Development of User-Interface Software Program for Double Weight Code Family for OCDMA

by

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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

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TRONOH, PERAK
JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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SAM MUN TEK

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ABSTRACT

Optical Code Division Multiple Access (OCDMA) offers high statistical multiplexing gain in a busty traffic environment and is thought to be a more suitable solution in local-area network. There have been many codes proposed OCDMA systems, such as Hadamard code, Modified Frequency Hopping (MFH) code and Double Weight (DW) code family. The inspiration of this study is to improve the Modified Double Weight (MDW) code to give a better performance and to enhance the detection technique of DW code family. There are few aspects that have been identified in this study. First of all, the construction of MDW code is studied. Besides, the equation-based construction technique is examined and is then simulated using Virtual Basic software version 6.0. The findings of the project will lead to a new development of the MDW code by having new user-interface software program to generate the DW codeword with an ease.

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LIST OF ABBREVIATIONS

OCDMA	:	Optical Code Division Multiple Access
MAI	:	Multiple Access Interference
DW	:	Double Weight Code
MDW	:	Modified Double Weight Code
FBGs	:	Fiber Bragg Gratings
WDM/SAC	:	Wavelength Division Multiplexing/Spectral Amplitude Coding
VPI	:	Virtual Photonics Instrument
PIIN	:	Phase Induced Intensity Noise
SNR	:	Signal to Noise Ratio
BER	:	Bit Error Rate

CHAPTER 1
INTRODUCTION

1.1 Background of Study

The optical fiber concept has been around for more than a century [17]. From the early experiments by John Tyndall in the guided transmission light, through the development of light-emitting diodes and lasers, and the emergence of dense wavelength-division multiplexing, the applications for optical fiber have continued to grow [18].

Optical fiber technologies in today modern telecommunication system permeate a variety of industries. The deployment of fiber-to-the-curb network has made possible for fiber optic to deliver high-definition broadcast (HDTV) at resolutions of 1080p [19]. Optical fiber provides extremely high bandwidth and has very less attenuation factor, which enables use for longer transmission without the need of demodulation [20-21]. The usage of light as carrier has allow different wavelengths that can be multiplexed on the same fiber in order to increase the overall bandwidth and thus can reduce cost and enable numerous user access [1].

OCDMA is an area of interest in the study of short haul optical networking due to its dynamic support for both wide and narrow bandwidth applications on a single network [11]. Moreover, large number of asynchronous users can be connected together with low latency and jitter allowing quality of service guarantees to be monitored at the physical layer [11]. Despite its robust signal security, it maintains a simplified network topology [11]. OCDMA aims for Terabit performance on Broadband Networks by reducing the cost of every aspect in optical network.

However, for improperly designed codes, Optical Code Division Multiple Access (OCDMA) suffers from various types of noise like Multiple Access Interference (MAI), photo detector, shot noise, dark current and thermal noise. The dominant source of noise is MAI and thus the cancellation or suppression of MAI is the major issue in OCDMA [2-3]. Many OCDMA codes have been designed to reduce the MAI and to enhance the performance of the system such as Prime Code [4], Optical Orthogonal Code [5] and Modified Frequency Hoping (MFH) [6].

1.2 Problem Statement

Due to the success of Code Division Multiple Access (CDMA) in wireless communication, researchers are trying to exploit the advantages of CDMA in optical communication system. Optical fibers offer a large transmission bandwidth and every user is distinguished by a unique code in CDMA and thus all user can use the entire bandwidth at the same time [11].

Besides OCDMA, there is also Time Division Multiple Access (TDMA) and Wavelength Division Multiple Access (WDMA) or Frequency Division Multiple Access (FDMA) but both have weaknesses such as dispersion and attenuation [11]. Thus, OCDMA appears to be the other alternative technique to support short-haul transmission for a high number of simultaneous users. OCDMA can operate asynchronously without packet collisions and slot allocation requirements are not needed in contradiction to TDMA and WDMA/FDMA [13].

For improperly designed codes, OCDMA suffers from various types of noise mainly from Multiple Access Interference (MAI) [2]. To solve the problem of MAI, several codes have been invented. For conventional time spreading OCDMA systems [3], Prime Code [4], Optical Orthogonal Code [15-17] have been proposed. For the wavelength-hopping time-spreading OCDMA system, Carrier Hopping [4], and Extended Carrier Hopping Prime codes [7] have been proposed. For the Spectral Amplitude Coding (SAC) OCDMA system [8], Hadamard [9], Modified Frequency

Hopping (MFH) code [6], and lately the Double Weight (DW) code [10] family have been proposed.

In this research, the Double Weight (MDW) code family is studied in detail. An improvement on the equation based construction technique is studied. User-interface software program is developed to generate the code based on the equation based construction technique.

1.3 Objective

The primary objective of this study is to develop user-interface software program to generate the MDW codeword based on the equation-based construction technique in MDW code family for OCDMA. The following approaches will be covered:

a. To develop user-interface software program to generate MDW codeword based on equation-based formula using Virtual Basic 6 (VB6).
b. To develop user-interface software program to calculate the minimum code length using VB6.
c. To theoretically understand the detection scheme based on the reduced set of Fiber Bragg Gratings (FBGs) for Wavelength Division Multiplexing/Spectral Amplitude Coding (WDM/SAC) scehme.

1.4 Scope of Study

In OCDMA, equation-based construction techniques for MDW code are studied to develop user-interface software program to generate the MDW codeword with an ease. Besides, user-interface software program is also developed to calculate the minimum code length construction using VB6.

In this research, a literature review on the DW and MDW code are studied. All the mathematical relations between the equation-based and the minimum code length are studied and discussed. The detection scheme base on the reduced set of Fiber Bragg Gratings (FBGs) for Wavelength Division Multiplexing/Spectral Amplitude Coding (WDM/SAC) scheme is also studied.

CHAPTER 2
LITERATURE REVIEW

2.1 Optical Code Division Multiple Access (OCDMA) Codes

Network architecture like star, bus or mesh requires a data signal to be encoded at the transmitter. After transmitting through the network, a decoder has to be capable of extracting the correct channel identified by a unique code in the presence of other codes in order for the user to recover the data [11]. There are few coding strategies that can be adopted to create the OCDMA network. These coding include incoherent, coherent, spectral, and hybrid techniques [13].

OCDMA combine the large bandwidth of fiber optic medium with the flexibility of CDMA to perform high speed connectivity. Each user is assigned a fixed unique code sequence [13]. OCDMA can operate asynchronously, without centralized control, and does not suffer from packet collisions. Statistical multiplexing gains can be high since the dedicated time or frequency slots do not have to be allocated [13].

Any OCDMA code can be represented in a general form of (L,w,λ_c) [2-3], where L is the code length, w is the code weight (the number of "1") and λ_c is the cross correlation or the number of overlapping sequences.

There are two types of correlation techniques; auto-correlation technique and cross-correlation technique. The use of auto-correlation is to determine the performance of a code sequence at an intended receiver in the presence of mutual interference. The cross-correlation represents the degree of mutual interference between two code sequences.

The auto-correlation property should be made as high possible to distinguish the signal in the presence of background noise. For a code sequence of $X = (x_1, x_2, \ldots x_N)$ it can be represented as:

$$\lambda_a = \sum_{i=1}^{L} x_i x_i \tag{2.1}$$

The cross-correlation property should be kept as low as possible to keep the Multiple Access Interference (MAI) as negligible as possible compared to the desired signal. For two code sequences $X = (x_1, x_2, \ldots x_N)$ and $Y = (y_1, y_2, \ldots\ldots y_N)$ it can be represented by:

$$\lambda_c = \sum_{i=1}^{L} x_i y_i \tag{2.2}$$

2.2 Double Weight (DW) Code

DW code family was proposed by Aljunid [10] and it offered good result compared with others OCDMA codes. The DW code is constructed using a basic matrix construction and a mapping construction technique.

The code is represented by using the dimension *K* x *N* matrix where *K* is the rows and *N* is the columns which represent the number of users and the minimum code length respectively. A basic DW code is given by 2 x 3 matrix is shown as follow:

$$\begin{matrix} 1 & 2 & 1 \\ \downarrow & \downarrow & \downarrow \end{matrix}$$

$$H_{M=1} = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

Figure 1: General Form of DW basic matrix construction

The $H_{M=1}$ has a chip combination sequence of 1, 2, 1 for the three columns. A chips combination sequence is defined by the summation of the values of the corresponding elements in every two rows. The purpose of the 1, 2, 1 combination is to maintain the cross correlation value of one; only one overlap between two chips will be allowed [10].

In order to increase the number of users, the mapping construction technique [10] is carried out shown as follow:

$$H_{M=2} = \left[\begin{array}{ccc|ccc} 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 \\ \hline 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 \end{array}\right] = \begin{bmatrix} 0 & H_1 \\ H_1 & 0 \end{bmatrix}$$

Figure 2: General Form of DW mapping construction

The basic matrix is repeated diagonally filling the empty spectrums with zeros ‘0’ while maintaining the 1, 2, 1 combination. The mapping construction technique can be applied to increase the number of users from the basic number to any number of users. The DW code is constructed based on the weight, cross-correlation, weighted chips and chip combination which have the following properties [10]:

1. Each code sequence has a weight of 2.
2. The cross-correlation is equal to 1.
3. The weighted chips are in pairs.
4. The chip combination is maintained at 1, 2, 1 combination for every three column.

2.3 Modified Double Weight (MDW) Code

MDW code is part of DW code family and thus both codes have the same properties except that MDW has a weight of more than two or multiple of two. Increases the code weight increases the signal power of the user and hence it also increases the SNR [10].

2.3.1 Matrix Construction Technique

Similar to DW code, MDW code is also constructed using *K x N* matrix as shown in Figure 3.

$$\left[\begin{array}{c|c} [\,A\,] & [\,B\,] \\ \hline [\,C\,] & [\,D\,] \end{array}\right]$$

Figure 3: General Form of MDW basic matrix construction

The matrix construction consists of a minimum number of *K* and *N* for a specific number of code weights. The construction of all matrixes A, B, C, and D depend on the weight *w*. A, B, C, and D definitions are as follow:

1. [A] consists of a $1 \times 3\sum_{j=1}^{\frac{w}{2}-1} j$ matrix of zeros.
2. [B] consists of a 1 x 3*n* matrix of $[\,X_2\,]$ for every 3 column. (i.e. a 1 x 3*n* matrix with *n* times repetition of $[\,X_2\,]$), where $n = \frac{w}{2}$.
3. [C] is the basic code matrix for the next smaller weight, *w* = 2(*n*-1).
4. [D] is an *n* x *n* matrix of $[\,X_3\,]$ as shown in (2.3).

$$[D] = [X_3] = \begin{bmatrix} 000 & 000 & [X_3] \\ 000 & [X_3] & 000 \\ [X_3] & 000 & 000 \end{bmatrix} \tag{2.3}$$

Where $[X_1]$, $[X_2]$ and $[X_3]$ are defined as follow:

$$X_1 = \begin{bmatrix} 0 & 0 & 0 \end{bmatrix} \tag{2.4}$$

$$X_2 = \begin{bmatrix} 0 & 1 & 1 \end{bmatrix} \tag{2.5}$$

$$X_3 = \begin{bmatrix} 1 & 1 & 0 \end{bmatrix} \tag{2.6}$$

In order to construct the matrix, the basic code length N_B (column size) and the basic number of user K_B (row size) have to be identified where:

$$N_B = 3\sum_{m=1}^{\frac{w}{2}} m \tag{2.7}$$

$$K_B = \frac{w}{2} + 1 \tag{2.8}$$

After studying the matrix construction of the MDW code, it can be observed that the cross-correlation is one. In order to obtain the specific code for a particular user, the construction of the entire matrix is required.

2.3.2 Mapping Construction Technique

Mapping construction technique is used in order to increase the number of users in the basic matrix technique for a specific weight [10]. In order to increase the number of users, the mapping construction technique repeats the basic matrix diagonally for any number of times required. The mapping construction technique is shown in Table 1 [10].

Table 1: MDW of Weight Four with Mapping Construction Technique

k^{th}	C_{18}	C_{17}	C_{16}	C_{15}	C_{14}	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1
1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**1**
2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**1**	**1**	**0**
3	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**
4	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
5	**0**	**1**	**1**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
6	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

The properties of MDW codes are as follows:

1. The maximum cross-correlation is 1.
2. The weight for MDW codes is of multiple 2 starting at the weight of 2.
3. The chip combination is maintained 1, 2, 1 for every three columns and thus the weighted chips are in pair.

Similar to matrix construction technique, the construction of the entire matrix is required since mapping construction technique is based on the matrix construction. For large number of users, matrix construction technique and mapping construction technique can be hard to handle and can be messy. Thus, it is essential to establish an equation based construction technique to derive each of the codeword separately.

2.3.3 Equation-Based Construction Technique

Equation-based construction technique was proposed by Mohammed [11] to derive each of the codeword separately. Two equations have been proposed for DW code family.

2.3.3.1 The First Equation

The equation is based on the distribution of ones ‘1’ in each codeword which is derived from the two patterns as shown in Table 2.

Table 2: MDW of Weight Six with Ones Pattern

k^{th}	C_{18}	C_{17}	C_{16}	C_{15}	C_{14}	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1
1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1	1
2	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	1	1	0
3	0	1	1	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0
4	1	1	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0

The grey pattern consists of pairs of ones which are repeated on the same line consecutively and separated by zeros. This pattern has an entirety of *w* for the first user and decreases by 2 for every consecutive user.

The black pattern consists of pair of ones which has a diagonal pattern starting at the user number two until the last user. Additional diagonal patterns start at every consecutive user shifted from the previous pattern until the last user. The last user has an entirety of *w*.

The proposed first equation [11] is as follow:

$$MDW_{i,j}=\begin{cases}1 & if \begin{cases} j=(n_1-1)+\left\lfloor {(n_1+1)}/{2}\right\rfloor + \sum_{m=0}^{i \bmod K_B-2}\left(\frac{3w}{2}-3m\right)+\left\lfloor {(i-1)}/{K_B}\right\rfloor N_B & for \quad n_1=\{1,2,..,w-2((i-1)\bmod K_B)\} \\ j=3((i-1)\bmod K_B)-2+\sum_{m=1}^{\left\lfloor (n_2-1)/2\right\rfloor}\left(\frac{3w}{2}-3m\right) + (n_2-1)\bmod 2+1+\left\lfloor {(i-1)}/{K_B}\right\rfloor N_B & for \quad n_2=\{1,2,...,2((i-1)\bmod K_B)\}\end{cases} \\ 0 & Otherwise\end{cases} \tag{2.9}$$

Where

1. The *mod* represents modulo division.
2. The symbol lower bounded $\lfloor x \rfloor$ denotes the integer portion of the real value of x.
3. The n_1 and n_2 represents the number of ones in each pattern.

The first partial equation represents the plotting of the grey pattern and the first two terms are used for plotting the pair of ones. The second two terms are used to shift the starting point of the pattern.

The second partial equation in the general formula plots the ones for the black pattern. The ones are grouped into diagonally shaped sets of pairs of ones.
For the user i:

$$1 \le i \le K \quad (2.10)$$

Where K is the total number of users.

For column j for the position of each chip:

$$1 \le j \le L \quad (2.11)$$

And L is the minimum code length where:

$$L = \sum_{m=1}^{i \bmod K_B} \left(\frac{3(w-2(m-1))}{2} - \frac{1}{i \bmod K_B} \right) + \left\lfloor \frac{i}{K_B} \right\rfloor N_B \quad (2.12)$$

2.3.3.2 The Second Equation

The second equation is based on the pattern of the basic building blocks of the basic matrix ([X_1],[X_2] and [X_3]). Similar to Table 2, but the pattern is now expanded as shown in Table 3.

Table 3: MDW of Weight Six with Basic Building Blocks Pattern

k^{th}	C_{18}	C_{17}	C_{16}	C_{15}	C_{14}	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1
1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1	1
2	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	1	1	0
3	0	1	1	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0
4	1	1	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0

From the definition of [X_1],[X_2] and [X_3] in equation (2.4), (2.5) and (2.6), Table 3 can be simplify to the basic blocks pattern as shown in Table 4.

Table 4: MDW of Weight Six with [X_1],[X_2] and [X_3]

k^{th}	6	5	4	3	2	1
1	X_1	X_1	X_1	X_2	X_2	X_2
2	X_1	X_2	X_2	X_1	X_1	X_3
3	X_2	X_1	X_3	X_1	X_3	X_1
4	X_3	X_3	X_1	X_3	X_1	X_1

The grey pattern consists of matrix [X_2] which is repeated on the same line consecutively. This pattern has an entirety of *w* for the first user and decreases by 2 for every consecutive user.

The black pattern consists of matrix [X_3] which has a diagonal pattern starting at the user number two until the last user. Additional diagonal patterns start at every consecutive user shifted from the previous pattern until the last user. The last user has an entirety of *w*.

The proposed second equation [11] is as follow:

$$MDW_{i,j} = \begin{cases} X_3 \quad if & \begin{aligned} j = (i-1)\bmod K_B + (n-1)\frac{w}{2} \\ -\sum_{m=1}^{n-1} m + \left\lfloor {(i-1)}/{K_B} \right\rfloor {N_B}/{3} \end{aligned} \quad for \quad n = \{1,2,....,(i-1)\bmod K_B\} \\ X_2 \quad if & \begin{aligned} j = \sum_{m=1}^{(i-1)\bmod K_B} (K_B - m) + n \\ + \left\lfloor {(i-1)}/{K_B} \right\rfloor {N_B}/{3} \end{aligned} \quad for \quad n = \{1,2,....,(K_B-1)-(i-1)\bmod K_B\} \\ X_1 \quad else & \end{cases} \tag{2.13}$$

The first partial equation represents the plotting of the grey pattern which is the matrix [X_3] and the second partial equation represents the plotting of the black pattern which is the matrix [X_2].

For the user *i*:

$$1 \le i \le K \tag{2.14}$$

Where *K* is the total number of users.

For column *j* for the position of each basic matrix:

$$1 \le j \le \left\lceil {i}/{K_B} \right\rceil N_B \tag{2.15}$$

Where $\lceil x \rceil$ is the ceiling function of *x*.

The code length L is:

$$L = \sum_{m=1}^{i \bmod K_B} \left(\frac{3(w-2(m-1))}{2} - \frac{1}{i \bmod K_B} \right) + \left\lfloor \frac{i}{K_B} \right\rfloor N_B \tag{2.16}$$

Which is the same as in equation (2.12).

2.4 Reduced set of Fiber Bragg Gratings (FBGs) WDM/SAC Detection.

Reduced set of Fiber Bragg Gratings (FBGs) WDM/SAC detection scheme was proposed by Mohammed [12]. A mathematical approach was proposed to select the wavelengths that can achieve both a reduction in the number of FBGs and minimization in the Phase Induced Intensity Noise (PIIN).

The basic matrix of the DW code family can be detected by using the complementary detection scheme and requires that all code sequences in the basic matrix all correlate ideally together ($\lambda = 1$). Figure 4 shows the complementary SAC decoder with Fiber Bragg Gratings (FBG).

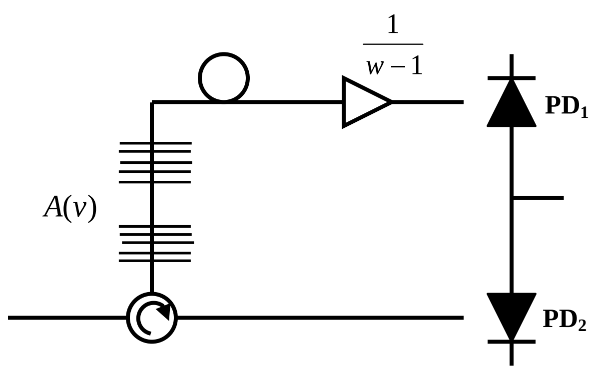

Figure 4: Complementary SAC decoder using FBGs

The correlation functions for each photodetecter for Figure 2 is given by:

$$R_{D1} = \begin{cases} w, & for \quad k = l \\ 1, & for \quad \left\lfloor \frac{l-1}{K_B} \right\rfloor K_B + 1 \le k \le \left\lfloor \frac{l-1}{K_B} \right\rfloor K_B + K_B \ \& \ k \ne l \\ 0, & else \end{cases} \tag{2.17}$$

$$R_{D2} = \begin{cases} 0, & for \quad k = l \\ 1, & for \quad \left\lfloor \frac{l-1}{K_B} \right\rfloor K_B + 1 \le k \le \left\lfloor \frac{l-1}{K_B} \right\rfloor K_B + K_B \ \& \ k \ne l \\ 0, & else \end{cases} \tag{2.18}$$

The Multiple Access Interference (MAI) can be cancelled by:

$$R_{D1} - R_{D2} = \begin{cases} w & k = l \\ 0 & else \end{cases} \tag{2.19}$$

The Phase Induced Intensity Noise (PIIN) can be calculated by:

$$\left\langle I_{pn}^2 \right\rangle = \frac{P_{sr}^2 \ B \Re^2 \ w}{2 \Delta v L^2} \frac{K}{N} \left[\ w + (K-1)/N \right] \tag{2.20}$$

The shot noise is given by:

$$\langle I_{sh}^2 \rangle = \frac{P_{sr} \ eB\Re}{L} \ \left[w + 2(K-1)/N \right] \tag{2.21}$$

The Signal to Noise Ratio (SNR) is calculated using the following equation:

$$SNR = \frac{\langle I^2 \rangle}{\langle I_{piin}^2 \rangle + \langle I_{sh}^2 \rangle + \langle I_{th}^2 \rangle} \tag{2.22}$$

The Bit Error Rate (BER) can be calculated by:

$$BER = \frac{1}{2} erfc\left(\sqrt{\frac{SNR}{8}} \right) \tag{2.23}$$

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

Project flow diagram in Figure 5 explains the flow of the whole project:

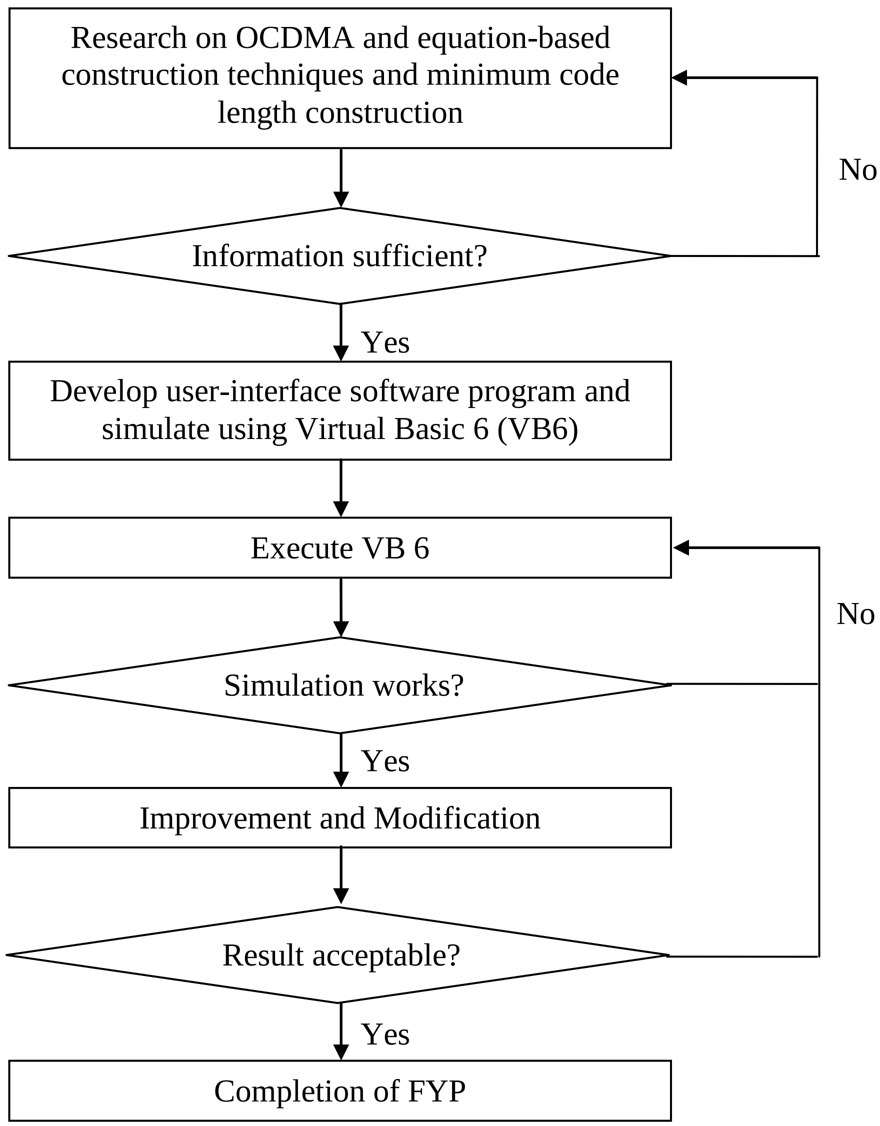

Figure 5: Project Flow Digram

3.2 Tools and Equipments

The tool or software required in order to implement this project is as follow:

1. Microsoft Virtual Basic (VB) software version 6.0.
2. Microsoft Office Excel software with macro-enabled version 2007.
3. Virtual Photonics Instrument (VPI) transmission maker software version 7.1.
4. Microsoft Office Publisher software version 2007.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Results for User-Interface Software Simulation

To ease the calculation, user-interface software program is developed for both generating of the codeword and the calculation for the minimum code length using Virtual Basic 6 (VB6).

Simulation flow chart diagram in Figure 6 explains the process of using the user-interface software program.

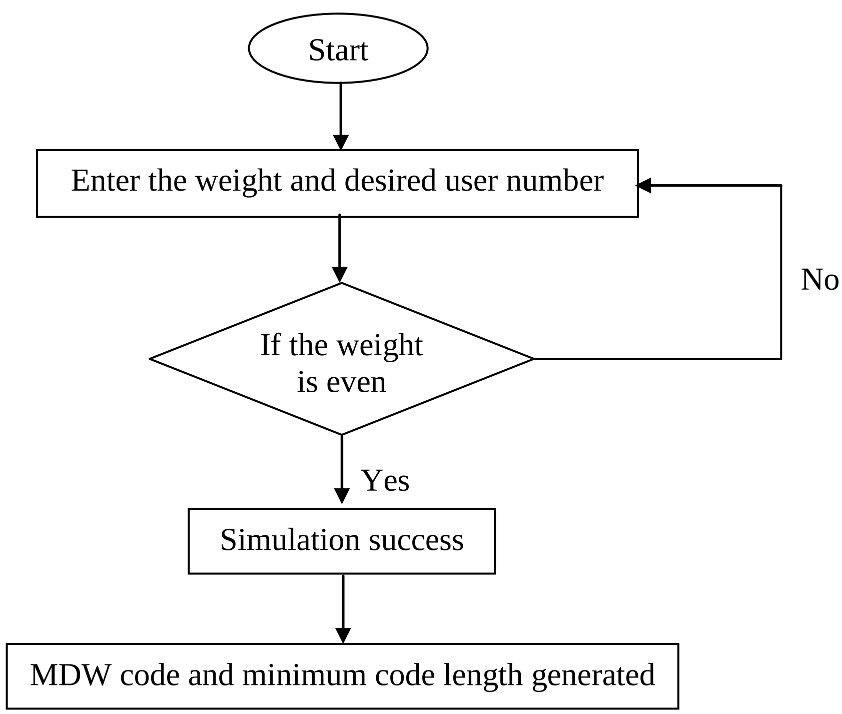

Figure 6: Simulation Flow Chart Diagram

For example, to generate the MDW codeword and the minimum code length using the user-interface software program for user number 5 with weight of 4. The simulation result is shown in Figure 7.

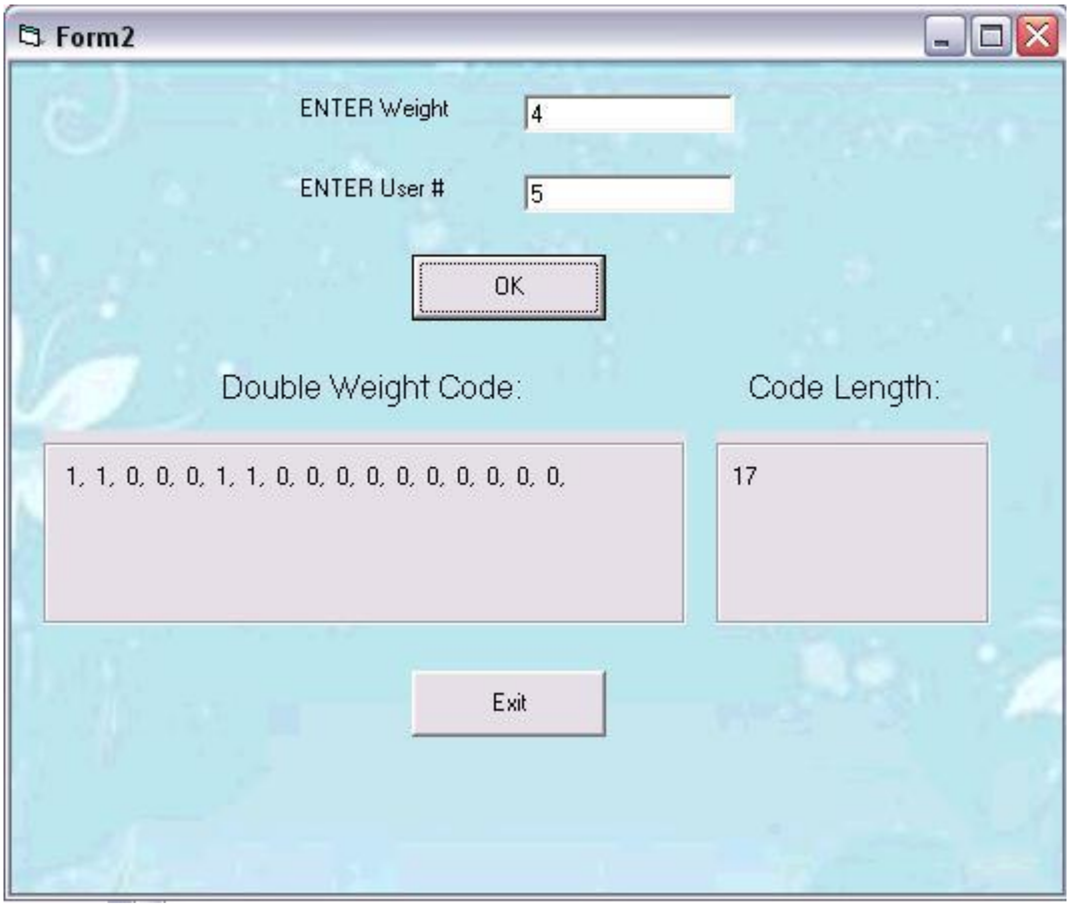

Figure 7: The simulation result of the MDW codeword and the minimum code length for user number 5 with weight of 4

It can be observed that the codeword obtained from the user-interface software shows in Figure 7 is the same as the codeword of user number 5 in Table 1 with the minimum code length of 17.

The manual calculation to derive the MDW codeword using equation (2.9) can be time consuming. Thus, to overcome the problem, a newly develop user-interface software program is developed. Unlike manual calculation, the user-interface software can perform the calculation and generate the codeword by putting only the weight and the desired user number.

From the user-interface software program, it has been further enhance by storing the codeword obtained from the result using Microsoft Excel macro-enabled software. Using the same weight from the previous example, the simulation result is shown in Figure 8.

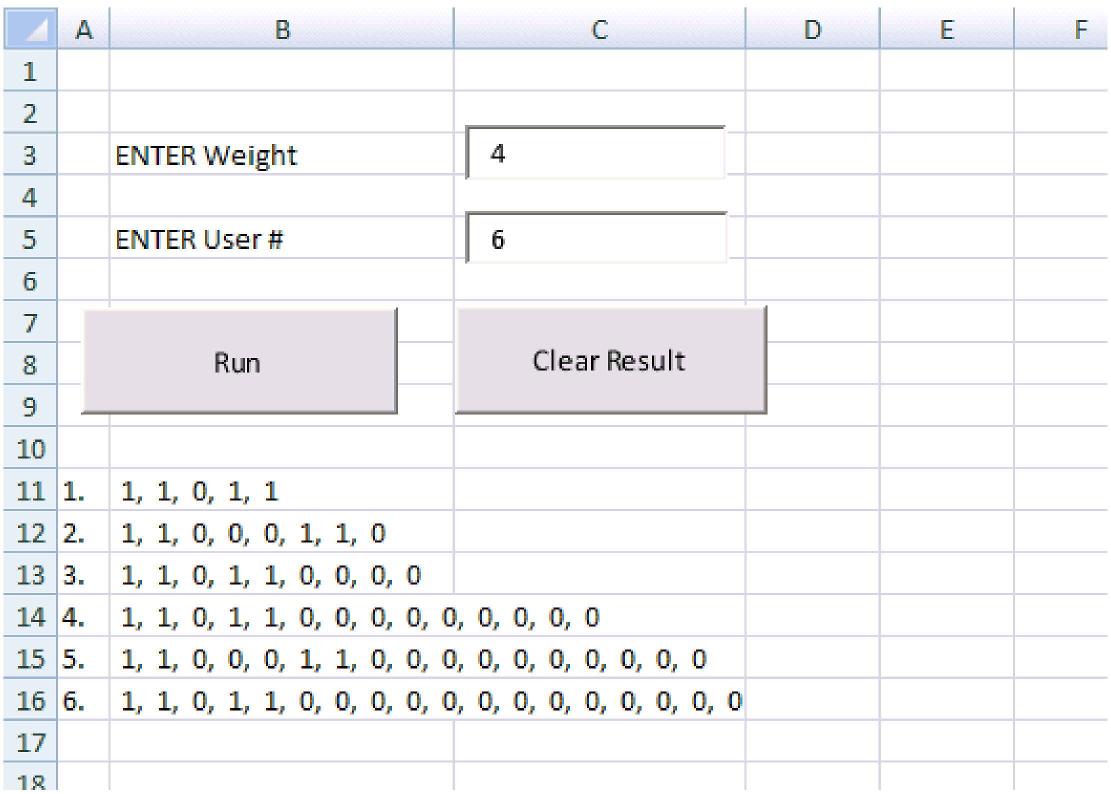

Figure 8: The simulation result of the MDW codeword in sequence with weight of 4 and number of user up to 6 users

It can be observed that the sequence of codeword obtained from the enhance user-interface software program shows in Figure 8 is the same as the sequence of codeword in Table 1. The codeword shows in the software program only display the first '1' and the rest that follow and it does not display the '0' at the pre codeword as in Table 1. The software program can generate the MDW codeword for any amount of users with any even weight.

In addition to the user-interface software program, a website is developed as a platform to spread the information of DW code family. The website contains the introduction of the DW code family, the basic construction technique, the user-interface software program and the eye diagrams of the detection scheme and is illustrated in Figure 9 to Figure 12 respectively.

Figure 9: The Home Page of the Website

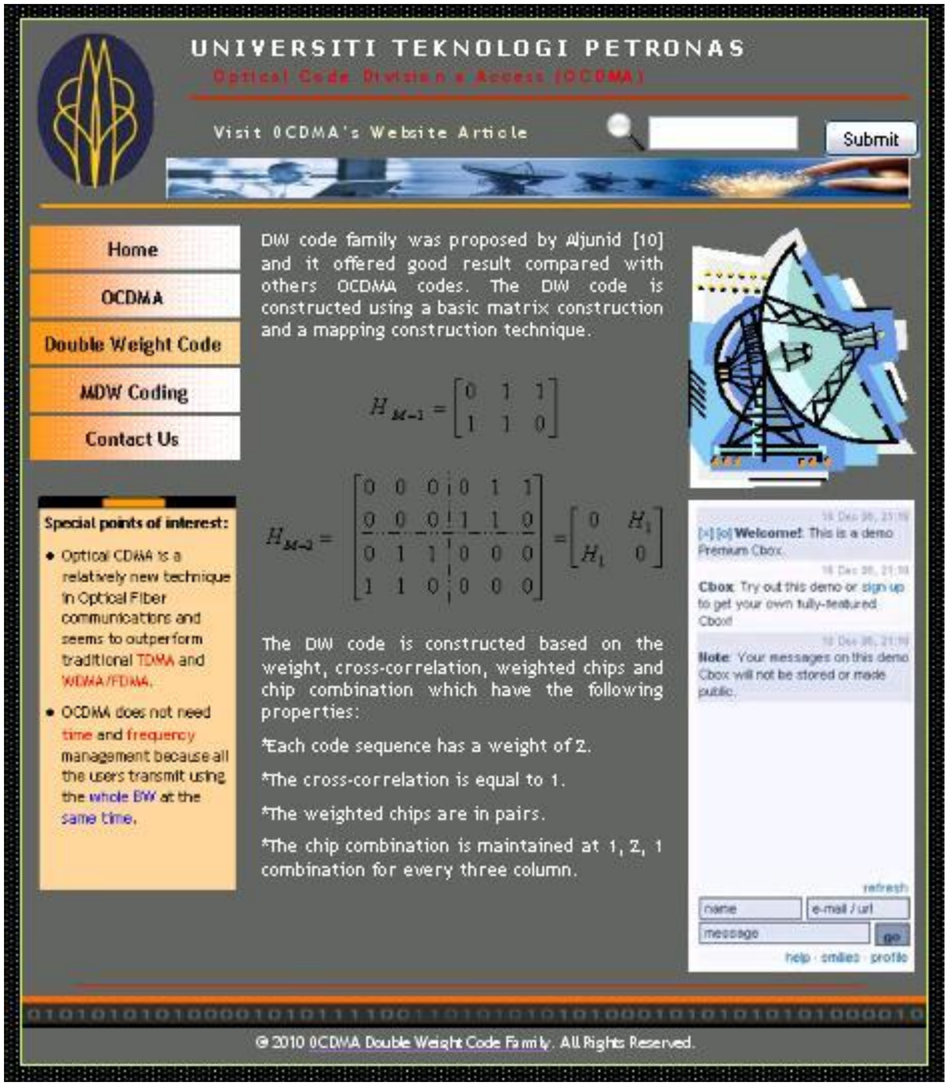

Figure 10: The Basic DW Construction Technique

Figure 11: The User-Interface Software Program

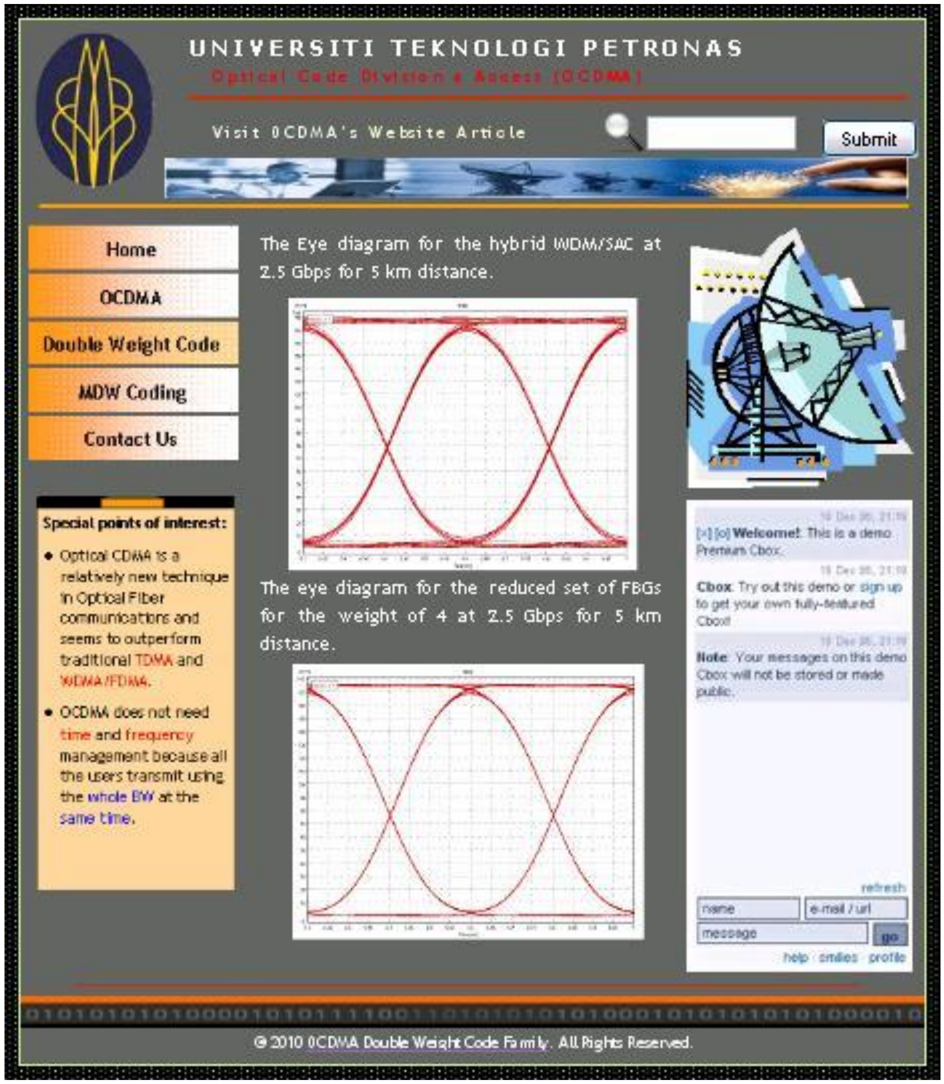

Figure 12: The Eye Diagrams for Detection Schemes

The website is a very popular tool that served as a platform which can transmit information. By using the website, the DW code information and the user-interface software are available to be accessed by anyone, anywhere and anytime.

The user-interface software that is inserted in the website is able to produce any specific codeword for any weight and number of users without any calculation. It creates simplicity and faster result to users.

4.2 Result for Detection Scheme Simulation

The performance of the reduced set of Fiber Bragg Gratings (FBGs) for WDM/SAC detection technique is evaluated and is compared for the DW code family. Only three types of noise are taken into account in the theoretical results which are the Phase Induced Intensity Noise (PIIN), Thermal Noise and Shot Noise.

Figure 13 shows the variation of the Bit Error Rate (BER) to the number of simultaneous users for the hybrid WDM/SAC and the reduced set of FBGs method systems [12].

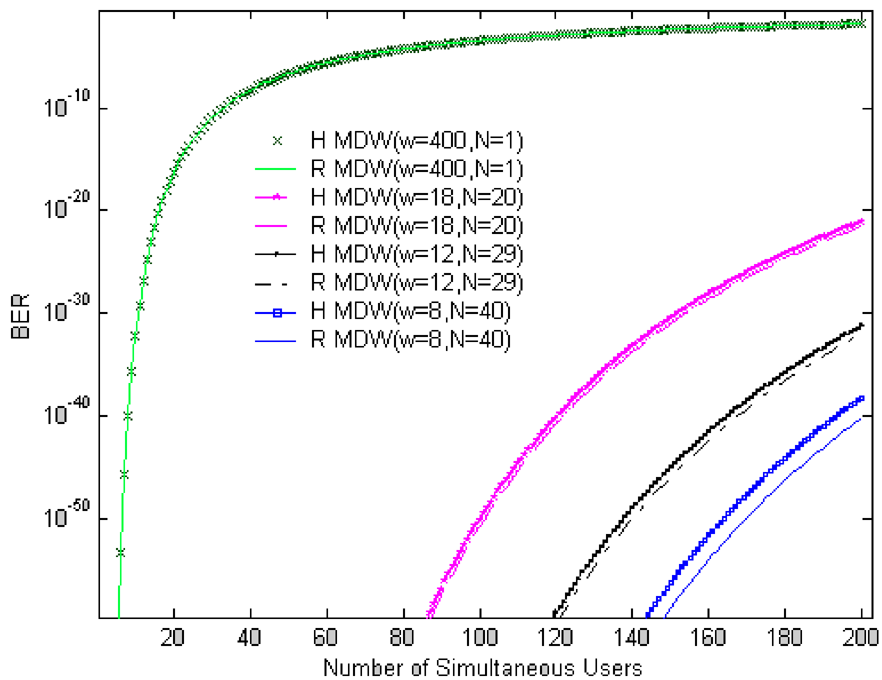

Figure 13: BER versus the number of active users for hybrid WDM/SAC and reduced set of FBGs

From the Figure 13, it illustrates that the reduce method on the hybrid WDM/SAC receiver gives a better BER. This is due to the fact that the PIIN is minimized on the second photodetector [12]. It can be observed that the performance improvement is clearer on the smaller weights.

The eye diagrams for the hybrid WDM/SAC detection scheme and reduced set of FBGs method are investigated. Figure 14 and 15 shows the eye diagram for the hybrid WDM/SAC and reduced set of FBGs for the weight of 4 at 2.5 Gbps for 5 km distance [12].

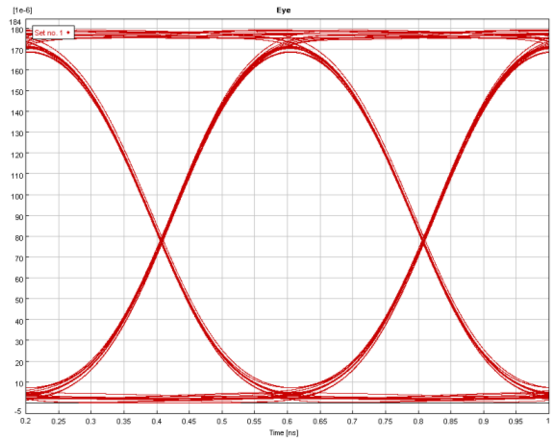

Figure 14: Eye Diagram for MDW Code with Hybrid WDM/SAC at 2.5 Gbps

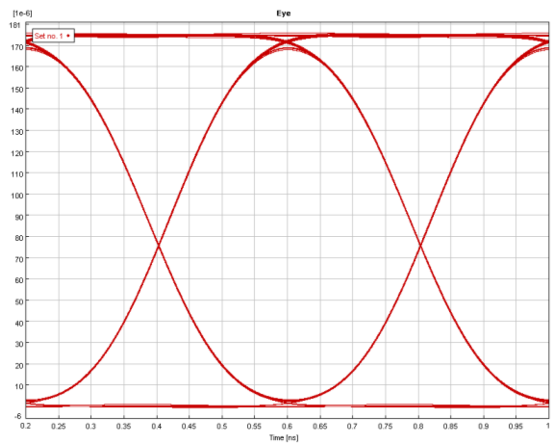

Figure 15: Eye Diagram for MDW Code with Reduced set of FBGs for Hybrid WDM/SAC at 2.5 Gbps

From the Figure 14 and Figure 15, both eye diagrams have a clear eye opening and can detect the intended signal accurately. However, the reduced set of FBGs shows higher precision than the hybrid WDM/SAC. This is due the PIIN that has been minimized at the second photodetector [12].

4.3 Discussion

The MDW code family can be categorized into three parts; the matrix construction technique, the mapping construction technique and the equation-based construction technique. The mapping construction technique is based on the matrix construction where it repeats the basic matrix diagonally for a number of times required in order to increase the number of users.

For large number of users, matrix construction technique and mapping construction technique can be hard to handle and time consuming. Thus, it is essential to establish an equation-based construction technique to derive each of the codeword separately.

However the equation-based technique may be complex and difficult to compute. Thus, to overcome the problem, user-interface software program is developed by using Virtual Basic 6. Unlike the calculation in equation-based technique, the software program can be simulated by having only the weight and the user number. Besides, the software gives a precise codeword as well as providing the minimum code length.

Moreover, an enhance version of the software program is also developed. The enhance version of the software program is capable to store the codeword that is generated by using Microsoft Excel. The user-interface software program can provide the result faster, accurate and creates simplicity to users.

In addition to that, a website is developed as a platform to transmit the information of the DW code family. DW code family is very new and needs to be promoted with its great advantages. The user-interface software program is inserted in the website and this serves whoever that needs the DW codeword with an ease.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The DW code family construction techniques are studied in detail which includes the existing technique, matrix construction technique, mapping construction technique and equation-based construction technique. A user-interface software program is developed based on the equation-based technique. The user-interface software program is simpler and precise and can obtain any specific codeword for any weight and number of users without any calculation and the need to construct the whole set of codeword sequences. Besides, the enhance version of the software is capable to store the codeword and a website is developed as a platform for DW code family where the DW code information and the user-interface software are available to be accessed by anyone, anywhere and anytime.

The DW code family detection techniques are also studied in detail which includes hybrid Wavelength Division Multiplexing/Spectral Amplitude Coding (WDM/SAC) and reduced set of Fiber Bragg Gratings (FBGs) for WDM/SAC. From the result obtained, the reduced set of FBGs for WDM/SAC minimizes the Phase Induced Intensity Noise (PIIN) and thus improves the performance. The simulation result can be done using the Virtual Photonics Instrument (VPI) transmission maker version 7.1

5.2 Recommendation

The current developed user-interface software program should be fully utilized and it is recommended that the detection scheme should be able to minimize the noise and able to detect a more accurate signal for long distance.

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APPENDICES

APPENDIX A: GANTT CHART

No	*Detail/Week*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	*Development of user-interface software*															
2	*Submission of Progress Report 1*															
3	*Submission of Progress Report 2*															
4	*Submission of Draft Report*															
5	*Submission of Final Report*															
6	*Submission of Technical Report*															
7	*Oral Presentation*															

Progress/Milestone