WLAN LOW NOISE AMPLIFIER USING HBT TECHNOLOGY

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This report is submitted in partial fulfillment of requirements for the award of Bachelor Degree of Electronic Engineering (Telecommunication Electronic Engineering) with honours

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DEDICATION

To my beloved father and mother

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ABSTRACT

Demand for WLAN system is increasing and keep improving with new technologies. One of the problems faced by WLAN system is noise caused by propagation through air, electron movement and interfacing signal that degrade the transceiver system performance. Then, this thesis presented a Low Noise Amplifier (LNA) design to overcome the weak receive signal pick up by antenna. This thesis shows the process done on the design simulation of Low Noise Amplifier with important characteristics such as gain, noise figure (NF), stability, power consumption and complexity. Advance Design System (ADS) is used to design and simulate the LNA circuit for 2.4GHz. Method that used in this design is single stage and BFP 640 NPN Silicon Germanium RF transistor by Infineon Technologies is choose due to the simplest configuration offered for an amplifier design. Then, the designed circuit is fabricated using FR4 board and to performance of the designed has been tested using Network Analyzer. The design has successfully minimized the noise figure and provides sufficient gain for WLAN transceiver system.

ABSTRAK

Permintaan terhadap sistem WLAN meningkat dari hari ke hari dengan pelbagai teknologi baru. Salah satu masalah yang terdapat di dalam sistem WLAN adalah hingar yang disebabkan oleh penyebaran melalui udara, pergerakan elektron dan isyarat antaramuka yang merendahkan pencapaian sistem pemancar-penerima tersebut. Seterusnya, tesis ini membentangkan tentang rekabentuk penguat hingar yang bertujuan untuk mengatasi isyarat yang lemah pada penerima yang dihantar ke antena. Tesis ini juga menunjukkan proses yang telah dilakukan untuk menyiapkan simulasi rekabentuk penguat hingar rendah dengan beberapa ciri penting seperti gandaan, angka hingar, kestabilan, penggunaan kuasa dan kekompleksan. Perisian *Advance Device Systme(ADS)* digunakan untuk merekabentuk dan membuat simulasi untuk litar penguat hingar rendah pada 2.4GHz. Kaedah yang digunakan ialah rekabentuk peringkat pertama dan Transistor NPN Silicon Germanium BFP640 yang dikeluarkan oleh Infineon Technologies dipilih berdasarkan ciri – ciri istimewa yang ditawarkan untuk rekabentuk penguat. Kemudian, litar yang telah direkabentuk dibina menggunakan papan jalur FR4 dan keupayaan rekabentuk tersebut diuji dengan menggunakan *Network Analyzer*. Rekabentuk ini berjaya meminimumkan sistem angka hingar ini dan menyediakan gandaan yang baik untuk sistem pemancar-penerima WLAN.

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LIST OF ABBREVIATIONS

°K	-	Kelvin
ADS	-	Advanced Design System
CDMA	-	Code-Division Multiple Access
CMOS	-	Complementary Metal Oxide Semiconductor
Db	-	Decibel
DBS	-	Direct Broadcast Satellite
FR4	-	Flame Retardant 4
GPS	-	Global Positioning System
GSM	-	Global System for Mobile
HBT	-	Heterojunction Bipolar Transistor
HEMT	-	High Electron Mobility Transistor
I_B	-	Base Current
Ic	-	Collector Current
IEC	-	International Electrotechnical Commission
IEEE	-	Electrical and Electronics Engineers
ISM	-	Industrial Scientific and Medical
JFET	-	Junction Gate Field-Effect Transistor
LNA	-	Low Noise Amplifier
OFDM	-	Orthogonal Frequency Division Multiplexing
PCB	-	Printed Circuit Board
RF	-	Radio Frequency
SiGe	-	Silicon Germinium
SMA	-	SubMiniature version A
SNR	-	Signal to Noise Ratio
SONET	-	Synchronous Optical Network
S-parameters	-	Scatter Parameters

UHF	-	Ultra-High Frequency
UV		Ultra Violet
V_{BE}	-	Base Emitter Voltage
V_{CE}	-	Collector Emitter Voltage
Z	-	Impedance
Zin	-	Input impedance
Zin	-	Normalize value of input impedance
Z_L		Load impedance
Zo		Characteristic impedance
Z_T		Transformer impedance
Ω		Ohm

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CHAPTER I

INTRODUCTION

1.1 Introduction

In a receiver design it is critical to have a good front end in order to have good overall system performance. Among the front end components, the Low Noise Amplifier, or LNA is very important in setting the noise figure of the entire system.

Low noise amplifiers represent one of the basic building blocks of the communication system. The purpose of the LNA is to amplify the received signal to acceptable levels while minimizing the noise it adds. Figure 1 shows a system level diagram of the wireless local area network. The reduction in the signal due to losses during transmission, reception and power dissipation in circuit components must be compensated by using a device to provide sufficient gain for the receiver circuit.[6]

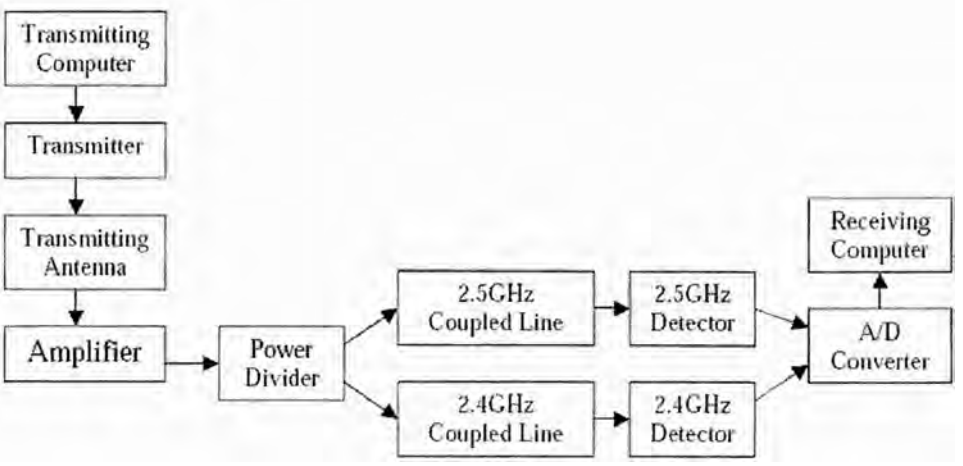

Figure 1.1: System Level Diagram - A Wireless Local Area Network

The approach taken to design the amplifier involves a series of chronological steps. No design is complete without some desired goals. The design specifications for the low noise amplifier were as follows:[6]

a) Gain > 20 dB
b) Noise Figure < 1.5 dB
c) Use microstrip – matching networks
d) S_{11} and S_{22}.<-15dB

1.2 Research Background

Over the past number of years, there is rapid changing in low noise technology. From early 1980s, the achievements of technological innovations especially in low noise technology not only improved devices, subsystems and systems, but also increased the demand in new market. Thus, high performances as well as low cost in fabrication make designer task more challenging.[7]

Although Low Noise Amplifier (LNA) performance was extremely good nowadays, the design engineer still had to make some complex system trades. Many LNA were large, heavy and consumed a lot of power. For an example in satellite ground terminals, low noise performance, lighter weight, low power and high

reliability of LNA are required. Unfortunately, it is not always achieved because of limitation in some factors.[7]

The bipolar junction transistor was the first solid-state active device to provide practical gain and Noise Figure (F) at microwave frequencies. Then, Silicon-Germanium (SiGe) Heterobipolar technology has generated worldwide interest for digital, analog and RF applications because it combines the transistor performance of III-V technologies with the manufacturability, high yield and low cost associated with conventional silicon integrated circuit (IC) fabrication. At present, SiGe technology development is mainly focused on NPN SiGe Heterobipolar transistors.[8]

From random processes such as the flow of charges or holes in an electron tube or solid-state device, propagation through the ionosphere or other ionized gas and the thermal vibration in any component at a temperature above absolute zero will produce some noise. Noise can be passed into a microwave system from external sources or generated within the system itself. In either case the noise level of the system sets the lower limit on the strength of a signal that can be detected in the presence of the noise. Thus, it is generally desired to minimize the residual noise level of communication receiver or radar to achieve the best performance [2]. Since the noise figure is the measured of receiver noise, it is important to obtained low noise figure as possible.

This project is concentrate on designing low noise amplifier, which has operating frequency at 2.4GHz. Wireless networking using the unlicensed 2.4-2.5GHz frequency band is the most popular form of radio based networking. The range of kit is massive with many hundreds of competitive kit available from simple PCMCIA cards for notebook computers up to powerful bridging units designed to link buildings.

1.3 Problem Statement

There are several problems with the current low noise amplifier system. In reality, wireless channel and the receiver circuit add noise. If noise become large enough compared to the desired signal, an error will occur. Then, most of the transistor is unable to handle higher noise and cannot operate at higher frequency. Another problem is low noise amplifier usually implies RF/wireless applications. But noise still a critical consideration for lower frequency analog applications. In order to avoid this, the purpose of this project is produced. To select the appropriate amplifier, firstly, understanding the noise parameters for a particular application are needed and the amplifier need to be determined whether the amplifier is suitable or not for this project.

1.4 Objectives

The objectives of the project are:

a) to study the characteristic and the specification of low noise amplifier (LNA), specifically on LNA 2.4GHz application and wireless applications.
b) to design and simulate a low noise amplifier 2.4GHz using Microwave design software with varies of parameters.
c) to fabricate and develop a low noise amplifier 2.4GHz using microstrip technology.
d) to learn and practice technical skills to overcome problems occurred in implementing the project.

1.5 Scopes of Work

This project is divided into several parts. Firstly, design and simulation part. This project will design WLAN LNA 2.4GHz. ADS2004 A is used in order to get the require results which are close to theoretical results. Secondly, the fabrication process will be done by using Microstrip, Printed Circuit Board (PCB) laminate like

standard low cost Flame Retardant 4 (FR4), SubMiniature version A (SMA) connector, Aluminum sheet and etching facilities. Lastly, testing and measurement part, this will include noise figure and gain of the circuit. The performance of the designed amplifier is verified on the board by using RF test equipment such as network analyzer and function generator.

1.6 Thesis Structure

This thesis is divided into five chapters and covered the research overview for LNA circuit design. Chapter 2 reports the literature review of the basic concepts in LNA circuit design. Chapter 3 described project methodology and development on how the design, simulation and fabrication process. The Advance Design System (ADS) software was used in order to design and simulate. The simulation and measurement results are reported in Chapter IV known as result. Chapter IV also discussed result from simulation and measurement. Chapter V concluded the research work and give suggestions for future development of the research project.

CHAPTER II

LITERATURE REVIEW

2.1 Low Noise Amplifier

The low noise amplifier (LNA) is a special type of electronic amplifier or amplifier used in communication systems to amplify very weak signals captured by an antenna. It is often located very close to the antenna. If the LNA is located close to the antenna, then losses in the feedline become less critical. This "active antenna" arrangement is frequently used in microwave systems like Global Positioning System (GPS), because coaxial cable feedline is very lossy at microwave frequencies.

It is a key component, which is placed at the front-end of a radio receiver circuit. Per Friis' formula, the overall noise figure of the receiver front-end is dominated by the first few stages.

Using a LNA, the noise of all the subsequent stages is reduced by the gain of the LNA and the noise of the LNA is injected directly into the received signal. Thus, it is necessary for a LNA to boost the desired signal power while adding as little noise and distortion as possible, so that the retrieval of this signal is possible in the later stages in the system.[11]

For low noise the amplifier needs to have a high amplification in its first stage. Therefore Junction Gate Field-Effect Transistor (JFET), High Electron

Mobility Transistor (HEMT) or Heterojunction Bipolar Transistor (HBT) is used and distributed amplifiers could be used. They are driven in a high current regime, which is not energy efficient, but reduces the relative amount of shot noise. Input and output matching circuits for narrow band circuits enhance the gain (see gain-bandwidth product) and do not use resistors, as these will add noise. Biasing is done by large resistors, because energy efficiency is not needed, and a large resistor prevents leakage of the weak signal out of the signal path or noise into the signal path. The application of LNA is shown on Figure 2.1 (basic Radio Frequency (RF) block consists of nine function blocks).

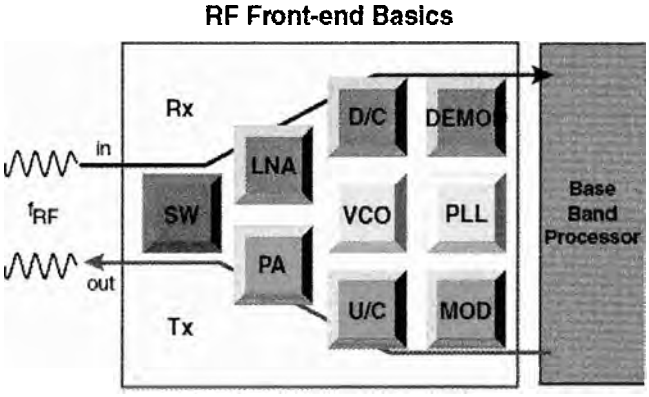

Figure 2.1: Microwave Basic Blocks

2.2 Microwaves

Microwaves are electromagnetic waves with wavelengths shorter than one meter and longer than one millimeter, or frequencies between 300 megahertz and 300 gigahertz.

Apparatus and techniques may be described as "microwave" when the wavelengths of signals are roughly the same as the dimensions of the equipment, so that lumped-element circuit theory is inaccurate. As a consequence, practical microwave technique tends to move away from the discrete resistors, capacitors, and inductors used with lower frequency radio waves. Instead, distributed circuit