Hybrid Subcarrier Multiplexed Spectral-Amplitude-Coding Optical CDMA System Performance for Point-to-Point Optical Transmissions

R. K. Z. Sahbudin[1*], M. K. Abdullah[1], M. D. A. Samad[1], M. A. Mahdi[1] and M. Ismail[2]

[1]*Department of Computer and Communication Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia*

[2]*Department of Electrical, Electronics and Systems, Faculty of Engineering, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia*

**Corresponding author. E-mail: ratna@eng.upm.edu.my*

ABSTRACT

A hybrid subcarrier multiplexed spectral-amplitude-coding optical code-division-multiple-access (SCM SAC-OCDMA) system is presented. This hybrid system is proposed for the purpose of combining the advantages of both techniques. The SCM technique is used because of its ability to enhance the channel data rate of OCDMA system. SAC-OCDMA is employed because of its ability to eliminate the multiple-access interference (MAI) when code sequences with fixed in-phase cross correlation are used. The system utilizes modified double-weight (MDW) code which is of a double-weight (DW) code family variation that has variable weight of greater than two. The performance of the hybrid system using MDW code to support point-to-point transmission, is shown through experimentally-simulated results of signal-to-noise ratio (SNR) and eye patterns for data rate of 155Mbps with various numbers of channels.

Key words: Hybrid SCM SAC-OCDMA, Multiple access interference, Modified double weight code, Subcarrier multiplexed

INTRODUCTION

In SCM system, the information signals are modulated onto different electrical carriers at radio or microwave frequencies and combined. The resulting signals are then used to modulate the intensity an optical carrier. At the receiver end, the optical signal is converted back to an electrical current by a photodetector. The particular signals can then be demultiplexed and demodulated, using conventional methods. The attractive feature of SCM is the independence of the different channels. This allows for great flexibility in the choice of modulation schemes. In addition to being flexible, the current SCM technology is also cost-effective as it provides a way to take advantage of the multi-gigahertz bandwidth of the fiber optics, using well-established microwave techniques for which components are commercially available. Furthermore, it is less expensive than the corresponding WDM technology (Thomas and Bala, 1999).

OCDMA are getting more attractive as multiple users can access the network asynchronously and simultaneously with a high level of transmission security (Wei and Ghafouri-Shiraz, 2002a). In the early days, incoherent OCDMA systems used pseudo-orthogonal sequences to encode signals in the time domain but the codes were too long and MAI limited the number of simultaneous users. MAI is the main factor for performance degradation in OCDMA system, especially when large numbers of users are involved. Therefore, SAC-OCDMA system was proposed because of its ability to eliminate the influence of MAI by using codes with fixed in-phase cross correlation (Djordjevic et al., 2004). Several code families that can be used in SAC-OCDMA systems are modified quadratic congruence codes (MQC) (Wei et al., 2001), M-sequence codes (Pearce and Aazhang, 1994), modified frequency hopping (MFH) (Wei and Ghafouri-Shiraz, 2002b), modified double-weight codes (MDW) (Aljunid et al., 2004), and etc. A code with length N, weight W and in-phase cross correlation λ can be denoted by (N, W, λ). The ability to totally suppress the MAI is due to the employment of subtraction techniques for codes with ideal in-phase cross correlation, λ=1 (Smith et al., 1998). Hence the purpose of combining SCM with SAC-OCDMA system is to combine the advantages of both techniques and it also allows for more effective use of available bandwidth.

In this study, the experimental simulation results for a point-to-point optical transmission of the hybrid SCM SAC-OCDMA system are presented.

THE CONFIGURATION OF SCM SAC-OCDMA FOR POINT-TO-POINT SYSTEM

This section describes the hybrid of SCM SAC-OCDMA for the point-to-point system. The simplest kind of lightwave systems is point-to-point links. The signals are transported from one place to another. The transmission distance can vary from less than a kilometer to thousands of kilometers.

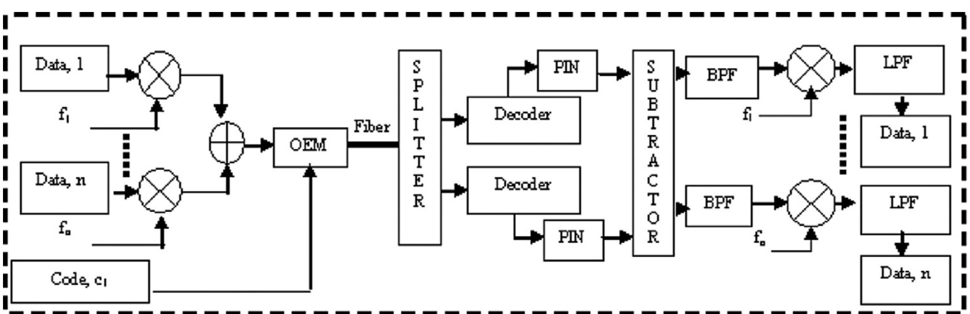

Figure 1. A block diagram for one code of hybrid SCM SAC-OCDMA system.

Figure 1 illustrates the block diagram of the system. The data signals multiply with the assigned subcarrier signals and then modulated the signals with a distinct codeword, using the optical external modulator (OEM). The received optical signals are decoded and converted to electrical signals which then are filtered and demodulated accordingly to recover the original data. The data are protected by the difference in either the codes or the subcarrier frequencies. Each filter only corresponds to the desired data tuned to its center frequency and with a matching code. Other signals are rejected. Therefore, the hybrid scheme is robust against interference and is more spectrally -efficient.

Generally there are two basic detection techniques, namely, coherent and incoherent. A system that consists of bipolar codewords is called a coherent system whereas a system that uses unipolar sequences in the signature code is called incoherent system. Incoherent detection has a less hardware complexity compared to coherent detection because it does not need phase synchronization. In this study, the incoherent detection using subtraction techniques is used.

EXPERIMENTAL SIMULATION SETUP

The hybrid system is designed and simulated, using OptiSystem Version 4.1 which is widely used for optical fiber simulations. The simulation was carried out for MDW which is another variation of a DW code family. MDW with weight=4 consists of [3 x 9] matrix and can be represented as (9, 4, 1) where N=9, W=4, and λ=1. The bit rate of each channel is 155 Mbps (STM-1). The ITU-T G.652 standard single-mode optical fiber without any amplifier is employed for a point-to-point optical transmission. The subcarrier frequencies are set at $\geq$ 2 times bit rate and equal channel spacing of 310 MHz. Each chip has a spectral width of 0.8nm. Positive-intrinsic-negative (PIN) photodiodes are used to convert the optical signals to electrical signals. The attenuation and dispersion were set at 0.25dB/km and 18ps/nm-km, respectively. The nonlinear effects were activated and specified according to the typical industry values to simulate the real environment as close as possible. The performances of the system are characterized by referring to the SNR and eye patterns.

RESULTS AND DISCUSSION

A study on SNR performance is carried out against the transmission distance. The results for 2 and 10 subcarriers are shown in Figure 2. It can be seen that SNR decreases as the transmission distance increases. The dispersion and attenuation increase as the optical fiber length increases, thus decreasing the SNR. The results show that the system can perform well and amplifiers or repeaters can be used for longer transmission distances.

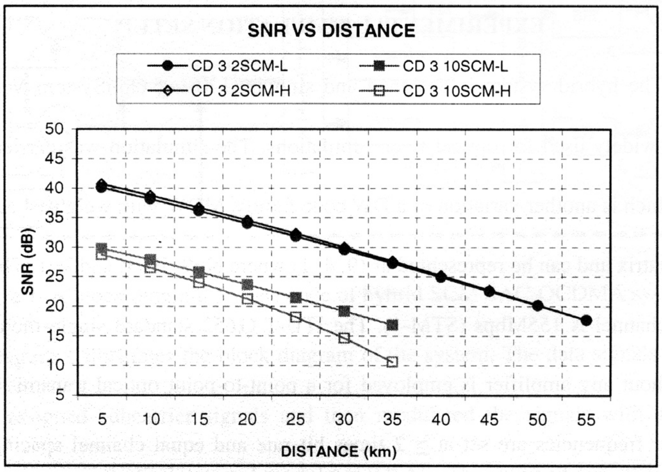

Figure 2. SNR vs distance for hybrid SCM SAC-OCDMA taken at the third code for lowest and highest subcarrier frequencies.

Figure 3 shows the effect of variation of transmitted input power on the system performance, taken at the first code for lowest and highest subcarrier frequencies. The distance of the optical fiber is set at 30km. It is expected that SNR will increase with increase of input power.

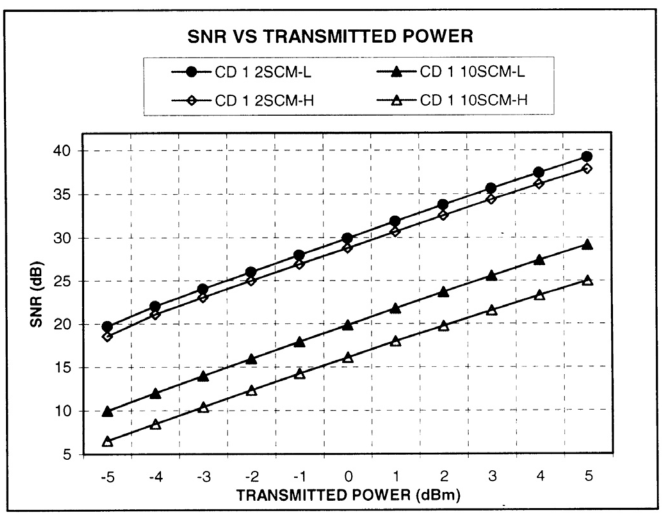

Figure 3. SNR vs Transmitted Power for hybrid SCM SAC-OCDMA taken at the first code for lowest and highest subcarrier frequencies.

Figure 4 and 5 depict the eye pattern of the received signal corresponding to BER 6.39e-21 and 1.66e-12, respectively. The total transmission rate for 10 subcarriers is 10 x 155Mbps x 3SAC-OCDMA = 4.65Gbps. As expected, the transmission quality for the system with 10 subcarrier frequencies suffer a little degradation when compared to the system with 2 subcarrier frequencies. The eye opening is smaller as the number of subcarrier is increased.

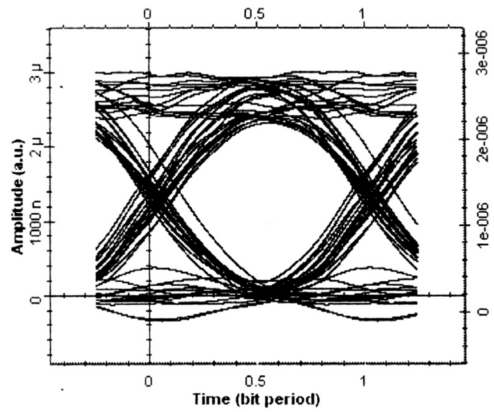

Figure 4. Eye pattern generated for hybrid SCM SAC-OCDMA at 50km with input power 5dBm taken at the first code for 2 subcarrier frequencies.

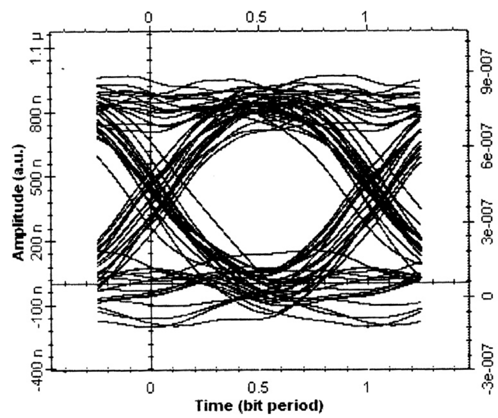

Figure 5. Eye pattern generated for hybrid SCM SAC-OCDMA at 50km with input power 5dBm taken at the first code for 10 subcarrier frequencies.

CONCLUSION

This paper presents the performance of the optical fiber link for the hybrid SCM SAC-OCDMA system. The results show the successful transmission of the hybrid system for 2 and 10 subcarriers without using any amplifier. This study proves the ability of a hybrid SCM SAC-OCDMA system to support high transmission rate with high level of security. The number of users can be easily increased by adding more subcarriers without increasing the number of SAC-OCDMA codes and the code length. The overall system cost can also be reduced as radio frequency or microwave components required are matured and often readily available. Thus, it can be concluded that the hybrid system offers a great potential as a flexible and powerful technique.

REFERENCES

Aljunid, S. A., M. Ismail, A. R. Ramli, B. M. Ali, and M. K. Abdullah. 2004. A New Family of Optical Code Sequences for Spectral Amplitude-Coding Optical CDMA Systems. IEEE Photonic Technology Letters 16(10):2383-2385.

Djordjevic, I. B., B. Vasic, and J. Rorison. 2004. Multi-weight Unipolar Codes for Multimedia Spectral-Amplitude-Coding Optical CDMA Systems. IEEE Communications Letters 8(4):259-261.

Pearce, M. B., and B. Aazhang. 1994. Multiuser Detection for Optical Code Division Multiple Access Systems. IEEE Transactions on Communications 42:1801-1810.

Smith, E. D. J., R. J. Blaikie, and D. P. Taylor. 1998. Performance Enhancement of Spectral Amplitude-Coding Optical CDMA using Pulse Position Modulation. IEEE Transactions on Communications 46(9):1176-1184.

Thomas, T. E., and K. Bala. 1999. Multiwavelength Optical Networks: A Layered Approach. Addison Wesley Longman.

Wei, Z., H. Ghafouri-Shiraz, and H. M. H. Shalaby. 2001. New Code Families for Fiber-Bragg Grating-Based Spectral Amplitude Coding CDMA Systems. IEEE Photonic Technology Letters 13(8):890-892.

Wei, Z., and H. Ghafouri-Shiraz. 2002a. Codes for Spectral-Amplitude-Coding Optical CDMA Systems. IEEE Journal of Lightwave Technology 20(8): 1284-1291.

Wei, Z., and H. Ghafouri-Shiraz. 2002b. Proposal of a Novel Code for Spectral Amplitude Coding Optical CDMA Systems. IEEE Photonic Technology Letters 14(3):414-416.