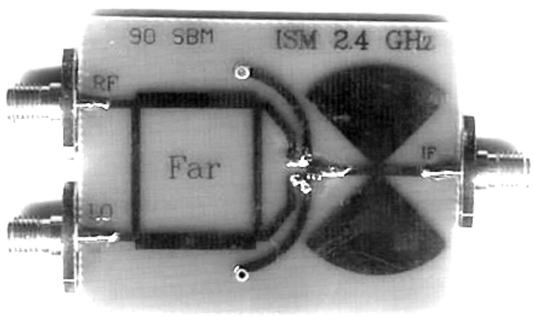

Fig. 5. Photograph of low distortion type 90-deg single balanced mixer

III. MEASURED RESULTS

The two types mixer what we proposed have been accomplished and measured. The RF frequency is 2450 MHz and LO frequency is 2380 MHz and therefore we can obtain IF signals at 70 MHz. A smaller IM3 (3rd order InterModulation) and a higher third-order intercept point (IP3) result in the lower distortion and higher rejecting ability. The IIP3 (input 3rd order intercept point) can be obtained by extending the fundamental and IM3 curves at the intercept point. From Fig. 6, the IIP3 of the general type is about 13 dBm. From Fig. 7, the IIP3 of the low-distortion type is about 16 dBm. All measured results of the mixers are shown in Table 1.

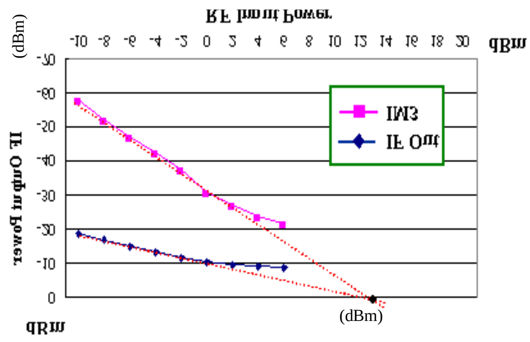

Fig. 6. Third order intermodulation for general type

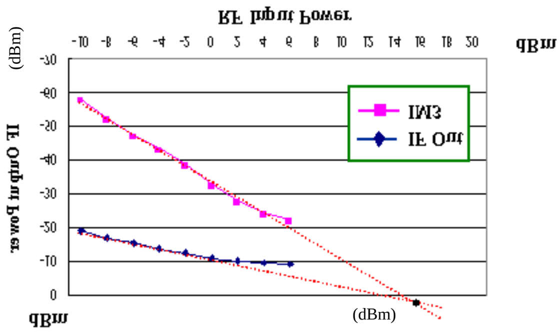

Fig. 7. Third order intermodulation for low-distortion type

IV. CONCLUSIONS

In our paper, two different types of 90-deg single balanced mixers have been designed and implemented for the ISM (industrial, scientific, and medical) 2.45 GHz band. It has been observed that input P1dB and IIP3 of the low-distortion type mixer are better than these of the other two types. This means that it has better linearity and can be used at higher input power for digital signal. Both mixers have their own features and characteristics. So we can choose them to apply in Bluetooth applications.

Table 1. Comparison of three different types of 90-degree hybrid mixers

	General type	Low Distortion type
LO power requirement	6.0 dBm	9.0 dBm
Conversion loss	8.3 dB	8.3 dB
IF output bandwidth	450.0 MHz	450.0 MHz
Input P_{1dB}	7.0 dBm	9.9 dBm
IIP3	14.0 dBm	16.5 dBm
LO-to-RF Isolation	8.2 dB	8.0 dB
LO-to-IF Isolation	11.0 dB	42.8 dB
RF-to-IF Isolation	13.0 dB	44.0 dB
Board Size	4 × 2.3 cm2	4.5 × 3.2 cm^2

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