G411

Design of Low Noise Amplifier for 2.35 GHz Long Term Evolution (LTE) Application

Fitri Yuli Zulkifli, Eufrasia Inti Alphatia Putri, Basari and Eko Tjipto Rahardjo
Antenna, Propagation and Microwave Research Group (AMRG)
Dept. of Electrical Engineering, Faculty of Engineering, Universitas Indonesia
Kampus Baru UI Depok, Indonesia

***Abstract*—In this paper, a Low Noise Amplifier (LNA) for Long Term Evolution (LTE) application is designed with the centre frequency at 2.35 GHz. Low Noise Amplifier is used to amplify the received low power RF signals. The LNA design uses inductive source degeneration with 24 dB voltage gain (S_{21}) and 4.5 V supply voltage. The Field Effect Transistor (FET) is used to design this LNA. The simulation result shows bandwidth of 282 MHz, with stab fact 0.659, VSWR 1.43, and noise figure is 1.185 dB at frequency 2.35 GHz. The Advanced Design Software (ADS) is used to simulate and show the specifications of the design.**

Keywords—Low Noise Amplifier, LTE, Noise Figure, FET

I. INTRODUCTION

Wireless communication is greatly improved and developed in this modern technology. Therefore, the technology that requires a communication system which can transmit a large amount of data continues to increase rapidly from the first generation (1G) technology to the present generation (4G) technology. 4G technology is the latest technology which is mobile broadband technology. Long Term Evolution (LTE) is a standard for wireless data communication technology and the evolution of the standard GSM/UMTS.

LTE consists of many types of equipment/devices to build the big system. One device needed is the RF receiver which usually consists of Low Noise Amplifier (LNA). To be used in multi-standards Radio Frequency (RF) technology for LTE, LNA is designed in the receiver and located at the first stage of a wireless communication near the antenna. It is often located very close to the antenna, thereby making losses in the feed-line less critical. The antenna receives small signal with large noise from the transmitter, therefore, the LNA amplifies the signal with contributing noise as low as possible to the next stage of the receiver. It is important to design LNA with low noise and high gain to meet a great specification.

Researches have been developed and have proposed the design of LNA for multi-bands applications [1], [2]. It is used for LTE and WLAN applications at the frequency of 2.35 GHz - 2.4 GHz. The LNA design in [1] has reached the highest gain of 22.5 dB while and in [2] achieved the lowest noise figure around 2 dB. In this paper, the LNA design is proposed to work with the center frequency of 2.35 GHz, provides a better noise figure which is less than 2 dB, and with a higher gain which is higher than 22.5 dB.

Design and simulation of the LNA is conducted by using Advanced Design Software (ADS).

II. DESIGN OF THE LNA

LNA is one of the most critical building blocks in modem integrated radio frequency (RF) transceivers for wireless communications. For low noise, the amplifier needs to have a high amplification in its first stage. Therefore Hetero Junction Field Effect Transistor (HJ-FETs) is used, which are not energy efficient, but reduce the relative amount of noise. Input and output matching circuits are used for the device matching. The matching technique uses the values of load and source reflection coefficients. Biasing is designed using large resistors, because energy efficiency is not of primary concern, and a large resistor prevents leakage of the weak signal out of the signal path or of noise into the signal path.

In designing LNA to meet all the standards, the first step is to determine the specification for the LNA. The second step is to choose the transistor and determine the DC bias to know the LNA operation. Transistor selection is the most important step in designing LNA. The transistor should provide high gain, low noise figure, low power consumption while preserving an easy matching frequency of operation. And the third step is to determine the input and output impedance of the LNA.

Figure 1 shows the LNA which uses an inductive source degeneration topology. M_1 is the common-source stage with the source inductive degeneration to provide enough power gain. M_2 is the common-gate stage that provides isolation for the input and output stages. Good matching can improve power transformation and noise performance. The common-gate transistor M_2 can reduce the Miller effect of the parasitic gate-drain capacitance of M_1, the input impedance of the input stage (M_1) can be written as [3], [4]:

$$Z_{in} = s(L_g + L_s) + \frac{1}{sC_{gs1}} + \frac{g_{m1}L_s}{C_{gs1}}, \quad (1)$$

Where C_{gs1} is the parasitic gate-source capacitance of M_1 and g_{m1} is the transconductance of M_1.

$$L_s = \frac{R_s C_{gs1}}{g_{m1}}, \quad (2)$$

and

$$(L_s + L_g) = \frac{1}{\omega_0^2 C_{gs1}}, \quad (3)$$

Where ω_0^2 is the operation frequency.

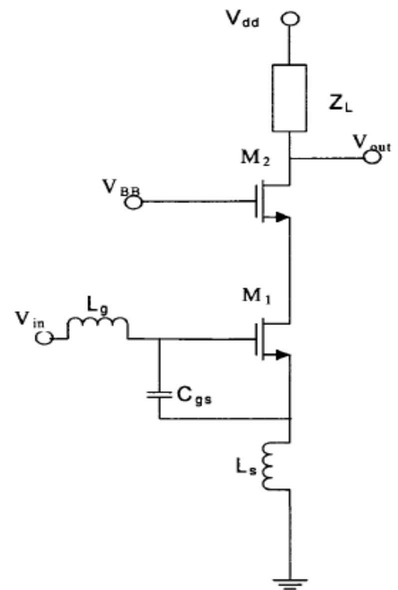

Fig 1. LNA with the Inductive Source Degeneration Topology [5]

For a LNA to work well, input matching must be achieved as well as a good noise figure performance. The porpose of input matching is to generate low input return loss across the entire bandwidth without adding more noise. The input matching network is implemented by second-order Chebyshev bandpass filter to achieve the wideband matching as shown in Fig. 2.

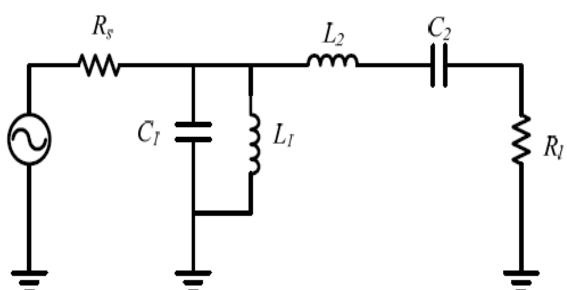

Fig 2. The Second-order Chebyshev Bandpass Filter

The LNA proposed in this paper is depicted in Fig. 3. The input impedance includes L_1, C_1, C_p, L_g, L_s, and C_{gs1}, can be written as [3], [4]:

$$Z_{in} = s(L_g + L_s) + \frac{1}{sC_T} + \frac{g_{m1} L_s}{C_T}, \quad (4)$$

To obtain matching condition, the source resistor R_s and load resistor R_l are 50Ω. The source inductor L_s of M_1 is used to generate a real term for input impedance matching. Set C_1 and L_1 in Fig. 2 equal to C_1 and L_1 in Fig.3,

$$C_1 = (C_{gs1} + C_p) = C_2, \quad (5)$$

and

$$L_1 = (L_g + L_s) = L_2 \quad (6)$$

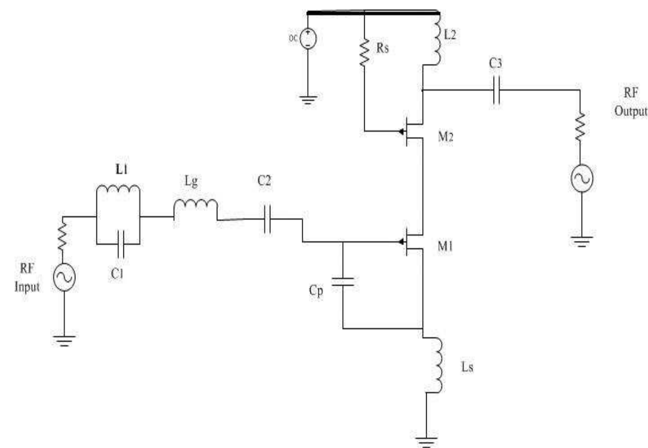

Fig 3. Design of the proposed LNA

III. Simulation Results

In this section, the simulation results of the LNA for LTE application is discussed. The LNA design has been simulated using ADS. The simulated S-parameter results are shown in Fig. 4 to Fig. 5. The diagram curve in Fig. 4 shows the return loss, while in Fig. 5 shows the VSWR result of the simulation.

Fig. 4 indicates the characteristic return loss (S_{11}) of the LNA. The simulation result shows the S_{11} is -15.032 dB at 2.35 GHz. The simulated LNA bandwidth is 282 MHz (S11 ≤ -10dB).

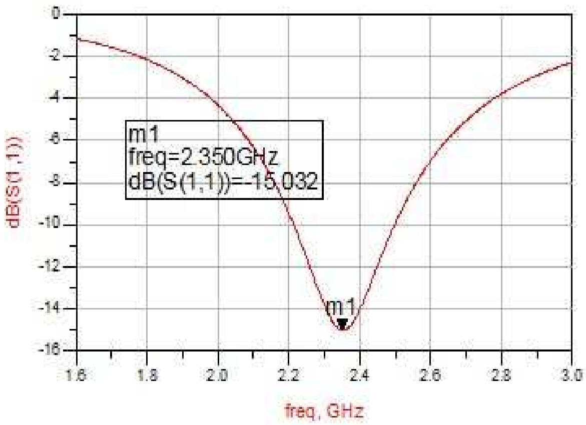

Fig. 4. Return Loss Diagram of the LNA

In Fig. 5, For VSWR < 2, the LNA bandwidth shows similar result as in Fig. 4. At the center frequency 2.35 GHz, VSWR simulated result is 1.431. This result is below the specified specification VSWR < 2.

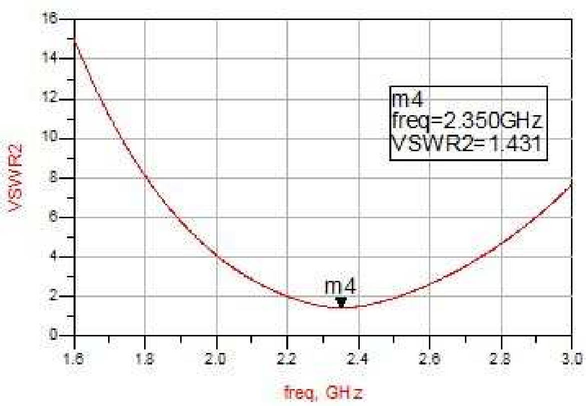

Fig. 5. VSWR Diagram of the LNA

Figure 6 shows the simulated gain (S_{21}) result of the LNA. The gain is 24.023 dB achieved at frequency 2.35 GHz.

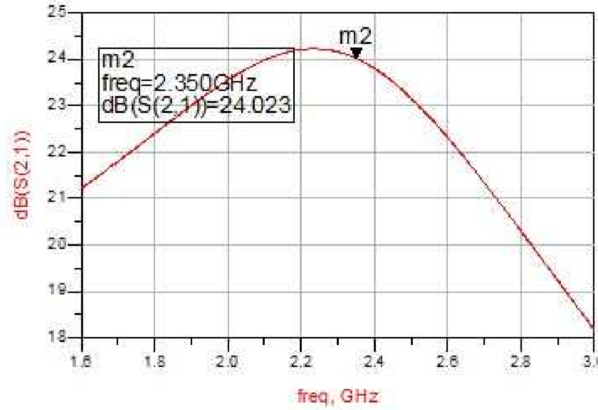

Fig. 6 Gain Diagram of the LNA

The simulated noise figure of the LNA at the frequency 2.35 GHz is 1.185 dB which is shown in Fig. 7, the noise figure is less than 2 dB, therefore, this parameter has met the desired specifications which is < 2 dB.

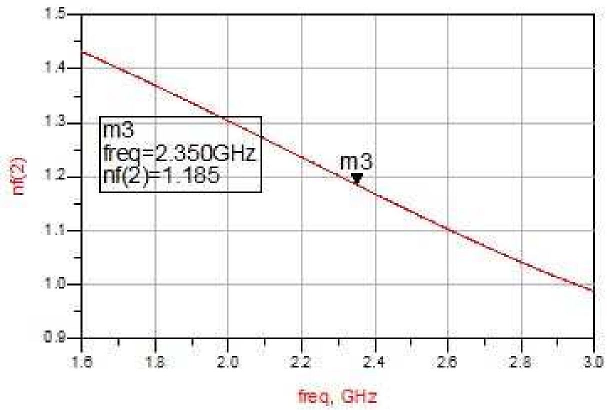

Fig. 7 Noise Figure of the LNA

An LNA is stable if it has a value of the parameter stab fact (K) is bigger than one (K >1). If K is less than one, then the LNA is in an unstable condition. Instability causes LNA experiencing oscillation, which will affect the performance of the LNA. Based on the simulation results in Fig. 8, it shows that at the frequency 2.35 GHz, the LNA design is in unstable condition. The Stab fact value is 0.659.

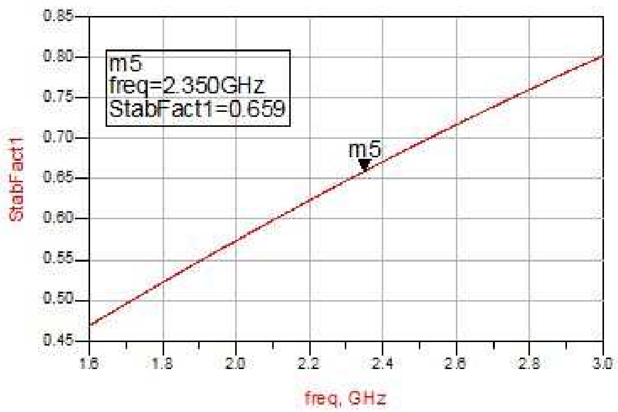

Fig. 8 Stability Factor Diagram of the LNA

From all of the simulated results of the proposed LNA, Table 1 shows all of the parameter results.

Table 1. Performance Summary of the LNA

Parameters	**Specification**	**Simulation Result**
Return Loss	< -10 dB	-15 dB
Gain	> 10 dB	24 dB
NF	< 2 dB	1.1 dB
VSWR	< 2	1.4
Stab Fact	> 1	0.6

IV. CONCLUSION

This paper proposes the LNA design with concurrent input and output matching networks for LTE application communication standards at the frequency 2.35 GHz. The simulated result shows bandwidth of 282 MHz. At frequency 2.35 GHz the parameter stab fact is 0.659, VSWR is 1.43, return loss is -15.032 dB, noise figure is 1.185 dB and gain above 24 dB. The LNA design shows good results which has reached the purposed specification of the LNA.

REFERENCES

[1] Sambit, D., Ashudeb D., Tarnn K. B., “A Gain Boosted Fully Concurrent Dual-Band Interstage Matched LNA Operating in 900 MHz/2.4 GHz with sub-2dB Noise Figure,” Communication Control and Computing Technologies (ICCCCT), 2010 IEEE International Conference. India. 2010

[2] Sambit D., Kunal D., Ashudeb D., Tarun K. B., “Fully Concurrent Dual-Band LNA Operating in 900 MHz/2.4 GHz Bands for Multi-Standard Wireless Receiver with sub-2dB Noise Figure,” Third International Conference on Emerging Trends in Engineering and Technology. India. 2010

[3] Shaeffer K. Derek, Lee H. Thomas, “A 1.5-V, 1.5-GHz CMOS Low Noise Amplifier,” IEEE Journal Of Solid-State Circuits, Vol. 32, No. 5, May 1997.

[4] Pozar, D. M. 2005. Microwave Engineering Third Edition.John Wiley & Son.Amherst.

[5] Chih, L. Hsiao, and Yi L. H., “A Low Supply Voltage Dualband Low Noise Amplifier Design,” The 13th IEEE International Symposium on Consumer Electronics (ISCE). 2009.