Hybrid OCDMA over WDM System for 60 Km Transmission in Optical Access Networks

N. Ahmed, S. A. Aljunid, A. Fadil, R. B. Ahmad, and M. A. Rashid

***Abstract*—In this paper, optical code division multiple access (OCDMA) over wavelength division multiplexing (WDM) system called hybrid system is proposed for supporting large numbers of subscriber and video data in optical access network. This system combines OCDMA and WDM to carry different types of data in one system. In order to design a system, the modified double weight (MDW) code is used as signature address because this code has flexible auto cross correlation properties which suppress multiple access interference (MAI) in a significant amount. The complementary subtraction technique is used to detect the signal in the receiver side. Finally, we ascertained by network simulation experiments that the proposed system provides better signal as compare to OCDMA system.**

***Index Terms*—MDW code, SAC-OCDMA, complementary detection, WDM and hybrid system.**

I. INTRODUCTION

Last one decade there has been a renewed interest in optical code-division multiplexing accesses (OCDMA) system for broadband access networks [1]. Optical code-division multiple-access (OCDMA) is the access offers cost-effective network deployment and management combined with physical layer security [2]. One of the main advantage of OCDMA system is that it allow multiple users to transmit information over the same channel. However, performance degradation is one of the big limitation of this system. In OCDMA system, multiple access interference (MAI) is a dominant source which degrade the system performance [3]. The spectral-amplitude-coding (SAC) technique was introduced to suppress the influence of MAI effect by employing codes with fixed in-phase cross-correlation λ [4]. Hence, many numbers of codes have been proposed to overcome the MAI effect from the system [5-9]. In OCDMA system, the data is encoded into OCs by the encoder at the transmitter side and multiple users share the same transmission by using a power splitter/combiner. At the receiver side, the system decoder recognizes the optical codes (OCs) by performing match filtering [10].

However, the OCDMA system network capacity is limited and spectral efficiency is low [11]. The network capacity can be increased by developing a hybrid SAC-OCDMA over WDM scheme. This system can support more number of active users because the WDM technology offers an enormous bandwidth of optical fibers and provides multiple parallel channels at reasonable data rates [13]. Past few years many researchers proposed hybrid system using various codes [12]. However, due to complex code (e.g. frequency-hopping codes) [8], the system performance is always degraded. It is then necessary to design a hybrid system with flexible code. Accordingly, we designed a SAC-OCDMA over WDM hybrid system using Modified Double Weight (MDW) code for our study to fulfill the subscriber's demand of transmitting high data traffic for long transmission. The main reason to choose the MDW code is that this code can successfully suppress the MAI effect using the complementary subtraction technique and flexible auto cross correlation [14].

The advantages of hybrid SAC-OCDMA-WDM network can support asynchronous operation, high speed connectivity, simplified network control, flexible bandwidth management, fairness improved security and service differentiation [15]. Therefore, in this paper we proposed a low cost hybrid system for long distance transmission. Our proposed system has a superior performance as compare to conventional OCDMA system. Therefore, the proposed system would be a prospective candidate for the future optical access network. The remainder of this paper is organized as follows. In Sec II, we review MDW code construction. We discuss about detection technique in Sec III. The Sec IV shows the system architecture. Network simulation setup is shown in Sec V. Results and discussions are shown in Sec VI, and finally some conclusions are drawn in Sec VII.

II. MODIFIED DOUBLE WEIGHT (MDW) CODE PROPARTIES

TABLE 1: MATRIX CONSTRUCTION FOR MDW CODE WHEN WEIGHT (W = 4)

K \ C	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1
1	0	0	0	0	***1***	***1***	0	***1***	***1***
2	0	***1***	***1***	0	0	0	***1***	***1***	0
3	***1***	***1***	0	***1***	***1***	0	0	0	0

The MDW code is a modified version of DW code family and both DW and MDW code properties are the same except that the MDW code has a weight more than two or any even number. Since the code weight increases the signal power of the system then the signal to noise ratio (SNR) for MDW code is high [14]. The MDW code can be represented by K x N matrix. The basic matrix for MDW code with weight 4 consists of a $[3 \times 9]$ matrix. The significant

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properties of MDW code is that the ideal cross-correlation is one (λ = 1) and sometime zero (λ = 0). An example of basic matrix construction for MDW code with chip sequences is presented in Table 1, where K indicates the number of users and C indicates the column number of the codes and represents the spectral position of the chips.

The spectral position of MDW code sequence construction for four weights is shown in Table 1, where $C_{1,K}$ is the first user weight and $C_{9,K}$ for the last user. The Kth user is given as $C_{4k} = C_N$ and $C_{1K} = C_{N-1}$. The MDW code possesses numerous advantages including high efficient, easy code construction, simple encoder/decoder design, existence for every natural number n and optimized code length. The MDW code is used as SAC code of each user group in our proposed scheme and the phase cross-correlations of resulting codes will be no more than ones from the original MDW codes. The comparison of BER among different codes with respect to the number of active user is shown in Fig. 1. The system parameters are based on a number of previously published papers.

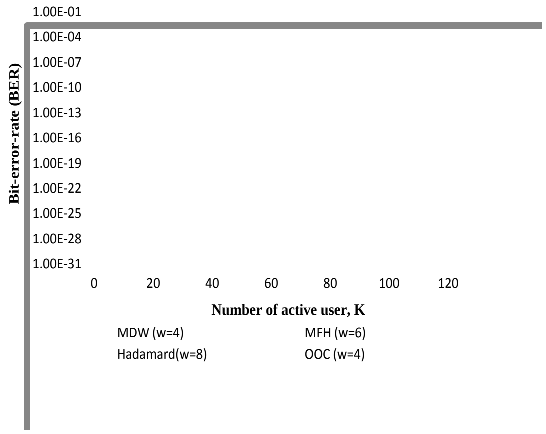


Fig. 1. Comparison of BER among different codes against number of simultaneous users at 622 Mb/s bit rate.

III. Complementary Detection Technique

The complementary subtraction detection technique is a well known detection technique, which is known as the balanced detection technique [8]. Its implementation is shown in Fig. 2, where the received signals are divided into two different complimentary branches of spectral chips. These two signals are then towards to the balanced detector that computes the difference of correlation. The cross correlations are defined as

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

where X and Y are the two OCDMA code sequences. The complementary of sequence (X) is given by ($\bar{X}$) whose elements are obtained from (X) by $\bar{X}_i = 1 - x_i$. Let X = 0011 and Y = 0110 and therefore $\bar{X}$= 1100. The periodic cross-correlation sequence between ($\bar{X}$) and (Y) is similar to Eq. (1) and is expressed as:

$$\theta_{X\,Y}(k) = \sum_{i=0}^{N-1} \bar{x}_i \, y_{i+k} \tag{2}$$

The code cross-correlation sequences are as follows

$$\theta_{XY}(k) = \grave{e}_{\bar{X}Y}(k) \tag{3}$$

The photodetectors detects two complementary inputs at the receiver. The cross-correlation output Z can be expressed as:

$$Z_{Comp} = \theta_{XY}(k) - \theta_{\bar{X}Y}(K) = 0 \tag{4}$$

There is no more cross correlation at the output of the subtractor when $Z_{Comp} = 0$ and the channel interferences between two channel are fully minimized.

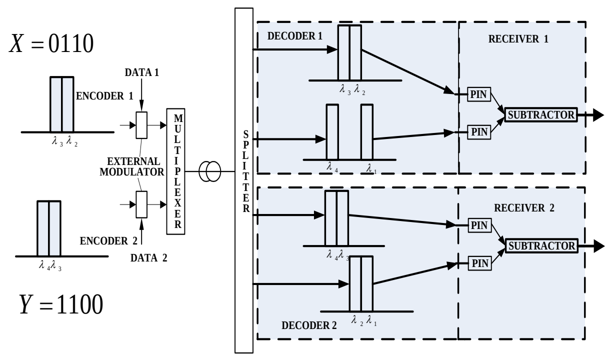


Fig. 2. Implementation of the Complementary Subtraction Technique.

IV. Proposed System Architecture

The proposed hybrid system is employing MDW code and combined with WDM channel. A simple technique has been applied for design hybrid system channel representation. For example, one WDM wavelengths will transmits signal for three OCDMA active users. The system simple block diagram is shown in Fig. 3. Both system chip has a spectral width of 0.8-nm. The Light Emitting Diodes (LEDs) is used as a broadband light source and the transmitted signal is sliced by demultiplexer into two signal. The first signal is used for OCDMA channel (4 × 4) which has been sliced by splitter and the second signal is transmitted for WDM signal. These signals are modulated by a modulator and combined using mulltiplexer. The standard single-mode optical fiber (SMF) is used for transmitting the signal to the receiver side and erbium drop amplifier (EDFA)is used for generate more power. The transmitted signal is sliced using demultiplexer to the receiver. The Fiber Bragg Grating (FBG) spectral phase decoder is used to decode the data at data sub matrix.

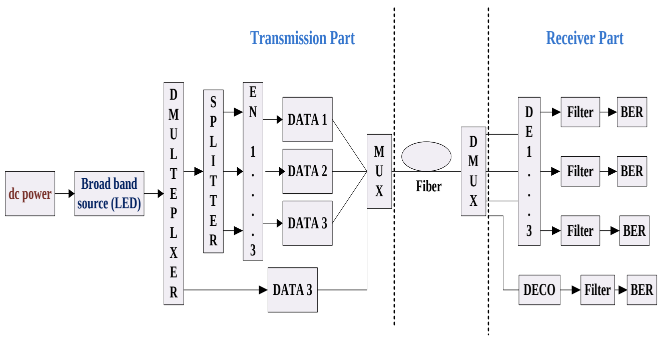


Fig. 3. Overall system block diagram of hybrid system with three OCDMA and one WDM user

In the receiver namely decoder, the complementary subtraction detection technique is used to detect the signal. The detected signal is then decoded by a Avalanche photo-detector (APD) followed by a 0.75 GHz low-pass filter (LPF) and error detector respectively. The power is transmitted between 0 to 10 dBm out from the broadband source. The random and uncurled noise is generated in the receiver side. The dark current value is 6 nA, and the thermal noise 1.8×10^{-21} W/Hz for each of the photo detectors. In the system, each user light source is assumed to be unpolarized that carries the spectrum flat bandwidth ΔV Hz.

V. Network Simulation

The simulation was carried out using simulation software, OptiSystem Version 9.0, accordance with the system architecture as shown in Fig. 3. We run the simulation on the system of 20-km ITU-T G.652 standard single-mode optical fiber (SMF) using NRZ modulation format at 622 Mb/s bit rates. All fiber parameters such as attenuation, group delay, group velocity dispersion, dispersion slop are activated during simulation. The average fiber loss is about 0.2 dBm including the splicing loss. The system insertion loss including multiplexer/demultiplexer is taken into the account 0.25 dBm and 2 dBm respectively. All fiber attenuation α (i.e., 0.25 dB/km), dispersion (i.e.,18 ps/nm km), non linear effects such as four wave mixing and self phase modulation were activated and specified according to the typical industrial values to simulate the real environment as close as possible. The erbium doped amplifier (EDFA) is used to generate the extra power with the gain at 11dB and noise figure 3.75dB. The typical system parameter listed in Table 3 were used throughout the simulation.

TABLE 2: Summary of System Parameters

Data rate of the system	622 Mb/s
Channel spacing	0.8-nm
Insertion loss	0.25 dBm
Mux/Dmux insertion loss	2 dBm
Fiber attenuation	0.25dB/km
BBS wavelength	1545-1565
EDFA gain	11dB
EDFA noise figure	3.75 dB

VI. Resutls and Discussion

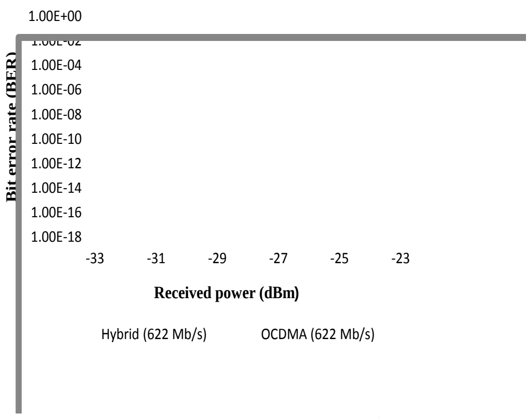
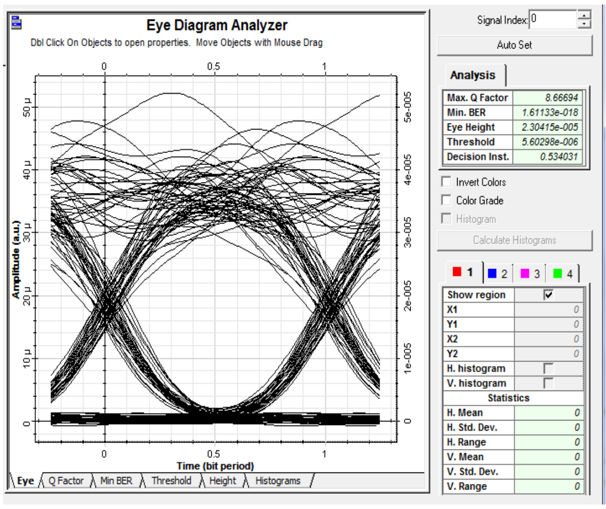


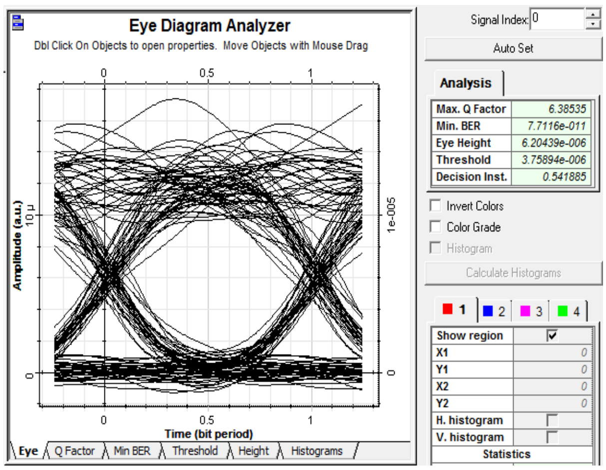
Fig. 5. Measured BER against received optical power for OCDMA-WDM and OCDMA system.

The bit-error-rate (BER) performances are evaluated for the proposed hybrid system. The comparison of BER between the proposed hybrid system and the conventional OCDMA system.

The BER performance of the hybrid system is better than the conventional OCDMA for the total length of fiber distance (60km). Fig. 5 shows the variation of measured BER against received optical power for both the hybrid system and the conventional OCDMA system. We observe that the proposed hybrid system offers better BER performance as compared to the conventional OCDMA system at various optical powers. The average received power for the first and last users of the hybrid system is about -26 dBm to -29 dBm, whereas the average received power for conventional OCDMA system is -28 dBm to -31 dBm. Although, the proposed hybrid system consumes a little bit more received power than OCDMA system and produce better signal quality, which has been ascertained from the eye diagrams as shown in Fig. 6.



(a) OCDMA-WDM system channel bit error rate (1^{-18})



(b) OCDMA channel bit error rate (1^{-11})

Fig. 6. Eye diagrams measured at 622 Mb/s

VII. Conclusion

We proposed a new hybrid OCDMA over WDM scheme using MDW code for long distance transmission (60 km). The BER performance of the system has been investigated against different received power with fixed fiber length. The signal quality of the hybrid system was also investigated using eye diagrams. It was found that the performance of the proposed system is better than the conventional OCDMA system and carry different types of data (e. g. voice and multimedia). Accordingly, the proposed system can be a promising solution for optical access networks offering flexibility, high spectral efficiency, cost effective as well as ensured security.

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