ADAPTIVE DIFFERENTIAL AMPLITUDE PULSE-POSITION MODULATION TECHNIQUE (DAPPM) USING FUZZY LOGIC FOR OPTICAL WIRELESS COMMUNICATION CHANNELS

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A project thesis submitted in partial
fulfillment of the requirement for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
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JULY 2012

Specially dedicated to my mother, husband, family, supervisor and friends.

ACKNOWLEDGEMENT

Firstly, the author would like to offer thanks and deepest gratitude from the bottom of her heart for all the support, encouragement and inspirations she obtained throughout the duration of this project. She is deeply indebted to her Project Supervisor Associate Professor Dr. Mohammad Faiz Liew bin Abdullah and wishes to express a million thanks for his exemplary guidance, monitoring and constant encouragement throughout the development of this project. In those moments of uncertainty and doubts when things used to turn dark without a clear understanding of the knowledge, he tried to share; his kind and patient way of explaining had indeed a soothing effect. The blessing, help and guidance given from time to time shall indeed carry the author a long way in the journey of her life to embark in the near future.

Besides that, special thanks to her mother, her husband, her family, colleagues and friends involved during the finishing of this project for their support, motivation and sharing of knowledge.

Last but not least, to all author well-wishers to who had helped her both directly and indirectly, she virtually falls short of words to express her gratitude. Therefore, the author ends this acknowledgement with only two words “Thank You!” in their reminiscence.

ABSTRACT

In the past few years, people have become increasingly demanding for high transmission rate, using high-speed data transfer rate, the number of user increased every year, therefore the high-speed optical wireless communication link have become more popular. Optical wireless communication has the potential for extremely high data rates of up to tens of Gigabits per second (Gb/s). An optical wireless channel is usually a non-directed link which can be categorized as either line-of-sight (LOS) or diffuses. Modulation techniques have attracted increasing attention in optical wireless communication, therefore in this project; a hybrid modulation technique named Differential Amplitude Pulse-Position Modulation (DAPPM) is proposed to improve the channel immunity by utilizing optimized modulation to channel. The average symbol length, unit transmission rate, channel capacity, peak-to-average power ratio (PAPR), transmission capacity, bandwidth requirement and power requirement of the DAPPM were determined and compared with other modulation schemes such as On-Off Key (OOK), Pulse-Amplitude Modulation (PAM), Pulse-Position Modulation (PPM), Differential Pulse-Position Modulation (DPPM), and Multilevel Digital Pulse Interval Modulation (MDPIM). Simulation result shows that DAPPM gives better bandwidth and power efficiency depending on the number of amplitude level (A) and the maximum length (L) of a symbol. In addition, the fuzzy logic module is developed to assist the adaptation process of differential amplitude pulse-position modulation. Mamdani fuzzy logic method is used in which the decisions made by the system will be approaching to what would be decided by the user in the real world.

ABSTRAK

Sejak kebelakangan ini, bilangan pengguna yang menggunakan kadar penghantaran dan pemindahan data yang berkelajuan tinggi semakin meningkat. Dengan itu, pautan komunikasi optik tanpa wayar yang berkelajuan tinggi menjadi semakin popular. Komunikasi tanpa wayar optik mempunyai potensi untuk menghantar data dengan kadar yang sangat tinggi sehingga berpuluh-puluh Gigabit per saat (Gb/s). Satu saluran wayarles optik yang pautan bukan-arahan boleh dikategorikan sebagai menggunakan *line-of-sight (LOS)* atau *diffuses*. Teknik modulasi telah semakin mendapat perhatian dalam komunikasi tanpa wayar optik. Dalam projek ini, satu teknik modulasi hibrid yang bernama *differential amplitude pulse-position modulation* (*DAPPM*) dicadangkan untuk meningkatkan imuniti saluran dengan menggunakan modulasi dioptimumkan kepada saluran. Purata panjang simbol, kadar penghantaran unit, saluran kapasiti, nisbah kuasa puncak-ke-purata (*PAPR*), kapasiti penghantaran, lebar jalur dan kuasa yang diperlukan untuk *DAPPM* akan ditentukan dan dibandingkan dengan pemodulatan yang lain seperti *on-off key (OOK), pulse-amplitude modulation (PAM), pulse-position modulation (PPM), differential pulse-position modulation (DPPM), and multilevel digital pulse interval modulation (MDPIM).* Hasil dapatan simulasi telah menunjukkan bahawa *DAPPM* akan memberikan lebar jalur dan kecekapan kuasa yang lebih baik bergantung kepada bilangan tahap amplitud (A) dan panjang maksimum (L) simbol. Di samping itu, *fuzzy logic module* akan dihasilkan untuk membantu proses penyesuaian bagi *differential amplitude pulse-position modulation (DAPPM)*. Kaedah *Mamdani fuzzy logic* digunakan supaya hasil dapatan daripada sistem ini adalah menghampiri dengan situasi sebenar.

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LIST OF SYMBOLS AND ABBREVIATIONS

A - Pulse amplitude
B - Bandwidth
C - Channel capacity
L - Average symbol length
M - Bit Resolution
N_0 - The power spectral density of the White Gaussian Noise
N(t) - Signal-Independent Noise
P_t - The average transmitted optical power
$Q(x)$ - The customary Q-function of digital telecommunication
R - Transmission rate
R_b - Information rate
T - Slot width
$x(t)$ - Instantaneous optical power
$y(t)$ - Output signal
τ - Pulse duration
r_p - Duty ratio
γ - Unit information transmission rate
AMI - Alternate-Mark Inversion
ATM - Asynchronous Transfer Mode
BER - Bit Error Rate
CPPM - Chaotic-Pulse-Position Modulation
DAPPM - Differential Amplitude Pulse-Position Modulation
DPIM - Digital Pulse-Interval Modulation
DPIWM - Digital Pulse Interval and Width Modulation.
DPPM - Differential Pulse-Position Modulation
FIS - Fuzzy Inference System

FL	-	Fuzzy Logic
FOV	-	Field-of-View
FSO	-	Free Space Optical
Gb/s	-	Gigabits per second
GUI	-	Graphic user interface
IM	-	Intensity Modulation
IM/DD	-	Intensity Modulation/Direct Detection
IR	-	Infrared
ISM	-	Industrial, Scientific and Medical
Km	-	Kilometer
LDs	-	Laser Diodes
LEDs	-	Light Emitting Diodes
LMDS	-	Local Multipoint Distribution Service
LOS	-	line-of-Sight
Mbps	-	Megabits per second
MDPIM	-	Multilevel Digital Pulse Interval Modulation Scheme
M. Eng	-	Master of Engineering
MPPM	-	Multi-Pulse pulse position modulation
NRZ	-	Non-Return-to Zero
NRZI	-	Non-Return-to-Zero-Inverted
NRZL	-	Non-Return-to-Zero-Level
PAM	-	Pulse-Amplitude Modulation
PAPR	-	Peak-to-average Power Ratio
PCM	-	Pulse-code modulation
PD	-	Proportional Derivative
PFM	-	Pulse Frequency Modulation
PI	-	Proportional–Integral
PID	-	Proportional–Integral–Derivative
PIM	-	Pulse Interval Modulation
PIWM	-	Pulse Interval and Width Modulation
PPM	-	Pulse Position Modulation
PSD	-	Power Spectral Density
PWM	-	Pulse-Width Modulation

RF	-	Radio Frequency
RZ	-	Return-to-Zero
SNR	-	Signal-to-Noise Ratio
SWFM	-	Square Wave Frequency Modulation
UTHM	-	Universiti Tun Hussein Onn Malaysia
OOK	-	On-Off Keying
OPPM	-	Overlapped Pulse Position Modulation
OW	-	Optical wireless
OWC	-	Optical wireless communication
VLSI	-	Very-Large-Scale Integration

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LIST OF PAPERS PUBLISHED FROM THIS PROJECT

NCEEE Conference Publication & Presentation:-

1. Bong, S.W. and Abdullah, M.F.L. Adaptive Differential Amplitude Pulse-Position Modulation Technique (DAPPM) using Fuzzy Logic for Optical Wireless Communication Channels. *National Conference on Electrical and Electronics Engineering* 2012. May 8 – 9, 2012, pp. 87-90.

Papers submitted to Journals:-

2. Abdullah, M.F.L. and Bong, S.W. Adaptive DAPPM Technique for Optical Wireless Communication Channels based on Fuzzy Logic. *IEEE Transactions on Communications*.
   Manuscript Identification Number: TCOM-TPS-12-0258

3. Abdullah, M.F.L. and Bong, S.W. Performance Analysis for Optical Wireless Communication Channels using Differential Amplitude Pulse-Position Modulation. *Microwave and Optical Technology Letters (MOT)*.
   Manuscript Identification Number: MOP-12-0508

Paper abstract accepted for CIE-TVET Conference:-

4. Bong, S.W. and Abdullah, M.F.L. Fuzzy Inference System Based Adaptive Modulation Scheme for Optical Wireless Communication. *National Conference on Research and Innovation in Technical and Vocational Education and Training (CIE-TVET 2012).*

CHAPTER 1

INTRODUCTION

1.1 Background of research

In recent years, the need to access wireless local area networks from desktop to portable and mobile formats has grown rapidly. High performance links are necessary to allow data exchange from these portable devices to established computing infrastructure such as backbone networks, data storage devices and user interface peripherals [1]. Many of these networks have been designed to support multimedia with high data rates, thus the systems require large bandwidth. Since radio communication systems have limited available bandwidth, a proposal to use indoor optical wireless communications has received wide interest [2].

Optical wireless communication has emerged as a viable technology for the next generation of indoor and outdoor broadband wireless applications. Applications range from short-range wireless communication links providing network access to portable computers, to last- mile links bridging gaps between end users and existing fiber optic communications backbones, and even laser communications in outer-space links [3]. Indoor optical wireless communication is also called wireless infrared communication, while outdoor optical wireless communication is commonly known as free space optical (FSO) communication [4]. An Optical wireless system diagram is shown in Figure 1.1.

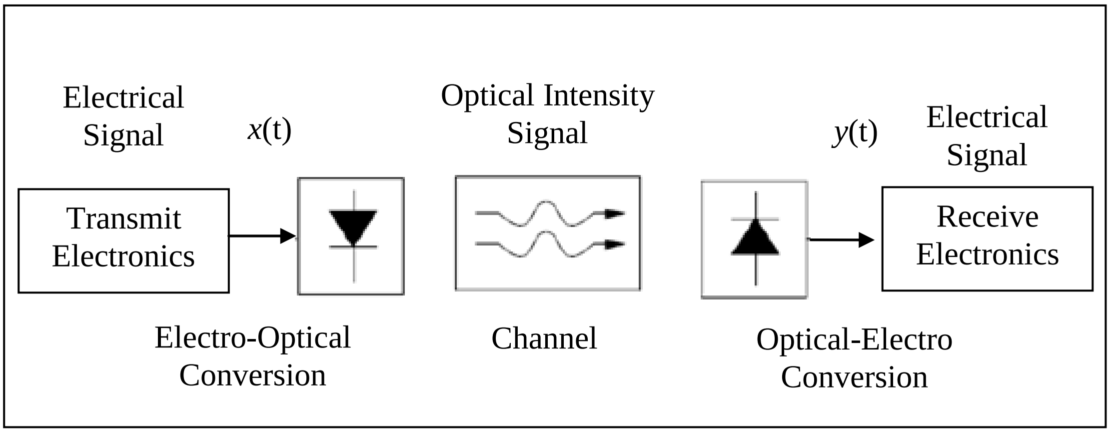

Figure 1.1: Block diagram of an optical intensity, direct detection communications channel [5].

Traditionally, wireless technology is always associated with radio transmission, although transmission by carriers other than radio frequency (RF) waves, such as optical waves, might be more advantageous for certain applications. The principal advantage of FSO technology is very high bandwidth availability, which could provide broadband wireless extensions to Internet backbones providing service to end-users. This could enable the prospect of delay-free web browsing and data library access, electronic commerce, streaming audio and video, video-on-demand, video teleconferencing, real-time medical imaging transfer, enterprise networking and work-sharing capabilities, which would require as much as a 100 Mbps data rate on a sustained basis. Summary of difference between FSO and RF technologies is shown in Table 1.1.

Table 1.1: Properties of terrestrial FSO and RF communications [4].

Properties	FSO Links	RF Links
Typical Data Rate	100Mbps to ~ Gbps	Less than 100 Mbps
Channel Security	High	Low
Component Dimension	Small	Large
Networking Architecture	Scalable	Non-scalable
Source of Signal Degradation	Atmospheric turbulence and obscuration	Multipath fading, rain, and user interferences

The free space optical wireless link is mainly applied in short range (less than 2 kilometers) and inter-building data connections complementary to existing RF networks [5]. Although challenged by several competitive RF bands, including the industrial, scientific and medical (ISM) radio bands, and the local multipoint distribution service (LMDS) bands [6], optical wireless showed promising features of higher data throughput and immunity to the interference which is usually suffered by RF systems. Table 1.2 presented a comparison of ISM, LMDS and optical wireless systems.

Table 1.2: Comparison of ISM, LMDS and FSO systems [7].

System	ISM Band	LMDS	Optical Wireless
Frequency	2.4 GHz	24-40GHz	30-60THz
Licensed	No	Yes	No
Multipoint Topology	Omni or Sectored	Omni or Sectored	Virtual Multipoint
Cell Radius	8-15Km	2-3Km	1-2Km
Downstream Bandwidth	3-8 Mbps per sector (per frequency)	155Mbps per sector	1.5Gbps per user
Upstream Bandwidth	3 Mbps peak per user	3-10Mbps per user	1.5 Gbps per user
Symmetric	No	No	Yes
Protocol Independence	No	No	Yes
Fade Mechanism	Heavy Rain	Rain	Thick Fog, Snow
Initial Investment for few subscribers	High	High	Low
Investment for 50-100 subscribers per cell	Medium	Medium	Medium

From the above table, optical wireless (OW) channel surpassed the RF system in the following aspects: downstream bandwidth per user/sector/frequency of OW system was nearly 10 times that of the LMDS system and up to 500 times that of the ISM system. The upstream bandwidth is similar to that of the downstream bandwidth. In the cell radius comparison, the OW system provided the shortest distance coverage, where ISM and LMDS systems can achieve a range which is 7.5 and 1.5 times further than the OW system respectively [6]. Noticeably, weather conditions had an impact on the reliability of the channel, which could affect the transmission data rate.

1.2 Problems statement

In optical communication applications, there is always tradeoff between system performance and costs. There is thus a pressing need to design a modulation technique for the real time situation.

As mentioned earlier, the optical wireless channel was limited by channel constraints such as the maximum allowable optical power and available bandwidth. Modulation schemes well suited to conventional channel were not necessarily perform well for the optical wireless channel [5]. The optical wireless channel can be easily affected by channel uncertainty. For example, distance between transmitter and receiver, distance from ambient light source or optical propagation path changes can result in bit error rate (BER) variation.

Optical wireless communications (OWC) [8] has the potential for extremely high data rates of up to tens of Gb/s. However, this capacity cannot yet be achieved because of the physical limitations of optical devices and the channel which exhibits path loss, noise from ambient light and the receiver, and multipath dispersion from multiple reflections off walls and objects in the room [9].

Besides that, the BER not only it will be affected by noise and transmitted signal power but also by the system modulation level and modulation state. Due to this constraint, adaptive Differential Amplitude Pulse-Position Modulation (DAPPM) technique using fuzzy logic for optical wireless communication channels is proposed to solve this problem.

1.3 Project objectives

At the end of this project the following objectives will be achieved:-

- (i) To analyze the performance of Differential Amplitude Pulse-Position Modulation (DAPPM) technique for optical wireless communication channel.
- (ii) To develop the fuzzy logic control module for DAPPM.
- (iii) To evaluate the achievable Bit Error Rate (BER), variation rate, and modulation level and state for DAPPM.

1.4 Scopes of project

- (i) The performance of DAPPM for optical wireless communication channel model is analysis and compare with the other modulation schemes.
- (ii) The Fuzzy logic control module for DAPPM is developed by using Graphic User Interface (GUI), MATLAB.
- (iii) The BER, variation rate, modulation level and state performance for DAPPM is determined.

1.5 Expected Result

The expected result from the proposed, Differential Amplitude Pulse-Position Modulation (DAPPM) technique will provides several advantages when the simulation results are compare between the DAPPM with On-Off Key (OOK), Pulse-Amplitude Modulation (PAM), Pulse-Position Modulation (PPM), Differential Pulse-Position Modulation (DPPM), and Multilevel Digital Pulse Interval Modulation (MDPIM) in terms of average symbol length, unit transmitssion rate, channel capacity, bandwidth requirement, peak-to-average power ratio (PAPR), normalized power and bandwidth required.

The adaptive DAPPM system will be develop using fuzzy inference system. This simulation result will shows that the fuzzy logic control module is very promising in controlling adaptive modulation scheme process for optical wireless communication channels.

1.6 Thesis structure outline

This thesis is a documentary to deliver the generated idea, the concepts applied, the activities done, and finally, the project product produced. The thesis consists of five chapters.

Chapter 1 discusses the background of the research. In addition, the objectives of project, problems statement, scopes of work, expected result and thesis structure outline are presented.

Chapter 2 contains literature review discussing the applications of optical wireless communication and modulation schemes. On the others hand, this chapter also includes the recent research of modulation schemes from the year 2006 until 2011 and the author’s view on these research. Furthermore, a review of fuzzy logic and the reason of using fuzzy logic control will be discusses in this chapter.

Chapter 3 concentrates on the performance of Differential Amplitude Pulse-Position Modulation (DAPPM) modulation for optical wireless communication channels analysis, and comparison between DAPPM with other modulation schemes in terms of average symbol length, unit transmission rate, channel capacity, bandwidth requirement, Peak-to-average power ratio (PAPR), transmission capacity and normalized power and bandwidth requirement analysis.

Chapter 4 presents the design of system architecture for a fuzzy logic controlled adaptive modulation system. Besides that, the design flow and simulation of the project is introduced. It provides a brief description on each procedure in completing the project. This chapter also covered MATLAB Fuzzy Inference System (FIS) result and analysis. The Fuzzy logic control module was developed to assist the adaptation process.

Finally, Chapter 5 presents the conclusions and suggestions for future work. Important results and methodology obtained from previous chapters are summarised, and the possibilities for future directions is discussed.

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