A High Efficiency *V*-Band Monolithic HEMT Power Amplifier

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***Abstract*—We report the performance of a monolithic V-band power amplifier using 0.15-μm double heterostructure pseudomorphic InGaAs/AlGaAs/GaAs HEMT's. The amplifier using a 400-μm device driving a 2 × 400-μm device. It has demonstrated output power of 313 mW (0.39 W/mm) with 8.95 dB power gain and 19.9% PAE at 59.5 GHz. These data represent the highest reported combination of output power, power gain, and power-added efficiency reported for a *V*-band monolithic power amplifier.**

I. Introduction

THERE is a considerable need and interest for a monolithic power amplifier operating at *V*-band for cross-links and covert communication applications. Recently, we have reported circuit results of 25.68 dBm (370 mW) and 11% power-added-efficiency at 60 GHz utilizing 0.15-μm passivated T-gate pseudomorphic HEMT fabrication process [1] and 26.83 dBm and 13.9% power-added efficiency from a unpassivated process [2].

In this letter, we are reporting the 60-GHz power performance of an improved monolithic power amplifier, which represents the best combination of output power, power gain, and power-added efficiency reported for a monolithic circuit. The improvement is achieved by utilizing a 400-μm prematched structure that has shown superior performance.

II. PM InGaAs HEMT

The PM InGaAs HEMT device employ a double heterostructure layer design and is discussed in an earlier paper [3]. The devices exhibit a maximum transconductance greater than 500 mS/mm and a maximum current density greater than 600 mA/mm. The gate-to-drain breakdown voltage defined at 1 mA/mm is typically greater than 10 V. The devices also demonstrate very low output conductance of less than 25 mS/mm and excellent pinchoff characteristics . The typical cutoff frequency is 90 GHz and maximum oscillation frequency of 200 GHz for a 80-μm device.

III. Amplifier Design

The monolithic *V*-band power amplifier design is based on a 4-mil-thick GaAs substrate. It consists of a 4-finger 400-μm driver stage driving a 4-finger 2 × 400-μm output amplifier stage. A 400-μm prematched device is the basis

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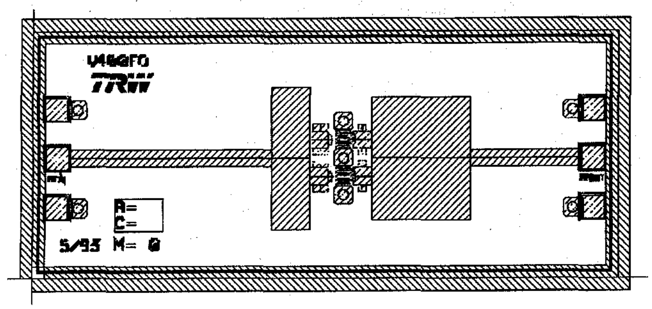

Fig. 1. Photograph of the *V*-band 400-μm prematched device.

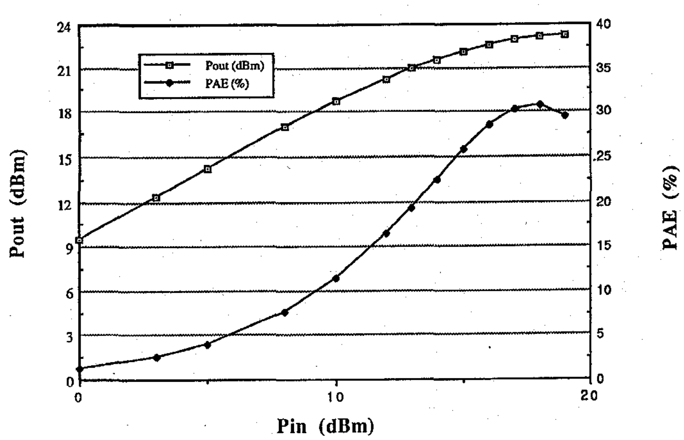

Fig. 2. Output power for the 400-μm prematched device.

of both the driver and the output stage. The prematches microstrip impedance transformers match the input and output impedance, respectively, from 3 ohms and 30 ohms to 50 ohms. Fig. 1 shows a layout of the 400-μm prematched device. Fig. 2 shows its measured performance with the chip mounted in a test fixture. The saturated output power is 23.2 dBm (520 mW/mm) with 30% power-added efficiency using Vds = 5.0 V and Ids = 115 ma.

The two-stage amplifier was constructed by using a 400-μm prematched device as the driver stage and two 400-μm prematched devices in a balanced lange coupler configuration for the output stage. The MMIC lange couplers used have .25dB loss @ 60 GHz. A photograph of the fabricated chip is shown in Fig. 3. The chip measured 4.1 mm × 2.6 mm. The chip accommodates 200-μm pitch GSG connecting pads to allow on-wafer test. Quarter-wavelength lines are added for

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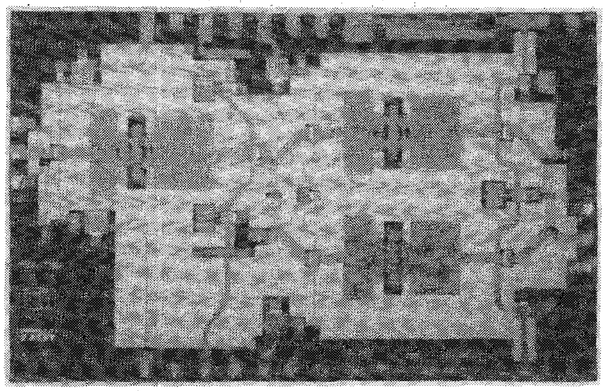

Fig. 3. Photograph of the V-band monolithic power amplifier.

biasing. To ease integration of the amplifier into a microwave assembly, the chip has been designed to bias from either the top or the bottom side of the chip. The bias lines also provide a RC shunt stabilization network to increase out of band circuit stability and allow stable on-wafer circuit tests.

IV. Circuit Performance

On-wafer small-signal S-parameters were measured for this circuit. Fig. 4 shows the measured gain performance from 58 to 62 GHz. The gain at 60 GHz is 13.8 dB. Input and output return losses are 5 dB and 13 dB, respectively. A second iteration design is being processed with improvements in the input return loss. For output power performance, the chip was mounted in a V-band waveguide test fixture. Finline waveguide-to-microstrip transitions fabricated on quartz substrates are used and each transition has loss of 0.5 dB at 60 GHz. Fig. 5 shows measured output power versus input power performance at 59.5 GHz with Vds = 5.0 V and Ids = 313 mA . The data presented here has been corrected for the transition loss. At an input power of 16 dBm, an output power of 24.95 dBm (313 mW) was measured. The corresponding power-added efficiency is 19.9%. At 61.5 GHz, the measured output power is 24.42 dBm (277 mW) with input power of 16 dBm. The corresponding power-added efficiency is 17.6%. To our knowledge, this is the highest efficiency performance ever reported for a V-band monolithic PA with this level of output power and gain.

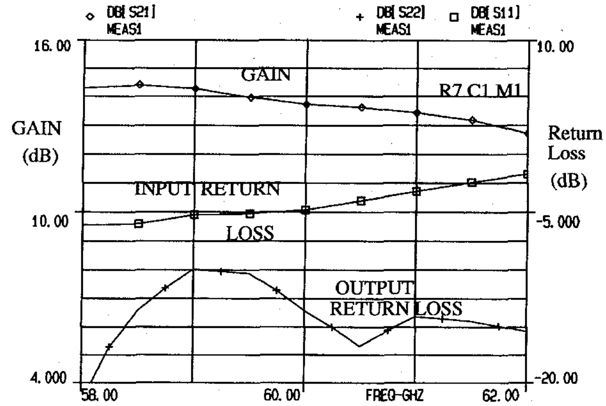

Fig. 4. V-band PA on-wafer measured S-parameters.

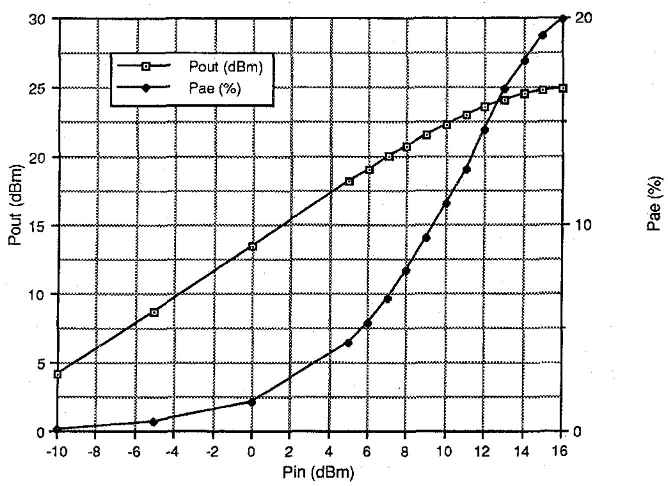

Fig. 5. V-band PA measured Pout versus Pin at 59.5 GHz.

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