DESIGN OF INTEGRATED LOW-NOISE AMPLIFIER AND FILTER FOR WIRELESS COMMUNICATION APPLICATION

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This report submitted in partial fulfillment of the requirements for the award of Bachelor of Electronic Engineering (Telecommunications Electronics) With Honours

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PROJEK SARJANA MUDA II

Tajuk Projek : **DESIGN OF INTEGRATED LOW-NOISE AMPLIFIER AND FILTER FOR WIRELESS COMMUNICATION APPLICATION**

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DECLARATION

I hereby, declared this report entitle "DESIGN OF INTEGRATED LOW-NOISE AMPLIFIER AND FILTER FOR WIRELESS COMMUNICATION APPLICATION" is the results of my own research except as cited in the references.

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APPROVAL

"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 : PM. DR. ZAHRILADHA BIN ZAKARIA
Date : 8 JUNE 2015

DEDICATION

This thesis is dedicated to my beloved parents,

Quee Lin Sai & Chiow Boon Ching

To my supervisor,

PM. Dr. Zahriladha Bin Zakaria

My friends and my fellow lecturers
Thank you for all your care, support and believe in me

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ABSTRACT

Nowadays, wideband communication systems have attracted a great deal of interest due to their wide bandwidth, viability to support high data rate capacity at low power for high-speed wireless communication. However, there are many challenging requirements are faced by the wideband communication systems. The design of low-noise amplifier which operates from 1.7 GHz to 2.7 GHz is difficult to design to operate in the wide spectrum and maintaining a noise figure < 1 dB, better input and output return loss < -10 dB and greater gain > 10 dB, thus shows a harder challenge for the designer to meet the goals for the wider frequency range. A notch filter/narrow-band bandstop filter which operate at 1.85 GHz to 1.99 GHz stopband frequency range is designed to eliminate the interference between the cellular band at 1.9 GHz and ISM band at 2.4 GHz. The thesis work presented here is the study and design of integrated low-noise amplifier and notch filter into one circuit for a wider frequency range 1.7 GHz to 2.7 GHz to explore the gain and noise figure improvement. The GaAs E-pHENT transistor based LNA and notch filter with lumped components are designed and simulated to test the gain, noise figure improvement, input and output return loss by using the Advanced Design System (ADS) software. After that design of integrated low-noise amplifier and notch filter and simulated to test again. Furthermore, the results from the simulations are analyzed and discussed. This type of design can be used by mobile phone, wireless LAN, Bluetooth device.

ABSTRAK

Pada masa kini, sistem komunikasi jalur lebar telah menarik banyak faedah kerana lebar jalur lebar mereka, daya maju untuk menyokong keupayaan kadar data yang tinggi pada kuasa rendah untuk system komunikasi wayarles berkelajuan tinggi. Walau bagaimanapun, terdapat banyak keperluan cabaran yang dihadapi oleh sistem komunikasi jalur lebar. Rekabentuk penguat hingar rendah yang beroperasi dari 1.7 GHz hingga 2.7 GHz adalah sukar untuk perekabentuk untuk beroperasi pada spektrum lebih luas dan lebih baik mengekalkan angka hingar < 1 dB, pekali pantulan yang lebih baik < -10 dB dan gadaan > 10 dB, ia menunjukkan cabaran yang sukar bagi perekabentuk untuk memenuhi matlamat-matlamat dalam julat frekuensi yang lebih meluas. Penapis takuk / sempit-band bandstop penapis yang beroperasi pada 1.85 GHz kepada julat frekuensi stopband 1.99 GHz direka untuk menghapuskan gangguan antara band selular pada 1.9 GHz dan ISM band pada 2.4 GHz. Kerja-kerja tesis yang dikemukakan di sini adalah kajian dan rekabentuk bersepadu penguat hingar rendah dan penapis takuk ke dalam satu litar untuk julat frekuensi yang luas 1.7 GHz kepada 2.7 GHz meneroka gadaan dan angka hingar. Penguat hingar rendah berdasarkan GaAs E-pHENT transistor dan penapis takuk dengan komponen-komponen lumped direka bentuk dan simulasi untuk menguji gadaan, angka hingar, input dan output kembali kerugian dengan menggunakan perisian *Advanced Design System (ADS)*. Selepas itu, rekabentuk yang bersepadu penguat hingar rendah dan penapis takuk kemudian simulasi untuk menguji sekali lagi. Tambahan pula, hasil daripada simulasi dianalisis dan dibincangkan. Jenis rekabentuk ini boleh digunakan oleh telefon bimbit, LAN tanpa wayar dan peranti Bluetooth.

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LIST OF ABBREVIATIONS

LNA	-	Low-Noise Amplifier
GPS	-	Global Positioning System
WLAN	-	Wireless Local Area Network
WiMAX	-	Worldwide Interoperability for Microwave Access
BW	-	Bandwidth
SNR	-	Signal-to-Noise Ratio
LO	-	Local-Oscillator
DSP	-	Digital Signal Processing
PCS	-	Personal Communications Services
ADC	-	Analog-to-Digital Converter
WLL	-	Wireless Local Loop
RLL	-	Run Length Limited
MMDS	-	Multichannel Multipoint Distribution Service
ADS	-	Advance Design System
RF	-	Radio Frequency
NF	-	Noise Figure
CMOS	-	Complementary Metal–Oxide–Semiconductor
EM	-	Electromagnetic
ISM	-	Industrial, Scientific and Medical
GSM	-	Global System for Mobile Communications
TDMA	-	Time Division Multiple Access
ITU	-	International Telecommunications Union

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CHAPTER I

INTRODUCTION

This chapter is about an introduction of project which includes an explanation of the project background, a brief introduction of wideband low-noise amplifier (LNA) and notch filter, method used in LNA design, objectives of a project, problem statement of the project, and the project scopes.

1.1 Introduction

Today, wireless communication technology is growing tremendously due to higher demand for high speed data communication. Cellular telephones, wireless local area networks (WLAN), global positioning system (GPS), and short-range data communication devices employing Bluetooth technologies are examples of portable wireless communication application [1]. Referable to the vast and insatiable need for affordable and low-power multi-standard portable devices, RF designers are urged to build up novel methodologies that take into account the invention of such products [1].

The low - noise amplifier is an important front end component in the radio receiver system. Ordinarily, the LNA is integrated into the receiver device such as an antenna to minimize losses and to avoid degradation of the signal-to-interference ratio (SNR). Later on a long distance transmission, the signal received by antenna

might be really faint and can't be retrieved. Therefore, the LNA is used to amplify the low power signal received by antenna to an accepted and useful level. An LNA is good as it adds little noise as possible in itself and has high gain.

The basis block diagram of RF receiver structure is presented as Figure 1.1. Before amplified by an LNA, the signal received by antenna is normally filtered by RF filter first and then unite with a local-oscillator (LO) to metamorphose to the base-band. After demodulated process, the signal is processed to an analog-to-digital converter (ADC) which translates the analog signal into a digital signal. Then, the digital signal is utilized in a digital signal processing unit (DSP). The primary step of signal amplification is complete by the LNA. Therefore, the properties of LNA can easily affect the overall noise and sensitivity parameter of the entire receiver [1].

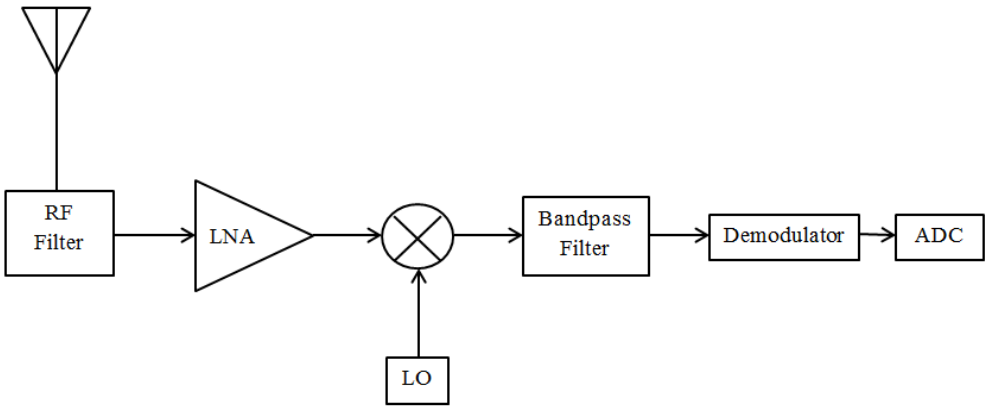

Figure 1.1: Basis Block Diagram of RF Receiver.

A notch filter greatly removes/ eliminates a specific frequency component of the input signal spectrum while lets the amplitude of other frequencies relatively unchanged and go. In general, a notch filter can be delineated as a band stop filter with a very narrow stop band and two pass bands. Figure 1.2 depicts the characteristic of a typical notch filter, the amplitude response is represented by $H_1(\omega)$, notch frequency is ω_d and BW mean 3-dB rejection bandwidth. BW would be zero, the pass band magnitude is unity (zero dB) and the attenuation at the notch frequency is infinite if a notch filter is ideal [2].

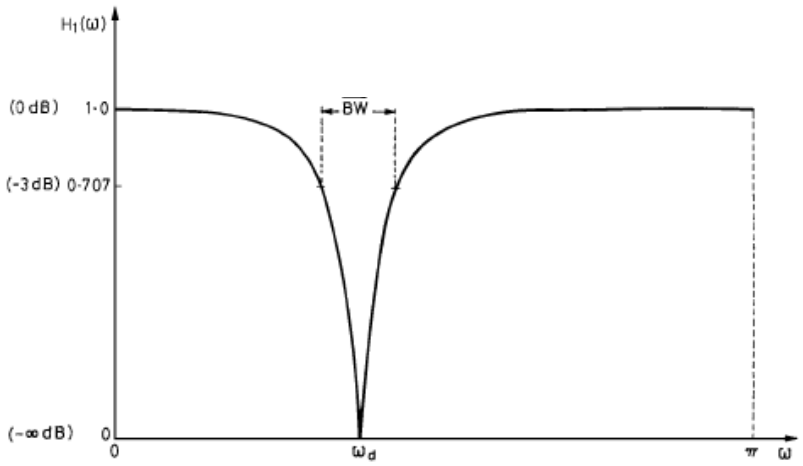

Figure 1.2: The Characteristic of Notch Filter.

Generally, LNA and Notch filter are two different blocks in a recipient. This project is attempting to integrate LNA and Notch filter in one block which is more cost effective and have less complexity of the circuit and the size of the receiver will go smaller as well. The integration of Low-Noise Amplifier and Notch Filter for wireless communication application which covers the frequency range of 1.7 GHz – 2.7 GHz is designed in this project. The wideband LNA are designed using transistor Avago Technologies' ATF-54143 for the whole design process. As referred to the data sheet at Appendix A, this type of transistor is built by GaAs Enhancement-mode pHEMT in a Surface Mount Plastic Package. Avago Technologies' ATF-54143 is a high dynamic range, low noise, E-PHEMT housed in a 4-lead SC-70 (SOT-343) surface mount plastic package. This transistor is optimized for 3V operation and exhibit exceptional RF performance, power efficiency and product consistency in the 450 MHz to 6 GHz frequency range. The transistor can be used in many applications, for example front end LNA for Cellular/PCS base stations, LNA for WLAN, WLL/RLL and MMDS applications.

1.2 Project Objectives

Wideband Low-noise amplifier (LNA) is an integrated component of most RF front end receiver systems. The main objectives of the thesis work are followed:

1. To study the background of LNA design and Notch filter.
2. To design an LNA and integrate with notch filter in order to minimize the undesired interferences from other frequency bands.
3. To analyze the performance of the LNA and LNA incorporated with notch filter based on electromagnetic (EM) simulations to determine return loss, notch response, stability, noise figure and gain.

1.3 Problem Statement

In general, a portable radio device such as mobile phone may include more than one radio operating in a cellular band, and a radio operating in the ISM band. The wideband low noise amplifier which covers 1.7-2.7 GHz range includes wireless LAN 802.11b, ISM band and cellular band. This environment presents a challenge since these radios may be in close physical proximity and located in the same physical instance. A high power interference such as cellular phone in the 1.9GHz frequency band may cause the ISM band receivers operating at 2.4 GHz to saturate since it is in close proximity to the 2.4 G Hz signal. This noise may cause a damaging consequence on the received wideband signal [3].

In operation, a cellular phone that support cellular and Wi-Fi services start transmitting in the 1.9 GHz spectrum during talks. If the Wi-Fi or Bluetooth radio goes to active and connect during this period, the 1.9 GHz cellular signals which have larger signal strength than the 2.4 G Hz ISM band spectrum may jam and interferes the Wi-Fi or Bluetooth signal. The high power interferes may degrade the operation of the LNA and mixer of Wi-Fi or Bluetooth receiver. Then, amplification of the Wi-Fi or Bluetooth signal may result in saturation in an Analog-to-Digital Converter (ADC) [3].

Some existing solutions may incorporate an on-board notch filter in the ISM band radio. This notch filter may be located between a low noise amplifier (LNA) and the mixer in the RF portion of the ISM band radio. This is to minimize the undesired interferences from other frequency bands [3].

1.4 Scope of Work

For this project, the scope is to design Integrated Low-Noise Amplifier and Notch Filter for wireless communication application which covers the frequency range of 1.7 GHz – 2.7 GHz. It can be split into five parts which are:

i. To study on how to design an integrated Low-Noise Amplifier and Notch Filter which covers the frequency range of 1.7 GHz – 2.7 GHz and can support wireless communication application.

ii. In design working process consists of three main parts which is simulation, testing, analysis and optimization.

iii. The S-parameter that is involved in the design such as noise figure, gain, return loss and notch response is analyzed.

iv. The design and simulation of integrated low noise amplifier and notch filter will be done by using Advanced Design System (ADS).

1.5 Chapter Review

Chapter 1 is about an introduction of project which includes an explanation of the project background, a brief introduction of the wideband low noise amplifier (LNA) and notch filter, objectives of a project, problem statement, and the project scopes.

Chapter 2 is about the background study define in details for integrated low noise amplifier and notch filter. The literature review of the low noise amplifier, especially on the parameters and the design techniques used in the design procedure to also define in detail.

Chapter 3 contains research methodologies which include the step to design the integrated low noise amplifier and notch filter. This chapter also includes detailed explanations of a low noise amplifier and notch filter design technique and calculation that involved.

Chapter 4 is discussing about the results and analysis the simulation of integrated low noise amplifier and notch filter from stability consideration until the implementation of the LNA and notch filter.

Chapter 5 reveals the main summarization and the conclusion of this project and finally the future works suggestions on this project.

CHAPTER II

LITERATURE REVIEW

This chapter defines about the background study define in details for integrated of a low noise amplifier and notch filter. The literature review of the low noise amplifier, especially on the parameters and the design techniques used in the design procedure to also set in detail.

2.1 Frequency Bands of 1.7 to 2.7 GHz

There are several frequency bands including in the 1.7 to 2.7 GHz frequency range, which is ISM band, GSM cellular bands and others.

2.1.1 ISM Band

The ISM (Industrial, Scientific and Medical) bands are open frequency bands, varying by region, that allow for operation without a license and free uses. The uses of these bands become very popular for short-range communication and low power communication electronics systems. The 2.4 GHz band is one of the ISM band, it utilized for worldwide operation and often hosts for standardized and proprietary protocols such as wireless LAN 802.11b, Bluetooth, ZigBee, Z-Wave and others [4].