UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ANALYSIS AND SIMULATION OF SERVICE QUALITY ENHANCEMENT BY APPLYING RADIO OVER FIBER (ROF) IN COMMUNICATION LINK

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Telecommunications) (Hons.)

by

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This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Telecommunications) (Hons.). The member of the supervisory is as follow:

……………………………….

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ABSTRACT

In telecommunication one of the technologies that are important is Radio over Fiber (RoF) systems. There has been a significant efforts dedicated to the merging of radio frequency and optical fiber technologies targeting the distribution of radio wave signals, in the recent years. The domain of Radio over Fiber (RoF) technologies and systems took birth from these endeavors. This kind of systems promises a secure, cost-effective, and high-capacity mobile and wireless access for the prospect facilitation of broadband, interactive, and multimedia wireless services. It is present a comprehensive performance analysis of several optimized fiber radio distribution schemes for millimeter- wave radio services. The analysis includes the noise and nonlinear characteristics of the transmitter (Tx)–receiver (Rx) pair integrated with the analog optical link in the downlink transmission of a given wavelength without optical amplification. Observation are focused on the parameter such as power loss, delay, signal-to-noise ratio (SNR) and other parameter that will be affected in service quality enhancement.

ABSTRAK

Dalam telekomunikasi salah satu teknologi yang penting ialah ‘Radio over Fibre’ (ROF) sistem. Terdapat usaha yang dikhususkan untuk menggabungan frekuensi radio dan teknologi gentian optik di mana menyasarkan pengagihan isyarat gelombang radio, pada kebelakangan tahun ini. Domain ‘Radio over Fibre’ (ROF) teknologi dan sistem tercipta dari usaha ini. Sistem jenis ini menjanjikan kos efektif dan berkapasiti tinggi yang selamat diakses, mudah alih dan tanpa wayar untuk memudahkan prospek jalur lebar, interaktif dan perkhidmatan multimedia tanpa wayar. Ia mewakili analisis prestasi komprehensif daripada beberapa skim pengedaran gentian radio dioptimumkan untuk perkhidmatan radio gelombang-millimeter. Analisis ini termasuk bunyi dan ciri-ciri tak linear daripada pemancar (Tx) -penerima (Rx) pasangan bersepadu dengan pautan optik analog dalam penghantaran pautan turun dari panjang gelombang tertentu tanpa pembesaran optik. Pemerhatian tertumpu kepada parameter seperti kehilangan kuasa, kelewatan, isyarat-kepada-hingar (SNR) dan parameter lain yang akan terjejas dalam peningkatan kualiti perkhidmatan.

DEDICATIONS

To my beloved father and mother

To my siblings

To my supervisor

To my academic advisor

To my lecturers

To my classmates

To my lovely friends

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LIST OF SYMBOLS AND ABBREVIATIONS

RAU	=	Remote Antenna Units
MU	=	Mobile Units
RF	=	Radio Frequency
IM-DD	=	Intensity Modulation with Direct Detection
LO	=	Local Oscillator
WLAN	=	Wireless Local Area Network
GSM	=	Global System for Mobile
BS	=	Base Station
IF	=	Intermediate Frequency
EDFA	=	Erbium Doped Fiber Amplifier
CW	=	Continuous Wave
MZM	=	Mach Zehner Modulator
RoF	=	Radio over Fiber
TDMA	=	Time Division Multiple Access
CSMA	=	Carrier Sense Multiple Access
SCM	=	Sub-Carrier Multiplexing

CHAPTER 1

INTRODUCTION

1.0 Introduction

In RoF systems, wireless signals are transported in optical form between a central station and a set of base stations before being radiated through the air. Each base station is adapted to communicate over a radio link with at least one user's mobile station located within the radio range of said base station. The advantage is that the equipment for WiFi, 3G and other protocols can be centralized in one place, with remote antennas attached via fiber optic serving all protocols. It greatly reduces the equipment and maintenance cost of the network. [Hal Hodson, 2012]

1.1 Background

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 radio link. Therefore, wireless signals are optically distributed to base stations directly at high frequencies and converted from the optical to electrical domain at the base stations before being amplified and radiated by an antenna. This project will simulate and analyze the RoF from the theoretical and simulation aspect. [Hal Hodson, 2012]

1.2 Statement of Purpose

Generally, the function of Radio over fiber (RoF) is an analog optical link transmitting modulated RF signals. An important application of RoF is its use to provide wireless coverage in the area where radio link is not possible. These zones can be areas inside a structure such as a tunnel, areas behind buildings, Mountainous places or secluded areas such as jungles. Also, by using an optical connection directly to the antenna, the equipment vendor can gain several advantages like low line losses and immunity to lightning strikes or electric discharges.

1.3 Objectives

The objectives are:

1. To have knowledge about convert Radio Frequency (RF) transmission to Fibre Optic (FO) receiver and vice versa.
2. To analyze the finding result.
3. To have knowledge in design Radio over Fibre (RoF) in high speed data.

1.4 Problem Statement

The scope of this project is to analyze and simulation the analog link transmitting modulated RF signals for fiber optic communication. After identifying the project title, the next thing to do is to study and research through reference materials such as the internet, books and information from the industry understand how Radio over Fiber for long-distance communication function simultaneously achieving the best quality performances. In addition, the methods and suitable techniques need to be identified in order to analyze how the radio over fiber can reached the destination in same quality in data transmission. The next stage is to present the animation that show how the Radio over Fiber works. After animation process is done, calculation process will be done. The calculation involves parameter such as gain, power loss, BER, SNR and other parameters that will be affected. In the process designing, it is divided into three aspects calculations, simulations and measurements, where all three aspect need to achieve a certain specification before it is implemented. On the other hand, if still do not meet specifications, the process will be executed repeatedly until satisfy. After, all aspects of designing have reached specification and from simulation and measurement results, the process of analyzing the collected data implemented. Lastly, when all the process is completed, all information is arranged and starts writing a final report.

1.5 Result Expectation

The result expectations are:

1. To design an attractive animation.
2. To design a capable friendly simulation program.
3. To see the differences in comparison between calculation and simulation.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Literature review is a process by reading, analyzing, evaluating, and summarizing scholarly materials about a specific topic. The result can be served as a part of a research and complied in this final year project report.

2.1 Radio over Fiber Technology

RF signals from a central location (headend) to Remote Antenna Units (RAUs). In narrowband communication systems and WLANs, RF signal processing functions such as frequency up-conversion, carrier modulation, and multiplexing, 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 fibre, 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 RAUs, as shown in Figure 2.1. By so doing, RAUs 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 wide-coverage broadband wireless communication systems, where a high density of BS/RAUs is necessary as discussed above.

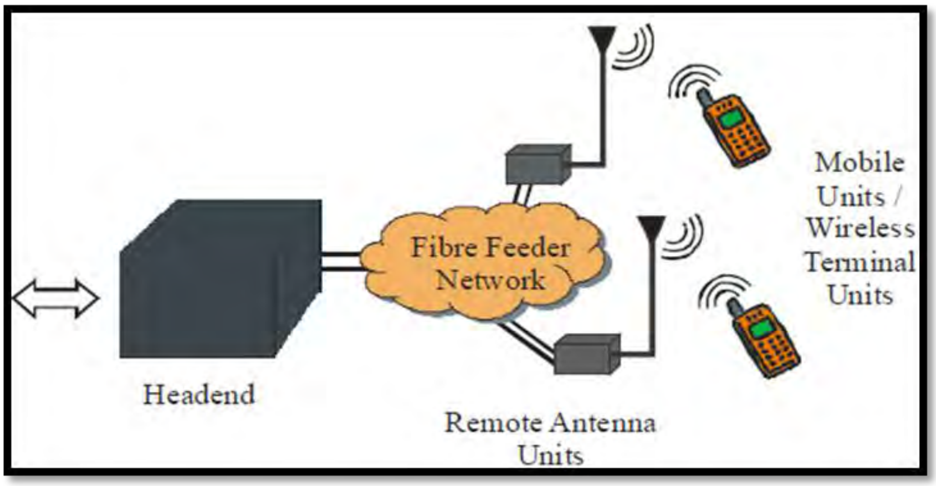

Figure 2.1: Radio over Fibre System Concept

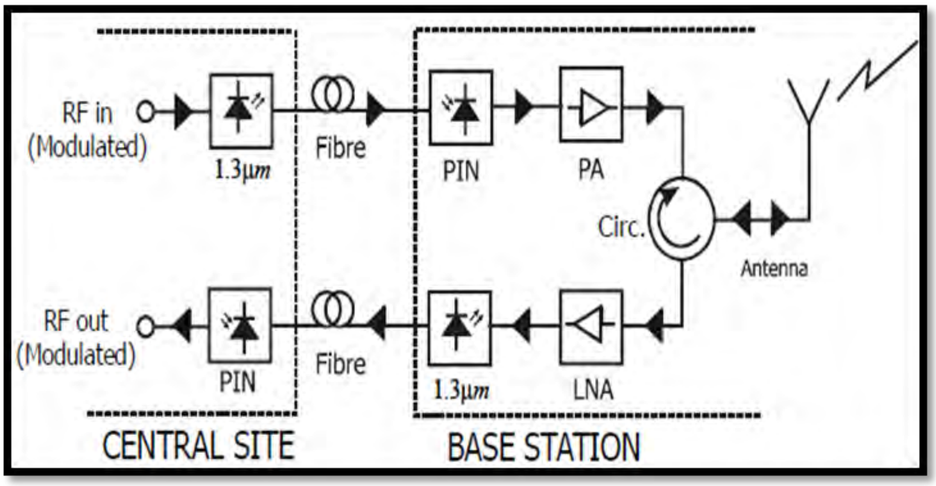

Figure 2.2: 900 MHz Fibre-Radio System

One of the pioneer RoF system implementations is depicted in Figure 2.2. Such a system may be used to distribute GSM signals, for example. The RF signal is used to directly modulate the laser diode in the central site (headend). The resulting intensity modulated optical signal is then transported over the length of the fibre to the BS (RAU). At the RAU, the transmitted RF signal is recovered by direct detection in the PIN photo detector. The signal is then amplified and radiated by the antenna. The uplink signal from the MU is transported from the RAU to the headend in the same way. This method of transporting RF signals over the fibre is called

Intensity Modulation with Direct Detection (IM-DD), and is the simplest form of the RoF link. While Figure 2.2 shows the transmission of the RF signal at its frequency, it is not always necessary to do that. For instance, a Local Oscillator (LO) signal, if available, may be used to down-convert the uplink carrier to an IF in the RAU. Doing so would allow for the use of low-frequency components for the up-link path in the RAU –leading to system cost savings. Instead of placing a separate LO in the RAU, it may be transported from the headend to the RAU by the RoF system. Once available at the RAU, the LO may then be used to achieve down-conversion of the uplink signals. This results in a much simpler RAU. In this configuration, the downlink becomes the crucial part of the RoF since it has to transport high-frequency signals. The transportation of high-frequency signals is more challenging because it requires high frequency components, and large link bandwidth. This means that high frequency signals are more susceptible to transmitter, receiver, and transmission link signal impairments. [Ajay K. & Dr.Navneet A., 2012]

2.1.1 Benefits of RoF Technology

Some of the advantages and benefits of the RoF technology compared with electronic signal distribution are given below.

❖ ***Low Attenuation Loss***

Electrical distribution of high-frequency microwave signals either in free space or through transmission lines is problematic and costly. In free space, losses due to absorption and reflection increase with frequency. In transmission lines, impedance rises with frequency as well, leading to very high losses. Therefore, distributing high frequency radio signals electrically over long distances requires expensive regenerating equipment. As for mm-waves, their distribution via the use of transmission lines is not feasible even for short distances. The alternative solution to this problem is to distribute baseband signals or signals at low intermediate frequencies (IF) from the switching centre (headend) to the BS. The baseband or IF signals are up-converted to the required microwave or mm-wave frequency at each base station, amplified and then radiated. Since, high performance LOs would be required for up-conversion at each base station, this arrangement leads to complex base stations with tight performance requirements. However, since optical fibre offers very low loss, RoF technology can be used to achieve both low-loss distribution of mm-waves, and simplification of RAUs at the same time. Therefore, by transmitting microwaves in the optical form, transmission distances are increased several folds and the required transmission powers reduced greatly.

- ***Large Bandwidth***

Optical fibres offer enormous bandwidth. There are three main transmission windows, which offer low attenuation, namely the 850 nm, 1310 nm, and 1550 nm wavelengths. But developments to exploit more optical capacity per single fibre are still continuing. The enormous bandwidth offered by optical fibres has other benefits apart from the high capacity for transmitting microwave signals. The high optical bandwidth enables high speed signal processing that may be more difficult or impossible to do in electronic systems. Furthermore, processing in the optical domain makes it possible to use cheaper low bandwidth optical components such as laser diodes and modulators, and still be able to handle high bandwidth signals. The utilization of the enormous bandwidth offered by optical fibres is severely hampered by the limitation in bandwidth of electronic systems, which are the primary sources and receivers of transmission data. This problem is referred to as the "*electronic bottleneck*". The solution around the electronic bottleneck lies in effective multiplexing. OTDM and DWDM techniques mentioned above are used in digital optical systems. In analogue optical systems including RoF technology, Sub-Carrier Multiplexing (SCM) is used to increase optical fibre bandwidth utilization. In SCM, several microwave subcarriers, which are modulated with digital or analogue data, are combined and used to modulate the optical signal, which is then carried on a single fibre. This makes RoF systems cost-effective.

- ***Immunity to Radio Frequency Interference***

Immunity to Electromagnetic Interference (EMI) is a very attractive property of optical fibre communications, especially for microwave transmission. This is so because signals are transmitted in the form of light through the fibre. Because of this immunity, fibre cables are preferred even for short connections at mm-waves. Related to EMI immunity is the immunity to eavesdropping, which is an important characteristic of optical fibre communications, as it provides privacy and security.

- ***Easy Installation and Maintenance***

In RoF systems, complex and expensive equipment is kept at the headend, thereby making the RAUs simpler. For instance, most RoF techniques eliminate the need for a LO and related equipment at the RAU. In such cases a photo detector, an RF amplifier, and an antenna make up the RAU. Modulation and switching equipment is kept in the headend and is shared by several RAUs. This arrangement leads to smaller and lighter RAUs, effectively reducing system installation and maintenance costs. Easy installation and low maintenance costs of RAUs are very important requirements for mm-wave systems, because of the large numbers of the required RAUs. In applications where RAUs are not easily accessible, the reduction in maintenance requirements leads to major operational cost savings. Smaller RAUs also lead to reduced environmental impact.

- ***Reduced Power Consumption***

Reduced power consumption is a consequence of having simple RAUs with reduced equipment. Most of the complex equipment is kept at the centralized headend. In some applications, the RAUs are operated in passive mode. For instance, some 5 GHz Fibre-Radio systems employing pico-cells can have the RAUs operate in passive mode. Reduced power consumption at the RAU is significant considering that RAUs are sometimes placed in remote locations not fed by the power grid.

- ***Multi-Operator and Multi-Service Operation***

RoF offers system operational flexibility. Depending on the microwave generation technique, the RoF distribution system can be made signal-format transparent. For instance the Intensity Modulation and Direct Detection (IM-DD) technique can be made to operate as a linear system and therefore as a transparent system. This can be achieved by using low dispersion fibre (SMF) in combination with pre-modulated RF subcarriers (SCM). In that case, the same RoF network can be used to distribute multi-operator and multi-service traffic, resulting in huge economic savings.

- ***Dynamic Resource Allocation***

Since the switching, modulation, and other RF functions are performed at a centralized headend, it is possible to allocate capacity dynamically. For instance in a RoF distribution system for GSM traffic, more capacity can be allocated to an area (e.g. shopping mall) during peak times and then re-allocated to other areas when off-peak (e.g. to populated residential areas in the evenings). This can be achieved by allocating optical wavelengths through Wavelength Division Multiplexing (WDM) as need arise. Allocating capacity dynamically as need for it arises obviates the requirement for allocating permanent capacity, which would be a waste of resources in cases where traffic loads vary frequently and by large margins. Furthermore, having the centralized headend facilitates the consolidation of other signal processing functions such as mobility functions, and macro diversity transmission.

2.2 Techniques for Transporting RF Signals over Optical Fiber

There are several optical techniques for generating and transporting microwave signals over fibre. By considering the frequency of the RF signal fed into the RoF link at the headend in comparison with the signal generated at the RAU the RoF techniques may be classified into three categories – namely RF-over-fibre (RFoF),