Design and Performance Evaluation of a 750MHz High-Efficiency Amplifier using Gallium Nitride Transistor

Seyed Alireza Mohadeskasaei [1], and Dragos Dancila [1,2]
(1) FREIA, Department of Physics and Astronomy, Uppsala University, Sweden
(2) Microwave Group, Department of Electrical Engineering, Uppsala University, Sweden

Summary

This article showcases the development and simulation of a Gallium Nitride (GaN) semiconductor-based power amplifier that operates at 750 MHz and delivers a continuous wave power of 200W with high efficiency. To achieve this, the transistor is biased in deep Class-AB mode, which enhances its efficiency. Additionally, load pull technique is employed to optimize the input and output impedances, while employing 1st and 2nd order microstrip Chebyshev filters for the output and input matching networks respectively. The resultant amplifier is able to deliver a remarkable slightly more than 200W with 85.5% of the drain efficiency at the operating frequency of 750 MHz.

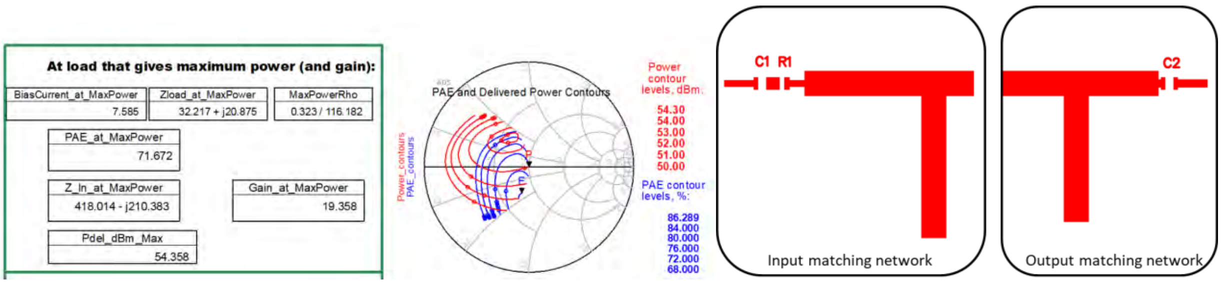
1. Introduction

The demand for high power and high efficiency amplifiers has increased significantly in recent years, particularly in the field of Radio Frequency (RF) high power applications. The use of Gallium Nitride (GaN) semiconductor technology has shown tremendous potential for achieving these goals [1-3] . One important frequency range for RF applications is the VHF/UHF range, which includes frequencies between 30MHz and 1GHz. In particular, the 700-900MHz band is widely used for communication systems, such as mobile phones, public safety radios, and television broadcasting. Within this range, the 750MHz frequency is of particular interest due to its use in applied physics applications.

In this paper, we present the design, simulation, and measurement of a high power amplifier at 750MHz. The amplifier is designed for use in an RF power source of the Radio Frequency Quadrupole (RFQ) and is required to provide high output power, excellent efficiency, and low distortion. We describe the design methodology used to optimize the amplifier's performance and present the results of simulations and measurements, including gain, output power, efficiency, and distortion.

2. Simulation, Fabrication, and Measurement Results

Initial simulations were performed using the large signal model of the transistor CGHV40180F offered by the manufacturer, i.e. Wolfspeed and using the simulations software Advanced Design System (ADS), from Keysight Technologies. The transistor gate is biased in the pinch off point i.e. -3 V, enabling to have a high efficiency performance using the harmonic engineering method. Then, the development of RF amplifier starts from load-pull simulations on the large signal model, as the input impedance is considered 2.5 ohm, see Figure 1. Figure 1(a) shows the simulation results for a diverse output impedances, illustrating the drain efficiency of 86% as the output power is compressed to 51dBm (125 Watt) and the output power of 54.3 dBm (269 Watt) as the drain efficiency is sacrificed to 71.6%. Therefore, optimum output impedance i.e. 2.7-j 4.2 Ohm regarding to the output power of 53 dBm (200 Watt) and the drain efficiency of 85.5% is considered. Thus, to realise the power amplifier, the transistor input/output optimum impedances are matched with 50 ohm as shown in Figure 1(b), demonstrating the resulting layout of the designed amplifier, with an expected performance, i.e. nominal output power of 200 W with an efficiency of more than 80% in continuous wave (CW) condition.



(a) (b)

Figure 1: (a) Simulation results of the amplifier as matching networks are considered, (b) layout of the input and output matching networks.

The design is realised on a low loss RF substrate from Rogers Corporation, i.e. RO3006 with a thickness of 1.27mm, a dielectric constant of 6.15, and dissipation factor of 0.002. The fabricated 200 W power amplifier prototype is shown in Figure 2, depicting the initially designed input and output matching networks in addition of decoupling capacitors (C1 and C2) and DC biasing network. It is evident that the new development in the project has achieved a measured output power of 205 W at its compression point, with a drain efficiency of 85.5% and a signal gain of 18 dB. This represents an improvement in the state of the art, as the closest comparable amplifier delivers only 200 watts.

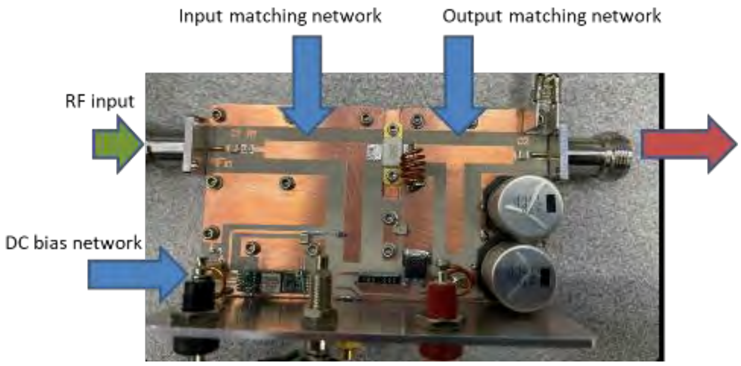


Figure 2: Fabricated 200-W 750MHz power amplifier

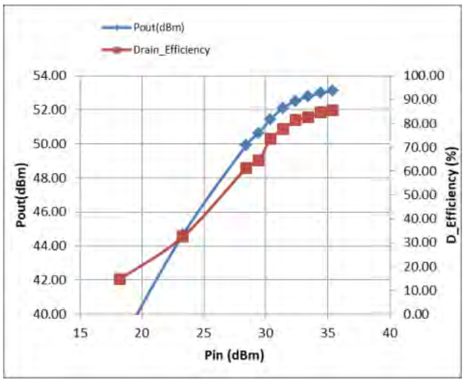


Fig. 3. Output power and drain efficiency measurement results

3. Acknowledgements

The project leading to this submission has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement GreenSSPA No 101025789. This project has also received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730.

References

[1]. He, J., Cheng, W. C., Wang, Q., Cheng, K., Yu, H., & Chai, Y. (2021). Recent advances in GaN-based power HEMT devices. Advanced Electronic Materials, 7(4), 2001045.

[2]. Dragos Dancila, "New RF Amplifiers based on GaN Semiconductors", Workshop on efficient RF sources, Jul 4 – 6, 2022, Bossey, Switzerland.

[3]. Dragos Dancila, "Highly efficient Solid-State Power Amplifiers for High Frequencies applications till the Megawatt range", Oct 24, 2022, PSI Villingen, Switzerland.