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Performance of OCDMA Systems with Different Detection Schemes Using Enhanced Double Weight (EDW) Code

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***Abstract*— This paper investigates the performance of enhanced double weight (EDW) code for spectral-amplitude-coding optical code division multiple access (SAC-OCDMA) system using different detection techniques. EDW code is the enhanced version of modified double weight code. Enhanced double weight code possesses ideal cross-correlation properties and weight can be any odd number which is greater than one. The experimental simulation results as well as the transmission performances are presented in this paper.**

Index Terms— OCDMA; EDW; Detection technique

I. INTRODUCTION

THE primary goal of the design of the OCDMA systems is the data extraction by a user in the presence of other users or in other words, the presence of multiple access interference (MAI). MAI is the dominant source of deterioration in an OCDMA system; therefore, a good design of the code sequences and detection scheme is important to reduce the affect of MAI [1].
The existence of multiple users accessing the same medium, at the same time and frequencies to transmit their data streams concurrently in the OCDMA systems will produce MAI. This is a dominant source of deterioration in an OCDMA system as a good design for the sequences of codes and detection scheme is crucial in minimizing the negative effects of the MAI. Nevertheless, Lei et al. [2] and Jen-Fa et al. [3] suggest that MAI can also be minimized using the subtraction techniques, which can be done at the detection system. Several detection techniques were proposed by many researchers [4-12], most of these researches [4-9] uses complementary subtraction technique, AND subtraction technique [10], the spectral direct detection technique (SDD) [11] and XOR subtraction detection [12]. In this paper, we will compare the complementary technique with spectral direct detection (SDD) technique; we will discuss in details the effect of distance, bit rate, and input power to the optical CDMA system. It will be observed that the performance of the OCDMA system using direct detection technique is better BER at the same bit rate as compared to that of complementary subtraction technique. Enhanced Double Weight (EDW) code [13] was used in the study.

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II. REVIEW OF EDW CODE

EDW code [13] is the enhanced version of Modified Double Weight MDW [14-15] code. The MDW code weight can be any even number that is greater than two while the enhanced double weight EDW code weight can be any odd number greater than one.

EDW code can be represented by using a $K \times N$ matrix. In EDW codes structures, the matrix K rows and N columns represent the number of users and the minimum code length respectively. In this paper, the EDW code with the weight of three is used as an example. The basic EDW code denoted by (6, 3, 1) is shown below

$$H_1 = \left| \begin{array}{cc|cc|cc} 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \end{array} \right| \tag{1}$$

From the basic matrix, a larger value of K can be achieved by using a mapping technique as shown in Equation 2.

$$H_2 = \begin{bmatrix} 0 & H_1 \\ H_1 & 0 \end{bmatrix} \tag{2}$$

EDW codes have the subsequent properties: ideal maximum cross-correlation $\lambda_{max} = 1$, EDW code weight, which can be any odd number greater than one, the weight pair structure maintained, the chip combination is maintained 1, 2, 1 for every consecutive pairs of codes, and the relation between the number of users K and code length N at weight of 3 is given by:

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$$N = 2K + \frac{4}{3}\left[\sin(\frac{K\pi}{3})\right]^2 \left[\frac{8}{3}\left[\sin(\frac{(K+1)\pi}{3})\right]^2 + \frac{4}{3}\left[\sin(\frac{(K+2)\pi}{3})\right]^2\right] \qquad (3)$$

III. Experimental Simulation Result

A simple schematic block diagram consisting of 2 users is illustrated in Figures 1 and 2 as an illustrative example (the study was carried out for 3 users). Each chip has a spectral width of 0.2nm. The tests were carried out using Optisys, an established commercial software at the rates of 2.5 Gbps and 10 Gbps for 10 km to 60 km.

The fibre used had the values of parameters taken from the data which are based on the G.652 Non Dispersion Shifted Fibre (NDSF) standard. This included the attenuation, group delay, group velocity dispersion, dispersion slope and effective index of refraction, which were all wavelength dependent. The non-linear effects such as the Four Wave Mixing and Self Phase Modulation (SPM) were also activated. At 1550 nm wavelength, the attenuation co-efficient was 0.25 dB/km, and the chromatic dispersion co-efficient was 18ps/nm-km and the polarization mode dispersion (PMD) co-efficient was 5 ps/√km. The transmit power used was 0 dBm out of the broadband source. The noises generated at the receivers were set to be random and totally uncorrelated. The dark current value was 5 nA and the thermal noise co-efficient was 1.8×10-23 W/Hz for each of the photo-detectors. The performance of the system was evaluated by referring to the bit error rate, output power.

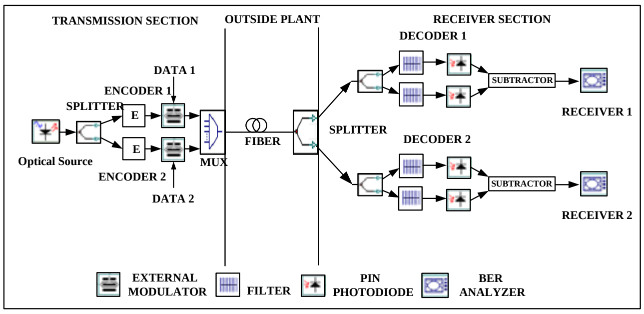

Fig. 1. Simulation setup for the OCDMA system with complementary technique.

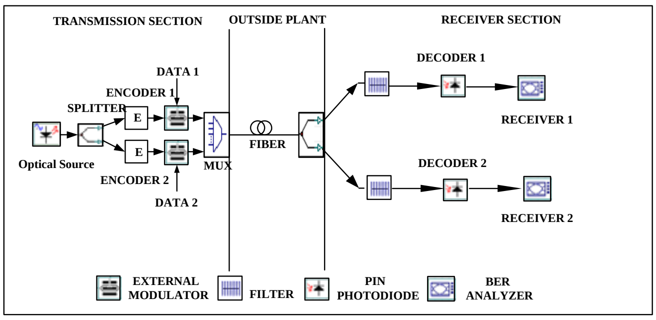

Fig. 2. Simulation setup for the OCDMA system with direct technique.

Figure 1 shows that the incoming signal was split into two parts at the receiver side, one to the decoder that had an identical filter structure with the encoder and the other to the decoder that had the complementary filter structure. A subtractor was used to subtract the overlapping data from the desired one. In Figure 2, no subtractors are needed at the receivers.

Figure 3 shows the the result for the direct detection technique shows better BER at the same bit rate as compared to that of the complementary subtraction technique. For example, by using BER of 10-12 as the transmission quality cut-off, it was found that the system using complementary subtraction technique could perform well up to 12 km only at STM-16 rate as compared to the direct detection technique which still gives excellent performance at the distance of 38 km. The performance of the direct technique is evident at all rates with supportable distance double of that supported by the conventional technique.

Figure 4 shows that the noise power for the complementary technique is higher than noise power for the direct technique at 2.5 Gbps. However, it is worth to note that the result for the complementary technique is measured up to 30 km only, because the system cannot support longer distance at acceptable BER performance.

Figure 4 shows a nearly linear reduction of the output power with distance for both direct and complementary techniques. For example, at a distance of 10 km, the output power for the direct technique is about –68.6 dBm as compared to –75.4 dBm for the complementary technique. This is about 6.8 dB higher power for the direct technique. However, the noise power for the direct technique at 10 km distance as shown in Figure 5.7 is about –101.7 dBm. This gives the optical signal to the noise ratio (OSNR) about 33.1 dB (OSNR = Output Power – Noise Power). For the complementary technique, the OSNR is 23 dB only. It should be noted that the result for the direct technique, the power loss can be reduced so the distance can be extended, and the total power loss for the direct technique can be reduced because of the lesser number of filters used in the decoder.

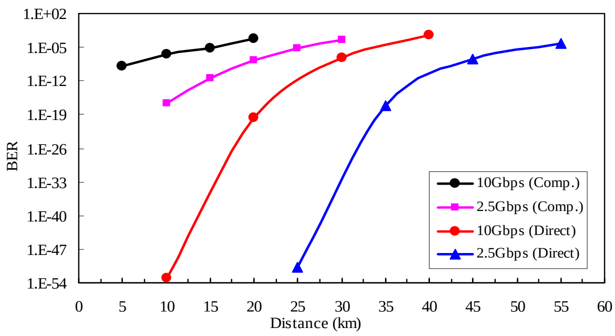

Fig. 3. BER versus distance for the OCDMA system using complementary and direct techniques at different transmission rates.

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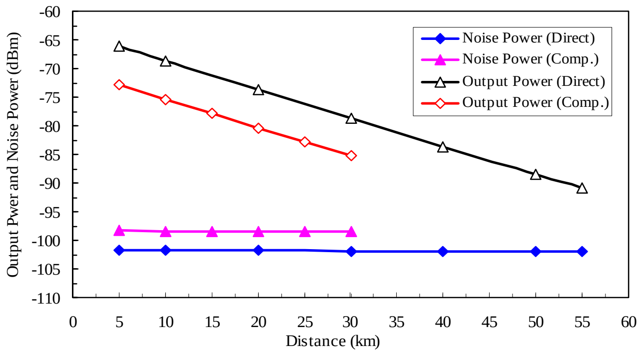

Fig. 4. Noise Power and Output Power versus Distance for Different Technique.

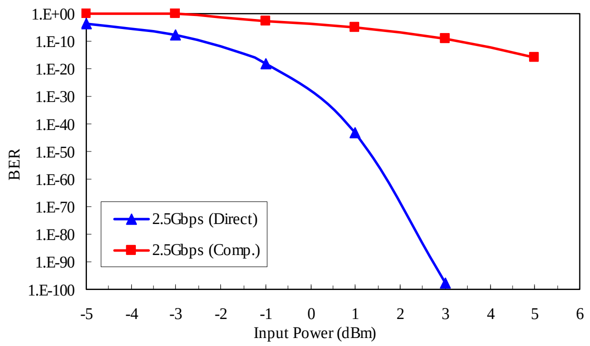

Fig. 5. BER versus input power for the different techniques.

Figure 5 shows that increasing the input power from -5 dBm to -3 dBm for techniques, there are small improvement in the performance of the system, while increasing the input power from -3 dBm to 3 dBm, the performance of the system using the direct technique improves significantly. However, the system with complementary technique gives small improvement in the performance as clearly shown.

IV. Conclusion

In this paper, subtraction and direct optical detection techniques based on the EDW code were studied to improve the optical code division multiple access (OCDMA) system performance. It has been shown through simulation that the BER performance of the OCDMA system using direct detection technique is better at the same bit rate as compared to that of complementary subtraction technique.

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