DESIGN OF LOW NOISE AMPLIFIER FOR WiMAX APPLICATION

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For the most beloved and supporting parents,

AZHAR BIN HAJI MOHD HARIS
WAN LATHIPAH BINTI WAN HUSSAIN

Dedicated, in thankful appreciation for the support, encouragement, love and understanding.

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ABSTRACT

Termed as the new era in wireless communications, WiMAX is the answer to anytime, anywhere access to information, offering reliable Internet connectivity all around the world. In the receiver part of WiMAX system, the most important device is the Low Noise Amplifier (LNA) which is located at the front-end of the receiver. The LNA main function is to provide the first signal of amplification and reduce the noise in the received signal. Without the LNA the signal that enters the system will be very weak and fill with noise. This will make it harder for the system to read the signal. There are two types of frequency band for WiMAX system which are the licensed and unlicensed band. In the licensed band, there are three frequency spectrum allocated which are 2.3 GHz, 2.5 GHz and 3.5 GHz. The project objective is to design a LNA using frequency 3.3 GHz to 3.8 GHz and the noise figure targeted are less than 2 dB and gain is larger than 10 dB. Transistor ATF-54143 Low Noise Enhancement Mode Pseudomorphic HEMT from Avago Technology will be used to design the LNA because it meet the specifications and recommended by Avago Technology to designs LNA for WiMAX application. The simulation for this project will be using AWR Microwave Office and starting from scratch the LNA will be design from 2-port network transistor, input and output matching and DC biasing to design a single stage LNA. Two technique of Broadband Amplifier design which is the Feedback Amplifier (FA) and Balance Amplifier (BA) will be design and simulate to find the best technique. The best technique is the Feedback Amplifier which gives nominal noise figure of 1.02 dB and gain of 12 dB.

ABSTRAK

Dinamakan sebagai era baru untuk komunikasi tanpa wayar, saling boleh kendali seluruh dunia untuk akses gelombang mikro (WiMAX) adalah jawapan untuk dimana sahaja dan bila-bila masa untuk sambungan internet yang bagus untuk mencari maklumat. Penguat Rendah Hingar (LNA) terletak di hadapan bahagian penerima di dalam sistem WiMAX dan memainkan peranan yang sangat penting untuk mengurangkan bising dalam isyarat dan menguatkan kekuatan isyarat. Tanpa LNA ini, isyarat yg masuk ke dalam sistem tidak dapat dibaca oleh sistem kerana kekuatan isyarat adalah sangat lemah dan ada terlalu banyak bising. WiMAX menggunakan frekuensi yang dilesen iaitu frekuensi 2.3 GHz, 2.5 GHz dan 3.5 GHZ untuk berfungsi. Untuk projek ini, frekuensi 3.5 GHz digunakan kerana banyak di dunia ini menggunakan frekuensi ini untuk berfungsi. Transistor ATF-54143 digunakan bersama perisian AWR untuk simulasi bagi membuat LNA ini. LNA ini direkabentuk untuk digunakan pada frekuensi 3.3 GHz sehingga 3.8 GHz dan mempunyai nilai hingar (NF) paling tinggi 2 dB dan penggandaan sekata lebih daripada 10 dB. Proses merekabentuk LNA ini bermula dari kosong iaitu dari pemilihan transistor hinggalah tamat membuat LNA. Dua kaedah untuk merekabentuk LNA telah dibuat dan disimulasikan dan kaedah terbaik akan dipilih. Dua teknik itu adalah Penguat Suap Balik (FA) dan Penguat Terimbang *(BA)*. Kaedah yang terbaik daripada dua kaedah tersebut adalah kaedah Penguat Suap Balik yang memberi nilai NF pada 1.02 dB dan penggandaan sekata pada 12 dB.

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LIST OF ABBREVIATIONS

Symbol	Definitions
BS	Base Station
CS	Central Station
BA	Balanced Amplifier
BWA	Broadband Wireless Access
CPE	Customer Premise Equipment
DA	Distributed Amplifier
FA	Feedback Amplifier
FCC	Federal Communications Commission
FET	Field Effect Transistor
IF	Intermediate Frequency
IL	Insertion Loss
IMD	Intermodulation Distortion
LNA	Low Noise Amplifier
MAG	Maximum Available Gain
MWO	Microwave Office
NF	Noise Figure
OFDM	Optical Time Division Multiplexing
OTDM	Orthogonal Frequency Division Multiplexing
PA	Power Amplifier
PAE	Power Added Efficiency
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
SOA	Safe Operating Area
VSWR	Voltage Standing Wave Ratio

WiMAX	Worldwide Interoperability for Microwave Access
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network

LIST OF SYMBOLS

Symbol	Definitions
C	Capacitor
dB	Decibel
f	Frequency
g	Element Values
G	Giga
H	Height
Hz	Hertz
I	Current
K	Rollet‟s Stability Factor
Km	Kilometer
L	Inductance
m	Meter
mA	Miliampere
mm	Milimeter
mW	Miliwatt
nm	Nanometer
π	Pi
P	Power
R	Resistance
S	Scattering
T	Tera
V	Voltage
ω	Angulare Frequency

Y	Admitance
Z	Impedance
δ	Fractional Bandwidth
ε_r	Relative Dielectric Constant
λ	Wavelength
Ω	Ohm

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CHAPTER I

INTRODUCTION

1.1 Project Background

Wireless communication is the transfer of information over a distance without the use of electrical conductors or cables. The distances of a wireless communication can be short as a few meters (e.g. television remote control) or long as thousands or millions of kilometers (e.g. radio communications). Wireless communication generally considered to be a branch of telecommunications.

Worldwide Interoperability for Microwave Access or better known as WiMAX is the next-generation of wireless technology designed to enable pervasive, high-speed mobile Internet access to the widest array of devices including notebook PCs, mobile phones, smart phones, and consumer electronics such as gaming devices, cameras, camcorders, music players, and more.

WiMAX can be used for wireless networking in much the same way as the more common Wi-Fi protocol. WiMAX is a second-generation protocol that allows for more efficient bandwidth use, interference avoidance, and is intended to allow higher data rates over longer distances.

The challenge to the WiMAX receiver chain designer is the wide dynamic range of received signal levels due to a highly variable transmission path. The WiMAX receiver's ability to effectively detect signals from a variable transmission path is critical to ensure system efficiency and data accuracy. Because of WiMAX's unique requirements, using a Low Noise Amplifier (LNA) at the RF front end of a WiMAX receiver is the best way to reduce the noise. A LNA is a simpler, space saving and more efficient solution which allows the receiver chain to have variable gain, low current consumption and excellent linearity.

Signal amplification is a fundamental function in all wireless communication systems. Amplifiers in the receiving chain that are closest to the antenna receive a weak electric signal. Simultaneously, strong interfering signals may be present. Hence, these low noise amplifiers mainly determine the system noise figure and intermodulation behavior of the overall receiver [1].

LNA is a key component in WiMAX systems, which is placed at the front-end of a radio receiver circuit, so that losses in the feed line become less critical. When using a low noise amplifier, noise is reduced by the noise figure and the gain of the amplifier. As the first stage of the receiver, LNA‟s are required to have a high gain and low Noise Figure (NF).

With the increasing acceptance of WiMAX as a substitute for the existing broadband wire-line infrastructure in the last mile, people are now designing and testing WiMAX CPE and BTS operating at around 3.5 GHz. This project presents the design of a 3.3 to 3.8 GHz LNA, suitable for IEEE 802.16a WiMAX customer premise equipment (CPE) and base transceiver stations (BTS), built on inexpensive FR4 copper laminate epoxy glass board material using the Avago Technologies ATF-54143 HEMT (High Electron Mobility Transistors).

1.2 Problem Statement

When signal travels wirelessly, the signal will face interference and when the signal arrives at the receiver there is some noise in the signal. Because of WiMAX's highly volatile transmission environment, low noise amplifiers are essential to improve received signal levels in order to ensure system efficiency and data accuracy.

A good LNA is a LNA that are able to achieve the required gain and provide a low noise figure according to the application that are being used. To design a LNA by using only single stage amplifier are very challenging because of the high gain, low noise figure and the stability of the amplifier cannot be achieved as what are needed for the application. But it is possible depending on the designs that are done.

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 using microstrip stub element matching is easier to design, simple and cost savings compare to two other matching.

The high loss tangent (tan δ) and relatively variable dielectric constant (ε_r) of the FR4 copper laminate epoxy glass material (tan δ = 0.04, ε_r = 4.6) generally limits its use to applications below 3 GHz. For higher frequencies, designers usually use more expensive materials such as the Rogers RO4350B glass-reinforced hydrocarbon/ceramic laminate2 with tan δ = 0.003 and ε_r = 3.48. Normally, the insertion loss for the FR4 board will increase rapidly when the operating frequency goes above 3 GHz, and designing 3 GHz circuits using FR4 material is usually not recommended [2].

When using high performance devices such as the ATF-54143, however, circuits designed on FR4 material can meet the customer‟s requirements for noise figure, gain and linearity. The biggest benefit to customers is the lower cost of the FR4 material. This is a critical concern for customers‟ main production.

1.3 Objective

LNA is one of the most important components of a wireless system. LNA usually located at the front-end of a receiver to reduce the noise. The objectives of the project that are discovered are design and simulate the Low Noise Amplifier (LNA) for WiMAX application for operating frequency of 3.3 GHz to 3.8 GHz. The noise figure targeted must be less than 2 dB.

1.4 Scope of Project

The scope of works for this project is to design a Low Noise Amplifier for WiMAX application which will cover the frequency range of 3.3GHz to 3.8GHz. The Design of Low Noise Amplifier will be divided into four parts which are calculation, simulation, comparison and analyzing.

(a) Calculation of the stability, gain and the maximum conjugate

(b) AWR software will be used for the simulation of Low Noise Amplifier.

(c) Analysis and comparison:

1) Calculation and simulation
2) Between design technique

1.5 Thesis Outline

Generally, the report will consists of six chapters which are; Chapter 1: Introduction, Chapter 2: Worldwide Interoperability for Microwave Access (WiMAX), Chapter 3: Low Noise Amplifier (LNA), Chapter 4: Research Methodology, Chapter 5: Results and Analysis and Chapter 6: Conclusion and Future works.

The first chapter represented the Introduction part. It is related to the background of the project, the objective, problem statement and scope of work that are planed and discovered for the project.