MODELING AND PERFORMANCE ANALYSIS OF THE ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM) SCHEME FOR RADIO OVER FIBER SYSTEM

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ABSTRACT

The demand for broadband services has driven a number of applications such as, mobile and satellite communications, wireless local area networks (WLANs), wireless local loop and mobile broadband service, etc. However, for wireless communication links, gigabit per second data transmission is required to keep up with the remarkable speed up and huge bandwidth criteria. One of the solutions to overcome this requirement is by using Orthogonal Frequency Division Multiplexing (OFDM) technique to distribute the data over a large number of carriers that are spaced apart at precise frequencies with overlapping bands. Hence by incorporating OFDM along with the optical fiber, the ROF system can be used for both short distance as well as long-haul transmission at very high data rate. In such ROF systems using, broadband microwave data signals are modulated onto an optical carrier at a central station, and then transported to remote sites or base station using optical fiber. The use of FFT for OFDM modulation provides orthogonality to the subcarriers, which prevents the demodulators from seeing frequencies other than their own. Radio over fiber (ROF) is a hybrid system that having both a fiber optic link and free-space radio path that applies the concept when radio signals are transmitted over optical fiber from central station (CS) to several remote base stations (BS). Radio over Fiber (ROF) is consider as 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 improves the system flexibility and provides a very large coverage area without increasing t he cost and complexity of the system very much. The project is about to simulate OFDM Radio Over Fiber using Optisystem and Matlab. This particular system was utilized to carry data rates 10Gbps and the modulation type for OFDM is 16QAM 4 bit per symbol enough for the study purpose. The finding of this project is the OFDM-ROF is suite with 4G application along with increasing users every year whole the world. The conclusion is the simulation of OFDM-ROF was success developed throughout objective.

ABSTRAK

Permintaan yang semakin tinggi dalam perkhidmatan jalur lebar telah membuka ruang dalam banyak aplikasi, termasuk komunikasi bergerak dan satelit, WLANs, dan layanan pita lebar bergerak lainnya. Walau bagaimanapun, dalam komunikasi tanpa wayar, penghantaran maklumat dalam giga bit sesaat diperlukan untuk memastikan kelajuan pantas dan kriteria bandwith besar. Antara jalan penyelesaian untuk mengatasi masalah tersebut ialah menggunakan teknik modulasi OFDM mendistribusikan data melalui banyak pembawa yang dipisahkan dengan frekuensi yang akurat dengan pita yang saling berdekatan. Kerana itu menggabungkan OFDM dengan serat optik, sistem RoF dapat digunakan untuk transmisi jarak dekat maupun jauh dengan kelajuan data yang tinggi. Dalam penggunaan sistem RoF, gelombang mikro pita lebar sinyal data dimodulasikan pada pembawa optikal di pemancar utama dan kemudian dikirimkan ke tempat yang berjauhan atau ke pangkalan pemancar lainnya dengan menggunakan serat optik. Penggunaan FFT pada modulasi memberikan *orthogonality* untuk setiap pembawa, yang dapat menghindarkan demodulator dalam membaca frekuensi yang bukan miliknya. *Radio over Fiber* (RoF) adalah suatu sistem hibrida yang mempunyai dua jalur transmisi, serat optik dan jalur bebas radio di mana menggunakan konsep di mana frekuensi radio dihantar melalui laluan optik dari stesen pusat ke stesen asas. Isyarat radio menggunakan gentian dianggap sebagai penggabungan gentian optik untuk penghantaran isyarat radio dalam rangkaian infrastruktur yang mempertimbangkan kos-efektif, praktikal dan sistem konfigurasi fleksibel secara relatif untuk penghantaran jarak jauh isyarat jalur frekuensi tanpa wayar. Ini meningkatkan kemudahan suai dan menyediakan cakupan wilayah yang lebih besar tanpa menyebabkan kenaikan dalam biaya dan kesukaran pada sistem. Projek ini berkisar dengan simulasi OFDM isyarat radio dalam gentian menggunakan perisian Optisystem dan Matlab. Sistem ini khas dibuat untuk dapat membawa data 10 Gbps dan jenis modulasi untuk OFDM ialah 16QAM 4 bit untuk setiap symbol cukup untuk tujuan uji kaji sahaja. Projek ini menemukan penggunaan OFDM isyarat radio dalam gentian ini sangat sesuai digunakan bagi pembangunan sistem 4G dengan pertambahan pengguna setiap tahun di seluruh dunia. Kesimpulannya, simulasi ini berjaya dibangunkan mengikut objektif projek.

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LIST OF ABBREVIATIONS

WLANs	-	Wireless local area networks
ROF	-	Radio Over Fiber
CS	-	Central station
BS	-	Base stations
DAS	-	Distributed Antenna System
SMF	-	Single mode Fiber
MMF	-	Multimode fiber
SRS	-	Stimulated Raman Scattering
SNR	-	Signal to Noise Ratio
OCDMA	-	Optical code-division multiple-access
MLSE	-	Maximum Likelihood Sequence Estimate
BER	-	Bit Error Rate
SC	-	Switching Centers
RAU	-	Remote antenna unit
OFDM	-	Optical Frequency Division Multiplexing
GIPOF	-	Graded Index Polymer Optical Fiber
IM-DD	-	Intensity modulated-direct detection
RAP	-	Radio access point
MBS	-	Mobile Broadband System
MVDS	-	Multipoint Video Distribution Services
B-ISDN	-	Broadband Integrated Services Digital Network
LOS	-	Line-of sight
RF	-	Radio Frequency
BB	-	Base Band

IF	-	Intermediate Frequency
MZM	-	Mach-Zehnder modulator
NRZ	-	Non return-to-zero
PRBS	-	Pseudo Random Bit Sequence
RZ	-	Return-to-zero
FP	-	Fabry Perot
DWDM	-	Dense Wavelength Division Multiplexing
CW	-	Continuous-wave
ISI	-	Inter-Symbol Interference
ICI	-	Inter-Carrier Interference
VDSL	-	Very high-speed Digital Subscriber Lines
QAM	-	Quadrature Amplitude Modulation
BPSK	-	Binary Phase Shift Keying
QPSK	-	Quadrature Phase Shift Keying
DAB	-	Digital Audio Broadcasting
HDTV	-	High Definition Television
ADSL	-	Asymmetric Digital Subscriber Lines
IFFT	-	Inverse Fast Fourier Transform
FFT	-	Fast Fourier Transformation
DSL	-	Digital subscriber loop
DFT	-	Discrete fourier transforms
IDFT	-	Inverse discrete Fourier transform
PSK	-	Phase-shift keying
I	-	Inphase
Q	-	Quadrature

LIST OF SYMBOLS

Xk	-	Data symbols
$\|\alpha i\|^2$	-	Channel gain
f	-	carrier spacing
Ttotal	-	Total symbol duration
T	-	Symbol duration
Tg	-	Guard interval
B	-	Channel spacing (MHz)
k	-	FFT size
N	-	Subcarriers
n_2	-	Cladding Refractive index
n_1	-	Core Refractive index
θ_c	-	Critical angle

CHAPTER 1

INTRODUCTION

1.1 Project Background

For many years, mobile radio communications have been the main form of communication technique to distribute RF signal for microcell or picocell radio base station over analogue optical links. Radio over Fibre (ROF) has been developed since 20th century and has been used efficiently for the provision of untethered access to broadband wireless communications in a range of applications including last mile solutions, extension of existing radio coverage and capacity, and backhaul. Future generation of mobile communication system must be capable of serving high quality and broadband services even in highly dense populated area. The radio-over-fiber is one of the promising systems which can be used along the emerging wireless technologies. Wireless networks based on ROF technologies have been proposed as a promising cost-effective solution to meet ever increasing user bandwidth and wireless demands. Such a technology is expected to play an important role in present and future wireless network since it provides end user with wireless access to the network while guarantee the increasing requirement for mobility.

Before ROF was introduced, physical installation has been constructed using passive copper cable distribution networks. Electronics and passive system components are concentrated at the base stations or repeater and the signal is distributed via copper cable. This is idle to give indoor coverage for smaller building. However, as the building grew larger, the usage of long copper cable will

cause signal loss. As a result, fibre was introduced. A simple design illustration of ROF concept is shown in the figure 1.1 below.

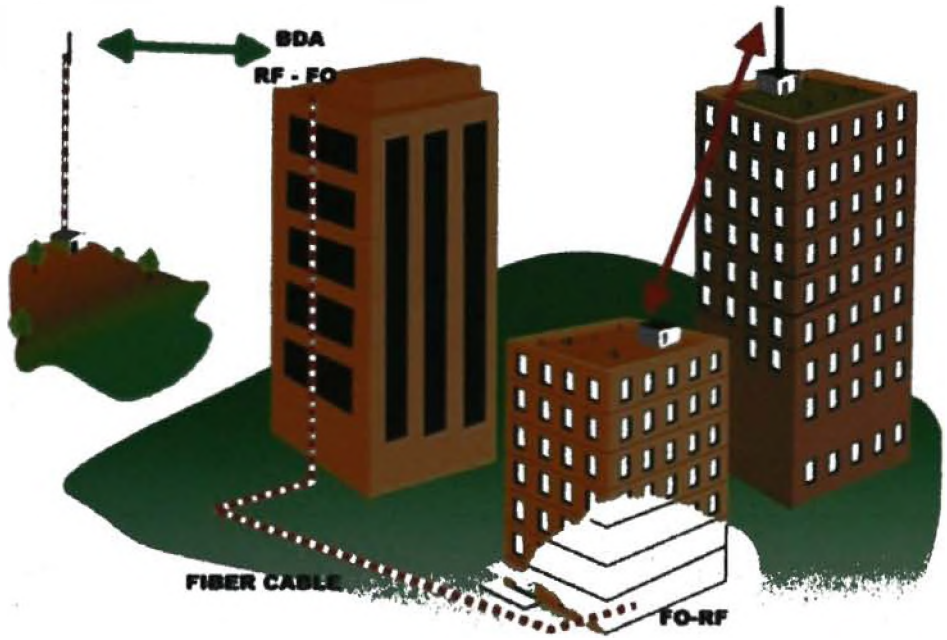

Figure 1.1 Radio Over Fiber Concept

Rof concept was introduced where radio signals are transmitted over optical fiber from Central Station(CS) to several remote Base Stations(BS) and it's technology has emerged as a potential candidate for the transport of microwave, cellular and wireless broadband signals for coverage extension, antenna remoting and other high speed applications. One of ROF applications is to be applied in Distributed Antenna System (DAS). This basically will provide the uniform coverage area of radio frequency (RF) services in a building to customer specification. A single mode (SMF) or multimode (MMF) optical fiber is used as a transport mode between the antenna and the base stations which offers minimal RF loss--which limits the distribution loss. These fibers which maximize the transmission rate.

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.

OFDM is a broadband multicarrier modulation method that offers superior performance and benefits over older, more traditional single-carrier modulation methods because it is a better fit with today's high-speed data requirements and operation in the UHF and microwave spectrum and also a promising candidate for achieving high data rate transmission in mobile environment. The application of OFDM to high data rate mobile communication system is being investigated by many researchers.

Hence by incorporating OFDM along with the optical fiber, the ROF system 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. Recently, it has been proved that OFDM is better compared to the conventional single carrier modulation for long haul optical transmission.

This thesis report will focus in investigating the modelling and analyze the performance of the OFDM scheme for radio-over-fiber system to utilized applications for WLAN IEEE 802.11 b/g standard, Digital Video Broadcasting (DVB) and Fiber-To-Home (FTH). The modelling work of the proposed method will involve in the use of suitable commercial optical system simulator, Optisystem 8.0/9.0 for performance optimization.

1.2 Problem Statement

In wireless communication links, gigabit per second data transmission is required to keep up with the remarkable speed up. The demands of human society for transmission bandwidths increase at a rapid speed. However, the limited spectrum resources and finite transmission distance greatly restrain the development of wireless communications. ROF is the next generation communication systems that

can utilize the high capacity of optical networks along with the mobility of wireless networks.

In optical communication nowadays, there is an urgent need to cater the service requirements of ultra-high speed and ultra-large capacity. By incorporating OFDM along with ROF solution, the system can be used for both short distance as well as long-haul transmission at very high data rate that enhance enhance the network's radio coverage. Large-capacity RF signals as well as ultra-wide band wireless access is achieved. This improves the system flexibility and provides seamless coverage area without increasing the cost and complexity of the system very much. In the case of further wireless communication system significant effort is done to reduce the multipath fading and small base station matched to demands made by the bigger number of mobile cells and high frequency applications.

The integration of both techniques emerged the possibility of cost-effective and high data rate ubiquitous wireless networks. OFDM is seen as the modulation technique for future broadband wireless communications because it provides increased robustness against frequency selective fading and narrowband interference, and is efficient in dealing with multipath delay spread.

1.3 Objectives

From the research, main cause of using ROF is to shift the system complexity away from the remote base station antenna and toward centralized radio signal processing installation. 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 objectives of this project are:

- To investigate the characteristics and performance of the deployment of OFDM scheme for wireless over fiber communication Link by modelling

and simulate the OFDM scheme for RoF using commercial software such as Optisystem 7.0/8.0 and Matlab.

- To predict and calculate the optimum parameter for the OFDM scheme using numerical simulation.

1.4 Scopes of Project

The scope of this research basically concentrates on 3 parts:

1. Design and analysis;
   - Understanding the basic principle of OFDM modulation technique and ROF through literature study
   - Review on the current progress of the ROF system especially on the OFDM of radio fiber.
2. System characterization;
   - Modeling and simulation of OFDM signals trough RoF network using commercial software; Optisystem 7.0 from Optiwave and Matlab.
   - Pre-exquisite method that only uses standard components of optical telecommunications.
   - The OFDM system are modelled for application based on WLAN IEEE802.11b/g standard (2.4 GHz).
3. Result Analysis
   - System performance analysis and optimization
   - The performance analysis parameters :
     - Signal-to-Noise Ratio (SNR)
     - Bit Error Rate (BER)

1.5 Methodology

This project is focus on the understanding of the performance analysis process in modelling the OFDM scheme in wireless over fiber communication link. This is important before moving into a higher process including development and full

system integration process. The overall project flow is shown in the chart in figure 1.2 on the next page.

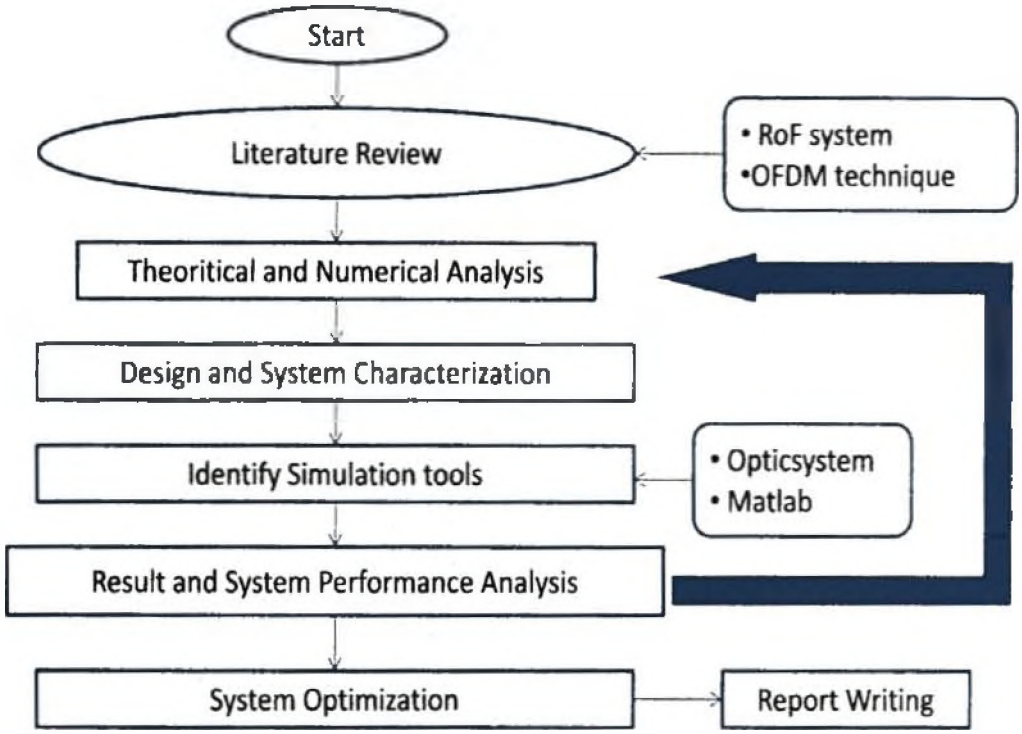

Figure 1.2: Project Flow Chart

The methodology starts with a thorough literature review on current design of ROF system and modulation techniques being used to generate OFDM signal of modulated RF. This will be followed by theoretical analysis of OFDM and ROF system. Main thing to analyze here is the basic concept of ROF system, OFDM modulation technique and incorporating OFDM along with ROF.

This will be followed by the modeling and designing the system and analyze characterization of the system modelled. Simulation will be done using commercial optical simulation software such as Optisystem and Matlab. The simulation result will be analyze and compared with the theoretical and numerical analysis plus previous work if any. Optimizing the system performance will involve the modeling in order to produce an improvement performance of simulation result.

OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks. It enables users to simulate and design next generation optical networks, current optical networks, a SONET and SDH ring networks, amplifiers, receivers and transmitters. The software is equipped with analysis tools such as eye diagrams, BER, Q-Factor, signal chirp and constellation diagrams.

Among the software comprehensive features:

- Four-wave Mixing, SBS, Self-Phase Modulation and Cross-Phase Modulation.
- Stimulated Raman Scattering (SRS) and full bi-directional capabilities.
- MLSE (Maximum Likelihood Sequence Estimate) and advanced component using the Viterbi algorithm.
- A robust library of multimode fiber models including parabolic-index and measured-index profile.
- The most advanced optical amplifier design library available.

OptiSystem also allow professional design environment which can simulate emerging passive optical networks (PON) technologies, such as the various optical code-division multiple-access (OCDMA) techniques for OCDMA-PON architectures. The robust simulation environment enables users to plan, test and simulate optical links in the physical layer of a variety of PON.

Finally after all the simulation had been done and all the result derived, compare the result with previous work and theoretical analysis. Then finished writing also writes some publications.

1.6 Thesis Outline

This thesis report will consist of six chapters with the details as shown below:

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

methodology and thesis outline.

Chapter 2 gives an overview of the current ROF link, its architecture, applications of ROF technology and advantages plus the fundamental review on some of the optical transmission components. Previous works done by others to model the optical transmission link for the same purpose will also be reviewed. Chapter 3 deals with the Orthogonal Frequency Division Multiplexing (OFDM) which consists of introduction, general principles and coded OFDM and also discusses the advantages and disadvantages of OFDM. The mathematical modelling of SBS in optical fiber will also be presented in this chapter

The OFDM - ROF system design technique and Optisytem software are using to model and implement the system will be elaborated in chapter 4. The principle of operation of the method proposed, its features, modelling work and parameters used are reviewed. In this chapter proposed OFDM with 16 QAM modulation systems for radio over fiber networks are presented. Chapter 5 on the other hand will analyze the simulation results and comparison will be made with the theoretical analysis and previous work. Optimizing the system performance which involves the improvement of the modeling is also being discussed here.

Finally chapter 6 gives the conclusion for the whole project whether the objectives of this project are met and if it is successful or not. Furthermore, it also provides suggestion for future recommendation works for development and modifications of the system presented in this project.

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