New family of algebraically designed Zero Cross-Correlation codes for use in CDMA fibre-optic networks

Garadi Ahmed[†], **Ali Djebbari**[††]

Telecommunications and Digital Signal Processing Laboratory, Sidi Bel Abbès University. 22000. Algeria

Abstract

In this paper we present a new technique for constructing zero cross correlation codes (ZCC). The proposed technique can be adapted to any weight and any number of users with minimum code length. Many techniques have been proposed for constructing zero cross correlation codes (ZCC), among the popular ones are detailed in [1]. However these codes suffer from various limitations one way or another. The code construction is complicated and the weight is always related to the number of users, especially for weight w more than one (e.g. ZCC [2]), or the code length is too long (e.g. ZCC [3] and ZCC [4]). Long code length is considered disadvantageous in its implementation since either very band sources or narrow filter bandwidths are required.

Key words:

Fiber Optical Code Division Multiple Access (FO-CDMA), Zero Cross-correlation (ZCC) code, Phase Induced Intensity noise (PIIN).

1. Introduction

Optical Code Division Multiple Access (OCDMA) systems are getting more and more attractive in the field of all-optical communications as multiple users can access the network simultaneously with high level of transmission security [5]. The OCDMA undergoes of different types of noise like intrinsic noise sources arising from the physical effects of the system design itself such as relative intensity noise (RIN), phase induced intensity noise (PIIN), thermal noise and shot noise, Phase Induced Intensity noise (PIIN). This last one is strongly related to Multiple Access Interference (MAI) due to the overlapping of spectra from different users.

The key to an effective OCDMA system is the choice of efficient address codes with good or almost zero correlation proprieties for encoding the source [6].

The main goal of this study is to develop a new ZCC code to improve the performance of optical network. The remainder of this paper is organized as follows. In section I we explain the basic idea of the codes ZCC and provide a definition for double weight code and the modified double weight code and we represents some methods used to build the code of ZCC, their properties, and their representation techniques. In the Section II we introduce our proposed method; Section III shows the performance evaluation and comparisons between the different methods of construction and the new method. Finally, conclusions are given in Section IV.

2. Idea and methods of construction ZCC Code

The basic idea of ZCC codes construction is obtained from DW and MDW codes [1], for the DW the code-weight is 2 and the code-length in terms of the maximum number of users, C, is as follows:

$$C = \begin{cases} \frac{3\times K}{2} & \text{for K is even} \\ \frac{3\times K}{2} + \frac{1}{2} & \text{for K is odd} \end{cases} \quad (1)$$

MDW code is a modified DW code family that has variable weights of greater than two.

For example for weight of 4 the code length for any given code length C, can be related to the number of user K through [6]:

$$C = 3K + \frac{8}{3}\left[\sin\left(\frac{K\pi}{3}\right)\right]^2 \quad (2)$$

For each three columns of MDW matrix, the combination of chip sequences are 1, 2, 1 (i.e. 0 +1, 1 +1, 1 +0) to maintain a maximum cross-correlation equal to 1 [1].

Then to get the cross correlation equal to zero the intersection columns should be eliminated, which contain the cross correlation value equal to one and after this removing the basic zero cross correlation matrix can be obtained as shows in Eq.3 [2] [3]

$$\begin{matrix} \mathbf{1} & \mathbf{1} \\ \blacktriangledown & \blacktriangledown \end{matrix}$$

$$Z_{M=1} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \quad (3)$$

Notice that Z1 has no overlapping of '1' for both users. In order to increase the number of users and codes, a mapping technique is used as below [2]:

$$Z_{M=2} = \begin{bmatrix} 0 & Z_1 \\ Z_1 & 0 \end{bmatrix} \quad (4)$$

Manuscript received December 5, 2011

Manuscript revised December 20, 2011

$$Z_{M=2}=\begin{bmatrix}0&0&0&1\\0&0&1&0\\0&1&0&0\\1&0&0&0\end{bmatrix} \quad (5)$$

$$Z_{M=3}=\begin{bmatrix}0&Z_2\\Z_2&0\end{bmatrix} \quad (6)$$

$$Z_{M=3}=\begin{bmatrix}0&0&0&0&0&0&0&1\\0&0&0&0&0&0&1&0\\0&0&0&0&0&1&0&0\\0&0&0&0&1&0&0&0\\0&0&0&1&0&0&0&0\\0&0&1&0&0&0&0&0\\0&1&0&0&0&0&0&0\\1&0&0&0&0&0&0&0\end{bmatrix} \quad (7)$$

From the mapping, it is noted that when the number of users K increase, the code length C increase as well. The pattern of mapped code is mirror diagonally expanded and K is equally increased with C. The relation between the number of mapping process M, number of users K and code length C is given by [1] [3]:

$$K_M=2^M \quad (8)$$

$$C_M=2^M\times w \quad (9)$$

The ZCC code has flexibility in number of weight consideration. To increase the number of weight, it needs to formulate using few steps so-called 'code transformation' [3]. In ZCC code, the basic code represent weight = 1. To transform the code from w=1 to w=2, the general form of transformation is given by:

$$Z_w=\begin{bmatrix}A&B\\C&D\end{bmatrix} \quad (10)$$

Where

$$Z_{w=1}=\begin{bmatrix}0&1\\1&0\end{bmatrix} \quad (11)$$

Where

[A] – consist of [1, w (w-1)] matrix of zero.

[B] – consist of w replication of matrix [0 1] (i.e. $\sum_{j=1}^{w}[0\ 1]$).

[C] – consist of duplication of matrix from w −1.

[D] – consist of diagonal pattern with alternate column zeros matrix.

For example the transformation code from w =1 to w=2→ w=3 are shown as [2]:

$$Z_2=\begin{bmatrix}0&0&0&1&0&1\\0&1&0&0&1&0\\1&0&1&0&0&0\end{bmatrix} \quad (12)$$

$$Z_3=\begin{bmatrix}0&0&0&0&0&0&0&1&0&1&0&1\\0&0&0&1&0&1&0&0&0&0&1&0\\0&1&0&0&1&0&0&0&1&0&0&0\\1&0&1&0&0&0&1&0&0&0&0&0\end{bmatrix}$$

The relationship between parameters KB, w and CB is given by [7]:

$$K_B=w+1 \quad (13)$$

$$C_B=w\times (w+1) \quad (14)$$

3. New construction of ZCC Code

With the aim of increasing the number of users with a variable weight (To increase the signal-to noise ration) we suggest using the following mapping by using the basic matrix ZW=1 for two users:

$$ZCC_{m=2}=\begin{bmatrix}0&ZCC_{m=1}\\ZCC_{m=1}&0\end{bmatrix}=\begin{bmatrix}0&0&0&1\\0&0&1&0\\0&1&0&0\\1&0&0&0\end{bmatrix}$$

The increase of the weight (w=2) for a fixed number of users, matrice of the code is a repetition w times the matrix Zm=2:

$$ZCC_{m=2,W=2}=[ZCC_{m=2}\quad ZCC_{m=2}] \quad (15)$$

$$ZCC_{m=2,W=2}=\begin{bmatrix}0&ZCC_{m=1}&0&ZCC_{m=1}\\ZCC_{m=1}&0&ZCC_{m=1}&0\end{bmatrix}$$

$$ZCC_{m=2,W=2}=\begin{bmatrix}0&0&0&1&0&0&0&1\\0&0&1&0&0&0&1&0\\0&1&0&0&0&1&0&0\\1&0&0&0&1&0&0&0\end{bmatrix} \quad (16)$$

For the user number i

$$1\le i\le K \quad (17)$$

K is the total number of users, and column j for the position of each chip:

$$1\le j\le C \quad (18)$$

The relationship between parameters K, w and C is given:

$$K_m=2^m \quad (19)$$

$$C_m=2^m\times (w) \quad (20)$$

The general formula for generating the ZCC code is given:

$$ZCC_{i,j}\begin{cases}1\ si\begin{cases}j=(w\times K)-\left([(m-1)\times 2^m]+(i-1)\right)\ pour\ i\le\frac{K}{2}\ et\ m=\{1,2,\ldots,w\}\\ j=(w\times K)-\left([(m-1)\times 2^m]+(i-1)+\frac{K}{2}\right)\ pour\ i>\frac{K}{2}\ et\ m=\{1,2,\ldots,w\}\end{cases}\\0\quad \text{Otherwise}\end{cases}$$

4. Code Comparaison

In this section, MDW, ZCC [3], ZCC [5] and new ZCC codes are compared. The parameters used in our Comparison are summarized in Table 1.

Table 1: Code Length of MDW code, ZCC [1], ZCC [2], and new ZCC codes

Codes	Code Length (C)	Cross correlation
MDW	$C=3K+8/3[\sin(K.\pi/3)]^2$	λ=1
ZCC [1]	$C=w\times(w+1)$ $K=w+1$	λ=0
ZCC[2]	$C_m=2^mC$ $K_m=2^mK$ With m=w	λ=0
New ZCC	$K_m=2^m$ $C_m=2^m\times(w)$	λ=0

Table 2: Comparison between MDW code, ZCC [1] and ZCC [2] and new ZCC code for K=30 users.

Codes	Wight (W)	Code Length (C)
MDW	4	45
ZCC [1]	29	870
ZCC[2]	4	320
New ZCC	4	128

For comparison, the table 2 shows that the cross correlation of MDW codes is fixed to one for any number of users, K while non-existent cross correlation of ZCC codes.

The code length of ZCC [3] code is long than ZCC [5] and new ZCC codes, These latter two have almost the same Code, but The method of construction of ZCC [5] code is more complicated than the new ZCC code and, Where the current matrix code relies on the matrix code past.

5. Conclusion

In this paper, the new ZCC code has been presented with simple algebraic way. The performances of different methods are detailed respectively. The study showed that the new ZCC code is the low code length between the existing methods. Furthermore, the ZCC [1] code could accommodate more users than the new ZCC For the same weight W, The use of the proposed ZCC gives numerous advantages among them: Large flexibility in choosing the number of users (code size), Code length shorter than those achieved for ZCC [2] and Simplicity of construction.

References

[1] M.S. Anuar a, S.A. Aljunid a, N.M. Saad and Saad I. Andonovic Journal of Applied sciences (7). 23 (2007).
[2] E. I. Babekir, N. M. Saad, N. Elfadel, A. Mohammed, A. Aziz, M. S. Anuar, S. A. Aljunid, M. K. Abdullah3 IJCSNS International Journal of Computer Science and Network Security VOL.7 No.7, July 2007.
[3] M.S. Anuar1, S.A. Aljunid1, N.M. Saad2, A. Mohammed, E.I. Babekir IJCSNS International Journal of Computer Science and Network Security, (6).12, December 2006.
[4] Mohammad Noshad, Student Member, IEEE, and Kambiz Jamshidi, Novel Codes Family for Modified Spectral Amplitude-Coding OCDMA Systems and Performance Analysis.
[5] M.S. Anuar, S.A. Aljunid, N.M. Saad, S.M. Hamzah, Optics Communications 282 (2009).
[6] Syed Alwee Aljunid, Zuraidah Zan, Siti Barirah Ahmad Anas and Mohd. Khazani Abdullah, A new code for optical code division multiple access systems, Malaysian Journal of Computer Science, Vol. 17 No. 2, December 2004, pp. 30-39
[7] B. D. Ivan B. Djordjevic, B. Vasic, Journal of Lightwave Technology, Vol 21, No. 9, September 2003.