THE DEVELOPMENT OF 5.8 GHZ FRONT END LOW NOISE AMPLIFIER

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

Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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PEMBANGUNAN PENGUAT RENDAH HINGAR SET HADAPAN BERFREKUENSI 5.8GHZ

MUHAMMAD HAFIZZULLAH BIN ZAKARIA

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Nama Penyelia : Prof.Madya Abdul Rani Bin Othman

Tarikh : 15/05/07

Dedicated to my lovely parent for all their encouragements, loves and cares …

LIST OF TABLE

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ABSTRACT

This thesis presents the development of 5.8GHz front end Low Noise Amplifier suitable for IEEE standard 8021.1g system. This amplifier uses FHX76LP Low noise SuperHEMT device designed for DBS application from Eudyna Device USA Inc. The objective of the research project is to perform circuit design, simulation and measurement, including circuit analysis and verification of a Low Noise Amplifier (LNA) system at 5.75 – 5.85 GHz for the input/output return loss less than 10dB. The gain of this Low Noise Amplifier (LNA) system is 36 dB and Noise Figure of 1.8 dB. The Low Noise Amplifier (LNA) system requires circuit analysis and verification in terms of circuit characteristic and performance. The IEEE 802.11a standard is used as references. The Low Noise Amplifier (LNA) system should meet this standard requirement and should operate properly for WLAN Bridge system. This project uses Ansoft Designer Software which available in the faculty. With this development, the amplifier can be used as part of front end receiver future Wireless Local Area Network (WLAN) at 5.8GHz.

ABSTRAK

Tesis ini membentangkan tentang pembangunan dan penyeledikan mengenai Penguat Rendah Hingar yang mematuhi sistem 802.1.1g yang mengikut piawaian IEEE. Penguat isyarat ini menggunakan peranti FHX76LP perendah hangar "SuperHEMT" yang mana ia direka bentuk oleh Eudyna Device USA Inc bagi aplikasi DBS. Objektif utama projek penyelidikan ini adalah untuk menghasilkan rekabentuk litar, simulasi dan pengukuran termasuklah penganalisaan dan pengesahan bagi Penguat Rendah Hingar di antara frekuensi 5.75GHz – 5.85 GHz yang mana masukkan dan keluaran kehilangan semula adalah kurang daripada 10dB. Penggandaan isyarat bagi Penguat Rendah Hingar ini ialah 36dB manakala Perangka Hingar ialah 1.8dB. Penguat Perendah Hingar memerlukan penganalisaan litar serta mematuhi perihal dan kemampuan litar. Sistem piawaian IEEE 802.11a dijadikan sebagai rujukan. Penguat Perendah Hingar mematuhi kepiawaian yang dikehendaki serta dapat beroperasi dengan baik untuk sistem penghubung bagi WLAN. Projek ini menggunakan perisian Ansoft Designer yang disediakan di fakulti ini. Dengan adanya pembangunan dan penyeledikan ini, Penguat Rendah Hingar ini dapat digunakan sebagai salah satu daripada peralatan penerima set hadapan bagi WLAN berfrekuensi 5.8GHz pada masa akan datang.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Wireless communications are breaking the bonds Internet users have had to wire connections [1]. In Wireless Local Area Network (WLAN) system, WLAN Bridge is designed to replace wired LAN bridge system where the major motivation and benefit from the system is eased the installation and deployment of the network. In past few years, the demand of WLAN technology grown very significantly. Besides, W-LAN's can be more economical and efficient than installing wired networks [1].

With the current technology of Orthogonal Frequency Division Multiplexing (OFDM) adopted in IEEE 802.11a standard, the WLAN Bridge system can provide high data rate up to 54 Mbps for Internet access. The radio frequency (RF) transceiver in WLAN Bridge system plays a paramount role for converting the Internet data (baseband) into the RF signal and vice versa so that the system can be communicating wirelessly. Therefore, the performance of the WLAN Bridge also relies on the Low Noise Amplifier (LNA) system where it must be well designed to minimize the impairments (or distortions) in the system.

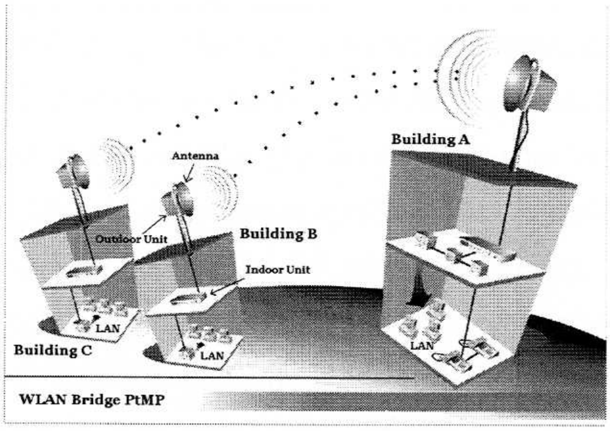
1.2 Objective

The objective of the research project is to perform system level design, simulation and measurement, including system level analysis and verification of a Low Noise Amplifier (LNA) system at 5.75 – 5.85 GHz and the input/output return loss is 10dB. The gain of this Low Noise Amplifier (LNA) system is 36 dB and Noise Figure of 1.8dB. The Low Noise Amplifier (LNA) system requires circuit analysis and verification in terms of circuit characteristic and performance. The IEEE 802.11a standard is used as references. The Low Noise Amplifier (LNA) system should meet this standard requirement and should operate properly for WLAN Bridge system.

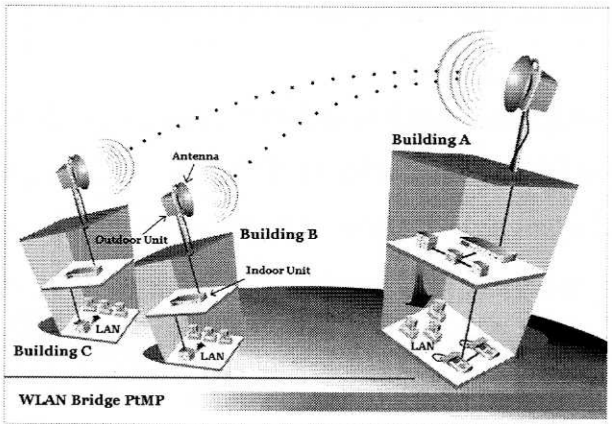
1.3 Research Background

Wireless technology has existed for many years, proving it to be a reliable communication medium in terms of cost and easy of deployment if compared with wired medium such as copper wire, coaxial cable and fiber-optic cable. According to David M. Pozar [3], the selection of various components and circuits including everything in between the transmitter's modulator input and the receiver's demodulator output can make or break an entire wireless system. Therefore, in the stage of RF transceiver (transmitter and receiver) design, the system of Low Noise Amplifier (LNA) system and receiver must be well designed to minimize the impairments in the RF system, so that the high performance of communication link can be achieved.

In data communication system, wireless technology can be implemented in bridge LAN to LAN or building to building [4]. This wireless bridge allows LANs in separated buildings to be connected over the distance ranging from several hundred meters to several kilometers where the area that the wired bridge is impossible to be deployed and installed. This thesis terms the wireless bridge system as WLAN Bridge. Figure 1.1 shows the WLAN Bridge system for point to point and point to multipoint configuration [4]. The system consists of antenna, indoor unit (IDU) and outdoor unit (ODU).



(a)



(b)

Figure 1.1: Configurations of WLAN Bridge system (a) point to point
(b) point to multipoint

It is not an easy task to design a Low Noise Amplifier (LNA) for WLAN Bridge system at the desired gain, power or frequency without neglecting the system performance. The system includes a couple of real RF components, such as mixer, amplifier, filters and local oscillator. Each of these components introduces different distortions such as thermal noise, phase noise, spurious frequencies and intermodulation distortion.

In a RF transceiver design, the distortions must be determined and reduced. Besides, the tradeoffs of multiple parameters in the RF components each can affect the others (known as RF design hexagon [5]) are the challenges to the RF designers in getting high performance communication system. This research work therefore aims to provide the best solution for the RF transceiver design, so that, the best performance of WLAN Bridge system can be achieved. According to Behzad Razavi [5], the inefficient simulation technique in design tools is another challenge to RF designers in getting accurate simulation result. Another thing is a multidisciplinary field such as wireless standard, microwave theory and communication theory where RF designers have to know a broad of knowledge to design a RF transceiver [8].

This research work is to design, simulate and measure a Low Noise Amplifier (LNA) system operating at 5.75 – 5.85 GHz (5 GHz upper U-NII band). This band is allocated for the use of outdoor links [9]. The system level analysis and verification are performed in terms of system characteristic and performance. Therefore, IEEE 802.11a standard is used for performance test such as constellation error, sensitivity and adjacent channel rejection. Federal Communications Commission (FCC) approved IEEE 802.11a standard in September 1999 that uses the unlicensed 5 GHz U-NII bands. The IEEE 802.11a uses OFDM, a new coding scheme that provides a significantly higher data rates up to 54 Mbps. The required speeds defined in IEEE 802.11a are 6, 12 and 24 Mbps with optional speeds up to 54 Mbps [10].

1.4 Research Scope

In this thesis, Low Noise Amplifier (LNA) system is the most important part and one of the expensive devices in RF block of Wireless LAN system [7]. Super high frequency amplifier is typical active circuit to amplify amplitude of signal like an amplifier for low frequency signal and is composed of BJT (Bipolar Junction Transistor) or FET (Field Effect Transistor) which also available at high frequencies. Basic concept and consideration in design and manufacturing of super high frequency amplifier are reviewed below. Figure 1.2 shows a typical single-stage amplifier including input/output matching networks.

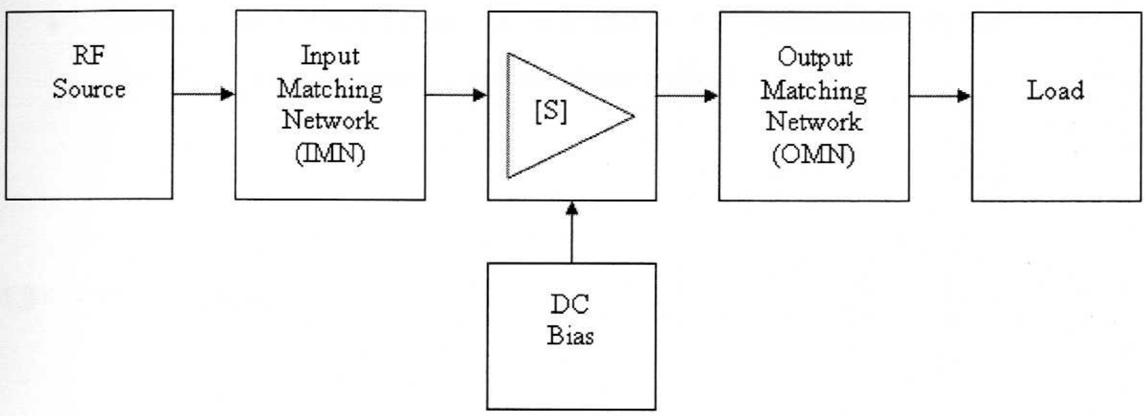


Figure 1.2 Typical amplifier system

In particular, a receiver should have pre-amplifier with low noise, if applicable. It is because of the noise characteristics of the first stage of receiver axert a large influence on the entire system. Basically, it is impossible to design an amplifier that fulfills minimum noise figure and maximum gain at the same time. These two factors are correlated each other and constant gain circle and constant noise figure are used to make a compromise between noise figure and gain.

The Low Noise Amplifier (LNA) design is based on the commercialized products (off-the-shelf). Therefore, this thesis focuses on the circuit tradeoff design, rather than system design tradeoff The scope of the research work comprises as follows:-

- Low Noise Amplifier (LNA) architecture is selected and the frequency plan is analyzed where the circuit design trade-off is taken into account.
- The selected Low Noise Amplifier (LNA) architecture is then **simulated** in the Ansoft Designer software based on the off-the-shelf component parameters such as gain, noise figure and frequency. The Low Noise Amplifier (LNA) model is simulated for system characteristic and performance analyses. In the simulation, the effects of **matching impedance circuit** on the system performance are analyzed.
- The Low Noise Amplifier (LNA) is measured for verification with the simulation result in terms of system characteristic.

1.5 Methodology

The design process is divided into three stages. In the initial stages, architecture of Low Noise Amplifier is selected and RF component for the Low Noise Amplifier are chosen based on the commercialized products. RF budget for Low Noise Amplifier design are calculated according to the parameters of the selected component in data sheet. The initial analysis of spurious frequencies is also covered in this stage. In the second stage, Low Noise Amplifier are modeled by using Ansoft Designer Student Version(SV)software according to the parameters of data sheet. The Low Noise Amplifier models are simulated for system characteristic such gain, input/output Return Loss and Noise Figure. In the third stage, the individual parameter of the Low Noise Amplifier is measured for verification with the parameter value that specified in the Low Noise Amplifier model. For verification, the measurement results are compared with the simulation result of Low Noise Amplifier.

1.6 Thesis Outline

This thesis is organized into six chapters to cover the research work related RF transceiver design.

Chapter 2 is the literature survey of the RF system for wireless communication applications, which covers the literature survey on the RF transceiver architectures and design. These will influence the selection of the RF transceiver architecture and the design method in the research work.

Chapter 3 discusses the first stage of Low Noise Amplifier design. The Low Noise Amplifier architecture for WLAN Bridge system, RF component characteristic, and spurious frequencies analysis are covered in this chapter.

Chapter 4 is mainly related on the Low Noise Amplifier design. Never less, the chapter begins with a short briefing related to the simulation and measurement process. This followed by explanations on the RF amplifier modeling.

Chapter 5 discussed and analyzed the simulation and measurement results of the Low Noise Amplifier design. The simulation results for the characteristic and performance of RF transceiver are discussed. The measurement of individual Low Noise Amplifier are discussed and compared with the parameter value that specified in simulation results in the RF transceiver prototype are also discussed.

Chapter 6 provides an overall conclusion of RF transceiver design conducted in this research work. It also provides discussion and recommendations on future works of this project.

1.7 Summary

This is an introductory chapter that defines the objectives and research scope of the project. The research background of the project is explained and thesis outline is highlighted. In the following chapters, the research work performed will be reported.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

A wireless local area network (LAN) is a flexible data communications system implemented as an extension to or as an alternative for, a wired LAN. Using radio frequency (RF) technology, wireless LANs transmit and receive data over the air, minimizing the need for wired connections. Thus, wireless LANs combine data connectivity with user mobility.

Wireless LANs have gained strong popularity in a number of vertical markets, including the health-care, retail, manufacturing, warehousing, and academia. These industries have profited from the productivity gains of using hand-held terminals and notebook computers to transmit real-time information to centralized hosts for processing. Today wireless LANs are becoming more widely recognized as a general-purpose connectivity alternative for a broad range of business customers.

RF system is commonly used term for any type of wireless communication that is accomplished via radio waves. RF system is part of the wireless communication system. In this thesis, RF system is defined as a complete system that involves a close integration of variety of components such as antenna, RF circuit and baseband modem.

This chapter discusses the literature survey of Low Noise Amplifier architectures and the design. The literature survey in this chapter influences the selection of Low Noise Amplifier transceiver and the implementation method of the RF transceiver design.

2.2 Literature survey on the RF transceiver architecture

Wireless technology has existed for many years, proving it to be a reliable communication medium in terms of cost and easy of deployment if compared with wired medium such as copper wire, coaxial cable and fiber-optic cable. According to David M. Pozar, the selection of various components and circuits including everything in between the transmitter's modulator input and the receiver's demodulator output can make or break an entire wireless system. Therefore, in the stage of RF transceiver (transmitter and receiver) design, the system of RF transmitter and receiver must be well designed to minimize the impairments in the RF system, so that the high performance of communication link can be achieved.

Most of wireless communication applications have a combination of both transmitter and receiver known as transceiver. The selection of RF transceiver architecture is important in the initial design of a RF system. The literature survey of RF transceiver architecture covers the conceptual of RF architectures and the configuration of sub-component in the architectures.

David M. Pozar [1], [11] discussed some of the fundamental principle of radio receiver architecture, beginning with the evolution of receivers to provide progressively improved performance. He discussed the general function of receiver architectures such as superheterodyne, direct-conversion and tuned-radio frequency (TRF). He also discussed the receiver requirements such as gain, selectivity, detection and isolation that influence the architecture of the RF system.

Behzard Razavi [3] discussed receiver architectures such as heterodyne, dual IF topology, homodyne, image-reject, digital IF, and sub-sampling receiver. He also discussed two types of transmitter architectures; direct-conversion transmitter and two-step transmitter. He discussed in detail the design trade offs and issues of the architectures. He mentioned that the complexity, cost, power dissipation and the number of external components (for RF IC) have been the primary criteria in selecting transceiver architecture.

Cotter W. Sayre [12] discussed the configuration of subcomponents for double-down conversion receiver (superheterodyne) and double conversion transmitter (two-step transmitter). He also discussed the requirement of the components such as filters (e.g. band pass filter and image reject filter), power amplifier and LNA in order to minimize distortions in the RF system such as noise, intermodulation distortion and spurious frequencies.

Peter Vizmuller [13] discussed a type of RF transmitter and receiver architecture; direct conversion transmitter and dual conversion receiver. He discussed the typical component used in the architecture such as power amplifier, LNA, filter and mixer. This includes the function of the components in the RF system. He mentioned that the primary motivation for selecting the receiver and transmitter architecture is the required system performance.

All types of RF architecture as mentioned above were not discussed in detail for specific wireless communication application. They generally discussed the architectures of RF transceiver for any kinds of wireless communication application. The next literature survey discussed the architectures of RF transceiver for specific application and implementation.