Uni-Planar MIC Balanced Multiplier
—— A Proposal of New Structure for MIC's ——

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Hiroyo Ogawa, Tetsuo Hirota and Akira Minagawa

NTT Electrical Communications Laboratories
Nippon Telegraph and Telephone Corporation
1-2356 Take, Yokosuka - shi
238-03 Japan

ABSTRACT

A novel uni-planar balanced MIC* (Microwave Integrated Circuit) multiplier is proposed and its characteristics discussed. The circuit uses a combination of coplanar waveguides and slotlines on one side of the substrate. The uni-planar MIC multiplier has been designed at the 13-GHz band and fabricated on an alumina substrate, and good performance has been achieved.

INTRODUCTION

Microwave Integrated Circuits (MIC's) have been successfully used in developing a number of microwave components [1]. Microstrip lines have been used as the main transmission line, however, coplanar waveguides and slotlines as well as finlines are recently utilized for realization of microwave circuits [2]-[4]. In addition to the use of these transmission lines, the structure by the combination of microstrip lines and slotlines, which is called the double-sided MIC, has been proposed and many functional circuits have been realized [5]-[7]. However the fabrication process and mounting structure of the double-sided MIC is complicated because of the use of the both surface substrate.

This paper proposes the "uni-planar" circuit configurations for MIC's. The uni-planar MIC does not have the disadvantages described above because it does not use the back side of the substrate. The uni-planar MIC has the same functions as the double-sided MIC does, and can have the potential to be applied to the monolithic MIC (MMIC) structure [8]. Features of the uni-planar MIC are summarized as follows:

(1) The fundamental components are coplanar waveguides, slotlines and bonding wires.
(2) The bonding wire connects coplanar waveguides with slotlines and does not deteriorate the circuit performance .
(3) Both the series and parallel T-junctions are fabricated by the combination of the fundamental components.
(4) The transition circuits from the coplanar waveguide to the slotline or vice versa are realized by the use of bonding wires.
(5) The performance of the circuit can be adjusted and optimized by changing the position of bonding wires.

This paper shows the balanced multiplier which utilizes the advantages of the uni-planar MIC described above. The uni-planar MIC balanced multiplier can be fabricated on one side of the substrate.

CIRCUIT CONFIGURATION

The circuit configuration of the uni-planar balanced MIC multiplier is shown in Fig. 1. The multiplier consists of coplanar waveguides, slotlines, bonding wires and two diodes. The bonding wire 1 is used to transform the coplanar waveguide mode to the slotline mode. The input signal and the odd harmonics do not couple to the output coplanar waveguide due to the bonding wire 2. The bias voltage is supplied into diodes through the bonding wire 3. All components required for realization of the balanced multiplier are fabricated on one side of the substrate. The slotline length between the diode and the bonding wire 2 is selected to a quarter wavelength of the input frequency.

The equivalent circuit of the multiplier is shown in Fig. 2. The balance / unbalance transition circuit plays an important role in the multiplier. The input power is supplied into two diodes in the out-of-phase. Arrows represent the schematic expression of the direction of the applied voltage or generated harmonics voltages. Since the second harmonics and higher even harmonics are generated from two diodes in the in-phase, these harmonics can be obtained from the output port. On the other hand, odd harmonics as well as the input signal propagate along the slotline in the out-of-phase, and these are short-circuited at the junction of slotlines and the coplanar waveguide.

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* Since the circuit utilizes only one substrate surface, it will be called an uniplanar circuit.

All odd harmonics are reflected and decoupled to the output port. Thus the balanced multiplier fabricated on one side of the substrate can be realized by the uni-planar MIC technique.

EXPERIMENTAL RESULTS

A. Coplanar waveguide / slotline transition

To confirm the behavior of the fundamental component of the uni-planar MIC, the coplanar waveguide / slotline transitions are fabricated by the usual photolithographic technique on an alumina substrate. Fig. 3 shows the circuit pattern of the transitions. After electroplating, two ground conductors of the coplanar waveguide are connected by bonding wires.

The frequency response of the transition is shown in Fig. 4. The insertion loss includes the transmission loss of two coaxial connectors and two coplanar waveguide/slotline transitions, and the conduction loss of the slotline(15mm) and the coplanar waveguide(14mm). The intrinsic loss of the transition is estimated to be less than 0.5 dB after eliminating above excess losses. These results show that the use of bonding wire structures does not interfere with the circuit performance and may allow development of various uni-planar circuits.

B. Balanced Multiplier

The circuit shown in Fig.1 is fabricated on an alumina substrate. Two beam-lead Schottky-barrier diodes are used in the multiplier. Fig.5 shows the conversion loss versus the input power. The input frequency is fixed at 6.5 GHz. As the forward bias voltage to the diodes increases, the minimum conversion loss can be obtained at the lower input power. The minimum conversion loss is 9.8 dB at a input power of 21.5 dBm and a forward bias voltage of 0 V.

The balanced circuit has the following advantages: (1) high isolation between the input and output ports is obtained, (2) even harmonics can couple to the output port, while odd harmonics cannot. Fig. 6 shows the isolation characteristics between the input and output ports. The isolation is greater than 23.5 dB. The return loss at the input port is also shown in Fig. 6. The return loss becomes worse as the input power decreases, because the diode impedance depends on the input power. The diode impedance increases as the input power decreases, and therefore the reflection of the input power increases. On the other hand, the diode impedance decreases as the input power increases, and then the return loss increases as shown in Fig. 6. Thus the balanced multiplier with high isolation has been achieved using the uni-planar MIC technique.

CONCLUSION

A novel uni-planar MIC balanced MIC multiplier has been proposed. It uses coplanar waveguides, slotlines and bonding wires on one side of the substrate. The fundamental component of the uni-planar MIC's, i.e., the coplanar waveguide / slotline transition, has been fabricated and tested. The experimental results show that the use of bonding wire structures allow development of various uni-planar circuits. The balanced multiplier has also been fabricated and good performance has been achieved, particularly, high isolation between the input and output ports has been obtained. This uni-planar MIC technique is promising for applications to such microwave circuits as modulators, frequency converters and amplifiers.

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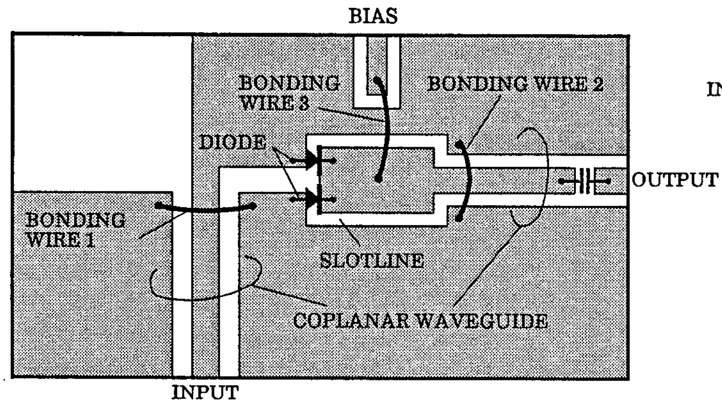

Fig.1. Circuit Configuration of uni-planar MIC balanced multiplier.

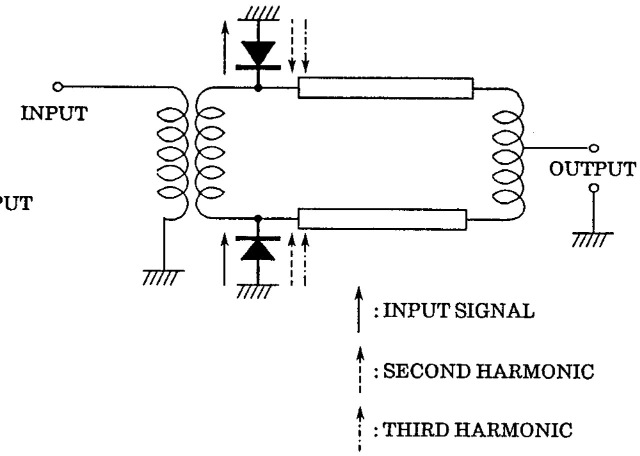

Fig.2. Equivalent circuit of uni-planar MIC balanced multiplier.

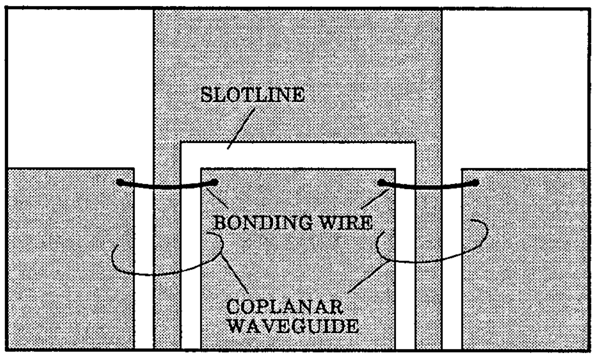

Fig.3. Circuit Configuration of coplanar waveguide/slotline transition.

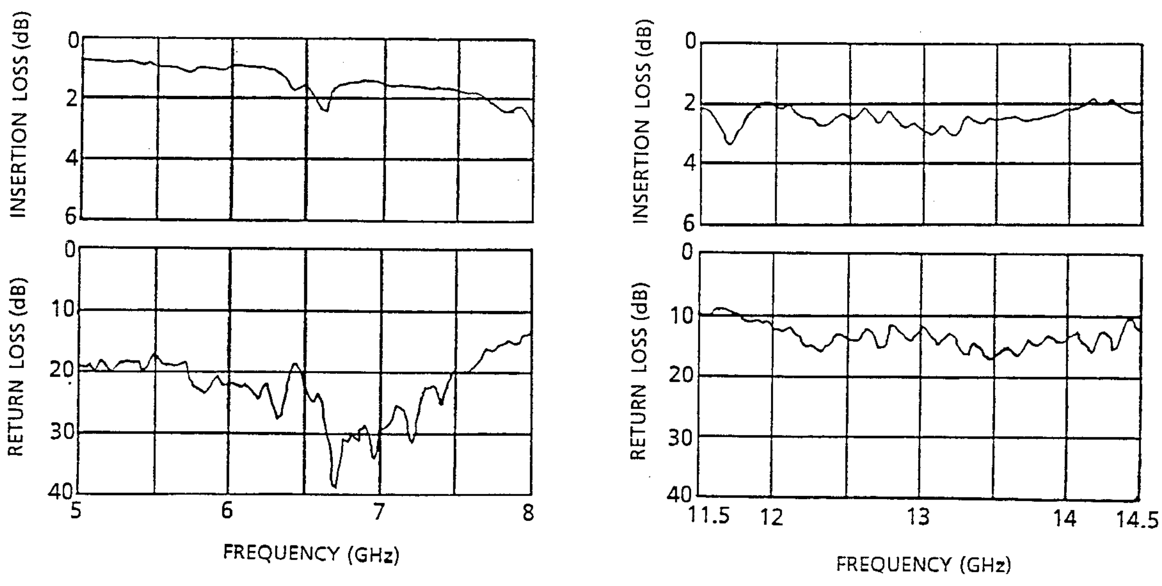

Fig.4. Frequency response of coplanar waveguide/slotline transition.

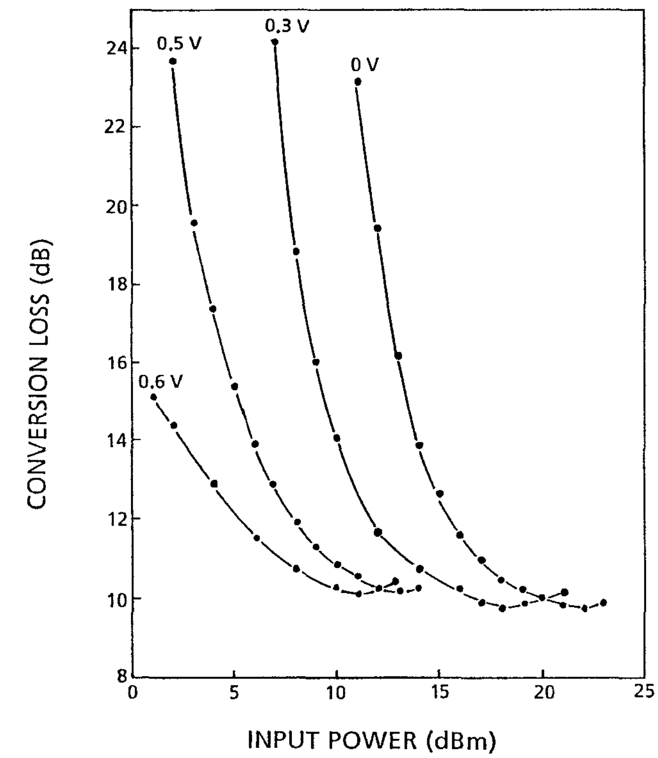

Fig.5. Conversion loss of balanced multiplier. The input frequency is 6.5 GHz.

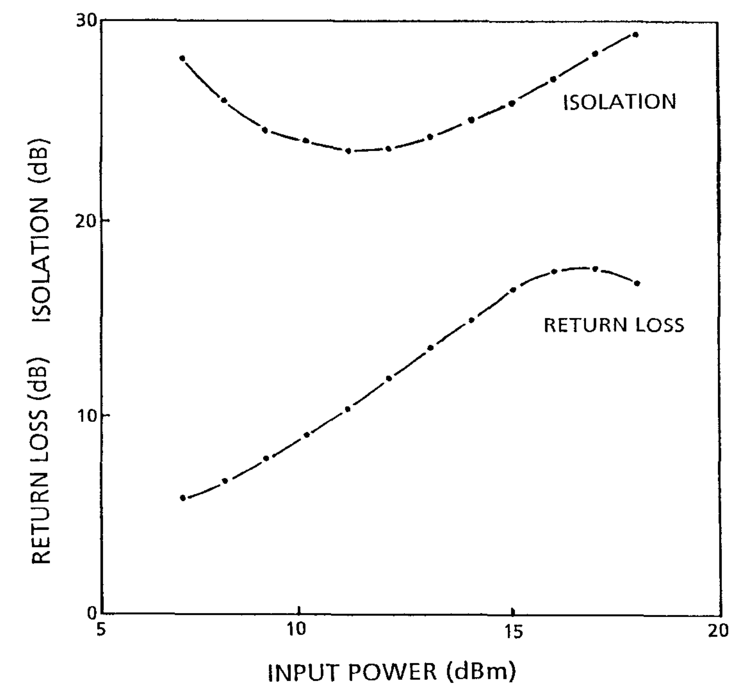

Fig.6. Isolation and return loss of balanced multiplier. The input frequency is 6.5GHz and the applied bias voltage is 0 V.