

# Analytical Solution of Dispersion Compensation Using Walsh Code over Pseudo Random Binary Sequence in Optisystem

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**Abstract** - Since dispersion severely damages the data transmission in optical fiber, we proposed a dispersion compensation model in order to achieve the high-speed optical communication system. Pseudo-random binary sequence (PRBS) is most commonly adopted as the input sequence to the optical network in previous proposed models. In this paper, we focused mainly on designing a dispersion compensation model that uses Gold sequence and Walsh code as its input sequence instead of PRBS. The values of Q-factor, bit error rate (BER), eye height and threshold are determined for each model and are compared with respect to 40 km fiber length using OPTISYSTEM simulation. The simulation results of the model having Walsh code are found to be better over PRBS with comparatively high Q-factor and low min. BER.

**Key Words:** Walsh code, PRBS, dispersion compensation, Q-factor, min. BER, Optisystem.

## 1. INTRODUCTION

The continuously increasing demands of bandwidth of communication system are giving rise to the need of installing new communication links, which would require huge investments. So it is preferred to increase the capacity of the existing fiber links of communication system carriers by using different methods in optical communication system [1]. The capacity of the system can be increased by minimizing the losses. Dispersion is considered to be one of the major parameter in optical fiber losses. Dispersion is a critical factor that limits the quality of signal transmission over optical links and leads to the broadening of light pulses. In previous research papers related to dispersion compensation technique, one of the most efficient technologies used to overcome chromatic dispersion problem is Fiber Bragg Grating (FBG) due to its low cost and its negligible effect. To encounter the attenuation effects various types of amplifiers such as Erbium doped fiber amplifier (EDFA), Semiconductor optical amplifier (SOA) and Raman amplifier have been introduced. However, EDFA still provide better results. In this paper, we propose a new model which includes the implementation of FBG and EDFA to overcome chromatic dispersion and to optimize the quality of the received signal. The main area of our

work is the type of input source used in the dispersion compensation network. In the first section, we present a study of the model previously proposed by other authors i.e. dispersion compensation network with PRBS as input sequence. Then using the optimized setting parameters we compare the transmission system under study with the proposed model having Walsh code as its input. The comparison has been done in terms of Q-Factor, BER, eye height, threshold value and their eye diagrams at the received signal. The simulation results demonstrate the high efficiency of the developed transmission system.

## 2. PSEUDO RANDOM BINARY SEQUENCE

A Pseudo random binary sequence, also commonly known as pseudo-noise (PN) sequence is used widely in digital communication. The bit pattern of a sequence never repeats if it is a truly random sequence. The meaning of the qualifier "pseudo" is that the sequence is not truly random. Basically, it is periodic with a specific period, and shows some characteristics of a random white sequence within that period. Thus PRBS is a semi-random sequence because it appears to be random within the length of sequence and hence fulfills the needs of randomness, but the whole sequence repeats indefinitely [2]. Pseudo random sequence plays a significant part in encoding of message for efficient message transmission. It is most commonly adopted input sequence to the optical network in previous models proposed by other authors.

PRBS is considered as an ideal test signal, since it simulates the random characteristics of a digital signal. It is a bit stream of occurring randomly '1's and '0's, with some unique properties. These sequences are statistically random sequences with low correlation property. These sequences can be generated very easily and quickly through some simple electronic circuits. PRBS is generated by Linear Feedback Shift Registers (LFSR). If the number of stages in LFSR is  $r$  then

$$P=2^r-1 \quad (1)$$

Equation (1) uses the parameter  $P$  that is the period of the sequence. PRBS serves as a reference pattern with known random characteristics for the analysis, optimization and

performance measurement of communication channels and systems. The OPTISYSTEM component ‘pseudo random bit sequence generator’ generates a sequence of  $N$  bits:

$$N = T_w \cdot B_r \tag{2}$$

Where  $T_w$  is the global parameter ‘Time window’ and  $B_r$  is the parameter ‘Bit rate’. The number of bits generated ‘ $N_G$ ’ is given as

$$N_G = N - n_l - n_t \tag{3}$$

Where  $n_l$  and  $n_t$  are the Number of leading zeros and the Number of trailing zeros.

### 3. WALSH CODE

Walsh codes are fixed length, mutually orthogonal error correcting codes having high auto correlation and low cross correlation properties. It is a linear code which encodes  $n$  bit messages into  $2^n$  bit orthogonal code words. Original message can be recovered even after about one-fourth of the bits have been corrupted. These codes have vital applications in communication systems. Their popularity is due to the ease of implementation.

Each Walsh code is orthogonal to all other Walsh codes, which means it is possible to identify and hence extract a particular Walsh code from a mixture of other Walsh codes. If the result of xoring two same length binary strings has the same number of 0s as 1s then they both are said to be orthogonal. The one of the methods of Walsh codes generation is from Hadamard matrices of orders which are a power of 2. The rows of  $2^N$  order matrix constitute the Walsh codes which encodes  $N$  bit sequences [3]. Hadamard matrices are built recursively, starting from  $H_1 = [0]$  and  $\forall n > 1$ .

$$H_{2n} = \begin{bmatrix} H_n & H_n \\ H_n & \overline{H_n} \end{bmatrix}$$

Where  $H_n$  is the complimentary of  $H_n$  (switching zeros and ones). Matrix  $H_{2n}$  is generated by placing matrix  $H_n$  in the first three quadrants, and placing the complimentary of  $H_n$  in the fourth quadrant.

The Hadamard matrix is a square array of plus ones and minus ones,  $\{+1, -1\}$ , with mutually orthogonal rows and columns. The matrix is said to be in its normal form if the first row and first column contain only plus ones. To express the Hadamard matrix using the logic elements (0, 1), we can replace “+1” with “0” and “-1” with “1”. The  $2 \times 2$  Hadamard matrix of order 2 is given as

$$H_{2n} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$$

A set of  $n$  length Walsh codes requires  $n$  lines to form a square matrix of  $n \times n$  Walsh code. The first line of Walsh matrix contains an all zeros string while the rest of the lines contains different combinations of bit 0 and 1. Each line of matrix is orthogonal and equal representation for binary bits. Walsh matrix is recursively defined as:

$$W_1 = [0] \quad W_{2n} = \begin{bmatrix} W_n & W_n \\ W_n & \overline{W_n} \end{bmatrix}$$

Where  $n$  is a power of 2, indicating the different dimensions of the matrix  $W$ .  $n$  also represents the logic NOT operation on all bits of the matrix.

Orthogonal codes are easily generated by starting with a seed of 0, repeating the 0 horizontally and vertically, and then complementing the 1 diagonally. This process is to be continued until the desired length codes are generated. Sequences generated through this process are referred as ‘Walsh’ code. The three matrices  $W_2, W_4$ , and  $W_8$  show the Walsh function of dimensions 2, 4, and 8 respectively.

$$W_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \quad W_4 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

$$W_8 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix}$$

Each row of the above matrices give us the walsh codes. For example, eight rows of matrix  $W_8$  represents eight different walsh codes, each of length 8. We can get rid of any multi-access interference by using Walsh code, because of its advantage of being orthogonal.

### 4. SIMULATION SETUP

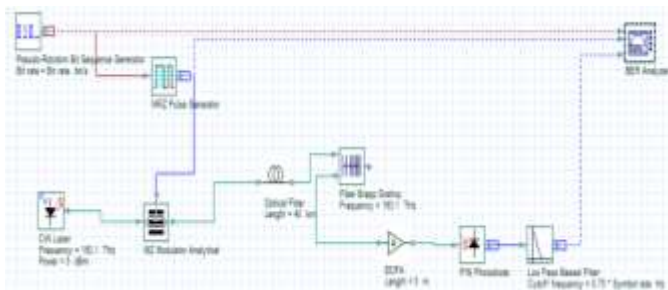
Simulation and designing of the optical transmission system has been done using OPTISYSTEM 15.0. It helps the users to test and simulate almost all kinds of optical fiber links. All the results are analyzed on the basis of different parameters using OPTISYSTEM simulation at 10 Giga bits per second (Gb/s) transmission systems. Table 1 describes the parameter for the simulation of dispersion compensation systems. All the parameters used in both the models are same except the input sequences.

**Table -1:** Simulation Parameter

Parameters	Values
C/W Input Power	5dbm
C/W laser Frequency	193.1THz
Reference Wavelength	1550nm
Mach-Zehnder modulator with extinction ratio	30 dB
Fiber Length	50km
Attenuation at cable section	0.2db/km
EDFA Length	5m
FBG Length	6mm

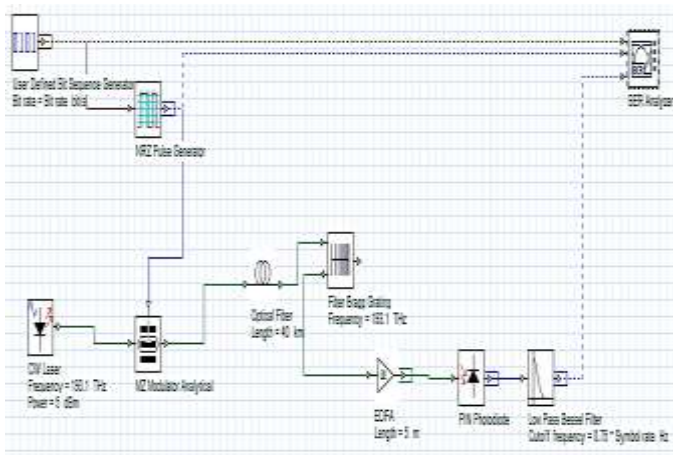
**5. ANALYSIS AND RESULTS**

In this section we will perform a comparative study of the results obtained by simulating both the models. The complete work represents the method to recover the losses generated due to dispersion. In this system design, evaluation has been done on the performance of Fiber Bragg Grating in order to compensate dispersion depending upon the types of input data used. Fig. 3 and 4 respectively shows the eye diagrams of Q-factor, min. BER, eye height and threshold for PRBS and Walsh code, received at BER analyzer by taking the simulation parameters mentioned in table 1.

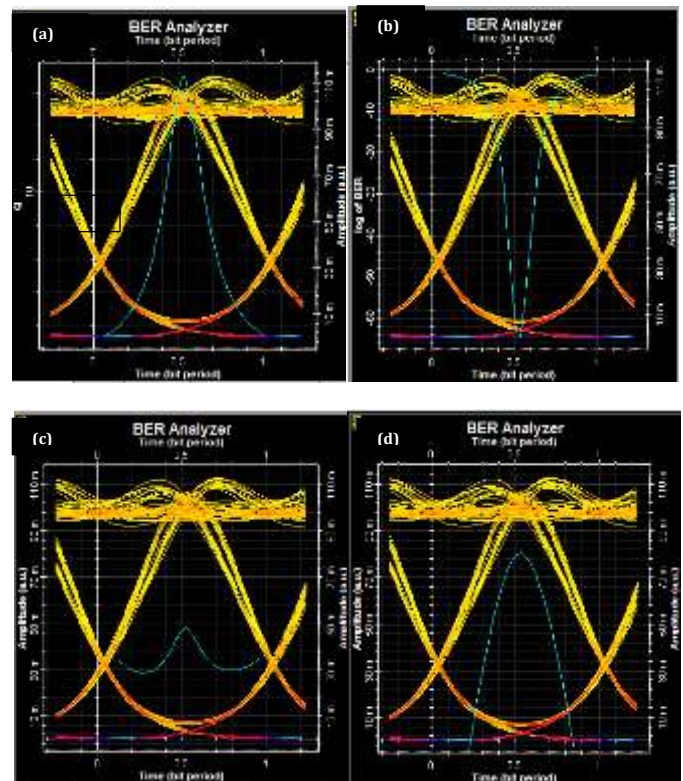


**Fig-1:** Simulation model for Pseudo Random Binary Sequence

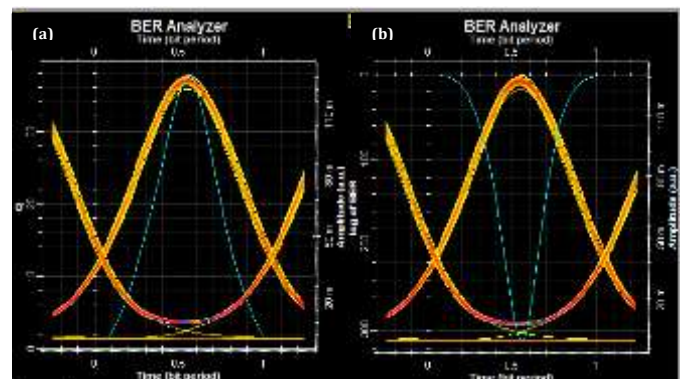
In our first model of dispersion compensation network, a PRBS is produced by data source. For second simulation network, we used the Walsh code '01010101' as user-defined sequence, chosen from the eight codes obtained through matrix 'W<sub>8</sub>' mentioned in section III. In both the models, a 10 Gb/s Non Return to Zero (NRZ) signal is launched onto 40 km long optical fiber.



**Fig-2:** Simulation model for Walsh code



**Fig-3:** BER analysis for Pseudo Random Binary Sequence with reference to (a) Q-factor (b) MIN BER (C) Threshold value (d) BER Pattern



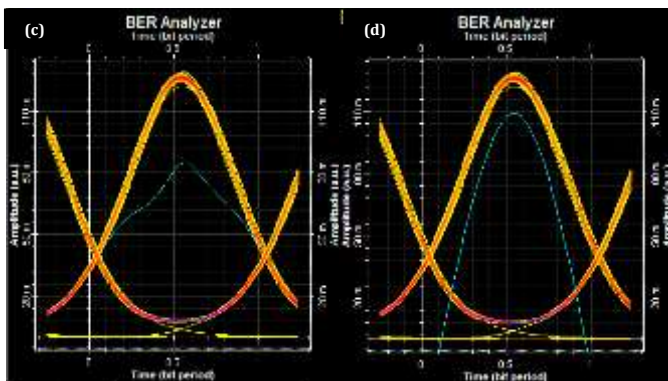


Fig.-3: BER analysis for Walsh code with reference to (a) Q-factor (b) MIN BER (C) Threshold value (d) BER Pattern

Table-2: Comparison of Simulated Values

Input sequence	Max. Q-factor	Min. BER	Eye Height	Threshold value
PN sequence	17.0274	2.57233 e-065	0.0803308	0.0477425
Walsh code	37.722	1.042e-311	0.109034	0.0850542

## 6. CONCLUSION

Walsh code and PRBS both of these concepts are used in error free communication. However, in this work, we observed that Walsh code model offers improved value of performance parameters such as Q-factor, Min. BER and Eye Height compared to PRBS model. During the analysis of simulation result it is also observed that the value of Q-factor for Walsh code i.e. 37.722 is very impressive as compared to the Q-factor of PRBS i.e. 17.0274. The results of min. BER and eye height also come out better for Walsh code. Since Q-factor is taken as one of the most important features to measure the performance of the system, so it is shown that the results of the simulation model with Walsh code offers a high dispersion compensated optical communication network. For future works, the proposed system can be modified for further development by using similar devices with different parameters and can be applied to a complicated system with a big number of channels to check its validation for the wavelength division multiplexing environment.

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