Simulation and Fabrication of 3.5W X-band Power Amplifier using Discrete GaN HEMT Transistors

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ABSTRACT:
This paper presents different steps of simulation and fabrication of a power amplifier, which was realized using a discrete GaN HEMT transistor in the frequency range of 8.8-9.2 GHz. The required wire bonds and matching circuits were characterized using three-dimensional simulations in HFSS and Momentum ADS software. The fabricated power amplifier provides an output power of 3.5W and a power gain of 13 dB.

KEYWORDS: GaN HEMT, Discrete GaN HEMT Transistors, Matching Circuit, Output Power, X-band.

1. INTRODUCTION

Implementing power amplifiers becomes more complex as the operating frequency and power output of the amplifiers increase. In high power and high-frequency amplifiers, the transistor must provide high breakdown voltage, low thermal resistance, small size, high output power, and suitable power gain [1]. GaN HEMT transistors with a high power density (about ten times higher than similar GaAs transistors) and small size are appropriate for realizing high power amplifiers in the X frequency band and higher bands [1]. These transistors have a relatively large input and output impedance, which facilitate the design of matching circuits [2].

Solid-state power amplifiers can be implemented using discrete transistors at very low prices and designing different impedance matching, bias, and suitable heat-shrinking circuits for them. Also, they can be realized based on the packaged transistors with internal input and output matching circuits at much higher prices. The design of the power amplifier using each of the discrete or packaged transistors has its characteristics. Features of using packaged transistors are:

- Usually, they have suitable input and output impedance matching circuits.
- They have suitable frequency and temperature specifications.
- Amplifier design is much easier with packaged transistors.
- Packaged transistors are almost expensive. Also, the price gap between packaged transistors and discrete ones will increase by increasing the operating frequency and output power.

In contrast, discrete transistors also have the following features:

- Different amplifiers with various frequency bands can be implemented using un-matched discrete transistors.
- They are cheaper in comparison with packaged transistors.
- The realization of a power amplifier using discrete transistors need accurate frequency and thermal designs, which can be time-consuming.

Designing a power amplifier using discrete transistors requires technical knowledge in high-frequency circuit design, thermal design and analysis, and thermomechanical analysis. This paper investigates the steps of simulation and design of an X-band power amplifier using discrete transistors.

2. THE PROPOSED POWER AMPLIFIER:

Qorvo TGF2023-01 transistor has been selected for the implementation of the proposed amplifier. It is unconditionally stable in the X band. Assembly of high-frequency transistors can be performed in different ways, the most important of which are wire bonding, ribbon bonding, and flip-chip. The wiring method, which is an old technology, is the easiest and cheapest way to connect transistors to matching circuits. In the proposed amplifier, 25 µm gold wire bands are used to connect the transistor to the impedance matching circuits, as shown in Fig. 1.

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Fig.1. Connecting the transistor to the substrate using wire bands.

The general circuit design process is as follows. First, wire bonds were modeled using HFSS software. Then, suitable structures were considered for the output and input impedance matching circuits and try to get the best possible answer in Momentum ADS software using different optimization methods. Finally, to be sure, the final designed circuit is also simulated by HFSS software to confirm the accuracy of the simulations.

Three-dimensional simulations of HFSS software were used to model parasitic elements of wire bands. The simulation results of the structure used for the TGF2023-01 transistor and the extracted circuit model are shown in Fig. 2.

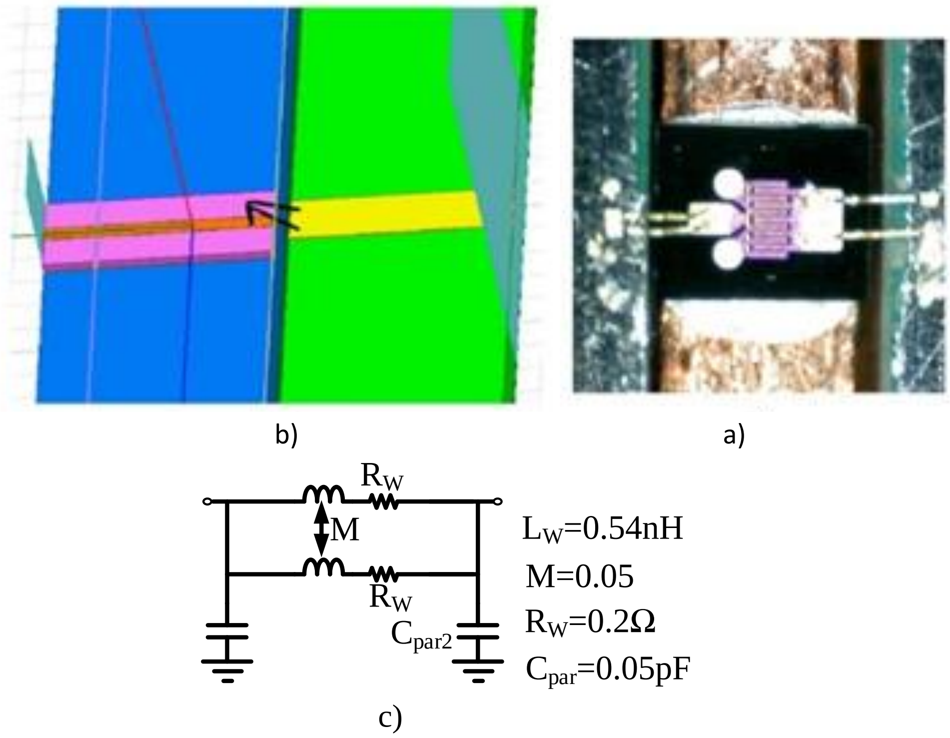

Fig. 2. a) wire-bonded transistor b) Simulation of the wire bonds of TGF2023-01 transistor and c) Extracted high-frequency model of wire bonds.

RO3010 10 mil substrate was used for the implementation of the proposed power amplifiers. A radial stub transmission line was used to increase the bandwidth [3] (Fig. 3). The dimensions of the proposed power amplifier are 1.5 *6.6 cm. The amplifier bias circuit is implemented using λ/4 line and bypass capacitors [4].

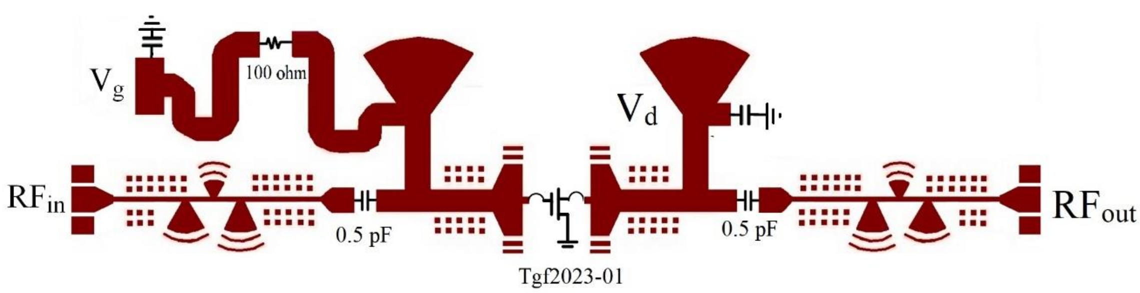

Fig.3. The proposed PA.

Figure 4 shows the fabricated power amplifier. Fig. 5 presents the simulation and measurement S- parameters of the proposed power amplifier. As it is shown, this amplifier has a small signal gain of a maximum of 13 dB.

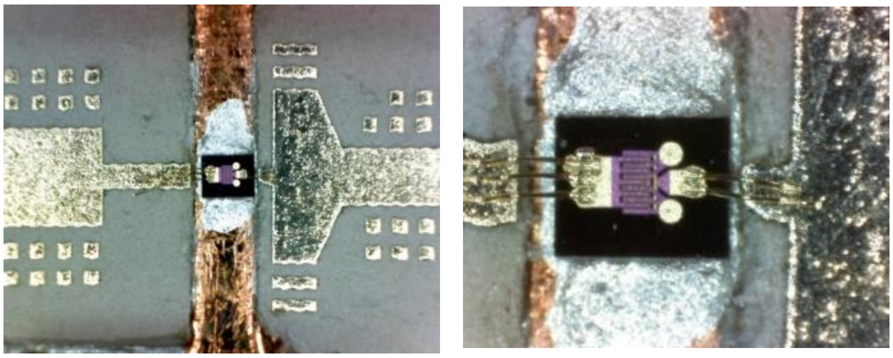

Fig.4. Implementation of the proposed amplifier.

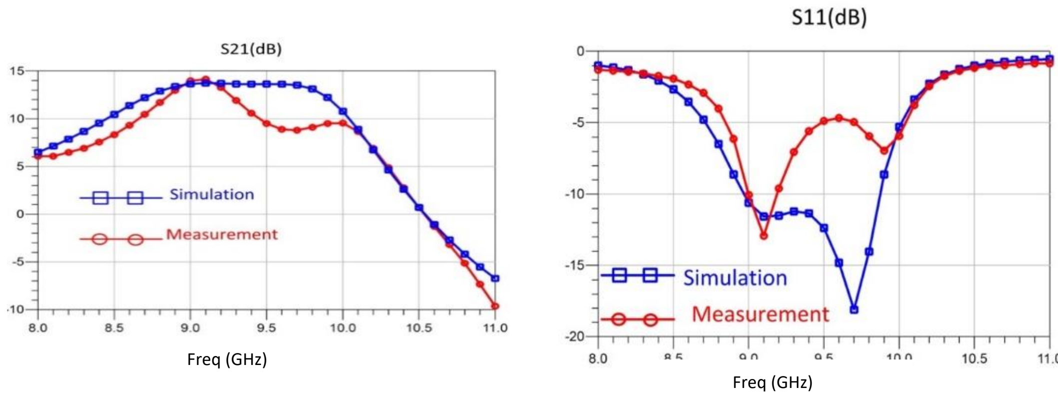

Fig. 5. simulation and measurement results of the proposed power amplifier.

Fig. 6 shows the measurement results of the presented amplifier in the large signal mode at a frequency of 9.3 GHz. As it is shown, it has a gain of 13 dB and maximum output power of 3.5 watts.

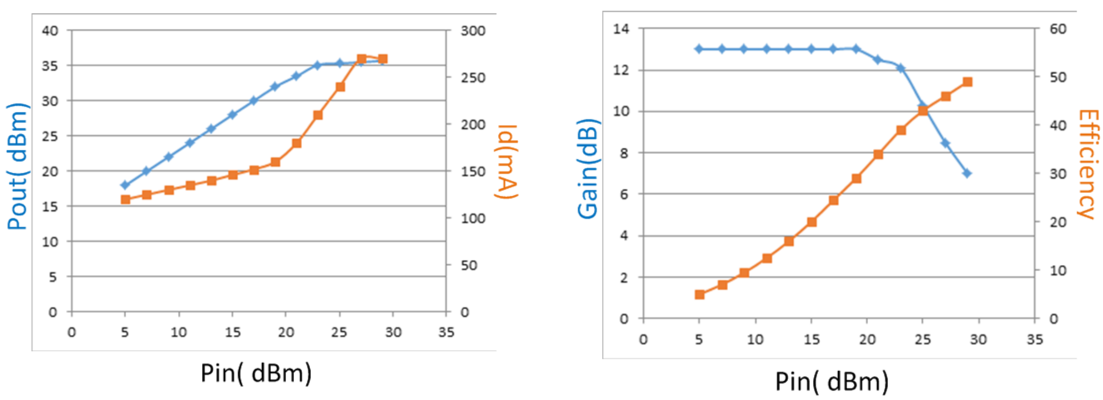

Fig. 6. Large signal measurement results of the proposed amplifier.

3. CONCLUSION

This paper describes tdifferent steps of simulation, manufacturing, and measurement of a 3.5 watt X band power amplifier. Wire band simulations, input and output matching circuits design, and optimization of the proposed amplifier specifications were performed in ADS software. The proposed amplifier, provid a power output of 13 dB and an output power of 3.5 watts in the frequency range of 8.8-9.2 GHz.

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