DESIGN OF A UWB AMPLIFIER BASED ON CSSDA FOR UWB APPLICATIONS

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

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Specially Dedicated:

To my beloved mom and dad

and of course to all my supportive friends…

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ABSTRACT

Ultrawideband (UWB) is a wireless technology that transmits an extremely low-power signal over a wide radio spectrum. Ultrawideband systems operate across a wide range of frequencies from 3.1 GHz to 10.6 GHz. As no carrier wave is needed, ultrawideband consumes extremely low power and a long battery life is possible. In this report, the UWB amplifier has been designed and simulated with Radio Frequency (RF) Computer Aided Design (CAD) TOOLS - the Advanced Design System 2004A (ADS 2004A) for operation frequency between 3 GHz and 10 GHz. This UWB amplifier was designed by using the Pseudomorphic High Electron Mobility Transistor (PHEMT) device, the FPD6836P70 produced by Filtronic Semiconductor UK Company. The main specifications requirement for the circuit was to get a flat gain around 15 dB± 5 dB and overall with a reflection coefficient below 10 dB. The first stage of designing the broadband amplifier is to select the type of transistor which is suitable for low noise amplifiers. After that, the biasing circuit input matching network and output matching network were designed. The simulations for the design in ADS2004A include the DC analysis and also S-parameter simulation. Optimization for the circuit was done by changing the lengths and widths values of the microstrip lines.

ABSTRAK

Ultra Jalur-Lebar (UWB) adalah technologi tanpa wayar yang menghantar isyarat kuasa rendah melalui satu jalur lebar bagi spectrum radio. Sistem Ultra Jalur-Lebar beroperasi merentasi satu julat frekuensi dari 3.1 GHz ke 10.6 GHz. Oleh sebab tiada gelombang pembawa diperlukan, Ultra Jalur Lebar boleh menggunakan kuasa yang tersangat rendah dan jangka hayat bateri adalah panjang. Dalam tesis ini, penguat Ultra Jalur Lebar direka cipta dan disimulasi dengan menggunakan perisian Radio Frequency (RF) Computer Aided Design (CAD) Tools - Advanced Design System 2004A (ADS2004A) untuk frekuensi operasi antara 3 GHz hingga 10 GHz. Penguat Ultra Jalur-Lebar juga telah direka dengan menggunakan peranti Pseudomorphic High Electron Mobility Transistor, iaitu model FPD6836P70 yang dibangunkan oleh syarikat Filtronic Semiconductor UK. Spesifikasi utama yang diperlukan untuk litar penguat adalah untuk mendapatkan satu gandaan rata sekitar 15 dB ± 5 dB pada keseluruhannya dengan pekali pantulan dibawah 10 dB. Peringkat pertama untuk merekacipta penguat jalur lebar ialah dengan memilih jenis transistor yang sesuai untuk penguat hingar rendah. Kemudian, litar pincangan padanan masukan dan litar pincangan padanan keluaran direka. Keseluruhan simulasi untuk litar penguat dibuat dalam perisian ADS2004A dan juga termasuk analisa arus terus (AT) dan juga simulasi parameter-S. Optimisasi bagi litar telah dilakukan dengan mengubah nilai panjang dan lebar pada garisan jalur mikro.

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LIST OF ABBREVIATIONS

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
° C	- Celsius
K °	- Kelvin
CF	- 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
GA	- Available gain
GT	- Transducer gain
H	- Substrate thickness
l	- Length of quarter-wave transformer
L	- Length
Ni	- Noise parameter
RF	- Radius of constant noise circle

rms	- Root mean square
V	- Volt
W	- Width
mA	- Milliampere
ml	- Milliliter
Z	- Impedance
Zo	- Characteristic impedance
ZT	- Transformer impedance
Zin	- Input impedance
ZL	- Load impedance
zin	- Normalize value of input impedance
zL	- Normalize value of load impedance
SiGe	- Silicon Germanium

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CHAPTER I

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 among the most critical active circuits that are employed in many 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 bandwidth amplifiers have been firmly established in the fields of microwave, optical communication, instrumentation and Electronic War (EW) [1].

The implementation of Low Noise Amplifier (LNA) in the front-ends is one of the challenging aspects in emerging Ultrawideband (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 reactively matched circuit, traveling wave circuit, cascade single stage distributed amplifier, feedback circuit or loss matched circuit in order to compensate for the variations of frequency [6].

The Cascade Single Stage Distributed Amplifier (CSSDA) was one of the broadband amplifier techniques based on Traveling Wave Amplifier, which had been employed for the broadband systems as it was being firmly established, reliable and robust devices that can be realized in MMIC and UWB technologies. In this project this broadband amplifier had been chosen and designed using Advanced Design System 2004A (ADS 2004A) due to the excellent bandwidth performance, low noise figure and also its popularity. 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 during designing and simulation.

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 are understood background study. 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.

Recently, several innovative wide-band LNA architectures have been proposed to take on this challenge. In this work, Cascade Single Stage Distributed amplifier (CSSDA) for broadband amplifier was introduced to replace the conventional distributed amplifier that suffered from relatively high power consumption. This work focuses on the design and analysis of CSSDA with emphasis on low power. The understandings the high gain, low noise figure and bandwidth of a CSSDA are discussed in detail in this report.

1.2 Problem Statement

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. 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. 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 developing of amplifier based on Cascade Single Stage Distributed Amplifier (CSSDA) will solve the problem above. The reason why the devices are connected in cascade is 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 is terminated. The concept of CSSDA was discussed in Chapter II. To select an appropriate amplifier, it is necessary to understand the noise parameters for a particular application and then determine whether the amplifier is indeed low noise.

1.3 Objectives

Ultrawideband Low Noise Amplifier (LNA) is an integrated component of most RF systems. The main purpose of this report is to document the learning process involved in the design and testing of a broadband amplifier for operating frequencies between 3 GHz and 10 GHz.

The objectives of this Ultrawdeband amplifier design are to understand the concept of UWB communication and RF amplifier system, to know the difference between narrow band amplifier and broadband amplifier, to design a broadband Low Noise Amplifier based on CSSDA techniques and to design a Low Noise Amplifier that can operate in UWB frequency that is between 3 GHz -10 GHz.

The design will use transistor FPD6836PP70 that is manufactured by Filtonic Semiconductor. This project involves familiarization and utilization of a RF CAD tool, Advanced Design System ADS2004A.

1.4 Scope of Work

The scope of work involves with circuit level design of Low Noise Amplifier. The selection of transistor is studied to ensure all the specification requirements are meet. The computer aided design (CAD) tools are used to design and simulate UWB amplifier.

The design process is started with single stage design for single frequency. The second method is designing two stages and three stages of the low amplifier by cascading each stage at different frequency. Then, the forward gain, reverse gain, noise figure, matching network and stability discussed and analyzed.

1.5 Methodology

This project will start with background study of UWB communication system, LNA design and CSSDA concept. This is done by find out all the journal, articles and books that related to this project either in website or any materials. After understanding all concepts which is relating, the study of software is done. In this project, designing and simulation any circuit are done by using ADS2004A as CAD tools software. Then the calculation of single stage amplifier with using the appropriate formulas needs to be done. Next, simulate single stage amplifier design with using CAD tool. Then, stage design of the amplifier based on CSSDA. It also has two process that is, calculation and simulation. After all the designing process is done, the circuit then discussed and analyzed as in Chapter IV.