LOW NOISE AMPLIFIER PERFORMANCE STUDY FOR WIRELESS MAN BASED ON IEEE 802.16A STANDARD

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“To my beloved family and friends, thanks for being there, throughout this journey”

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ABSTRACT

In a rapid expanding worldwide wireless communications industry today, the demand for Wireless Metropolitan Area Network (WMAN) systems is growing very fast as well. New WMAN system based on IEEE 802.16a standard delivers high data rate with the optional bandwidth, better spectral efficiency, improved performance under multipath fading conditions and less interference in low-mobility wireless conditions than earlier systems. To support high data in the systems multi-carrier modulation, Orthogonal Frequency Division Multiplex (OFDM) is used. In practice, component such as low noise amplifier (LNA) should be chosen based on low cost. On the other hand, the effect of non-linear distortion must be considered very carefully because the OFDM system is very sensitive to it. So, the WMAN system must be tested and verified by using measurements so as to see the the system meets the requirements of the IEEE standard. For RF receiver tests in particular, bit error rate (BER) and packet error rate (PER) are required. There are several possible approaches to test the complete WMAN system. However, in this project, a special method that combines test equipment and simulation software has been developed to verify a low noise amplifier (LNA) prototype by measuring the bit error rate (BER) and packet error rate (PER) performance. Comparison has been made between the simulated and tested performances of LNA. The results show that the LNA is within the specification and standard.

ABSTRAK

Saban hari, permintaan terhadap sistem *Wireless Metropolitan Area Network (WMAN)* meningkat dengan drastik selaras dengan industri komunikasi wayarles yang pesat membangun. Sistem WMAN yang berasaskan piawaian IEEE 802.16a mampu menghantar data pada kadar yang tinggi dengan pilihan berbagai kadar jalur lebar, kecekapan spektra yang lebih baik, persembahan yang lebih memberangsangkan dan kurang interferen berbanding dengan sistem sebelum ini. Untuk membekalkan kadar data yang tinggi, satu teknik dinamakan *Orthogonal Frequency Division Multiplex (OFDM)* digunakan. Secara praktik, komponen seperti *low noise amplifier (LNA)* perlu dipilih berdasarkan kos yang rendah. Pada masa yang sama, kesan seperti *non-linear distortion* harus diambilkira dengan teliti kerana sistem OFDM sangat sensitif terhadap kesan seperti ini. Oleh itu, sistem WMAN harus diuji dan ditentusahkan untuk memastikan sistem berada pada taraf piawaian IEEE yang diingini. Bagi penerima frekuensi radio, persembahan seperti *bit error rate (BER)* dan *packet error rate (PER)* perlu diperoleh. Terdapat pelbagai cara untuk menguji satu sistem WMAN. Walau bagaimanapun, dalam projek sarjana ini, satu kaedah unik yang menggabungkan peralatan dan perisian simulasi dibangunkan untuk menentusahkan LNA dengan mengukur persembahan BER dan PERnya. Perbandingan dibuat di antara keputusan persembahan yang diperoleh dari simulasi dan dari pengujian terhadap LNA ini. Keputusan menunjukkan LNA yang diuji berada pada taraf piawaian dan spesifikasi yang diperlukan.

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LIST OF SYMBOLS

E_b	-	Energy-per-bit
F	-	Noise Figure
F_{center}	-	Center Frequency
F_{IF}	-	Frequency IF
f_{LO}	-	Frequency Local Oscillator
F_{RF}	-	Frequency RF
G	-	Gain
K_{vco}	-	Tuning Constant
N	-	Noise
N_{BW}	-	Receiver Noise Bandwidth
N_O	-	Noise Density
Pin	-	Input Power
Pout	-	Output Power
R	-	Data Rate
S	-	Signal
T	-	Temperature
T_b	-	Bit Time
$V_{carrier}$	-	Carrier Voltage
V_{out}	-	Output Voltage
V_{tune}	-	Tuning Voltage
ω_{osc}	-	Angular Frequency

LIST OF ABBREVIATION

ADS	-	Advanced Design System
AP	-	Access Point
AWGN	-	Additive White Gaussian Noise
BER	-	Bit Error Rate
BS	-	Band Select
CDMA	-	Code Division Multiple Access
CRC	-	Cyclic Redundancy Check
CS	-	Channel Select
DC	-	Direct Current
DSL	-	Digital Subscriber Line
DSSS	-	Direct Sequence Spread Spectrum
DUT	-	Device Under Test
ESG	-	Electronic Signal Generator
EDA	-	Electronic Design Automation
FET	-	Field effect transistor
FER	-	Frame Error Rate
GPIB	-	General Purpose Interface Bus
3G	-	Third Generation
GP	-	Good Packet
IEEE	-	Institute of Electrical and Electronics Engineer
IF	-	Intermediate Frequency
IMD	-	Intermodulation Distortion

IPTV	-	Internet Protocol Television
IIP3	-	Input at Third Order Intercept Point
IR	-	Image Reject
LNA	-	Low Noise Amplifier
LO	-	Local Oscillator
LOS	-	Line of Sight
MAC	-	Medium Access Control
NF	-	Noise Figure
OFDM	-	Orthogonal Frequency Division Multiplexing
PE	-	Probability of Error
PER	-	Packet Error Rate
PSDU	-	Physical Sublayer Service Data Units
QPSK	-	Quadrature Phase Shift Keying
RF	-	Radio Frequency
SDF	-	Standard Data Format
SNR	-	Signal-to Noise Ratio
TD-SCDMA	-	Time Division-Direct Sequence Code Division Multiple Access
UNII	-	Unlicensed National Information Structure
USB	-	Universal Serial Bus
VOIP	-	Voice over Internet Protocol
VSA	-	Vector Signal Analyzer
WEP	-	Wired Equivalent Privacy
WiMAX	-	Worldwide Interoperability for Microwave Access
Wi-FI	-	Wireless Fidelity
WLAN	-	Wireless Local Area Network
WMAN	-	Wireless Metropolitan Area Network

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Due to the development of communication technology, the wireless communication system grows rapidly to compete in the world market. Nowadays, many systems in wireless communication have been introduced for a variety of application such as wireless internet, 3G, Bluetooth, EDGE and many more. There are many reasons why this technology becomes important today. For areas poorly served by wired infrastructure, wireless is a good alternative to overcome this limitation. Wireless MAN (IEEE 802.16a) is a standard for MANs (metropolitan-area network), as opposed to the LANs (local-area networks) served by the more well-known Wi-Fi (**Wi**reless **Fi**delity). Wireless MAN is introduced to improve wireless LAN (IEEE 802.11a) standard by providing increased bandwidth and stronger encryption.

With coverage of areas ranging up to 30 kilometers radius, wireless MAN enables delivery of broadband services to residential and small-to-medium-sized business customers, and large corporations in urban, suburban and rural areas without requiring direct line-of-sight. Wireless MAN is not introduced to replace the

wireless LAN. The purpose of designated is to extend the wireless LAN application that can connect IEEE 802.11a hotspots with each other and to other parts of internet.

Orthogonal Frequency Division Multiplexing (OFDM) is adopted in wireless MAN to support high data rate up to 70Mbps for internet access. Wireless MAN uses of OFDM and scheduled MAC allows wireless mesh network to be more robust and reliable.

1.2 Project Background

Wireless MAN is a standards-based wireless technology providing high-speed data and voice services in networks covering long distances and wide ranges without the need for direct line-of-sight with a base station. Therefore, a high complexity in the digital system part as well as very accurate signal processing in the analog RF subsystem is required. High transmission rates within band limited radio channels affect the growing complexity of the devices and require the following [4]:

i) very high transmission frequencies must be used

ii) sophisticated modulation and coding technologies are used to achieve a high spectral efficiency

iii) high requirements for the RF front-end (robustness against interferer, adjacent channels and high linearity

The additional requirements such as low power consumption and low costs must take into consideration for system designed. System level simulators like ADS (Advanced Design System) or MATLAB can be implemented to build an executable specification.

Wireless MAN can cover a large geographical area without line of sight with higher data rate transmission by introducing OFDM technique. The high transmission data rate needs high requirements for RF front end. The performance of the RF subsystem will be tested by using ADS (Advanced Design System) simulation tool. The signal from ADS must be captured by ESG (Electronic Signal Generator). The system must be verified by Vector Signal Analyzer.

Recently, the performance test of RF subsystem has been done by undergraduate student from Wireless Communication Centre (WCC) of Universiti Teknologi Malaysia (UTM) for wireless LAN standard. IEEE 802.16a extends this coverage while offering the features consistent with the stringent demands of operators in a wide variety of deployment scenarios. The Wireless MAN technology fills a critical need in the end-to-end wireless network by bridging the gap between IEEE 802.11 wireless LANs and the wide area network.

Wireless MAN standard published [12] on 1 April 2003 for urban area coverage wireless access addresses frequencies from 2-11GHz including licensed and unlicensed bands. This project will be focused on unlicensed band with upper U-NII 5.725-5.825 GHz frequency. This band is allocated for the use of indoor links. The RF transceiver has been designed with a selected architecture of superheterodyne receiver and two-step transmitter. The modeled of RF transceiver has been analyzed in the Advanced Digital System (ADS) 2002C software for system characteristic and performance [4]. This project extends the limited benefits offered in Wireless LAN by doing some modification in the AWGN channel for wireless LAN. The same concept with WLAN is applied. Wireless MAN is a new wireless internet standard. ADS 2002C software does not support the Wireless MAN system itself. Therefore, the same wireless LAN source will be used instead of Wireless MAN source. The IEEE 802.16a standard specifies channel size ranging from 1.25 up to 20MHz [1] with many options in between. The unique method is implemented in this project by doing the simulation for the multiple channel bandwidths which the 5MHz, 10MHz and 20MHZ are chosen to see the performance

of overall RF receiver. The best performance of these three bandwidth range is used as a project based for the next steps of simulation.

1.3 Problem Statement

Major problem in RF System will certainly degrade the performance of RF system are nonlinearity and Noise. The nonlinearity phenomena are harmonic generation, intermodulation distortion (IMD), gain compression and spurious response. The noises are thermal noise, phase noise and image noise. These problems will affect the RF system. So, the early intention of this project is to judge how these nonlinearities and noises will affect the RF system by measuring the BER and PER performance.

Normally, after a RF transceiver has been designed, the system will be tested and verified. This is to ensure the standard of the system as well as its reliability. A powerful instrument as well as simulation software will be implemented. In this project a unique method need to be identified to complete the task of verification.

1.4 Objective

The objective of this project is to perform simulation and measurement on a RF receiver including the system and subsystem level analysis as well as verification of its subsystem in wireless MAN based on IEEE 802.16a standard

1.5 Project Scope

Generally in radio transmitter receiver, the system is divided into two sections, analog section and digital section. Analog section consists RF part and IF part. Second section is digital part. All the baseband processing such as demodulating, channel decoding and deinterleaving is done in this part. This project is focused on RF part consist of main components such as low noise amplifier, mixer, amplifier, filters (band-select filter, image-reject filter and channel select filter), and local oscillator.

A wireless MAN superheterodyne receiver might look likes a block diagram shown in figure 1.1. The performance for the subsystem to be studied is LNA. This project will cover some important features and specifications of Wireless MAN that will be focused on fixed broadband access and the concepts and techniques of LNA including the simulation by using ADS and testing to obtain the performance of the system. LNA will be verified for its specification and standard.

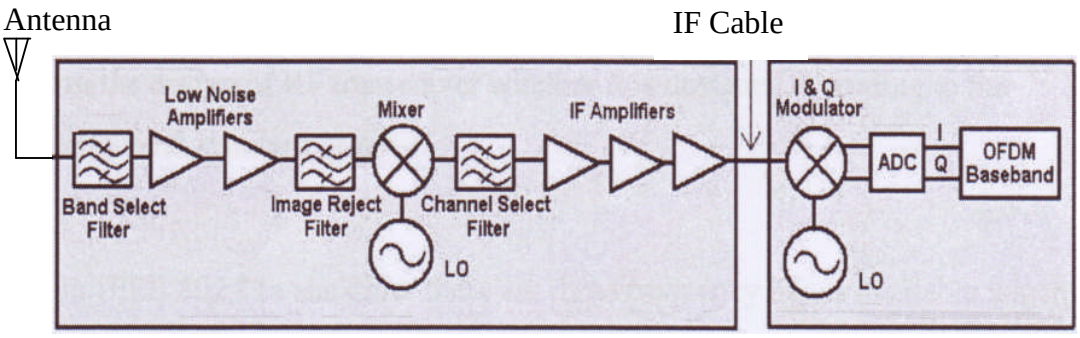

Figure 1.1: Superheterodyne Receiver

In IEEE 802.16a standard, three frequency bands are available for U-NII band. There are lower U-NII band (5.150-5.250 GHz), middle U-NII band (5.250-5.350 GHz) and upper U-NII band (5.725-5.825GHz) where the maximum allowable

output power are 40mW (16.02dBm), 200mW (23dBm) and 800mW (29dBm) respectively. In wireless MAN, the transceiver under study is using the upper band for its frequency operation.

1.6 Project Contribution

As mentioned earlier, this project is extended from undergraduate student by doing some modification of Wireless LAN source. So, the same concept as WLAN will be implemented in this project. This is continuative work of the previous researcher which is to design, simulate and measure a RF transceiver operating at 5.725-5.825 GHz. This is then lead to the important purpose purpose of the project which is to verify the real subsystem of the designed RF transceiver.

In short, at the end of the project, the overall system level performance of the RF receiver will be obtained by simulation. The performance of BER and PER with minimum noise must be achieved as a result of this WMAN system. After the simulation has been done, the real subsystem of the RF receiver –low noise amplifier will be verified for its specification and standard. So, the results in simulation will then become the reference for the verification process. Hence, a method of verification is identified and this will become a very useful way for the other similar design and development of such transceiver or other typical devices.