MULTIPLE INPUT MULTIPLE OUTPUT ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING BASED PHOTONIC ACCESS POINT

NORLIZIANI BINTI ZAMURI

UNIVERSITI TEKNOLOGI MALAYSIA

MULTIPLE INPUT MULTIPLE OUTPUT ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING BASED PHOTONIC ACCESS POINT

NORLIZIANI BINTI ZAMURI

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical - Electronics & Telecommunications)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2012

To my beloved family and friends

ACKNOWLEDGEMENT

All praise is to the Al-Mighty Allah S.W.T, The Merciful and Beneficent for the strength and blessing throughout the entire time until the completion of this project report. Peace be upon our prophet Muhammad S.A.W, who has given light to mankind.

I wish to express my sincere appreciation and gratitude to my Supervisor, Assoc. Prof. Dr. Razali bin Ngah, for his guidance, counsels, and putting much effort through his useful advice in this course.

I also would like to thank my lecturers who have taught me throughout the semesters. Last but not least, to all my colleagues who were involved either directly or indirectly in this course, their contribution is highly appreciated. The kindness, cooperation and support from all of the above mentioned people would always be remembered.

ABSTRACT

One type of fiber-optic access system, Fiber-to-the-Home (FTTH) network is designed to deliver broadband services to end-users over fiber. With the rapid increasing activity in FTTH deployments in Malaysia and the general desire to eventually migrate to these systems, the opportunities to simplify and cost reduce the deployment of such advanced networks has never been more significant. By implementing radio over fiber technology, this will lead to the reduction in the overall costs required to deploy photonic access point in FTTH networks today. The advanced Multiple-Input Multiple-Output (MIMO) system can provide higher capacity gain or higher diversity gain in the broadband networks. The combination of MIMO and Orthogonal Frequency Division Multiplexing (OFDM) can harvest the benefits of high bit rate and low complexity equalization, respectively. The purpose of this study is to design and simulate the implementation of MIMO-OFDM based photonic access point. The system has been design to accommodate Wireless Local Area Network (WLAN) 802.11n standard which is using data rate 130Mbps over carrier frequency 2.4GHz. The design is simulated using OptiSystem software. The performances were analyzed and presented in eye diagram and graphs from the simulation results.

ABSTRAK

Satu jenis sistem akses gentian fiber optik, rangkaian fiber ke rumah (FTTH) direka untuk memberikan perkhidmatan jalur lebar kepada pengguna melalui fiber. Dengan aktiviti yang pesat membangun dalam pelaksanaan FTTH di Malaysia dan keinginan untuk berhijrah ke sistem ini, peluang untuk memudahkan dan mengurangkan kos pelaksanaan rangkaian yang maju seperti ini tidak pernah menjadi yang lebih penting. Dengan melaksanakan radio melalui teknologi fiber, ini akan membawa kepada pengurangan dalam kos keseluruhan yang diperlukan untuk membangunkan pusat akses photonik dalam rangkaian FTTH hari ini. Sistem *Multiple Input Multiple Output* (MIMO) yang maju boleh memberikan keuntungan kapasiti yang lebih tinggi atau kepelbagaian keuntungan yang lebih tinggi dalam rangkaian jalur lebar. Gabungan MIMO dan *Orthogonal Frequency Division Multiplexing* (OFDM) boleh menghasilkan kadar bit yang tinggi dan penyamaan kerumitan yang rendah. Tujuan kajian ini adalah untuk merekabentuk dan mensimulasi pelaksanaan MIMO-OFDM berasaskan pusat akses photonik. Sistem ini sudah direka bentuk untuk menampung Rangkaian Kawasan Tempatan Tanpa Wayar (WLAN) 802.11n yang menggunakan kadar data 130Mbps melalui frekuensi pembawa 2.4GHz. Reka bentuk ini disimulasi dengan menggunakan perisian OptiSystem. Prestasi dianalisis dan dibentangkan dalam bentuk *eye diagram* dan graf daripada keputusan simulasi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADC	-	Analogue-To-Digital Converter
AWG	-	Arrayed Waveguide
AWGN	-	Additive White Gaussian Noise
BBGP	-	Broadband To The General Population
BER	-	Bit Error Rate
BIDI	-	Bidirectional
BPON	-	Broadband Passive Optical Network
BS	-	Base Station
CBS	-	Central Base Station
CD	-	Compact Disc
CO	-	Central Office
CW	-	Continuos-Wave
DAC	-	Digital-To-Analogue Converter
DMT	-	Discrete Multi-Tone Modulation
DPSK	-	Differential Phase-Shift Keying
DQPSK	-	Differential Quadrature Phase-Shift Keying
DSL	-	Digital Subscriber Line
DSSS	-	Direct Sequence Spread Spectrum
DW	-	Double Weight
EDW OCDMA	-	Enhanced Double Weight Optical Code Division Multiple Access
EPON	-	Ethernet Passive Optical Network
FDM	-	Frequency-Division Multiplexing
FFT	-	Fast Fourier Transform
FHSS	-	Frequency Hopping Spread Spectrum
FTTH	-	Fiber To The Home
GPON	-	Gigabit Passive Optical Network
GUI	-	Graphical User Interface

HR/DSSS	-	High-Rate Direct Sequence Layer
HSBB	-	High Speed Broadband
ICI	-	Causing Inter-Carrier Interference
IPTV	-	Internet Protocol television
ISI	-	Inter-Symbol Interference
ITU-R	-	International Telecommunication Union Recommendation
LAN	-	Local Area Network
LiNb MZM	-	Lithium Niobate Mach-Zehnder Modulator
LOS	-	Line Of Sight
MAC	-	Medium Access Control
MCS	-	Modulation And Coding Scheme
MFH	-	Modified Frequency Hopping
MFN	-	Multi-Frequency Broadcast Networks
MIMO	-	Multiple-Input Multiple-Output
MLD	-	Maximum Likelihood Detector
MMSE	-	Minimum-Mean-Squared-Error
MPDU	-	MAC Protocol Data Units
MS	-	Mobile Station
MSDU	-	MAC Service Data Units
NRZ	-	Non Return To Zero
O/E	-	Optical-To-Electrical
OFDM	-	Orthogonal Frequency Division Multiplexing
OLT	-	Optical Line Terminal
ONT	-	Optical Network Terminal
ONU	-	Optical Network Units
OSP	-	Outside Plant
P2P	-	Point-To-Point
P2MP	-	Point-To-Multipoint
PAP	-	Photonic Access Point
PAPR	-	Peak-To-Average Power Ratio
PBRS	-	Pseudo-Random Bit Sequence
PER	-	Packet-Error-Rate
PHY	-	Physical Layer
PON	-	Passive Optical Network

PSK	-	Phase-Shift Keying
QAM	-	Quadrature Amplitude Modulation
RF	-	Radio Frequency
RoF	-	Radio Over Fiber
RS	-	Remote Station
S2P	-	Two-Port Network S-Parameter
SCM	-	Subcarrier Multiplexing
SFN	-	Single-Frequency Networks
SDM	-	Space Division Multiplexing
SDMA	-	Space Division Multiple Access
SNR	-	Signal To Noise Ratio
STBC	-	Space-Time Block Codes
STC	-	Space Time Coding
STTC	-	Spacetime Trellis Codes
TM	-	Telekom Malaysia
WDM	-	Wavelength Division Multiplexing
WLAN	-	Wireless Local Area Network
VoiP	-	Voice Over Internet Protocol

CHAPTER 1

INTRODUCTION

1.1 Introduction

As part of ongoing efforts to support the nation’s call for higher broadband speeds, new Fiber-to-the-Home (FTTH) broadband access solution was introduced in Malaysia which offers users the preliminary step towards the digital home experience. The FTTH solution will be targeted at users requiring premium broadband services. FTTH is an end to end fiber optic connection for the deployment of high speed broadband services to the homes. Unlike Digital Subscriber Line (DSL) technology, it offers higher speeds and better throughput quality compared to copper wires.

FTTH's immense capacity allows for the easy deployment of triple-play application services (voice, video and data). With such high powered capability, users will discover the ease of use with having IPTV content, video-on-demand entertainment, gaming, Voice over internet protocol (VoiP) services and data applications delivered, all via the convenience of a single fiber enabled broadband connection.

With the everincreasing activity in FTTH deployments, and the general desire to eventually migrate to these systems, the opportunities to simplify and cost reduce the deployment of such advanced networks has never been more significant. Radio-over-Fiber (RoF) techniques apply to FTTH distributions to reach the customer premises with the services to be received with full-standard low-cost equipment.

RoF refers to a technology to facilitate wireless access whereby light is modulated by a radio signal and transmitted over an optical fiber link. 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. RoF makes use of the concept of a Remote Station (RS). In this project, the RS is referred as Photonic Access Point (PAP). This station only consists of optical-to-electrical (O/E), optional frequency up or down converter, amplifiers, and antenna.

The resource management and signal generation circuitry of the Base Station (BS) can be moved to a centralized location and shared between several access points, thus simplifying the architecture. Simpler structure of photonic access point means lower cost of infrastructure, lower power consumption by devices and simpler maintenance all contributed to lowering the overall installation and maintenance cost.

By introducing Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) in the PAP, it will increase the date rates received at the users. The combination of MIMO-OFDM is considered as the best solution to provide high data rates under frequency-selective fading channels. OFDM is one of the most popular physical layer technologies for current broadband wireless communications due to its high spectral efficiency and robustness to frequency selective fading.

The use of MIMO technology in combination with OFDM increases the diversity gain and/or the system capacity by exploiting spatial domain. Through modeling, simulations, and extensive experiments, the behaviour and performance of a RoF downlink employing MIMO-OFDM was investigated.

1.2 Problem Statement

In term of commercial, the deployments of FTTH in Malaysia become an issue due to the installation of fiber under or inside the home. User's house needs to be drilled in order to insert fiber to the home. This method is not agreed by some user's because they don't want their house been drilled.

On the engineering side, the move towards enhanced mobility will lead to a need for wireless infrastructure that provides increased bandwidth per user. Wireless coverage of the end-user domain, be it outdoors or indoors (in-building), is poised to become an essential part of broadband communication networks. In order to offer integrated broadband services, these systems will need to offer higher data transmission capacities well beyond the present-day standards of wireless systems.

The need for increased capacity per unit area leads to higher operating frequencies and smaller radio cells, especially in indoor applications where the high operating frequencies encounter tremendously high losses through the building walls. To reduce the system installation and maintenance costs of such systems, it is imperative to make the radio antenna units as simple as possible. This may be achieved by consolidating signal processing functions at a centralized headend, through RoF technology.

1.3 Objectives

The main objective of this project is to simulate MIMO-OFDM based access point for FTTH application using RoF technology. The proposed design will reduce the cost required to deploy FTTH network in Malaysia. Higher data rates could be achieved by employing a 2x2 MIMO system and higher level modulation scheme, which is 64-QAM. The access point will be operating at 2.4GHz using 802.11n standard.

1.4 Scope of Project

The scopes of work are proposed as a guideline so that this project is narrowed to a certain boundaries. This is to ensure this project achieves its objectives. Firstly, MIMO-OFDM will be implemented in FTTH network using RoF technology. The downlink system start from Optical Line Transmission (OLT) up to the end user will be designed.

Spatial multiplexing of 2x2 antennas is used for the MIMO antenna. The information signal transmitted will be modulated with a carrier frequency of 2.4GHz before being transmitted into the fiber by laser. Since ITU-R designated 900 MHz, 2.4 GHz, and 5 GHz frequency bands as unlicensed for ISM communities, therefore, 2.4 GHz is chosen to employ in IEEE 802.11n WLAN. This project will utilize OptiSystem software for the design and simulation.

1.5 Thesis Outline

This thesis consists of six chapters and organizes as follows:

Chapter 1 describes a brief introduction to this project. This introductory part of this thesis consists of problem statement, objective, scope of work and followed by thesis outline.

Chapter 2 contains the literature review part of this project. This part is enlightened the general description of FTTH architectures and how it has been deployed in Malaysia. The introduction to the RoF technology, OFDM, MIMO and MIMO-OFDM in WLAN also is discussed in this chapter. Being focused on MIMO-OFDM technology, related research to this technology is studied.

Chapter 3 describes the methodology carried out in doing this research. Briefly, after literature reviews are done, designing and simulating the system are realized using OptiSystem software. Prior to the designing and simulating the system, a specific parameter needed to be determined. As the simulation succeeded, the results are analyzed using various analysis tools available and has been discussed.

Chapter 4 presents the system design and simulation of this project. The system is modeled based on the study and previous researches. The system is simulated from OLT up to end user. Main signal processing is done in Central Base Station (CBS), then transmitted through optical fiber and received at PAP before being transmitted to the end user using wireless medium.

Chapter 5 presented the results obtained from simulations in OptiSystem. Various tools such as Electrical Constellation Visualizer, RF Spectrum Analyzer, Optical Spectrum Analyzer and Eye Diagram Analyzer are used in order to obtain the result in form of graph signal. The results has been analyzed and discussed.

Chapter 6 concludes the whole project. This chapter also provides a few recommendations of future work for development and modification of the system.

REFERENCES

1. Multicom. (2011). Three Fundamental Architectures for FTTH. Retrieved October 8, 2011 from http://www.multicominc.com/stimulus/FTTH_architectures.htm

2. Mohammoud Munsor Mohammoud Hadow. (April 2008). Radio Access Point Design For Radio Over Fiber Technology. Master of Engineering Thesis. Universiti Teknologi Malaysia, Skudai.

3. Pardeep Kaur and R.S.Kaler. (2007). Radio Over Fiber Networks. *Proceedings of National Conference on Challenges & Opportunities in Information Technology (COIT-2007) RIMT-IET, Mandi Gobindgarh.* March 23, 2007.

4. D.Opati. Radio over Fiber Technology for Wireless Access. GSDC Croatia Ericsson Nikola Tesla d.d. Krapinska 45, HR-10001 Zagreb.

5. MyConvergence (2009). HSBB Malaysia's Drive for High Speed Broadband. A publication of Malaysian Communications and Multimedia Commission, Vol. 3 /No. 1, January 2009.

6. Robertson, P.; Kaiser, S. "The effects of Doppler spreads in OFDM(A) mobile radio systems", Vehicular Technology Conference, 1999. VTC 1999 - Fall. IEEE VTS.

7. Coleri, S. Ergen, M. Puri, A. Bahai, A. (2002) "Channel estimation techniques based on pilot arrangement in OFDM systems". IEEE Transactions on Broadcasting, September 2002.

8. Hoeher, P. Kaiser, S. Robertson, P. (1997) "Two-dimensional pilot-symbol-aided channel estimation by Wienerfiltering". IEEE International Conference on Acoustics, Speech, and Signal Processing, ICASSP-97, 1997.

9. Wikipedia. (2012). Orthogonal Frequency Division Multiplexing. Retrieved June 19, 2012, from http://en.wikipedia.org/wiki/Orthogonal_frequency - division_multiplexing

10. Agilent Technologies, Inc. (2010). *Agilent MIMO Channel Modeling and Emulation Test Challenges.* USA. January 22, 2010. 5989-8973EN

11. AirMagnet Inc. (2008). Whitepaper | 802.11n Primer. USA. August 05, 2008.

12. Inscape Data. (2011). Introduction to 802.11n Outdoor Wireless Networks. March 29, 2011.

13. Rick S. Blum, Ye (Geoffrey) Li, Jack H. Winters, and Qing Yan. (2001). Improved Space–Time Coding for MIMO-OFDM Wireless Communications. *IEEE Transactions On Communications,* Vol. 49, No. 11, November 2001

14. Ali Z. Ghazi Zahid, Feras N. Hasoon, Hesham Bakarman and Sahbudin Shaari (2009). Implementing EDW in Point to Multipoint Optical Access Network for FTTH Applications. *Proceedings of the 2009 IEEE 9th Malaysia International Conference on Communications 15 -17 December 2009 Kuala Lumpur Malaysia.*

15. Tim C.W. Schenk, Guido Dolmans and Isabella Modonesi (2004). Throughput of a MIMO OFDM based WLAN system. *Proc. Symposium IEEE Benelux Chapter on Communications and Vehicular Technology, 2004 (SCVT2004), Gent, Belgium.* November 2004.

16. Tsern-Huei Lee, Jing-Rong Hsieh, Ming-Chih Huang, and Yu-Wen Huang. (2009). *A Bandwidth Efficient Pairing Strategy for the MIMO-OFDM Based WLANs*. Department of Communications Engineering National Chiao Tung University HsinChu, Taiwan.

17. Gordon L. St¨uber, John Barry, Steve W. McLaughlin, Ye (Geoffrey) Li, Mary Ann Ingram, Thomas G.Pratt. (2004). *Broadband MIMO-OFDM Wireless Communications.* School of Electrical and Computer Engineering Georgia Institute of Technology Atlanta, GA 30332.

18. Asuman Yavanoğlu, Özgür Ertuğ, Erdem Yazgan. *Improving the Spectral Efficiency of IEEE 802.11n MIMO-OFDM WLAN Communication Systems using Compact Space-Multimode Diversity Stacked Circular Microstrip Antenna Arrays*. EURASIP Journal on Wireless Communcations and Networking.

19. Xiongsheng Yao , Wenhu Xu, C.P Liang , Xiaowei Zhu and Wei Hong. (2008). *Design and Realization of a Highly Integrated IEEE802.11n Wireless Access Point Radio*. ICMMT2008 Proceedings

20. Ferdian Yunazar. (2009). *Modeling And Performance Analysis Of The Ofdm Scheme For Radio Over Fiber System*. Master Thesis. Universiti Teknologi Malaysia, Skudai.

21. Teguh Prakoso, Razali Ngah, and Tharek Abdul Rahman. (2008) Representation of Antenna in Two-Port Network S-Parameter. *IEEE International RF And Microwave Conference Proceedings*. Kuala Lumpur, Malaysia. December 2-4, 2008.

22. David Wake, Anthony Nkansah, and Nathan J. Gomes. (2010). Radio Over Fiber Link Design for Next Generation Wireless Systems. *Journal Of Lightwave Technology*. Vol. 28, No. 16, August 15, 2010.

23. Shikha Nema, Dr Aditya Goel and Dr R P Singh. (2009). Integrated DWDM and MIMO-OFDM System for 4G High Capacity Mobile Communication. *Signal Processing: An International Journal*. Volume 3 Issue 5, 2009.

24. Recommendation ITU-R. (02/2012). P.1411-6. Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems

and radio local area networks in the frequency range 300 MHz to 100 GHz, P Series Radiowave Propagation.

25. Recommendation ITU-R. (02/2012). P.1238-7. Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 900 MHz to 100 GHz, P Series Radiowave Propagation.

26. Wikipedia. (2012). IEEE 802.11n-2009. Retrieved June 20, 2012, from http://en.wikipedia.org/wiki/IEEE_802.11n

27. Hoon Kim, Jae Hun Cho, Sangho Kim, Ki-Uk Song, Hanlim Lee, Jaehoon Lee, Byungjik Kim, Yunje Oh, Jaekon Lee, and Seongtaek Hwang. (2007). Radio-Over-Fiber System for TDD-Based OFDMA Wireless Communication Systems. *Journal Of Lightwave Technology*. Vol. 25, No. 11, November 2007.

28. Shu-Hao Fan, Hung-Chang Chien, Arshad Chowdhury, Cheng Liu, Wei Jian, Yu-Ting Hsueh, and Gee-Kung Chang. (2010). A Novel Radio-over-Fiber System Using the xy-MIMO Wireless Technique for Enhanced Radio Spectral Efficiency. *ECOC 2010*. 19-23 September 2010, Torino, Italy.

29. Paul DeBeasi. (2008). 802.11n: Enterprise Deploymeny Considerations. Burton Group. Vol.1, May 16, 2008.

30. Wi-Fi Alliance. (2009). Wi-Fi CERTIFIED™ n: Longer-Range, Faster-Throughput, Multimedia-Grade Wi-Fi® Networks. September 2009.

31. Lu Dong. (2007). *MIMO Selection and Modeling Evaluations for Indoor Wireless Environments*. Degree Doctor of Philosophy. Georgia Institute of Technology. December 2007.

32. Jon W. Wallace and Michael A. Jensen. (2002). Modeling the Indoor MIMO Wireless Channel. *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION.* VOL. 50, NO. 5, MAY 2002.

33. D. S. Polydorou and C. N. Capsalis. (1994). A New Path Loss Prediction Statistical Model For Indoor Wireless Communications. *International Journal of Infrared and Millimeter Waves.* Vol. 15, No. 1, 1994

34. Xinrong Li, Robert Akl and Dinesh Tummala. (2006). Indoor Propagation Modeling at 2.4 GHz For IEEE 802.11 Networks. *The Sixth IASTED International Multi-Conference, Canada*. July 3-5, 2006.

35. Haruka Mikamori and Koyu Chinen. (2011). WiMAX RoF Design for Cost Effective Access Points. *World Academy of Science, Engineering and Technology*.

36. Soo-Jin Park, Chang-Hee Lee, Ki-Tae Jeong, Hyung-Jin Park, Jeong-Gyun Ahn, and Kil-Ho Song. (2004). Fiber-to-the-Home Services Based on Wavelength-Division-Multiplexing Passive Optical Network. *Journal Of Lightwave Technology*, Vol. 22, No. 11, November 2004.

37. Pardeep Kaur and R.S.Kaler. (2007). Radio Over Fiber Networks. *Proceedings of National Conference on Challenges & Opportunities in Information Technology (COIT-2007)*. RIMT-IET, Mandi Gobindgarh. March 23, 2007.

38. Long Bora, Heau Jo Kang, Yoon Ho Kim. (2008). MIMO-OFDM for the Better Quality Link of Wireless Network. *2008 International Conference on Information Security and Assurance.*

39. Asuman Yavanog˘lu, O¨zgu¨r Ertug. (2011). Spectral and Power Efficiency of IEEE802.11n MIMO-OFDM WLAN Systems using Higher-order Space-Multimode Diversity Compact Stacked Circular Microstrip Antenna Arrays. *IEEE 19th Signal Processing and Communications Applications Conference (SIU 2011).*

40. Nadia Binti Mohamed Nawawi. (2009). Wireless Local Area Network System Employing Free Space Optic Communication Link. Bachelor Degree. Universiti Teknologi Malaysia, Skudai.