94 GHz Planar GaAs Monolithic Balanced Mixer

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ABSTRACT

A 94 GHz GaAs monolithic balanced mixer in a planar microstrip integrated circuit configuration has been demonstrated. A double sideband noise figure of 5.6 dB has been achieved at 94.5 GHz. This includes a 1.5 dB noise contribution of the IF preamplifier. The chip size is 0.076 x .034 inch with integral beam leads.

I. INTRODUCTION

While several monolithic mixers have been constructed [1-3], this is believed to be the first monolithic rat race mixer at 94 GHz. A double sideband noise figure of 5.6 dB was obtained at 94.5 GHz. This includes a 1.5 dB noise contribution of the IF preamplifier but not transmission line and mismatch losses which are about 5 dB. The monolithic mixer consists of a pair of GaAs planar Schottky barrier mixer diodes, the matching circuitry and the LO and RF transmission lines. The chip of .076 x .034 in. size is connected between two quartz microstrip probe transitions. Computer aided design and low frequency models were used for the design of the mixer circuit. The microstrip circuit approach will permit the integration of multiple functions on a single chip for low cost receiver applications at mm-wave frequencies.

II. CIRCUIT DESIGN

The configuration of the planar monolithic balanced mixer is illustrated in Figure 1. It consists of a rat race hybrid, two monolithically integrated diodes, matching circuits and beam lead RF interconnects. The IF output filter, which is off chip, is connected to the local oscillator input line. This helps reduce the size of the chip but has little effect on mixer performance. The mixer is relatively insensitive to local oscillator noise since the Schottky diodes are antiphase with respect to this input. On the right and left of the rat race hybrid are filters to suppress the response of the mixer at the sum of the local oscillator and signal frequencies. These filters, which are formed by two shunt stubs, a short high impedance transmission line and the diode capacitance, are needed to optimize the mixer conversion loss. A ground for the local oscillator and signal frequencies is provided by an open-circuited quarter wave stub. The IF ground is connected to the pads at the top and bottom of the chip.

III. CHIP FABRICATION

The monolithic mixer has been fabricated using the process outlined in Figure 2. The circuits are fabricated on n-n^+ layers grown by VPE on a semi-insulating substrate. The n^+ layer has a doping density of approximately $2 \times 10^{18} cm^{-3}$ and is 3 microns thick. The n layer on top of the n^+ layer has a doping density near 5×10^{16} and is about 0.1 microns thick.

The first step in fabricating the mixers is (a) formation of the ohmic contacts (Ni/Au-Ge/Ni) by a liftoff process. After alloying these contacts (b) they are covered by SiON using plasma assisted CVD. The Schottky contacts (Mo-Au) are fabricated by dielectric assisted liftoff and the diodes isolated by deep mesa etching using a combination of ion milling and wet etching. The surface of the wafer is planarized (c) using spin-on polyimide and wet etching. Formation of an air bridge contact to the Schottky and beam leads for interconnects finishes topside processing. After thinning the wafers to 6 mils and backside metallization the mixers were separated by sawing. A photograph of one of the mixer diodes in a completed mixer is given in Figure 3.

IV. MONOLITHIC 94 GHz MIXER PERFORMANCE

The diode parameters obtained are listed below. Note that C_t includes transmission line capacitance. The junction capacitance itself should be about 15 fF.

Ideality n	1.06	
Series Resistance R_s	15.	ohms
Total Capacitance C_t	.125	pF
Reverse Current	1	ma at 6V

The noise figure calculated for a similar mixer diode and its matching circuit is given in Figure 4.[4] This does not include the effect of losses and mismatch in either the circuit or test fixture. The measured noise figure for a monolithic mixer excluding 5 dB transition losses is shown in Figure 6. This includes the effect of a 1.5 dB NF IF preamplifier. The noise figure versus local oscillator power is plotted for this same mixer (#1) in Figure 7.

Another mixer, with slightly better performance, is also indicated. It is clear from these results that further optimization is possible but monolithic mixers appear to be promising devices for use at these frequencies.

V. CONCLUSION

A monolithic GaAs balanced mixer with minimum chip size is potentially useful for 94 GHz applications.

ACKNOWLEDGEMENT

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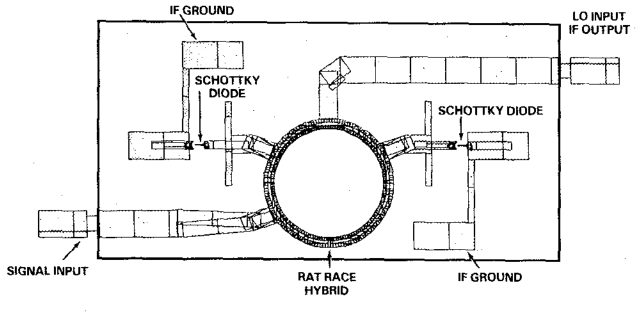

FIGURE 1. 94 GHz PLANAR MONOLITHIC BALANCED MIXER LAYOUT

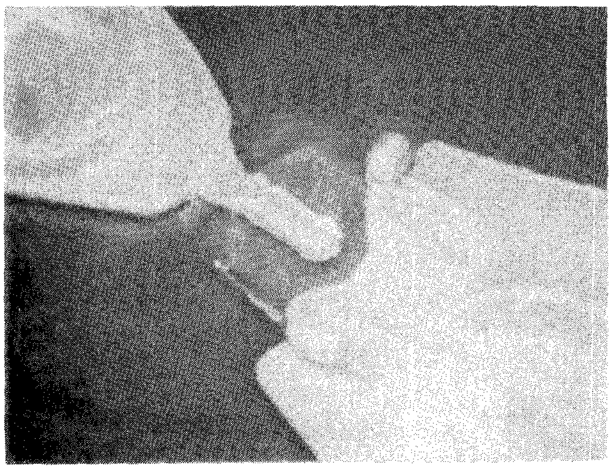

Figure 3. Schottky Diode Used in Monolithic Mixer.

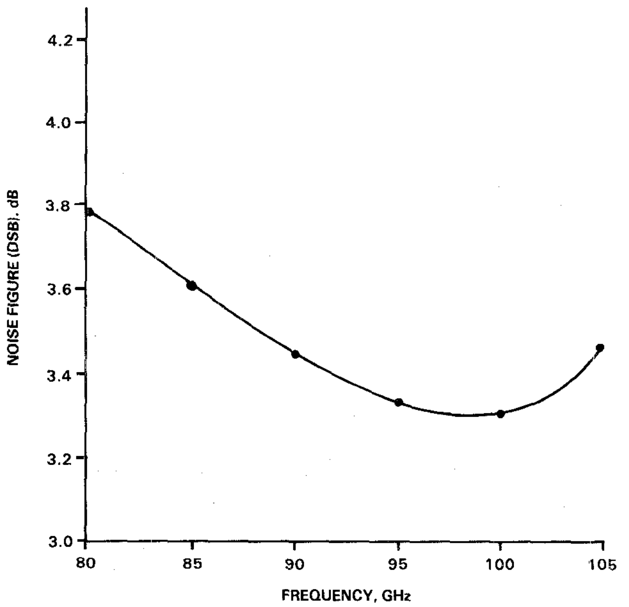

Figure 4. GHz Monolithic Mixer Calculated Noise Figure Including 1.5 dB IF Preamplifier Noise but Excluding Rat-Race and Transition

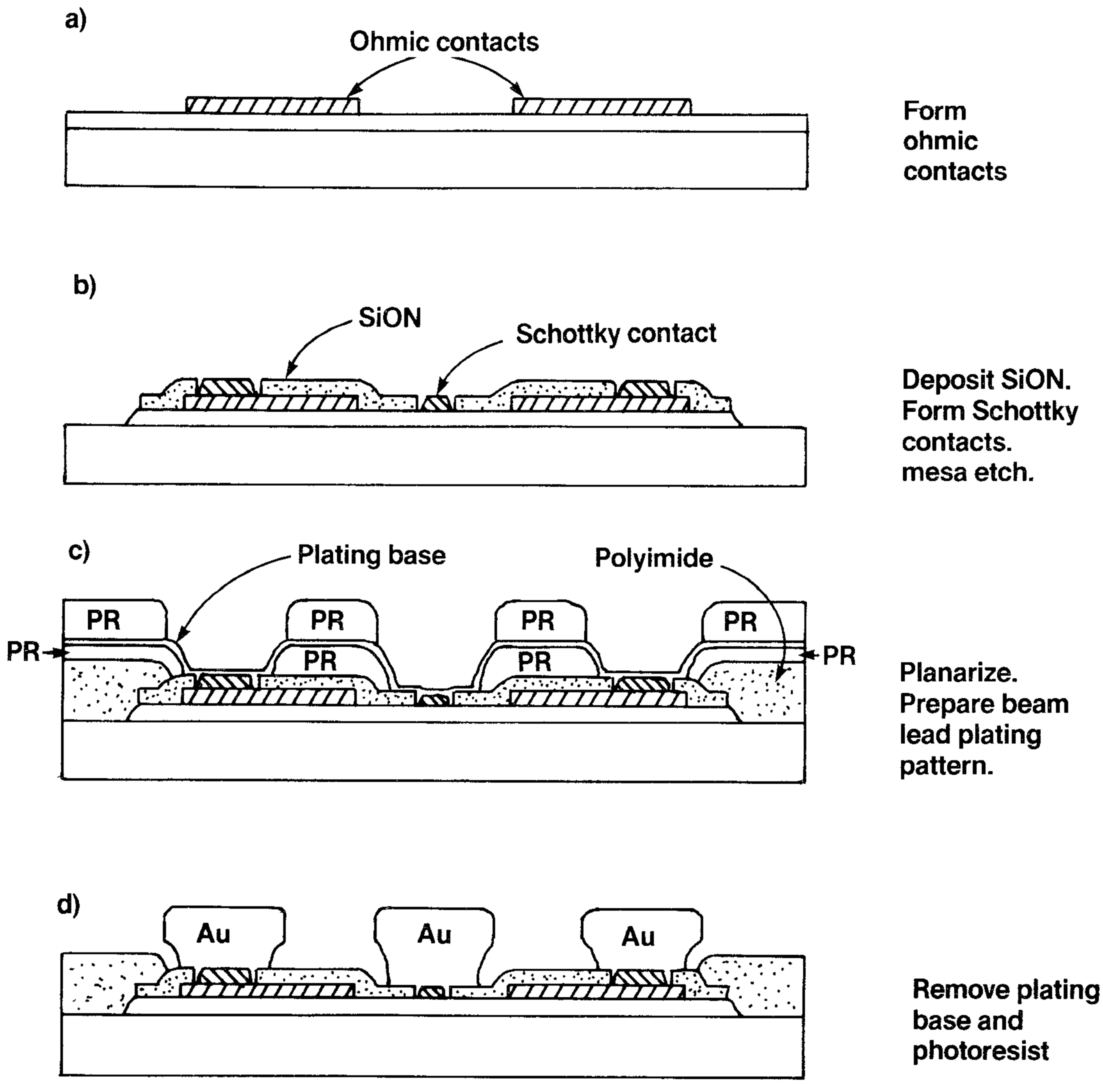

Figure 2. 94 GHz Monolithic Mixer Fabrication

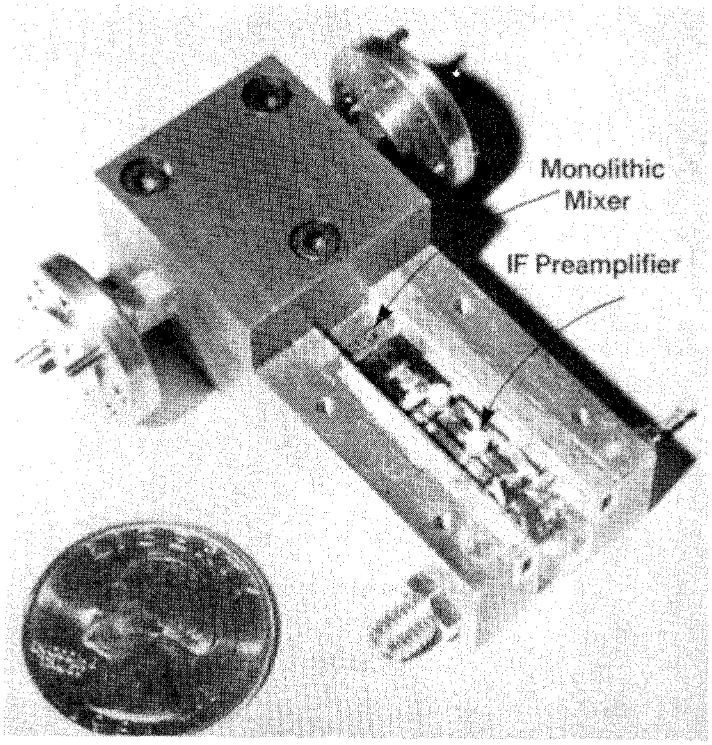

Figure 5. Packaged Monolithic 94 GHz Mixer

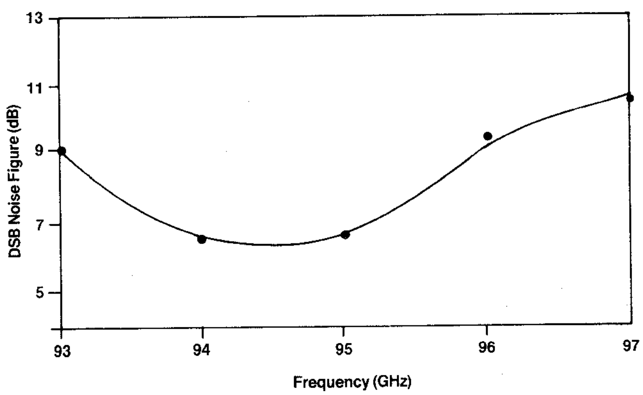

Figure 6. Noise Figure versus Frequency Excluding 5 dB Transition Losses

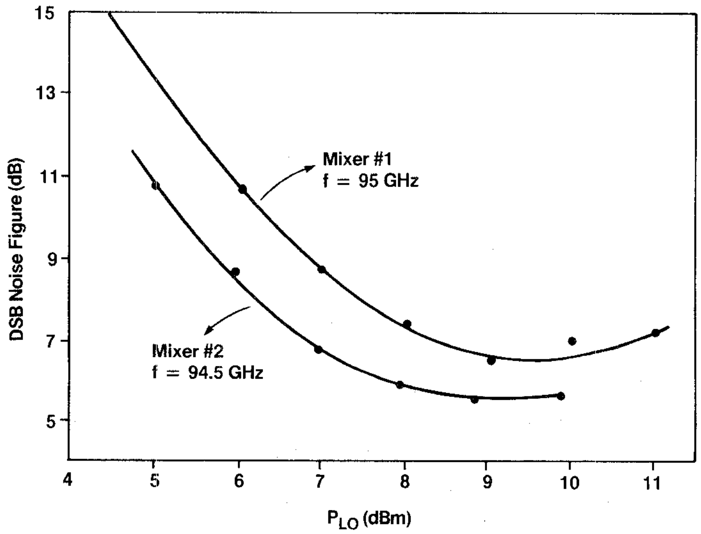

Figure 7. Noise Figure vs. Local Oscillator Power Excluding 5 dB Transition Loss