Optimum design of 60WAlGaN/GaN Broadband RF Amplifier for S-Band Operation

Naufal Zaidan Nabhan[1], Basuki Rachmatul Alam[2,3]
[1] : Telcom Reseacrh Group, School of Electrical Engineering and Informatics, Institute of Technology Bandung
[2] : Microelectronic Center , Institute of Technology Bandung Bandung 40132, Indonesia
[3] : Teaching Factory Manufacturing Electronics, Politeknik Negeri Batam, Batam 29461 Indonesia

E-mail : naufalzaidan6@gmail.com, br_alam@yahoo.com;

Abstract *– Design and simulation of broadband 60W RF Amplifier using AlGaN/GaN HEMT die for 2,7GHz – 3,3GHz (S-Band) has been accomplished Load pull optimization and multi-section impedance matching based on fully distributed element cross, line, step and stub as matching elements have been implemented to achieve rf broadband characteristics in the S-band frequency range. The AlGaN/GaN HEMT 60W RF High Power Amplifier has shown gain of 11.967 dB and drain efficiency of 56% at saturated output power of 48 dBm.*

I. INTRODUCTION

High Power RF Broadband Amplifiers are highly needed in long distance digital broadband telecommunication and services, as well as long sensing of AESA Radar of reflected DSP Signal modulation in high accuracy and fast response on aerial object interpretation. Power amplifier performance is affected by parameters such as output power, efficiency, and linearity. Due to high output power of RF high power amplifier (HPA), the output signal of HPA shows non linearity effect that cause degradation of the modulation of Radar signal. Non-linearity effects such as harmonic distortion, gain compression, and intermodulation may hamper the received signal interpretation [13].

In this work, RF High Power Amplifier employing AGaN/GaN HEMT is designed to produce output power of 60 W in frequency of 2.7 - 3.3 GHz using Harmonic Balanced software. The design of RF High Power Amplifier consists of impendence matching network and bias network that can be achieved using microstrip elements. RF High Power Amplifier work on class AB to get higher gain and effieciency based on datasheet of transistor. AlGaN/GaN HEMT die needs to be placed on the Printed Circuit Board. AlGaN/GaN HEMT die is placed on the die base of MoCu heatsink underlying the RF PCB of HPA. The drain and gate bonding pad of the AlGaN/GaN HEMT are connected to drain and gate of RF PCB of the RF HPA. respectively by wirebonding technique. The finished power amplifier simulation produces output power of 46.967 dBm with efficiency of 56%.

II. LOAD PULL OPTIMIZATION AND SIMULATNEOUS BROADBAND IMPEDANCE MATCHING

A. Load Pull Optimization

RF High Power Amplifier employing AlGaN/GaN HEMT 60W die biased at the chosen V_{GS}, V_{DS} and dc drain current, firstly went through Load Pull optimization to find optimum load and source impedances at center frequency of 3GHz. The topology of the load pull is shown below.

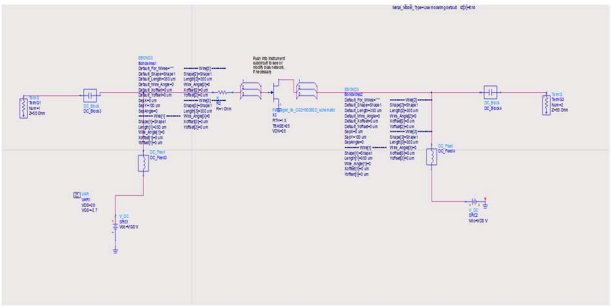

Figure 1. Topology of Load Pull measurement

The load pull has delivered the optimum RF power of 46 [dBm] and PAE of 58.904 % at frequency of 3 GHz . The optimum load impedance Z_L 6.627 + j*5.130 [Ω] and optimum source impedance of Z_S 1.339 – j*0.586 [Ω] as shown below.

At load that gives maximum power (and gain):

BiasCurrent_at_MaxPower	Zload_at_MaxPower	MaxPowerRho
2.267	6.627 + j5.130	0.768 / 168.079

PAE_at_MaxPower
58.904

Z_In_at_MaxPower	Gain_at_MaxPower
1.339 + j0.586	11.001

Pdel_dBm_Max
46.001

Figure 2. Optimum power performance and impedance as a result of Load Pull optimization.

Notice that Z_S is the conjugate of Z_{In}. Based on this optimum load, Z_{Lopt} [Ω] and optimum source Z_{Sopt} [Ω] impedances, simultaneous broadband impedance matching have been carried out.

B. *Broadband Simultaneous Impedance Matching*

Simultaneous broadband impedance matching was performed using optimum load impedance, Z_{Lopt} and optimum source impedance, Z_{Sopt} Ω . The impedance matching network is realized using microstrip. The input impedance is shown below.

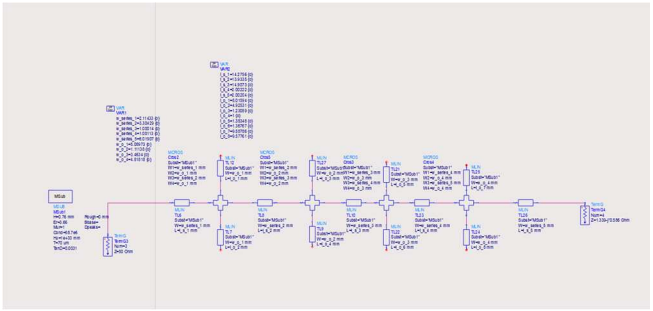

Figure 3. Impedance Macthing Network at input of RF High Power RF Amplifier

Based on Z_{Sopt} impedance that is resulted from loadpull analysis, set to characteristic impedance, Z_O = 50 Ω. The input impedance matching has resulted as shown below.

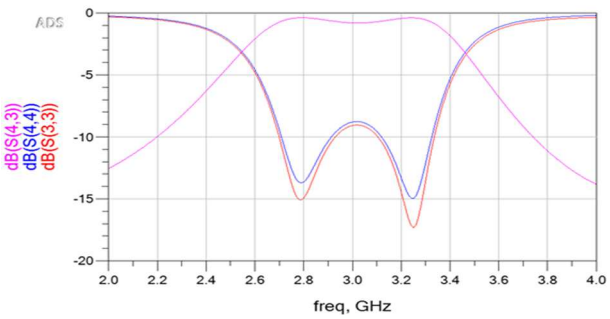

Figure 4. S-parameters of the input impedance matching

The S-parameter result of input impedance matching network shows that from frequency of 2.7 until 3.3 GHz is not good enough due to S-parameter value that exists above -10 dB. Value of S-parameter needs to maintain above -10 dB in order to attenuate reflection signal. The result above causes the S-parameter result did not match the specification.

At the output, impedance matching network has been carried out.

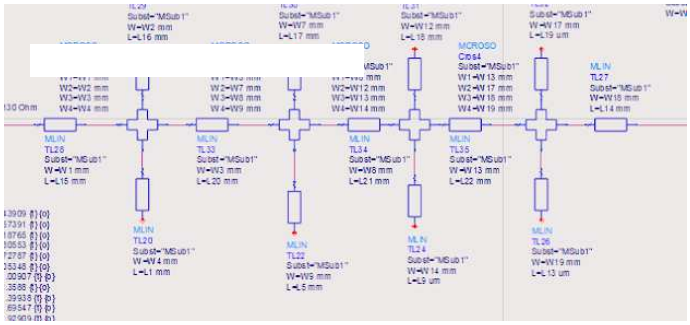

Figure 5. S-parameters of the output impedance matching

The output impedance matching network has been implemented by matching the , Z_{Lopt} to the output connector set at the characteristic impedance, Z_O = 50Ω. The output impedance matching result is shown below.

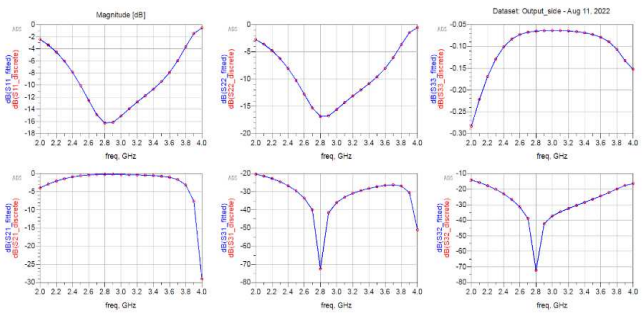

Figure 6. S-parameters result of the output impedance matching

The S-parameter result of output impedance matching network is better than S-parameter result of input impedance and match the specification below -10 dB. It decreases the reflected signal.

C. *Total Integrated RF 60W Power Amplifier Simulation*

The AlGaN/ GaN HEMT with input and output impedance matching network including the bias and stability circuit network are integrated and finally HB (Harmonic Balanced) simulated. The schematic network is shown below

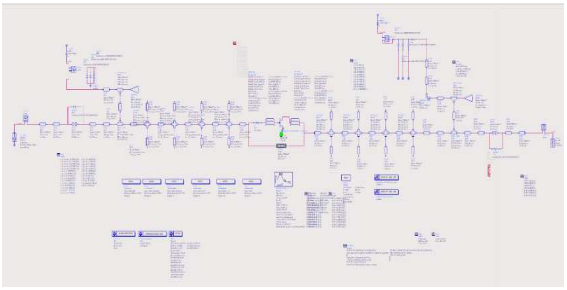

Figure 7. Total integrated circuit of 60W RF High Power Amplifier

III. RF POWER PERFORMANCE RESULTS AND ANALYSIS

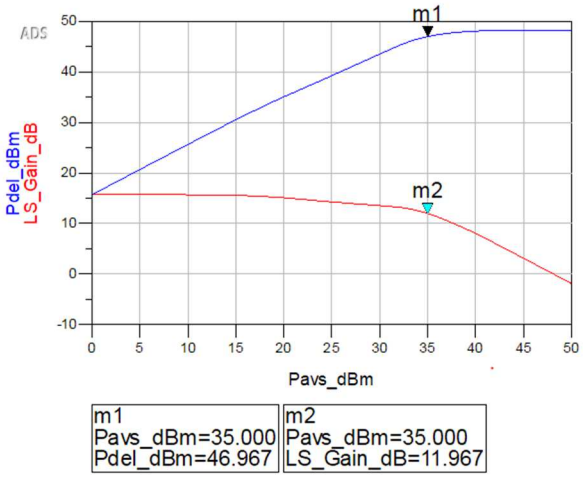

Figure 8. Power output and gain vs power input of AlGaN/GaN HEMT 60W RF High Power Amplifier

Power output of AlGaN/GaN HEMT 60W RF High Power Amplifier has saturated on 46.967 dBm with the input power of 35 dBm. It shows that the peak power of RF High Power Amplifier in linear region has a power output of 46.967 dBm and gain of 11.967 dB with efficiency of 56%. The more input power given to this RF High Power Amplifier increase the non-linearity effect of RF High Power Amplifier that makes RF signal in another frequency appear and interfere another signal.

The gain of AlGaN/GaN HEMT 60W RF High Power Amplifier match the specification on datasheet. AlGaN/GaN HEMT 60W RF High Power Amplifier can produce 60 W output power if the value of input power is raised based on the gain information above.

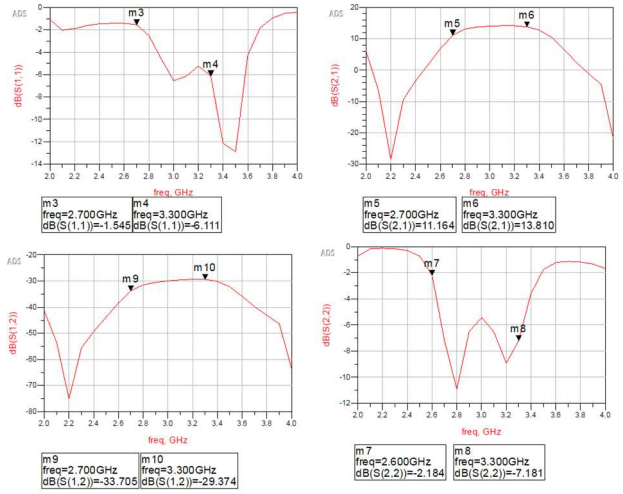

Figure 9. S-parameter of integrated schematic design of RF High Power Amplifier

S-parameter value in integrated circuit of RF High Power Amplifier is far enough from the specification. The integration of impedance matching circuit and bias circuit to transistor causes mismatch and affected the S-parameter of RF High Power Amplifier. The addition of passive components such as capacitor and resistor affect it too.

IV. CONCLUSION AND REMARKS

The design process of AlGaN/GaN HEMT 60W RF High Power Amplifier using die can produce gain of 11.967 dB and output power of 46.967 dBm. Power output of RF HPA amplifier shows saturation point at 46.967 dBm with input power of 35 dBm. However, The S-parameter of AlGaN/GaN HEMT 60W RF High Power Amplifier did not match the specification. For further works, the design can be implemented into the next process such as co-simulation

to apply electromagnetic effects in AlGaN/GaN HEMT 60W RF High Power Amplifier.

REFERENCES

[1]. A. Khusaidi, B.R. Alam, "Characterization and Modeling of a GaAs HFET toward design of a Linear High Power Amplifier", APMC 2000, Sydney, Australia, December, 2000.

[2]. Saripudin, A, M.T. Hutabarat M.T, B.R. Alam, "Characterization of Non-linear Behavior of GaAs HFET Power Amplifier IC Based on Multitone Simulation and Simulation", IEEE-APCCAS, Singapore, December 2002.

[3]. A.Saripudin, M.T. Hutabarat, B.R. Alam, "Nonlinear Characterization of RF LDMOS Power Amplifier Under Multitone Excitation" Asia Pacific Microwave Conference (APMC) 2003, Seoul, Korea, November 2003.

[4]. Kenington, Peter. B, *"High-Linearity RF Amplifier Design.* Artech House. Inc, 2000

[5]. B.R. Alam, A.Saripudin, M.T. Hutabarat, "The effect of Bias and Load Impedance to Non-Linearity Characteristics of RF LD-MOSFET", Proceeding 2011 ICEEI, Bandung,July 2011

[6]. Agilent Technology: "3GPP Long Term Evolution: *System Overview, Product Development, and Test Challenges*": Application Note, 2009.

[7]. Xu, S.; Foo, P.; Wen, J.; Liu, Y.; Lin, F. & Ren, C, " RF LDMOS with extreme low parasitic feedback capacitance and highhot-carrier immunity", *Electron Devices Meeting*, 1999 IEDM Technical Digest. International, (1999), (201-204).

[8]. Wood, A.; Brakensiek, W.; Dragon, C.; & Bruger, W. "120 watt, 2 GHz Si LDMOS RF power transistor for PCS base station applications", *IEEE MTT-S Int. MicrowaveSymp. Dig.*, (1998), (707–710).

[9]. A.Saripudin, I.B. Armanto, M.T. Hutabarat , B.R. Alam, "*The Effect of Bias and Load Impedance to Non-linearity Characteristics of RF LD-MOSFET*", Proceedings of 2011 International Conference on Electrical Engineering and Informatics (ICEEI), July 2011, Bandung, Indonesia.

[10]. Darwin "Perancangan dan Implementasi Penguat Daya Doherty untuk Base Station pada sistem Long Term Evolution 1,8GHz",Tugas Akhir, Program Studi Teknik Elektro, Sekolah Teknik Elektro dan Informatika, ITB, Juni, 2012.

[11]. Basuki R. Alam, "Modeling and Analysis of VIA Effect to LD-MOSFET RF Amplifier Performance", Proceedings of IEEE Conference, EDSSC 2015, Singapore, June 2015.

[12]. Basuki R. Alam, "Broadband Performance of multi-sectins of step-line impedance matching of LD-MOSFET RF Amplifier at 900MHZ LTE Band", Proceedings of ICEEI 2015, Bali, 10-11 August 2015.

[13]. S. P. Yadav and S. C. Bera, "Nonlinearity effect of Power Amplifiers in wireless communication systems," 2014 International Conference on Electronics, Communication and Computational Engineering (ICECCE), 2014, pp. 12-17, doi: 10.1109/ICECCE.2014.7086613.

[14]. NXP Product Data Sheet. *"BLS6G2731-6G LDMOS S-Band Radar Power Transistor"*. NXP Phillips December 2014

[15] Data Sheet : RO4000® Series High Frequency Circuit Materials, Rogers Corp.