50 - 100GHz Octave Band MMIC Mixers

Keigo Kamozaki, Naoyuki Kurita, Takuma Tanimoto, *Hiroshi Ohta
Tohru Nakamura, and Hiroshi Kondoh

Hitachi, Ltd., Central Research Lab. *Hitachi ULSI Engineering, Ltd.
1-280 Higashi-Koigakubo, Kokubunji-shi, Tokyo, 185, Japan
E-mail: kamozaki@crl.hitachi.co.jp

Abstract

Single-balanced MMIC mixers covering RF and LO bands of 50-100GHz have been developed. A Marchand balun and a side-coupled balun in microstrip configurations were compared for LO drive ports of the mixers. The Marchand balun type demonstrated a conversion loss of 11.6dB±2.8dB over a 50-103.5GHz band, whereas the side-coupled balun type achieved a conversion loss of 11.6±2.2dB from 50GHz to 95GHz. These results represent the widest bandwidth reported to date in mm-wave bands.

Introduction

Recently, there has been a steady advance in implementing mm-wave systems in monolithically integrated circuits for their small size and the potentials of achieving low cost in high volume production. 60GHz wireless LANs and 77GHz automotive radar are among the most focused mm-wave applications today.

Broadband MMIC chips covering dual bands will facilitate further cost reproduction of RF front ends for the emerging mm-wave applications and also offer a wider margin of MMIC characteristics to process variations.

This paper describes newly developed broadband MMIC mixers which achieved a dual band coverage from 50GHz to 100GHz by using two types of planar baluns for LO drives: a Marchand balun and a side-coupled balun.

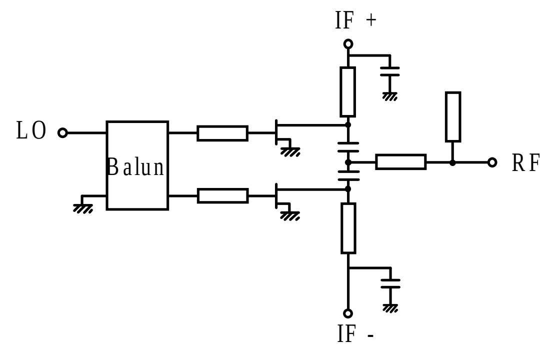

Fig. 1 Schematic diagram of mixer

Mixer design

The mixers has been designed on a 0.15μm gate P-HMET based MMIC process on a 80μm thick GaAs substrate. The active device is a double hetero structure AlGaAs/InGaAs/GaAs FET with a f_t of 80GHz and a f_{max} greater than 160GHz.

The schematic diagram of the designed mixer is shown in Fig.1, where the balanced outputs of a LO balun are coupled to the gates of two P-HEMTs used as switched resister. An RF signal is fed to the drain of the FETs. A bias voltage of -0.4V was applied to the FET gates to minimize a required level of LO drive. The gate width of the FETs was chosen to be 35μm in order to achieve good impedance matching on the RF port. An IF signal is extracted from the FET drains and is connected to an external 1:1.5 transformer. The external transformer was decided to be employed to reduce MMIC chip size and prevent degradation of noise figure due to 1/f noise of an on-chip IF amplifier. Two types of baluns, as described below, are examined as the key element for achieving

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broadband performance of the mixers.

1) Mixer with a Marchand Balun

Fig. 2 shows an equivalent circuit of a Marchand balun. Marchand baluns have been commonly used for broadband mixers for many years because of compensation techniques available to maintain balanced outputs with a reduced phase slope over a multi-octave bandwidth. Such a broadband balun, however, usually requires a suspended, low dielectric constant substrate or thick substrate to realize shorted stubs Zs of high impedance which is considered impractical for MMIC realization. The new mixer, a photo of which is shown in Fig. 3, has adopted a Marchand balun to achieve an octave band operation within the MMIC restrictions. Fig. 4 depicts the structure of the designed balun which utilizes two layers of metal separated by a SiO_2 dielectric layer of 1μm thickness. Shorted lines Zs are realized by microstrip lines using the lower metal layer terminated with grounding via holes. The inductance of a via hole helps reduced a required length of transmission lines, thus contributing to a reduction of chip size. Lines Z1 and Z2 uses the top metal of layer for signal and the signal lines of the Zs lines for grounding. A line width of 100 μm was chosen for the Zs lines to assure its grounding effects to the Z1 and Z2 lines. The other parameters were optimized by using the equivalent circuit in Fig. 2 to attain the widest bandwidth.

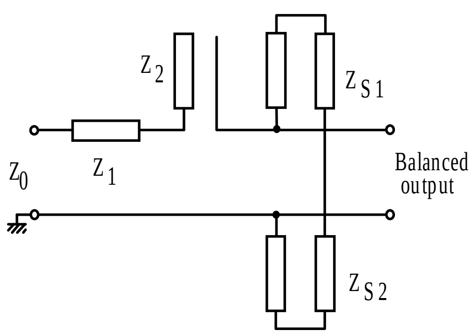

Fig. 2 An equivalent circuit of Marchand balun

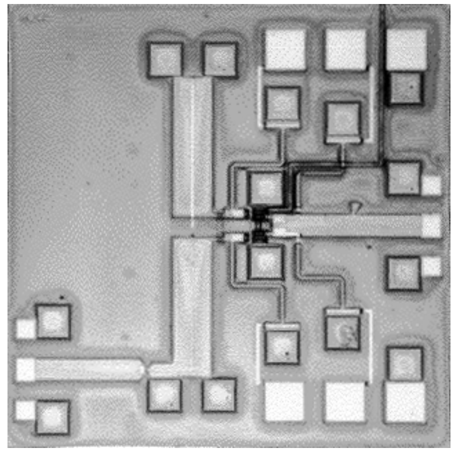

Fig. 3 MMIC mixer using Marchand balun

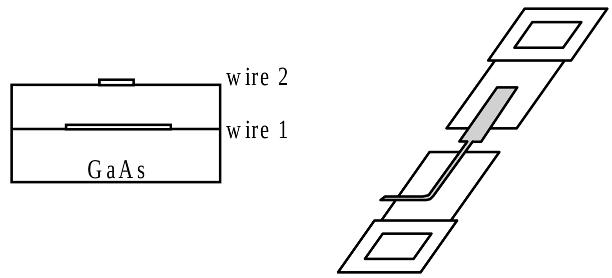

Fig. 4 Structure of designed Marchand balun

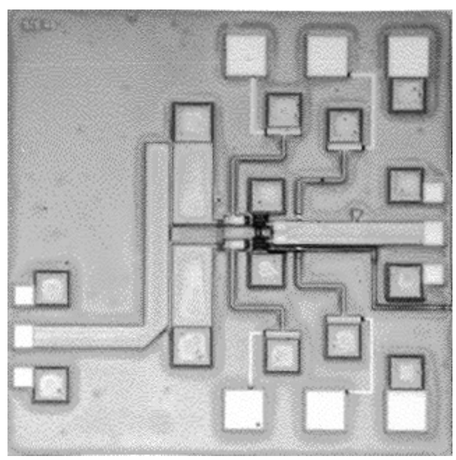

Fig. 5 MMIC mixer using side-coupled balun

2) Mixer with a Side-coupled Balun

The chip photo of a MMIC mixer using a side-coupled balun is shown in Fig. 5.

A side-coupled balun utilizes single layer of metal. The structure of side-coupled balun is simpler than the one of the Marchand balun. However a side-coupled balun can not obtain broader bandwidth characteristics than a Marchand balun.

Fig. 6 shows an equivalent circuit of a side-coupled balun. The side-coupled balun consists of a ideal transformer, a transmission line, two quarter-wavelength short stubs and a quarter wavelength open stub at center frequency.

In the side-couple balun design, equivalent circuit parameters; a coupling coefficient of the ideal transformer N, the impedance of an open stub Z2 and short stubs Zs were determined to obtain a required bandwidth, while considering layout realization. Two microstrip lines Zs short-circuited by via holes are coupled to an open-ended line. The Zs lines are approximately of a quarter wavelength at the center frequency of the design. As in the case of the Marchand balun, the via holes shortened a required length of the Zs lines by 20%. The final dimension of the coupled line structure was optimized for a wide bandwidth by using electromagnetic field simulation.

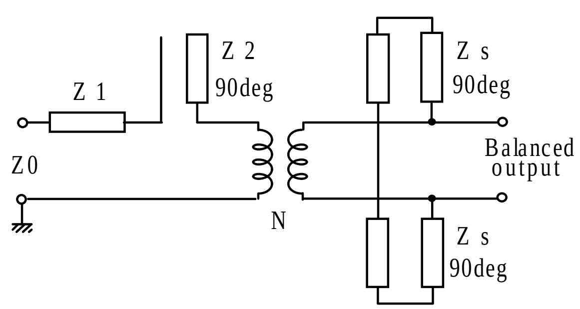

Fig 6 An equivalent circuit of side-coupled balun

Measured Performance of Mixers

Both types of mixers shown in Figs. 3 and 5 have the same chip size of 1.2x1.2mm^2. Figs. 7 and 8 plot the measured conversion loss of the mixers. The mixers are configured as down converter with 50MHz IF frequency. The mixers exhibited broadband characteristics enough to cover both 60 and 77GHz bands. The mixers exhibited conversion loss of 8.8dB for the Marchand balun type and 9.9 dB for the side-coupled balun type at 77GHz for a LO drive power of 4dBm, respectively. The isolation of 25 dB between LO to RF ports was achieved over 50 - 75GHz band for both mixers. The equivalent RF input power at the 1dB gain compression point was 0dBm at 77GHz. Table 1 gives a summary of the MMIC mixer performance. The mixer with the Marchand balun demonstrated the conversion loss of 11.6±2.8dB over a 50-103.5GHz frequency range, whereas the mixer with the side-coupled balun covered a 50-95GHz band with a conversion loss of 11.6±2.2dB.

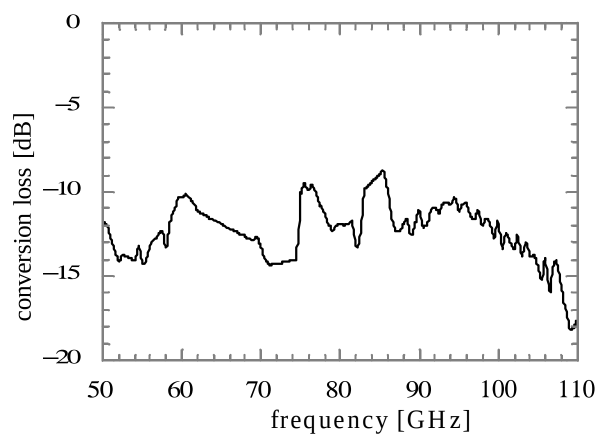

Fig. 7 Conversion loss of MMIC mixer Marchand balun

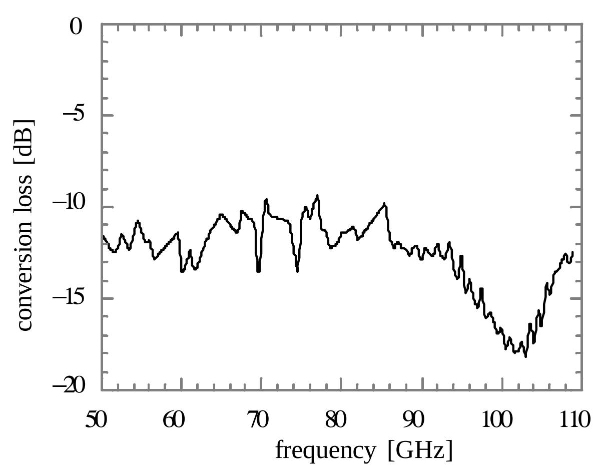

Fig. 8 Conversion loss of MMIC mixer using side-coupled balun

These results represent the widest bandwidth for MMIC mixers in mm-bands, as shown in Fig. 9 where MMIC mixer performance previously reported are compared with the one from this work [3]-[11].

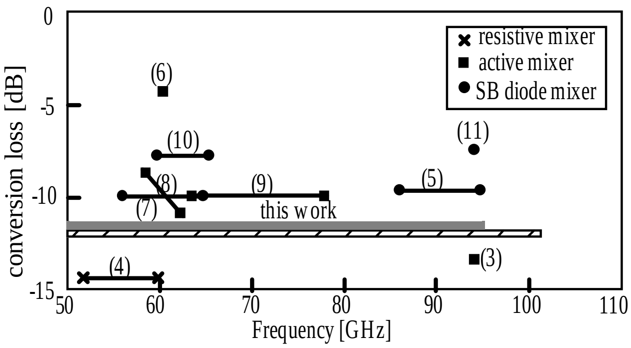

Fig. 9 Conversion loss performance of previously reported MMIC mixers

Table 1. Summary of the MMIC mixer performance

Balun type	Multi layer Marchand Balun	Side coupled Balun
frequency range	50 - 103.5	50 - 95
conversion loss	11.6	11.6
flatness	±2.8	±2.2
conversion loss at 62GHz	-11.2	-12.5
conversion loss at 77GHz	-8.8	-9.9

Conclusion

Single balanced MMIC resistive mixers achieved octave band performance by utilizing a Marchad balun and a side coupled balun on a GaAs substrate. Both mixers are usable for both 60 and 77GHz applications.

Acknowledgment

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