DESIGN OF A LOW NOISE AMPLIFIER FOR 5-6GHz APPLICATIONS

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Date : **3 MAY 2007**

To my beloved mother, father, family and my friend

&

Mr. Abd Majid Bin Darsono and other members.

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ABSTRACT

The following report presents the process done on the design simulation of a low noise amplifier. The purpose of the amplifier is to amplify the received RF path of a Wireless local area network (WLAN). The design methodology required the analysis of the transistor stability and proper matching network selection. The design of an LNA in Radio Frequency (RF) circuits requires the trade-off of many importance characteristics such as gain, noise figure (NF), stability, power consumption and complexity. This situation forces designers to make choices in the design of RF circuits. The design specifications for this amplifier were not very demanding (compared to the industry) due to the nature of it being a first time design. This was the main reason why the BFP640 NPN Silicon Germanium RF transistor (Infineon Technologies) was chosen over others due to the simplest configuration it offers for an amplifier design. Several measurement techniques using design tool Advanced Design System (ADS) for simulations where the noise circles and available gain circles are the tools that give the most guidance on the design tradeoffs, while FR4 strip board is used for fabrication purposed and the Network Analyzer for the practical testing of the amplifier were used to verify the performance of the designed amplifier.

ABSTRAK

Laporan ini menyatakan penyelesaian proses dalam rekabentuk penguat hingar rendah. Penguat/amplifier ini bertujuan untuk menguatkan laluan terima frekuensi radio untuk Wayarles Rangkaian Tempatan (WLAN).Rekabentuk metodologinya memerlukan analisis bagi kestabilan transistor dan pemilihan rangkaian padanan. Rekabentuk untuk penguat hingar rendah dalam litar frekuensi radio memerlukan banyak perbincangan mengenai kepentingan ciri-cirinya,contohnya seperti gandaan, angka hingar, kestabilan, penggunaan kuasa dan kekompleksan. Situasi ini memerlukan perekabentuk membuat keputusan dalam merekabentuk litar frekuensi radio. Spesifikasi rekabentuk untuk penguat ini tidak terlalu memerlukan kemahiran atau tenaga yang banyak (berbanding dengan industri) ini wajar semasa pertama kali merekabentuknya. Maka ia merupakan tujuan mengapa RF transistor BFP640 NPN Silicon Germanium (Infineon Technologies) dipilih untuk tatarajah mudah bagi merekabentuk penguat ini. Beberapa teknik pengukuran menggunakan perisian Advanced Design System (ADS) digunakan untuk penyelesaian, dimana hingar bulatan dan gandaan bulatan tersedia ada merupakan perkakasan sebagai panduan untuk merekabentuk. Manakala papan jalur FR4 digunakan untuk tujuan pembikinan dan analisis rangkaian untuk pengujian praktikal bagi penguat untuk menentukan perlaksanaan merekabentuk penguat .

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LIST OF ABREVIATIONS

ADS	- Advance Design System
B	- Bandwidth
CAD	- Computer Aided Tool
CMOS	- Complementary Metal-oxide Semiconductor
DC	- Direct current
F	- Noise Figure
BJT	- Bipolar Junction Transistor
FR4	- Flame Retardant 4
Freq	- Frequency
GaAs	- Gallium Arsenide
GHz	- Giga Hertz
IEEE	- Institute of Electrical and Electronic Engineering
K	- Rollet stability factor
k	- *Boltzman's constant*
LAN	- Local Area Network
LNA	- Low Noise Amplifier
mag	- Magnitude
MESFET	- Metal Semiconductor Field Effect Transistor
MHz	- Mega Hertz
MMIC	- Monolithic Microwave Integrated Circuit
MOSFET	- Metal Oxide Field Effect Transistor
N	- Noise Figure Parameter
P	- Power
pHEMT	- Pseudomorphic High Electron Mobility Transistors

R	- Resistance
RF	- Radio Frequency
RFIC	- Radio Frequency Integrated Circuit
UNII	- Unlicensed National Information Infrastructure
VSWR	- Voltage Standing Wave Ratio
WLAN	- Wireless Local Area Network
Γ	- Reflection Coefficient
Γ_{vt}	- Input reflection coefficient
Γ_{Λ}	- Load reflection coefficient
Γ_{Σ}	- Source reflection coefficient
*	- Multiply
λ	- Wavelength
Δ	- Determinant of the scattering matrix
Ω	- Ohm
°X	- Celsius
°K	- Kelvin
C_F	- Center of constant noise circle
dB	- Decibel
E_Eff	- Electrical length
Freq	- Frequency in ADS
Fmin	- Minimum noise figure (equivalent to NFmin from ADS)
g	- Gram
G	- Gain
G_A	- Available gain
G_T	- Transducer gain
H	- Substrate thickness
l	- Length of quarter-wave transformer
L	- Length
N_i	- Noise parameter
R_F	- Radius of constant noise circle

rms	- Root mean square
V	- Volt
W	- Width
mA	- Milliampere
ml	- Milliliter
Z	- Impedance
Z_o	- Characteristic impedance
Z_T	- Transformer impedance
Z_{in}	- Input impedance
Z_L	- Load impedance
z_{in}	- Normalize value of input impedance
z_L	- Normalize value of load impedance
SiGe	- Silicon Germanium

LIST OF APPENDICES

CHAPTER I

1.1 INTRODUCTION

In today wireless communication system, Low Noise Amplifier (LNA) is the first amplifier device in the receiver chain. 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 1.1 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.

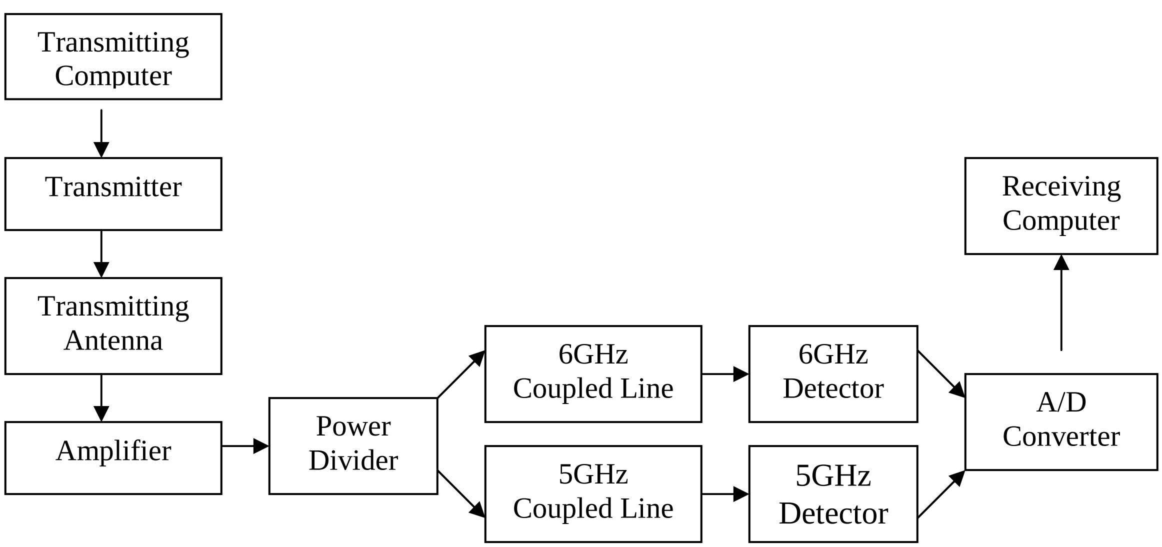

Figure 1.1: System level diagram of the wireless local area network.

As the name implies, it is used to amplify the low level signal that presents at the receiver input to level that is well above the noise threshold of the subsequent stages, without significantly contribute to that noise itself. Low Noise Amplifier can be considered as a key component and it performance has significant impact to the whole communication system, because the noise figure of the receiver is dominated by the first stage of the cascaded amplifiers. The noise of the Low Noise Amplifier will pass to the subsequent stages which then be reduced by the gain of the Low Noise Amplifier and the gain of rest of the cascaded amplifiers. To ensure the retrieval of signal is possible in the later stage of the communication systems, it is necessary that the Low Noise Amplifier is able to amplify the received signal to an acceptable power without adding much noise or cause distortion to the received signal. [1]

In this project, a high-performance, low-cost, highly repeatable two-stage low noise amplifier (LNA) for use in 5GHz to 6GHz wireless applications is presented. The final product used throughout this project is BFP640 NPN Silicon Germanium RF transistor, for WLANs systems and cordless phones using the 5GHz to 6GHz frequency range. The BFP640 silicon germanium RF transistor offers a high performance, power-efficient solution for a broad range of high-frequency low noise amplifier (LNA) designs.

This project will deals mostly with Low Noise Amplifier design, fabricating and testing the amplifier using microstrip technology. 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: [9]

- Frequency Band = 5-6GHz
- Noise Figure > 1.2dB
- Power Gain > 15dB
- S_{11} and S_{22} < -15dB
- Use Microstrip = Matching Network

1.2 PROBLEM STATEMENTS

In general, the RF performance of the Low Noise Amplifier is very good as it able to achieve the required gain and provides low noise figure. As for the different biasing circuit, active biasing does not offer much advantage over the passive biasing circuit. The only improvement recorded is the noise figure performance of the Low Noise Amplifier with active biasing circuit. The bipolar junction transistor was the first solid-state active device to provide practical gain and noise figure (F) at microwave frequencies.

The matching networks can be changed to lump elements for space reduction and cost saving. Low Noise Amplifier usually implies RF/wireless applications. But noise is also a critical consideration for lower frequency analog applications. In order to avoid this, the purpose of this project comes in. To select an appropriate amplifier, first understand the noise parameters for a particular application and then determined whether an amplifier is indeed low noise.

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.

1.3 OBJECTIVES

The objective of the research project is to design, simulate and fabricate Low Noise Amplifier (LNA) at 5 to 6 GHz. The designed require low noise figure, sufficient gain, technically stable and a good matching network in a specified frequency range.

The gain is expectedly higher than 15 dB and noise figure value must below than 1.2dB. The designed LNA should able to work under unconditionally stable state along the frequency band. Finally, the designed LNA should work properly in the Wireless Local Area Network (WLAN) environment.

1.4 SCOPES OF WORK

Scope of this project can be divided into three parts:

1. Simulation – It will be done by varying parameters using Advanced Design System (ADS) in order to get the required results which are close to the theoretical results.
2. Fabricating – The fabrication of the Low Noise Amplifier will be done using Microstrip, PCB laminate (e.g.: Standard low cost FR-4), aluminums sheet, etching facilities.
3. Test analysis– A test analysis is the last stage in this project. The performance of the designed amplifier circuit is verified on board using the RF testing equipment such as the vector network analyzer and cable.

1.5 THESIS STRUCTURE

The thesis is divided into five chapters and covers the research works that have been through for Low Noise Amplifier circuit design. Chapter 2 reports the literature review of the basic concepts in Low Noise Amplifier circuit design. Chapter 3 describes the design and simulation process. The Advance Design System (ADS) software was used to do the design and simulation process. The simulation and measurement results are reported in Chapter 4. This chapter also includes discussion from simulation and measurement results. Chapter 5 concludes the research work and gives suggestion for future development of the research project.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

One of the largest growth areas in electronics over the past decade has undoubtedly been in applications of wireless communication. Semiconductor technologies have been a key to this growth, bringing added convenience and accessibility through advantages in cost, size, and power dissipation. Wireless products and systems thrive on this increased utility, the commercial momentum of which has been fueling further investment in integrated circuit designs and technology. The resulting advancement in system capabilities has developed greater interest and receptiveness on the part of the consumer, leading to more applications being envisioned, and necessitating more available spectrum to support the wireless infrastructure. [6]

To obtain this added bandwidth and alleviate interference, the frequencies of the communication channels are necessarily edging upward, placing yet more demands on the technologies used to implement the wireless systems. Several recently opened ISM bands in the 5-6GHz range have been allocated for unlicensed operation of broadband wireless links between portable devices, computers, and the Internet.

This chapter develops some basic principles used in the analysis and design of microwave Low Noise Amplifier (LNA). The most important design considerations in a microwave Low Noise Amplifier are stability, power gain, and bandwidth, noise, and dc requirements. Research has been done to study:

- Low Noise Amplifier properties (briefly).
- Low Noise Amplifier design.
- Transistor specifications.
- Types of software (e.g.: Microwave Office and Advanced Design System (ADS)).

Figure 2.1 shows a design flow of this project.

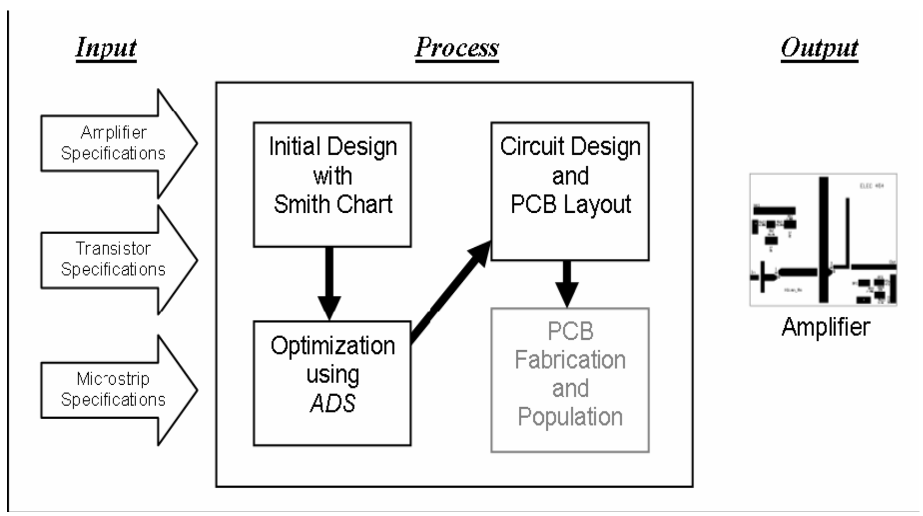

Figure 2.1: Design flow of the project.

This chapter will discuss about microwave transistor, DC biasing, two port power gain, stability and noise in two-port.