# LOW NOISE AMPLIFIER AT 2.4GHZ FOR WLAN APPLICATION

**SITI ADLINA BTE MD ALI**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**
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SITI ADLINA BTE MD ALI

This report is submitted in partial fulfillment of requirements for the Degree of Bachelor in Electrical Engineering (Telecommunication Electronics)

Faculty of Electronic and Computer Enginnering
Universiti Teknikal Malaysia Melaka

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"I hereby declare that this report is the result of my own work except for quotes as citied in the references."

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| Signature | :………………………………………… |
| Author | : SITI ADLINA BTE MD ALI |
| Date | : |

“I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) with honors.”

Signature : ..............................................

Supervisor’s Name : MR. ZOINOL ABIDIN BIN ABD AZIZ

Date :

For beloved mother and father

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# ABSTRACT

Wireless LAN technology is one of the needed facilities nowadays. The best coverage of Wireless LAN depends on performance of the amplifier inside the receiver block diagram. The demand of the first amplifier is low noise that can minimize the noise level of the received signal. The noise will be attenuation, interference, crosstalk and power adjacent which is added during transmission. The amplifier is known as Low Noise Amplifier (LNA). This project present of the Low Noise Amplifier at 2.4 GHz by using ATF 54143. LNA designed involve three different methods which are maximum gain, low noise and specified gain design methods. All the design was simulate in ADS2006 to perform noise figure, s parameters and stability simulations. Maximum Gain method gives maximum value of gain which is 14.549 dB and noise as 0.54 dB. For Low Noise Amplifier method, it gives the minimum value of noise which is 0.0162 dB while gain as 6.742 dB. While for Specified Gain design method, gain produced is 9.774 dB and noise is 0.5 dB.

**ABSTRAK**

Teknologi LAN tanpa wayar adalah satu kemudahan yang amat di perlukan sekarang. Liputan LAN tanpa wayar bergantung kepada prestasi penguat di dalam rajah blok penerima. Kepentingan penguat yang utama ialag hingar yang rendah dimana akan merendahkan paras hingar pada signal penerima. Hingar terdiri daripada pengurangan, campuran isyarat, cakap silang dan kuasa bersebelahan dmana hingar ini wujud semasaproses penghantaran. Penguat tersebut dikenali sebagai Low Noise Amplifier (LNA). Projek ini akan mereka Low Noise Amplifier pada 2.4 GHz dengan menggunakan ATF 54143. Rekaan LNA terdiri daripada tiga kaedah yang berlainan iaitu gain yang maksimum, hingar yang minimum dan gain yang ditentukan. Semua kaedah disimulasi menggunakan ADS2006 untuk simulasi hingar, s parameters dan kestabilan. Kaedah gain yang maksimum memberikan gain sebanyak12.549 dB dan hingar sebanyak 0.54 dB. Bagi kaedah hingar yang minimum, gain terhasil sebanyak 6.742 dB manakala hingar terhasil sebanyak 0.0162 dB. Manakala, kaedahgain yang ditentukan, gain dan hingar yang terhasil adalah sebanyak 9.774 dB dan 0.54 dB.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Over recent years, the interest in microwave techniques for communication systems has grown tremendously and also the development and the performance of microwave active and passive circuits for wireless technologies has become extremely advanced. Microwave amplifiers have become one of the most critical active circuits that employed in the system applications, [1]. Low Noise Amplifies (LNA's) are found in many applications, especially, LNA's are used to amplify the received low power signal and separate it from the noise floor, [2]

As a main function block in the RF receiver front-end, a Low Noise Amplifier plays critical role of reducing level of noise present in the signal received at antenna. Signal received at antenna has noise due to attenuation, interference, crosstalk, power adjacent. So, LNA will decrease the noise level so receiver will identify which one is useful signal.

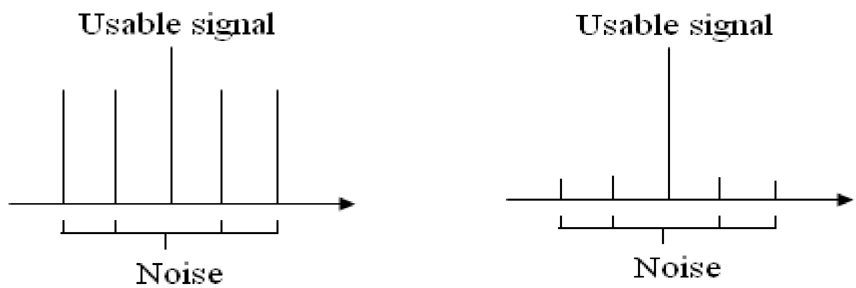

Figure 1 Low Noise Amplifier signal a) Input of LNA b) Output of LNA

## 1.2 Problem Statement

In general, received signals at receiver of Wireless LAN antenna contain noise. The medium between transmitter and receiver of Wireless LAN antenna is air, so the possibility of having noise is high. The noises are due to attenuation, interference, crosstalk and power adjacent. Transmission line also contributes to produce noise in the signal. So, received signals at receiver's antenna will have usable signal adding by noise which cannot be differentiate.

The only solution of this problem is adding Low Noise Amplifier at the first stage of receiver. The main function of LNA is to reduce the noise level present in received signal. Therefore it will gives dominant effect of noise on overall system. To select an appropriate amplifier, first understand the noise parameters for a particular application and then determined whether an amplifier is indeed low noise [3].

## 1.3 Objectives

The objectives of this Low Noise Amplifier design are to design and simulate Low Noise Amplifier circuit for WLAN application. The design, simulate and measure steps will considers stability, gain and noise figure parameters. While the design process will be done by calculates related parameters by using ideal microwave amplifier equations.

## 1.4 Scope of Work

The scope of work for this project can be divided into four parts which are:

- The first part is designing Low Noise Amplifier by using ATF 54143 – It involves selection of proper transistor, checking the transistor stability and calculates the gain and noise figure parameters by using maximum gain method. All the parameters will be calculated by using ideal microwave amplifier equations.

- The second part is simulation by using Advanced Design System (ADS2006) to make sure the results are close to the calculated design parameters.

These two steps will be used to design Single Stage Low Noise Amplifier with three different methods which are Design for Maximum Gain, Low Noise Amplifier Design and Design for Specified Gain

## 1.5 Methodology

The first step of this project is review the background of designing Low Noise Amplifier and the application in Wireless LAN system. Reviewing of LNA done by find all journals, articles, books, and website which are related. Most of the journals and articles are referring to ***Institute of Electrical and Electronics Engineers*** (IEEE) website.

Then, the second step is design process which done by calculate stability, gain and noise figure of the ATF 54143 transistor at 2.4 GHz by using maximum gain method. The parameters calculation will refer to ideal microwave amplifier equations.

The third step is simulation process that done by using Advance Design System (ADS). Before start the simulation, the study of the ADS software is done. The simulation will consider stability, gain and noise figure of the ATF 54143 transistor at 2.4 GHz. All the simulation parameters will more less same to calculated parameters.

All the third steps will be used to design Single Stage Low Noise Amplifier with three different methods which are Design for Maximum Gain, Low Noise Amplifier Design and Design for Specified Gain

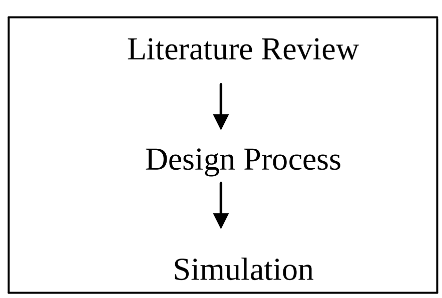


Figure 2 Project Methodology

# CHAPTER 2

# BACKGROUND STUDY

## 2.1 Introduction to WLAN Basics

New communication systems operate in the frequency range 1-100 GHz; third generation mobile phone telephony utilizes the frequency band 1.9-2.2 GHz, wireless local area networks (WLAN's) operate at the frequency band 2.4-5 GHz and automobile radar system work at 77 GHz. WLAN's data communication systems are implemented as an alternative to wired local area. It is the most convenient way to establish high speed Internet and Internet connections and distributes data throughout the area.

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A Wireless LAN (WLAN) is Wireless Local Area Network which links two or more devices by using Spread Spectrum or Orthogonal Frequency Division Multiplexing (OFDM). This enables communications between devices in a limited area. Users can move around within a broad coverage area and still be connected to the network. The advantages of WLAN are easy installation and location freedom suitable for home user and public business [4].

## 2.2 Standard of WLAN

The market of Wireless Local Area network (WLAN) is in constant explosion since its appearance in the 90's. The constant demand on increased speed has pushed the early 802.11 standard. It is also known as WiFi with 2 Mb/s data rate to move 802.11b standard with 11 Mb/s data rate and finally to the 802.11g which reaches 54 Mb/s data rate. Both 802.11b and 802.11g standards are operates at 2.4 GHz. IEEE 802.11 is family of wireless standards [4].

Table 1 WLAN IEEE 802.11 Standard [5]

| **Protocol** | **802.11a** | **802.11b** | **802.11g** |
|---|---|---|---|
| **Release Date** | 1999 | 1999 | 2003 |
| **Frequency (GHz)** | 5.15-5.35<br>5.47-5.725<br>5.725-5.875 | 2.4-2.5 | 2.4-2.5 |
| **Max Bandwidth (Mbps)** | 54 | 11 | 54 |
| **Range Indoor (m)** | 25 | 35 | 25 |
| **Range Outdoor (m)** | 75 | 100 | 75 |

802.11b works on the frequency of 2.4 GHz with maximum bandwidth of 11 Mbps. 802.11b uses DSSS (Direct-sequence spread spectrum) and CCK (Complementary Code Keying) on the frequency 2.4 to 2.483 GHZ. DSSS is the modulation technique in which transmitted signal takes up more bandwidth than the information signal that is being modulated. Its range in the indoor environment is about 35 meters and 100 meters in outdoor environment.

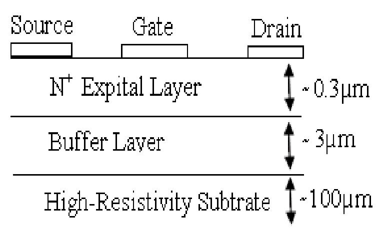
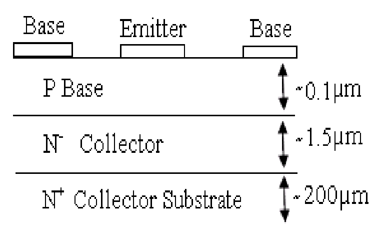
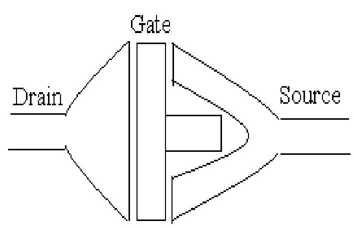
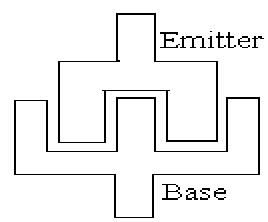
802.11g was released in June 2003. It works on frequency of 2.4 GHz, but its maximum bandwidth is 54 Mbps. 802.11g uses Orthogonal Frequency-Division Multiplexing (OFDM) for 54, 48, 36, 24, 18, 12, 9, 6 Mbps. For 11 and 5.5 Mbps it uses CCK and DSSS (like 802.11b). Its range in the indoor environment is about 25 meters and 75 meters in outdoor environment.

## 2.3 Characteristics of Microwave Transistors

Microwave transistors are used as amplifiers, oscillators, switches, phase shifters, mixers and active filters. Most of these applications used either silicon bipolar transistors or GaAs field effect transistors (FETs). Silicon bipolar device technology is very mature and inexpensive compared to GaAs transistor technology. Bipolar transistors are capable of higher gain and power capacity at lower frequencies, but GaAs FETs generally have better noise figures and can operate at much higher frequencies.

Microwave Field Effect transistors can be used at frequencies well into the millimeter wave range with high gain and low noise figure, making them the device of choice for hybrid and monolothic integrated circuits at frequencies above 5 to 10 GHz [5]. In order to operate the transistor, positive $\mathbf{V_{ds}}$ is supply to drain port. An input signal voltage on the gate then modulates majority electron carriers from drain producing voltage amplification. The gate length of the transistor limits the maximum frquency of operation. FET's have gate lenghts 0.3 to 0.6 µm with upper frequency lomits of 100 to50 GHz.

Microwave bipolar transistors are usually of the NPN type and are often preferred over GaAs FETs at frequencies below 2 to 4 GHz because of the higher gain and lower cost [5]. Noise figure of bipolar transistors is not good as FETs because bipolar transistors are subject to shot noise as well as thermal noise effects. Figure 3 summarizes the cross section, top view and equivalent circuit of transistors GaAs FETs and Silicon Bipolar.

<table>
<tr><th>Transistor</th><th>GaAs FET</th><th>Silicon Bipolar Transistor</th></tr>
<tr><td>Cross Section of Transistor</td><td>
</td><td>
</td></tr>
<tr><td>Top View of Transistor</td><td>
</td><td>
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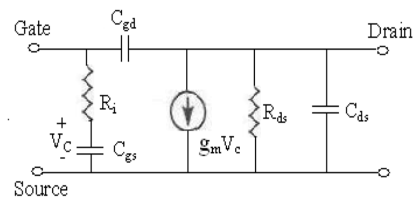
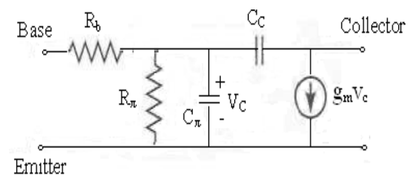
<tr>
<td>Equivalent Circuit</td>
<td>Common Source Configuration<br><br><br>$R_i$ (series resistance) = 75Ω<br>$R_{ds}$ (drain to source resistance) = 40Ω<br>$C_{gs}$ (gate to source capacitance) = 0.3pF<br>$C_{ds}$ (drain to source capacitance) = 0.12pF<br>$C_{gd}$ (gate to drain capacitance) = 0.01pF<br>$g_m$ (transconductance) = 40ms</td>
<td>Common Emitter Configuration<br><br><br>$R_b$ (base resistance) = 7 Ω<br>$R_\pi$ (equivalent π resistance) = 110 Ω<br>$C_\pi$ (equivalent π capacitance) = 18 pF<br>$C_c$ (collector capacitance) = 18 pF<br>$g_m$ (transconductance) = 900ms</td>
</tr>
</table>

Figure 3 The cross section, top view and equivalent circuit of transistors GaAs FETs and Silicon Bipolar. [5]

## 2.4 Single Stage Transistor Amplifier

Basically, amplifier is devices that will be used to amplify the receive signal to the appropriate amplitude correspond to the transistor’s gain. Amplifier distribute into two groups which are Radio Frequency (RF) amplifier and analog amplifier. The RF amplifier will be used for high frequency while analog amplifier will be used for low frequency. Power Amplifier and Low Noise Amplifier are a part of RF amplifier while Audio Amplifier and Optical Amplifier are a part of Analog Amplifier.