An Approach for Enhancement of Bit Error Rate Analysis in SAC-OCDMA

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Abstract

In this paper, a new method is presented to calculate the execution of Spectral Amplitude Coding Optical Code Division Multiple Access (SAC-OCDMA) network. A new code proposed is Dynamically Cyclic Shift (DCS) code to assess the execution of the network. Bit error rate is the parameter of performance studied. A Dynamically Cyclic Shift (DCS) algorithm is used at the transmitter section and a detection technique called AND-Subtraction technique is used at the receiver. The most astonishing aspect in the detection techniques the reduction of Multiple Access Interference (MAI) and the correlation values lies between 0 and 1, for the developed DCS code. SAC-OCDMA network is more consideration in view of their capacity to totally avoid multiple access obstruction by utilizing code successions with settled in phase cross correlation (λ_c). The performance is calculated using the Signal to Noise Ratio (SNR) and the experiment is simulated at 8 Gb/s for a link length of 15 km using optisystem™ ver.12 simulation software from optiwave. The BER obtained is 4.66×10^{-17} using DCS code.

1. Introduction

In optical domain using coding for multiple admittances and multiplexing transmittance is accomplished with implementation of optical code division multiple access for future multiple access networks. When one is to be inherited user it should transmit allotted code; when zero is to be inherited user it will not transmit allotted code. The system functioning is debased because of MAI particularly once prominent figure of users are tangled in recent times because of multiple access interference be abstracted in theory ones code with frozen in phase cross correlation is used spectral amplitude coding optical CDMA.

Multiple access (SAC-OCDMA) drawn a great attention codes using for optical code division multiple access systems utilize intensity revelation should be unipolar and orthogonal (minimal cross correlation is maintained) and perpetual weight to get miserable values for probability of errors outstanding to multiple access interference. Thus class of codes called optical orthogonal codes (OOC) was intended.

In spectral amplitude coding OOK is assumed as each data bit I is conveyed by a bipolar (−1, +1) code word, but data zeros are not transmitted. In addition, amplitude coding means that optical intensity is used for transmission. So, only the '+1' elements of bipolar code words are transmitted in wave lengths but the '−1' code elements are not transmitted.

Projected a code class with cross correlation with incisively match to one for moderate issue of Phased-Induced Intensity Noise (PIIN) projected modified double weight family for SAC-OCDMA access system operation and increase the figure of concurrent users by code pattern. Thus this code is having varying cross correlation ($\lambda_c \leq 1$) because of this property the cause of PIIN is minimized1. They have swap off among the number of concurrent users and length of the code.

Random Diagonal Code (RDC) for SAC-OCDMA unit is configured by splitting the sequence to two sections namely communal section and secondary data section. RDC amend operation of system and increase quantity of concurrent users. Trade off exists among λ_c, weight

value for code section and $\lambda_c = 0$ for data section4. Here we are projecting dynamic cyclic shift code, has implication to overthrow all restrictions which were reported in SAC-OCDMA access codes7.

DCS has attributed of altering code length and λ_c lies among 0 to 1. It minimizes the cause of PIIN noise. It offers more concurrent users without increasing the hamming distance of the user code in detection scheme AND-subtraction is used to suppress the MAI. As the number of users increases bit error rate also increases proportionally because of PIIN. AND-Subtraction technique improves the BER values[6] compared to remaining code generation techniques. Thus user nodes can be increased without affecting quality of service.

The remaining paper is arranged as: In Section II, DCS code was designed. In Section IIISAC-OCDMA detection methods are mentioned and efficient method is briefed. Section IV describes the theoretical calculation of BER by calculating the effect of PIIN noise, shot and thermal noise and in section V, simulation analysis and finally conclusion.

2. Dynamically Cyclic Shift (DCS) Code

The parameters of dynamically cyclic shift code (N, L, λ_c) where N represents the length of the code, L represents weight of the code and λ_c represents the phase cross-correlation and equated as

$$\lambda_c = \sum_{i=1}^{N} x_{iy_i} \qquad (1)$$

Where x = (X$_1$, X$_2$, … X$_N$) and y = (Y$_1$, Y$_2$, … Y$_N$) are two different sequences representing the user code. When $\lambda_c = 1$, it is considered that the code possess ideal cross-correlation properties.

2.1 Algorithm of DCS Code

The DCS code comprises of two sections namely the weight section and dynamic section.

- Step 1: Weight sequence is constructed utilizing the worth of weight (L). As stated by this esteem, the weight succession, g^j can be written as g^j = g^0, g^1, … g^{L-1} where j = 0, 1, 2, … L − 1.

Initializing the weight sequence,

$$g^0 = 2^0, g^1 = 2^1 \qquad (2)$$

As the quality of g^j ≥ 2 the accompanying mathematical statement is utilized to compute remaining components

$$g^j = g^{j-1} + 2^j \qquad (3)$$

As per above equations in the weight section the place of 1's can be written as

$$g^i = \begin{cases} 1, & for \ j = 0, 1, 2, 3, \ldots L-1 \\ 0 & elsewhere \end{cases} \qquad (4)$$

- Step 2: Dynamic section of zero's represented as $T_i = T_1, T_2, \ldots T_D$, D is the largest length of the dynamic which is as positive number. $\lambda_c \geq 1$ is the condition to be satisfied for least cross-correlation, need to check the values of D always greater than 7.
- Step 3: The conditions used in the weight section and dynamic section is put together to form code sequences (S).

$$S_1 = g^j + T$$
$$S_1 = g^0, g^1, g^2, \ldots g^{L-1} + T_1, T_2, \ldots T_D \qquad (5)$$

S$_1$ represents the code of the user-1, and the code for remaining users can be generated by cyclic shifting of each bit.

User's code length is expressed as,

$$N = \sum_{j=1}^{L-1} 2^j + D \qquad (6)$$

The length of user code (N) is equal to maximum number of users that can participate in the dynamically cyclic sequence. Now let us take weight L = 3, value of D is 8, and following the procedure in the algorithm. The value of 1 is assigned at particular value of g^j, and hence we get the orthogonal sequence as follows.

$$S_1 = \{1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0\}$$
$$S_2 = \{0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0\}$$
$$S_3 = \{0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0\}$$
$$S_4 = \{0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0\}$$
$$S_5 = \{0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0\}$$
$$S_6 = \{0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0\}$$
$$S_7 = \{0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0\}$$

$S_8 = \{0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 0\}$

$S_9 = \{0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 1\}$

$S_{10} = \{1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\ 0\ 0\}$

$S_{11} = \{0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\ 0\}$

$S_{12} = \{0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\}$

$S_{13} = \{0\ 0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\}$

$S_{14} = \{1\ 0\ 0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\}$

3. SAC-OCDMA Detection Methods

The types of detection techniques are AND-subtraction method and complementary detection method, out of which AND-subtraction is efficient detection method.

3.1 AND-Subtraciton Method

The AND-subtraction scheme is used as revelation scheme in receiver, this scheme is highly proficient to overcome multiple user interference and complication for receiver section has diminished and the following of the system has been increased at the receiver spectral amplitude signal fragmented into two section, namely user x and user y. In AND-subtraction technique3 is described below; cross-correlation $\{\theta_{xy}(k)\}$ is calculated as per the equation shown. Calculate $\{\theta_{AND(x,y)y}(k)\}$, where $\{\theta_{AND(x,y)}(k)\}$ denotes the logical AND operation of codes x and y. Let us assume x = 1100 and y = 0101 and therefore AND (x,y) = 0100.

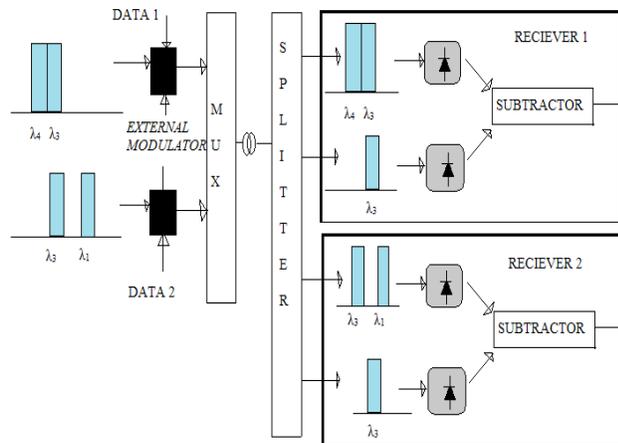$$Z_{AND} = \theta_{xy}(k) - \theta_{(AND(X,y),y)}(k) = 0 \qquad (7)$$

Figure 1. Implementation of AND-Subtraction method.

The MAI and the channel noise can be eliminated. The operation can be explained by taking a double weight code as follows.

4. Bit Error Rate (BER) Theoretical Expression

Thermal noise, shot noise and phase induced intensity noise (PIIN) were taken into account for analyzing bit error rate, the revelation scheme used for projected system depends upon AND detection scheme exploits fiber Bragg-grating[2] and photo detector in next stage. BER is calculated by Gaussian estimated phase noise of fields obtained when incoherent lights were united and projected on photo detector grounds, the intensity noise condition as output from photo detector source coherent time (τ_c) is given by

$$\tau_c = \frac{\int_0^\infty G^2(v)dv}{\left(\int_0^\infty G(v)dv\right)^2} \qquad (8)$$

G (v) represents the power spectral density of single side band.

SNR decides the optical receiver functioning, qualitative explanation of optical receiver can be obtained from Q-factor performance. It proposes minimum signal to noise ratio requisite to get a particular BER.

Signal to noise ratio is characterized as the ratio of average signal power to average noise power.

$$SNR = \frac{I^2}{\sigma^2} \qquad (9)$$

σ^2 is the variance of various noises like shot noise, thermal noise, PIIN noise[2].

| User 1 (X) | 1 | 1 | 0 | 0 |
| User 2 (Y) | 0 | 1 | 0 | 1 |

$$\theta_{XY}(k) = \sum_{i=0}^{N-1} X_i Y_{i+1}$$

$$\theta_{XY} = 1$$

AND(X, Y) = 0 1 0 0

$$\theta_{(AND(X,Y),Y)} = 1$$

$$Z_{AND} = \theta_{XY}(k) - \theta_{(AND(X,Y),Y)}(k) = 0$$

Figure 2. Implementation of AND-subtraction technique for generated DCS codes.

$$\sigma^2 \left\langle i_{shot}^2 \right\rangle + \left\langle i_{PIIN}^2 \right\rangle + \left\langle i_{Thermal}^2 \right\rangle$$

$$\sigma^2 = 2qwi_{avg} + i_{avg}^2 w\tau_c + \frac{4KTw}{z_i} \tag{10}$$

q - Charge of electron.
Z_L - Load resister of receiver.
w - Electrical bandwidth.
T - Absolute noise temperature of the receiver.
K - Boltzmann constant.
I_{avg} - average photo current.
$I^2{}_{avg}$ - PSD of average photo current.

Equation mentioned above denotes the shot noise PIIN noise and thermal noise. When both the PIIN and shot noise is considered, the tally of the arrived photons obeys negative binomial distribution. The BER gets lowered by this type of distribution compared to Gaussian distribution due to its lower probability values.

S_k (i) is i^{th} element for k^{th} sequence in DCS generated codes. AND-subtraction. In equation (11) AND{$(C_{kT}(i)$, $C_k(i)C_l(i))$} is applicable to k = l, k ≠ l. λ_c for $C_k(i)C_l(i)$ is L when k = l.

$$\sum_{i=1}^{N} c_k(i)c_l(i) = \begin{cases} W, \ for \ k = l \\ 1, \ for \ k \neq l \ and \ non \ zero \ hamming \\ \quad weight \ between \ code \ sequence \\ 0, \ for \ k \neq l \ and \ zero \ hamming \\ \quad distance \ between \ code \ sequence \end{cases} \tag{11}$$

$$\sum_{i=1}^{N} C_{KT}(i)(C_K(i)C_l(i)) = \begin{cases} 1, \ for \ k = l \ and \ KT = \begin{cases} k+1, if \ k < l \\ k-1, if \ k > l \end{cases} \\ 0, \ for \ k \neq l \ and \ KT = \begin{cases} k+1, if \ k < l \\ k-1, if \ k > l \end{cases} \end{cases} \tag{12}$$

MAI is completely nullified. When k ≠ l ($C_{kT}(i)$ $C_k(i)$ $C_l(i)$) is subtracted from the original correlation sequence is L – 1.

Therefore,

$$\sum_{i=1}^{N} C_k(i)C_l(i) - \sum_{i=1}^{N} C_{kT}(i)(C_k(i)C_l(i)) = \begin{cases} L-1, & for \ k = l \\ 0 & for \ k \neq l \end{cases} \tag{13}$$

When k = 1, weight L is null denotes that MAI is completely removed only by using AND-subtraction detection scheme.
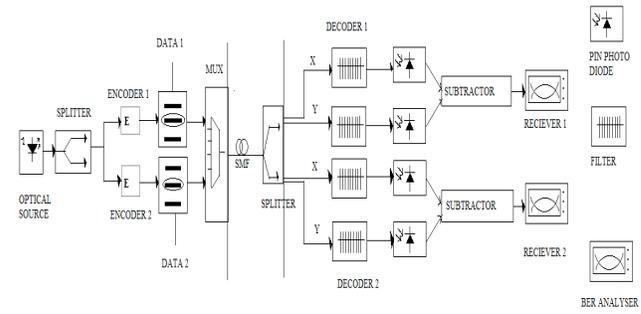

Figure 3. Block Diagram of AND-Subtraction method for user generated user code.

1. Bandwidth of light source spectrum is flat and not polarized.

$$\left[f_0 - \frac{\Delta f}{2}, f_0 + \frac{\Delta f}{2} \right]$$

f_0 - Center frequency
Δf - Optical source bandwidth (in Hz)

2. Each and every components of the power spectrum has indistinguishable spectral widths.
3. Power of the users at receiver is same.
4. Bit streams of users are synchronized.

Power spectral density r(v) can be expressed as (5)

$$r(v) = \frac{P_{Sr}}{\Delta v} \sum_{k=1}^{L} d_k \sum_{i=1}^{N} c_k(i) rect(i) \tag{14}$$

Where,

P_{Sr} - Effective source power at receiver.
N - Number of users accessing the channel.
K - Bit sequence length.
d_k - bit of kth user. The data bit may be 1 or 0.

$$rect(i) = u\left[f - f_0 - \frac{\Delta f}{2N(-N+2i-2)} \right]$$
$$- u\left[f - f_0 - \frac{\Delta f}{2N}(-N+2i) \right] = u\left[\frac{\Delta f}{N} \right] \tag{15}$$

Where u (v) is a unit step signal.

Sum of incident power of both PIN diode's input of Figure is represented as,

$$\int_0^{\infty} G_1(V)df = \int_0^{\infty} \left[\frac{P_{sr}}{\Delta v} \sum_{k=1}^{K} d_k \sum_{i=1}^{N} C_k(i)C_l(i) \left\{ u\left[\left(\frac{\Delta f}{N} \right) \right] \right\} \right] d$$

$$= \frac{P_{Sr}L}{N} + \frac{P_{Sr}}{N} \sum_{k=l, k \neq l}^{K} d_k \tag{16}$$

$$\int_0^\infty G_2(V) = \int_0^\infty \left[\frac{P_{sr}}{\Delta v} \sum_{k=1}^K d_k \sum_{i=1}^N C_{KT}(i)(C_k(i)C_l(i)) \left\{ u\left[\frac{\Delta v}{N}\right] \right\} \right] dv$$

$$= \frac{P_{sr}}{N} + \frac{P_{sr}}{N} \sum_{K=L, K\neq L}^N d_k \qquad (17)$$

At the receiver, difference of two PIN diode currents represent the authenticated user

$$I = I_1 - I_2 \qquad (18)$$

Where I denotes the difference of currents at PIN diode 1 and 2 respectively

(16) + (17)

$$I = R\left[\int_0^\infty G_1(f)df - \int_0^\infty G_2(f)df \right] = \frac{RPsr(L-1)}{N} \qquad (19)$$

R - Responsivity of PIN diode

$$R = \frac{\eta q}{hf_c}$$

Where,

η - Quantum efficiency.

q - Charge of the electron = $1.6 \times 10{-}19$ C.

h - Planck's constant = $6.6260 \times 10{-}34$ m2 Kg/S.

f_c - Optical signal's center frequency (Hz).

The power of shot noise is

$$<i_{shot}^2> = 2qw(I_1 + I_2)$$

$$= 2qwR\left[\int_0^\infty G_1(f)df + \int_0^\infty G_2(f)df \right]$$

$$= 2qwR\left[\frac{P_{sr}(L+3)}{N} \right] \qquad (20)$$

By approximating the summation

$$\sum_{k=1}^K C_k \cong \frac{KL}{N}$$

$$\sum_{k=1}^K C_{KT} \cong \frac{KL}{N}$$

The noise power is represented as

$$\left\langle i_{PIIN}^2 \right\rangle = I_1^2 w \tau_{C1} + I_2^2 w \tau_{C2}$$

$$\left\langle i_{PIIN}^2 \right\rangle = R^2 w\left[\int_0^\infty G_1^2(f)df + \int_0^\infty G_2^2(f)df \right]$$

$$= R^2 w \frac{P_{sr}^2}{N\Delta f} \sum_{i=1}^N \left\{ C_l(i)\left[\sum_{k=1}^K d_k C_k(i) \right]\left[\sum_{m=1}^K d_m C_m(i) \right] \right\}$$

$$+ R^2 w \frac{P_{sr}^2}{N\Delta f} \sum_{i=1}^N \left\{ C_k(i)C_l(i)\left[\sum_{m=1}^K d_k C_k(i) \right]\left[\sum_{m=1}^K d_m C_m(i) \right] \right\}$$

$$\left\langle i_{PIIN}^2 \right\rangle = R^2 w \frac{P_{sr}^2}{N\Delta f} \sum_{i=1}^N \left\{ \frac{C_l(i)KL}{N}\left[\sum_{k=1}^K C_k(i) \right] \right\}$$

$$+ R^2 w \frac{P_{sr}^2}{N\Delta f} \sum_{i=1}^N \left\{ \frac{C_k(i)C_l(i)KL}{N}\left[\sum_{k=1}^K C_{KT}(i) \right] \right\}$$

$$= w \frac{P_{sr}^2}{N\Delta f} * \frac{KL}{N} \sum_{i=1}^N \left\{ C_l(i)\left[\sum_{k=1}^K C_k(i)C_l(i) \right] \right\}$$

$$+ R^2 w \frac{P_{sr}^2}{N\Delta f} * \frac{KL}{N} \sum_{i=1}^N \left\{ \sum_{i=1}^K C_{KT}(i)C_k(i)C_l(i) \right\}$$

$$\left\langle i_{PIIN}^2 \right\rangle = \frac{R^2 P_{Sr}^2 wKL(L+3)}{N^2 \Delta f} \qquad (21)$$

Thermal noise is

$$\left\langle i_{thermal}^2 \right\rangle = \frac{4KTw}{z_L} \qquad (22)$$

$$SNR = \frac{I^2}{\sigma^2} = \frac{\left(\left(\frac{RP_{sr}(L-1)}{N}\right)\right)}{\left(\frac{qwRP_{sr}(L+3)}{N}\right) + \left(\frac{wR^2 P_{sr}^2 KL(L+3)}{2N^2 \Delta f}\right) + \left(\frac{4KTw}{z_L}\right)}$$

$$(23)$$

Probability or chance of transmitting 0 or 1 is 0.5. Finally, the signal to noise ratio of the AND-subtraction detection technique is represented as (see (23)).

As we found out SNR value for the AND-subtraction technique and bit error rate is calculated from SNR equation as shown below,

$$BER = \frac{1}{2} erfc\left(\sqrt{\frac{SNR}{8}}\right) \qquad (24)$$

5. Simulation Analysis

The circuit is simulated in optisystem version 12. A two user schematic diagram is shown in the Figure. Chirp of spectral width 0.8nm. Data rate at which the simulation had been processed is 10 Gbps for 15km distance with single mode step index fiber (SMF). The dispersion loss and attenuation loss of the optical fiber is 18 psnm^{-1}Km^{-1} and 0.25 dB/km respectively. In the simulation the four wave mixing and self-phase modulation are enabled to have a better process in the experimental setup. The dark current of the PIN diode at the receiver end is 5nA and the thermal noise coefficient is 1.8×10^{-23} W/Hz. The eye diagram and the bit error rate (BER) values are shown in the figure. The BER obtained is 6.46677×10^{-18} which indicates the better performance to other code generation techniques. The eye opening is also wide enough to distinguish between the data 1 or 0. Degree of distortion is nothing but the vertical opening of the eye.

As the length of the fiber increases the attenuation loss and dispersion loss increases to detrain the performance of the system and hence increases the BER. For the design of perfect system, the length should be small and the rate at which the data is transmitted should be high. But in spectral amplitude coding Optical CDMA the dispersion effect is compensated due to the use of dynamic cyclic shift algorithm.
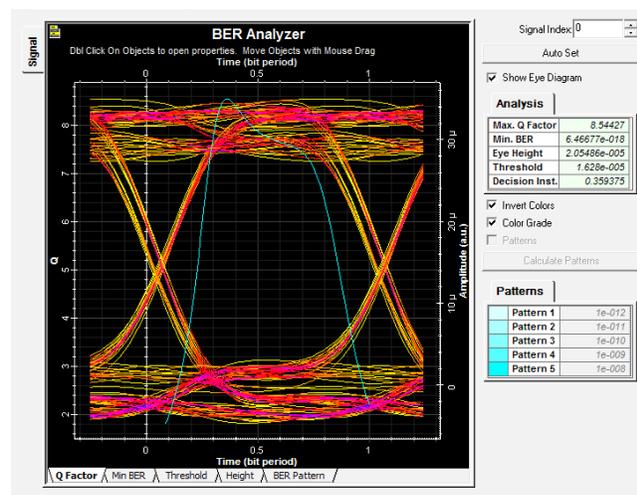

Figure 4. Eye diagram for 8 Gbps over a fiber link of 15 km for DCS generated codes.

6. Conclusion

Thus the performance of bit error rate is executed successfully for dynamic cyclic shift (DCS) code. The theoretical calculation and simulation is performed accurately. The results proves that AND-subtraction technique is the best detection technique for SAC-OCDMA which improves the performance by reducing the multiple access interference (MAI) and phased intensity induced noise (PIIN) significantly. In the next step for six users, there would be an error free communication at a transmission of 10Gbps. Hence it is known that multiple access interference (MAI) is removed. Hence this type of code generation can be used to thee next generation SAC-OCDMA systems.

7. References

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