# Design and Performance of a New Uniplanar Diode Mixer

Pang-Cheng Hsu, Cam Nguyen, and Mark Kintis

***Abstract*—We report the development of a new uniplanar singly balanced diode mixer. The new mixer employs a novel 180° out-of-phase power divider using slotline and coplanar waveguide. Good results were obtained for the first-designed mixer. The conversion loss is between 6.5–10 dB for the radio-frequency (RF) signal from 10 to 11.6 GHz and the LO signal of 6 dBm at 7 GHz. The LO-to-RF, RF-to-IF, and LO-to-IF isolations are more than 16, 20, and 38 dB, respectively. These results signify the feasibility of the new mixer and hence demonstrate an attractive device for microwave and millimeter-wave integrated circuits.**

***Index Terms*—Microwave and millimeter-wave integrated circuits, mixer, planar mixer.**

## I. Introduction

UNIPLANAR circuits have been recognized as and played a crucial role in the advance of microwave and millimeter-wave integrated circuits (IC's). Research in this area has received a significant attention and has produced many good uniplanar circuits, for example, mixers [1]–[3]. The impetus of the development of uniplanar circuits is to achieve low cost and miniaturization with performances comparable to or better than those of nonuniplanar circuits. Industry is always striving to create new uniplanar IC's in search of better products and performances.

In this paper, we report the design and performance of a new uniplanar singly diode mixer. The mixer employs a novel 180° out-of-phase power divider using slotline and coplanar waveguide (CPW). These two transmission lines are perhaps the most commonly used structures for uniplanar circuits. The first-designed mixer exhibits a conversion loss between 6.5–10 dB for a radio-frequency (RF) signal sweeping from 10 to 11.6 GHz and an LO signal of 6 dBm at 7 GHz. The LO-to-RF, RF-to-intermediate frequency (IF), and LO-to-IF isolations are more than 16, 20, and 38 dB, respectively.

## II. Mixer Design

Figs. 1 and 2 show the layout and equivalent circuit of the new mixer. The RF signal reaches the two diodes with equal amplitudes and 180° out-of-phases via the CPW and CPW-slotline out-of-phase power divider. The LO signal arrives in-phase at the diodes through the CPW end-coupled bandpass filter. The diodes are mounted across the slotlines' gaps with opposite polarities, allowing the produced IF signals to be combined and then extracted at the output of the CPW low-pass filter. The insert in Fig. 1 shows details of the 180° out-of-phase power divider and diode connections.

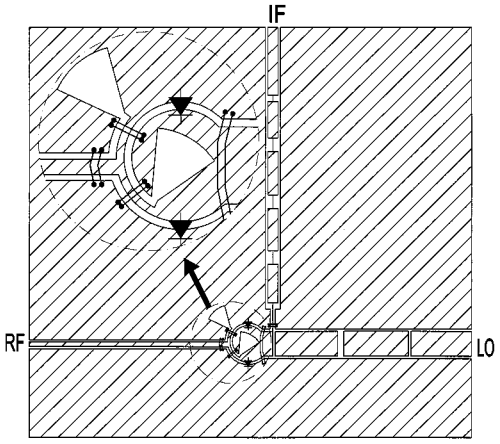


Fig. 1. Layout of the new uniplanar singly balanced diode mixer.

The CPW-slotline power divider splits the RF signal on the CPW into two signals of equal amplitudes and 180° out of phases on the slotlines. This device not only performs the 180°out-of-phase division but also the transitions from the CPW to slotlines. The design of these transitions was reported in [4]. The CPW end-coupled bandpass filter was designed based on the procedure in [5], passing the LO signal and providing approximately an open circuit at both the RF and IF frequencies. The LO signal reaches the two diodes in phase through this bandpass filter. Some of the LO power continues to propagate toward the RF port through the slotlines where the diodes are mounted. These signals, however, are combined out of phase by the slotline-CPW transitions and hence cancelled each other at the RF port. The low-pass filter consists of CPW's of high and low characteristic impedances and was designed to pass the IF signal while providing an approximate open circuit at the RF and LO frequencies. The isolations between the RF and LO and IF signals are enhanced by the inherent isolation between the slotline and CPW modes. Note that air bridges are used along CPW's for maintaining equal potentials of the ground planes for suppression of the slotline mode.

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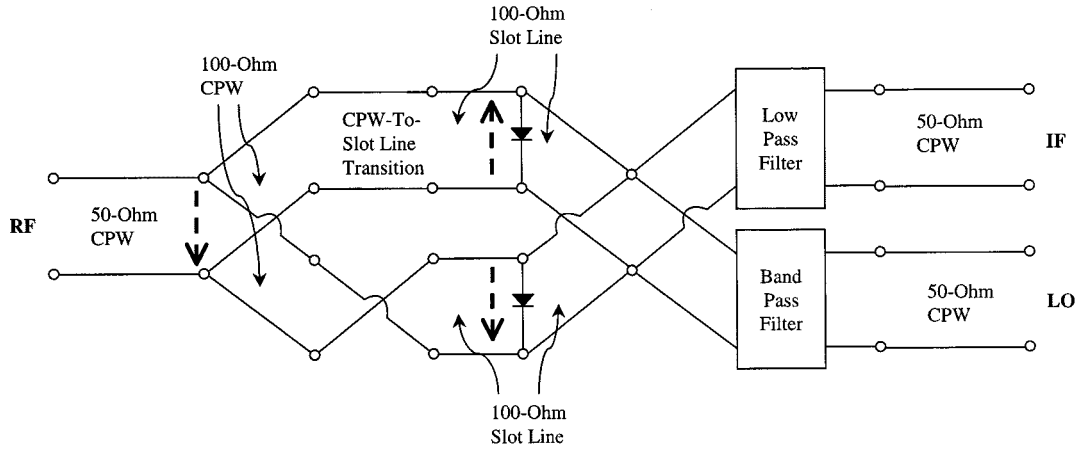


Fig. 2. Equivalent circuit of the mixer. Dashed arrows show the RF electric fields' directions.

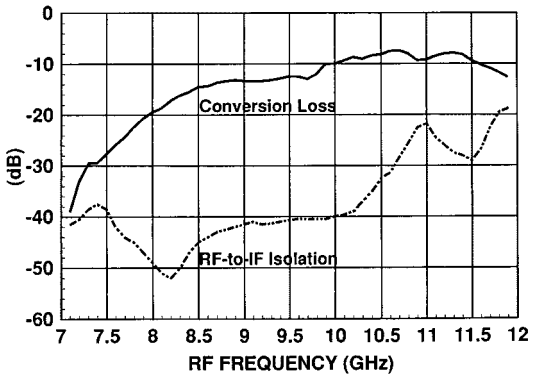


Fig. 3. Measured conversion loss and RF–IF isolation versus RF frequency.

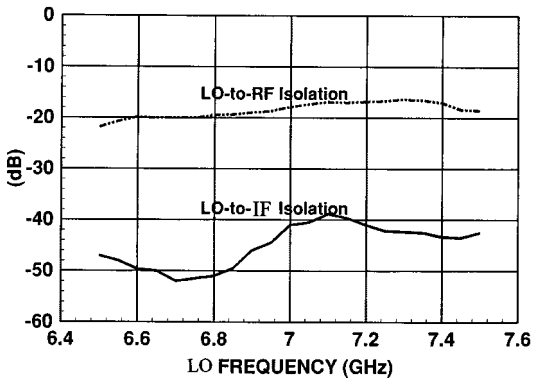


Fig. 4. Measured isolations between the LO and RF and IF ports.

## III. Mixer Performance

The mixer was fabricated on an RT/Duroid dielectric substrate with a relative dielectric constant of 6.15 and a thickness of 0.050 in. The diodes used are ALPHA DME 2333 silicon beam-lead Schottky barrier diodes.

Fig. 3 shows the measured conversion loss and RF-to-IF isolation versus RF frequency for an LO signal of 6 dBm at 7 GHz. Over the RF frequency range of 10–11.6 GHz, the conversion loss is from 6.5 to 10 dB, and the RF-to-IF isolation is better than 20 dB. The RF power is kept constant at −10 dBm. Fig. 4 shows the measured LO-to-RF and LO-to-IF isolations versus LO frequency. The isolations from LO to RF and IF ports are better than 16 and 38 dB, respectively, for the LO frequency from 6.5 to 7.5 GHz. The conversion loss of the mixer as a function of the LO power at 7 GHz is exhibited in Fig. 5. The RF frequency is −10 dBm at 10.5 GHz. The conversion loss begins to saturate around 6 dBm and changes very little as the LO power is increased to around 10 dBm.

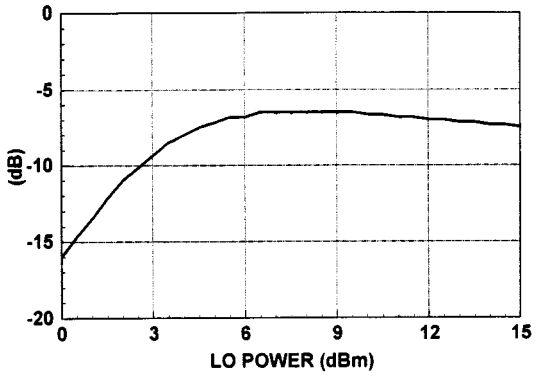


Fig. 5. Measured conversion loss versus LO power at 7 GHz.

## IV. Conclusions

We report the development of a new singly balanced diode mixer. The mixer is completely uniplanar and utilizes a novel out-of-phase power divider along with the slotline and CPW. The first-designed mixer exhibits a conversion loss between 6.5–10 dB and an RF-to-IF isolation better than 20 dB when the RF is swept from 10 to 11.6 GHz and the LO signal is fixed at 7 GHz and 6 dBm. The measured isolations between the LO and RF and IF ports are more than 16 and 38 dB, respectively, over the LO frequency range of 6.5–7.5 GHz. Although these initial results are not spectacular, they demonstrate a useful performance and, most importantly, the feasibility of the new mixer topology, which is attractive for

microwave and millimeter-wave IC's. With further optimizations, a better performance can be expected.

## ACKNOWLEDGMENT

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## REFERENCES

[1] S. A. Maas and K. W. Chang, "A broadband, planar, doubly balanced monolithic Ka-band diode mixer," *IEEE Trans. Microwave Theory Tech.*, vol. 41, pp. 2330–2335, Dec. 1993.

[2] H. Matsuura, K. Tezuka, I. Aoki, A. Miura, M. Yamanaka, T. Yakihara, S. Kobayashi, S. Oka, T. Fujita, and D. Murata *et al.*, "A monolithic W-band CPW rat-race mixer with HBT IF amplifier," in *1996 IEEE MTT-S Dig.*, pp. 389–392.

[3] P. C. Hsu, C. Nguyen, and M. Kintis, "A new uniplanar broad-band singly balanced diode mixer," *IEEE Trans. Microwave Theory Tech.*, vol. 46, pp. 1782–1784, Nov. 1998.

[4] C. H. Ho, fL. Fan, and K. Chang, "New uniplanar coplanar waveguide hybrid-ring couplers and magic-T's," *IEEE Trans. Microwave Theory Tech.*, vol. 42, pp. 2440–2448, Dec. 1994.

[5] C. Nguyen and K. Chang, "Design and performance of millimeter-wave end-coupled band-pass filters," *Int. J. Inf. Millim.-Waves*, vol. 6, no. 7, pp. 497–509, July 1985.