

Hybrid SAC/Optical CDMA-WDM overlay System for Enhancing Network Security

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Abstract—An enhancement of data networks security using a hybrid WDM and SAC/Optical CDMA System is proposed. Secure transmission for dedicated users is achieved by overlaying a covert channel onto a multichannel WDM network. The covert channel is spectrally encoded using spectral amplitude coding (SAC) with unipolar Modified Double Weight (MDW) as the signature address code. OCDMA improves service availability in the presence of physical infrastructure attacks. With the use of WDM channels, the difficulty for an eavesdropper to intercept and decode the secure signal is increased. A simulation is presented as a demonstration of the concept.

Index Terms—Optical fiber communications, optical networks, optical code division multiple access (OCDMA), spectral amplitude coding (SAC), wavelength division multiplexing (WDM), modified double weight (MDW).

I. INTRODUCTION

Getting more attractive concerns for some applications such as military networks and enterprise networks. Optical code-division multiple-access (OCDMA) technology allows asynchronous access to the network while providing enhanced security for both confidentiality and availability protection. Spectral amplitude coding for optical code-division multiple-access (SAC/OCDMA) scheme yields a significant reduction in the effects of multiple access interference (MAI) and therefore provides an attractive solution for burst and asynchronous environments [1].

Many codes have been proposed for the SAC/OCDMA systems, e.g., Hadamard [2], m-sequences [3], Balanced Incomplete Block Design (BIBD) [4], Modified Quadratic Convergence (MQC) [5], Modified Frequency Hopping (MFH) [6], and most recently the Double Weight (DW) code family [7]. Modified double-weight (MDW) is a DW code family variation that has variable weights of greater than two. MDW code is able to provide a much better performance compared to Hadamard and modified frequency-hopping codes [7].

OCDMA can be overlaid onto the existing WDM networks in order to expand the transmission capacity and add some additional functions in the networks such as increasing the levels of security.

Indeed, OCDMA provides an additional layer of security that can supplement data encryption by hiding the existence of data transmission underneath the public channel. Recently the hybrid WDM/OCDMA has been proposed for security and demonstrations of WDM/OCDMA transmission have been performed [8-11]. These studies were focused on hybrid WDM and Spectral-phase-coding (SPE)/OCDMA networks or hybrid WDM and Wavelength-hopping time-spreading (WHTS)/OCDMA networks. Some other studies were concentrated on hybrid WDM and SAC/OCDMA schemes [1, 12-15] without using covertness of signal transmission. Only one type of signal using laser sources with SAC/OCDMA technique was utilized. In other words, the SAC/OCDMA signals have not been overlaid with WDM signals in the same spectral region. Some other researchers [16, 17] proposed techniques using hybrid SAC/OCDMA-overlay WDM system, but complex codes such as frequency hopping have been adopted. However, the previous studies have not evaluated using hybrid Modified double-weight (MDW) code of SAC/OCDMA - WDM overlay system.

In this paper, an enhancement of data networks security using hybrid WDM and SAC/OCDMA system is proposed. The simple MDW code of SAC/OCDMA-overlay WDM channels is used. The low complexity receiver includes notch filters for the hybrid system to suppress WDM interference for detection of optical broadband CDMA signals. In this paper we evaluate the performance of our system by simulation. In the following section we give a brief description of our proposed system, followed by the simulation setup and simulation results. Finally the conclusion of the paper is provided. It should be noted that we have also shown by simulation that the eavesdropper signal can be detected.

II. SYSTEM DESCRIPTION

In a hybrid WDM-OCDMA system, the network traffic consists of narrow-band WDM signals overlaid with optical broad-band CDMA signals in the same spectral region. The main idea in the proposed system is to eliminate or attenuate the WDM signals by using notch filters. In fact a notch filter is a simplest technique among other techniques used for optical-carrier suppression [18]. Our SAC/OCDMA with unipolar Modified Double Weight (MDW) consists of a single LED source, 3 point-to-point transmission channels with 4 code

weight and 622 Mbps data rate, as shown in Fig. 1. A MDW code with weight of four denoted by $(N, 4, 1)$ for any given code length N and number of user K is given by the equations in [7]. The public WDM system setup consists of CW laser sources for 4 channels that are modulated at 2.5 Gbps for each user. The two systems are using ON-OFF keying modulation and are combined together over a single fiber link.

At the receiver side of the system, the WDM receiver consists of a narrowband-pass filter followed by O/E conversion. The SAC/CDMA receiver is based on the well known balanced receiver with notch filters designed for the hybrid system and *pin* photo detector. It is worth mentioning that the WDM network here can be an access -based (without amplifiers), metro-based or long haul network (with EDFA amplifiers).

III. SIMULATION SETUP

The setup of the hybrid scheme illustrated in Fig. 1 has been simulated using the OptiSystem version 7 software. The MDW code sequence for the 3 users used in the simulation is $(9, 4, 1)$, while 4 WDM channels are used. The hybrid system parameters are as follows; the wavelength is 1557 nm for both techniques, the frequency spacing is 100 GHz for WDM technique, the bandwidth of filters of encoder and decoder for MDW is 0.8 nm, the fiber attenuation is 0.2 dB/km, the fiber dispersion is 17 ps/nm-km, the dispersion slope is 0.075 ps/ $\sqrt{\text{km}}$, the external modulator extinction is 30 dB, the fiber length is 20 km, the bandwidth of notch filter is 12 GHz, the dark current is 5 nA, The thermal noise coefficient of the photo detectors are 1.8×10^{-23} W/Hz and 1.8×10^{-22} W/Hz for SAC OCDMA and WDM, respectively, and the data rates used are 622 Mbps and 2.5 Gbps for SAC OCDMA and WDM, respectively. The simulation is kept as real as possible by activating all the attenuation parameters like insertion loss and nonlinearities.

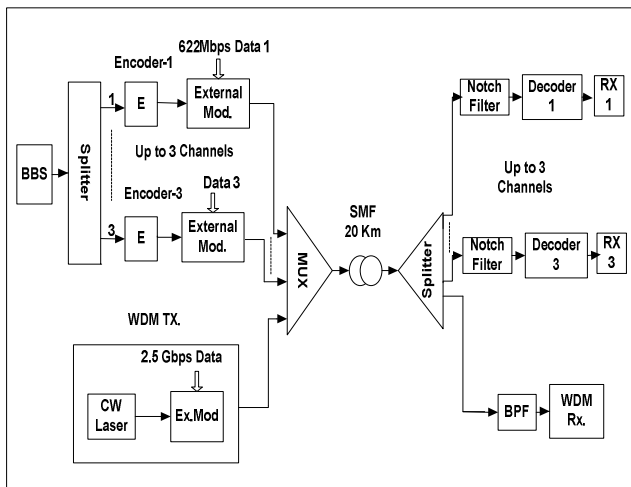


Fig. 1. Block-diagram of the hybrid system.

The combined signal is transmitted through the optical fiber link and is split into two parts, one for the receivers of SAC/OCDMA signals, composed of notch filters, match decoders and AND-subtraction techniques, and the other part is for the receiver of the WDM system, composed of narrowband-pass filters to attenuate the broad-band signal and standard receiver parts of WDM.

The first experiment is done using the previous parameters without using amplifiers while the second experiment was executed with the presence of an EDFA amplifier followed by a fiber length of 80 km, as shown in Fig. 2. The parameters of the EDFA amplifier are 20 dB, 10 dBm and 4 dB for gain, power, and noise figure, respectively.

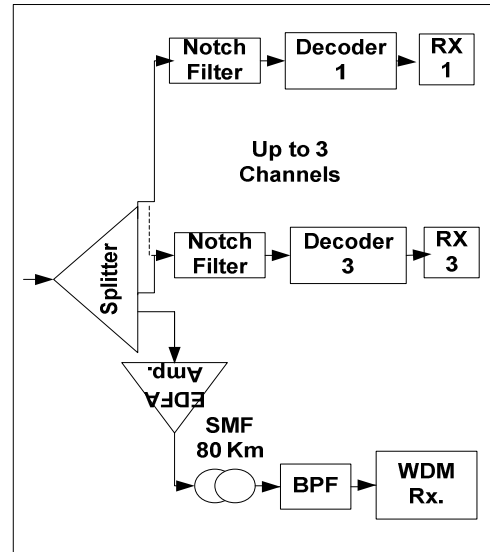


Fig. 2. EDFA amplifier for WDM network.

Fig. 3 shows the eavesdropper's receiver is based on observing the authorized transmitted signal based on the decoder which is the same as the user's decoder. But the eavesdropper does not have the notch filter as the authorized user has. Therefore, the combined signal has passed through the receiver of the eavesdropper.

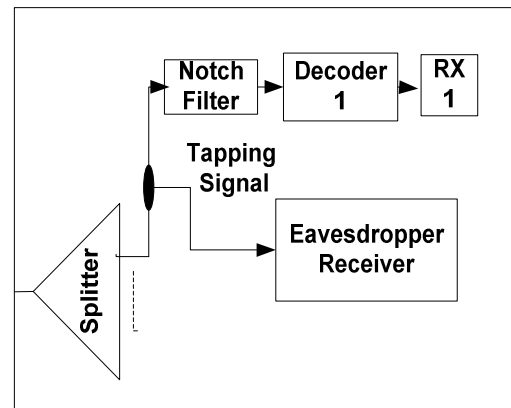
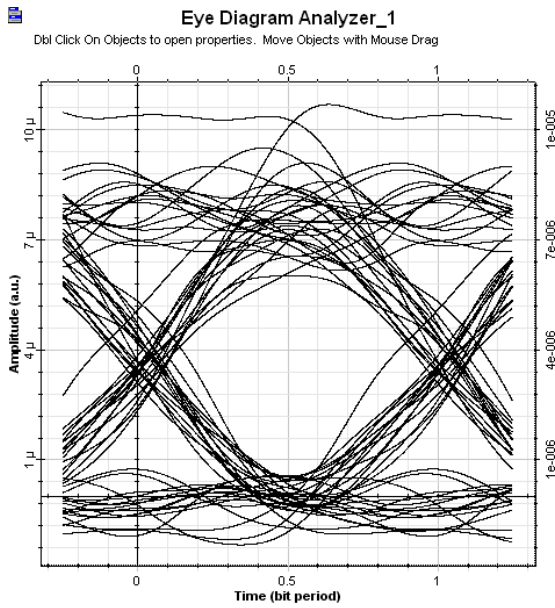


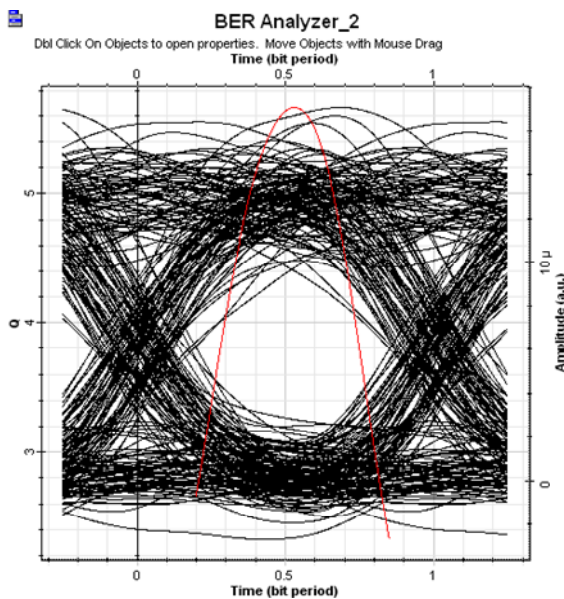
Fig. 3. Eavesdropper intercepting authorized user's signals.

IV. SIMULATION RESULTS

The performance of the system is evaluated using both the eye Diagram and the Bit Error Rate (BER). Fig. 4(a) and (b) show the Eye Diagram for the hybrid system that has 622 Mbps bit rate for SAC/OCDMA and 2.5 Gbps bit rate for WDM. The distance was set at 20 km and no amplifiers were used in the WDM network. BER values of 1.7×10^{-8} and 7.4×10^{-9} for user 1 of SAC/OCDMA and WDM respectively is obtained from the simulation experiment. BER values for other users are nearly the same. It is obvious these results from the hybrid system are less efficiency than the non-hybrid's results. This is because there are no overlapping signals between the separate networks and some effects such as the effects of multiple bit rates were not considered.



(a)



(b)

Fig. 4. Eye-diagrams for the hybrid system. (a) user 1 of SAC/OCDMA (b) user 1 of WDM.

Next, the EDFA amplifier and 80 km fiber length were added to the WDM network, as shown in Fig. 2. Results of the eye-diagram for user 1 in the WDM network is displayed in Fig. 5 where the BER is valued at about 4.8×10^{-18} .

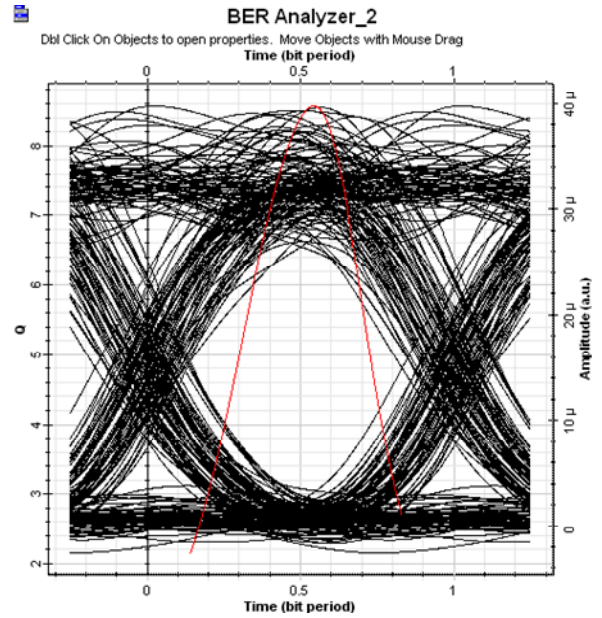


Fig. 5. Eye-diagram for user 1 of WDM network after EDFA amplifier and 80 km distance.

Fig. 6 shows the eye-diagram for the eavesdropper interceptor which has a bad performance with BER of 7.2×10^{-3} . This is the worst case result for the authorized user assuming that the eavesdropper used the same decoder as the authorized user. In other words, if the eavesdropper used a particular code interceptor based on classical detection theory, the BER will increase. Hence, it has been proven that the eavesdropper will never know the authorized user's signal using a SAC/OCDMA-WDM overlay scheme. In comparison, a network which uses the SAC/OCDMA scheme only will allow the eavesdropper to tap the authorized user's signal with much success.

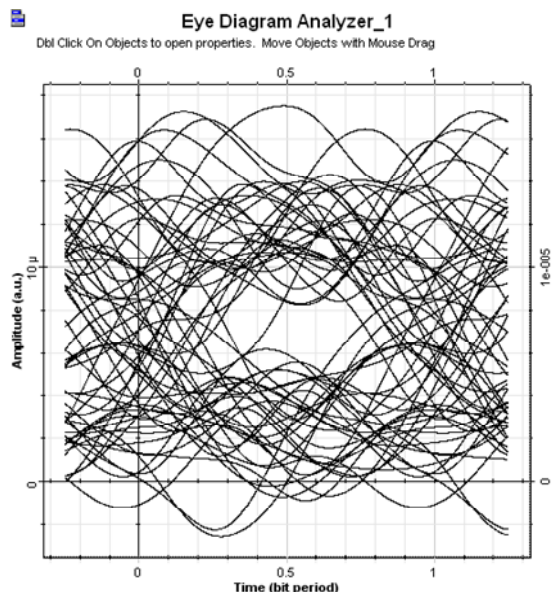


Fig. 6. Bad signal in the eye-diagram for the eavesdropper interceptor.

V. CONCLUSION

The proposed SAC/OCDMA–WDM overlay scheme provides enhanced data confidentiality compared to SAC/OCDMA only scheme. The separation process between different techniques with various data rates is presented and the design parameters are illustrated for simulation. The performance and enhancing security of the hybrid system is investigated by measuring both the bit-error-rates (BERs) and Eye-diagrams. An enhancement of data networks security can be increased for this system by using long transmitted code and many channels from WDM transmitter.

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