A 80W 2-stage GaN HEMT Doherty Amplifier with -50dBc ACLR, 42% Efficiency 32dB Gain with DPD for W-CDMA Base station

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Abstract — A 2-stage 80W amplifier, which consists of a 450W saturated power GaN HEMT Doherty amplifier and a 30W driver, was developed. At first we developed the 450W GaN HEMT Doherty amplifier and obtained saturation power of 56.5dBm(450W) and drain efficiency of 55% at 6dB back-off power showing typical Doherty amplifier behavior. Then we built the 2-stage amplifier up with the 30W driver stage amplifier. With this amplifier we obtained 42% efficiency (including 30W driver amplifier) and -50dBc ACLR at the average power of 49dBm(80W) with saturation power of 56.5dBm and Gain of 32dB.

Index Terms — Doherty, GaN HEMT, digital predistortion(DPD)

I. INTRODUCTION

Modern digital wireless communication systems, such as W-CDMA or WiMAX, use wide frequency band modulation signals that have high peak-to-average ratio (PAR). Therefore power amplifiers must operate in large back-off region (around 8dB back-off for W-CDMA base stations) to handle the modulation signals. Recently several Efficiency enhancement techniques are investigated for high PAR applications, such as Doherty amplifier, envelope tracking (ET), EER, LINC and so on. Among them, the Doherty amplifiers have been developed with Si-LDMOS[1][2], GaAs FET[3] and HBT for practical use.

On the other hand, high power and high efficiency GaN HEMTs, which have high current density and high breakdown voltage, have been developed for wireless communications in the last few years[4]. In this paper we demonstrate a high power, high efficiency and high gain 2-stage GaN HEMT Doherty amplifier for W-CDMA base stations.

II. DOHERTY AMPLIFIER AND GaN HEMT

The Doherty amplifier is one of the efficiency enhancement techniques for large back-off region from saturation power[5]. Fig.1 shows well-known Doherty amplifier configuration and its efficiency characteristics. If the main and the peak amplifiers have the same power, the first efficiency peak is obtained at 6dB back-off power, where the main amplifier saturates. Average operation power of 8dB back-off for W-CDMA is close to this first efficiency peak, therefore the saturation efficiency is very important for the Doherty amplifier components.

Fig.2 shows typical Pin-Pout and efficiency characteristics of a 200W GaN HEMT(Eudyna, EGN21A180IV), which has two 100W(36mm gate width) GaN HEMT dies with partially matched input and output circuits in a small size package(24x18mm)[6]. The high drain efficiency of 63% at the high saturation power of 200W at 2.14GHz with 50V operation was obtained. We used this high efficiency 200W GaN HEMT for the Doherty amplifier.
III. Doherty Amplifier Circuit Design

To realize the Doherty amplifier, we performed large signal load-pull simulation. We simulated at Plane-A, the terminal of GaN HEMT current generator and Plane-B, the terminal matched to 50ohm as defined in Fig.3. Fig.4(a) shows load-pull simulation results for a 200W GaN HEMT at Plane-A.

Fig. 6 shows a photograph of the 450W GaN HEMT Doherty amplifier including two 200W GaN HEMTs. We employed a 90-degree hybrid coupler for the input divider to reduce the interaction between the main and the peak amplifiers, which is important to reduce imbalance of IMD. Low loss variable capacitors are used in the input and output matching circuits for easy matching optimization.

Fig.7 shows Pin-Pout characteristics of the 450W GaN HEMT Doherty amplifier with pulsed RF operation with 50V operation at 2.14GHz. Efficiency characteristics with CW operation are shown in Fig.8. The main and the peak amplifiers were biased at Class-AB and Class-C respectively. We obtained saturation power of 56.5dBm(450W), drain efficiency of 55% at 6dB back-off power, showing typical Doherty amplifier behavior. At the output power of 48.5dBm(8dB back-off), 48% drain efficiency and 15dB power gain were obtained.

Fig.3. Definition of load-Pull simulation plane for 200W GaN HEMT; Plane A (current generator) and Plane B(50ohm matched)

Normalized impedance(Z0) is equal to the optimum impedance(Zopt) of output power in this Smith chart. In the ideal Doherty amplifier, the optimum load(target) impedance for the main amplifier at less than 6dB back-off power(off state of peak amplifier) is two times as the impedance at the maximum output power. Fig.4(b) shows load-pull simulation results for the 200W GaN HEMT at Plane-B. The target impedance is transformed by parasitic components and matching network. The target impedance locates on the concentric circle of 25ohm, which means that the target impedance can be converted from 25ohm load impedance by 50ohm transmission line. As a result of the above analysis, the Doherty network was designed as a schematic shown in Fig.5.
IV. 2-stage Amplifier and DPD Operation

Fig. 9 shows typical Pin-Pout characteristics of a 30W GaN HEMT driver amplifier (Eudyna, EGN21A030MK). The saturation power of 47dBm (50W) is high enough to drive the final stage 450W GaN HEMT Doherty amplifier. We built the 2-stage amplifier up by connecting the 450W Doherty amplifier and the 30W driver amplifier directly as shown in Fig. 10. We applied the digital pre-distortion (DPD) technique as well to maximize linearity performance.

The signal conditions are 2-carrier W-CDMA 7.8dB PAR, 0.01% (2-carrier total), 5MHz spacing and 2.14GHz center frequency. We employed PMC-Sierra, PALADIN-15 chipsets for the DPD operation. To obtain higher ACLR correction with the DPD operation, we adjusted the gate bias voltage of the peak amplifier a little closer to Class-B from deep Class-C.

Fig. 11 shows Pin-Pout characteristics of the 2-stage 80W GaN HEMT Doherty amplifier with pulsed RF operation at 50V operation. The saturation power of 56.5dBm and Gain of 32dB at the output power of 49dBm were obtained. The ACLR and the efficiency characteristics with DPD operation are shown in Fig. 12. We obtained 42% efficiency (including a 30W driver amplifier) and -50dBc ACLR at the average power of 49dBm (80W).
A 2-stage 80W average power amplifier including a 450W GaN HEMT Doherty amplifier and a 30W driver are successfully developed. We obtained 42% efficiency (including a 30W driver amplifier) and -50dBc ACLR at the average power of 49dBm (80W) with saturation power of 56.5dBm and Gain of 32dB. These results will contribute to the efficiency enhancement design of high power amplifiers for base station applications.

REFERENCES