Spectral Amplitude Direct Decoding OCDMA System Using High Power LED Source with MDW Codes at 2.5 Gbps

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Abstract- This paper describes an experimental of 2.5 Gbps two users spectral-amplitude-coding optical code-division-multiple-access (SAC-OCDMA) system with spectral amplitude direct decoding technique using high power LED source. The optical coding is based on modified double weight (MDW) codes employing fiber Bragg grating encoder. A tunable bandpass filter decoder is tuned with a proper design on the basis of the correlation between the two users to totally eliminate the multiple access interference. Some preliminary experimental results as well as the transmission performances are presented in this paper.

Index Terms- Optical-code-division multiple access (OCDMA), modified double weight (DW) code, multiple access interference, spectral amplitude direct decoding.

I. INTRODUCTION

Optical code-division-multiple-access (OCDMA) technique was adapted from the successful implementation in the wireless networks. CDMA technique allows multiple users to access the channel with zero waiting time provided that the destinations are different. However theoretical analysis of OCDMA systems has shown that multiple access interference (MAI) is the main reason that degrades the performance of the system especially when a large number of users are involved [1]. Consequently, spectral-amplitude-coding optical code-division-multiple-access (SAC-OCDMA) technique was introduced as the effect of MAI can be completely eliminated when the code sequences with fixed in-phase cross correlation are used [3]. This elimination is realized by using balanced detection [1,4]. Nevertheless, the performance of the system is still limited by the phase-induced intensity noise (PIIN) [6,4]. The effect of PIIN is proportional to the square of photocurrent and the system performance cannot be improved by simply increasing the received optical power [2]. Hence, a detection technique named as spectral amplitude direct decoding technique is proposed to suppress the effect of PIIN.

In this paper we present a preliminary experiment on the SAC-OCDMA system using MDW code [4]. A high power LED source is used and encoded according to the MDW code. The transmission of the data is 2.5Gbps. The proposed detection technique is capable of completely avoiding both MAI and PIIN effects. The principles of the technique and the condition required for the codes and its application will be explained subsequently.
II. SPECTRAL AMPLITUDE DIRECT DECODING DETECTION

Fig. 1 depicts the implementation of spectral amplitude direct decoding detection for OCDMA system. The property of spectral amplitude direct decoding technique is different from complementary subtraction. This system consists of two sets of encoders, tunable decoders followed by receivers. Only two filters are required for the decoder, each for $\lambda_2$ and $\lambda_4$. The purpose of this setup is to eliminate the MAI between signals of user 1 and user 2. The intended signal is filtered using the corresponding decoder. No subtractors are needed at the receivers. Interestingly, this technique has successfully eliminated the MAI because only the intended signal spectral chips in the optical domain are filtered. It is possible because the code properties possess one uncorrelated signal chip that contains the information for each of the users. Due to that, the effect of PIIN is suppressed at the receiver. Consequently, this will improve the system performance.

Although MAI can be eliminated using this technique, it is only applicable to codes with fixed in-phase cross correlation. Many of the reported codes such as MQC [5], MFH [1], and MDW [4] possess this property.

![Implementation of spectral amplitude direct decoding technique.](image)

III. EXPERIMENTAL SETUP AND RESULTS

The setup was dictated mainly by availability of equipment. The experiment provides some preliminary insight into the SAC-OCDMA system performance. A block diagram of the experimental setup is shown in Figure 2. A high power broadband LED is employed because we can generate more users by encoded the spectrum of its broadband source. The center wavelength of the spectral must be carefully designed and encoded in order to maintain the orthogonality between users. The broadband LED source signal is split and encoded according to the MDW code by two separate encoders, representing user 1 and 2, respectively. Then, the spectral amplitudes are modulated with OOK data using optical external modulator. All the spectral chips are then will be combined and amplified before they are fed into the 20km fiber spool. A tunable bandpass filter is used to spectrally decode the signal in order to recover the user’s original information data. Both users are independently data modulated.

A fiber grating is employed as an encoder 1 as shown in Fig. 2. It is used to spectrally encode the broadband LED source into $N$ component chips with centered wavelengths ($\lambda_1$, $\lambda_2$, $\ldots$, $\lambda_N$). User 1 is assigned with signature $X_{T1} = (1, 1, 0, 1, 1)$ of central wavelength $\lambda_1$, $\lambda_2$, $\lambda_4$ and $\lambda_5$ and user 2 is assigned with signature $X_{T2} = (0, 0, 1, 1, 0)$ of central wavelength $\lambda_3$ and $\lambda_4$. The received spectral for user 1 and user 2 must have signature code of $X_{R1} = (0, 0, 0, 1, 1)$ and $X_{R2} = (0, 0, 1, 0, 0)$, respectively which is the uncorrelated signature for both users. Therefore a tunable bandpass filter is used as a decoder to decode the uncorrelated signature before the spectral are detected by the photodetector.
At the transmitter, the power of the LED source is set at 23.38 dBm. The data rate of 2.5-Gbps, consisting of $2^{31} - 1$ pseudorandom bit sequences (PRBS). The choice of this data rate was dictated by the availability of hardware for this experiment. Furthermore, the pulse coding scheme used is NRZ (Non Return Zero).

The end-to-end BER measurements as a function of the received optical power for both users are shown in Fig. 3. The bottom curve corresponds to the encoded signal connected directly to the decoder and followed with STM-16 receiver. We observed that the performance of the system degraded due to the losses of the devices and the fiber.

Fig. 4 shows the performance of the system as a function of the received optical power for two users and one user. It is observed that the performance of the system has not caused significant deterioration as the number of user is increased. The system performance of more than 2 users strongly depends on the losses in the system and the ability of the receiver filters to filter out the noises and decode the intended user signature. The eye pattern properly decoded for user 1 clearly demonstrates the ability to properly decode the desired user and separate it from the MAI.

The optical spectrums for user 1 and user 2 are shown in Fig. 5 (a) and (b), respectively. The combined spectrums from both encoders are shown in Fig. 5 (c).
V. CONCLUSIONS

This paper describes the proposed spectral amplitude direct decoding technique, hardware implementation issues and measured transmission performance. The advantage of this SAC-OCDMA system using spectral amplitude direct decoding technique is that the transmitted signal can be recovered without the interference of other users. This technique also requires less number of filters in the decoder. Thus, the total power loss and complexity can be reduced. However, this system is vulnerable to higher bit rate and longer transmission distance. Other factors that influence the performance are due to all implementation inaccuracies as well as interfering signals. Efforts are currently underway to investigate the performance of SAC-OCDMA system under this detection technique with higher number of users with high power broadband source.

REFERENCES


