# MODELING AND PERFORMANCE ANALYSIS OF THE OFDM SCHEME FOR RADIO OVER FIBER SYSTEM

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# MODELING AND PERFORMANCE ANALYSIS OF THE OFDM SCHEME FOR RADIO OVER FIBER SYSTEM

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# ABSTRACT

Radio over fiber (ROF) is an hybrid system that having both a fiber optic link and free-space radio path. 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 base-stations then transmit the RF signals over small areas using microwave antennas. Such system is important in a number of applications, including mobile and satellite communications, wireless local area networks (WLANs), wireless local loop and mobile broadband service, etc. 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 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. In this project author investigates the feasibility of OFDM as modulation technique for a RoF based on WLAN system in consistency with IEEE 802.11g. Result from Optisystem model shows the performance of OFDM signal through the RoF networks. The system was utilized to carry data rates 20Mbps, using carrier frequency 2.4 GHz and the modulation type for OFDM is 16QAM 4 bit per symbol. Total power of the signal was decreasing while the fiber length of the RoF networks was increased from 10 – 50 km.

# ABSTRAK

*Radio over Fiber* (RoF) adalah suatu sistem hibrida yang mempunyai dua jalur transmisi, serat optik dan jalur bebas radio. 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. Pangkalan pemancar kemudian mentransmisikan sinyal RF untuk area yang lebih kecil dengan menggunakan antena gelombang mikro. Sistem yang seperti ini sangatlah penting dalam banyak aplikasi, termasuk komunikasi bergerak dan satelit, WLANs, dan layanan pita lebar bergerak lainnya. Teknik modulasi OFDM mendistribusikan data melalui banyak pembawa yang dipisahkan dengan frekuensi yang akurat dengan pita yang saling berdekatan. Penggunaan FFT pada modulasi memberikan *orthogonality* untuk setiap pembawa, yang dapat menghindarkan demodulator dalam membaca frekuensi yang bukan miliknya. Kerana itu menggabungkan OFDM dengan serat optik, sistem RoF dapat digunakan untuk transmisi jarak dekat maupun jauh dengan kelajuan data yang tinggi. Ini meningkatkan kemudahan suai dan menyediakan cakupan wilayah yang lebih besar tanpa menyebabkan kenaikan dalam biaya dan kesukaran pada sistem. Dalam projek ini penulis meniliti kemungkinan modulasi OFDM untuk RoF berdasarkan sistem WLAN IEEE 802.11g. Hasil yang didapat dari model Optisystem, memperlihatkan performa sinyal OFDM melalui jaringan RoF. Sistem ini dibuat untuk dapat membawa data 20 Mbps, menggunakan frekuensi pembawa 2.4 GHz dan tipe modulasi untuk OFDM ialah 16QAM 4 bit untuk setiap simbol. Total power yang dihasilkan oleh sinyal OFDM tersebut menurun seiring dengan ditambahkannya panjang pada serat optik dalam jaringan RoF dari 10 hingga 50 Km.

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| | | |
|---|---|---|
| XPM | - | Cross Phase Modulation |
| SPM | - | Simple-Phase Modulation |
| LD | - | Laser Diode |
| PD | - | Photo Detector |
| LED | - | Light Emitting Diode |
| APD | - | Avalanche Photodiode |
| SCM | - | Sub-carrier Multiplexing |
| WDM | - | Wavelength Division Multiplexing |
| SNR | - | Signal to Noise Ratio |
| CNR | - | Carrier to Noise Ratio |
| DWDM | - | Dense Wavelength Division Multiplexing |
| BW | - | Bandwidth |
| OSSB | - | Optical Single Side Band |
| ODSB | - | Optical Double Side Band |
| OTDM | - | Optical time Division Multiplexing |
| OCDM | - | Optical Code Division Multiplexing |
| EAM | - | Electro Absorption Modulator |
| SMF | - | Single Mode Fiber |
| MMF | - | Multi mode Fiber |
| GRIN | - | Graded Index |
| RF | - | Radio Frequency |
| MZM | - | Mach-Zehnder Modulator |
| CSNRZ | - | Carrier Suppressed Non return to Zero |
| EDFA | - | Erbium Doped Fiber Amplifier |

| | | |
|---|---|---|
| RZ | - | Return to Zero |
| NRZ | - | Non return to Zero |
| PMD | - | Polarization Mode Dispersion |
| PRBS | - | Pseudo Random Bit Sequence |
| RoF | - | Radio over Fiber |
| CW | - | Continuous Wave |
| IMD | - | Inter modulation distortion |
| OFDM | - | Orthogonal Frequency Division Multiplexing |
| ASK | - | Amplitude Shift Keying |
| FSK | - | Frequency Shift Keying |
| PSK | - | Pahse Shift Keying |
| QAM | - | Quadrature Amplitude Modulation |
| BPSK | - | Binary Phase Shift Keying |
| QPSK | - | Quadrature Phase Shift Keying |
| OQPSK | - | Offset Quadrature Phase Shift Keying |
| OOK | - | On Off Keying |
| BER | - | Bit Error rate |
| MPSK | - | Minimum Phase Shift Keying |
| CATV | - | Cable television |
| TDM | - | Time division multiplexing |
| OCDMA | - | Optical Code Division Multiple Access |
| FTTx | - | Fiber To The Home, curb, etc. |
| MH | - | Mobile Home |
| SONET | - | Synchronous Optical Network |
| DFB | - | Distributed Feedback Laser |
| SDH | - | Synchronous Digital Hierarchy |
| MAN | - | Metropolitan Area Network |
| LAN | - | Local Area Network |
| BS | - | Base Station |
| MS | - | Mobile Station |
| CS | - | Central Station |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| $\lambda$ | - | *Wavelength* |
| $h$ | - | Blank's Constant |
| C | - | Velocity of Light |
| Eg | - | Energy Gap |
| fc | - | Cut-off frequency |
| $\eta$ | - | Quantum Efficiency |
| $\Re$ | - | Responsivity |
| ip | - | Photocurrent |
| Po | - | Optical Power |
| q | - | Electron Charge |
| T | - | Temperature |
| K | - | Boltzmann Constant |
| B | - | Bandwidth |
| $R$ | - | Nominally matched Resistance |
| $Vth$ | - | The rms value for the thermal noise voltage |
| $\Delta P^2$ | - | Mean square amplitude of the noise fluctuations |
| $\alpha$ | - | Mie Scattering Coefficient |
| P(Z) | - | The laser Power at Z |
| P(I) | - | Output optical power |
| I | - | The current injected to the active region |
| V | - | Volume of the active region |
| Q | - | Photon Density |

# CHAPTER 1

# INTRODUCTION

## 1.1 Project Background

Radio-over-fiber (RoF) is a technology used to distribute RF signals over analog optical links. In such RoF systems, broadband microwave data signals are modulated onto an optical carrier at a central station (CS), and then transported to remote sites or base station (BS) using optical fiber. The base-stations then transmit the RF signals over small areas using microwave antennas as shown below in Figure 1.1[1] [2].

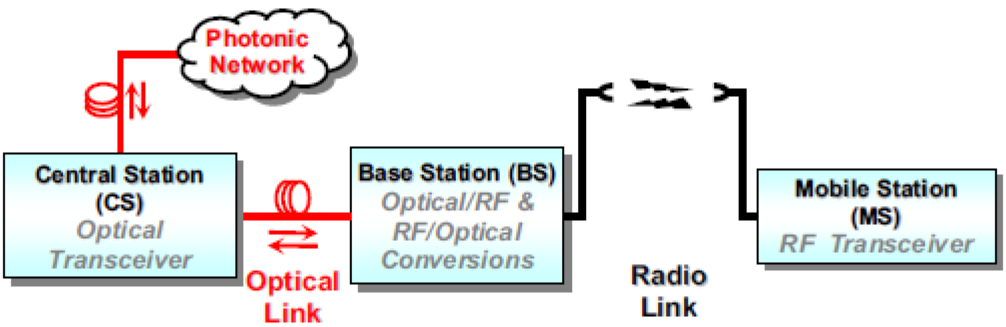


**Figure 1.1** General RoF systems

Such technology is expected to play an important role in present and future wireless networks since it provides an end user with a truly broadband access to the network while guaranteeing the increasing requirement for mobility.

ROF is very attractive technique for wireless access network infrastructure, because it can transmit microwaves and millimeter-waves through optical fibers for a long distance. Moreover, 5 GHz ROF link using a direct modulation scheme has been developed to support some important future wireless systems such as wireless local area networks (WLAN) intelligent transport systems (ITS), and the 4th generation cellular systems.

In particular, ROF is promising technique for WLAN infrastructures because ROF technique can manage WLAN modems at a base station (BS) and can solve serious interference problem between wireless signals caused by proliferated WLAN access points (APs).

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 OFDM has the best spectral efficiency, resiliency to RF interference, and lower multi-path distortion. LAN, which uses OFDM is the current trend for indoor wideband communication with a drawback of limited coverage area of few meters, but supports high data rate.

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.

There are so many previous research papers and works that have been done by several people recently in terms of using OFDM modulation technique or multicarrier transmission for sending and receiving data through Radio over Fiber Networks. For example **A. Marwanto and S. M. Idrus** in their paper which titled *SCM/WDM Radio over Fiber for Broadband Communication*, the author shown the study about multiplexing carrier used for Radio Over Fiber Network Technology, and their result that the outcomes of bandwidth was increased to 60 GHz by applying of 16 Channel of SCM combined with WDM in optical fiber link. Another paper from **Guruprakash Singh and Arokiaswami Alphones** which titled *OFDM Modulation Study for a Radio-over-Fiber System for Wireless LAN (IEEE 802.11,* they has made an analysis of theoretical performance for OFDM using different technique of digital modulation such as PSK, BPSK, QPSK and QAM. Their result shows that QAM provide better spectral efficiency and lower detection error probability.

Meanwhile **Dhivagar. B, Ganesh Madhan.M, and Xavier Fernando** in their paper works which titled *Analysis of OFDM signal Through Optical Fiber for Radio over Fiber Transmission* has investigate the impact of fiber dispersion on the transmission performance of OFDM based IEEE 802.11.g, WLAN signal for different distances. The results show that using different fiber length it is clear that significant coverage extension is possible with very minimum penalty. And another work from **I. A. Kostko, M. E. Mousa Pasandi, M. M. Sisto, S. Larochelle, L. A. Rusch, and D. V. Plant** which titled *A radio-over-fiber link for OFDM transmission without RF amplification*. Their work is to increase OFDM signal transmission quality over the optically amplified link by joint optimization of the PD impedance matching and MZM bias. Their result show that the amplification can be moved from electrical to optical, which allows having an optical amplifier at the central office and simplifying the base station.

Based on those previous papers and studies, there are so many researches and works in the field of using multicarrier transmission technique especially OFDM to transmitted and received data through optical link in Radio over Fiber Networks.

Meanwhile in this project author working on modeling and analyze 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). The project model has simulated by using commercial software, Optisystem 7.0.

## 1.2 Problem Statement

A key initiative in the deployment of new wireless services is to cost effectively extends and enhance the network's radio coverage. 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. To meet these requirements one of best solution is the combination of Orthogonal Frequency Division Multiplexing (OFDM) digital modulation and radio over fiber (ROF) technology.

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 [l]. While RoF is the next generation communications system that can utilize the high capacity of optical networks along with the mobility of wireless networks.

## 1.3 Objectives

The first objective of this project is to model and simulate the OFDM scheme for RoF using commercial software, Optisystem 7.0 from Optiwave. The second objective is to investigate and analyze the feasibility performance of OFDM for RoF in term of Eye diagram and the effect of total length with the fiber dispersion.

## 1.4 Scope of Work

The scopes of this project are:

1. Understanding the basic principle of OFDM modulation technique and RoF through literature study.
2. Modeling and simulation of OFDM signals through RoF network using commercial software, Optisystem 7.0 from Optiwave.
3. The OFDM system is modeled for application based on WLAN IEEE 802.11 b/g standard (2.4 GHz).

## 1.5 Methodology

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

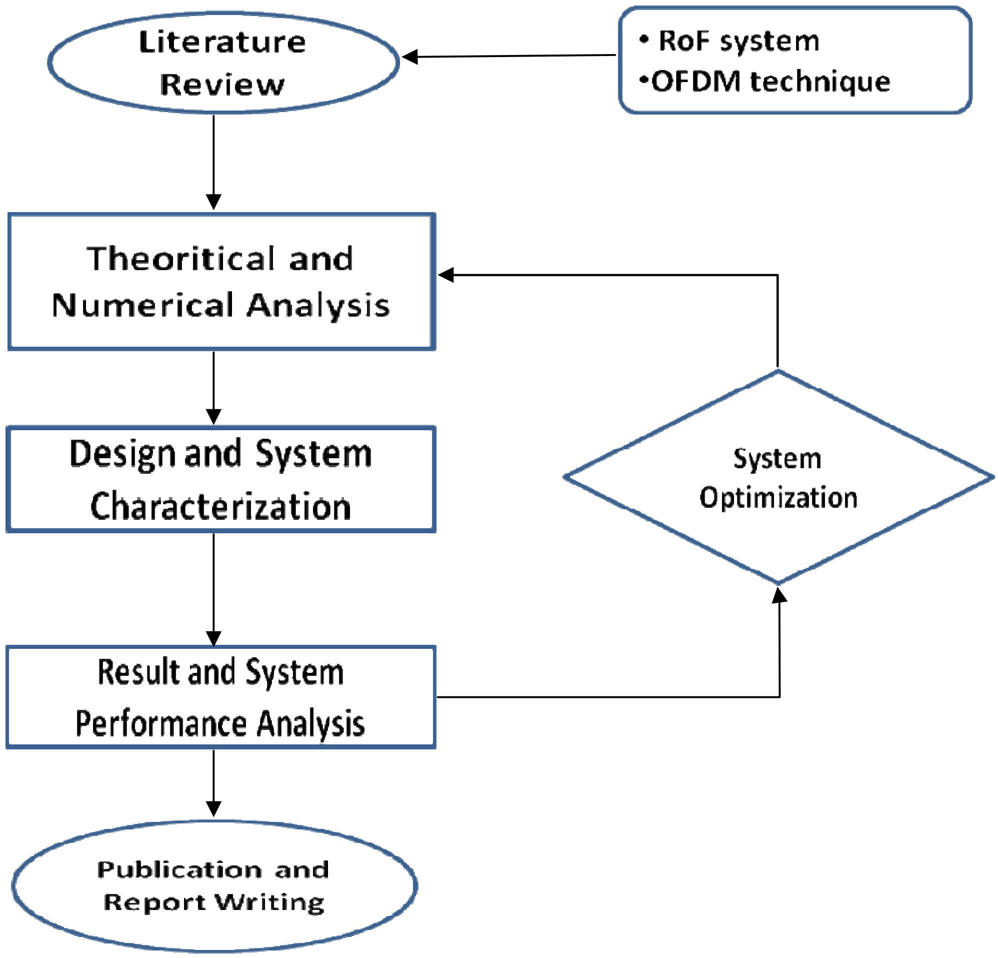


**Figure 1.2** Project Flow Chart

First the methodologies start with literature study and review on the RoF system and OFDM modulation technique. Then understood the modeling design of OFDM modulation technique for RoF system. After that followed by theoritical 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. Sooner after fully understand about the theoretical part, then starting to design and model the system and analyze characterization of the system modeled. The OFDM-RoF system was modeled and simulated using commercial software, which is Optisystem 7.0 from Optiwave.

Next is analyzing the result and system performance which is obtained from the simulation model. While analyzing the result, the system is being optimize to get a better performance and best simulation result. This would be done with referring to the theoretical and numerical analysis part again to double check whether some part is missing or some problem were occurring when understanding the theory.

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

These projects comprise of six chapters and organize as follows:

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 is literature review of this project which is explaining some basic theory of Radio over Fiber, with the benefits and architecture of RoF. Also explain the parts of optical transmission link and the applications of RoF technology.

Chapter 3 presents the Orthogonal Frequency Division Multiplexing (OFDM). Consist of introduction, general principles and coded OFDM and also discusses the advantages and disadvantages of OFDM.

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