A W-BAND MONOLITHIC GaAs CROSSBAR MIXER

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ABSTRACT

A fully monolithic crossbar mixer has been designed and fabricated for operation at W-band (75 to 110 GHz). A typical conversion loss of 9 dB with a variation of less than ±0.5 dB has been measured, and a minimum conversion loss of 7.5 dB has been measured at 76 GHz.

INTRODUCTION

This paper describes the design, fabrication and performance of a W-band monolithic crossbar mixer. The monolithic crossbar mixer was fabricated with two in situ GaAs Schottky barrier diodes on a 4-mil thick semi-insulating GaAs substrate. The crossbar structure of the mixer was fabricated in a suspended stripline circuit. A special probe coupling was provided for the LO port which substantially reduces the susceptive loading of the IF port, resulting in extremely flat response over an IF of 8.5 GHz. The typical conversion loss measured was 9 dB for broadband operation, while for a narrow band case, a minimum conversion loss of 7.5 dB was measured at 76 GHz.

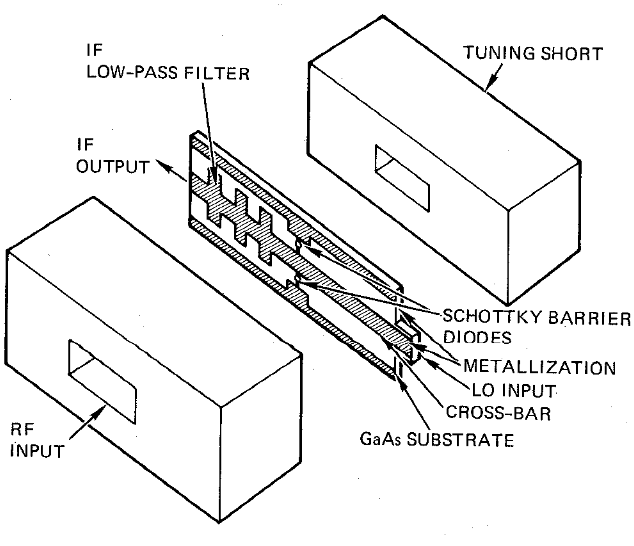

Figure 1. Schematic Diagram of Planar Crossbar Mixer

MIXER DESIGN

The heart of the monolithic crossbar mixer is a circuit substrate board comprising a pair of in situ GaAs Schottky barrier diodes connected across the stripline on the substrate, as shown in Figure 1. In operation, the LO signal is injected through a waveguide-to-suspended stripline transition and applied to the Schottky barrier diodes with the polarity shown in Figure 2. LO coupling to the diodes is through a specially designed E-probe with appropriate matching circuits as shown in Figure 3. This new probe design not only substantially reduces the size of the mixer housing but also the susceptive loading of the IF port due to excessive line length. As a result, a broader bandwidth and flatter response is achieved than with a conventional crossbar mixer. The RF signal is applied directly from the waveguide to the diode pair. The IF signal is extracted via a microstrip line etched on the same substrate.

Electrically, the mixer is well matched at the RF and IF ports by virtue of the series connection of the diodes as seen from the RF port, and the parallel connection as seen from the IF. This provides a higher impedance level to the RF signal and a lower impedance level to the IF signal than that of a single diode mixer. Therefore, an inherent impedance match condition for both the RF and IF signals is achieved for broadband performance. Basically, the planar crossbar mixer consists of a circuit board sandwiched between a split-block metal housing. One half of the housing consists of a built-in back-short for the RF signal, and the other half is a waveguide port for coupling the RF signal to the mixer diodes. As the LO signal is fed through the center conductor of the circuit board, it provides the right phase difference to the two diodes for a single balanced mixer operation. In addition, because of the orthogonality of the LO and RF E-fields, it also provides excellent RF to LO isolation. This design does not require any hybrid

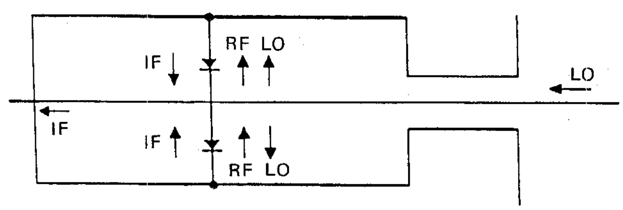

Figure 2. Diode Polarity of the Crossbar Mixer

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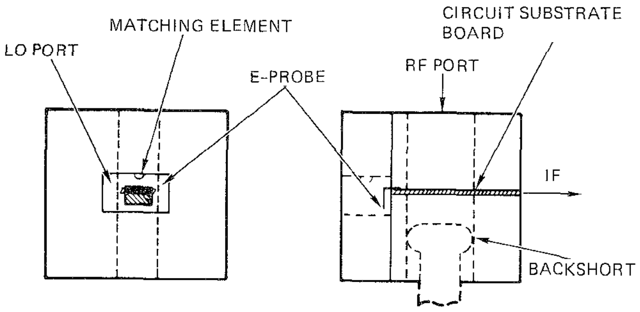

Figure 3. LO Probe Coupling Arrangement of the Mixer

coupler or RF diplexer, and therefore greatly simplifies the hardware design.

MONOLITHIC MIXER FABRICATION

In the fabrication of the monolithic crossbar mixer, an epitaxial layer-structure of n-n^+ grown in a semi-insulating substrate has been used. The typical characteristics of the epitaxial layers are:

Layers	Carrier Concentration (cm^{-3})	Thickness (μm)
n	$1 \sim 2 \times 10^{17}$	$0.1 \sim 0.15$
n^+	$>1 \times 10^{18}$	$2 \sim 3$

The GaAs substrate with the epi-layers serve not only as the dielectric substrate material for the crossbar mixer circuit but also as the starting material for device fabrication. The processing procedures for the fabrication of the monolithic mixers follows in general the conventional integrated circuit techniques. The two Schottky barrier diodes are fabricated in situ on the substrate utilizing the GaAs beam lead diode fabrication techniques developed at Hughes. Figure 4 shows the processing sequence for the fabrication of the monolithic mixer. First, a two layer epitaxial structure of n on n^+ is initially grown on a semi-insulating GaAs substrate by VPE, followed then by a proton bombardment process to convert the n and n^+ layers outside of the diodes to high resistivity material for isolation. In the ohmic contact area, a Se^+ implanted process is used to form a high conductivity channel to the n^+ layer, followed then by depositing and alloying the ohmic contact metallization, AuGe/Ni/Au, in the implanted area. Figure 5 shows the completed monolithic crossbar mixer.

RF PERFORMANCE

The mechanical configuration of the W-band monolithic crossbar mixer with a built-in LO is shown on the right hand side of Figure 6. On the left hand side is the detached LO housing built with the Hughes high power Gunn diode. RF performance of the monolithic crossbar mixer is encouraging. The conversion loss measured over an RF range of 84.6 to 93.1 GHz displays an extremely uniform response as shown in Figure 7. The typical conversion loss is 9 dB with a variation of less than $\pm$0.5 dB over an IF range of 0.5 to 8.5 GHz. For a narrow band operation, a minimum conversion loss of 7.5 dB was measured at an RF of 76 GHz and an IF of 15.5 GHz.

CONCLUSIONS

In conclusion, a W-band fully monolithic crossbar mixer with an extremely uniform response was successfully fabricated on a 4-mil thick semi-insulating GaAs substrate using planar integrated circuit techniques. RF performance of the monolithic mixer is compatible to

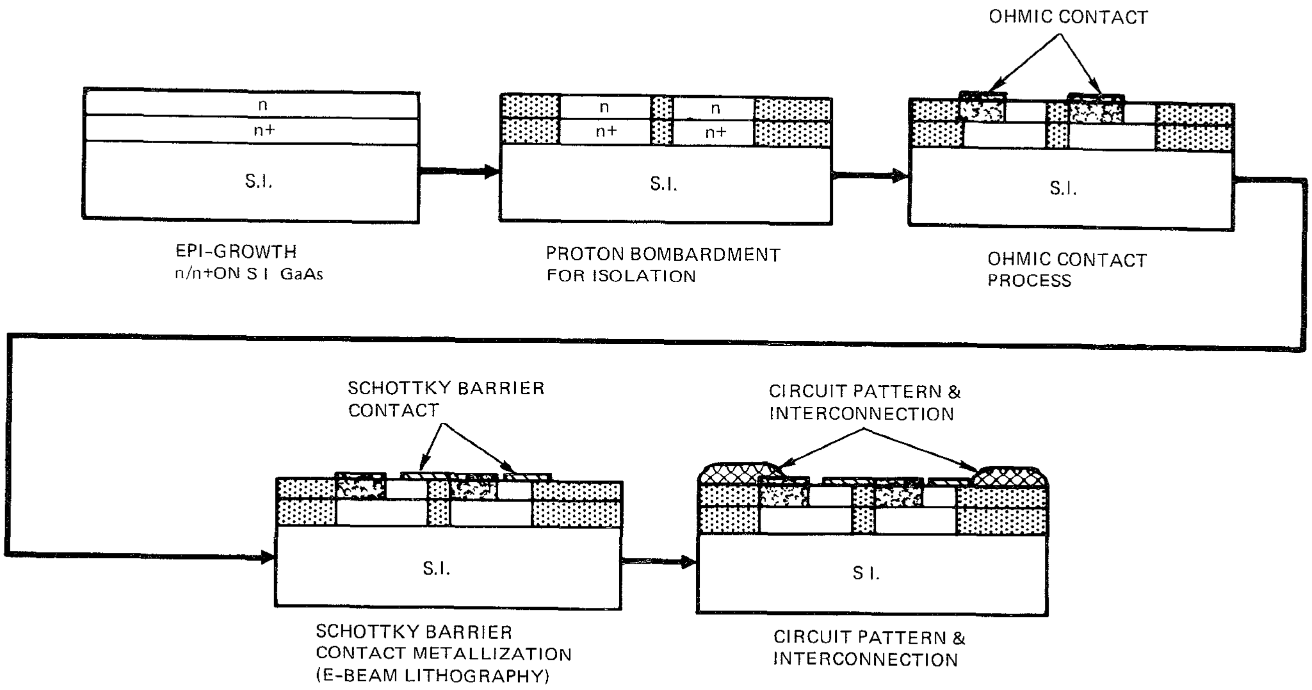

Figure 4. Monolithic Mixer Circuit Processing Sequence

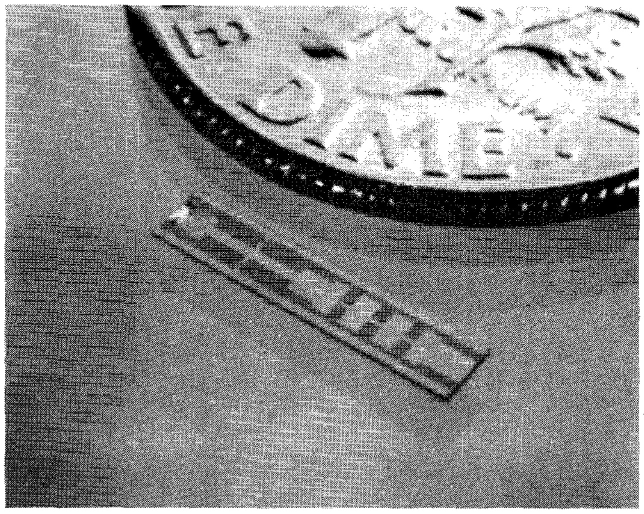

Figure 5. W-band Monolithic Crossbar Mixer

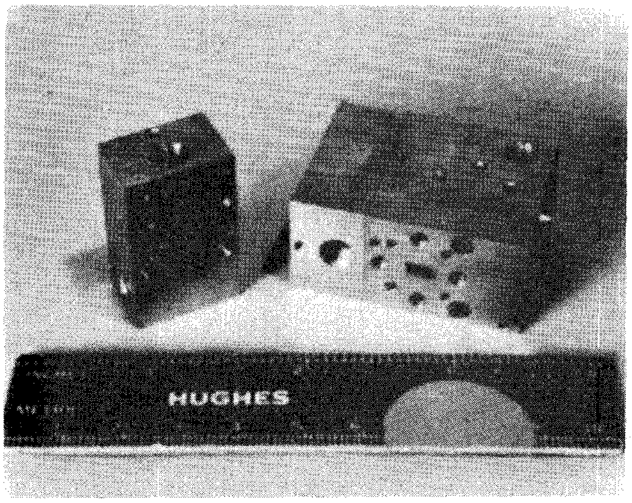

Figure 6. Monolithic Crossbar Mixer/LO Assembly

that of its waveguide counterpart. The success of this development offers potentially low cost batch-processing of millimeter-wave integrated circuits and future integration of millimeter-wave components, all on the same common GaAs substrate.

ACKNOWLEDGEMENTS

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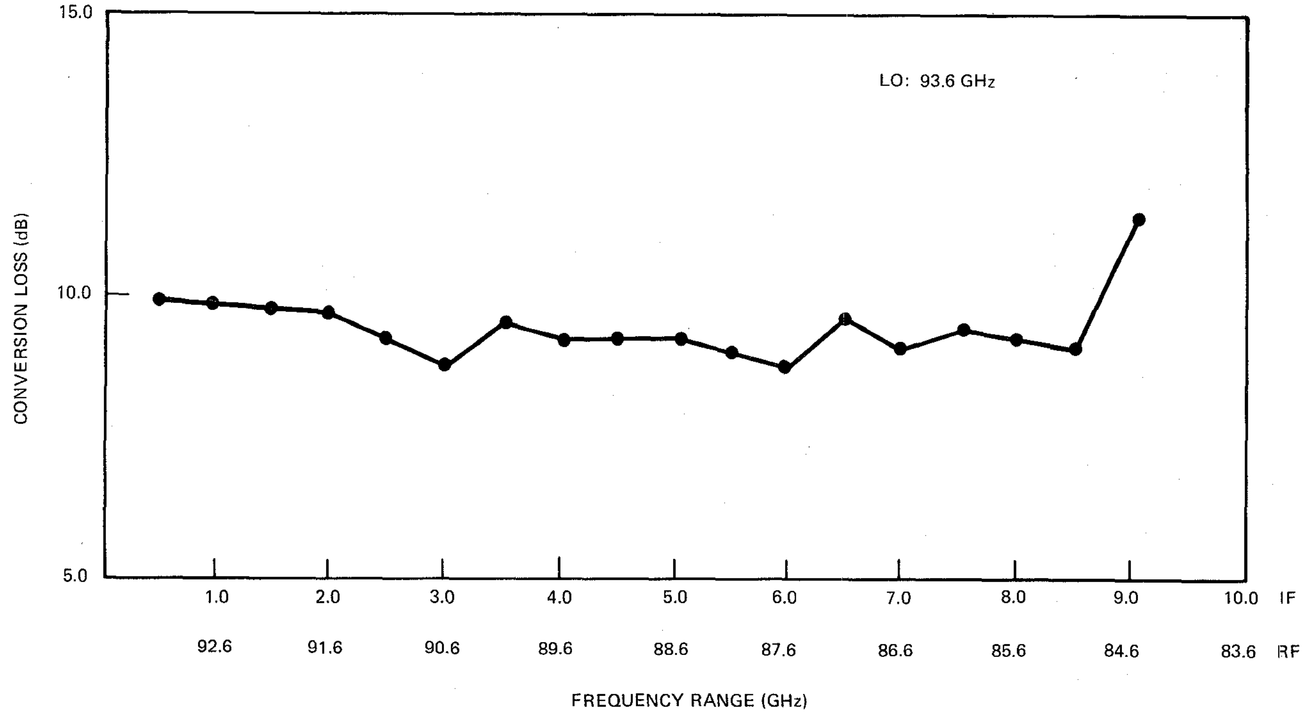

Figure 7. Conversion Loss Versus Frequency of a W-band Monolithic Crossbar Mixer