DESIGN OF LOW NOISE AMPLIFIER FOR RADIO OVER FIBER TECHNOLOGY

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

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Tajuk Projek : A LOW NOISE AMPLIFIER FOR RADIO OVER FIBER TECHNOLOGY

Sesi Pengajian :

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To my beloved Parents and all my Lecturers

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ABSTRACT

Radio over Fiber (RoF) is integration of optical fiber for radio signal transmission within network infrastructures that is considered to be cost-effective, practical and relatively flexible system configuration for long-haul transport of millimetric frequency band wireless signals.This project is about to simulate the low noise amplifier in a Radio Access Point in Radio over Fiber technology. The low-noise amplifier (LNA) is a special type of electronic amplifier or amplifier used in communication systems to amplify very weak signals captured by an antenna. It is often located very close to the antenna, so that losses in the feedline become less critical. This active antenna arrangement is frequently used in microwave systems like GPS, because coaxial cable feedline is very lossy at microwave frequencies. The implementation of design is based on microstrip technology and Microwave Office software is used to perform the simulation of front end design. In the simulation, the analyses of scattering parameters are concerned which presents the gain and return loss of the front end. At the end of design, a low noise amplifier produced as a RF front end of RAP for RoF technology. The new designed low noise amplifier operates at 5.2GHz in the RF front end for the system of radio over fiber technology. The LNA designed function to amplify extremely low signals without adding noise, thus preserving the required Signal-to-Noise Ratio (SNR) of the system at extremely low power levels. At the end of this design, the result shows that the value of calculated noise figure and the simulated noise figure is similar to the simulation values, its 0.93678dB. Its shows that the input and output port network is matched perfectly and the biasing were completed.

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ABSTRAK

Radio melalui Fiber (RoF) adalah integrasi dari serat optik untuk penghantaran isyarat radio dalam rangkaian infrastruktur yang dianggap berkesan dari segi kos, praktis dan relatif fleksibel sistem konfigurasi untuk pengangkutan jarak jauh pita frekuensi wayarles isyarat millimeter. Projek ini adalah untuk mensimulasikan penguat suara rendah di sebuah Radio Access Point di Radio melalui teknologi Fiber. Penguat suara rendah (LNA) adalah jenis khusus dari penguat elektronik atau penguat yang digunakan di dalam sistem komunikasi untuk menguatkan isyarat-isyarat sangat lemah diperangkap oleh antena. LNA sering diletakkan berhampiran dengan antena, sehingga kerugian di garisan yang memasuki baris menjadi kurang penting. Implementasi dari rancangan didasarkan pada teknologi mikrostrip dan perisisan Microwave Office digunakan untuk melakukan simulasi LNA yang ditempatkan dihadapan dan belakang pusat yang mengakses isyarat radio frekuensi. Dalam simulasi, analisis parameter hamburan prihatin yang menyajikan kemasukan dan keluaran kembali dari belakang pusat yang mengakses isyarat radio frekuensi. Akhir sekali, penguat suara rendah (LNA) dihasilkan sebagai penghujung depan Radio frekuensi (RF) dari Pusat mengakses isyarat radio (RAP) bagi teknologi RoF. Penguat suara rendah yang terhasil beroperasi pada 5.2GHz pada sistem radio melalui teknologi fiber. LNA direka ini berfungsi untuk menguatkan isyarat-isyarat yang sangat rendah tanpa menambah suara, dengan demikian menjaga yang diperlukan Signal-to-Noise Ratio (SNR) daripada sistem pada peringkat kuasa yang sangat rendah. Pada akhir desain ini, hasilnya menunjukkan bahawa nilai angka hingar dikira dan nombor hingar disimulasikan serupa dengan nilai-nilai simulasi iaitu 0.93678dB. Ini menunjukkan bahawa input dan output port rangkaian yang berpadanan dengan sempurna dan biasing itu selesai.

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CHAPTER I

INTRODUCTION

1.1 Introduction

Radio over Fiber (RoF) application has attracted much attention recently because of the increasing demand for capacity/coverage and the benefits it offers in terms of low-cost base station deployment in macrocellular system. RoF systems are now being used extensively for enhanced cellular coverage inside buildings such as office blocks, shopping malls and airport terminal. RoF is fundamentally an analog transmission system because it distributes the radio waveform, directly at the radio carrier frequency, from a central unit to a Radio Access Point (RAP). Note that although this transmission system is analog, the radio system itself may be digital such as GSM.

Mainstream optical fiber technology is digital. Telecommunication networks use synchronous digital hierarchy transmission technology in their cores. Fiber-based data networks such as fiber distributed data interface and gigabit Ethernet all use digital transmission. Fiber transmission links to base stations in mobile communications systems are digital. Digital optical fiber transmission links are therefore ubiquitous in telecommunications and data communications, constituting a high volume market worth billions of dollars worldwide.

In order to reduce the system cost, radio over fiber (RoF) technology has been proposed since it provides functionally simple base station or radio access point (RAP) that are interconnected to switching center or otherwise known as central station (CS) via an optical fiber. The advantages of using such system for delivering radio signal from a CS to RAPs have long been recognized [1]. By using single mode fiber with very low losses, typically 0.2 dB/km, it is possible to provide a transmission infrastructure that is capable of transmitting of the useable radio frequency spectrum (DC to 300 GHz).

In new concept of wireless architecture using this technology, all the signal processing associated with the base station, usually found in the RAP, can now be moved to the CS. Consequently, the RAP becomes a small module that only consists of an electroabsorption modulator (EAM), a bandpass filter (BPF), a power amplifier (PA) and a low noise amplifier (LNA). In practice, some loss of simplicity may need to be traded for increased range. The benefits of such a system result directly from the shift of complexity away from the antenna unit to the CS. In other words, centralization can be used to aid simplification.

Since, it was first demonstrated for cordless or mobile telephone service in 1990 by Cooper [2], a lot a research has been carried out to investigate its limitation and develop new and high performance of RoF technologies. Recently, the research efforts have been devoted to the development of physical layer such as simple RAP development and radio signal transport techniques over fiber, but few have been reported about upper level and resource management issues for RoF network. Their target applications range from mobile cellular networks, wireless local area network (WLAN) at millimeter (mm) wave bands and broadband wireless access network to road vehicle communication.

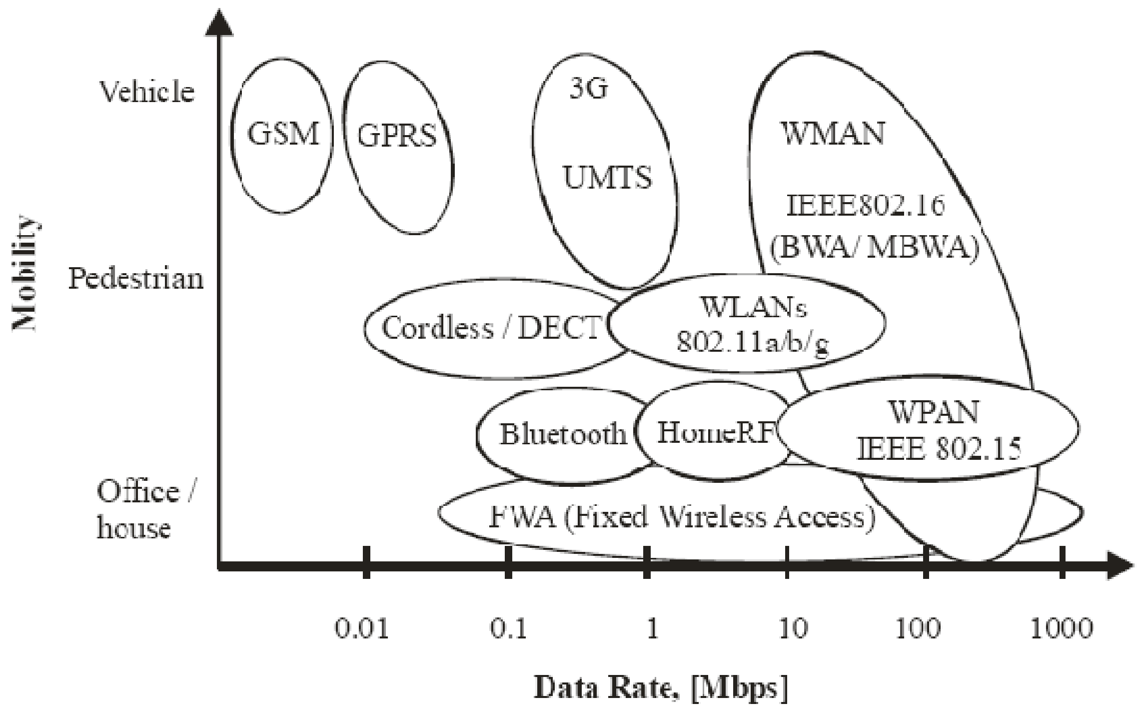

Figure 1.1 Present and future wireless communication System [3]

1.2 Problem Statements

In the passive RAP, EAM is used as a remote transceiver. The only components required at the RAP are the EAM and an antenna. There are practical limitations on the amount of power that can produce by the RAP which can affect the dynamic range. A PA is placed between the EAM and the antenna in order to improve the dynamic range of passive picocell (RAP). Picocells use low power and low capacity base stations that are small, light, relatively low cost and easy to install [4]. A nonlinearity effect of fiber transmission also considered in the RoF technology which produced at least two frequency components propagates together at the RAP. BPF is needed to remove out undesired frequency component and pass through the signal at the operating frequency. The RF front end consist of low noise amplifier and bandpass filter which operating at 5.2GHz. Therefore, the focus of this project is to design a LNA which operate in the RF front end for the system of radio over fiber technology.

The problem will be faced in this project is, when there is no LNA at the front-end of a radio receiver circuit, the overall noise figure of the receiver front-end can't be dominated. Beside that, without the LNA in the active radio access point, the noise of all the subsequent can't be reduced. On the other hand, if there is no LNA in the Radio over Fiber System, there is no component which can act as to boost the desired signal power which make the retrieval of this signal is possible in the later stages in the system.

1.3 Objective

To design a Low Noise Amplifier (LNA) for Radio over Fiber Technology (RoF) which operate at 5.2GHz in the front-end of a radio receiver circuit using Microwave Office (MWO) software

To implement a technology whereby light is modulated by a radio signal and transmitted over an optical fiber link to facilitate wireless access

1.4 Scopes

In order to achieve the objective of this project, there are following scopes that will be covered:

i) To study the concept of the RoF technology.
ii) It focus to simulate a LNA which in downlink transmission of RAP
iii) Design and simulate a LNA placed in the front-end of a radio receiver circuit
iv) The LNA operates at 5.2GHz
v) Unconditional stability at the lowest possible current drawn from the amplifier
vi) MWO software are used to perform the simulation and the scattering parameters are analyzed. Beside that, the noise figure and gain also have to be considered in the analysis part.

vii) After completed the design of the LNA, the simulation of the circuit is done and followed by the analysis of the observation of the simulation

1.5 Project Report Outline

The thesis is structured as follows. Chapter 1 discusses the general introduction of this project.

Chapter 2 outlines the literature review of this project, which is including the basic introduction of RoF (Radio over Fiber) and further knowledge about RoF and their characteristics. Beside that, it’s also include the literature review of the Low Noise Amplifier (LNA).

Chapter 3 outlines the research methodology of this project. Its cover the flow and process involve in this project. It also include the transistor choosen for the LNA construction and the procedure involve. The specification of the LNA that need to design are explained in detail.

Chapter 4 contains the calculation and simulation results. Its show the comparison between the calculation and simulation results. All the parameter such as the gain, noise figure, matching component calculation were included. The simulation process also show the analysis of all the parameter involved in constructing the LNA.

Chapter 5 is the overall conclusion of this project and the future work related to this field. There is an explaination on how to improve and update the LNA quality and performaneces for long term.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter will inform further explanatory about radio over fiber and the low noise amplifier. There will be explanation about overview of RoF, the technology, system and concept of RoF. The benefit of radio over fiber also stated. And there is also explaination about LNA, LNA in RoF technology and the application of LNA. Furthermore, there are also told the advantages using RoF in the mobile communication networks and applications of using RoF.

Generally, one natural way to increase capacity of wireless communication systems is to deploy smaller cells (micro and picocell). This is generally difficult to achieve at low frequency microwave carriers, but by reducing the radiated power at the antenna, the cell size may be reduced somewhat. Picocells are also easier to form inside buildings, where the high losses induced by the building walls help to limit the cell size. In contrast, the high propagation losses, which radio waves experience at mm wave frequencies, together with the line-of-site requirements, help to form small cells. Another way to increase the capacity of wireless communication systems is to increase the carrier frequencies, to avoid the congested Industrial, Scientific and Medical (ISM) band frequencies. Higher carrier frequencies offer greater modulation bandwidth, but may lead to increased costs of radio front ends in the base stations and the mobile unit.

Table 2.1 Frequencies for Broadband Wireless Communication Systems [2]

Frequency	Wireless System
2 GHz	UMTS / 3G Systems
2.4 GHz	IEEE 802.11 b/g WLAN
5 GHz	IEEE 802.11 a WLAN
2 – 11 GHz	IEEE 802.16 WiMAX
17/19	Indoor Wireless (Radio) LANs
28 GHz	Fixed wireless access – Local point to Multipoint (LMDS) /
38 GHz	Fixed wireless access, Picocellular
58 GHz	Indoor wireless LANs
57 – 64 GHz	IEEE 802.15 WPAN
10 – 66 GHz	IEEE 802.16 - WiMAX

Smaller cell sizes lead to improved spectral efficiency through increased frequency reuse. But, at the same time, smaller cell sizes mean that large numbers of RAP are needed in order to achieve the wide coverage required of ubiquitous communication systems. Furthermore, extensive feeder networks are needed to service the large number of RAP. Therefore, unless the cost of the RAP, and the feeder network are significantly low, the system wide installation an maintenance costs of such systems would be rendered prohibitively high. This is where RoF technology comes in.

RoF technology was first developed in early 1980s in United States for military applications [5]. It was used to distance the radar emitters (dish) far from the control electronics and personnel, because of the development of radar-seeking missiles (anti radiation missiles). Since then the international research community has spent much time investigating the limitations of RoF and trying to develop new, higher performance RoF technologies. Many laboratory demonstrations and field trials have been performed, but currently RoF still remains a niche application within the broad remit of optical fiber technology.

This chapter also include further information of a low noise amplifier that operates at 5.2GHz. Generally, an amplifier is any device that changes, usually increases, the amplitude of a signal. The relationship of the input to the output of an amplifier usually expressed as a function of the input frequency is called the transfer function of the amplifier, and the magnitude of the transfer function is termed the gain. Basic transistor amplifies by producing a large change in collector current for a small change in base current.Most of the amplifier today used transistor devices such as Si, or SiGe, BJTs, GaAs or Inp FETs, or GaAs HEMTs. Microwave transistors amplifier are rugged, low cost, reliable and can be easily integrated in both hybrid an monolithic integrated circuitry.

2.2 RoF overview

RoF technology entails the use of optical fiber links to distribute RF signals from a CS to RAP. In narrowband communication systems and WLAN, RF signal processing functions such as frequency up-conversion, carrier modulation, and multiplexing, are performed at the RAP, and immediately fed into the antenna. RoF makes it possible to centralize the RF signal processing functions in one shared location (headend), and then to use optical fiber, which offers low signal loss (0.3 dB/km for 1550 nm, and 0.5 dB/km for 1310 nm wavelengths) to distribute the RF signals to the base station (BS) or RAP.

RAPs are simplified significantly, as they only need to perform optoelectronic conversion and amplification functions. The centralization of RF signal processing functions enables equipment sharing, dynamic allocation of resources, and simplified system operation and maintenance. These benefits can translate into major system installation and operational savings, especially in widecoverage broadband wireless communication systems, where a high density of RAP is necessary.

By using highly linear optical fiber links to distribute RF signals from a central location to radio access points (RAPs) RoF allows the RAPs to be extremely simple since they only need to contain optoelectronic conversion devices and amplifiers. All communication functions such as coding, modulation and up conversion can be performed at a central location. A simple RAP means small and light enclosures (easier and more flexible installation) and low cost (in terms of equipment cost and maintenance costs). Centralization results in equipment sharing, dynamic source allocation and more effective management. All of this adds up to an access technology that makes life easier and cheaper for operators.

Reasoning why RoF is able to shift system complexity away from the antenna is that optical fiber is an excellent low-loss (0.2 dB/km optical loss at 1550 nm) and highbandwidth (50 THz) transmission medium. Transmission takes place at the radio carrier frequency rather than the more conventional digital base band systems. The optical links in RoF are therefore analog in nature, in that they reproduce the carrier waveform. The radio carrier can be modulated with a digital modulation scheme such as GMSK (in GSM) or QPSK (in UMTS).

In a RoF link, laser light is modulated by a radio signal and transported over an optical fiber medium. The laser modulation is analog since the radio-frequency carrier signal is an analog signal. The modulation may occur at the radio signal frequency or at some intermediate frequency if frequency conversion is utilized. The basic configuration of an analog fiber optic link consists of a bi-directional interface containing the analog laser transmitter and photodiode receiver located at a base station or remote antenna unit, paired with an analog laser transmitter and photodiode receiver located at a radio