2-D Extended EDW: The New Scheme of Two Dimensional Wavelength-Time Coding for Optical Code Division Multiple Access System

by

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LIST OF ABBREVIATIONS

1-D	One Dimensional
2-D	Two Dimensional
2-D DPD	2-D Diluted Difference Code
2-D EDW	2-D Enhanced Double Weight
2-D MDW	2-D Modified Double Weight
2-D PD	2-D Perfect Different
BER	Bit Error Rate
BLS	Bandwidth Light Source
CDMA	Code Division Multiple Access
DW	Double Weight
EDW	Enhanced Double Weight
FBG	Fibre Bragg Grating
FCC	Flexible Cross Correlation
LED	Light Emitting Diode
M Matrices	Maximal-area Matrices
MAI	Multiple Access Interference
MDW	Modified Double Weight
MFH	Modified Frequency Hoping
MQC	Modified Quadratic Congruence
MUI	Multiple User Interference
MUX/DEMUX	Multiplexer/Demultiplexer
NRZ	Non Return to Zero
OCDMA	Optical Code Division Multiple Access

PIIN	Phase Induced Intensity Noise
PSD	Power Spectral Density
SAC	Spectral Amplitude Coding
SLDs	Super luminescence diodes
SNR	Signal Noise Ratio
TDMA	Time Division Multiple Access
TOFDLs	Tuneable Fibre Delay Line
WDMA	Wavelength Division Multiple Access
ZCC	Zero Cross- correlation

2-D Extended EDW: Skim Baru Sistem Dua Dimensi Pembahagian Kod Optik Berbilang Capaian (OCDMA)

ABSTRAK

Beberapa tahun kebelakangan ini, terdapat peningkatan minat yang tinggi terhadap penyelidikan dalam sistem Pembahagian Kod Optik Berbilang Capaian (OCDMA), terutama pada sistem pengekodan dua dimensi (2-D) OCDMA. Ini disebabkan oleh keupayaannya untuk menampung perkhidmatan jalur lebar bersepadu yang membolehkan capaian yang pantas kepada web maklumat yang mega dengan kebolehpercayaan yang tinggi. Walau bagaimanapun, dengan pelbagai sumbangan yang sangat besar, penyelesaian pengekodan 2-D OCDMA masih terhad. Penyelidikan ini bertujuan untuk mempersembahkan formulasi baru kod panjang gelombang masa untuk sistem Spektrum Amplitud Kod (SAC), yang dirujuk sebagai *2-D Extended EDW*. Kod 2-D ini telah diasaskan daripada kod satu dimensi pemberat berganda tertingkat (1-D EDW). Sistem ini direka secara berkesan untuk meningkatkan bilangan maksima pengguna secara serentak dan mengurangkan hingar dengan nilai kadar ralat bit (BER) yang lebih rendah, dan mencapai penggunaan kuasa efektif yang rendah. Penyelidikan ini melibatkan tiga fasa utama, iaitu mereka bentuk kod, analisis numerik dan pelaksanaan kod litar dalam persekitaran simulasi. Dalam mereka bentuk kod, sifat korelasi silang (cross-correlation) yang baik nilainya dirumuskan, dapatan ini telah memberikan kesan yang amat efektif untuk penindasan hingar yang dominan dalam sistem OCDMA iaitu hingar keamatan fasa teraruh (PIIN) dan gangguan berbilang capaian (MAI). Hasil analisis secara numerik telah menunjukkan bahawa kod *2-D Extended EDW* memperoleh prestasi yang lebih baik pada aspek BER dan kekardinalan, apabila dibandingkan dengan kod 1-D EDW dan kod 2-D yang lain, seperti 2-D M Matrices dan 2-D MQC. Pencapaian peningkatan kekardinalan (bilangan pengguna maksimum di bawah BER=10^{-9}) adalah kira-kira 200% dan 36% telah direkodkan apabila dibandingkan dengan kod 1-D EDW dan kod 2-D MQC. Tambahan pula, sistem kod baru 2-D ini juga menggunakan kuasa efektif sistem yang lebih rendah berbanding dengan kod 2-D yang lain, iaitu -19dBm. Dalam menilai prestasi litar kod *2-D Extended EDW* secara simulasi dengan menggunakan perisian Optisys, dapatan menunjukkan bahawa data dapat dihantar secara berkesan dalam rangkaian optik.

***2-D Extended EDW*: The New Scheme of Two Dimensional Wavelength-Time Coding for Optical Code Division Multiple Access System**

ABSTRACT

In recent years, there has been growing research interest in Optical Code Division Multiple Access (OCDMA) system especially in term of two dimensional (2-D) OCDMA coding. This is due to its ability to serve as an integrated broadband service that enables instant accesses to huge web of information with high reliability transmission system. However, with the enormous contributions, there are still limited solution for 2-D OCDMA coding. This work is aimed at presenting a new formulation of 2-D wavelength-time code for Spectral Amplitude Code (SAC) OCDMA system which has been referred as 2-D Extended EDW. This 2-D code has been based from one-dimensional Enhanced Double Weight (1-D EDW). The system is designed to effectively increase simultaneous users and reduce noise with lower Bit Error Rate (BER) value to attain lower transmitted effective power consumption. This research work involved three main phases, that are designing of the code, extensive numerical analysis and implementation of the code in simulation environment. In designing the code, a good property of cross-correlation is formulated, which has resulted in effective Phase Induced Intensity noise (PIIN) and multiple access interference (MAI) suppression. The outcomes of the extensive numerical analysis have shown that 2-D Extended EDW code had significantly gained a better performance in terms of BER and cardinality when compared with 1-D EDW code and other 2-D codes, such as 2-D M Matrices and 2-D MQC. The achievement of the cardinality (maximum users under BER= 10^{-9}) is about 200% and 36%, has been recorded in comparison with 1-D EDW and 2-D MQC respectively. Furthermore, the 2-D Extended EDW code also consumes lower power effectiveness for the system when compared with others 2-D codes, which is -19 dBm. In evaluating its performance in the simulation environment by using Optisys software system, the results revealed that the data can be transmitted efficiently in the optical network.

CHAPTER 1

INTRODUCTION

1.1 Overview

For the last three decades, research on Optical Code Division Multiple Access (OCDMA) has attracted great interest in the optical studies and is anticipated as a promising realization of OCDMA in future technology (Salehi, 1989; Wei, 2001; Hmud, Hasoon & Shaari, 2008) . This is due to the special characteristics of OCDMA system in many aspects such as enhancing information security, simplified and decentralized network, improve network control, improve spectral efficiency and increase flexibility in the granularity of bandwidth offered (Yin, Ma, Li & Zhu, 2009; Norazimah, Al-Khafaji, Aljunid & Fadhil, 2012).

OCDMA mimics the concept of multiplexing, which is adapted from the successful deployment of Code Division Multiple Access (CDMA) and the implementation in the wireless network (Aljunid, Zan, Anas, & Abdullah, 2004; Hasoon , Aljunid , Abdullah & Shaari, 2006, Zahid, Hasoon & Shaari, 2006; Ahmed, Faye, Saad & Aljunid, 2009). Uniquely, the OCDMA technique utilizes code sequences to distinguish the channel which supports multiple simultaneous transmissions on the same time slot and the same frequency (Yin & Richardson, 2007; Rashidi, Aljunid, Ghani, Anuar & Fadhil, 2012; Din Keraf, Aljunid, Arief, Anuar, Rashidi, Ehkan et. al., 2012).

This chapter is aimed at providing a full introduction and relating the study in the right context. It highlights the importance of OCDMA concept and its great potential for future communication system. Research motivation of the OCDMA study is deliberated in Section 1.3. The scope and objectives of the research are discussed in

Section 1.4 and 1.5 respectively. Finally, the organisation of the thesis is presented in Section 1.6.

1.2 Introduction to OCDMA

It is obvious nowadays that people are demanding an integrated broadband service to accommodate various types of information to be transmitted across the network. It implies the quest and aspiration to have a network that can transmit various types of data in a very high speed, very high bandwidth and capable to perform parallel transmissions effectively and efficiently is of the essence. In addition, the technology should maintain a secured and error-free transmission system.

Interestingly, communication technology nowadays has opened the flood gates of information dissemination and enables instant access to a very huge web of information (Morelle, Julien, Cances, & Dumas, 2008). The optical network system offers huge bandwidth for multiple access operation and has gained lot of attention. Traditionally, multiple access in optical fibre can be can be classified as Time Division Multiple Access, (TDMA) and Wavelength Division Multiple Access (WDMA). TDMA is an access system that distinguishes each channel using different time slots, whereas WDMA uses different wavelength for each channel. Currently the deployment of TDMA and WDMA as a multiple access technique in optical network have been extensively explore and utilized.

CDMA is another form of multiple access technique that has been used by various radio communication technologies. It is a form of multiplexing, which allows numerous signals to occupy a single transmission channel. In order to realize this property, it optimizes the use of available bandwidth using different pseudo-random

code sequences for each user (Zhang, M., 2012). This novel idea is implemented without the interference between the users. Consequently, CDMA employs spread spectrum technology (Jyoti, V., 2009). This technology modulates the coded signal with a higher bandwidth than the data being communicated (Shiraz & Karbassian, 2012; Rashidi, Aljunid, Ghani, Fadhil, & Anuar, 2012). This technique decreases the potential interference to other receivers while at the same time, interestingly achieving privacy. These are attributed to the application of the spread spectrum technology. The technology multiplexes the sending signal guarantying the received signal at any receiving end only through de-multiplexing when the code sequences are strictly matched. Users do not have to worry about privacy, trust, security, and reliability anymore. Issues about data ownership, systems vulnerability, information manipulation, false propaganda, plagiarism and malware can be tackled effectively by employing this communication technology.

Spread spectrum generally makes use of a sequential noise-like signal structure to spread the normally narrowband information signal over a relatively wideband (radio) band of frequencies. In particular, a CDMA user inserts its code or address in each data bit asynchronously. CDMA consistently provides better capacity for voice and data communications than other commercial mobile technologies, allowing more subscribers to connect at any given time. This multiplexing technique has become a common platform on which 3G and advanced technologies are built.

Recent technology in optical networks that combine large bandwidth of fibre medium with the flexibility and successful CDMA multiplexing is called Optical Code Division Multiple Access (OCDMA). It is receiving great attention due to its potential of serving large bandwidth, secure data transmission to the internet users and also achieving high-speed connectivity (Stok & Sargent, 2002; Din Keraf, Aljunid, Arief,

Nurol, Anuar, Rashidi, et. al., 2014). In encoding process, each user will be recognized by a unique code, as an address that spreads over a relatively wide bandwidth. At the receiver side, the decoding process will extract the original data. Encoding process involves multiplying the data bit by a code sequence either in the time domain, wavelength domain, or combination of both, which is considered as two dimensional coding (Fouli & Maier, 2007).

OCDMA is potentially envisioned to offer various attractive solutions for next-generation of broadband communication. The OCDMA can support a large number of users than other multiplexing techniques, especially when the two dimensional of coding is used. OCDMA allows an asynchronous transmissions between transmitter and receiver. The transmission can be operated without any synchronization algorithm, with efficient access and high level of information security in the network. Furthermore, the less cost and less complexity configuration can be implemented based on employing incoherent sources (Ashour, Shaari, Menon & Bakarman, 2012; Al-Khafaji, Aljunid, Amphawan & Fadhil, 2012; Kavehad & Zaccarin, 1995).

1.3 Motivation

Establishing the code to improve the system performance is one of the most popular studies in the OCDMA system. Therefore, its is crucial to design a proper code sequence that can make the major source of noise in OCDMA system, multiple access interference (MAI) mitigated (Wei & Shiraz, 2002; Anuar, Aljunid, Saad, Mohammad & Babekir, 2006; Rashidi, Aljunid, Ghani, Hilal, Fadhil & Anuar, 2013). MAI is the interference resulting from other users transmitting at the same time, which will arise when the cardinality increases (Salehi, 1989; Anuar, Aljunid, Saad & Hamzah, 2009). The cardinality of the system is also proportional to the length of the code (Yin &

Richardson, 2007). Larger code length will improve correlation properties among code sequences, thus upgrading the system performance, in terms of lower bit error rate (BER) and reduce multiples access interference (MAI). However in 1-D coding, in order to improve the performance in term of number of users results in code length and bandwidth expansion respectively (Kadhim, Fadhil, Aljunid & Razalli, 2014).

Most of the previous 1-D codes were designed with the good property ties, such as an ideal cross-correlation and simple encoder/decoder design (Anuar et. al., 2009; Hason et. al., 2006; Aljunid et. al., 2004). However the 1-D code system is relatively unsupportive to many active users, due to the limited allowable code length it offers. Therefore, the increment of cardinality will result in more serious MAI (Yin et. al. 2007; Nurol, Arief, Anuar, Aljunid, Din Keraf & Arif, 2014). Thus, in order to overcome the shortcoming of one-dimensional codes, where the number of codewords is very small, the 2-D OCDMA system is introduced (Aishah, Anuar, Aljunid & Arief, 2013). It would be a very good approach to enhance cardinality, with less MAI to achieve better BER.

Phase induced intensity noise (PIIN) is another dominant noise that need to be resolved. This noise can severely influence the performance of SAC-OCDMA system, which rises due to the usage of non coherent broadband light sources (Wei, 2001; Junita, Aljunid, Anuar, Arief, Rahim, Ahmad, et. al., 2012). PIIN is strongly related to the MAI due to the overlapping chips or spectrum among the simultaneous users. Zou Wei and Ghafouri-Shiraz in (Wei et. al., 2002) have introduced spectral coding with a fix in phase spectral cross correlation equal to one in order to suppress PIIN and remove the MAI. PIIN can be suppressed, by lowering as small as possible the value of cross-correlation (Anuar et. al., 2009; Hmud et. al., 2008).

In recent years, there have been an obvious increment number amount of literatures on 2-D incoherent spectral temporal OCDMA system. The literatures have revealed that the 2-D systems enhance the performance of 1-D codes, in terms of the cardinality, BER and low effective power consumed. Most of the 2-D codes portrayed the constant result which are high ability to supress PIIN and eliminate MAI. Furthermore the codes system also has great impact on improving the channels' transmission signal quality. Although the system of 2-D OCDMA system become more complex, as compared with 1-D system, there exist a tradeoff between the complexity of the system and the achievement of the performance.

While it is acknowledged that the advantages of 2-D coding systems are enormous, it is believed that there are a lot of further improvements that can be suggested. Most 2-D coding systems are derived based on 1-D systems. Enhance Double weight (EDW) is among the best performance of one dimensional code in OCDMA system. The code had been proposed by F.N. Hasoon (Hasoon et. al., 2006). It is one of the double weight family codes, and has good properties such as ideal cross-correlation, simple encoder/decoder design, and existence for every natural number (Menon, Zahid, Mandeep & Shaari, 2011).

However the 1-D EDW code still need to be improved in terms of its performance of BER, cardinality and the ability to suppress PIIN and eliminate MAI. Thus the researcher believe that the system gain better performance by developing 2-D EDW coding. To the best of researcher knowledge, there are no other works on formulating this coding yet. Likewise, this thesis also proposes to develop and explore the enhancement performance of 2-D EDW code in term of BER, cardinality, effective power and the ability to reduce MAI and PIIN in OCDMA system.

1.4 Scope of Research

In OCDMA system, designing a successful code for isolating the users is one of the main issues that has to be tackled, due to its importance to mitigate the deleterious effect of MAI. The research presented in this thesis focuses on the code design of incoherent 2-D spectral temporal, SAC OCDMA system, namely 2-D Extended EDW code. Fig. 1.1 illustrates the scope of the research, it is shown that the research will be focus on the family of Spectral Amplitude Coding (SAC) codes, and used wavelength-time or spectral-temporal technique to perform 2-D coding in OCDMA system.

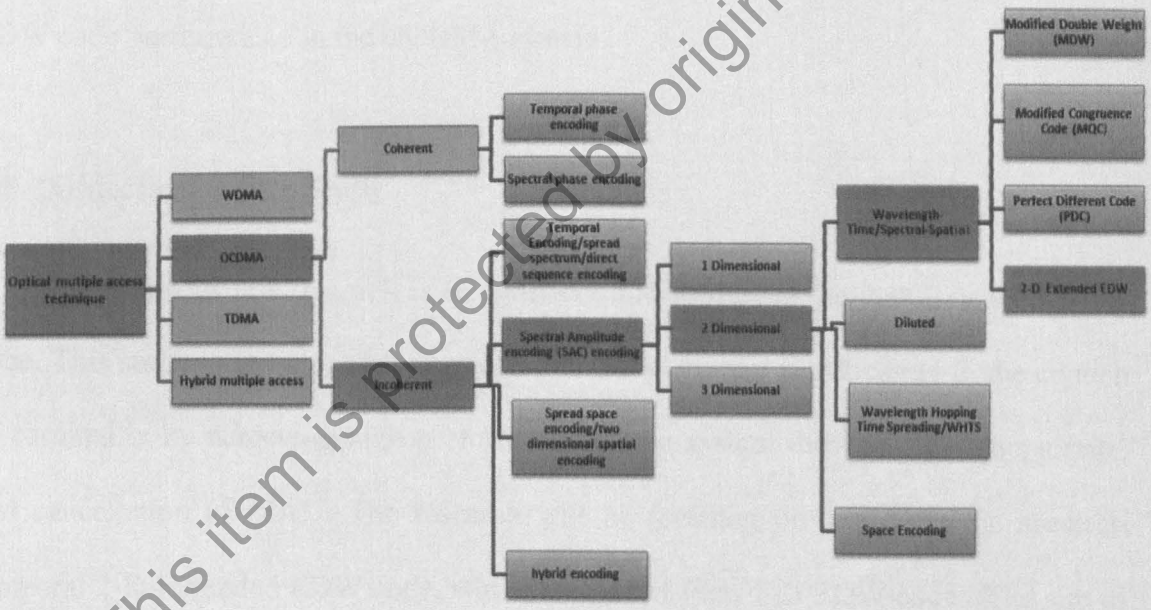

Figure 1.1: Layout scope of the research

The code is developed by merging two difference weight of 1-D EDW code sequences into 2-D spectral temporal scheme. The utilization of the wideband incoherent source, in encoding and decoding techniques are more practical due to low complexity and cost effectiveness. However in SAC-OCDMA coding system, the usage of broadband sources, will introduce PIIN, and degrades the performance. PIIN can be suppressed through code construction by lowering the constant in phase cross