DEVELOPMENT OF OFDM IN WDM-RADIO OVER FIBER ACCESS NETWORK

WONG SIE WOO

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Tun Hussein Onn University of Malaysia

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To my beloved late father, may his soul rest peacefully in heaven.
My beloved mother, brothers, sisters and my soul mate for their endless supports,
and inspiration.

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ABSTRACT

Radio over Fiber (RoF) is one of the latest technologies in optical communication systems that provide effective convergence of optical and wireless access network system. RoF is a technology whereby light is modulated by a radio signal and transmitted over an optical fiber link to facilities wireless access. Wavelength-Division Multiplexing (WDM) is a multiplexing technique for fiber optic system to multiplex a number of optical carrier signals onto a single-mode fiber optic (SMF) by using difference wavelengths of laser light to carrier different signals which promising solutions to the ever increasing demand for bandwidth. Orthogonal Frequency Division Multiplexing (OFDM) technique distributes the data over a large number of carriers that are spaced apart at precise frequencies with overlapping bands. The use of FFT for modulation provides orthogonality to the sub- carriers, which prevents the demodulators from seeing frequencies other than their own. Hence by incorporating OFDM along with the optical fiber, the RoF system with WDM can be used for both short distance as well as long-haul transmission at very high data rate. This improves the system flexibility and provides a very large coverage area without increasing the cost and complexity of the system very much. This project investigates the feasibility of OFDM as a modulation technique to transmit the basebands signal over SMF. RF-to-optical up-conversion and optical-to-RF down-conversion have been modeled and used as optical modulator and optical demodulator respectively. Result from Optisystem model shows the performance of OFDM signal through the WDM RoF access network. The system was utilized to carry data rates 10Gbps, the modulation type for OFDM is 4 QAM 2 bit per symbol for each channel and OFDM demodulator are employed together with coherent detection at receiver part to receive the OFDM signals over a SMF network transmission. The signal power is decreasing while the length of optical fiber was increasing for channel 1 does not apply to other channels.

ABSTRAK

Radio over Fiber (RoF) merupakan satu teknologi terkini dalam sistem komunikasi optik yang tertumpu kepada keberkesanan sistem gentian optik dan sistem rangkaian tanpa wayar. RoF adalah satu teknologi yang menggunakan cahaya untuk memudulatkan isyarat radio dan kemudiannya dihantar melalui rangkaian gentian optik untuk kemudahan capaian tanpa wayar. Wavelength-Division Multiplexing (WDM) adalah teknik pemultipleksan dalam sistem gentian optik untuk memultipleks beberapa isyarat pembawa optik melalui gentian optik mod tuggal (SMF) dengan cahaya laser yang pelbagai panjang gelombang untuk membawa pelbagai isyarat bagi memenuhi permintaan lebar jalur yang semakin meningkat. Orthogonal Frequency Division Multiplexing (OFDM) adalah satu teknik yang menyalurkan data dengan banyak pembawa yang dijarakkan secara bertindihan di antara jalur. Penggunaan FFT pada modulasi memberikan keortogonan untuk setiap pembawa bagi mengelakkan penyahmodulat menerima frekuensi yang bukan dimiliknya. Oleh itu, dengan menggabungkan OFDM dan gentian optik, sistem RoF bersama WDM dapat digunakan untuk penghantaran data yang berkadaran tinggi secara jarak pendek dan jarak jauh. Ini meningkatkan fleksibiliti sistem dan menyediakan kawasan yang sangat luas tanpa meningkatkan kos serta kerumitan sistem. Projek ini mengkaji kebolehlaksanaan OFDM sebagai satu teknik modulasi untuk menghantar isyarat jalur asas melalui SMF. Penukaran bentuk RF ke bentuk optik dan juga sebaliknya telah dimodelkan serta digunakan sebagai pemodulat optik dan penyahmodulat optik. Keputusan dari model Optisystem menunjukkan prestasi isyarat OFDM melalui rangkaian WDM RoF. Sistem tersebut digunakan untuk membawa data berkadaran 10Gbps, dan pemodulatan OFDM 4 QAM 2 bit per simbol bagi setiap saluran serta penyahmodulat OFDM berserta dengan pengesanan koheren di bahagian penerima untuk menerima isyarat OFDM melalui rangkaian gentian optik. Kuasa isyarat telah berkurangan manakala panjang gentian optik telah meningkat untuk saluran 1 dan keadaan ini tidak berlaku untuk saluran yang lain.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

λ	-	Wavelength
ADC	-	Analog to digital converter
ASK	-	Amplitude shift keying
BER	-	Bit Error Rate
BPSK	-	binary phase shift keying
BS	-	Base Station
CATV	-	Cable Television
CBS	-	Central base station
CO	-	Central Office
COFDM	-	Coded OFDM
CO-OFDM	-	Coherent Optical - Orthogonal Frequency Division Multiplexing
CW laser diode	-	Continuous wave laser diode
DAC	-	Digital to analog converter
DFA	-	Doped fiber amplifier
DPSK	-	Differential phase-shift keying
DWDM	-	Dense Wavelength Division Multiplexing
E/O	-	Electrical to optical
EDFA	-	Erbium Doped Fiber Amplifier
FDM	-	Frequency Division Multiplexing

FFT	-	Fast Fourier Transform
FM	-	Frequency modulation
I/Q	-	I - in phase; Q - quadrature (90 degree phase shift)
ICI	-	Inter-carrier Interference
IF	-	Intermediate Frequency
IFFT	-	Inverse Fast Fourier Transform
ISI	-	Inter-symbol Interference
LAN	-	Local Area Network
LiNbO3	-	Lithium noibate
MCM	-	Multicarrier Modulation Method
MSC	-	Mobile Switching Centre
MZM	-	Mach–Zehnder modulator
NRZ	-	Non return-to-zero
O/E	-	Optical to electrical
OFDM	-	Orthogonal Frequency Division Multiplexing
OOK	-	On-off keying
OTDM	-	Optical Time Division Multiplexing
OTR	-	Optical-to-RF down-conversion
PBRS	-	Pseudo-random bit sequence
PM	-	Frequency modulation
PON	-	Passive optical network
PSK	-	Phase-shift keying
QAM	-	Quadrature amplitude modulation
QPSK	-	Quadrature Phase-Shift Keying
RAP	-	Radio access point

RAU	-	Remote access unit
RF	-	Radio Frequency
RoF	-	Radio over Fiber
RS	-	Remote Site
RTO	-	RF-to-optical up-conversion
RZ	-	Return-to-zero
SC	-	Switching Centre
SMF	-	Single-Mode Fiber
WDM	-	Wavelength-Division Multiplexing
WLAN	-	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

1.1 Project Background

Many studies had been conducted in relation to Orthogonal Frequency Division Multiplexing (OFDM), Radio over Fiber (RoF) and Wavelength-Division Multiplexing (WDM) networking to transform something that can improves the efficiency on high speed and low cost accessing networks. All the researchers need to face great challenges on designing a quality access networks that can meet the above criteria for the needs of consumers in terms of speed and efficiency data transmission. Therefore, the understanding of each component in the access network such as OFDM, WDM and RoF are in urgent great demand.

OFDM is a method of encoding digital data transmission on various carrier frequencies [1] [2]. For instance, in the mobile communication systems, OFDM technique works on splitting a radio spectrum into several sub-channels at the base station. In conjunction, the signal strength at the sub-channel and the channel number assigned to the different devices can be changed as required. Nowadays, OFDM is very popular for Wideband digital communication, both wire and wireless. In a broad context, it is used in applications such as digital television and audio broadcasting, DSL broadband Internet access, wireless networks, and 4G mobile communications.

In addition, the Wavelength-Division Multiplexing (WDM) is a multiplexing technique for fiber optic system to multiplex a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e. colours) of laser light to carry different signals. This technique allows a multiplication in capacity and it is possible to perform bidirectional communications over one strand of fiber optic.

Radio over Fiber (RoF) refers to a technology whereby light is modulated by a radio signal and transmitted over an optical fiber link to facilitate wireless access. Although radio transmission over fiber serves as multiple purposes in cable television (CATV) networks and satellite base stations, the term RoF is usually applied where there is wireless access.

RoF has made cost-effective, high-data-rate mobile wireless broadband networks, an inherent immunity to electromagnetic interference and reduction on power consumption. Moreover, it provides a huge bandwidth which is convenience for installation and maintenance at ease operational flexibility. [3 - 7]

Apart from that, this system is designed for the compatibility to the wave-multiplexing (WDM) and the wave-division-multiplexing passive optical networks (WDM-PON). It also works well on flexibility to both wired and wireless users at the same time for using the same optical infrastructure which is distributed to its customers. [7 - 10]

The Orthogonal frequency division multiplexing (OFDM) is a promising technology which has a very high spectrum efficiency and robust dispersion tolerance. It is specially designed to improve the system capability and transmission distance over fiber and air links. Recently, several OFDM based access systems have been proposed, such as OFDM modulated WDM-PON, OFDM based metro access and OFDM-ROF wireless system. Nonetheless, the convergence system of OFDM in WDM-Radio Over Fiber access networks has never been analyzed, which can improve the spectral efficiency of the wireless access system, also support the seamless integration between air and optical transmission. Additionally, the re-modulation technology reduces the cost and complexity in base station (BS), while an integrate modulator can be used to generate the RoF and PON signal simultaneously in central station (CS). [6] [8 – 9] [11 – 13]

According to the previously mentioned studies, many researches and works were done in the field of using multicarrier transmission technique especially OFDM for transmitting and receiving data through optical link in Radio over Fiber Networks. Meanwhile this project work is based on modeling and analyzing the performance of the OFDM scheme for Radio over Fiber system to utilized applications based on WLAN IEEE 802.11 b/g standard (2.4 GHz). This project model was simulated using commercial software, Optisystem 10.0.

1.2 Problem Statement

The demand of the broadband services today has driven research on millimeter (mm) - wave frequency band communications for wireless access network in terms of speed, efficiency, spectrum availability and compact size of radio frequency devices. Nevertheless, the mm-wave signal has suffered many losses in the transmission as well as atmospheric attenuation. One of the solution to overcome these problems is the use of low-attenuation, electromagnetic interference- free optical fiber. Apparently, Radio over Fiber (RoF) is considered to be cost effective, practical and relatively flexible system configuration for long-haul transport of millimetric frequency band wireless signals using multicarrier modulation - Orthogonal Frequency-Division Multiplexing (OFDM). In order to maximize the bandwidth usage and prevention on cross-talk in a single fiber optic, the Wavelength-Division Multiplexing (WDM) is positioned to the access networks.

1.3 Project Objectives

The first objective of this project is to investigate OFDM in WDM Radio over Fiber Access network. The second objective is to model and simulate the OFDM scheme for RoF using commercial software, Optisystem 10.0 from Optiwave. The third objective is to analyze the feasibility performance of OFDM in WDM Radio over Fiber Access network in terms of Bit Error Rate (BER) and the effect of fiber length to signal power from OFDM signals at the receiver part.

1.4 Scope of Project

The scopes of this project are:

1. Understanding the basic principle of OFDM modulation technique, WDM and RoF through literature study.
2. Modeling and simulation of OFDM signals through RoF network using commercial software, Optisystem 10.0 from Optiwave.
3. Perform analysis of the design system in terms of Bit Error Rate (BER) and the effect of fiber length to signal power from OFDM signals at the receiver part.

1.5 Methodology

The methodology of this project is described in the following flow chart in Figure 1.1.

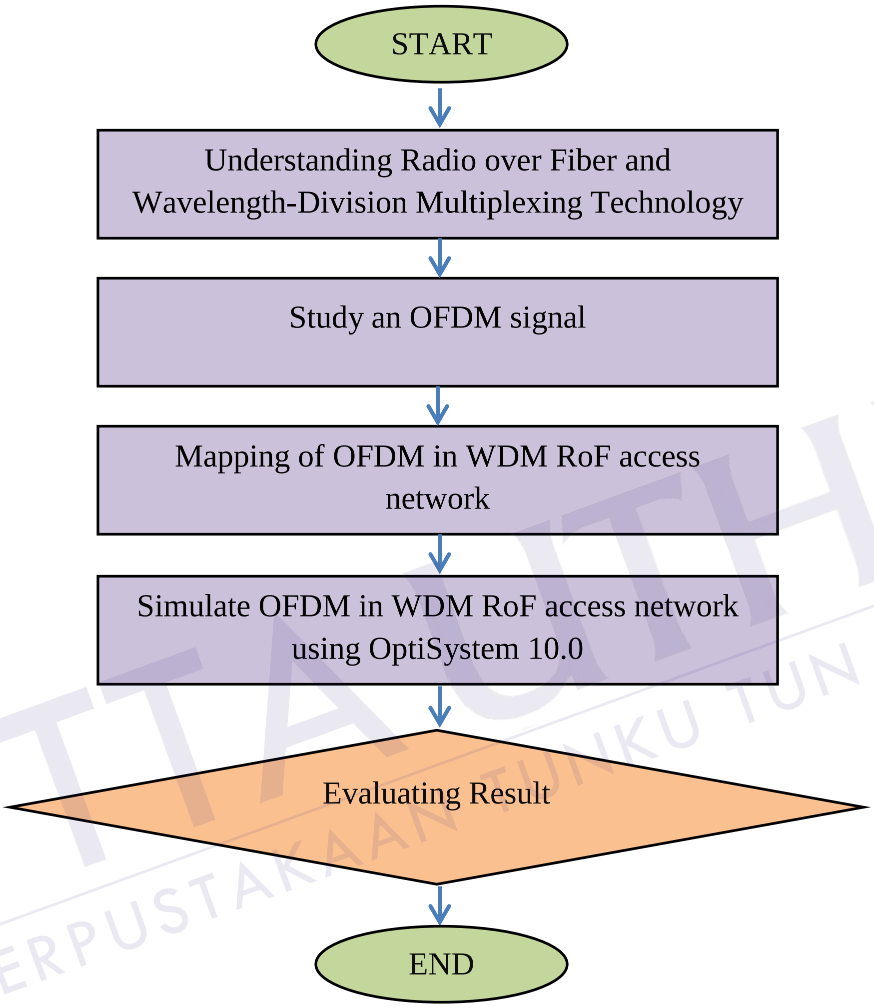

Figure 1.1: Project Flow Chart

The first step is to perform literature study, review and understands the current development of RoF system and OFDM modulation technique. The next step is to identify and understood the modeling design of OFDM modulation technique for RoF system. The main aim of this project is to analyze the basic concept of RoF system, OFDM modulation technique and incorporating OFDM along with WDM RoF access network. Then, the system will be designed and modeled to represent the connection from transmitter to receiver. The chosen simulation software will be identified and applied to the system such as Optisystem 10.0 from Optiwave which is a commercial software.

The following step is to analyze the result and system performance of the simulation model. While analyzing the results, the proposed system is being optimized to obtain a better performance and best simulation results. This is done by referring to theoretical and numerical analysis of OFDM and WDM to verify the proposed system.

Finally the simulation result produce is to compare with the previous works and theoretical analysis.

1.6 Thesis Outline

This thesis comprises of six chapters and is organize as follows:

Chapter 1 is the introductory part of this project which consists of project background, problem statement, and objective, scope of work, followed by methodology and thesis outline.

Chapter 2 presents the literature review of this project which is explaining some basic theory of Radio over Fiber, the benefits and architecture of RoF. This chapter also explains the optical transmission link and the applications of RoF technology.

Chapter 3 presents the theoretical work of Orthogonal Frequency Division Multiplexing (OFDM). This chapter consists of introduction, general principles and coded OFDM, Coherent Optical OFDM (CO-OFDM and also discusses the advantages and disadvantages of OFDM.

Chapter 4 discusses the methodology of this project in terms of integrating the OFDM in WDM RoF technique, Optisytem 10.0 software is used to model and implement the system. In this chapter the proposed OFDM with 4 QAM modulation systems for WDM radio over fiber access network are presented.

Chapter 5 discusses the simulation result and analysis of the proposed OFDM in WDM RoF system. The performance of the system in term of BER and the power signal at the receiver part are explained in this chapter.

Chapter 6 provides the conclusion for the whole project and also provides the recommendation of future works for developing and modifications of the system presented in this project.

CHAPTER 2

RADIO OVER FIBER

2.1 Introduction

Nowadays, due to the various demands of system users, data capacity for wireless communication has been radically expanded from voices and simple messages to multimedia with evolutionary future services. Radio over Fiber (RoF) systems could be the answer to many urgent needs of the telecommunication networks, as they could provide the necessary bandwidth for the transmission of broadband data to end-users, other benefits are low attenuation loss, and immunity to radio frequency interference [14 - 17]. In a RoF system, most of the signal processing processes (including coding, Multiplexing, and RF generation and modulation) are carried out by the Central Office (CO), which makes the Base Station (BS) cost-effective. Therefore, RoF will become a key technology in the next generation of mobile communication system [19 - 24].

RoF means that a fiber optic link where the optical signal is modulated at radio frequencies (RF) and transmitted via the optical fiber to the receiving end. When reaching the receiving end, the RF signal is demodulated and transmitted to the corresponding wireless user. RF modulation is in most cases digital, in any usual form, for example PSK, QAM, TCM, etc.

This modulation can be done directly with the RF signal or at an intermediate frequency (IF). RoF technique has the potentiality for the backbone of the wireless access network. Such architecture can give several advantages, such as reduced complexity at the antenna site, radio carriers can be allocated dynamically to different antenna sites, Transparency and scalability [28].

RoF technology is now ubiquitous in the telecommunications infrastructure. Fiber optics and WDM technology have increased significantly in the transmission capacity of today's transport networks. Therefore they are playing an important role in supporting the rapidly increasing data traffic.

2.2 Radio over Fiber

RoF technology is a technology by which microwave (electrical) signals are distributed by means of optical components and techniques. A RoF system includes a Central Site (CS) and a Remote Site (RS) connected to an optical fiber link or network. The signal between CS and BS is transmitted in the optical band via RoF network. This architecture makes the design of BSs quite simple. In the simplest case, the BS include mainly from optical-to-electrical (O/E) and electrical-to-optical (E/O) converters, an antenna and some microwave circuitry (two amplifiers and a diplexer). In the event of an application area is in a GSM network, and then CS could be the Mobile Switching Centre (MSC) and RS the base station (BS). As for narrowband communication systems and wireless Local Area Networks (WLANs), the CS would be the head-end while the Radio Access Point (RAP) would act as the RS. RoF systems span a wide range (usually in the GHz region) and depend on the nature of the applications to distribute the frequencies of the radio signals.

Besides transportation and mobility functions, RoF systems are also designed to perform added radio-system functionalities. These functions include data modulation, signal processing, and frequency conversion (up and down) [26] [27]. As shown in Figure 2.1, RoF systems were primarily used to transport microwave signals and to achieve mobility functions in the CS.

The centralization of RF signal processing functions have many benefits such as enables equipment sharing, dynamic allocation of resources, and simplifies system operation and maintenance. These advantages could be translated into major system installation and operational savings, particularly in wide-coverage broadband wireless communication systems, where a high density is necessary. Figure 2.2 shows the concept of RoF system.

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