W-band Monolithic Low Noise Amplifiers for Advanced Microwave Scanning Radiometer

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***Abstract*— Monolithic low noise amplifiers using 0.15-μm AlGaAs/InGaAs/GaAs pseudomorphic HEMTs with a passivation film have been developed at W-band for the Advanced Microwave Scanning Radiometer. A two-stage monolithic amplifier has achieved a noise figure of 3.4 dB with a small signal gain of 8.7 dB at 91 GHz. A six-stage amplifier cascading three two-stage monolithic amplifier chips has achieved a noise figure of 4.2 dB with a small signal gain of 29.7 dB at 91 GHz. Taking into account the minimum noise figure of 2.5 dB with an associated gain of 4.3 dB of 0.15 × 60 μm^2 PHEMTs at 90 GHz, these results demonstrate that a good noise matching has been successfully achieved.**

I. Introduction

ADVANCED microwave scanning radiometer (AMSR) is under development to be on board the ADEOS-II satellite to observe Earth environments including sea surface temperature, water vapor, sea ice distribution, etc. To enhance the resolution of the instrument, an extremely low noise and high gain amplifier module is required. At W-band and higher frequencies, InP based HEMT devices have shown better performance than GaAs based HEMT devices on a discrete device level [1]–[3]. However GaAs MMIC processes provide a superior maturity in comparison with InP MMIC processes. W-band and D-band monolithic low noise amplifiers using GaAs based HEMT devices have demonstrated excellent noise figure and gain performance [4], [5].

The purpose of this letter is to present current results of W-band monolithic low noise amplifiers based on 0.15 μm AlGaAs/InGaAs/GaAs pseudomorphic HEMT's with a passivation film developed for use in the spaceborne radiometer, AMSR. To achieve low noise and high gain in a two-stage monolithic amplifier, a reactive matching method is employed in the design of input noise matching and output gain matching circuits. The circuits are comprised of double open-circuited stubs based on the results of on-carrier S-parameter measurements up to 50 GHz and noise parameter measurements at 60 and 90 GHz. The two-stage monolithic amplifier has achieved a noise figure of 3.4 dB with a small signal gain of 8.7 dB at 91 GHz. This result is comparable with the best noise figure data reported in [4], [5].

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II. Device Performance

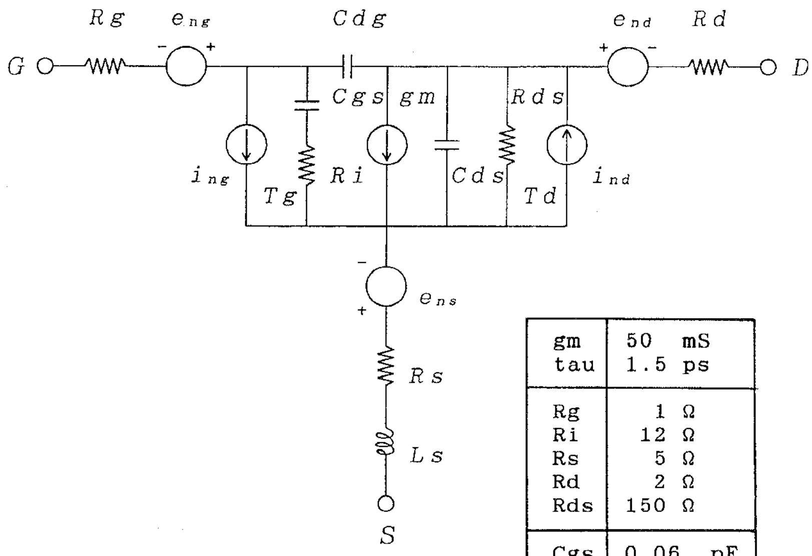
AlGaAs/InGaAs/GaAs pseudomorphic HEMT's [6], [7] with a gate length of 0.15 μm and a gate periphery of 60 μm were mounted on a carrier-type fixture and evaluated by I-V measurements, S-parameters up to 50 GHz, and noise parameters at 60 and 90 GHz. The small signal equivalent circuit and noise model parameters [8] were obtained from fitting measured S-parameters and noise parameters, which are shown in Fig. 1. The 0.15 × 60 μm^2 PHEMT showed a DC transconductance (gm) of around 600 mS/mm, an f_T of 133 GHz, and an $f_{\max}$ of 186 GHz for $V_d = 2$ V and $V_g = 0$ V. The measured minimum noise figure was 2.5 dB with an associated gain of 4.3 dB at 90 GHz. The calculated noise parameters were $\Gamma_{\rm opt} = 0.42\angle 140°$, $R_n = 10\ \Omega$, $T_g = 105$ K, and $T_d = 1175$ K at 90 GHz. The maximum available gain was 5.6 dB at 90 GHz.

III. Circuit Design

A schematic diagram of the two-stage monolithic amplifier is shown in Fig. 2. To achieve low noise and high gain of the amplifier, a reactive matching method was employed in the design of input noise matching and output gain matching circuits comprised of double open-circuited stubs, based on the results of S-parameter and noise parameter measurements. In addition to these double open-circuited stubs, the amplifier employs edge coupled lines for DC block, radial stubs for RF bypass, and resistors in the gate and drain bias circuits for high stability at low frequencies. Parameters for the circuit shown in Fig. 2 were optimized to achieve a small signal gain of greater than 8 dB and a noise figure of less than 4 dB for 86 to 92 GHz by using the noise model shown in Fig. 1.

IV. Fabrication and Performance

A photograph of the two-stage monolithic amplifier chip with the chip dimensions of 1.2 × 2.6 × 0.1 mm^3 is shown in Fig. 3. DC and RF characteristics were evaluated by using the wafer prober [9]. The measured noise figure of 3.4 dB with a small signal gain of 8.7 dB was obtained at 91 GHz, as shown in Fig. 4. Bias conditions are $V_d = 2$ V and $I_d = 6$ mA for each stage. The calculated gain and noise figure are also plotted in Fig. 4. A good agreement between the measured



gm	50 mS
tau	1.5 ps
Rg	1 Ω
Ri	12 Ω
Rs	5 Ω
Rd	2 Ω
Rds	150 Ω
Cgs	0.06 pF
Cdg	0.009 pF
Cds	0.04 pF
Ls	0.008 nH

Fig. 1. Noise model of 0.15×60 μm^2 AlGaAs/InGaAs/GaAs pseudomorphic HEMT's.

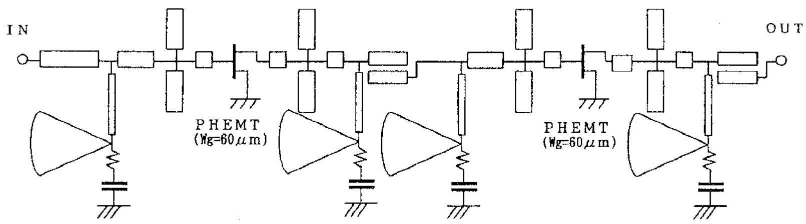


Fig. 2. Schematic diagram of the two-stage monolithic amplifier.

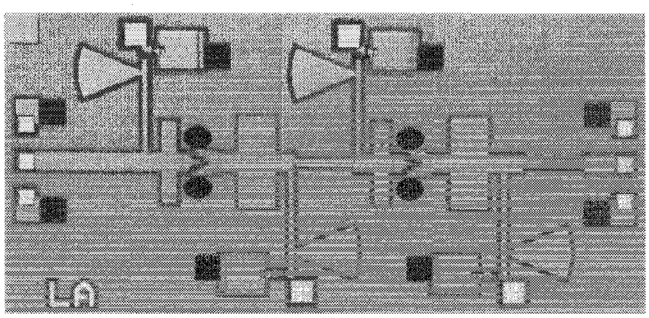


Fig. 3. Photograph of the two-stage monolithic amplifier chip.

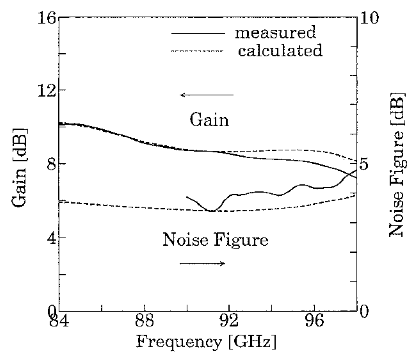


Fig. 4. Measured and calculated noise figure and gain of the two-stage monolithic amplifier.

and calculated results has been achieved for both gain and noise figure. Taking into account the minimum noise figure of 2.5 dB with an associated gain of 4.3 dB at 90 GHz of 0.15×60 μm^2 PHEMT's, a good noise matching has been accomplished. The measured 1 dB compressed power was +9 dBm at 94 GHz for $V_d = 2$ V and $I_d = 12$ mA/stage.

Three two-stage monolithic amplifier chips were cascaded and mounted on a carrier-type fixture having waveguide-to-microstrip transition. The measured noise figure and gain of the six-stage amplifier are plotted in Fig. 5, which shows a noise figure of 4.2 dB with a small signal gain of 29.7 dB at 91 GHz. The 1st and 2nd stage amplifiers are biased for low noise with $V_d = 2$ V and $I_d = 6$ mA for each stage. The 3rd to final stage amplifiers are biased for high gain with $V_d = 2$ V and $I_d = 12$ mA for each stage.

V. Conclusion

We have demonstrated a W-band monolithic two-stage low noise amplifier having an excellent noise figure performance comparable with the best data ever reported by a monolithic amplifier using GaAs-based HEMT devices. At 91 GHz, a noise figure of 3.4 dB with a small signal gain of 8.7 dB

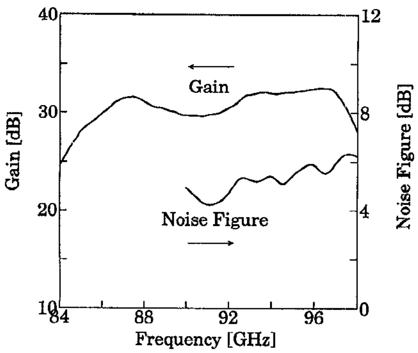


Fig. 5. Measured noise figure and gain of the six-stage amplifier.

has been achieved. In addition a six-stage amplifier cascading three two-stage monolithic amplifier chips has been presented, which shows a noise figure of 4.2 dB with a small signal gain of 29.7 dB at 91 GHz. It can be expected that these results significantly improve the radiometric performance of the Advanced Microwave Scanning Radiometer to be on board the ADEOS-II satellite.

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