A *V*-band, High Gain, Low Noise, Monolithic PHEMT Amplifier Mounted on a Small Hermetically Sealed Metal Package

Yasushi Itoh, *Senior Member, IEEE*, Yoshie Horiie, Kazuhiko Nakahara, Naohito Yoshida, Takayuki Katoh, and Tadashi Takagi, *Member, IEEE*

Abstract—*V*-band, high gain, low noise, monolithic amplifiers based on 0.15-μm AlGaAs/InGaAs/GaAs pseudomorphic HEMT's have been developed. The four-stage amplifier has been assembled on a small hermetically sealed metal package and has achieved a noise figure of 3 dB with a small signal gain of 42.2 dB at 51 GHz. The overall amplifier measured 14.2 × 20.0 × 2.3 mm^3. The two-stage amplifier has been mounted on a carrier-type fixture and has achieved a noise figure of 2.5 dB with a small signal gain of 20.4 dB at 51.5 GHz. These results represent the best noise figure and the highest gain ever achieved by a monolithic amplifier using GaAs– or InP–based HEMT devices at these frequencies.

I. Introduction

V-BAND, high gain, low noise, monolithic amplifiers are a key component in receivers of imaging and radiometric sensors, a collision avoidance radar, and a wireless LAN to improve the receiver noise figure and resolution of sensors. Multi-stage high gain amplifiers consisting of waveguide-to-microstrip transition and carrier-type amplifier modules have been reported [1], [2]. These amplifiers, however, do not have a hermetically sealed structure. To address this problem, we developed a small hermetically sealed metal package. At *V*-band and higher frequencies, InP based HEMT devices have shown better performance than GaAs based HEMT devices on a discrete device level [3]–[6]. However, GaAs MMIC process provides a superior maturity in comparison with InP MMIC process. Therefore we employed GaAs based HEMT devices instead of InP based HEMT devices.

The purpose of this work was to present *V*-band, high gain, low noise, monolithic amplifiers using 0.15-μm AlGaAs/InGaAs/GaAs pseudomorphic HEMT's mounted on a small hermetically sealed metal package. In the design of input and output matching circuits, low impedance quarter-wavelength impedance transformers instead of open-circuited stubs were employed to achieve low noise and high gain because of low loss characteristics of low impedance transformers and capacitive impedances of the HEMT at *V*-band. The results reported in this letter are the best noise figure and the highest gain ever achieved by a monolithic amplifier using GaAs or InP based HEMT devices.

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Y. Itoh, K. Nakahara, and T. Takagi are with Electro-Optics & Microwave Systems Laboratory, Mitsubishi Electric Corporation, Kanagawa, 247 Japan.

Y. Horiie is with Communication Equipment Works, Mitsubishi Electric Corporation, Hyogo, 661 Japan.

N. Yoshida and T. Katoh are with Optoelectronic and Microwave Devices Laboratory, Mitsubishi Electric Corporation, Hyogo, 664 Japan.

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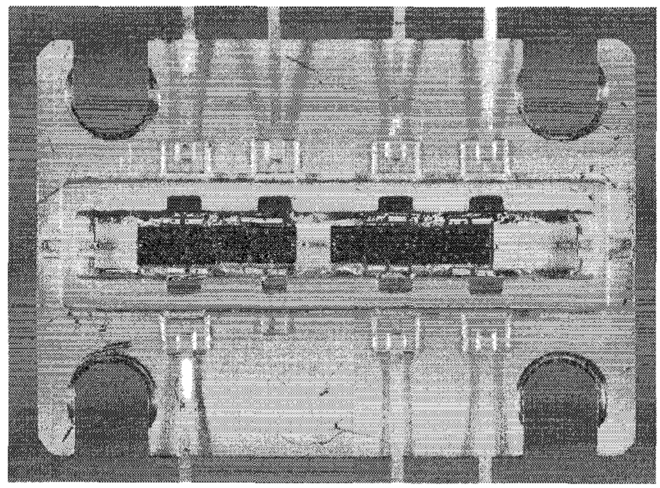

Fig. 1. Photograph of the four-stage amplifier.

II. Circuit Design

A photograph of the four-stage amplifier is shown in Fig. 1. It consists of four single-stage MMIC amplifier chips, three through lines, eight bypass capacitors, and a hermetically sealed metal package. The overall amplifier measured 14.2 × 20.0 × 2.3 mm^3. Fig. 2 shows a photograph of the single-stage MMIC amplifier chip with the chip dimensions of 1.2 × 2.6 × 0.1 mm^3. The amplifier utilizes a 0.15 × 60 μm^2 AlGaAs/InGaAs/GaAs pseudomorphic HEMT [7], [8] having a dc transconductance of 600 mS/mm, a $V_{\rm th}$ of −0.5 V, an f_t of 133 GHz, and an $f_{\max}$ of 186 GHz for V_d =2 V. To achieve high gain and good return loss of the amplifier, a reactive matching method is incorporated into the design of input and output matching circuits comprised of low impedance quarter-wavelength impedance transformers instead of open-circuited stubs because of low loss characteristics of low impedance transformers and capacitive impedances of the HEMT at *V*-band. In addition to these transformers, the amplifier employs an edge coupled line for DC block, radial stubs for RF bypass, and resistors in bias circuits for high stability at low frequencies.

These MMIC chips are assembled on a small hermetically sealed metal package with inner dimensions of 2.3 × 17.2 × 1.5 mm^3. To avoid oscillations related to waveguide moding, the

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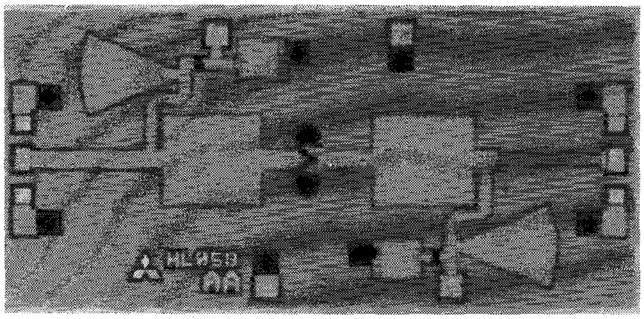

Fig. 2. Photograph of the single-stage MMIC amplifier chip.

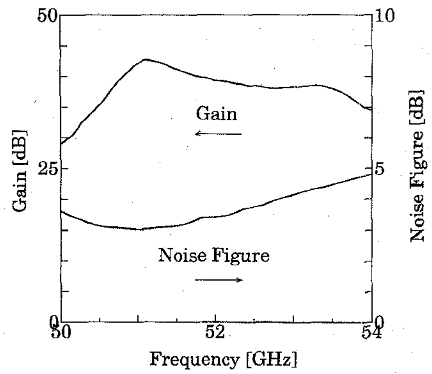

Fig. 3. Measured noise figure and gain of the four-stage amplifier.

width of inner side of package was designed so that the cutoff frequency becomes higher than 60 GHz. Input and output terminals of the package employ a ceramic substrate having a triplate structure to achieve high hermetic sealing. The width of this substrate was also designed so that the cutoff frequency becomes higher than 60 GHz. The measured insertion loss and return loss of this triplate line are approximately 0.4 dB and better than -12 dB from 50 to 60 GHz. Bypass capacitors having a capacitance of around 100 pF are integrated in both gate and drain bias circuits to suppress the low-frequency oscillation.

III. Performance

DC and RF characteristics of each single-stage MMIC amplifier were evaluated by using a wafer prober before assembling to achieve a high yield of the multi-stage amplifier. The measured noise figure and gain of the four-stage amplifier are plotted in Fig. 3, which demonstrate a noise figure of 3 dB and a small signal gain of 42.2 dB at 51 GHz. The data were taken at a drain voltage of 2 V and a drain current of 6 mA for the 1st and 2nd stage amplifiers to achieve low noise figure. The 3rd and final stage amplifiers are biased for high gain with a drain voltage of 2 V and a drain current of 12 mA. The data shown in Fig. 3 include an insertion loss of the package and three through lines. This amplifier was finally stable at all bias conditions without using millimeter-wave absorbers within the package. The measured 1 dB compressed power was +7.7 dBm at 51 GHz.

Two single-stage MMIC amplifier chips were cascaded and mounted on a carrier-type fixture. The measured noise figure, gain, return loss of this two-stage amplifier are shown in Fig. 4,

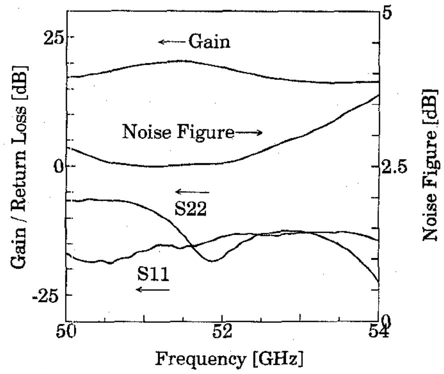

Fig. 4. Measured noise figure, gain and return loss of the two-stage amplifier.

which demonstrate a noise figure of 2.5 dB, a small signal gain of 20.4 dB, an input return loss of -15.5 dB, and an output return loss of -13.4 dB at 51.5 GHz. Both the 1st and 2nd stage amplifiers are biased for low noise figure with a drain voltage of 2 V and a drain current of 6 mA. The noise figure measurement set-up is based on a WR-15 waveguide system having waveguide-to-coplanar or waveguide-to-coaxial transition.

IV. Conclusion

V-band, high gain, low noise, monolithic amplifiers based on 0.15-μm AlGaAs/InGaAs/GaAs pseudomorphic HEMT's has been developed. The four-stage amplifier has been assembled on a small hermetically sealed metal package and has achieved a noise figure of 3 dB with a small signal gain of 42.2 dB at 51 GHz. This result demonstrates that this amplifier design would be a good candidate for achieving highly stable, high gain, low noise, monolithic amplifier modules having a hermetically sealed structure at millimeter-wave frequencies.

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