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SAC- OCDMA System Using Different Detection Techniques

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Abstract : *In this paper, we investigate the optimum received power for spectral amplitude coding optical code division multiple access (SAC-OCDMA) at different transmission distances using modified-AND subtraction detection technique and single photodiode (SPD) detection technique. We also investigate the effect of avalanche photodiode (APD) gain on the received power. Simulation results show that: 1) the received power decreases while the bit error rate (BER) increases with the transmission distance, and 2) both the received power and the BER increase with the APD gain for the same transmission distance.*
Keywords: *APD, modified-AND subtraction detection technique, phase induced intensity noise (PIIN), SAC-OCDMA, SPD*

1. INTRODUCTION

Recently, optical code division multiple access (OCDMA) technique is getting more attractive due to its several features as its ability to support asynchronous access, bursty traffic, secure transmission and effective cost [1, 2]. The main drawback of OCDMA is that its performance and capacity are limited by multiple access interference (MAI) [3, 4]. Researchers proposed spectral amplitude coding (SAC) from all types of OCDMA due to its ability in restrain MAI when using a suitable detection technique at the receiver with fixed in-phase cross correlation codes [5]. Low cost broadband sources such as light emitting diodes (LEDs) can be used for SAC-OCDMA system. However, the performance of SAC-OCDMA is still limited by phase induced intensity noise (PIIN) that results from using broadband light sources [6]. Modified-AND subtraction detection technique and SPD detection technique are used for reducing PIIN and MAI [7].

In this work, enhanced double weight codes (EDW) are used as the signature codes for SAC-OCDMA systems with modified-AND subtraction detection and SPD detection techniques when APDs are used.

The remainder of this paper is organized as follows. In Sec 2, we give a detailed explanation about the detection techniques, followed by the network simulation setup in Sec.3. Section 4 is devoted for the results and discussion. Finally, the conclusion of the paper is provided in Sec.5.

II. DETECTION TECHNIQUES

2.1 MODIFIED-AND SUBTRACTION DETECTION

The SAC-OCDMA receiver diagram of this technique is shown in Fig. 1 [7]. The received optical signal is split by splitter 1 into two parts, one to the upper decoding branches and the other to the AND decoder through an attenuator. The attenuator ensures that, the interference signal has an equivalent power incident on each photo detector in the case of an inactive user. The decoder filters are placed in a parallel configuration. This structure divides the spectrum of the decoded signals. It is worth to note that, both splitters (1 and 2) and the attenuator could be replaced by a single coupler with an appropriate coupling ratio in order to get a more cost-effective receiver. The decoder has a spectral response matched to the active user, whereas the AND decoder has overlapped bins from different interferers. These overlapped bins can be represented mathematically by AND operation between the active user and interferers [8]. This technique can be performed using the inexpensive fiber Bragg-gratings (FBGs) to decode the received signal because of their low insertion losses, good spectral resolution, small size, and light weight [10]. The photo detector is composed of two photodiodes (PD and s-PD) which are connected electrically in opposition. The output signal is proportional to the power difference of the two optical inputs. In the presence of an interferer, the difference between the two signals is cancelled out. The output signal is then low-pass filtered to reduce the out-of-band high-frequency noise. After the decision circuit, the original data is restored.

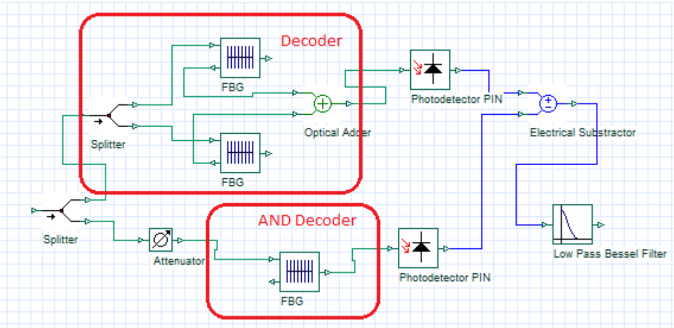


Figure 1 Modified-AND subtraction detection.

2.2 SINGLE PHOTODIODE DETECTION

The structure of SAC-OCDMA receiver diagram using EDW code is illustrated in Fig. 2 [10]. The incoming signal is decoded using the same spectral response of the encoder for. The decoder detects *w* power units (P.U.) for active user or λ P.U. for interferers, where the weight *w* represents the number of occupied frequency bins in the user's encoder, and the in-phase cross-correlation λ is the maximum number of common frequency bins occupied by any two codes of the family [10]. The remainder of the signal from the decoder is then transmitted to the subtractive decoder (s-Decoder) to cancel out signals with mismatched signatures, i.e., interferers. The s-Decoder contains only frequency bins from different interferers. After optical subtraction, the output from the s-Decoder is either zero P.U. for active user or λ P.U. for interferers. This technique can be performed using low cost uniform FBGs to decode the received signal. This implies that, the interference signals are cancelled in the optical domain before the conversion of the signals to the electrical domain. As a consequence, the new SPD scheme alleviates both PIIN and MAI in the optical domain.

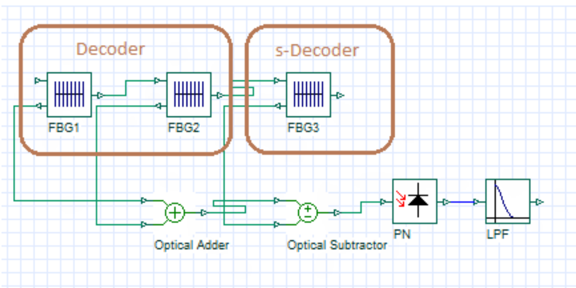
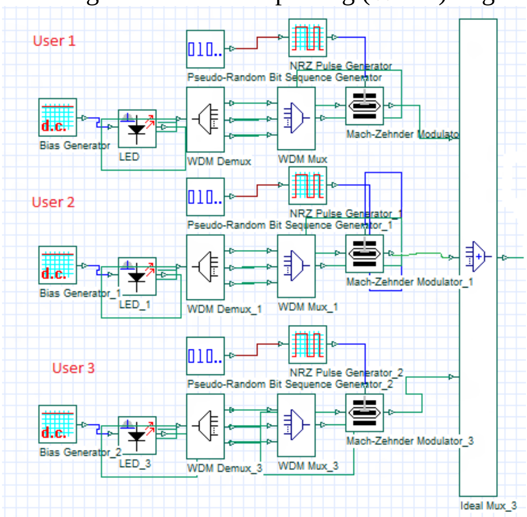


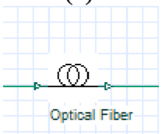
Figure 2 SPD detection

III. NETWORK SIMULATION SETUP

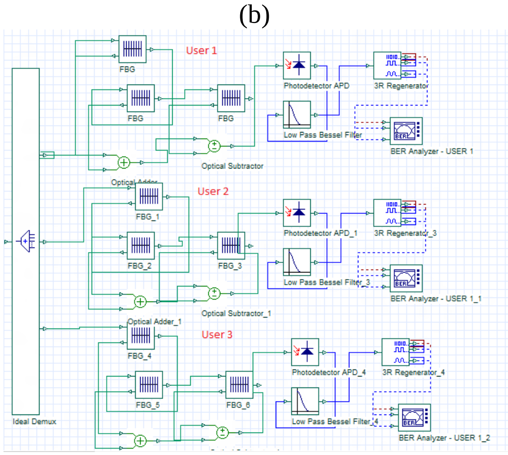
The simple schematic block diagram of three users SAC-OCDMA using EDW code with modified-AND subtraction detection and SPD detection techniques are presented in Fig.3. As indicated in Fig.3, the transmitter of the SAC-OCDMA system using EDW code consists of one LED for each user at 622 Mbps which is sliced to three wavelengths using wavelength division multiplexing (WDM) to generate the OCDMA codes.



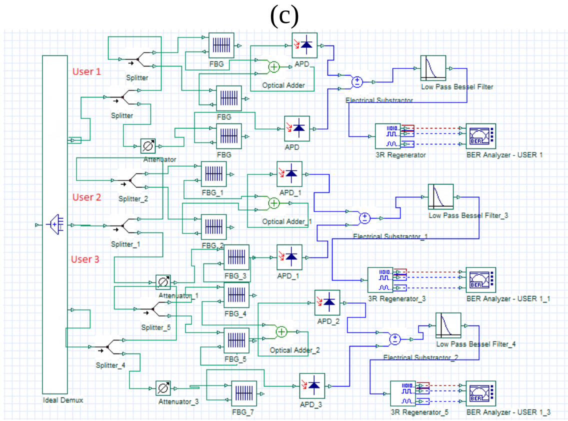
(a)



(b)



(c)



(d)

Figure 3 Block diagram of three users SAC-OCDMA (a) transmitter using EDW code (b) channel (c) receiver using SPD detection (d) receiver using modified-AND subtraction detection.

EDW codes are characterized by unity cross-correlation. EDW codes are denoted by (N, w,λ), where N is the code length which can be related to the number of users K through [11],

$$L=2k+\frac{4}{3}\left[\sin\left(\frac{k\pi}{3}\right)\right]^2\frac{8}{3}\left[\sin\left(\frac{(k+1)\pi}{3}\right)\right]^2+\frac{4}{3}\left[\sin\left(\frac{(k+2)\pi}{3}\right)\right]^2 \quad (1)$$

Table 1 shows the EDW code sequences for w = 3, that is used for the three users. The corresponding selected wavelengths are also shown in Table 1.

Table 1 EDW code with w = 3 and N = 6 and the corresponding wavelengths.

N	1	2	3	4	5	6
Wavelengths (nm)	1550	1550.8	1551.6	1552.4	1553.2	1554
	0	0	1	1	0	1
Code sequences	0	1	0	0	1	1
	1	1	0	1	0	0

The information signals are generated from the pseudo random bit generator with the non-return-to-zero (NRZ) line coding before being modulated with the codes using an external Mach Zehnder modulator. Each chip has a spectral width of 0.8 nm. The attenuation and the dispersion coefficients of the single mode fiber (SMF) at a wavelength of 1550 nm are 0.2 dB/km and 17 ps/km/nm, respectively, according to the ITU-T G.652 standard. The signals are then combined using ideal multiplexer before launched to the SMF.

The SAC-OCDMA receiver uses two different detection techniques which are the modified-AND subtraction detection and the SPD detection. In both detection techniques, FBGs use the same bandwidth but with different Bragg wavelengths as to decode the signal. The APD then converts the signal to the electrical domain. The resultant signal is filtered by fourth order Bessel low pass filter, which is used to reject noise and interference components that lie outside the information signal spectrum.

IV. RESULTS AND DISCUSSION

The network simulation set up shown in Fig. 3 has been simulated using optisystem (version 7.0) with the parameters shown in Table 2. The optimum received power is evaluated for SAC-OCDMA system using EDW code with three users at 622 Mbps and at different transmission distances and different APD gain for different detection techniques.

Figure 4 displays the relation between the fiber length and the measured BER for both the modified-AND subtraction detection and SPD detection techniques.

Table 2 Typical parameters used for simulation.

LED bandwidth	30 nm
LED input power	9 dBm
Signal Data	128 PN sequence
Chip spectral width	0.8 nm
Signal format	NRZ
External modulator extinction	30 dB
Data rate	622 Mbps
FBGs reflectivity	0.99
Fiber dispersion, D	17 ps/nm/km
Fiber dispersion slope, S	0.075 ps/nm^2/km
APD gain	10
Dark current	5 nA
Thermal noise coefficient	1.8×10^{-23}
Receiver filter bandwidth	0.75×Bit Rate
Number of users	3

Figure 4 clearly shows that, the SAC-OCDMA system when using SPD detection can travel a distance 120 km with BER 4.08×10^{-12}, while using the modified-AND subtraction detection the distance becomes 60 km with BER 2.43×10^{-12}. Therefore, the SPD detection technique is preferred.

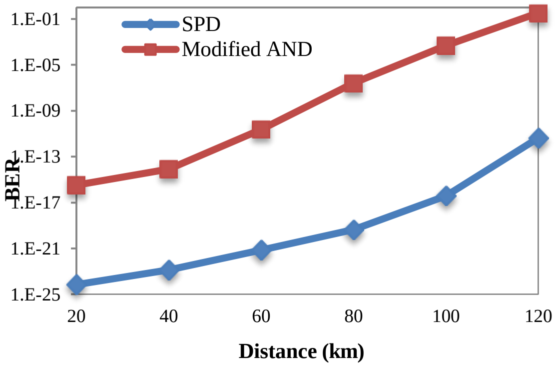


Figure 4 BER against fiber length using different detection techniques.

The received power is demonstrated against fiber length in Fig. 5 for both detection techniques. It is seen that, when the received power decreases with the fiber length in both techniques and the SPD detection technique yields the greater received power.

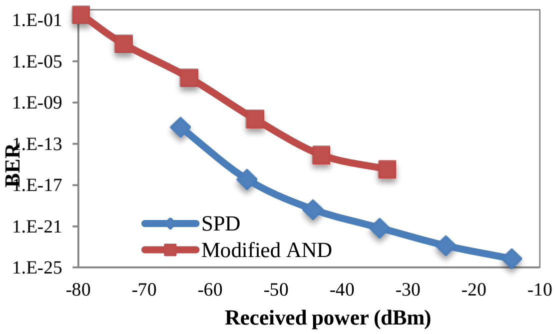


Figure 5 Received power against fiber length in different detection techniques.

Figure 6 presents the relation between the received power and BER at different transmission distances for both detection techniques at constant bit rate 600 Mbps. One notices that, the optimum received power with standard error free transmission value (BER $\cong 10^{-9}$) is -53 dBm and -64 dBm for modified-AND subtraction and SPD detection, respectively. Referring to Fig. 5, this corresponds to distances 60 km and 120 km, respectively.

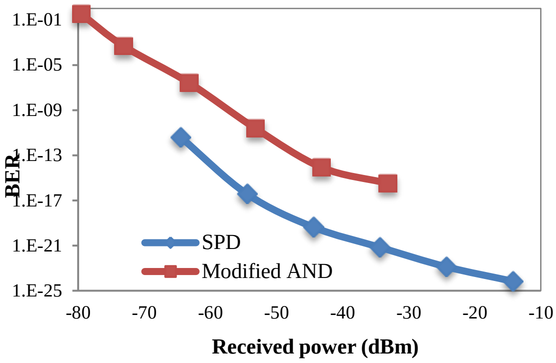


Figure 6 BER versus the received power in different detection techniques.

Figure 7 depicts the effect of APD gain on the received power for both detection techniques at 622 Mbps and at distance 20 km. It is clear that, the received power increases with the APD gain. However, one cannot use higher gain APD because using higher gain produces bad BER [12].

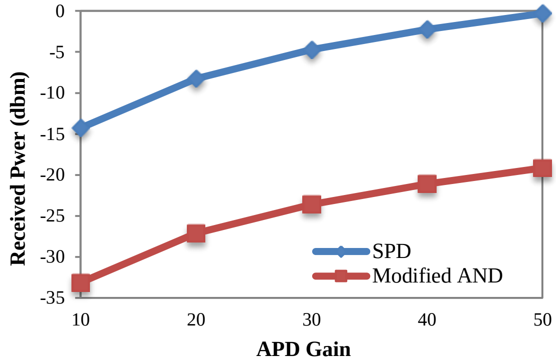


Fig. 7 Received power against APD gain in different detection techniques.

V. CONCLUSION

In-band transmission of OCDMA has been analyzed using numerical simulation to find out the optimum received power at 622 Mbps and different transmission distances. Both modified-AND subtraction detection technique and SPD detection techniques with APDs are used at the receiver. EDW codes are used as signature addresses of the system. Different APD gains are used at a constant transmission distance. The results show that, modified-AND subtraction and the SPD detection techniques yield an optimum received power of -53 dBm at 60 km and -64 dBm at 120 km, respectively, at a transmitted power of 9 dBm. Considering these advantages, this implies the feasibility of the proposed system to be suitable for Fiber-to-the-Home (FTTH) access network to fulfill the consumer's demands.

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