W-band InP Based HEMT MMIC Low Noise Amplifiers

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This paper presents the designs and measurement results of a three-stage and a four-stage W-band monolithic microwave integrated circuits (MMIC) including a three-stage and a four-stage low noise amplifiers. The MMIC chips are fabricated with a 0.1-μm gate-length InP-based HEMT MMIC technology.

1 Introduction

InP HEMTs have very high gain, low noise figure in millimeter wave frequency range. W-band low noise amplifier is a key component of next generation satellite communication systems, wireless LAN, and radio telescope receivers [1]. Some W-band low noise amplifiers developed on GaAs based HEMT [2]-[4] and InP based HEMT [5]-[7] were reported previously. The InP low noise amplifiers demonstrated better gain and noise figure performances. This paper presents two InP HEMT MMIC low noise amplifiers for W-band radio telescope receiver applications. The measured peak gain of the three-stage amplifier is 14.5 dB at 102 GHz, and the room-temperature noise figure is between 2.9 and 4.5 dB from 90 to 98 GHz. The four-stage amplifier has 20-dB measured gain from 85 to 105 GHz with a 22.5-dB peak gain at 93 GHz.

2 HEMT Device Characteristic and MMIC Technology

The HEMT device used in this design is TRW's 0.1-μm InP based HEMT MMIC process. The unit current gain frequency (f_T) is about 190 GHz, and the maximum oscillation frequency is over 300 GHz for 2-finger 40-μm device under 1-V drain-to-source biased condition. Other passive components include thin-film resistors, MIM capacitors, spiral inductors, and air-bridges. The wafer is thinned to 3-mil for the gold plating of the backside and reactive ion etching via holes are used for dc grounding.

3 Circuit Design

The three-stage and four-stage low noise amplifiers utilize four-finger 40-μm and 30-μm HEMT device, respectively. The small-signal HEMT models were developed by TRW. The matching networks are all realized with the inductive T-transformer using high and low impedance microstrip lines. Radial stubs provide in-band RF short circuit, and the RC networks are utilized in the bias networks for lower frequency bypassing. DC biases are fed by the bypassing networks of shunt short stubs. The passive circuits included the discontinuities of the transmission line and radial stubs were simulated by a full-wave EM simulator (Sonnet software). The whole circuits of the amplifiers were simulated by the circuit simulator (HP/EEsof Libra). Fig. 1 and Fig. 2 show

the schematics of the complete three-stage and four-stage amplifiers, and the layouts are shown in Fig. 3 and Fig. 4. The chip sizes of three-stage and four-stage amplifiers are 2.1 mm x 1.5 mm and 3 mm x 1.5 mm, respectively.

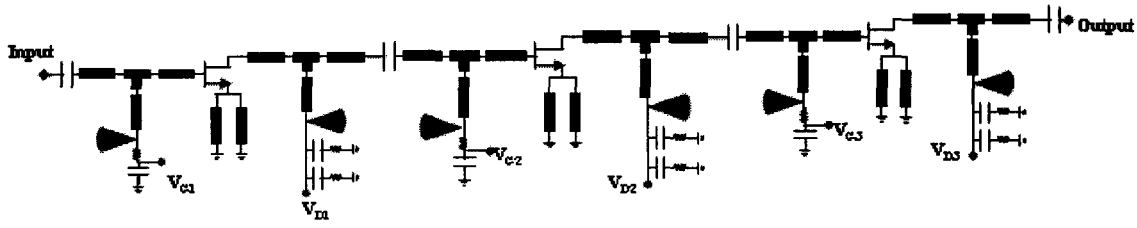

Fig. 1. Schematic of the three-stage low noise amplifier.

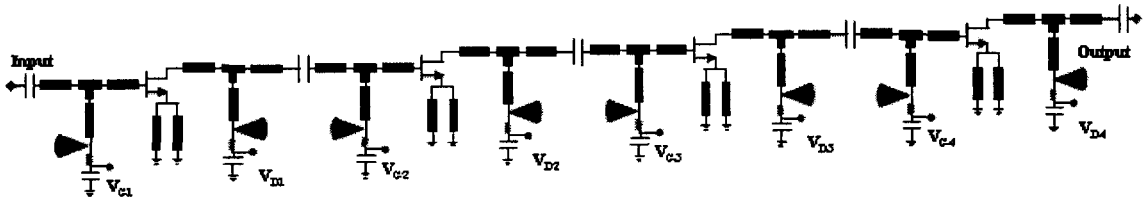

Fig. 2. Schematic of the four-stage low noise amplifier.

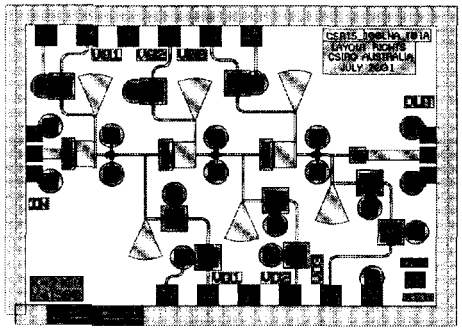

Fig. 3. Layout of the three-stage low noise amplifier (Chip size 2.1 x 1.5 mm^2).

4 Circuit Measurements

The amplifiers were tested via on-wafer probing. The measured return losses and small-signal gain of the three-stage amplifier is shown in Fig. 5. The three-stage amplifier has 14.5-dB peak gain at 102 GHz. At 97 GHz, the input and output return losses are 13 dB and 10.3 dB, respectively. The bias condition of the three-stage amplifier is 0.9 V, 6 mA for each stage. Room-temperature noise figure of this amplifier was also measured via on-wafer probe, the results are shown in Fig. 6. The noise figure is between 2.9 and 4.5 dB from 90 to 98 GHz, and the gain performance is consistent with the S-parameter measurement results in Fig. 5.

Fig. 7 shows the measured return losses and small-signal gain of the four-stage amplifier.

The peak gain of the four-stage amplifier is 22.5 dB at 93 dB, and the small-signal gain is better than 20 dB from 84 to 106 GHz. The DC consumption of the four-stage amplifier is 1 V, 6 mA for each stage.

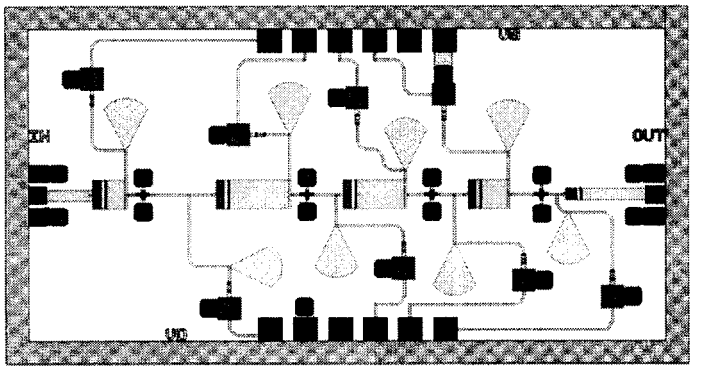

Fig. 4. Layout of the four-stage low noise amplifier (Chip size 3 x 1.5 mm^2).

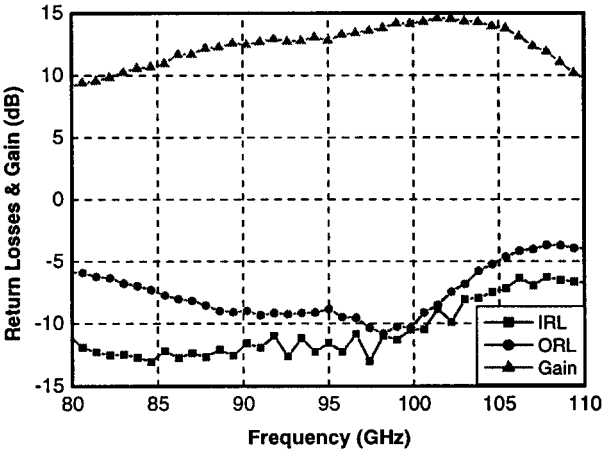

Fig. 5. Measured small-signal gain and return losses of the three-stage low noise amplifier.

5 Summary

A three-stage and a four-stage W-band InP HEMT MMIC low noise amplifiers are designed, fabricated and measured. The measured peak gain of the three-stage amplifier is 14.5 dB at 102 GHz, and the room-temperature noise figure is between 2.9 and 4.5 dB from 90 to 98 GHz. The four-stage amplifier has a 22.5-dB peak gain at 93 GHz.

Acknowledgement

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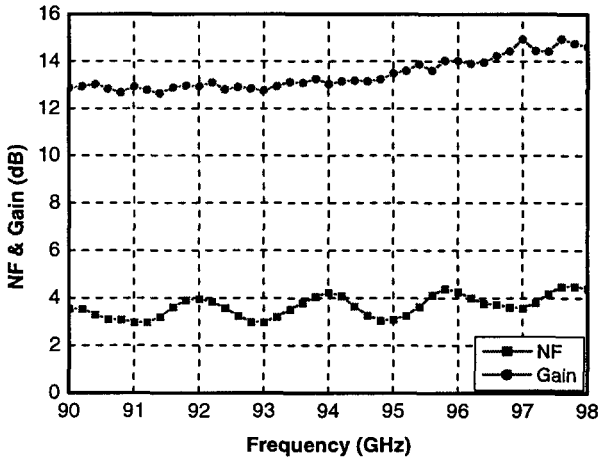

Fig. 6. Measured noise figure and gain of the three-stage low noise amplifier under room temperature.

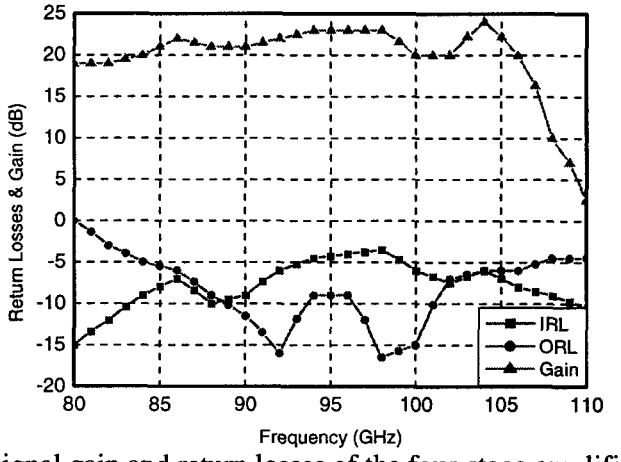

Fig. 7. Measured small-signal gain and return losses of the four-stage amplifier.

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