Performance Evaluation Analysis of Wavelength/Time 2-D Modified Double Weight Code in OCDMA

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***Abstract*—**The work in this paper a simulation of two-dimension (2-D) modified double weight (MDW) optical code division multiple access (OCDMA) wavelength-time and 2-D difference perfect code PDC, focusing on a comparison between the two codes with k_1 =4 (the code weight of spectra code sequence), k_2 =2 (the code weight of time-chip) for 2-D MDW code and k_1 =3, k_2 =2 for 2-D PDC with four users. The simulation is done with Optisystem program V11, can notice that 2-D MDW code indicates substantial performance improvements in bit error rate (BER), data rate and distance and achieves good performance; below 10^{-9} BER error floor for lowest effective transmitted power (P_{sr}) reached -20 dB and successfully suppresses PIIIN and mitigating MAI compared with PDC.

***Keywords*—**One Dimension Modified Double weight (1D-MDW). Two Dimension Modified Double Weight (2D-MDW), Optical Code Division Multiple Access (OCDMA), Phase Induced Intensity Noise (PIIN), Multiple Access Interference MAI.

I. Introduction

2-D OCDMA emerging research attracts huge research interest, it offers a large optical fiber bandwidth and flexibility of high speed access, dynamic bandwidth assignment and high security [1]. The challenges that can see in OCDMA system are improved cardinality, suppress phase induced intensity noise PIIN, and mitigate multiple access interference MAI [2]. However a proper design of 2-D OCDMA could result in auto-correlation with minimum or zero side lobe and cross-correlation small than 1-D OCMA [3].

The high weight and short length result in a high signal to noise ratio (SNR) and low BER therefore various 2-D OCDMA techniques have been developed in designing the code sequences with emphasizing on specific code properties, headed for suppressing interferences and enhancing BER [4]. 2-D wavelength-time OCDMA system is anticipated to be an alternative to the next generation OCDMA system [5]. There are some factors contributing towards improvement OCDMA code sequences system performance, cross-correlation and auto-correlation properties, detection technique and BER and important to mention that the increment in code weight will improve the correlation properties, SNR and BER [5].

Many new 2-D OCDMA codes have been developed such as 2-D Hybrid FCC MDW code, which has a good correlation properties, and have ability to suppress MAI [6], Choe code, which possessed larger capacity and good spectral efficiency [7], 2-D Perfect Difference (PDC), eliminate the MAI and improve the system performance by suppressing the PIIN [8]. 2-D MDW code which have fixed in-phase spectral cross-correlation equal to '1' signature sequences to reduce the effect of PIIN and removing MAI and offers an enhanced performance for the family of MDW codes[9]. 2-D MDW code is envisioned as a possible solution to overcome the limitation of 1-D wavelength –time OCDMA codes that improved a high numbers of users a result BER improvement [10].

The structure of this paper is starting with 2-D MDW code construction in section 2, section3 will be the cross-correlation of the code. The system setup in section and simulation result in section 4.finally the conclusion in section 5.

II. Essential of 2-D MDW Code Algorithm

All 2-D MDW codes are developed from 1–D MDW code [6] , where M as number of wavelengths , N as temporal code length ,W as a weight , $\lambda^{\lceil a \rceil}$ and $\lambda^{\lceil c \rceil}$are auto- and cross-correlation values are denoted by ($M \times N$,W , $\lambda^{\lceil a \rceil}$, $\lambda^{\lceil c \rceil}$) the jth user's 2-D codes $C^{j}_{M,N}$ in Eq.(1), is a matrix M of row vectors $d^{j}_{K,N}$ related to the temporal spreading $d^{j}_{1,N}$ =[$C^{j}_{K,1}, C^{j}_{K,2}$,………., $C^{j}_{K,N-1}, C^{j}_{K,N}$] where $C^{j}_{K,i} \in$ {0,1} and K is the emitted wavelength of $K \in$ {1,……..,M }.

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http://dx.doi.org/10.15242/IJCCIE.ER0116117

$$C^{j}_{M,N} = \begin{pmatrix} d^{j}_{1,N} \\ d^{j}_{2,N} \\ . \\ . \\ . \\ d^{j}_{M-1,N} \\ d^{j}_{M,N} \end{pmatrix} \quad (1)$$

The signals $r_{K,N}(t)$ are sum of temporal spreading data of F^u users carried on the wavelength λ^k and expressed as $r_{K,N}(t) = \sum_{i=1}^{F^u} b_i^j(t) d^j_{K,N}$, where (t) is ith data bit jth user and F^u is number of users. The M signals $r^j{}_{K,N}(t)$ are multiplexed and total signal $R_{M,N}(t)$ transmitted on optical fiber is expressed as a matrix of ($M \times N$):

$$R_{M,N}(t) = \begin{pmatrix} r_{1,N}(t) \\ r_{2,N}(t) \\ . \\ . \\ . \\ r_{M-1,N}(t) \\ r_{M,N}(t) \end{pmatrix} \quad (2)$$

2-D MDW OCDMA network consists of M, N pairs of transmitters and receivers. $A^{g,h}$ represents the code where g $\in$ (1,2,3,……., $M-1$) and h $\in$ (1,2,3,……, $N-1$) . X^g and Y^k are spectral and spatial encoding. Table 1 shows some 2-D MDW code projection.

TABLE I

2-D MDW CODES FOR k_1 = 4 AND k_2 =2

$X_{g,h}$	[000011011]	[011000110]	[110110000]
0	000000000	000000000	000000000
1	000011011	011000110	110110000
1	000011011	011000110	110110000
1	000011011	011000110	110110000
1	000011011	011000110	110110000
0	000000000	000000000	000000000

III. THE 2-D MDW CROSS-CORRELATION

X = [x ^{0}, x ^{1}, x ^{2} …., x $^{M-1}$], Y = [y ^{0} ,y ^{1} ,y ^{2} ,……y $^{N-1}$] are code sequences of 1-D MDW code. The 2-D MDW cross-correlation can be derived through four characteristic matrices:

$A^{(d)}$, where d $\in$ (0,1,2,3) are defined as $A^{(0)} = Y^T X$, $A^{(1)} = Y^T \bar{X}$ and $A^{(2)} = \bar{Y} X$ and $A^{(3)} = \bar{Y}^T \bar{X}$. The cross-correlation of 2-D MDW code $A^{(d)}$ and $A_{g,h}$ can be expressed as:

$R^{(d)}$ (g, h) = $\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} a_{ij}^{(d)} a_{(i+g)(j+h)}$, where $a_{ij}^{(d)}$ is(i, j)th of $A^{(d)}$ and $a_{(i+g)(j+h)}$ is (i,j)th of $A_{g,h}$:

g ϵ (1,2,3,.., $M-1$) and h ϵ (1,2,3,……, $N-1$).

Table 2 [6], shows the cross-correlation of 2-D MDW code generated from $R^{(d)}$ (g,h), where $R^{(3)}$ (g,h) has nonzero value when g≠0 ∩ h≠0 .

TABLE II

2-D MDW CODE CROSS-CORRELATION

$X_{g.h}$	$R^{(0)}_{(g,h)}$	$R^{(1)}_{(g,h)}$	$R^{(2)}_{(g,h)}$	$R^{(3)}_{(g,h)}$
g = 0 ,h = 0	$k_1 k_2$	0	0	0
g = 0 ,h ≠ 0	k_1	k_1	0	0
g ≠ 0 ,h = 0	k_2	0	k_2 (k_1 -1)	0
g ≠ 0 ,h ≠ 0	1	1	k_1 -1	k_1 -1

When g≠0 ∩ h≠0; $R^{(1)}$ (g,h), $R^{(2)}$ (g,h) and $R^{(3)}$ (g,h) indicates the specific relationships . Cross-correlation function can be written by using $R^{(3)}$ (g,h) to eliminate influence due to $A_{g,h}$ from $R^{(0)}$ (g,h), $R^{(1)}$ (g,h) and $R^{(2)}$ (g,h) when g≠0 ∩ h≠0 . New derived 2-D MDW cross-correlation function is expressed as:

$$R^{(0)}_{(g,h)} - R^{(1)}_{(g,h)} - \frac{R^{(2)}(g,h)}{k_1-1} - \frac{R^{(3)}(g,h)}{k_1-1} = \begin{cases} k_1 . k_2 & \text{for } g = 0 \text{ and } h = 1 \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

IV. 2- D MDW CODE SIMULATION SETUP AND RESULTS

The result of simulation for the 2-D MDW OCDMA system compared with 2-D PDC OCDMA of four users and eye pattern are shown in the figures below. The wavelength chip is set to an increment of 0.8 nm spectral width, with varied data rate for as distance varied using ITU-TG.652 standard single mode optical fiber and the attenuation α (i.e., 0.2dB/km). The performance is measured based on the BERs and eye pattern analysis. As we varied the system, data rate of 622 Mbps and 1 Gbps with fiber length from 5 km to 30 km for four users.

Figure 1 can shows the eye diagram for the 2-D MDW code with data rate of 622Mbps detected by the AND-subtraction technique with k_1 =4, k_2 =2 for 2-D MDW code, where the BER value is 5 ×10ˆ-52 for fibre length equal 10 km. The high performances of the system are characterized by referring to the bit-error rate (BER) based on the properties of 2-D MDW code in term of length of the code and the cross-correlation.

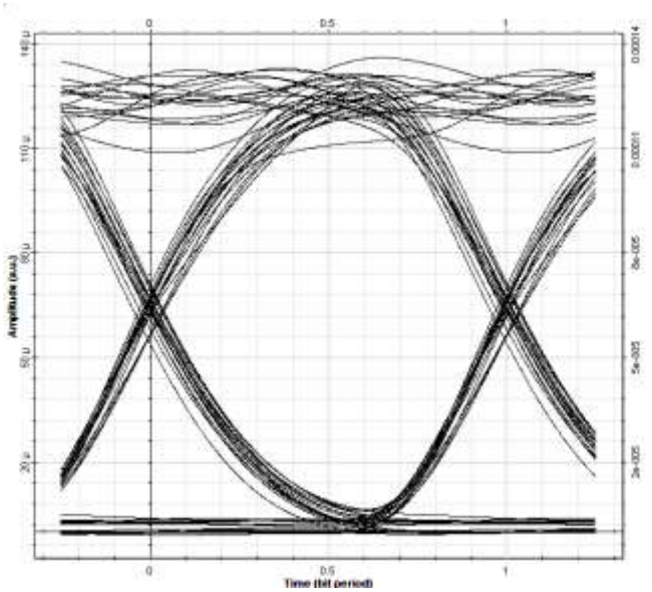

Fig. 1: eye diagram for data rate 622 Mbps

Fig.2 shows the eye diagram for the 2-D MDW code with data rate of 1Gbps where the BER=7 × 10ˆ-17 for the same transmission distance and using of AND-Subtraction detection technique. As the bit rate increases the vertical distance between the top of the eye opening and maximum signal level gives the degree of distortion. The more the eye closes, the more difficult it is to distinguish between 1s and 0s in the signal.

In figure 3 the simulation results depend on the relation between the data bit rate and the transmission distance at data bit rate of 622 Mbps the 2-D MDW OCDMA system can reach 20 km below 10^{-9} BER. For 2-D PDC OCDMA can achieve BER equal to 10^{-9} with fiber length equal 16 km, when increase transmission distance results in higher utilization of receive power and interference in the system and subsequently deteriorate the system performance. However, as the bit rate increases to data bit rate of 1 Gbps for the 2-D MDW OCDMA network still below 10^{-9} for transmission distance equal 12 km and for 2-D PDC code the transmission distance equal 9 km. Moreover when transmission distance 7 km, BER =10^{-9} exactly of data bit rate 1.5 Gbps for 2-D MDW code, for 2-D PDC OCDMA network BER can be 10^{-9} for bit rate equal to 1.5 Gbps at the transmission distance 6 km.2-D MDW. Finally this result clearly shows that the 2-D MDW code is better than 2-D PDC for high bit rate under long transmission distance.

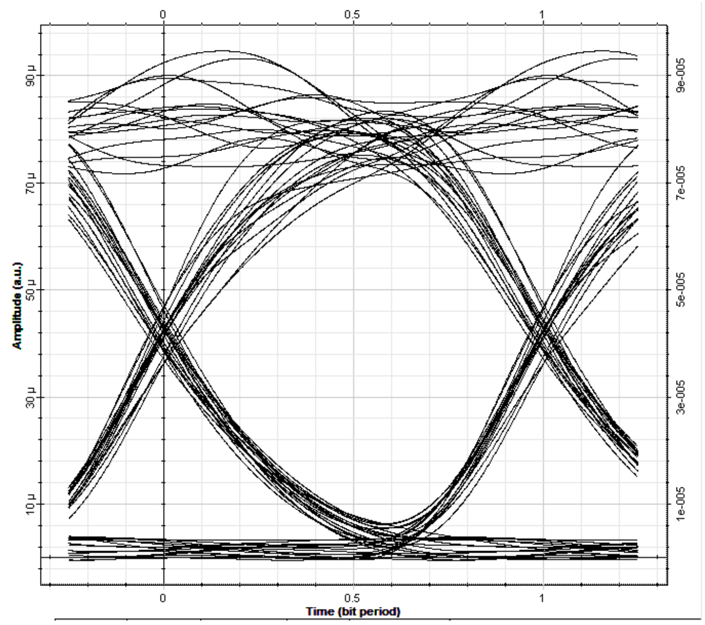

Fig 2: eye diagrm for data rate 1 Gbps

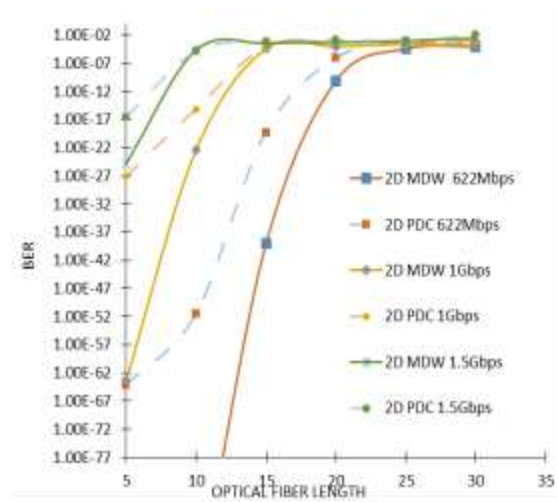

Fig. 3: Performance simulation of BER versus fiber length of 2-D MDW and 2-D PDC

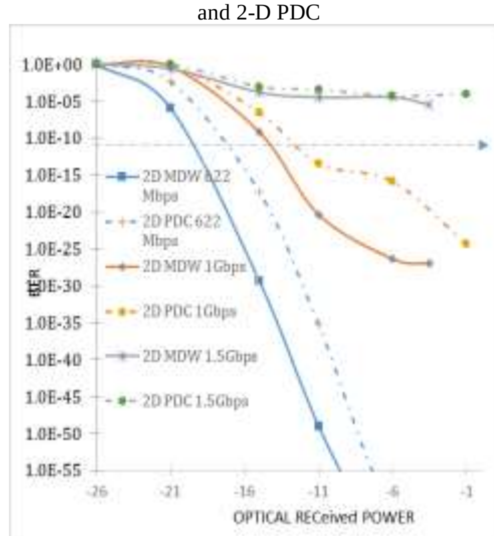

Fig. 4: BER versus P $_{sr}$ with four numbers of users with different bit rates

As shown in fig. 4 the BER versus P^{sr} with four numbers of users of 2-D MDW OCDMA and 2-D PDC OCDMA for different data bit rates 622 Mbps, 1 Gbps and 1.5 Gbps, with transmission distance 10 Km distance. For 2-D MDW meet the optical transmission requirement with lowest effective transmitted source power P^{sr} at -20 dBm compare to 2-D PDC OCDMA at 622 Mbps the effective received power equal -17dBm, but when increase the bit rate to 1 Gbps P^{sr} equal -14 dBm for 2-D MDW OCDMA but for 2-D PDC P^{sr} equal -11 dBm that mean for this bit rate 2-D MDW OCDMA receive a clear signal in low effective power. However, for 1.5 Gbps and sure for highest bit rates the both of codes P^{sr} is above 10^{-9} BER error. Depend on this results the 2-D MDW has advantage over the 2-D PDC due to the ability to extremely suppress PIIN. This is achieved through good property of minimum cross-correlation.

V. CONCLUSION

Resolution can be made from the simulation for 2-D MDW improved the good performance at high bit rates with different optical fiber length and receive power that can be -20 dBm comparing with 2-D PDC. 2-D PDC code code has a good performance simulation analysis and in-phase cross-correlation code sequences are exactly one, but has disadvantage it's required lengthy code as the number of the user increases. 2-D MDW result's scheme has better tolerance to PIIN, the code properties restrain the system degradation.

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