94 GHz Monolithic GaAs Balanced Mixers

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ABSTRACT

A millimeter wave monolithic GaAs balanced mixer integrated circuit using a pair of planar Schottky barrier diodes with RF matching elements on a semi-insulating GaAs substrate has been developed for 94 GHz receiver applications. The GaAs chip is used as a suspended stripline in a WR-10 waveguide circuit. A double sideband noise figure of 6.3 dB has been achieved with a local oscillator power of 8 dBm. This includes a contribution of a 1.5dB noise figure due to the IF preamplifier (5-500MHz).

INTRODUCTION

Monolithic integration of passive elements and active devices on GaAs substrates becomes increasingly attractive for millimeter wave integrated circuits near 94GHz where reduced circuit size becomes difficult to handle and repeatable performance is hard to achieve with hybrid circuit techniques. The monolithic circuit approach offers excellent control of parasitics by precision delineation of both circuit and device designs. As frequency is increased, the monolithic chip size is significantly reduced and the cost of the circuit decreases.

The advantages of monolithic techniques at millimeter wavelengths have long been recognized. Early efforts have successfully demonstrated the feasibility of monolithic GaAs circuits using the microstrip integrated circuit (MIC) approach (1,2,3). This paper presents the results on a 94 GHz monolithic GaAs balanced mixer circuit using the suspended stripline circuit technique. Recently several investigators have demonstrated excellent performance using this technique in hybird form (4,5). This work is an extension of our earlier work at Ka-band frequencies (6).

CIRCUIT DESIGN

The mixer configuration, shown in Figure 1, is a cross bar circuit with a GaAs chip serving as a suspended stripline. The GaAs monolithic chip consists of two planar Schottky barrier mixer diodes and matching circuit for coupling LO and RF waveguide ports. A waveguide to suspended stripline transition is used to couple the LO power to the mixer diodes. The configuration of the transition was optimized experimentally using a 2-4GHz low-frequency scaled model. The diodes are electrically in parallel with respect to the local oscillator and are in a direction such that the induced LO currents in the diodes are 180° out of phase. The two diodes are physically close to each other and can have nearly identical device parameters because they are monolithically fabricated. Such a well matched diode pair gives excellent LO noise suppression.

The diodes are electrically in series with respect to the RF waveguide and can be impedance-matched easily with full height waveguide. They are located at the center line of the waveguide broadwall and each grounded to the center of the broadwall by a gold wire with 1 mil diameter. The monolithic chip which is .210"x.025"x.004" is connected to a low pass filter via a high impedance line by a one mil wire. The low pass filter, which consists of 5 cascaded high and low impedance sections, is fabricated on a 4 mil quartz substrate. The size of the LP filter is .050"x.250". An OSSM connector is used to bring the IF signal out. The monolithic chip and the MIC LP filter are mounted on a wafer-type waveguide package as shown in Figure 2. The wafer is sandwiched between the input section and a waveguide section for tuning shorts. The circuit component is shown before and after assembly in Figures 3 and 4, respectively.

CHIP FABRICATION

The monolithic mixer diodes have been fabricated on two-layer epitaxial material

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grown by the hydride process (AsH_3, Hcl, Ga, H_2) on 10mil semi-insulating GaAs substrates. The doping density and thickness are $2x10^{18} cm^{-3}$ and 2 micron for the first layer and $9x10^{16} cm^{-3}$ and 0.1 micron for the top layer. An abrupt transition from the low-doped to high-doped region has been achieved reproducibly with a depth of 200±50A for a decade change of doping density.

A direct liftoff technique has been used to form both the Schottky barrier (TiW/Au) and ohmic contact (AuGe/Ni/TiW/Au) metallizations. The metal thickness is 2000A. The diodes are isolated from the circuit parasitics by using the proton bombardment technique(7) with a 3 micron thick gold film to protect the active region. After the protect layer is removed, overlay metallization is then deposited for the RF matching circuits. A selective plating technique is used to increase the thickness of circuit metallization to 1.2 microns. The substrate is then thinned to 4 mils before individual chips are cut from the large wafer and mounted in a package.

Diodes with a zero-biased cutoff frequency of better than 600 GHz and an ideality factor of 1.10 have been achieved. Figure 5 shows a microphotograph of a Schottky barrier diode with a two-micron finger. The I-V characteristics of a monolithic diode pair is shown in Figure 6.

RF PERFORMANCE

Figure 7 shows a typical plot of double sideband noise figure as a function of local oscillator power for a monolithic balanced mixer at 94 GHz. Figure 8 gives the noise figure vs. frequency curve of a monolithic balanced mixer for fixed tuning operation near 95 GHz. A DSB noise figure of 6.3 dB has been achieved at 94 GHz with a LO power of 8 dBm. This includes the contribution of the 1.5 dB noise figure of the IF preamplifier (5-500 MHz).

CONCLUSION

A monolithic GaAs balanced mixer integrated circuit with a chip size of .210"x.025" has been demonstrated in a 94 GHz cross bar mixer circuit with a DSB noise figure of 6.3 dB including the noise from the IF preamplifier (5-500 MHz).

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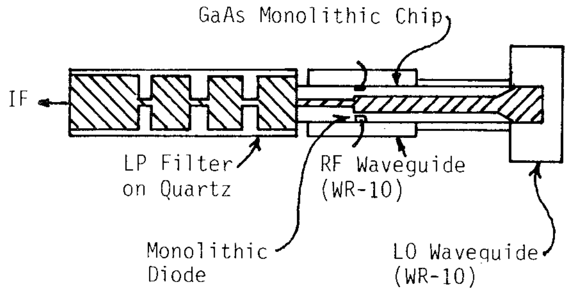

Figure 1: Features of the 94 GHz monolithic GaAs balanced mixer circuit.

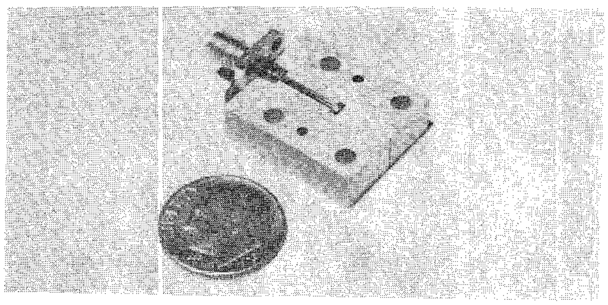

Figure 2: 94 GHz monolithic GaAs balanced mixer chip mounted with a hybrid MIC LP Filter on a wafer-type package.

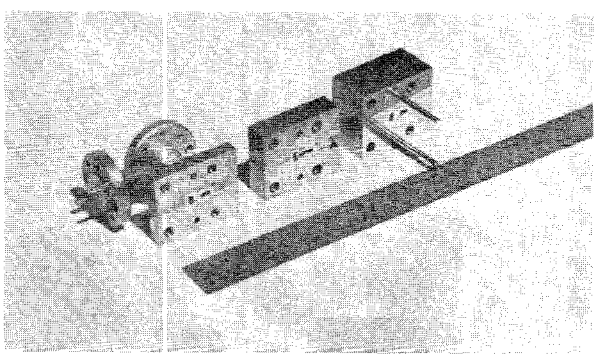

Figure 3: Disassembled balanced mixer circuit components.

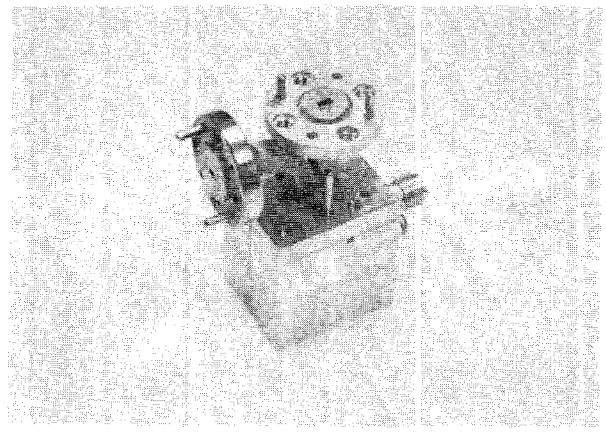

Figure 4: 94 GHz Monolithic GaAs balanced mixer circuit.

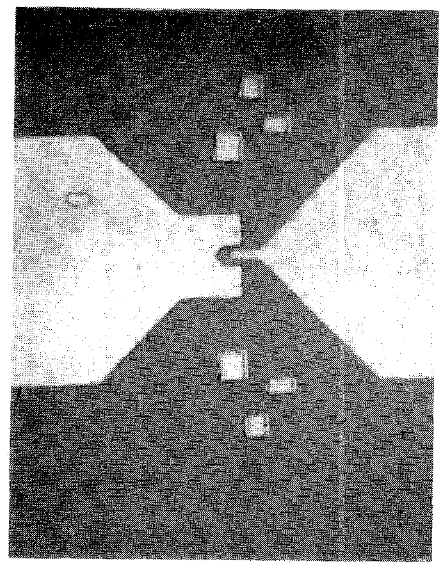

Figure 5: Microphotograph of planar Schottky barrier diode.

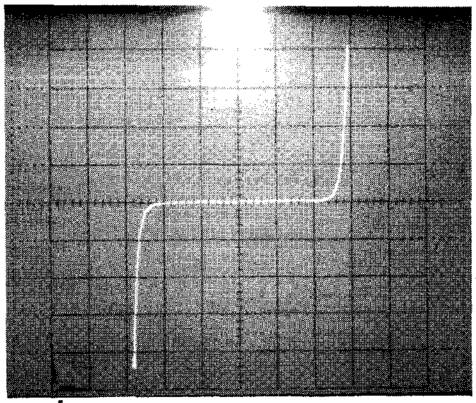

Figure 6: I-V characteristics of the monolithic diode pair (Horizontal Scale: .2V/Div, Vertical Scale: 1 μ A/Div.)

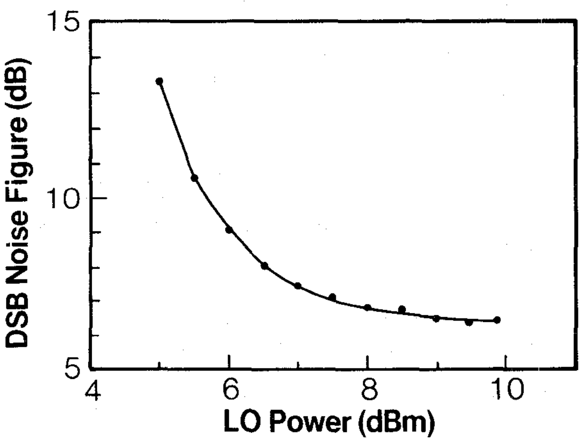

Figure 7: Noise Figure vs. LO Power for Monolithic Balanced Mixer at 94.1 GHz

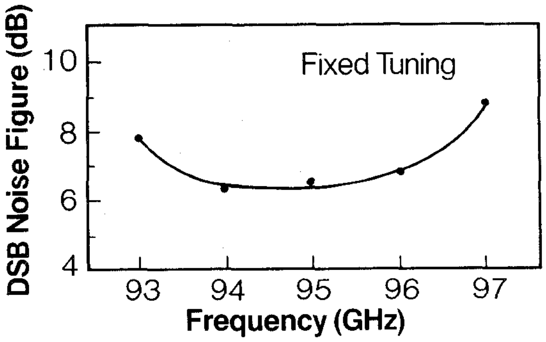

Figure 8: Noise Figure vs. Frequency for a Monolithic GaAs Balanced Mixer.