DESIGN OF LOW NOISE AMPLIFIER FOR ULTRAWIDE BAND APPLICATION

RAJA AHMAD KAMIL BIN RAJA YACOB

This report is submitted in partial fulfillment of the requirements for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) With Honors

Faculty of Electronic and Computer Engineering

Universiti Teknikal Malaysia Melaka

May 2009

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek	:	DESIGN OF LOW NOISE AMPLIFIER FOR ULTRAWIDEBAND APPLICATION
Sesi Pengajian	:	2008/2009

Saya RAJA AHMAD KAMIL BIN RAJA YACOB mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (√)

☐	SULIT*	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD*	(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐	TIDAK TERHAD	

Disahkan oleh:

(TANDATANGAN PENULIS) (COP DAN TANDATANGAN PENYELIA)

Alamat Tetap: NO. 8, JALAN 11,
TAMAN GOMBAK,
68100 BATU CAVES,
SELANGOR D.E.

Tarikh: April 27, 2009 Tarikh: ....

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

Signature :

Author : Raja Ahmad Kamil Bin Raja Yacob

Date : April 27, 2009

"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 :

Author : Mr. Azahari Bin Salleh

Date : April 27, 2009

For beloved and supporting parents,

Rosnani Bte Md Yusoff

Raja Yacob Bin Raja Abdullah

ACKNOWLEDGEMENT

First of all, praise to Allah SWT, Most Merciful for His guidance and blessing. Lots of thanks to my beloved family, who‟s given constant encouragement and love I have relied throughout my time at the university. Their unflinching courage and conviction will always inspire me, and I hope to continue, in my own small way, the noble mission to which they gave their lives. It is to them that I dedicate this work.

I would like to express my deep and sincere gratitude to my supervisor; Mr. Azahari Bin Salleh. His wide knowledge and his logical way of thinking have been of great help for me. Furthermore, he always helps and guides me in fulfilling and understands the task to be done.

Finally, I would like to express appreciation to all my friends and other people who have helped me with my work and for their cooperation, support and encouragement directly or indirectly. Thank you.

ABSTRACT

Over the years, wireless communication becomes most important communication type in the world because of its ability to evolve. Low Noise Amplifier (LNA) is located at front end of receiver system, which makes it one of the important parts to retrieve signals. Federal Communication Commission has licensing on the use of Ultra Wide Band (UWB) frequency (ranging from 3.1 GHz to 10.6 GHz) due to its benefits that are transmits information using very low power, short impulses thinly spreading over a wide bandwidth, high data rate and less multipath fading [1]. From statement above, this project is to design a LNA that will work on UWB spectrum using transistor pHEMT Mitsubishi Semiconductor MGF4941AL in AWR Microwave Office. Beginning from a sketch, this project will show steps to design using several methods, that is; Cascaded 3-Pin-Point Amplifier, 3-Stage Balance Amplifier and 3-Stage Feedback Amplifier, and analyze the LNA designed. The LNA designed operate in UWB spectrum, Noise Figure (NF) < -3dB, constant gain > 15dB, and matched over the bandwidth. The best technique is 3-Stage Feedback Amplifier which gave S_{21} value as high as 39.93dB with fluctuation only 0.71dB, and NF as low as 1.647dB maximum.

ABSTRAK

Semakin dunia melangkah ke hadapan, komunikasi tanpa wayar menjadi satu fenomena yang rancak dan penting kepada tamadun manusia berdasarkan keupayaannya untuk maju. Lokasi Penguat Rendah Hingar (LNA) adalah di hadapan sistem penerima; mengakibatkan ianya menjadi satu komponen yang penting dalam penerimaan isyarat. Pertubuhan Komunikasi Bersatu (*Federal Communication Commission* - FCC) meluluskan penggunaan frekuensi Jalur Amat Lebar (*UltraWide Band* - UWB) (dari 3.1 GHz ke 10.6 GHz) kerana kelebihan-kelebihan yang wujud seperti menghantar isyarat dengan menggunakan kuasa yang amat rendah, jejarum halus bertebaran di sepanjang jalur lebar, kadar penghantaran isyarat yang tinggi dan kurang resapan dari saluran yang banyak [1]. Daripada pernyataan-pernyataan di atas, objectif projek ini adalah untuk merekabentuk LNA yang akan berfungsi dalam jalur lebar UWB berasaskan transistor pHEMT Mitsubishi Semiconductor MGF4941AL dengan menggunakan perisian AWR Microwave Office. Proses merekabentuk LNA ini dilakukan menggunakan 3 kaedah; *Cascaded 3-Pin-Point Amplifier, 3-Stage Balance Amplifier* dan *3-Stage Feedback Amplifier*, serta analisa. LNA yg direkabentuk adalah berfungsi dalam jalur lebar UWB, Hingar (*Noise Figure* - NF) kurang dari 3dB, penggandaan sekata lebih dari 15dB. Kaedah terbaik ialah *3-Stage Feedback Amplifier* yang memberi nilai S_{21} setinggi 39.93dB dengan perolakan nilai hanya sebanyak 0.71dB dan NF serendah 1.647dB paling tinggi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

UWB	-	Ultra-Wide Band
LNA	-	Low Noise Amplifier
RF	-	Radio Frequency
MMIC	-	Monolithic Microwave Integrated Circuit
FCC	-	Federal Communication Commission
SNR	-	Signal to Noise Ratio
PAN	-	Personal Area Network
DS-CDMA	-	Direct Sequence Code Division Multiple Access
MB-OFDM	-	Multi-Band Orthogonal Frequency Division Multiplexing
CMOS	-	Complementary Metal-Oxide Semiconductor
FET	-	Field Effect Transistor
MAI	-	Multiple Access Interference

CHAPTER 1

PROJECT BACKGROUND

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. Broadband amplifiers with good performance have been successfully realized in the past 3 decade in hybrid and monolithic technologies. Therefore the wide bandwidths amplifiers have been firmly establish in the fields of microwave, optical communication, instrumentation and Electronic Wars (EW).

The implementation of LNA front-ends is one of the challenging aspects in emerging Ultra Wide-Band (UWB) radio frequency (RF) systems. The design of broadband amplifier introduces new difficulties which require careful considerations. Basically, the design of amplifier over a broad frequency range is a matter of properly designing the Maximum Conjugate matched circuit, Balance Amplifier, Feedback Amplifier in order to compensate for the variations of frequency [6].

The techniques that mentioned above, had been employed for the broadband systems as it is being firmly establish, reliable and robust devices that can be realized in MMIC and UWB technologies. In this project, this method of broadband amplifier had been choose and design using Microwave Office due to the excellent bandwidth performance, low noise figure and also this devices become very popular. This is because the input and output capacitances of the active devices are absorbed in the distributed structures. As a result, the amplifier can exhibits very low sensitivities in process variations when designing and simulate.

As the first stage of the receiver, LNAs are required to have high gain and low Noise Figure (NF). Many implementations of narrow band LNAs exist in background study part and understood. From the perspective of a basic two-port, it can be shown that the optimum driving source susceptance for minimum NF is inductive in character, but has a capacitive variation. Furthermore, the optimum driving conductance should vary linearly with frequency. Achieving such a noise match, together with a good source impedance termination is especially difficult for wide-band systems as it involves synthesizing a network that provides these characteristics over a large frequency range [13].

Recently, several innovative wide-band LNA architectures have been proposed to take on this challenge. In this work, 3 different techniques are used for Ultra-Wide Band amplifier to replace the conventional distributed amplifier that suffers from relatively high power consumption. This work focuses on the design and analysis of techniques with emphasis on low power. In order to understand the high gain, low noise figure and bandwidth of the techniques are discussed in detail in this report.

1.2 Problem Statement

In general, the RF performance of the LNA is very good as it able to achieve the required gain and provides low noise figure. But designing of the only single stage amplifier, the high gain, low noise figure and the stability of the amplifier cannot be achieved as we needed. 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 LNA with active biasing circuit. The matching networks can be changed to lump elements for space reduction and cost saving. LNA usually implies RF/wireless applications. But noise is also a critical consideration for lower frequency analog applications. In order to avoid this, the developing of amplifier based several techniques will solve the problem above. The reason why the devices are connected in cascade so that the signal power injected at matched input port is coupled and amplified by transconductance G_m of each device before at the end of the matched output will be terminate. To select an appropriate amplifier, first understand the noise parameters for a particular application and then determined whether an amplifier is indeed low noise [16].

1.3 Objectives

LNA is an integrated component of most RF systems. The main purpose of this report are to document the learning process involved in the design and testing of broadband amplifier that been used between 3.1GHz till 10.6GHz operating frequency and to have constant gain possible inside the frequency band.

The objectives of this Ultrawideband LNA design are to understand the concept of UWB communication and RF amplifier system, to know the different between narrow band amplifier and broadband amplifier, to design a broadband LNA based on Maximum Conjugate Matching technique, Balance Amplifier, and Feedback Amplifier to design a LNA that can operate in UWB frequency that is between 3.1GHz -10.6GHz, to have constant gain possible, to have a constant gain and to have Noise Figure less than 3 dB.

The design will use transistor MGF4941AL manufactured by Mitsubishi Semiconductor. This project involved familiarization and utilization of Microwave Office.

1.4 Scope of Work

The scope of work for this project can be divided into two parts; first is simulation – It will be done by varying parameters using AWR Microwave Office in order to get the required results which are close to the theoretical results. For example is to meet specifications of overall constant gain at above 15 dB, the reflection coefficient, S_{11} and S_{22} below -10dB. Then the second part comes the optimization of the simulation done.

1.5 Thesis Outline

Chapter 1 is about project background for this paper, brief introduction of UWB and LNA, methods used, objectives, and scope of works.

Chapter 2 defines in details about UWB and LNA and methods used.

Chapter 3 contains research methodology including transistor selection and steps to design LNA.

Chapter 4 discuss about result from this project; which is S-parameter analysis, and Noise Figure analysis.

Chapter 5 reveals the best technique, result from best technique, and future works suggestion on this project.

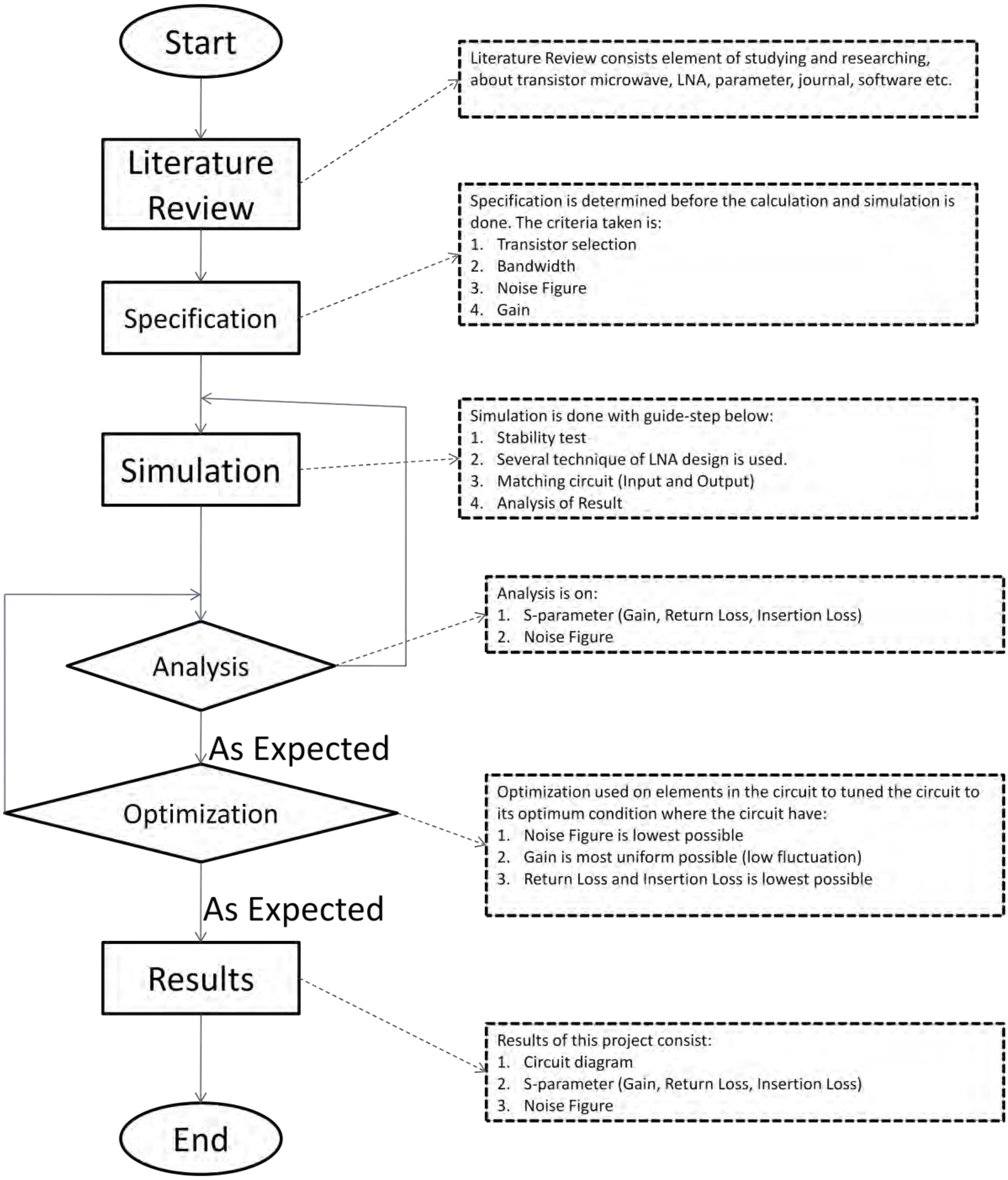

Figure 1.1: General Flow Chart of Designing UWB Amplifier

CHAPTER 2

ULTRAWIDE BAND AND LOW NOISE AMPLIFIER

2.1 UWB Basics

By traditional definition, ultra wideband technology employs very narrow pulses, of the order of a few nano-seconds, in order to establish high data rate communications [3]. These narrow pulses translates to energy spread over a wide frequency band, and hence the name ultra-wideband (also called Impulse radio). Very high data rates can be achieved over a short distance in devices employing the UWB technology.

On Feb. 14 2002, the Federal Communications Commission (FCC) opened up the spectrum from 3.1 GHz to 10.6 GHz for unlicensed use of the UWB technology. Having such a huge and free spectrum at one‟s disposal is especially alluring for the industry and academia alike. However, one of the important conditions is that the power levels of the UWB signal in this spectrum must be low enough to avoid interference with the already existing technologies. The FCC specifies the power emission levels suitable for co-existing with other technologies in the UWB allocated band [2]. The spectrum mask for both indoor and outdoor emissions is shown in Figure 2.1.

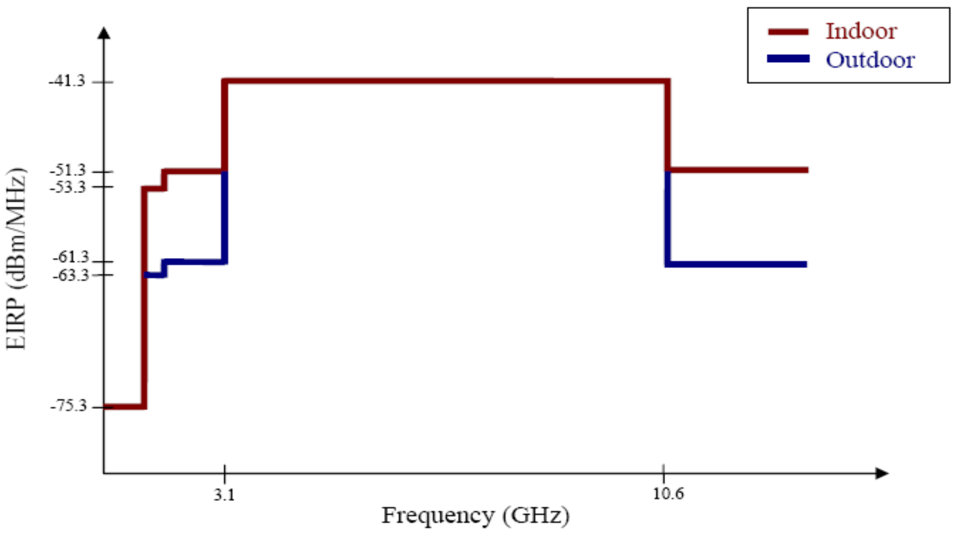

Figure 2.1: Acceptable power levels for indoor and outdoor emissions [1]

The FCC defines a UWB transmitter as "an intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20 or has a UWB bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth."

Fractional bandwidth is the bandwidth expressed as a fraction of the center frequency. If f_H is the highest frequency limit with signal 10dB below peak emission and f_L is the lowest frequency limit with signal 10dB below peak emission, the fractional bandwidth is defined as

$$\eta = \frac{2(f_H - f_L)}{f_H + f_L} \tag{2.1}$$

For UWB, the limits of η are given by 0.20< η <1.0.

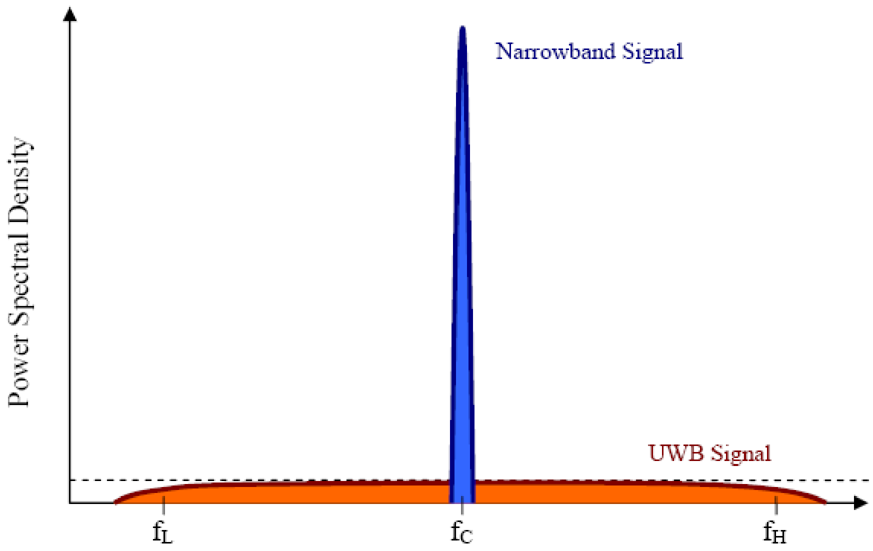

Figure 2.2: Power levels of UWB signal and a typical narrowband signal [1]

2.2 UWB Applications

The wide spectrum allocated to UWB directly translates into a wireless channel with high spatial capacities. This is obtained from the famous Shannon‟s channel capacity theorem

$$C = B.\log_2(1 + SNR) \quad (2.2)$$

Where C is the channel capacity in bits/second, B is the bandwidth in Hertz and SNR is the Signal-to-Noise Ratio.

Expression 2.2 shows a linear relation of the channel capacity with bandwidth and logarithmic relation with the SNR. Unlike narrowband systems whose data rate is limited by the bandwidth and SNR, UWB systems can achieve high data rates