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**PERFORMANCE ANALYSIS OF DW CODE
FAMILY FOR SAC-OCDMA, FTTH
NETWORK**

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By

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بسم الله الرحمن الرحيم

Praised to Him, Allah The Most Gracious and The Most Merciful and may His shalawat with salaam always for Prophet Mohammad (p.b.u.h) and his holy progeny eternally. Uncountable thanks for my mother for their love and blessings which always gives me strength through this life and further step of my way. I would also like to thank them for their continuous support, for their patience, encouragement and extra care. The deepest thanks from my heart go to my precious wife and my children whom really changed my life to the best in my study I would like to express my gratitude and thanks to Professor Dr. syed alwee aljunid for his patience and supervising my work with high quality standard. I would never forget my most sincere thanks to my co-supervisor Dr. Hilal A. fadhil his guidance, and encouragement. Without their help, I would not have been able to achieve what I have achieved.

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LIST OF SYMBOLS, ABBREVIATIONS OR NUMENCLATURE

Term	Description
APD	<i>Avalanche Photodiode</i>
ADSL	<i>Asymmetric Digital Subscriber Line</i>
AWG	<i>Arrayed Waveguide Grating</i>
ASE	<i>Amplifier Spontaneous Emission</i>
BER	<i>Bit Error Rate</i>
CO	<i>Central Office</i>
EDFA	<i>Erbium Doped Fiber Multiplexing</i>
FPGA	<i>Field Programmable Gate Array</i>
FFH	<i>Fast Frequency Hopping</i>
FBG	<i>Fiber Bragg Grating</i>
FTTH	<i>Fiber To The Home</i>
FWM	<i>Four Wave Modulation</i>
Gbps	<i>Giga bit per second</i>
GPON	<i>Gigabit PON</i>
LED	<i>Light Emitting Diode</i>
MAI	<i>Multiple Access Interference</i>
Mbps	<i>Mega bit per second</i>
MFH	<i>Modified Frequency Hoping</i>
MQC	<i>Modified Quadratic Congruence</i>
NRZ	<i>Non Return to Zero</i>

NIU	<i>Network Interface Unit</i>
NDSF	<i>Non Dispersion Shifted Fiber</i>
OLT	<i>Optical Line Terminal</i>
ONU	<i>Optical Network Unit</i>
OCC	<i>Optical Orthogonal Code</i>
OCDMA	<i>Optical Code Division Multiple Access</i>
OOK	<i>On-Off Keying</i>
P2P	<i>Point-to-Point</i>
P2MP	<i>Point-to-Multipoint</i>
PD	<i>Photo Diode</i>
PSD	<i>Power Spectral Density</i>
POTS	<i>Plain Old Telephone Service</i>
PIIN	<i>Phase Induced Intensity Noise</i>
RN	<i>Remote Node</i>
RD	<i>Random Diagonal</i>
RZ	<i>Return to Zero</i>
SAC	<i>Spectral Amplitude Coding</i>
SNR	<i>Signal-to-Noise Ratio</i>
SMF	<i>Single Mode Fiber</i>
SPM	<i>Self Phase Modulation</i>

Prestasi analisis kod DW keluarga untuk OCDMA, rangkaian FTTH

ABSTRAK

Teknik capaian gandaan perlu dalam memenuhi permintaan komunikasi berkelajuan tinggi dan berkapasiti tinggi dalam rangkaian optik, dimana ia membolehkan gentian jalur lebar dikongsi oleh ramai pengguna. Capaian gandaan pembahagian kod optik atau “optical code division multiple access (OCDMA)” semakin mendapat perhatian kerana potensi penggunaan dalam rangkaian optik kawasan setempat. Akan tetapi, sistem OCDMA secara keseluruhannya dikekang oleh hingar gangguan capaian gandaan atau “multiple access interference (MAI)” berpunca dari penggunaan ramai pengguna serentak yang mana akan meningkatkan ralat bit. Untuk mengurangkan kekangan ini, kod amplitud spektra OCDMA atau “Spectral Amplitude OCDMA (SAC-OCDMA)” digunakan di dalam tesis ini. Kelebihan sistem SAC-OCDMA berbanding sistem OCDMA biasa adalah apabila teknik pengesanan yang sesuai digunakan, MAI akan dihilangkan secara keseluruhannya. Ini dengan mengurangkan kesan MAI atau meningkatkan prestasi walaupun dengan kehadiran MAI. Banyak kod telah diusulkan untuk sistem SAC-OCDMA contohnya kod Hadamard, kod Modified Quadratic Congruence (MQC), kod Double Weight dan kod Random Diagonal. Penggerak untuk kajian ini adalah untuk menilai prestasi kod Modified Double Weight (MDW) dan kod Enhanced Double Weight (EDW) dalam meningkatkan keseluruhan prestasi sistem optik OCDMA. Tiga peringkat dibahagikan di dalam kajian ini. Pertama, perbincangan yang komprehensif dilakukan ke atas kesemua aspek penting dalam kod MDW dari segi aspek kelebihanannya. Kedua, simulasi perisian untuk sistem SAC-OCDMA dalam keluarga kod MDW menggunakan sistem optik komersial “Optisystem™ versi 7.0” telah dijalankan. Akhir sekali, simulasi eksperimen untuk analisis prestasi kajian rangkaian OCDMA realistik dinilai. Analisis ini dijalankan menggunakan sistem parameter realistik contohnya serakan kromatik, MAI, hingar penerima (arus gelap, hingar pendek dan hingar terma penerima) dan jalur lebar diod pemancar cahaya. Kami menganalisa kemungkinan ralat rangkaian dengan mengambil kira parameter ini. Prestasi sistem OCDMA dianalisis dan dibandingkan dengan format signal yang berbeza (NRZ & NZ) di bahagian pemancar, dan dengan pelbagai pengesanan cahaya (PIN & APD). Parameter sistem berdasarkan kod MDW dan EDW digunakan dengan mengambil kira pelbagai parameter reka bentuk; jarak, kadar bit, kuasa input, kuasa penerima dan jarak cip. Kesan parameter ini dinilai pada nilai ralat kadar bit atau “bit error rate (BER)”. Format NRZ dengan BER 2.2×10^{-23} dilihat lebih baik dari RZ dengan BER 1.03×10^{-18} . Walaubagaimanapun, pengesanan cahaya APD dengan BER 6.9×10^{-22} meningkatkan prestasi keseluruhan sistem MDW-OCDMA berbanding pengesanan cahaya PIN dengan BER 6.2×10^{-15} . Sistem yang menggunakan teknik pengesanan penolakan AND (dengan BER 2.2×10^{-16}) menawarkan prestasi sistem yang lebih baik berbanding teknik pengesanan pelengkap (dengan BER 4.01×10^{-11}). Teknologi gentian ke rumah atau “fiber to the home (FTTH)” merupakan penyelesaian pada rangkaian OCDMA generasi akan datang untuk rangkain yang lebih laju dan aplikasi jalur lebar yang lebih tinggi. Perbandingan antara penerima dengan diod pemancar cahaya atau “light emitting diode (LED)” dengan kuasa penghantar -6dBm, dan komponen penerima yang sesuai untuk aplikasi FTTH titik ke titik sehingga jarak penghantaran 50km dengan kuasa output penerima -14dBm.

“Performance analysis of DW code family for OCDMA, FTTH network”

ABSTRACT

Multiple access techniques are required to meet the demand for high-speed and large-capacity communications in optical networks, which allow multiple users to share the fiber bandwidth. Optical Code-Division Multiple-Access (OCDMA) is receiving increased attention due to its potential applications for local area optical networks. OCDMA systems, however, generally, suffers from Multiple Access Interference (MAI) noise which originated from other simultaneous users severely increases the likelihood of occurrence of bit errors. To mitigate this limitation, Spectral Amplitude Coding (SAC) OCDMA is used throughout this thesis. The advantage of SAC-OCDMA over conventional OCDMA systems is that, when using appropriate detection technique, the MAI can totally be suppressed. This either reduces the effect of MAI or improves the performance even in the presence of MAI. Many codes have been proposed for SAC-OCDMA systems such as Hadamard code, Modified Quadratic Congruence (MQC) code, Modified Frequency Hopping (MFH) code, Double Weight (DW) code and Random Diagonal (RD) code. The motivation of this research is to evaluate the performance of Modified Double Weigh (MDW) code and Enhanced Double Weigh (EDW) to enhance the overall performance of optical OCDMA systems. Three stages are divided in this research. Firstly, a comprehensive discussion takes place on all important aspects of MDW codes from advantages point of view. Secondly, a software simulation for SAC OCDMA system with the MDW code families using a commercial optical system, “Optisystem™ ver.7.0” is conducted. Finally, experimental simulation tests to analyze the performance of a realistic OCDMA network have been evaluated. This analysis has been carried out including realistic system parameters such as chromatic dispersion, Multiple Access Interference (MAI), receiver noises (dark current, shot noise and receiver thermal noise) and photodiode bandwidth. We analyze the error probability of the network taking into account these parameters. The performance of OCDMA system has been analyzed and compared with different signal formats (NRZ & RZ) at the transmitter part, and with the various photo detectors (PIN & APD) at the receiver part. The system parameters based on the MDW and EDW codes are carried out taking into account various design parameters; distance, bit rate, input power, received power and chip spacing. The effect of these parameters on the system is evaluated in terms of bit error rate (BER) values. It has been shown that an NRZ format with a Bit Error Rate (BER) of 2.2×10^{-23} is improved over the RZ with a BER of 1.03×10^{-18} . However, the APD photodetector of BER 6.9×10^{-22} enhances the overall MDW-OCDMA system performance compared with a BER 6.2×10^{-15} photodetector. It is also shown that the system using AND-Subtraction detection technique (with a BER of 2.2×10^{-16}) offers better system performance compared with Complementary detection technique (with a BER of 4.01×10^{-11}). Fiber-To-The Home (FTTH) technology is a promising solution of the next generation OCDMA networks for faster networks and higher- bandwidth applications. The comparisons between the transmitter with a Light Emitting Diode (LED) of -6dBm transmitted power, and the receiver component are suitable for a point-to-point FTTH application up to 80 Km transmission distance with a received output power of -14 dBm.

CHAPTER ONE

INTRODUCTION

1.1 Background

The Optical Code-Division Multiple-Access (OCDMA) is a promising technology for use in optical access networks carrying busy and asynchronous traffic (A. Stok and E. H. Sargent, Dec. 2000). In OCDMA, each user is identified by a different code or address. OCDMA user enters a number (or address) in each data bit and asynchronously initiates transmission. The fiber-optic OCDMA, the field of optical signals that carry data exhibits a set of signal processing, (i.e., the code). Hence, this modifies its time and/or frequency appearance, in a way recognizable only by the intended receiver who knows the code. Otherwise, only noise-like bursts are observed. The advantages of OCDMA include the flexibility in the allocation of channels, the ability to operate asynchronously, enhanced privacy, and increased capacity in bursty-nature networks (Fathallah 2000).

Multiple access communication system is a communication system where the number of users shares a common transmission medium to convey your message to the number of destinations (Behrouz A. Forouzan, 2001). One of the key issues to be addressed in moving from one's communication system to multi-user communication so that we can effectively share the available transmission medium among all users. OCDMA system is recognized as one of the most important technology to support many users simultaneously in shared media, and in some cases can increase the transmission capacity of optical fiber

(CF, Moreno, A., and Corrado, CJ, 2006). OCDMA is an exciting development in the short hauls optical networks, because it can support both wide and narrow bandwidth applications on the same network, it connects a large number of asynchronous users with low latency and jitter, and enables quality of service guarantees to manage the physical layer, provides robust security and the signal is a simplified network topology.

1.2 Problem Statement:

Optical Code Division Multiple-Access (OCDMA) system is getting more and more attractive in the field of all-optical communications as multiple users can access the network asynchronously and simultaneously with a high level of security (Salehi; J.A, & Brackett; C. A. 1989). Recently, Spectral Amplitude technique is the new system based on OCDMA where the unwanted signals appear as noise to the decoder called Multiple-Access Interference (MAI) is suppressed. MAI is the main source of noise in OCDMA and is limiting factor to the system performance. Therefore, in a well-designed OCDMA system where the MAI is overcome, users can successfully communicate asynchronously and regardless of network.

Optical CDMA (OCDMA) systems have received more attention because OCDMA allows many users share the same transmission medium asynchronously and simultaneously with a high level of transmission security (X.Wang, N. Wada, Tetsuya Miyazaki, Gabriella Cincotti, and Ken-ichi Kitayama, 2007). The system based on Light Emitting Diode (LED) as a power source suffering from various limitations-in one way or another in the either short fiber distances or long distance which is not exceeds 50 km Length. This system is used for low cost, no need for bumping and bumping the side of the laser.

In this thesis, we propose a system designed in order to compare two different parameters, one at the transmitter section and the other parameters at the receiver section. Furthermore, many researchers have been discussed the Return –to- Zero (RZ) and Non Return-to-Zero (NRZ) data format performances with different parameters (Ms.A. Sangeetha; May 2009. Weiming Mao, 2002. E. Yamada, H. Kubota-1997. C. Furst; Guo-Wei Lu.). In contrast to the previous papers, we quantify the improvement by RZ & NRZ for different values of BER, Bit Rates, Fiber length and Received power. From the above reasons, this work aims to evaluate the system implementing a module to compare between RZ and NRZ, because pulse generators (for the transmitter part) and between PIN and APD photo detector (on the received part). This work is based on Double Weight (DW) family, Modified Double Weight (MDW) and Enhanced Double Weight (EDW) code.

1.3 Research Objectives:

The main goal of this research is to evaluate the system performance of OCDMA technique based on MDW and EDW codes. The objective research is:

1. To evaluate the OCDMA system performance analysis using the MDW and EDW codes.
2. To evaluate the OCDMA system performance analysis based on RZ and NRZ line codes.
3. To evaluate the OCDMA system performance analysis based on PIN and APD at the receiver side.

4. To evaluate the OCDMA system detection techniques performance based on AND-Subtraction and Complementary –Subtraction techniques.
5. Utilizing the performance of MDW and EDW codes in access-FTTH network Point-To-Point (P2P) and Point-To-Multipoint (P2MP).

1.4 Scope of the Project:

To study the performance analysis of a system design in OCDMA network, six approaches were followed in this project.

- i. The first approach is designing a system using NRZ data format at the transmitter side and PIN photodiode at the receiver side.
- ii. The second approach is designing another system using RZ data format at the transmitter side and APD photodiode at the receiver side.
- iii. The third approach is to use AND-Subtraction detection technique in both first and second approach (i and ii).
- iv. The fourth approach is to evaluate the system performance using Complementary – Subtraction detection technique in both first and second approach.
- v. The fifth approach is to evaluate the system design based on MDW code for both first and second approach.
- vi. Finally, the sixth approach is to build a system design based on EDW code for both first and second approach and comparisons is made with the optisystem software. Since the results obtained help us to design a better system based on SAC-OCDMA, although this system depend on the LED laser as a power source and can transfer data up to 100km fiber distance. From the result found using the software

simulation, some conclusion will be made up. Next the comparison will be decided whether this development may be successful or not. However, as far as the scope of work of this study is concerned, the simulation results are expected to be sufficient to prove the viability of the new performance analysis.

1.5 Thesis Outline

This thesis is structured into five chapters which are the introduction, literature review, Methodology, Performance Analysis, and conclusions and future work. Chapter 1 discusses the project background, problem statement, Objective and Scope of the project. Chapter 2 presents the details of the parameters characteristics and illustrates the DW code family construction is illustrated. Chapter 3 will discuss the employed parameters and simulates the Double Weight Code and Modified Double Weight used in the proposed system used in this research. Chapter 4 presents the simulation results of the proposed system based on Optisystem software version 7.0 which almost replicate a real system. The relation of BER and the Data Rate has been studied using two types of modulation detection techniques in RZ and NRZ, PIN and APD format conversion based on MDW and EDW codes in AND Subtraction detection scheme and complementary detection techniques used at the receivers systems. These detection techniques could be used at the Fiber-To-The-Home (FTTH) Access Network, in which different requirements are studied from the investigation. Finally, chapter 5 summarizes and discusses the results obtained in the thesis.

CHAPTER TWO

Optical Code Division Multiple Access (OCDMA) System

2.1 Introduction:

This chapter discussed in detail the Optical Code Division Multiple Access (OCDMA) system. It starts with a discussion on, OCDMA system, SAC-OCDMA codes, system component, OCDMA equipment, detection technique, Simulation Analysis, and Next-Generation FTTH Passive Optical Networks.

2.2 OCDMA System

Optical Code –Division Multiple Access (OCDMA) systems are getting more and more attractive in the field of all optical communications as multiple users can access the network asynchronously and simultaneously with high level of security (Salehi, J.A. 1989 & Salehi, J.A. & Brackett, C. A. 1989). An OCDMA user modulates its code (or address) with each data bit and asynchronously initiates transmission. Hence, this modifies its spectrum appearance, in a way recognizable only by the intended receiver. Otherwise, only noise-like bursts are observed (Pearce, M. B. & Aazhang, B. 1994). The advantages of OCDMA technique over other multiplexing techniques such as Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) are numerous (Maric, S. V., Kostic, Z. I. & Titlebaum, E. L. 1993 & Prucnal, P., Santoro, M. & Ting, F. 1986). Major progression of OCDMA research has been achieved worldwide in recent years (Galli, Menendez, Narimanov, & Prucnal, 2008; Gupta & Saxena, 2007; Jen-Fa Huang, &

Huang, 2009; X. Wang et al., 2006). OCDMA schemes may be classified according to the choice of coherent versus incoherent processing. The scheme is based on incoherent processing (other than optical power), and broadband incoherent (noise) sources are generally the easiest to implement, but offer relatively poor performance. Figure 2.1 shows the conceptual OCDMA network. At the transmitter side of an OCDMA system, an OCDMA encoder is used to encode the input data bit stream into an optical signal depending on the mark sequence that is discrete for each user on the system. This encoded signal is multiplexed with the signal generated from all other users, (Salehi, 1989) and (Wei et al; 2001). They described that an encoder apparatus in the optical OCDMA network, is employed in each transmitter to encode any modulated data bit with the predetermined code to each proposed user. In point of fact, these encoded bits which do not match the codes are not wholly rejected by the encoder and some noises or also known as interference may also pass through the decoder. At the receiver side, an OCDMA decoder uses a matched filter that corresponds to the signature sequence of the desired user (Aminata Amadou Garba and Jan Bajcsy, 2007).

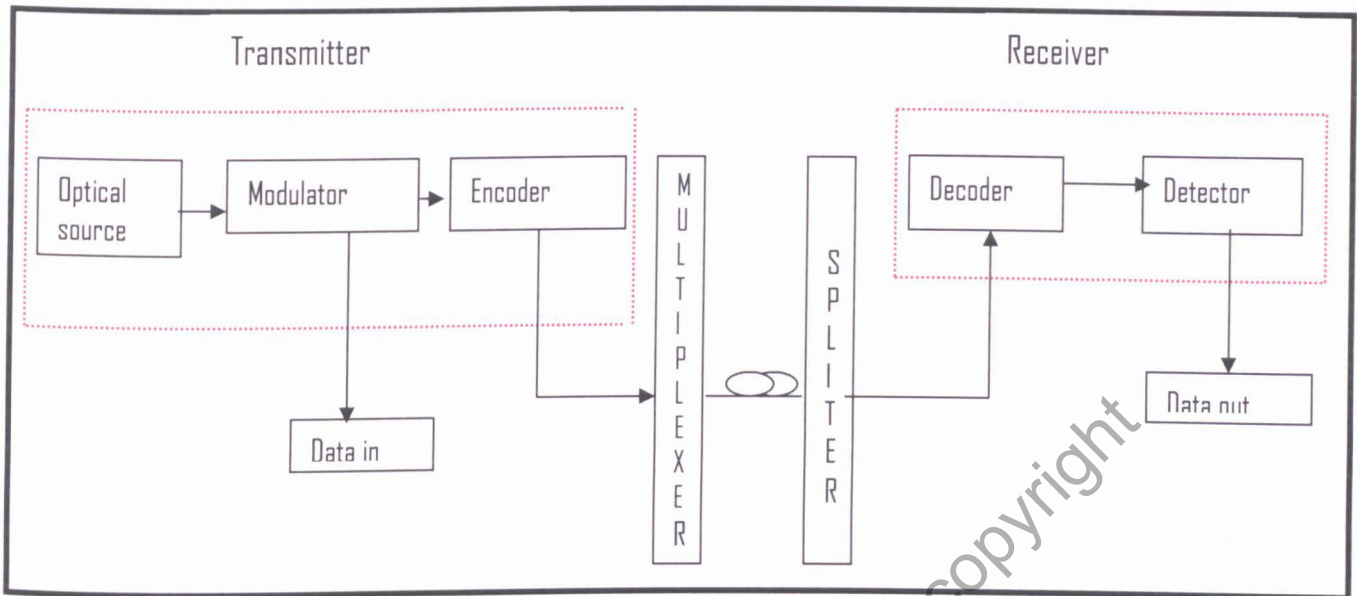


Fig 2.1 Optical CDMA block diagram

2.3 Spectral Amplitude Coding (SAC- OCDMA)

Zaccarin and Kavehrad first described and demonstrated the idea of frequency encoding in OCDMA (D. Zaccarin, and M. Kavehrad, 1993 & M. Kavehrad, and D. Zaccarin, 1995). The block diagram of their proposed system is shown in Figure 2.1. At the transmitter side, a spectral amplitude encoder is used to selectively block or transmit certain frequency components according to the spreading code. At the receiver side, a balanced receiver filters the incoming signal with the same spectral amplitude filter used at the transmitter as well as its complementary filter (Hossam M.H. Shalaby, 2008). For an unmatched transmitter, half of the transmitted spectral components will match the direct filter and the other half will match the complementary filter (In the case of m-sequence or Hadamard codes). Since the output of the balanced receiver represents the difference between the two