DESIGN AND PERFORMANCE OF A 94 GHZ HEMT MIXER*

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ABSTRACT

A 94 GHz HEMT mixer was designed and fabricated using 0.1 µm gate HEMT device and hybrid MIC circuit. The mixer downconverts the 92-96 GHz RF to a 8-12 GHz IF. At 4-dBm LO drive, the mixer showed 5.8 dB conversion loss, 12.4 dB noise figure, and -3.2 dBm input power at the 1-dB gain compression point.

INTRODUCTION

A HEMT mixer is very suitable for 94 GHz missile seeker application due to its small size, low LO power requirement, and capability of monolithic integration with a HEMT LNA. MESEFET and HEMT mixers have been demonstrated from X-band to Q-band with conversion gains (1-4). This paper describes the design and measured performance of a single-ended 94 GHz active mixer using 0.1 µm HEMT device and hybrid MIC circuit. At 4-dBm LO drive, the mixer showed a minimum conversion loss of 5.8 dB, 12.4 dB noise figure, and -3.2 dBm input power at 1-dB compression point. This the first reported W-band HEMT mixer and the first W-band active mixer.

DEVICE PERFORMANCE

TRW-fabricated 60x0.1 µm gate AlGaAs/GaAs HEMT device was used in the mixer design. The 0.1 µm gate geometry was patterned by electron beam lithography. Cutoff frequency of the 0.1 µm devices measures typically from 96 to 110 GHz. Figure 1 shows the measured maximum available gain of this type of HEMT device as function of frequency. Maximum frequency of oscillation is from 158 to 170 GHz. Low noise amplifiers using HEMT devices from the same wafer showed 2 dB gain and 5 dB noise figure at 94 GHz. A small signal model of the 60x0.1 µm HEMT device was constructed from on-wafer S-parameter measurement. Typical device parameters are: g_m = 18 mS, input capacitance = 0.025 pF, and input resistance = 20 Ohm. Figure 2 shows the measured drain current vs. gate bias of the 60x0.1 µm HEMT device. In the mixer operation, the HEMT device is biased near the pinch-off to produce a time-varying transconductance that closely resembles the square law waveform. The predicted minimum conversion loss of the mixer is 4.4 dB using the theory developed in (5).

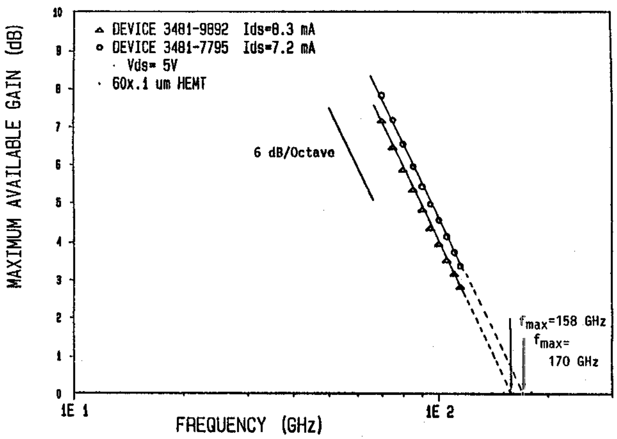

Figure 1. Measured maximum available gain as a function of frequency of two 60x0.1 µm HEMT devices.

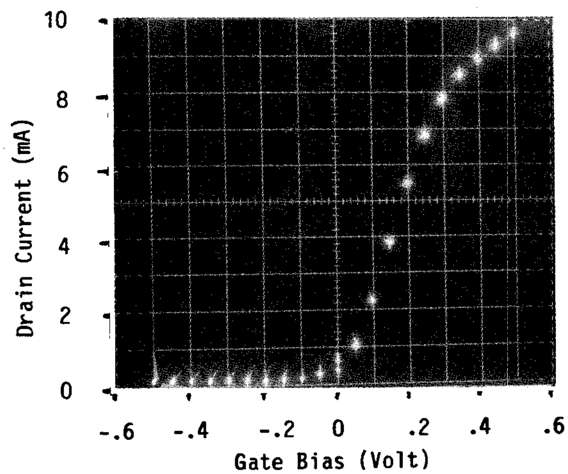

Figure 2. Drain current vs. gate bias voltage of the 60x0.1 µm HEMT device.

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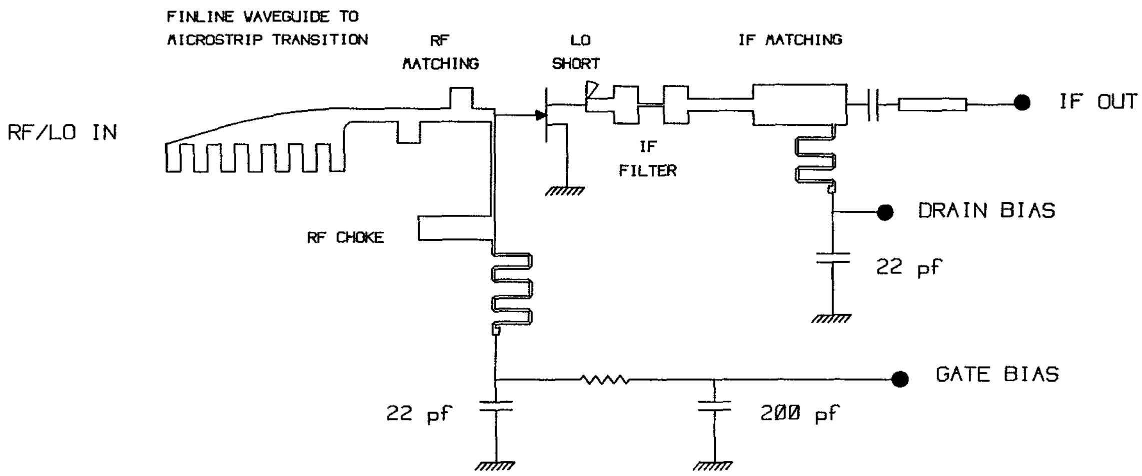

Figure 3. Schematic of the 94 GHz HEMT mixer.

MIXER DESIGN

The mixer design follows the guidelines described in (1,5). Figure 3 shows the schematic of the HEMT mixer. The RF and LO power is coupled to the HEMT device via a finline waveguide-to-microstrip transition. The input circuit is tuned for best RF match. The input bias circuit also provide a short circuit at the IF signal at X-band. An external waveguide coupler was used for the testing purpose. The output circuit consists of a radial stub which presents a short circuit to harmonics at the LO frequency, a low pass filter to reject the RF frequency, and an IF matching circuit. For stability concern, the IF load impedence presented to the device is only limited to 180 Ohm. For minimum size and reasonable microstrip dimension, the W-band circuits and the IF circuit were fabricated separately on 5 mil quartz and 10 mil alumina substrates, respectively. Figure 4 shows a picture of the fabricated mixer.

EXPERIMENTAL RESULTS

The measurement results presented in this paper include the finline transition loss of about 1 dB. Figure 5 shows the measured conversion loss as a function of LO frequency at 94 GHz RF and 4 dBm LO power. A minimum conversion loss of 5.6 dB was obtained at 9 GHz IF. Figure 6 shows the conversion loss and noise figure of the mixer as a function of RF frequency at 4-dBm LO drive. The minimum conversion loss and noise figure is 5.8 dB and 12.4 dB, respectively. This performance compares favorably to a waveguide diode mixer biased at 10 dBm LO drive. At the same LO power, the mixer showed less than 7 dB conversion loss and lower than 14 dB noise figure over a 1.5 GHz bandwidth. Circuit simulation has shown that the mixer bandwidth is mainly limited by the frequency response of the IF matching circuit. Figure 7 shows the mixer conversion loss at 94 GHz as a function of LO power. The mixer conversion loss decreases with increasing LO power and showed a minimum at 4-dBm LO drive. The mixer conversion loss then increases with the LO power due to gain reduction of the HEMT device, whose gate is partially forward biased by the LO. It is worth noting that the mixer conversion loss is only 8 dB

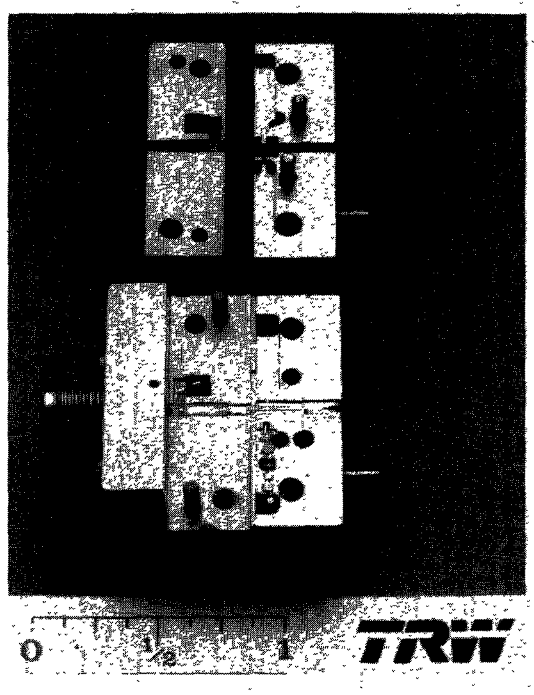

Figure 4. Photograph of the fabricated 94 GHz HEMT mixer.

at 0 dBm LO drive. Figure 8 shows the measured IF output power as a function of RF input power. The input power at 1-dB compression point is about -3.2 dBm at 4 dBm LO drive. This somewhat low input power at 1-dB compression point is also observed in the 44 GHz HEMT mixer (4). For missile seeker application, this is not a severe problem since the RF signal is normally quite low.

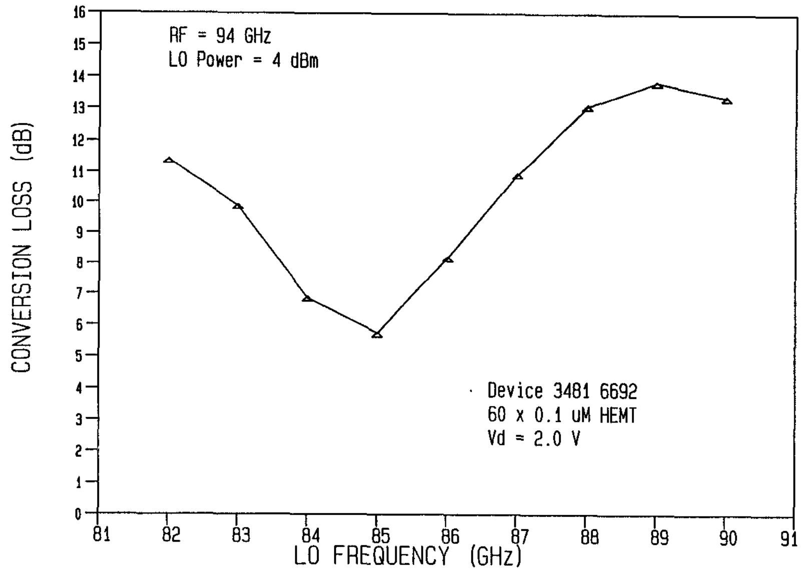

Figure 5. Measured conversion loss as a function of LO frequency of the HEMT mixer. Test fixture loss is included in the data.

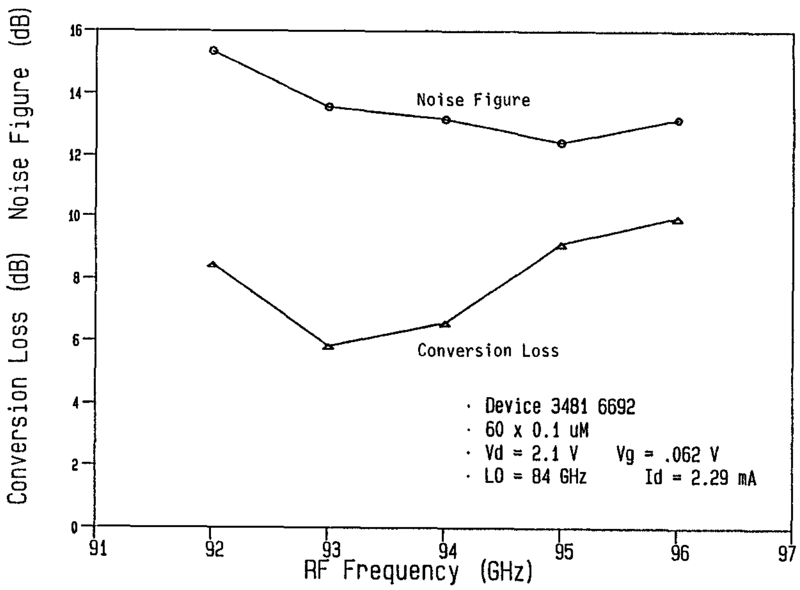

Figure 6. Measured conversion loss and noise figure as a function of RF frequency of the HEMT mixer. Test fixture loss is included in the data.

CONCLUSION

A 94 GHz mixer was designed and tested which demonstrated low conversion loss and noise figure at a very low LO power. This property makes the HEMT mixer very suitable for 94 GHz missile seeker application where available W-band LO power is extremely low. The HEMT mixer can be monolithically integrated with a HEMT LNA to form a low cost, small size and weight, receiver front end for use in the millimeter wave smart munition. The 94 GHz HEMT mixer should also work with similar performance at lower IF frequencies. Work in this direction is underway at TRW and will be reported when results are available.

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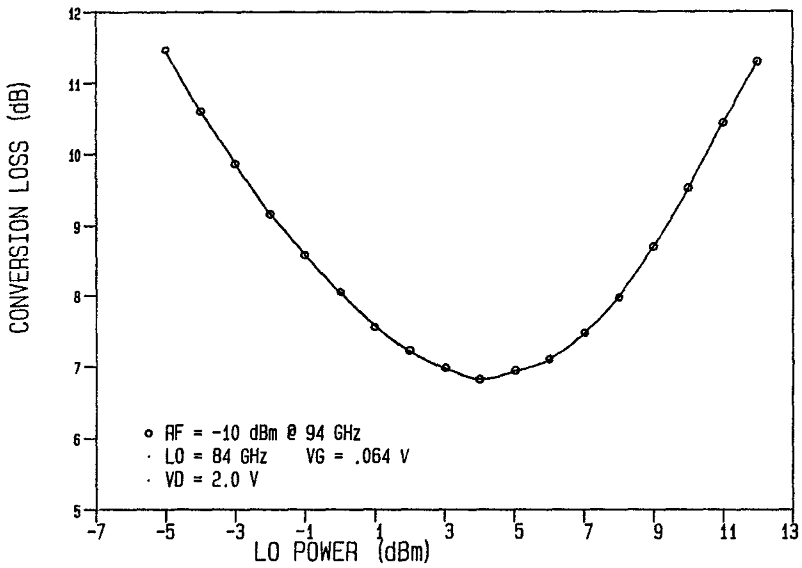

Figure 7. Measured conversion loss as a function of the LO power.

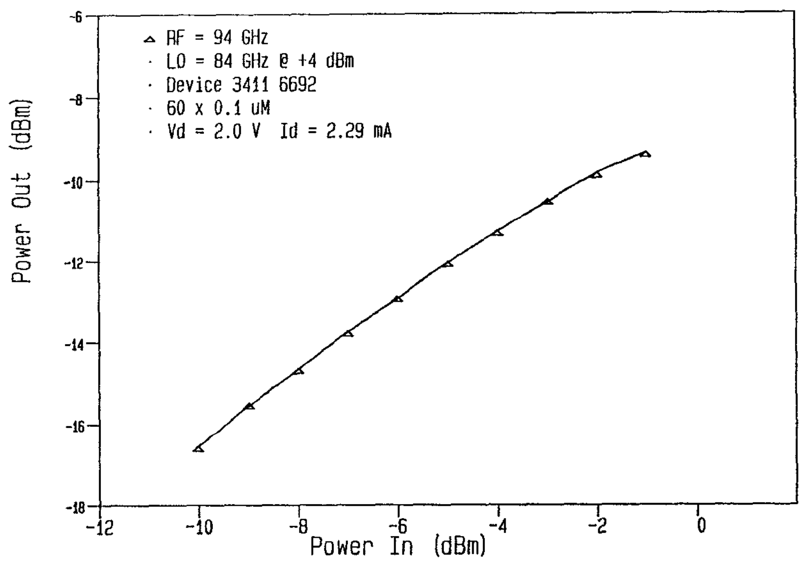

Figure 8. Measured IF ouput power vs. RF input power at 94 GHz .