A 100W High-Efficiency GaN HEMT Amplifier for S-Band Wireless System

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Abstract **We have successfully developed a 100W AlGaN/GaN power amplifier with a bandwidth of 300MHz in S-band, operating at 50V drain bias voltage. This amplifier consists of one HEMT die developed for L/S-band frequency operation and a single-ended package. The developed amplifier has an output power of 100W and a high linear gain of more than 13.5dB in the frequency range of 2.6GHz to 2.9GHz under CW or pulsed conditions [200usec (pulse width) and 2msec(period)]. High drain efficiency of 58% was also achieved at an output power of 100W and frequency of 2.8GHz. To the best of our knowledge this is the first report of 100W AlGaN/GaN HEMT amplifier developed for S-band high power application.**

I. Introduction

There are a strong demand for wideband high output power S-band devices used for MMDS, WiMAX and radar. High saturation power is usually obtained by increasing total gate width of the field effect transistor(FET). However, the wide gate width causes lower input and output impedance, resulting in higher mismatching losses and consequently lower saturated output power. One alternative is to use high drain-voltage operation with smaller gate width, which can provide high output power with low mismatch losses. Furthermore, devices with broadband capabilities can be obtained by the high voltage operation because higher chip impedance makes the transformation ratio to 50-ohm lower. In this sense, AlGaN/GaN HEMTs have a strong potential for the broadband high power device application because of their high breakdown voltage, which makes high voltage operation possible.

Despite this advantage for GaN-related device, there are a few reports of high power AlGaN/GaN HEMT developed for S-band application, although there are many reports for L-band applications [1],[2],[3]. In this paper, we have successfully fabricated a S-band AlGaN/GaN amplifier, which exhibited high output power of 100W and high linear gain of more than 13.5dB with a frequency range of 2.6GHz to 3.0GHz under pulsed CW condition and 50V operation. High efficiency of 58% was also achieved at frequency of 2.8GHz. To our knowledge this is the first report of AlGaN/GaN HEMT amplifier with more than 100W output power developed for S-band high power application. The newly developed device also exhibits the highest efficiency ever reported for S-band GaN-related amplifier.

II. Device Fabrication

Figure 1 shows the schematic cross-section of the fabricated AlGaN/GaN HEMT epi structure used in this study. The epitaxial layers were grown by MOCVD on the semi-insulating SiC substrates. Ti/Al and Ni/Au metalization process was used to form ohmic and Schottky contacts, respectively. SiN film was deposited using plasma CVD as a surface passivation layer. Details of the device structure and fabrication process were previously reported [4]. As described in the previous paper we could suppress the current collapse of the fabricated device by adopting this device structure [4].

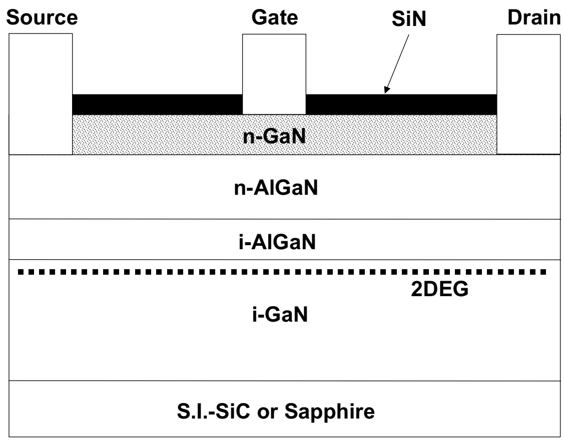

Fig.1 Schematic view of investigated device structure

III. CIRCUIT DESIGN OPTIMIZATION

Load-pull measurement was used to optimize the power and efficiency using a unit FET cell with a one sixteenth gate width of 100W chip, it was found that the best source and load impedance for maximum Power and Efficiency at 2.8GHz is 6.26+j8.97 and 32.0+j30.0 ohms, respectively, which is shown in Fig.2.

This result demonstrated a higher impedance when compared with 10V operation GaAs chip. Fig.3 shows the loadpull measurement of GaAs and GaN chip at the same output power conditon. The comparison of the result at the same output power indicated that GaN chip impedance is 10 times higher than that of GaAs. Therefore, lower transfomation ratio gives the advantage for designing matching circuit for broadband devices.

The AlGaN/GaN chip has a total gate width of 36 mm and a unit gate width of 400um. The AlGaN/GaN HEMT die together with internal matching circuits were mounted in ceramic/metal package in a single-ended configuration which have been developed for S-band 100W power device. This is shown in Fig.4 and it is a very simple circuit. The internal matching circuits consist of high dielectric-constant micro chip capacitors and wires, which form a low pass filter network. The flange size of this package is 24.0mm x 17.4mm. The impedance of both input and output ports were designed to be 50ohm.

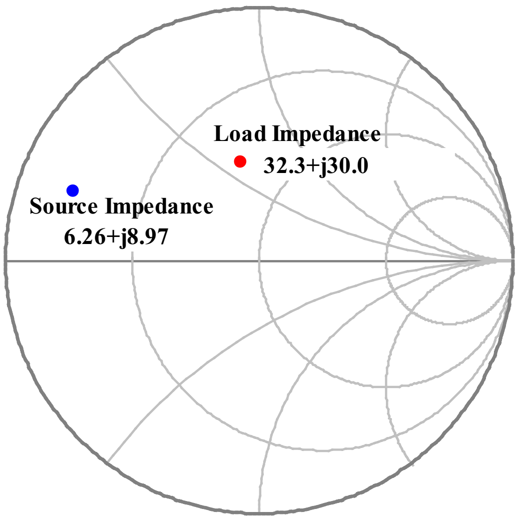

Fig.2 Source and load impedance of GaN unit FET cell. Frequency is 2.8GHz, VDS=50V and Idsq=30mA

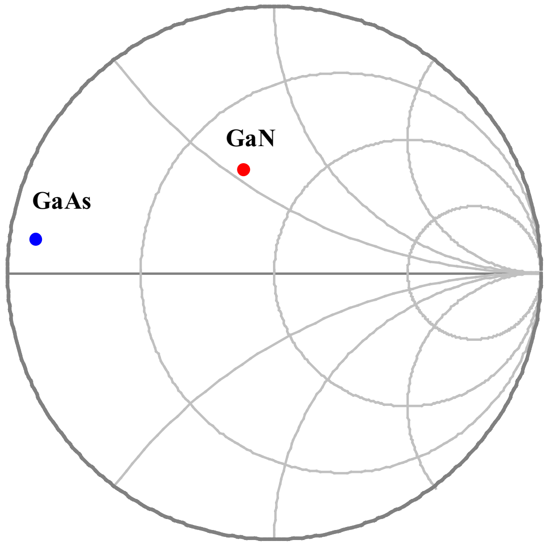

Fig.3 Comparison of GaN and GaAs load Impedance at the same output power .

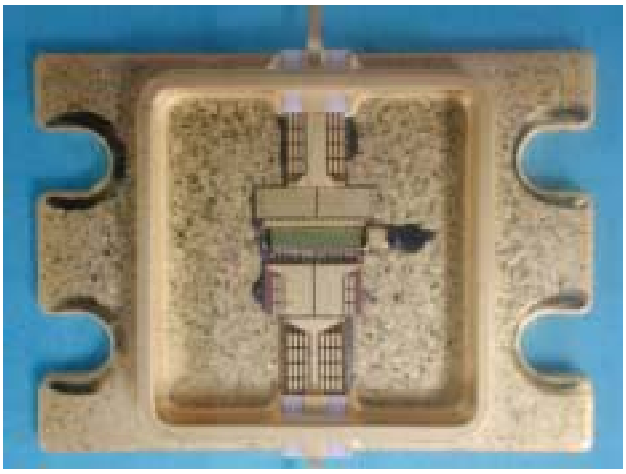

Figure 4. Photograph of 100W Device

IV. RF PERFORMANCE

We have evaluated pulsed RF performance of the device. Figure 5 shows the RF performance under pulsed condition [200usec (pulse width) with 2msec(period)] and also the pulsed gate bias is synchronized with input RF signal. The measured frequency was 2.8GHz. The drain bias voltage and quiescent drain current is 50V and 500mA (near class B operation), respectively. As shown in figure 5, we could obtain high saturated output power of 100W and associated drain efficiency of 58%. To our knowledge, this is the highest saturated output power and drain efficiency of one die of AlGaN/GaN in S-band. We evaluated the frequency response of the amplifier in terms of output power, linear gain and drain efficiency. The result is shown in Fig.6. We obtained saturated output power of 100W and linear gain of 13.5dB with wide frequency range of 2.6GHz to 2.9GHz. This result indicates that the developed AlGaN/GaN HEMT is suitable for the application of wideband high power amplifier such as radar, high-capacity data transmission etc.

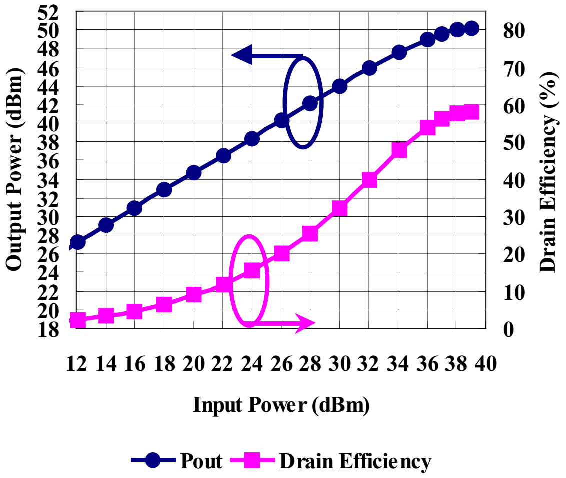

Fig.5 Output power and drain efficiency vs. input power. Vds=50V Idsq=500mA.

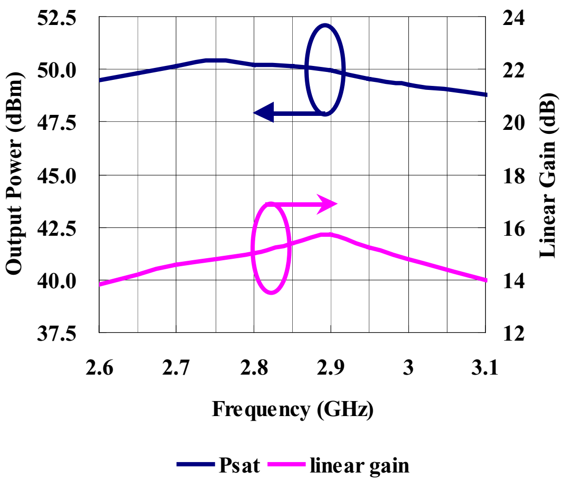

Fig.6 Performance of output power and linear gain vs frequency . Vds=50V Idsq=500mA.

V. RF WAVEFORM AND PHASE CHARACTERISTICS

Pulse performance is key factor for wireless system. We have evaluated pulse droop performance of the device. We also measured waveforms of amplified output signals and phase change (d-phase) between pulsed input signals, using signal source analyzer. Figure 7 and 8 are the waveforms of input and output signals and d-phase at output power of 40dBm and 50dBm. Pulse droop of output waveform at an output power of 40dBm and 50dBm is 0.4dB and 0.2dB, respectively. Furthermore, d-phase profile is straightforward and almost doesn't change within one-pulse form. Figure 9 is amplitude and d-phase pulse droop of output power. We obtained d-phase droop of 2.0 deg at 2.8GHz. This result shows that the developed device is suitable for the application of pulsed operation such as TDD application and radar.

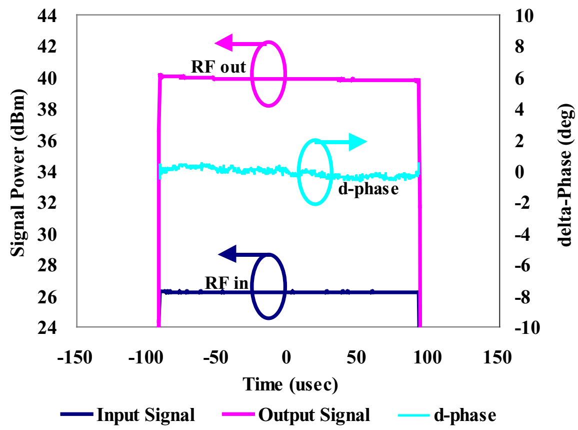

Fig 7. Waveform of input signal, output signal and d-phase at output power of 40dBm. Vds=50V Idsq=500mA f=2.8GHz

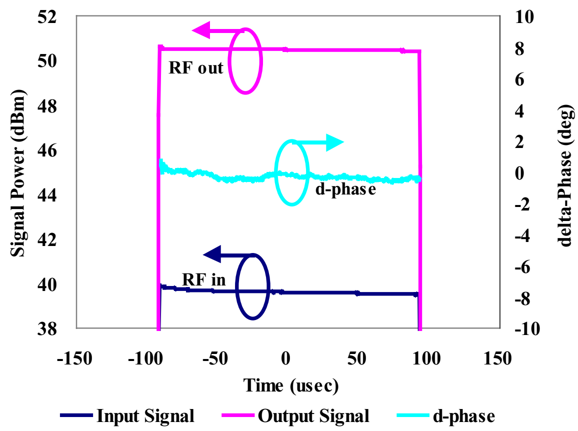

Fig 8. Waveform of input signal, output signal and d-phase at output power of 50dBm. Vds=50V Idsq=500mA f=2.8GHz

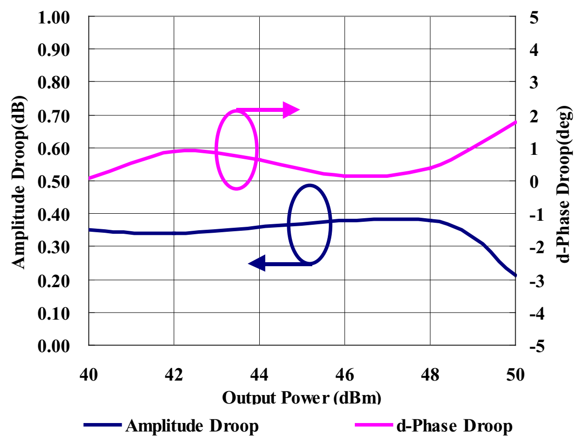

Fig.9 Amplitude and d-phase droop vs output power at pulsed condition[200usec (pulse width) with 2msec(period)]. Vds=50V Idsq=500mA f=2.8GHz

VI. Conclusion

We have successfully developed a 100W AlGaN/GaN power amplifier with a bandwidth of 300MHz in S-band operating at 50V drain bias voltage. The developed amplifier exhibits an output power of 100W and high linear gain of more than 13.5dB in the frequency range of 2.6GHz to 2.9GHz under the pulsed CW conditions[200usec(pulse width)/2msec(period)]. High drain efficiency of 58% was also achieved at an output power of 100W and frequency of 2.8GHz. We believe this is the first report of S-band AlGaN/GaN HEMT amplifier with more than 100W output power.

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References

[1] Y. Tateno et.al. "A High Power and High Efficiency GaN HEMT Amplifier for W-CDMA Base Station Applications" 2004, IEEE MTT-S Workshop Digest.

[2] T. Kikkawa et.al. " An over 200-W output power GaN HEMT push-pull amplifier with high reliability " Microwave Symposium Digest, 2004 IEEE MTT-S International ,Volume: 3 , 6-11 June 2004 Pages:1347 - 1350 Vol.3

[3] K. Joshin et.al. " A 174 W high-efficiency GaN HEMT power amplifier for W-CDMA base station applications " 2003, IEDM Technical Digest, Pages:12.6.1 - 12.6.3.

[4] T. Kikkawa et.al. "Surface-charge controlled AlGaN/GaN-power HFET without current collapse and gm dispersion" 2001. IEDM Technical Digest. International , Pages:25.4.1 - 25.4.4