Enhancing Performance of OCDMA using Dynamic Cyclic Shift Codes

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Abstract
Optical Code Division Multiple Access (OCDMA) is one of the competing technologies for future multiple access networks and it realised multiplexing transmission and multiple accesses by coding in the optical domain, which supports multiple simultaneous transmissions in the same time slot and the same frequency. The analysis results ascertained that the DCS code with AND detection technique can improve the system performance by reducing the MAI effect significantly. The simulation is performed by using OptiSystem Version 9.0 and found that DCS codes are more efficient in construction and application.

Keywords
AND-Subtraction, BER, DCS, MAI, OCDMA

I. Introduction

OSCDMA technique is one of the multiplexing techniques that is becoming popular because of the flexibility in allocation of channels, ability to operate asynchronously, enhanced privacy and increased capacity in bursty nature networks. The performance of OSCDMA strongly depends on the codes properties and the detection technique. The codes are designed in such a way to be sufficiently different that the probability of mistaken one code from another is very low. Unfortunately, when many users are actively transmitting, many overlaps may result. A receiver may then erroneously conclude that its target code was sent. This phenomenon is known as an error arising due to Multiple Access Interference (MAI) or multiple user interference (MUI)[1-2].

Each user in a CDMA system uses a different code to modulate their signal. Choosing the codes used to modulate the signal is very important in the performance of CDMA systems. The best performance will occur when there is good separation between the signal of a desired user and the signals of other users. The separation of the signals is made by correlating the received signal with the locally generated code of the desired user. If the signal matches the desired user's code then the correlation function will be high and the system can extract that signal. If the desired user's code has nothing in common with the signal the correlation should be as close to zero as possible (thus eliminating the signal); this is referred to as cross-correlation. If the code is correlated with the signal at any time offset other than zero, the correlation should be as close to zero as possible. This is referred to as auto-correlation and is used to reject multi-path interference.

The effect of MAI can be eliminated by using subtraction detection technique. The use of power at the balanced photodiode is different with different number of active users, it is hard to predict the MAI value in normal operation conditions where the number of users fluctuates over time. Therefore, it is extremely important to design a detection technique in such a way that MAI is minimized regardless of the number of users and maintain the performance of the system at the minimum cost [3].

II. Types of Codes

In general, CDMA belongs to two basic categories: synchronous and asynchronous.

A. Synchronous Codes

Here, a low frequency data signal is time multiplied with a high frequency pure sine wave carrier, and transmitted. This is effectively a frequency convolution of the two signals, resulting in a carrier with narrow sidebands.

B. Asynchronous Codes

Unique "pseudo-random" or "pseudo-noise" (PN) sequences are used in asynchronous CDMA systems. A PN code is a binary sequence that appears random but can be reproduced in a deterministic manner by intended receivers. These PN codes are used to encode and decode a user's signal in asynchronous CDMA.

III. And-Subtraction Detection Technique

When many users are actively transmitting, many overlaps may result.

A receiver may then erroneously conclude that its target code was sent. This phenomenon is known as an error arising due to multiple access interference (MAI) [1][2].The effect of MAI can be eliminated by subtraction technique. However, [4][5]have proposed AND subtraction technique which has better performance than other subtraction technique. The number of filters that are needed in the decoders depend on the code weight ,W and the basic code row size. Moreover AND-subtraction technique does not require attenuator to eliminate MAI. Therefore, the use of fewer components to implement the AND subtraction technique leads to the substantial cost reduction in the overall system as compared to other subtraction technique [6].
When incoherent light fields are mixed and incident upon a photodetector, the phase noise of the fields causes an intensity noise term in the photodetector output. The source coherence time τc is expressed as [7,8]:

$$\tau_c = \frac{\int_0^{\infty} G^2(v)dv}{[G(v)dv]^2} \qquad (1)$$

where G(v) is the Power Spectral Density (PSD) of the thermal source. If $C_k(i)$ denotes the i^{th} element of the k^{th} code sequence, the code properties for AND subtraction technique can be written as:

$$\sum_{i=1}^{N} C_k(i)C_l(i) = \begin{cases} W, & k = l \text{ in the same sector} \\ 1, & k \neq l \text{ in the same sector} \\ 0, & k \neq l \text{ not in the same sector} \end{cases} \qquad (2)$$

And

$$\sum_{i=1}^{N} C_k(i)(C_k(i)C_l(i)) = \begin{cases} W, & \text{for } k = l\} \text{in the same sector} \\ 1, & \text{for } k \neq l\} \text{in the same sector} \\ 0, & \text{for } k \neq l\ \} \text{not in the same sector} \end{cases} \qquad (3)$$

The condition of k and l in the same sector meaning that both code sequences are in same column.

$$\left\{ \sum_{i=1}^{N} C_k(i) C_l(i) \right\} - \left\{ \sum_{i=1}^{N} C_k(i) (C_k(i) C_l(i)) \right\} = \begin{cases} W-1, & k = l \\ 0, & k \neq l \end{cases} \quad (4)$$

Hence, the weight is zero when k≠l, meaning MAI can be fully removed by using AND subtraction detection technique, fig 1[9].

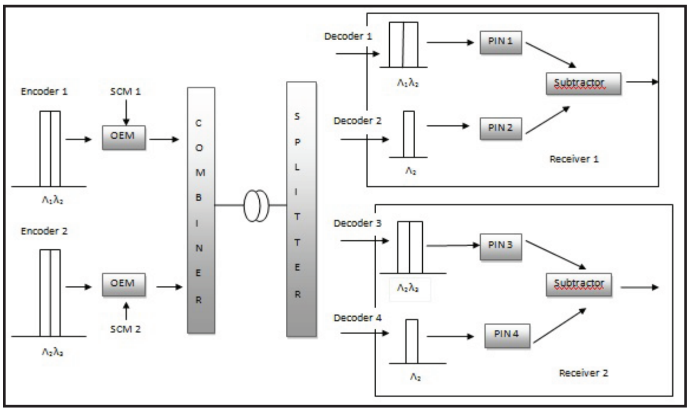

Fig. 1: Block Diagram of AND- Subtraction Detection Technique

IV. Dyanamic Cyclic Shift Codes

The DCS code consist of two parts – weight part and dynamic part. The code word is obtained by combining both parts. The algorithm for code formation is given in fig. 2 [10].

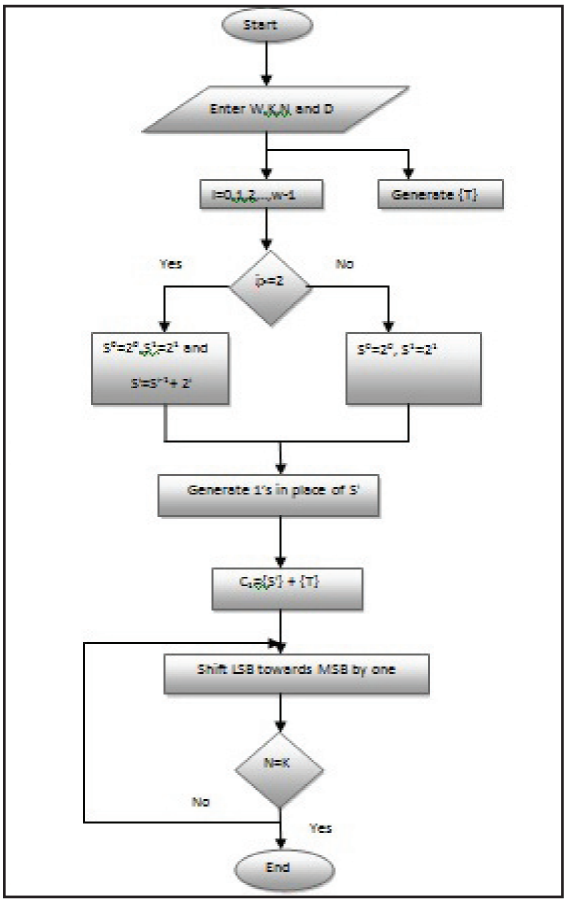

Fig. 2 Algorithm for DCS Code Formation

The noise present in SNR consist of shot noise, thermal noise and PIIN [11-12]. The effect of PIIN and shot noise follow the negative binomial distribution [13].

IV. Performance Analysis

The performance is analysed using simulation software Optisystem version 9.0. The simulation was carried out at 10 Gbps and length was varied from 20 km to 100 km for 8 users. The characteristics like BER, quality factor, power and eye diagram were analysed. The simulation environment was kept close to the industry standards. The dark current was set at 5nA, attenuation was 0.25 dB/km, dispersion was 18 ps/nm km and the non-linear effects were activated.

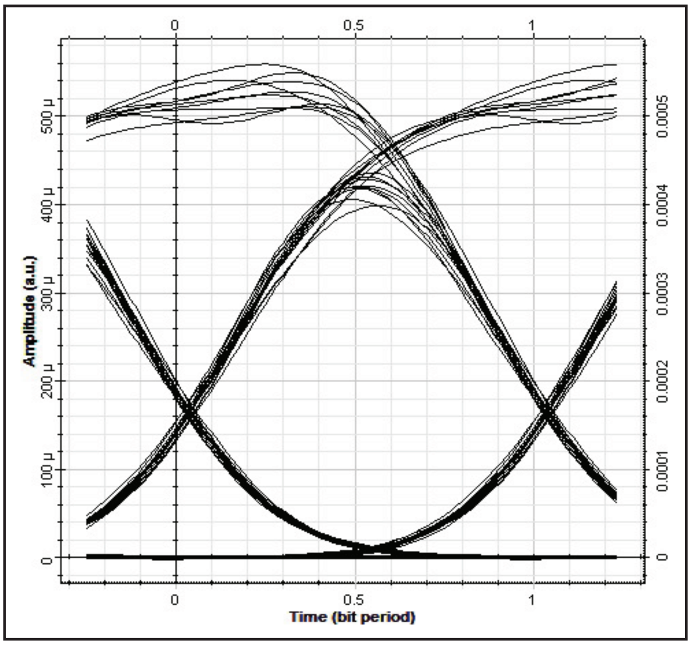

Fig. 3: Eye Diagram for 8 users at 10Gbps for length= 20km and Weight =3

It is clearly seen in eye diagram fig.3 that the noise is totally removed and eye height is large. Fig 4 shows that the quality factor is acceptable fairly up till 75 km . The curve goes on decreasing with the increasing distance because unavoidable noises effect the system along the optical fiber length. Fig. 5 shows the variation of BER with the distance. The BER is very less initially at 50 km and increases with the distance .It is acceptable upto 75 km and more.

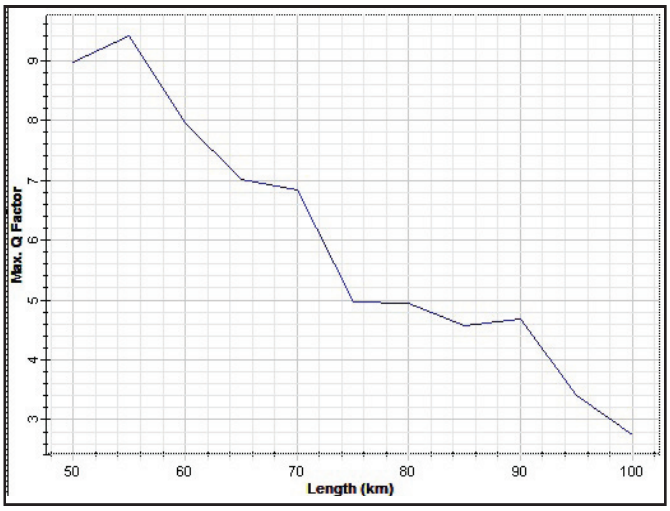

Fig. 4: Trend of Maximum Quality Factor

The signal has power for very large distance as seen from fig. 6 .

From all the observations we can conclude that the dynamic cyclic shift codes are very efficient for large number of users and long distance communication.

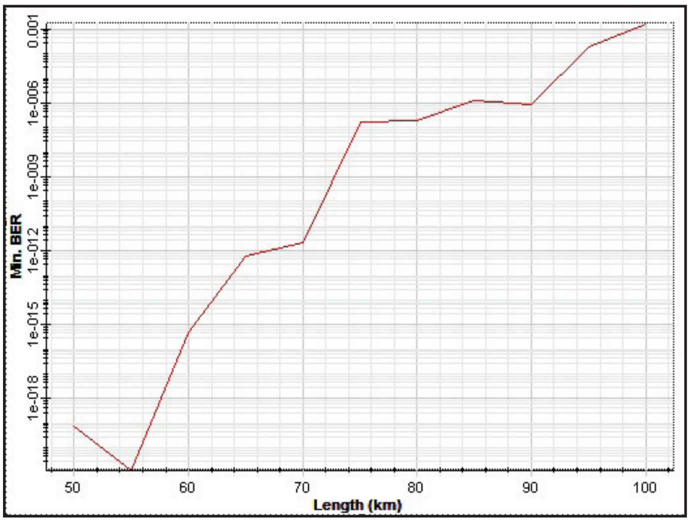

Fig. 5: Graphical Analysis of BER

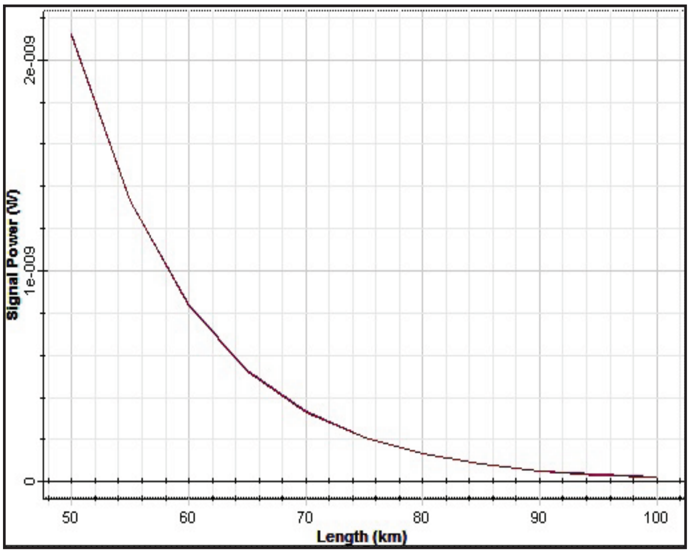

Fig. 6: Signal Power Vs Length Graph

V. Conclusion

Presently, OCDMA is acquiring a large section of communication. So it is very important to keep on enhancing the performance in the optical domain. The dynamic cyclic shift codes are excellent for large distance communication and can be implemented in metropolitan areas at a high speed. All the parameters needed for promising data transfer were studied and promising results were obtained. These codes were easy in design and implementation and the subtraction technique used at the decoder section is also capable of fully removing the MAI effect.

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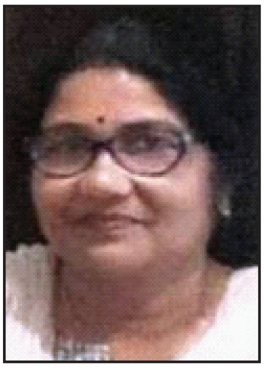

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