2-D WAVELENGTH/TIME MDW CODE OPTIMIZATION FOR CARDINALITY ENHANCEMENT IN OCDMA SYSTEM

by

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A thesis submitted in fulfillment of the requirements for the degree of Master of Science in Communication Engineering

School of Computer and Communication Engineering
UNIVERSITI MALAYSIA PERLIS

2018

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ACKNOWLEDGMENT

ALHAMDULILLAH. Praise to Allah Almighty for giving me the strength, patience and ability to complete this thesis. First, I would like to express my sincere gratitude to my supervisor Ir. Ts. Dr. Mohd Rashidi bin Che Beson, for his excellent idea, invaluable guidance and constant support in making this research project possible. Then, I would like to thank my co-supervisor Professor Dr. Syed Alwee Aljunid bin Syed Junid for his kind support. My thanks to all my friends and lecturers in School of Computer and Communication Engineering University Malaysia Perlis (UniMAP) for their help and support at every step during this study.

Specially thank you to my dear husband Mohamad Syahir bin Ahmad Fadzullah, my beloved mother Noraini binti Samid, my beloved father Mohamad Saufe bin Draman and my siblings Muhammad Nizam, Khairani, and Mohamad Arif for all supports, patience, understanding and being helpful throughout my study. And always pray for me to succeed.

I also wish to extend my thank appreciation to all those who have contributed directly and indirectly to the preparation of this study. I hope I can make you all proud of me. Lot of love to all.

Thank You Very Much.

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LIST OF ABBREVIATIONS

APD	Avalanche Photodiode
CDMA	Code Division Multiple Access
DW	Double Weight
FDMA	Frequency Division Multiple Access
FH	Frequency Hopping
HCC	Hyperbolic Congruence Codes
LED	Light Emitting Diode
MAI	Multiple Access Interferences
Mbps	Mega Bit Per Second
MDW	Modified Double Weight
MFH	Modified Frequency Hopping
NRZ	Non-Return-Zero
OCDMA	Optical Code Division Multiple Access
OOC	Optical Orthogonal Codes
PDC	Perfect Difference Codes
PIIN	Phase-Induced Intensity Noise
PIN	Positive-Intrinsic Negative
PC	Prime Codes
QCC	Quadratic Congruence Codes
RZ	Return-Zero
SAC	Spectral Amplitude Coding
SNR	Signal Noise Ratio
SLED	Superluminent Light Emitting Diode
TDMA	Time Division Multiple Access
W/T	Wavelength/Time
1-D	One-Dimensional
2-D	Two-Dimensional
3-D	Three-Dimensional

LIST OF SYMBOLS

B	Electrical bandwidth
H_M	Hadamard matrix
C	Light velocity
e	Electron charge
K_b	Boltzmann’s constant
R_L	Receiver load resistor
T_n	Receiver noise temperature
M	Code weight
M_B	The basic code’s column size
N	Code length
N_B	The basic code’s row size
W	Weight
λ_0	Operating wavelength
λ_a	Auto-correlation
λ_c	Cross-correlation
η	PD quantum efficiency

Peningkatan Dalam OCDMA Sistem Untuk Pengoptimuman Kardinaliti Dua-Dimensi (2-D) Panjang Gelombang/Masa (W/T) Kod MDW

ABSTRAK

Pada masa kini, sebagai teras pembahagian sistem kod optik berbilang akses (OCDMA), beberapa teknik akses pelbagai telah dicipta untuk hubungan antara gentian optik. Ini dapat memberikan keupayaan pemindahan data yang besar dengan eksploitasi had medium optik. Tambahan pula, tujuan utama dalam mengkaji OCDMA ialah ukuran pengekodan sebagai contoh, kod satu-dimensi (1-D) yang tersebar dalam masa dan kod dua-dimensi (2-D) yang tersebar dalam kedua-dua panjang gelombang dan masa adalah termasuk dengan jelas di dalam sistem. Walaupun dengan kelebihan yang berpotensi, terdapat beberapa isu yang menguji inovasi ini. Tujuan OCDMA digunakan adalah untuk mengatasi akses pelbagai gangguan (MAI) bunyi dan fasa teraruh intensiti bunyi (PIIN) yang menggalakkan jumlah kadar ralat bit (BER). Bunyi MAI dan PIIN dapat dikurangkan dan direndahkan dengan menggunakan kumpulan kod dengan minimum silang korelasi. Dalam tesis ini, dua-dimensi (2-D) panjang gelombang / masa (W / T) tidak keruan kod mengubah berat berganda (MDW) OCDMA dianalisis dan ditunjukkan. Peruntukan W / T dalam tesis ini adalah untuk membuat sistem tidak segerak berterusan dengan masa tanpa sebarang halangan. Reka bentuk kod dianalisis dalam teori dan simulasi untuk mencapai objektif projek. Hasil yang baik dalam pengurangan optimum PIIN dibanding dalam kod 2-D MDW yang dicadangkan dengan kod lain seperti 2-D kod perbezaan sempurna (PDC) dan kod 1-D MDW. Kod yang dicadangkan mencapai prestasi berskala tinggi dengan peningkatan dari segi kardinaliti, kadar bit, kesilapan kadar bit (BER) dan jarak. Pada 10^{-9} (BER), kardinaliti kod mencapai 251 nombor serentak dari pengguna dan berkesan menerima kuasa (P_{sr}) yang paling rendah dicapai ialah pada -16.5 dBm. Dengan membandingkan antara alat kajian; fotodiod runtuhan (APD) mencapai 19 km panjang berbanding fotodiod PIIN sebanyak 18 km dalam sistem ini. Oleh itu, simulasi kod 2-D W / T MDW OCDMA berjaya mengurangkan MAI dan menyekat PIIN dalam hasil kajian panjang gentian optik dan penerimaan kuasa.

2-D Wavelength/Time MDW Code Optimization For Cardinality Enhancement In OCDMA System

ABSTRACT

The explosive growth of bandwidth demand, together with advance in latest communication services and emerging applications has inspired huge interest in application of code division multiple access (CDMA) technique in optical network. As a core of an optical code division multiple access (OCDMA) system, several multiple access techniques have been created for optical fiber correspondence. The aim of using OCDMA is to overcome the multiple access interference (MAI) noise and phase induced intensity noise (PIIN) which encourages the amount of bit error rate (BER). The MAI and PIIN can be reduced and suppress by using the perfect code property with minimum cross-correlation. In this thesis, the incoherent two-dimensional (2-D) wavelength/time (W/T) modified double weight (MDW) code OCDMA is analysed and demonstrated. The allocation of W/T in this thesis is to make the system asynchronously continuous with time without any objection. The good result in optimum PIIN suppression in comparison within the proposed 2-D MDW code with other codes such as 2-D Perfect Difference Code (PDC) and 1-D MDW code. The 2-D W/T MDW code achieves high scalability with the improvement in term of cardinality, bit rate, bit error rate (BER) and distance. At 10^{-9} (BER), the code cardinality reaches 251 simultaneous number of users and the lowest effective received power (P_{sr}) is achieved at -16.5 dBm. By comparing within parameter; avalanche photodiode (APD) are achieved 19 km longer compare with PIIN photodiode there is 18 km in this system. Thus, the 2-D W/T MDW OCDMA code simulation has successfully reduced MAI and suppress PIIN which result in optical fiber length and effective received power.

CHAPTER 1: INTRODUCTION

1.1 Project Background

Currently, technology is the important thing that makes our life easier. We are surrounded by technology everywhere, for example at homes, in industry, in business and in the medical profession also. Network system is the part of the technology that get high demand from people. This system was exceeding the limits of the fiber physical properties and more advance techniques will be needed to increase the system performance and overcome the noise (Wood, 2016).

Optical communication or known as optical telecommunication is the communication at a distance by using light to carry information. Electronic devices are the platform to relies on optical fibers to carry signal to their destinations. Since 1970s, the development of low-loss optical fiber cables in optical communication became the most popular method of communication components.

In optical communication, it consists of three parts: transmitter (T_x), receiver (R_x) and optical fiber. The function of T_x is to convert and transmit an electronic signal into a light signal. For R_x, it's converts light from optical fiber into electricity by using photoelectric effect. The optical communication also provides high bandwidth, exceptionally low loss, great transmission and no electromagnetic interference.

Code division multiple access (CDMA) is the system that has been used in military communication before. And now CDMA system is used in wireless communication system for public. Because of the increasing number of user, the system is upgraded to optical code division multiple access (OCDMA). OCDMA can improves sign-capacity bandwidth of the optical fiber. It also can assist both extensive and slim bandwidth application on a single network and will get the large numbers of asynchronous users (Yin and Richardson, 2007; Memon et al., 2014).

1.2 Problem Statement

OCDMA system is the one of tough system are used for multiplexing high speed telecommunication signals. This is because it does not need dedicated time or frequency synchronization and it allows flexible network design. Further, the cardinality of the code used can affected the bit error rate (BER) in turns the number of users. In OCDMA, the new users can be contained in the system by simply using the codes with higher cardinality. Although, developing codes with good properties is a challenging assignment in the OCDMA system (Chang et al., 2005).

In OCDMA systems, a number of users significantly degraded the system functionality due to existing of multiple access interference (MAI) (Singh, 2011; Jianqiang, 2001). There are several noises arising from the physical effects of the system design. For example, phase induce intensity noise (PIIN) (Arief et al., 2012), thermal noise and shot noise. PIIN will be significantly associated with MAI due in order to overlapping spectra by different users. Otherwise, PIIN depends on how many interfering end users and also cannot end up being improved through improving the particular fed power or added in amplification for the phone facet since, indicate amplification is definitely combined with an equal number of noises and also cannot improve percentage connected with indicate capacity to noises power (Arief et al., 2013).

According to the survey in OCDMA systems, there are many codes were proposed in this system. For example, Perfect Difference Code (PDC) (Lin et al., 2005), Modified Quadratic Congruence (MQC) code (Wei et al., 2001), Zero Cross-Correlation (ZCC) (Anuar et al., 2009) and Flexible Cross-Correlation (FCC) (Rashidi et al., 2014). However, these codes have several limitations such as the construction is complicated, the code is too long or the even natural number of the code is fixed and poorer cross-correlation. It is highly estimated that the proposed code sequence will increase the system performance in term of high cardinality or active number of users, can enhance the BER error floor, and also suppressing MAI and PIIN noise.

1.3 Research Objectives

The main goal of this research is to investigate the performance of two-dimensional (2-D) wavelength/time (W/T) MDW OCDMA system. The objectives of this research as following:

(i) To investigate performance of the in OCDMA system in term of cardinality or number of simultaneous users.

(ii) To analyze the theoretical and simulated results based on the ability of 2-D W/T MDW code for suppressing MAI and PIIN noise.

1.4 Scopes of Research

The research work focused on the investigation of 2-D MDW code by using OCDMA technique. The development of the suggested codes was focusing on incoherent W/T coding based on the matrix combination way.

This code is the evolution from one-dimensional (1-D) MDW code. The code with the mathematical calculation is in matrix system. The row is for the number of user and the column is for temporal code length. Nevertheless, this system also wants to overcome the noise for example shot noise, thermal noise and phase-induce intensity noise in term of deterioration of BER.

The results are only based on the simulation and theory. All the simulation part was done by using the optical simulator Optical Communication System Design Software or Optisystem Version 7.0 from Optiwave.

1.5 Research Contributions

(i) The 2-D W/T MDW code has been examined and it was increasing the number of simultaneous user or cardinality and at the same time can suppressing PIIN and reducing MAI.

(ii) The performance of 2-D MDW code in OCDMA system by replacing the difference parameters such as optical fiber length, data rate and effective received power has been done and thoroughly analyse via simulation comparing with existing code for results in simulation.

1.6 Thesis Organizations

This thesis contains 5 chapters. Chapter 1 comprises overview of fiber optic communication and OCDMA system. This chapter also includes the research background of the project, problem statement, research objectives, scope of project and the organization of the proposed project.

Chapter 2 presents the literature review. It includes the introduction of literature review, types of multiple access technique, types and characteristics of OCDMA encoding, advantages and disadvantages of OCDMA compare to other techniques, various OCDMA codes and lastly the development of MDW code and 2-D MDW code.

Chapter 3 discuss about project flow or methodology. It shows the flow chart of the project and the parameter are used in this project. Other than that, it briefly explained the consideration of noise in this project and the formula used. Also the little bit summary of the simulator used in the analysis medium to get the result.

Chapter 4 covers the result from the simulation of the design also the result from theoretical. This result is the comparison between the proposed code with other codes. Other than that, the result is from the proposed code itself that is between the parameters in the code design.

Chapter 5 is the last chapter. Overall about the proposed project are concluding in this chapter. Some recommendation is related to this proposed code also discussed in this chapter for the future works.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In case of mobile communication, the only restraint on communication is the bandwidth restraint which means it has a limited frequency range that can be used for communication. Hence, it must allow multiple users communicate in the same frequency range (Rishabh Dev, 2012). This chapter describes the overview of multiple access technique such as;

1. Frequency Division Multiple Access (FDMA)
2. Time Division Multiple Access (TDMA)
3. Code Division Multiple Access (CDMA) or optical CDMA (OCDMA)

More review on OCDMA are discussed to implement in this project. Furthermore, the various codes existed also examined in this study.

2.2 Multiple Access Techniques

Multiple access technique is one of the essential functions of access networks. They provide multiple access to the channel. This is due to the limitation of frequency range to cover up all the wireless communication systems (Rishabh Dev, 2012).

In wireless communication systems, it is often desirable to allow the subscriber to send information simultaneously from the mobile station to the base station while receiving information from the base station to the mobile station. Access methods allow many users to share these limited channels to provide the economy of scale necessary for a successful communications business (Lou Frenzel, 2013).

The three basic multiple access are FDMA, TDMA and CDMA. Figure 2.1 shows the classification of multiple access technique.

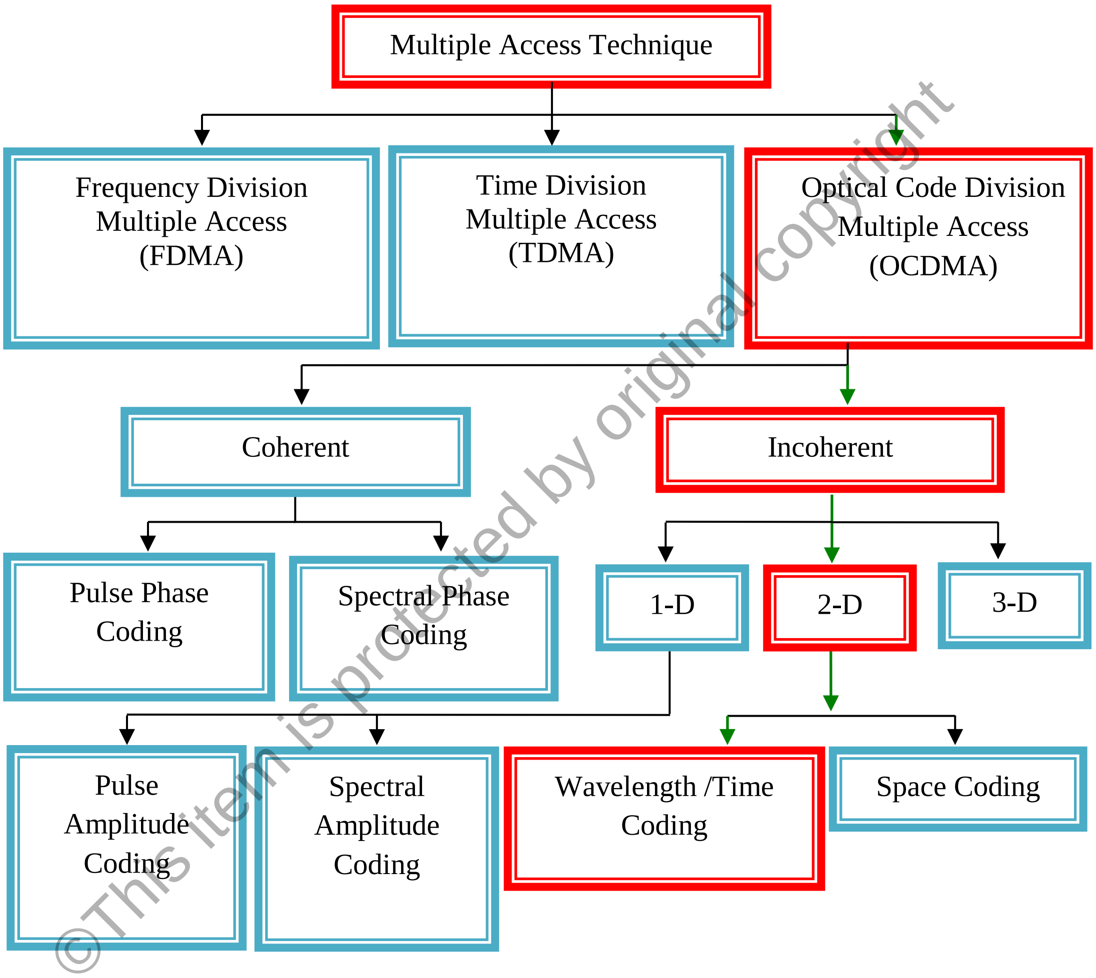


Figure 2.1 Classification of Multiple Access Techniques (Singh, 2012)

2.2.1 Frequency Division Multiple Access (FDMA)

FDMA is mainly used for analog transmission. The device can be separated directly into frequencies due to the technological innovation where the whole bandwidth accessible. Furthermore, this particular section is performed involving not for overlapping frequencies which can be subsequently allocated in order to every single interacting couple. Other alternative is usually to punch straight down the current frequencies into a lot narrower quantity which often are not really capable. Throughout FDMA, almost all people discuss the particular satellite television together although every single person sends from individual volume (S. Singh, 2012).

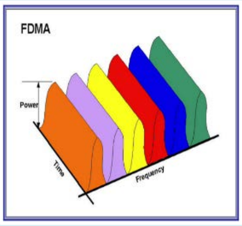
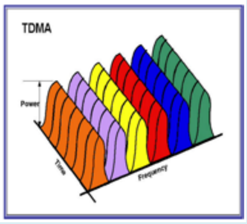
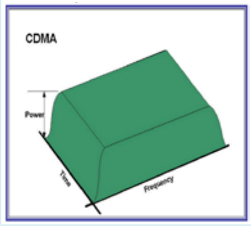
2.2.2 Time Division Multiple Access (TDMA)

TDMA is also just like FDMA and OCDMA that is certainly distributed channel normally throughout radio network for the technological innovation and also digital process. Through separating the item in three-time slot request to expand the measure of information that can be conveyed, TDMA enables many people to express the actual volume. Whenever time slot is used in order to broadcast one particular bit or maybe with rapid succession or with a different part of each signal with sequential files format. In any other case, just the particular part of that bandwidth tends to be involved. The item enables many people to express the identical transmission method radio frequency in a while. Other than that, it can be helpful for squeezed movie as well as additional high-speed information despite the fact that these methods assist slower voice data transmission (Guowang Miao, 2016).

2.2.3 Optical Code Division Multiple Access (OCDMA)

Code Division Multiple Access (CDMA) is a "spread spectrum" innovation, permitting numerous users to involve in the same recurrence band in the meantime. Its' allowing many users to occupy the same time and frequency allocations in a given space. OCDMA is the fundamental prerequisites for each of the code is that the auto-correlation of that to be amplified and the cross correlation is minimized (Minal and Kaler, 2012; Guowang Miao, 2016). Table 2.1 below demonstrates the differences between these three codes.

Table 2.1 Comparison between TDMA, FDMA, CDMA (Dev, 2012)

Approach	FDMA	TDMA	CDMA
Pattern			
Idea	Segment the frequency band into disjoint sub bands	Segments sending time into disjoint time slots demand driven or fixed patterns.	Spread the spectrum using orthogonal codes
Terminals	Every terminal has its own frequency uninterrupted	All terminals are active for short periods of time on same frequency.	All terminals can be active at the same place at the same moment uninterrupted.
Signal separation	Filtering in the frequency domain.	Synchronization in time domain	Code plus special receivers.
Transmission scheme	Continuous	Discontinuous	Continuous
Cell capacity	Limited	Limited	No absolute limit on channel capacity but it is an interference limited system
Advantages	Simple, established, robust	Established fully digital, flexible	Flexible, less frequency planning needed, soft handover
Disadvantages	Inflexible, frequencies are scarce resource	Synchronization difficult	Complex receivers, needs more complicated power control for senders

2.3 Types and Characteristics of OCDMA Coding

OCDMA systems can be divided into two broad categories. There are coherent (Marhic, 1993) OCDMA systems and incoherent (Andovonic and Tancevski, 1996) OCDMA systems.

2.3.1 Coherent OCDMA System

The coherent OCDMA system is to manipulate phases that are detected at receiving terminals by superimposing of the amplitudes of optical field. Other than that, it appears to be the most viable technologies for the implementation OCDMA systems. There are two encoding involve in coherent OCDMA systems (Marhic, 1993; Wu and Narimanov, 2006).

2.3.1.1 Pulse Phase Coding

This coding is bipolar codes. The number of dimension is 1-D. Because of pulse phase coding is bipolar codes, it requires ultrashort coherent optical pulse source, which are susceptible to the nonlinearity and dispersion of fibre optic. The wireless CDMA can be employed and their cross-correlation functions are close-to-zero. Therefore, the multi-access interference (MAI) in the systems can be greatly reduced (Marhic, 1993).