Analysis of High-Speed Optical fiber communication Using Walsh Code and gold Sequence

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Abstract — Optisystem 15.0 software is used to analyze all the results of proposed model. Fiber Bragg Grating (FBG) is taken as the main dispersion compensation parameter for the design of our system. The simulation results of Walsh code appears to be more efficient than all. Thus the use of Walsh code leads to a large amount of dispersion compensation by providing high value of Q-factor and it proves to be the optimum input sequence for a high dispersion compensated optical communication system. Optical fibers are free from radio-frequency interference, electromagnetic interference or switching transients that gives electromagnetic pulses because of the reason that they form a dielectric waveguide. Therefore the optical communication system operation remains affected by transmission which is taking place through environment that is electrically noisy and also no shielding form EMI is required for the fiber cable.

Keywords: Walsh Code, PRBS, Dispersion Compensation, Q-Factor, Min. BER, Optisystem

I. INTRODUCTION

The optical communication system with these characteristics arises significantly from the low-loss property of optical fiber cables that increases the transmitted signal strength by providing the reduction in necessity of Intermediate repeaters or line amplifiers. Hence the reliability of system can be generally increased in comparison with conventional critical conductor systems by using lesser number of optical repeaters or amplifiers in optical system. Moreover, the dependability of the optical components is not any more an issue with anticipated lifetimes of 20 to 30 years being very normal. Both these elements additionally have a tendency to diminish maintenance time and costs. The factor of costs reduction has raised the optical fiber communications as a tough competitor for electrical line as well as microwave radio transmission systems. Therefore, many advantages are foreseen by optical fiber transmission medium using a light wave carrier Moreover, by using optical amplifiers even thousand kilometers transmission distances can be realized. Worldwide, Transoceanic light-wave systems have been installed in a great number that creates a large fiber optic network internationally. Application of short-haul telecommunication wraps the traffic within a city and any local-loop. Typically, these types of systems work efficiently with short haul networks. It might be watched that the best dispersion of a transmitted light pulse is displayed by multimode step index fiber while gives an impressively enhanced performance. The single-mode fiber is also capable of the greatest transmission bandwidths since it gives the minimum pulse broadening. The transmission bandwidths are presently in the range of gigahertz. Such high-speed optical systems are commonly tested and analyzed with the help of Random binary sequences (RBS).

II. RANDOM BINARY SEQUENCE

A Random Binary Sequence (RBS) consists of a stream of bits containing both '1's and '0's which are unpredictable and difficult to produce. The issue is that generating completely random sequences is very hard in practical systems and simulations.

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 the properties of PN sequences make it efficient for speech encryption. Nevertheless, adjacent bits correlation becomes significantly less, particularly due to the third property, hence making the PN sequences more impactful to be used in systems like CDMA. Hence, a very good auto-correlation and cross-correlation properties are must have for a PN sequence and also it must keep up with some randomness properties for being useful. A pseudo random binary sequence can be generated using shift registers and modulo-2 adders. The shift register used for this purpose is a linear feedback shift register (LFSR). Some specific outputs of LFSR are modulo-2 added and then this output of adder is fed back to the register. Only specific outputs, or taps, can be used to generate a PN or maximal length sequence. An N-bit shift register generates a PRBS of 2N – 1 bit. When all the shift registers have seed pattern of 1's, then according to the depicted operation of given figure, register contents changes and a series of PRBS is put out. It returns to the top of the bit sequence right after the final bit. A 15-bit pseudo random binary sequence is generated with the operation

$$P = 2^r - 1 \quad (1.1)$$

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:

$$N = T_w . B_r \quad (1.2)$$

Where *Tw* is the global parameter 'Time window' and *Br* is the parameter 'Bit rate'. The number of bits generated 'N_G' is given as

$$NG = N - n_l - n_t \quad (1.3)$$

Where n_l and n_t are the Number of leading zeros and the Number of trailing zeros. Besides PRBS, another class of orthogonal sequences that are often used in optical communication systems is the Walsh codes.

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III. WALSH CODE

The Walsh codes are the fixed length mutually orthogonal error correcting codes with high auto correlation and low correlation functions. This is a linear code that encodes n bit messages into orthogonal 2n bit code words. It can recover original message.

Square matrix of n×n Walsh code contains a set of n length Walsh codes and it requires n lines to form. An all-zero string is written in the first line of the Walsh matrix and there are many other combinations of bit (0 and 1) in the rest of the lines. Each line of matrix is orthogonal and gives equal representation for binary bits. Recursively we have the definition of Walsh matrix as:

$$W_1 = [0]$$

$$W_{2n} = \begin{bmatrix} W_n & W_n \\ W_n & W_n \end{bmatrix}$$

Fig. 1: Recursive definition of Walsh matrix W_{2n}

Where n is a power of 2, indicating the different dimensions of the matrix W. In recursive construction, some parts of the matrices are used to indicate the logical negation (NOT operation) of others. 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 *2N* order matrix constitute the Walsh codes which encodes N bit sequences [3]. Hadamard matrices are built recursively, starting from $H1 = [0]$ and $\forall n > 1$.

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

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□2 Hadamard matrix of order 2 is given as

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

Fig. 2: Hadamard matrix of order 2

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.

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

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

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

Fig. 3: Walsh matrices W_2, W_4, and W_8 representing orthogonal codes used for encoding

Each row of the above matrices gives us the Walsh codes. For example, eight rows of matrix W8 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.

IV. SIMULATION PLATFORM

All the parameters used in both the models are same except the input sequences. Since OptiSystem platform is used for designing and simulation of our model, thus the features, advantages and applications of this software are discussed here. The designing components with reference to OptiSystem 15.0 are also described along with the simulation setup of the proposed system. Being a creative optical communication framework simulation package, OptiSystem designs, tests, and upgrades any type of optical link in the physical layer. This includes its application in a wide spectrum optical network, including analog video broadcasting systems as well as large networks like intercontinental spines. OptiSystem does not depend on other simulation structures and that is because it is said to be a stand-alone item. This library includes realistic and wavelength-dependent parameters. We can examine the impact of any specific device specifications on the performance of system through the parameter sweeps. OptiSystem software full fills the demand of the booming photonics market for an optical system design tool that is powerful as well as easy-to-use. It is developed with an extensive component library for user needs. The design and simulation of all three proposed models are carried out using OptiSystem 15.0. It contains a wide range of components according to the user's demand of implementation. Besides the sequence generators mentioned before, some additional elements from OptiSystem were used to set up the simulation model. Table I describes the parameter for the simulation of dispersion compensation systems.

Parameters	Values
C/W Input Power	5dbm
C/W laser Frequency	193.1THZ
Reference Wavelength	1550nm

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Mach-Zehnder modulator with extinction ratio	30 dB
Fiber Length	50km
Attenuation at cable section	0.2db/km
EDFA Length	5m
FBG Length	6mm

Table I: Simulation Parameter

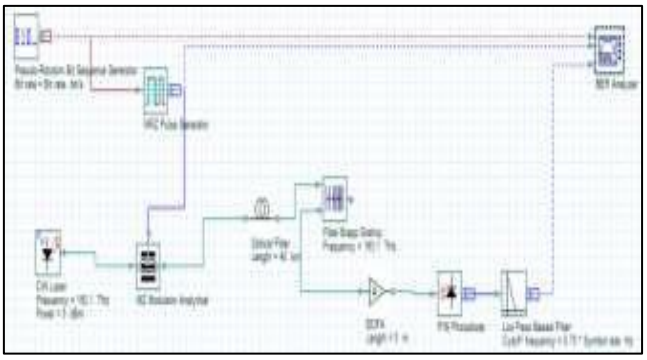

Fig. 4: Simulation model for Pseudo Random Binary Sequence

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 'W8' 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.

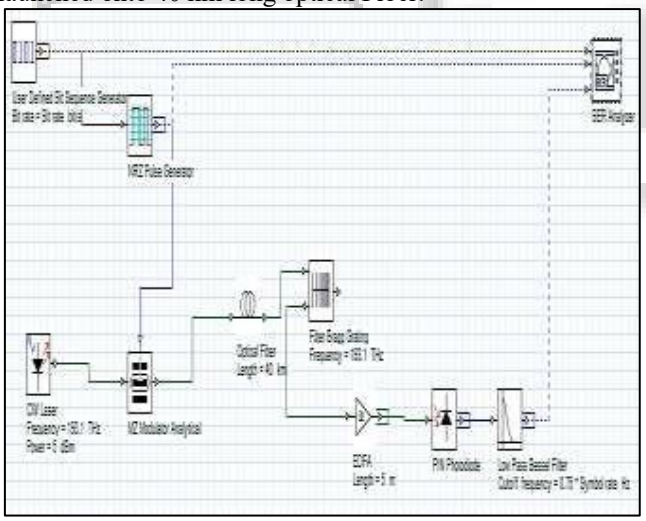

Fig. 5: Simulation model for Walsh code

V. RESULTS

After analysing the values of all the parameters of BER analysis for all three fiber lengths, a comparison table of these simulation values is made which shows that simulation results of the proposed model come out to be satisfactory even if we increase the length of the fiber. This proves the compatibility of our optical system. The list of the simulation values for gold sequence model is shown

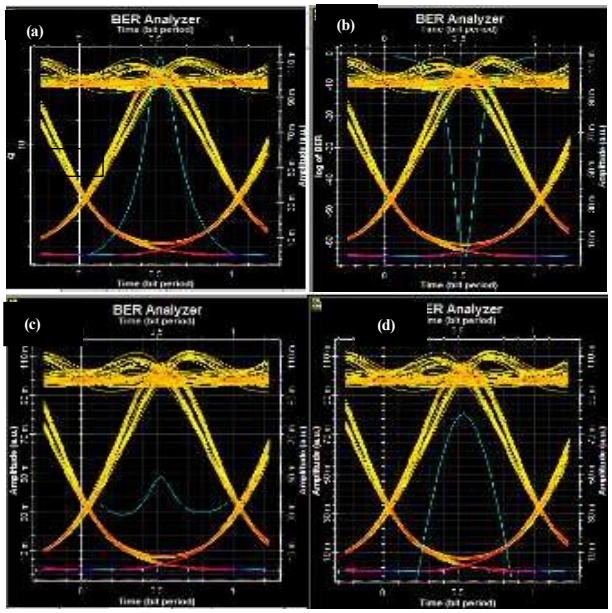

Fig. 6: BER analysis for Pseudo Random Binary Sequence with reference to (a) Q-factor (b) MIN BER (C) Threshold value (d) BER Pattern

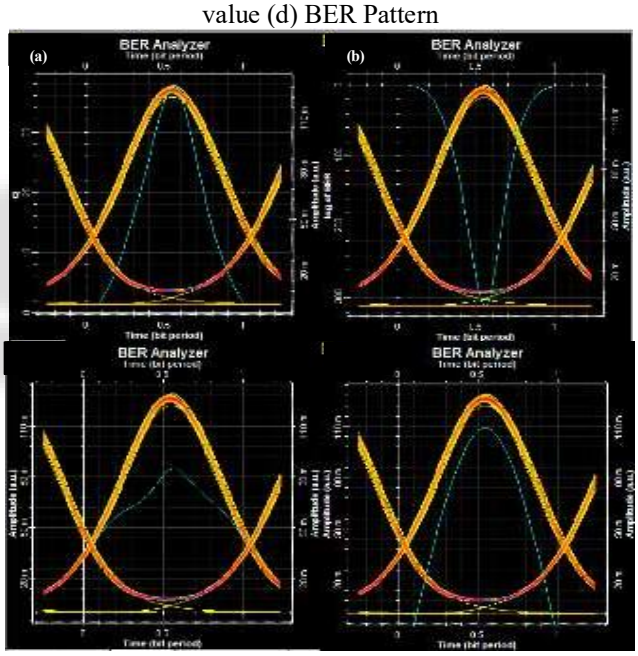

Fig. 7: BER analysis for Walsh code with reference to (a) Q-factor (b) MIN BER (C) Threshold value (d) BER Pattern

+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

Table II: Comparison of Simulated Values

VI. CONCLUSION

The result analysis of all three input sequence models has been done for three different fiber lengths. Now to find out the optimum input sequence among all, we compared the results of all three input bit sequences in table II. The simulation results of Walsh code parameters - max. Q-factor

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and min. BER, shown in bold text are better than gold code and PRBS. It can be observed that the results of the Walsh code based proposed systems are verified for three channel lengths and for all the distances the results are comparatively most impressive that means synchronization does not lost and the system offers negligible dispersion in the channel.

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