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Bit Error Rate Performance of Various Code Signals for Optical Code Division Multiple Access System Based on AND Detection Technique

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Abstract

Optical code division multiple access system (OCDMA) has been important with increasing demands of high capacity and speed for communication in optical networks. Due to OCDMA technique high efficiency is achieved, hence fiber bandwidth is fully used. In this paper we will focus on different codes i.e MD (Multi Diagonal) FCC (Flexible cross correlation), DCS (Dynamic cyclic shift) code with BER parameter. Due to this codes we will eliminated MAI (multiple access interference) and improve BER (bit error rate), PIIN (Phase induced intensity noise) and make orthogonality between users in the system .We will use AND subtraction detection technique to implement these codes with technique of OCDMA using optiwave system design tool.

Index Terms*: OCDMA (optical CDMA), BER (Bit error rate), MAI (Multiple access interference), FCC (Flexible cross correlation), DCS (Dynamic cyclic shift), PIIN (Phase induced intensity noise).*

1. Introduction

In ancient times, in order to increase the transmission speed of information humans have started to learn, how to use optical signals for communication. However the utility of these methods are very limited due to the error rate is very high. Now optical communication involves optical fiber as the communication median as from one point to another uses light as a carrier. Optical fiber communication started in the early 1960s, when ruby laser is invented, together with the propose of optical communication via dielectric waveguides or glass optical fiber by Kao and Hock ham during 1966s. Initial, optical fiber is not popular, where the fiber exhibits very high attenuation than the coaxial cables. 1970s, the Company manufactured a fiber-optic with an attenuation of 17dB/km. The advantages of fiber-optics are mainly due to its enormous commination capacity, low transmission loss, Immunity to electromagnetic interference and etc. Together with the numbers of advantages of fiber-optics many development, research and application on optical fiber communication system have come to a period. Optical CDMA started during the late 1970s in the area of fiber delays lines for optical processing that is based on incoherent and coherent optical match filtering. Coherent OCDMA is based on using interference of the incoming optical signals to convert electric field values into intensity variations that can then be detected by a photo receiver .Thus it enables cancellation of the undesired user channels through destructive interference. Incoherent OCDMA detects the signals by superposition the incoming optical signal. Optical encoding/decoding can be performed in frequency domain and time domain. As for the OCDMA that's performing in time domain, it is known as the frequency –hopping FH-OCDMA. A modulated information signal is changed over a wide set of discrete frequencies according to a well-defined pseudo random code sequence. In order to receive the signal, a narrowband frequency filter is incorporated within the receiver whose tuning sequence is synchronized to that of the transmitter.

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Optical CDMA is getting more attention because of its ability to support asynchronous burst communication with higher level of security. Optical code division multiple access system (OCDMA) has been important with increasing demands of high capacity and speed for communication in optical networks. Due to OCDMA technique high efficiency is achieved hence fiber bandwidth is fully used.

In these paper we will discuss about different codes i.e MD, FCC and DCS with the Bit error rate (BER) parameter using optiwave system design tool Due to this codes we will eliminated MAI(multiple access interference) and improve BER (bit error rate) , PIIN(Phase induced intensity noise) and make orthogonality between users in the system .We will use AND detection technique to implement these codes with different parameters.
In these paper there are 5 sections, which are: 1) Introduction 2) Construction of codes 3) System performance analysis 4) Numerical and simulation analysis 5) Conclusion

2. Construction of Codes

2.1 MD code Construction

The MD code is characterized by the following parameters (N,W, kc) where N is the code length (number of total chips), W is the code weight (chips that have a value of 1), and λc is the inphase cross correlation. The Cross-correlation theorem could be defined as follows: In linear algebra, the identity matrix or unit matrix of size N is the N-by-N square matrix with ones on the main diagonal and zeros elsewhere. It is denoted by IN, or simply by I if the size is immaterial or can be trivially determined by the context.

$$I_1=[1] \quad I_2=\begin{matrix}1 & 0\\ 0 & 1\end{matrix} \quad I_3=\begin{matrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{matrix} \ldots\ldots\ldots \quad I_N=\begin{matrix}1 & 0 & 0\\ 0 & 1 & 0\\ . & 0 & \ldots.\end{matrix}$$

Using the notation that is sometimes used to concisely describe diagonal matrices, we can write: IN = diag(1, 1, . . . , 1). An orthogonal matrix is a square matrix with real entries whose columns (and rows) are orthogonal unit vectors (i.e., orthogonal). Equivalently, a matrix A is orthogonal if its transpose is equal to its inverse:

$A^TA = AA^T=1$: Alternatively; AT $=A^{-1}$
A square matrix whose transpose is also its inverse is called an orthogonal matrix; that is, A is orthogonal if $A^TA=AA^T=I_N$, the identity matrix, i.e., $A^T= A^{-1}$.
For example, A(N _ N) square matrix, A is said to be orthogonal if $AA^T = A^TA = I_{NXN}$.
The cross-correlation theorem states that cretin sets of complementary sequences have cross-correlation functions that sum to zero by using all pairwise permutations. Here, all cross-correlation function permutations are required in order that their sum be identically equal to zero. For example, if the rows and columns of a (K X N) matrix are orthogonal and all the columns except one sum to zero, then the sum of all cross-correlations between nonidentical code words is zero. So if xij is an entry from X and yij is an entry from Y, then an entry from the product C = XY is given by Cij $\sum_{K=1}^{N} X_{ik} Y_{kj}$. For the code sequences X = (x1, x2, x3, . . ., xN) and Y = (y1, y2, y3, . . . , yN), the cross-correlation function can be represented by: $\lambda_c=\sum_{i=1}^{0} 04EX_IY_I$
When $\lambda_C= 0$, it is considered that the code possesses zero cross correlation properties. The matrix of the MD code consists of a KXN matrix functionally depending on the value of the number of users (K), and code weight (W). For MD code the choice of weight value is free, but should be more than 1(W > 1).

2.2 FCC (Flexible Cross Correlation) Code

Optical codes are family of K (for K users) binary [0, 1] sequences of length N, Hamming-weight w (the number of "1" in each codeword) and the maximum cross-correlation, λmax. The optimum code set is one having flexible cross-correlation properties to support the maximum number of users with minimum code length. This ensures guaranteed quality of services with least error probabilities for giving number of users K at least for the short haul optical networking. Now, let A= {an} and B= {bn} be the sequences of length N such that;

$\{a_i\}$ = '0' or '1' , i= 0,……N-1 }
$\{b_i\}$= '0' or '1' , i= 0,……N-1} (1)
The auto and cross-correlation functions of these sequences are defined, respectively
$\lambda_a(\tau) = \sum_{i=1}^{N} a_i\ a_{i+\tau} = W \quad \text{for } \tau = 0$ (2)

$\lambda_{ab}(\tau) = \sum_{i=1}^{N} a_i b_{i+\tau} \leq 1 \quad \text{for } \tau = 0$ (3)

Since an is a {0, 1} binary sequence, the maximum value of λa (τ) in equation (2) is for τ=0 and is equal to w, the Hamming-weight of the sequence can be expressed as;

$\lambda a(0) = w$ (4)

If λam & λabm denote the maximum out of phase auto–correlation and cross-correlation values respectively, then an optical code of length N and Hamming-weight w can be written as (N,w,λam, λabm). A (N,w,λam,λabm)- for FCC code is called the constant-weight symmetric FCC when λa =, λab = λmax, and we used the shorthand notation of an (N, w, λmax) for the largest possible cardinality (number of users). It may also be noted that for an optical code a_n with Hamming-weight 'w' for auto-correlation can be written as follows:
$\lambda_{a\,max} = \lambda_a(0) = \sum_{n=0}^{N-1} a_i a_i = w$ (5)

In practice for K users, it is required to have a K number of codes in a set for given values of (N, w, λmax). The codes described by equation (1) can also be represented in vector form as;

A= $\{a_i\}$ for i= 0,1 …… N-1 (6)
B= $\{b_i\}$ for i= 0,1…….N-1

Where, A and B are vectors of length N with elements as defined by equation (6). In terms of the vectors $A$and B, equations (2) and (3) can be written as;
$\lambda_A(0) = AA^T = W$
$\lambda_{AB}(0) = AB^T$ (7)
Where A_T and B_T denote the transpose of vectors A and B, respectively.

2.3) Dynamic cyclic shift code(DCS)

We have developed a new code referred to as DCS, which includes the parameters N, W and λc ,where N denotes the code length (i.e., the number of total chips), W the code weight, and λc indicates the in-phase cross-correlation. The cross-correlation λc between any pair of code sequences must be small enough. This property would ensure that each code sequence can be easily distinguished from every other address sequence. In other words, we seek to make the MAI which remains insignificant when compared to the

energy contained in the information received. For code sequences $X = (x1, x2, ...xN)$ and $Y = (y1, y2, ...yN)$, the cross-correlation is given by $\lambda c = \sum_{i=1}^{N} xiyi$
The codes with ideal in-phase cross-correlation ($\lambda c \leq 1$) are required in the OCDMA systems since these codes eliminate multi-user interference and suppress the effect of the PIIN. The technique utilised for constructing the DCS code is detailed further below.
The new code family suggested here is represented as
$(N=\sum_{i=1}^{W-1} 2^i + D, W, \lambda_c)$ where i=(0,1,……W-1), denotes a positive integer number and *D* represents the dynamic part. The next steps are followed to construct the DCS code words:

Step 1

First we construct a sequence S^i of integer numbers that are elements of the Galois field GF(*N*) = {1, 2,….., *N*} over an integer number *N*, using the expression

$$S^i = \begin{cases} (2^i) \pmod{N}, & i = 0,1 \\ (S^{i-1} + 2^i) \pmod{N}, & i=2,3\ldots\ldots W-1 \end{cases} \quad (1)$$

Here S^i, N, and W are the elements over the Galois field GF(N).

Step 2

After that we construct a sequence *Ti* of binary numbers (0, 1) basing on the generated sequence *Si* and using the mapping method

$$T_i = \begin{cases} 1 & for\ Si \\ 0 & otherwise \end{cases} \quad (2)$$

Step 3

Now we combine the binary sequence of each *Ti* that has been generated in the step 2, to get
the first code sequence of the first user. The elements of the first code word are given by

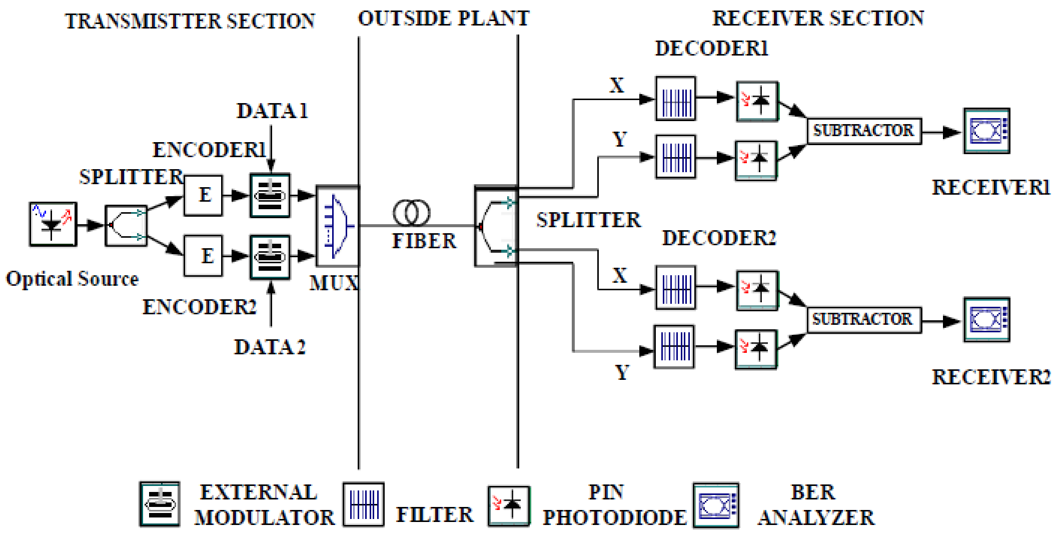
$$C_1 = T_0 + T_1 + T_2 \ldots\ldots\ldots\ldots T_{W-1} \quad (3)$$

The method for producing the binary sequence (0, 1) based on GF(N) .

3. System Performance Analysis

3.1 AND subtraction Detection Technique for Codes

The AND subtraction technique has been used as a detection method. This technique is fully capable of eliminating the MAI, reducing complexity of receiver and improving performance of the system. In the frame of this technique, a spectral amplitude signal at the receiver side is split into two branches. The upper branch is the signal for a user X associated with cross-correlation between X and Y, and the lower branch should be a cross-correlation result from the AND operation between X and Y, which have the same cross-correlation magnitude associated with the signal in the upper branch.



4) Numerical and Simulation Analysis

4.1) Numerical Analysis

The performance of the DCS code has been compared numerically with the recently suggested codes such as the KS code, the EDW code, the MFH code, FCC . We evaluate the BER and the SNR using

$$SNR=\frac{I^2}{\sigma^2}=\frac{\left\{ RPsr(W-1)/N \right\}^2}{\frac{eBRPsr(W+3)}{N}+\frac{BR^2\,P^2srKW(W+3)}{N^2\,\Delta v}+P^2sr\;R^2m^6_{n,k}\left[\frac{D_{1,1,1}}{32}+\frac{D_{2,1}}{64}\right]+\frac{4K_bT_n}{R_L}}$$

Here $D_{1,1,1}$ is the three-tone third-order inter-modulation at $fi + fK - fl$, and $D_{2,1}$ represents the two-tone third-order inter-modulation at $2\,fi - fK$

$$BER=\frac{1}{2}erfc(\sqrt{SNR/8})$$

Typical parameters used in our numerical analysis and calculation

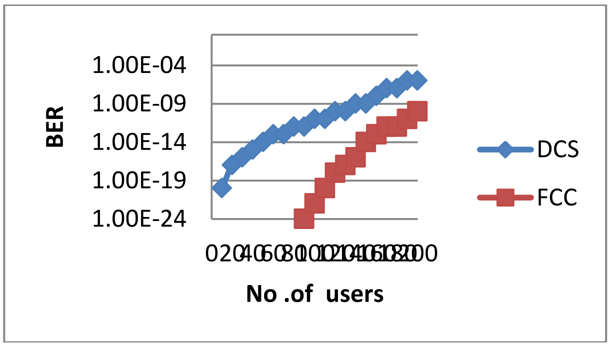
Symbol	Parameter	Value
H	Quantum efficiency of photo-detector	0.6
P_{sr}	Broadband effective power	–10 dBm
B	Electrical bandwidth	80 MHz
λ_o	Operating wavelength	1550 nm
R_b	Data bit rate	155 M bit/s
T_n	Receiver noise temperature	300 K
R_L	Receiver load resistor	1030 Ω

BER PERFORMANCE:

FCC	W=4	DCS	W=4	MD	W=4
BER	ACTIVE USE	BER	ACTIVE USE	BER	ACTIVE USE

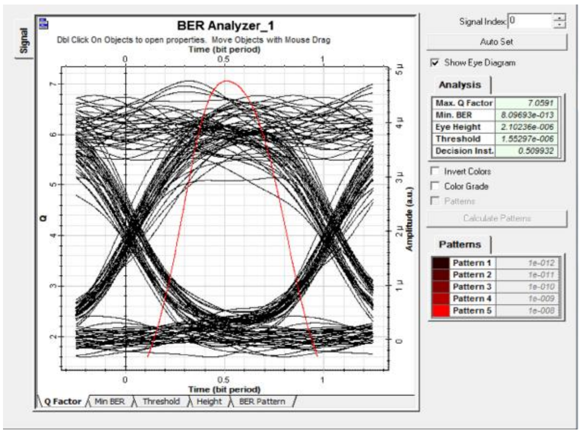
	R(K)		R(K)		R(K)
1E X 10^{-35}	40	1E X 10^{-35}	58	1E X 10^{-35}	40
1E X 10^{-28}	60	1E X 10^{-34}	60	1E X 10^{-34}	55
1E X 10^{-23}	65	1E X 10^{-32}	65	1E X 10^{-32}	60
1E X 10^{-19}	80	1E X 10^{-31}	70	1E X 10^{-31}	80
1E X 10^{-17}	90	1E X 10^{-30}	80	1E X 10^{-30}	85
1E X 10^{-16}	100	1E X 10^{-29}	85	1E X 10^{-29}	100
: :	110	: :	90	: :	110
: :	: :	: :	: :	: :	: :
1EX10^{-8}	180	1EX10^{-8}	180	1EX10^{-8}	180

The relationship between the number of simultaneous users and the BER for theMD, DCS and FCC code having W=4 . It is clearly seen that the performance of the DCS code is much higher when compared to the FCC codes. The maximum acceptable BER is 10–9 that we achieved by the DCS code compared. We can ascertain from this fact that the DCS code has a small length, the number of the active users is equal to the code size and the cross-correlation is $\lambda c = 1$ or $\lambda c = 0$



4.2) Simulation Analysis

The hybrid system has been simulated using the software "*OptiSimTM*", The simulation is implemented for the two-subcarrier channel basing on the DCS and FCC code. Here we adopt the data rate 155 Mbit/s for each subcarrier channel. Furthermore, the subcarrier frequencies are set to be equal or larger than two times (the Niquest frequency) the bit rate. Each optical channel has the spectral width of 0.8 nm. The simulation has been carried out for a standard single-mode optical fibre ITU-T G.652. All the parameters that describe the attenuation (0.25 dB/km), the dispersion (18 ps/(nm per km), and the nonlinear effects (four-wave mixing and self-phase modulation), have been activated and specified according to their typical industrial values, in order to simulate a real environment as close as possible. The noise generated at the receivers has been set to be random and totally uncorrelated. The dark current value has been put to be 5 nA. We have also used the thermal noise coefficient 1.8×10–23 W/Hz for each of the photo-detectors. The performance of the system has been characterised by referring to the BER and the eye diagram pattern. The effect of fibre distance on the performance of our system having two subcarrier frequencies for different light source powers. It is clear that the dispersion has significant impact on the system performance when the fibre length increases. Our simulation results indicate that the system performance is deteriorating by about more than one order of magnitude, whenever the dispersion effect is activated in the simulation model. In addition, our results testify that the system performance is worsening as the fibre length increases from 20 to 50 km. The PIIN for MD, DCS and FCC code that DCS code will eliminated MAI(multiple access interference) and improve BER (bit error rate) , PIIN(Phase induced intensity noise) and make orthogonality between users in the system.



5) Conclusion

The system degradation due to *PIIN* can be suppressed using flexible cross-correlation property offered by MD, FCC code and DCS , results in enhancing BER performance. The proposed DCS code is robust in term of received power, Psr as well as a reliable number of simultaneous users. The performance of the proposed DCS code achieves high cardinality (number of simultaneous users) and low received power in comparison to FCC code. The performance of the system is revealed to improve significantly, because the total loss is reduced as the AND detection technique requires less number of filters in the decoder. In addition, making use of the code words with less crosscorrelation value mitigates the PIIN, which improves the overall system performance. It suppresses the MAI, as compared to the system that uses the other SAC codes, and enables carrying large numbers of code words and subcarrier channels.

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