An 800-W AlGaN/GaN HEMT for S-band High-Power Application

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Abstract

We have developed an 800-W AlGaN/GaN HEMT operating at S-band. The AlGaN/GaN HEMT showed excellent performance, which is output power of over 800 W, high linear gain of 14.0 dB and high efficiency of 50% over the wide frequency range of 2.9-3.3 GHz, operating at 65-V drain bias voltage under pulsed conditions, at a duty of 10% and pulse width of 200 µs. With 70-V drain bias operation, the peak power reached 912 W with 56.4 % drain efficiency, at 2.9 GHz. To the best of our knowledge, this is the highest power ever reported for S-band transistors.

INTRODUCTION

AlGaN/GaN HEMTs have excellent capabilities such as high power, high efficiency and high gain with high voltage operation due to their excellent material properties. Especially their high power is suitable for high-power radar application such as air traffic control or surveillance. In the previous paper, we have reported a 500-W AlGaN/GaN HEMT power amplifier at 1.5 GHz and demonstrated high power performance at L-band.[1] At S-band, an internally-matched 550-W GaN HEMT at 3.45 GHz with a very short pulse of 2 µs at a duty of 2 % has been reported. [2]

In this paper, we report our latest result, an 800-W AlGaN/GaN HEMT with the operating frequency in S-band. The device shows output power of over 800 W and a high linear gain of 14.0 dB over the wide frequency range of 2.9-3.3 GHz, operating at 65-V drain bias voltage under pulsed conditions, at a duty of 10% and pulse width of 200 µs.

Figure 1 shows the output power of the AlGaN/GaN HEMT devices that have been reported until now. To the best of our knowledge, this is the highest power ever reported for S-band transistors.

DEVICE FABRICATION

The AlGaN/GaN HEMT chip structure is the same as one used in Eudyna standard GaN HEMT products, and was fabricated with epitaxial layers grown on semi-insulating SiC substrates. Details of the device structure and fabrication process were previously reported. [3]

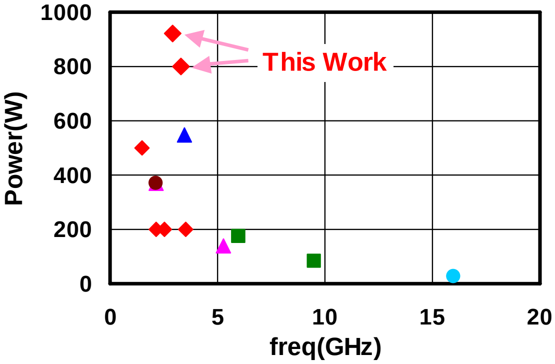

Figure 1. Reported Output Power of the GaN HEMT devices.

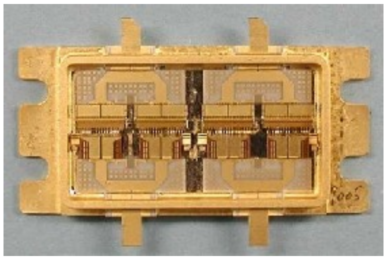

Figure 2. Top View of S-band 800-W AlGaN/GaN HEMT.

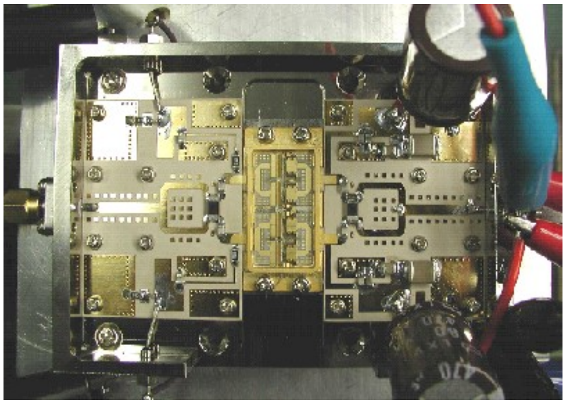

Figure 3. S-band 800-W AlGaN/GaN HEMT and test fixture.

Figure 2 shows the top view of the developed AlGaN/GaN HEMT. The package size is 36.4 mm x 17.4 mm. The device consists of four of the AlGaN/GaN chip, which has a gate width of 36 mm with a unit gate width of 375 µm.

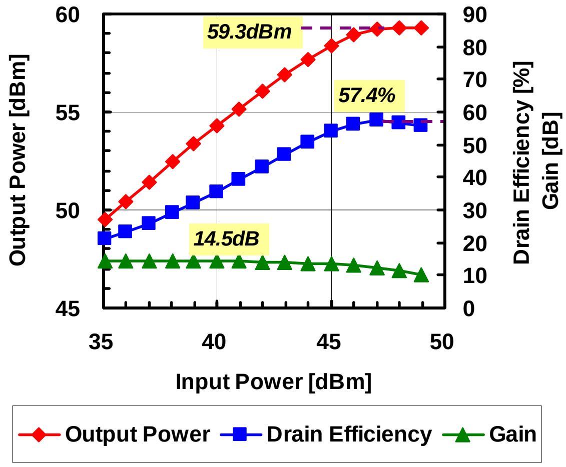

Figure 4. Pulsed Power Performance of 800-W AlGaN/GaN HEMT. V_{DS} = 65 V, I_{DS}(dc) = 2.0 A, Pulse Width = 200 µs, Duty = 10%

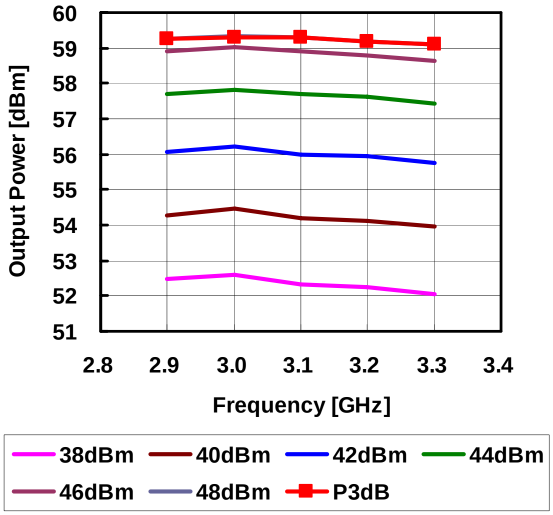

Figure 5. Frequency Response of 800-W AlGaN/GaN HEMT. V_{DS} = 65 V, I_{DS}(dc) = 2.0 A, Pulse Width = 200 µs, Duty = 10%

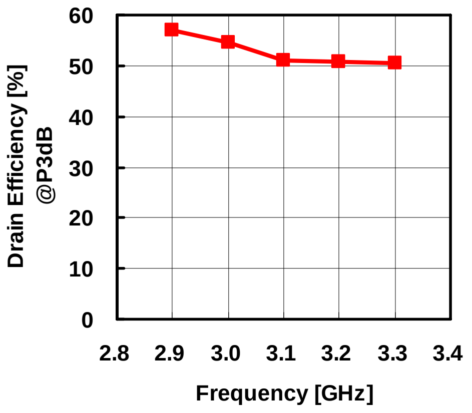

Figure 6. Frequency Response of Drain Efficiency at P3dB. V_{DS} = 65 V, I_{DS}(dc) = 2.0 A, Pulse Width = 200 µs, Duty = 10%

RF PERFORMANCE

We have evaluated pulsed RF performance with the test fixture shown in Figure 3.

Figure 4 shows the RF performance under pulsed conditions at a duty of 10% and pulse width of 200 µs.

The pulsed gate bias is synchronized with the input RF signal. The measured frequency was 2.9 GHz. The drain bias voltage and quiescent drain current are 65 V and 2.0 A (near Class-B operation), respectively. As shown in Figure 4, we could obtain high saturated output power of 840 W and associated drain efficiency of 57% with linear gain of 14.5 dB. Figure 5 shows the frequency response of output power at 2.9 GHz to 3.3 GHz. The device showed excellent broadband capability, with gain flatness of lower than 0.5 dB over 400 MHz bandwidth. Figure 6 shows the frequency response of drain efficiency. Drain efficiency of 50 % was achieved over the frequency band.

Figure 7 shows the drain bias voltage dependence of output power and drain efficiency at 2.9 GHz. At the drain voltage of 70 V, we could obtain 912 W of output power and 56.4% drain efficiency.

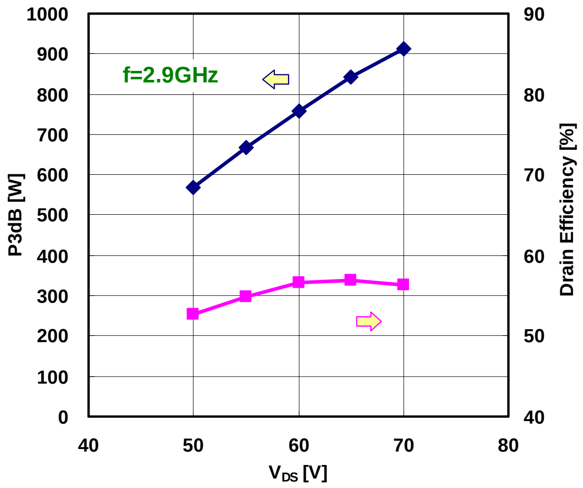

Figure 7. Drain Bias Voltage Dependence I_{DS}(dc) = 2.0 A, Pulse Width = 200 µs, Duty = 10%

Pulsed performance is one of key factors for radar application. We have evaluated pulse droop performance of the device. Figure 8 and 9 show the power droop and phase droop for a 200 µs pulse. Power droop and phase droop at an output power of 59.0 dBm are 0.31 dB and 3.9 deg, respectively.

These results indicate that the developed AlGaN/GaN HEMT is suitable for the S-band high power radar application.

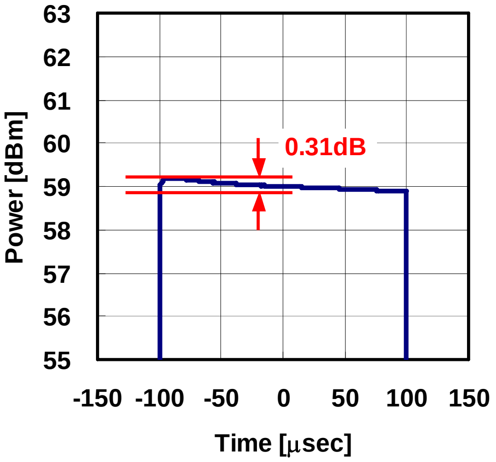

Figure 8. Power Droop for a 200 μs Pulse at an output power of 59.0 dBm. Frequency = 2.9 GHz, V_{DS} = 65 V, I_{DS}(dc) = 2.0 A

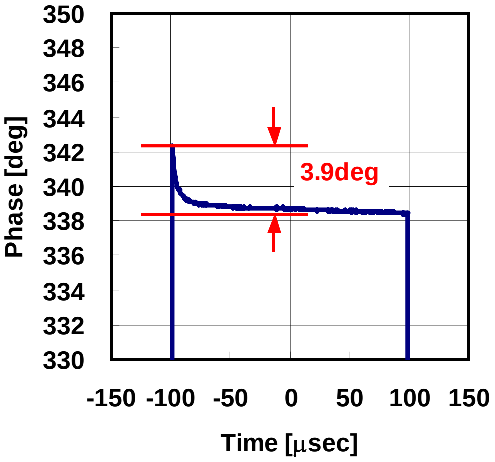

Figure 9. Phase Droop for a 200 μs Pulse at an output power of 59.0 dBm. Frequency = 2.9 GHz, V_{DS} = 65 V, I_{DS}(dc) = 2.0 A

THERMAL ANALYSIS AT PULSED OPERATING CONDITION

To predict the practical lifetime at a high power pulsed operating condition, we measured actual chip temperature using an infrared thermometer. At the same time, we performed thermal analysis considering transient thermal response. At the pulsed operating condition, the channel temperature is the function of the pulse width and the duty cycle, since it is decided by the balance of heat generation at on-power and dissipation at off-power state. To simulate this behavior, we used transient thermal resistance measured by the Delta-V_{gs} method.

Figure 10 shows the infrared thermal images for the various pulse conditions at the case temperature of 40ºC. Figure 11 shows the simulation result of the peak channel temperature with the corresponding pulse conditions. The simulation results showed good agreement with the infrared thermal images. As shown in the figures, the peak channel temperature is around 10ºC at the condition of the Pulse width of 500 μs with 10% duty, and 110ºC at pulse width of 200 μs with 20% duty, respectively. These results show the developed AlGaN/GaN HEMT has sufficient thermal handling capability for actual S-band high power radar application.

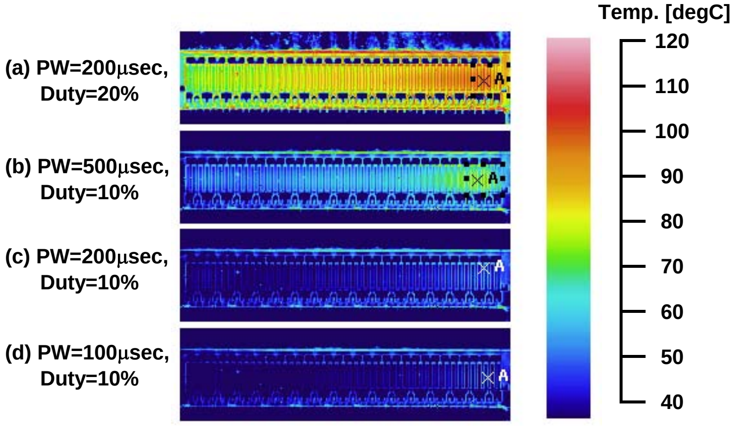

Figure 10. IR Photograph of AlGaN/GaN HEMT chip at various Pulsed Operating Conditions. Frequency = 2.9 GHz, V_{DS} = 65 V, Pout = 59 dBm

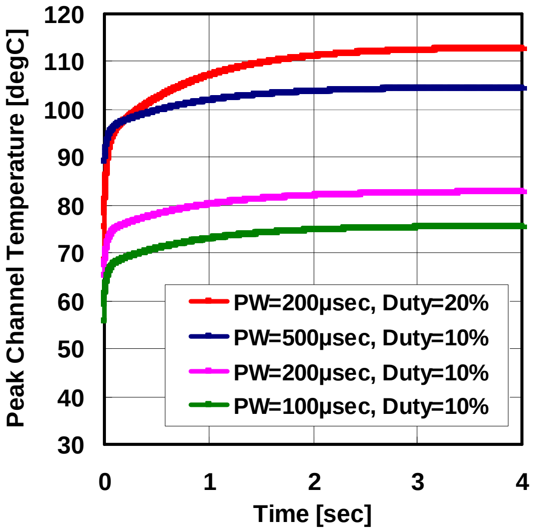

Figure 11. Simulation Result of peak channel temperature at various pulsed operating conditions.

CONCLUSION

We have successfully developed an 800-W AlGaN/GaN HEMT in S-band operating at 65 V drain bias voltage. The developed AlGaN/GaN HEMT exhibits an output power of 800 W, high linear gain of 14 dB and drain efficiency of 50% at the frequency range of 2.9-3.3 GHz under pulsed conditions, at a duty of 10% with a pulse width of 200-μs. At 70-V drain bias operation, the device showed peak power of 912 W with 56.4 % of drain efficiency at 2.9 GHz. We believe this is the highest power ever reported for S-band transistors.

ACKNOWLEDGEMENTS

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REFERENCES

[1] A.Maekawa et al, *A 500W Push-Pull AlGaN/GaN HEMT Amplifier for L-band High Power Application*, 2006 IEEE MTT-S Digest, pp722-725, June 2006

[2] Y.F. Wu et al, *An Internally-matched GaN HEMT Amplifier with 550-watt Peak Power at 3.5GHz*, 2006 IEEE IEDM Technical Digest, pp419-421, December 2006

[3] J. Nikaido et al, *A Highly Uniform and reliable AlGaN/GaN HEMT*, 2005 CS MANTECH Technical Digest, pp151-154, April 2005

ACRONYMS

HEMT: High Electron Mobility Transistor
IR: Infrared