SUBHARMONIC MIXER USING PLANAR DOPED BARRIER DIODES

C-2

S. Dixon*, R.J. Malik*, J. Paul**
P. Yen**, T.R. Aucoin*, and L.T. Yaun**
*US Army Electronics Technology & Devices Laboratory
Fort Monmouth, N.J. 07703
**Hughes Aircraft Co., Torrance, Calif. 90509

ABSTRACT

As a part of an Electronics Technology and Devices Laboratory internal effort, a novel subharmonically pumped mixer using planar doped barrier (PDB) diodes has been designed and fabricated. It adopts a configuration which is used primarily to optimize the MBE grown PDB diodes. A conversion loss, in the order of 6 dB has been achieved using a 1.2 GHz local oscillator and a signal frequency of 2.0 GHz.

Introduction

A novel subharmonically pumped mixer using planar doped barrier (PDB) diodes has been designed and fabricated monolithically in GaAs by molecular beam epitaxy. The PDB structure has an n^+-i-p^+-i-n^+ configuration in which for this application, an extremely narrow p^+ region is positioned half-way between two regions of nominally undoped semi-conductor bounded by two heavily doped n^+ regions. This PDB technology provides independent and continuous control of the barrier height and the asymmetry of the I-V characteristics through variation of the acceptor charge density and the undoped region widths. This is in direct contrast to metal-semiconductor structures where the properties are very sensitive to surface preparations and the barrier height is usually fixed. In this paper, we discuss and evaluate the PDB diodes in a subharmonic mixer structure.

Mixer Diodes and Design

The PDB diodes used in the mixer were grown in a Varian-360 Molecular Beam Epitaxy System, at the Electron Technology and Devices Laboratory. High purity elemental sources of gallium, arsenic, germanium, and beryllium were evaporated from pyrolytic baron nitride crucibles. Each source was individually shuttered and monitored by an ion guage in the substrate position (Wood, 1976)[1]. The dopant flux densities, $J_x(T)$ atoms - cm^{-2} - s^{-1}, were determined as a function of the dopant source temperature from previous growth experiments by van der Pauw measurements of uniformly doped epilayers.

The critical parameters which determine the zero-bias barrier height, as well as the I-V characteristics are the acceptor charge density, and the thickness of the two undoped regions. Fortunately, MBE allows for very precise control of all three parameters which account for the excellent agreement between theory and experiment as well as the uniformity of diode characteristics found across the wafers.

Test diodes were fabricated from grown epilayers using the following process. An array of 100μm diameter circular mesas were formed by conventional photolithography and chemical etching down to the n^+ substrate with 1:1:16H_2SO_4:H_2O_2:H_2O[2]. A photoresist guard ring was formed over the circumference of the mesa and evaporated 88 Au/12 Ge was lifted off to obtain the simple diode structure.

These diodes, with series resistance of 7 ohmes and a capacitance of 1.8 PF, were evaluated as a sub-harmonic mixer using a coplanar waveguide fixture fabricated on a 1"X1"X.015" Al_2O_3 substrate. The diode wafer was sliced into squares of about 0.080" X 0.080". This 80 mil chip was then bonded to one end of the coplanar waveguide as shown in Figure 1.

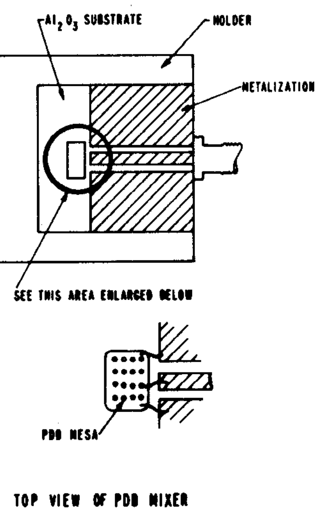

Fig. 1: Cross Sectional View of Harmonic mixer.

The electrical connections to the chip were made by wire bonding. This subharmonic mixer circuit implementation was considerably simplified since one PDB diode will replace two Schottky barrier diodes currently used in balanced mixers.

Results

A diode test-fixture, as shown in figure 2, has

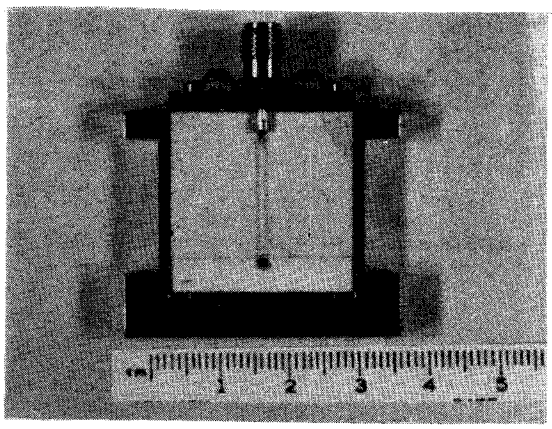

Fig. 2: PDB Diode Test Structure

0149-645X/82/0000-0027 $00.75 © 1982 IEEE

been fabricated and evaluated. Using separate signal generators as the local oscillator and the signal source, conversion loss was measured as a function of several different parameters. Figure 3 shows the conversion loss of a PDB diode with an asymmetrical I-V curve. As can be seen, the conversion loss varies from 14 dB to 8.0 dB as the intermediate frequency (IF) is changed from 400 MHz to 2.0 GHz. For this case the local oscillator frequency is fixed at 1.2 GHz with a pump power of 9.0 dBm. Figure 4 shows the conversion loss for a PDB diode with a symmetrical I-V curve. With the local oscillator frequency fixed at 1.2 GHz, the conversion loss varied from 8.0 dB to 5.0 dB over an IF frequency range from 200 MHz to 1.8 GHz. Figure 5 shows the measured I-V characteristics of the symmetrical PDB diode which uses one diode to replace two Schottky barrier diodes in a conventional balanced mixer. At pumping conditions, the curve will be bent toward the vertical axis and eventually will become a straight line. Figure 6 shows the comparison of the conversion loss of both the symmetrical and asymmetrical PDB diode. This data shows the dramatic decrease in conversion loss when the PDB diode has a symmetric I-V characteristic. Figure 7 shows the conversion loss for a fixed intermediate frequency of 400 MHz. The minimum conversion loss is 5.0 dB at a signal frequency of 1.8 GHz. The frequency reponse of the conversion loss is relatively flat. The loss variation is 3.0 dB for a frequency range of 400 MHz to 2.0 GHz.

Conclusions

Subharmonic mixing in a planar-doped-barrier (PDB) diode has been demonstrated in a coplanar waveguide structure at 2.0 GHz. The RF data reveals the possibilities of adapting the PDB diode for state of the art mixer applications. The low frequency model evaluated will be used to optimize the PDB diode for operation at much higher frequencies.

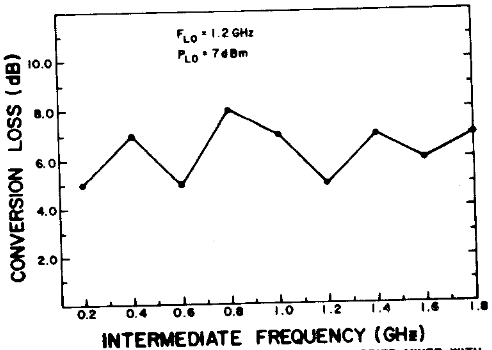

Fig. 4: CONVERSION LOSS OF SYMMETRICAL PLANAR-DOPED BARRIER MIXER WITH FIXED LOCAL OSCILLATOR FREQUENCY OF 1.2 GHz

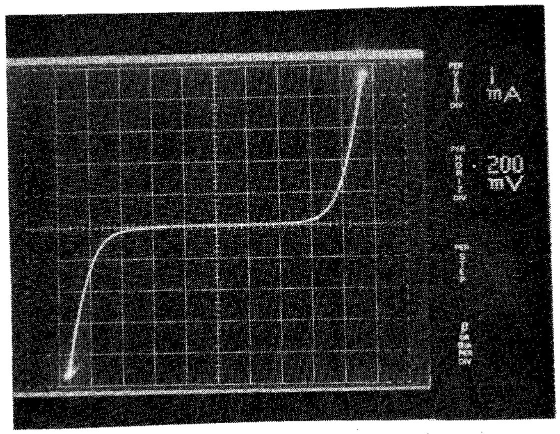

Fig. 5: Symmetric I-V characteristic of PDB Diode

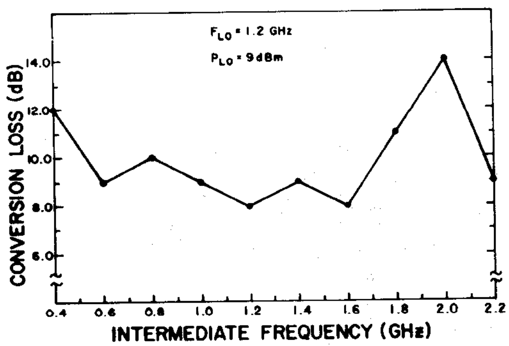

Fig. 3: CONVERSION LOSS OF ASYMMETRICAL PDB MIXER WITH FIXED LOCAL OSCILLATOR FREQUENCY OF 1.20 GHz

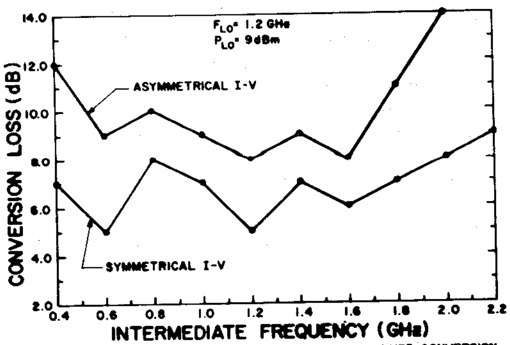

Fig. 6: COMPARISON OF SYMMETRICAL AND ASYMMETRICAL PDB MIXER CONVERSION LOSS VERSUS INTERMEDIATE FREQUENCY

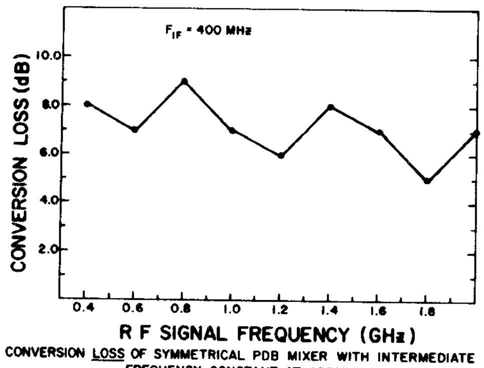

Fig. 7: CONVERSION LOSS OF SYMMETRICAL PDB MIXER WITH INTERMEDIATE FREQUENCY CONSTANT AT 400MHz

REFERENCES

1. Wood, CEC 1976, Appl. Phys. Lett. 29, 746

2. R.J. Malik et. al, Proc. 1980 Sym. on GaAs and related compounds, Ist. Phys. Conf. Ser No. 56, 697-710