

Bit error rate (BER) performance of return-to-zero and non-return-to-zero data signals optical code division multiple access (OCDMA) system based on AND detection scheme in fiber-to-the-home (FTTH) networks

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In this paper, we will focus on the modulation format used to create the optical pulses, which are return-to-zero (RZ), and non-return-to-zero (NRZ). Bit error rate (BER) performance is evaluated based on double weight (DW) code. Optical code division multiple access (OCDMA) system is considered a promising technique for fiber-to-the-home (FTTH) access networks. The performance of RZ against NRZ is compared through simulation by using the Optisystem software version 7. We used two networks designed as follows: one used a RZ pulse generator and the second used a NRZ pulse generator, and both systems were tested with and without erbium doped fiber amplifier (EDFA). It has been found that the NRZ pulse generator in this system is better than the RZ pulse generator for all simulation results. The conversion used a Mach–Zehnder interferometer (MZI) wavelength converter. Also, we are proposing a detection scheme known as the AND subtraction detection technique implemented with fiber Bragg grating (FBG) which acts as an encoder and decoder. This FBG is used to encode and decode the spectral amplitude coding DW code in the OCDMA system. The performances are characterized through BER and bit rate (BR), and also the received power at various bit rates.

Keywords: spectral amplitudes coding – optical code division multiple access (SAC-OCDMA), detection scheme, subtraction technique, non-return-to-zero (NRZ) and return-to-zero (RZ) pulse generator.

1. Introduction

A simple way was used in optical communication to convert binary information from electrical to optical. Electrical bit “1” was associated with a higher optical intensity, while bit “0” was associated with a lower optical intensity. Two formats are included in this modulation group: non-return-to-zero (NRZ) and return-to-zero (RZ). NRZ is the oldest and simplest modulation format and is obtained by switching a laser source between ON or OFF. RZ describes a line code used in telecommunication signals in which the signal drops to zero between each pulse. This takes place even if a number

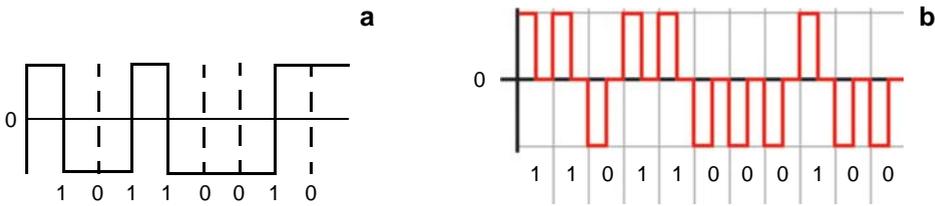


Fig. 1. Non-return-to-zero (a), and return-to-zero (b) data signal format.

of consecutive “0” or “1” occurs in the signal. The signal is self-clocking. This means that a separate clock does not need to be sent alongside the signal, but suffers from using twice the bandwidth to achieve the same data-rate as compared to NRZ format. Although RZ contains a provision for synchronization, it still has a DC component resulting in “baseline wander” during long strings of “0” or “1” bits, just like the line code in NRZ. The NRZ and RZ data signals formats are presented in Figs. 1a and 1b, respectively [1].

In this paper, we demonstrate all optical format conversions between RZ and NRZ using a Mach–Zehnder type interferometer wavelength converter. For the conversion from RZ to NRZ, we use a duplicator to make multiple copies of the input RZ pulses within one bit period before the RZ signal is injected into the wavelength converter [6]. This step can be achieved modulating the output of the laser using

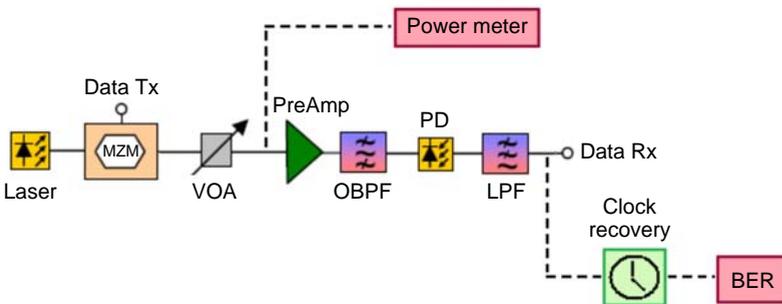


Fig. 2. Structure for NRZ-OOK.

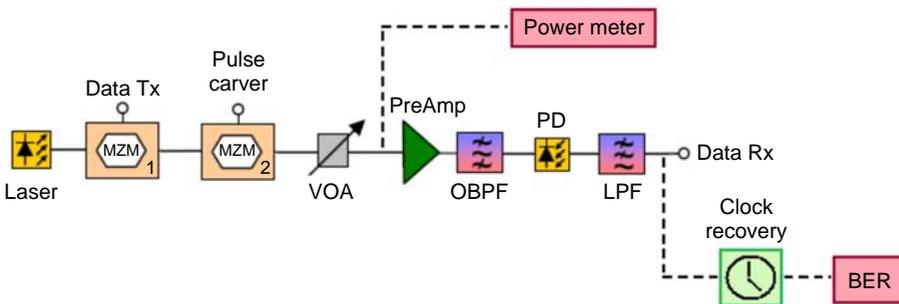


Fig. 3. Structure for RZ-OOK.

a MZM. For case of OOK, the modulator is biased at 50% transmission and is driven from maximum to minimum transmission as illustrated in Fig. 2. Figure 3 illustrates the construction of RZ-OOK. The two diagrams are used for simulation set up. These two data formats have found extensive use although the RZ data format requires twice the NRZ transmission bandwidth. It is quiet and useful in application [1].

2. Double weight (DW) code – construction

The new proposed code families are referred to as double weight (DW) codes. It can be constructed using the following steps.

Step 1. The DW code can be represented by using $K \times N$ matrix. In DW codes structures, the matrix K rows and N columns will represent the number of users and the minimum code length, respectively. A basic DW code is given by a 2×3 matrix:

$$H_1 = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

Notice that H_1 has a chip combination sequence of 1 and 0 for the three columns.

Step 2. A simple mapping technique is used to increase the number of codes as follows:

$$H_2 = \left| \begin{array}{ccc|ccc} 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 \end{array} \right| = \begin{bmatrix} 0 & H_1 \\ H_1 & 0 \end{bmatrix}$$

Note that as the number of users, K , increases, the code length, N , also increases. The relationship between the two parameters, K and N , is given by:

$$N = \begin{cases} \frac{3}{2}K & \text{for } K \text{ is even} \\ \frac{3}{2}K + \frac{1}{2} & \text{for } K \text{ is odd} \end{cases}$$

The Table shows the DW code conservation for four users.

T a b l e. DW code sequences.

$K \backslash N$	6	5	4	3	2	1
1	0	0	0	0	1	1
2	0	0	0	1	1	0
3	0	1	1	0	0	0
4	1	1	0	0	0	0

It is important that the weight positions are maintained in pairs, so that a smaller number of filters can be used in the encoder and decoder. This way, a filter with the bandwidth twice of the chip width can be used, instead of two different filters [7].

3. AND subtraction detection technique

In the AND subtraction detection technique, the cross-correlation $\theta_{xy}(K)$ is substituted by $\theta(x&y)y$, where $\theta(x, y)$ represents the AND operation between the sequences X and Y . For example, let $X = 1100$ and $Y = 0110$ and therefore $(X \text{ AND } Y) = 0100$. Figure 4 depicts the proposed AND subtraction technique.

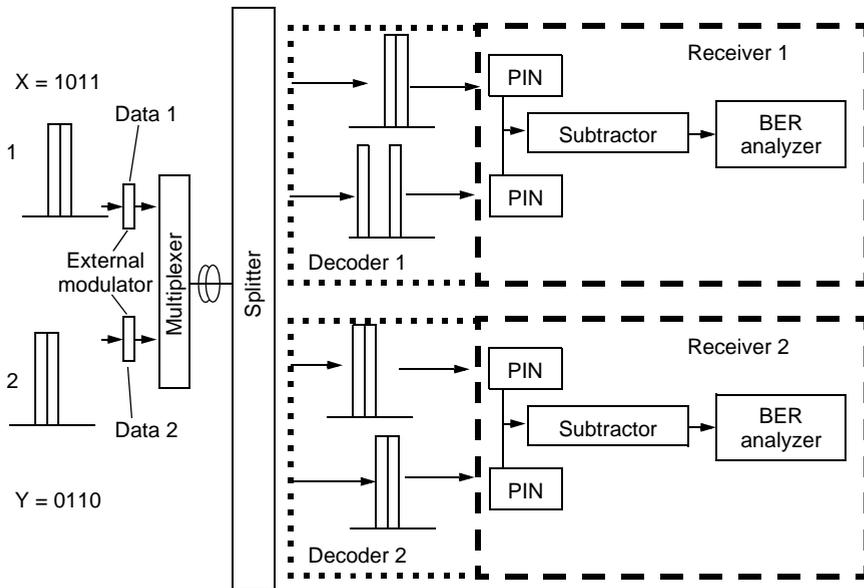


Fig. 4. Implementation of the AND subtraction technique.

At the receiver,

$$Z \text{ AND} = \theta_{xy}(K) - \theta(x&y)y(K) = 0$$

The equation above shows that, with the AND subtraction technique, MAI or the interference from other channels can also be cancelled out. Optical code-division multiple access (OCDMA) systems are getting more and more attractive in the field of all optical communications as multiple users can access the network asynchronously and simultaneously with high level of security. Optical spectrum code-division multiple access (OSCDMA) is a multiplexing technique adapted from the successful implementation in a wireless network [2].

4. Simulation setup

The simulation has been carried out by using an Optisystem software version 7 to study the performance between RZ and NRZ using the DW code in fiber-to-the-home (FTTH) access network for two users. In point-to-multipoint (P2MP), the network has been divided into two sets – with EDFA amplifier and without EDFA amplifier. A simple schematic block diagram for P2MP is illustrated in Fig. 5. The system is represented by three sections: a transmitter section, fiber optic length and receiver section. In the transmitter part for P2MP each of optical line terminals (OLT) consists of five components: pseudo random bit sequence (PRBS) generators, NRZ pulse generators, single light source diode (LED), filters and external modulators. In this work we used two models. One used a RZ pulse generator, with and without EDFA, and the second model used a NRZ pulse generator, also with and without EDFA. The fiber Bragg grating (FBG) is used as a filter in an encoder and decoder. The function of the encoder is to encode the source according to the specific code it uses [3]. The modulators are Mach–Zehnder modulators – intensity modulators based on an interferometric principle. The signals coming from the transmitter will be combined by a multiplexer and drive into a single fiber. The fiber length section

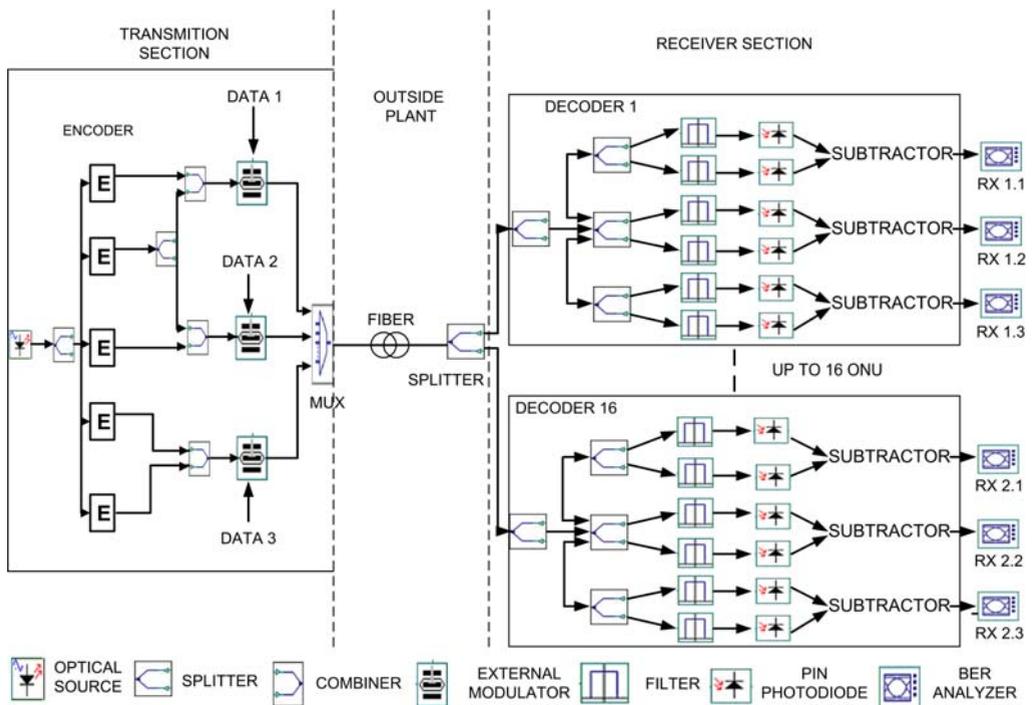


Fig. 5. Point-to-multipoint network simulation setup for AND subtraction detection technique.

includes the fiber cables used for the transmission, at 1550 nm wavelength. In this system, the splitter in ratio 1:16 is used representing the branches to the drop part on optical network unit (ONU) [4]. At the receiver part, it shows the equipment at the customer premises. The incoming signal is split into two parts, one to the decoder that has an identical filter with the encoder and the other to the decoder that has the complementary filter. An electrical subtraction is used to subtract the overlapping data from the wanted one. The performance of the system refers to the BER at BER analyzer. With the same setup, we place the EDFA with 20 dB gain, immediately after the transmitter, to launch power signals into the fiber to see the difference in performance of FTTH system by using OSCDMA multiplexing scheme [5].

5. Performance analysis

The performance of RZ and NRZ in P2P, and P2MP, was achieved fully from the results of the Optisystem 7. The simulations were carried out for DW with two SCM channels. A simple model shown in Fig. 5 consists of two users. Each user has a spectral width of 0.8 nm. The tests were carried out with the ITU-G652 standard single-mode optical fiber. The effect of varying bit rates related to the BER at 30 km transmission fiber length for NRZ, RZ, and both are illustrated in Figs. 6a, 6b and 6c, respectively.

The reason for this is as follows: the improvements in receiver sensitivity or reduced the duty cycle. An optical RZ pulse width with 50% duty cycle will have twice the peak power of an NRZ pulse. Also, an RZ has a wider optical bandwidth than on

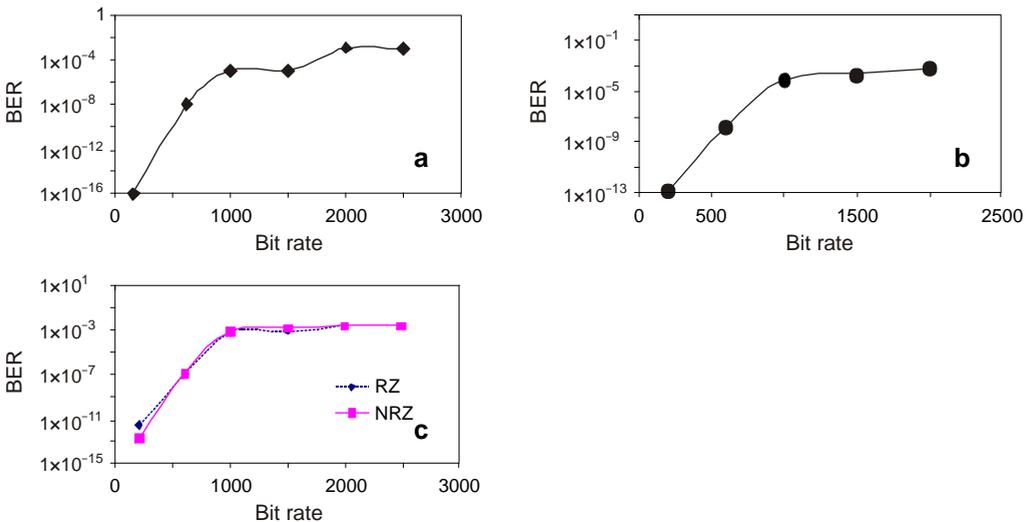


Fig. 6. NRZ performance in P2MP (a), RZ performance in P2MP (b), relation between RZ and NRZ (c).

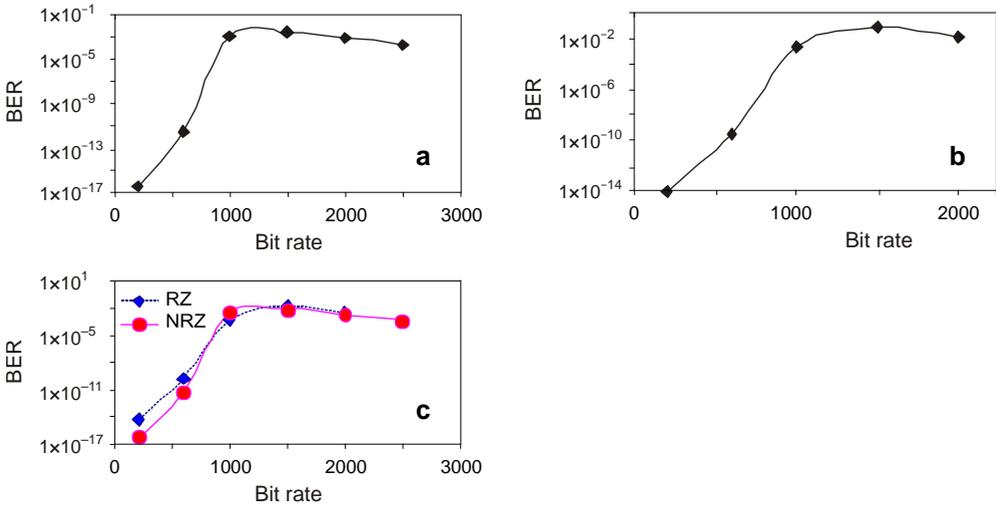
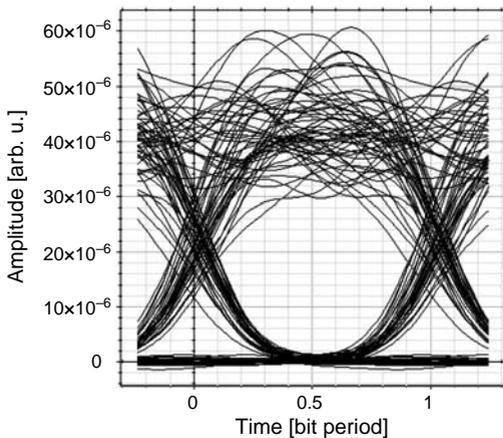


Fig. 7. NRZ performance in P2P (a), RZ performance in P2P (b), relation between RZ and NRZ (c).

NRZ pulse. It is more affected by dispersion, as can be seen from the eye diagrams in Figs. 8 and 9. Finally, RZ pulses have larger peak power and as such are more susceptible to FWM, SPM, and XPM.

From Figures 6 and 7, it seems that the system which is used: NRZ is better than RZ in our model. This is because the signal bandwidth of NRZ is about 50% smaller than the RZ format. This is illustrated better in the maximum bit rate value 2 Gbps, 2.5 Gbps when we used RZ and NRZ, respectively.



▲ Fig. 8. Eye diagram user 1 with AND subtraction detection technique NRZ; BER = 1×10^{-14} .

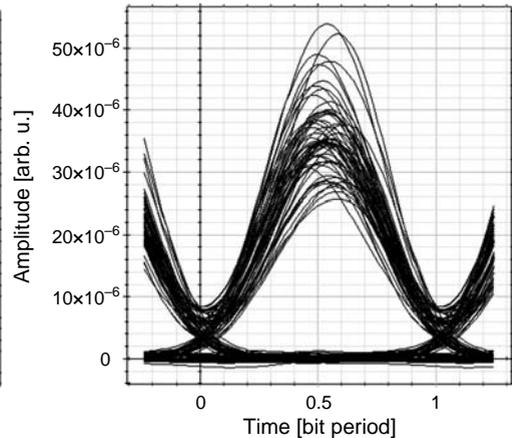
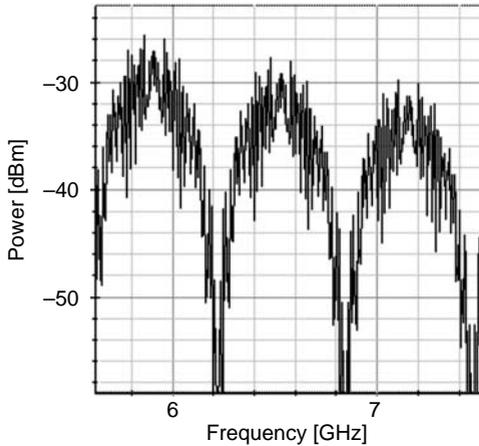
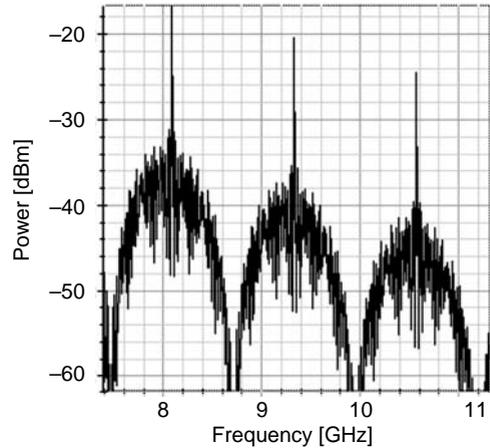


Fig. 9. Eye diagram user 1 with AND subtraction detection technique RZ; BER = 1×10^{-12} .



▲
Fig. 10. NRZ RF spectrum signal.



▲
Fig. 11. RZ RF spectrum signal.

We can also demonstrate the difference in the shape of RZ and NRZ in Figs. 10 and 11 from which it clearly appears that the frequency bandwidth in NRZ with 26 dBm power is equal to 50% of that bandwidth in RZ with 23 dBm power.

6. Conclusions

In this paper, we have discussed that the RZ is more affected by the dispersion and the dispersion slop. For DW OCDMA system, P2MP will perform better than P2P in most causes using RZ and NRZ signal formats. It has been shown that NRZ may be a better choice for a system with a large number of channels.

Finally, implementing the RZ modulation scheme requires a higher bandwidth driver on the transmitter end. This scheme can also be implemented using two optical modulators. However, this solution may be expensive, since a higher bandwidth driver may be more cost effective than two optical modulators.

References

- [1] CANO ADALID J., *Modulation Format Conversion in Future Optical Networks*, Research Center COM Technical University of Denmark March, 2009.
- [2] ZHANG X., JI Y., CHEN X., *Code Routing Technique in Optical Network*, Beijing University Posts and Telecommunications, Beijing, China, pp. 416–419.
- [3] ZAN Z., ALJUNID S.A., YAACOB M.H., ABDULLAH M.K., SHAARI S., *Design configuration of encoder and decoder modules for modified double weight (MDW) code spectral amplitudes coding (SAC) optical code division multiple access (OCDMA) based on fiber Bragg grating*, Second International Conference on Advanced Optoelectronics and Lasers, Vol. 2, September 12, 2005.
- [4] CHAO-CHIN YANG JEN-FA HUANG SHIN-PIN TSENG, *Optical CDMA network codecs structured with M-sequence codes over waveguide-grating routers*, IEEE Photonics Technology Letters **16**(2), 2004, pp. 641–643.

- [5] ALJUNID S.A., ISMAIL M., RAMLI A.R., ALI B.M., ABDULLAH M.K., *A new family of optical code sequences for spectral amplitude-coding optical CDMA systems*, IEEE Photonics Technology Letters **16**(10), 2004, pp. 2383–2385.
- [6] NORTE D., WILLNER A.E., *Experimental demonstrations of all-optical conversions between the RZ and NRZ data formats incorporating noninverting wavelength shifting leading to format transparency*, IEEE Photonics Technology Letters **8**(5), 1996 , pp. 712–714.
- [7] HASOON F.N. , ALJUNID S.A., *Spectral amplitude coding ocdma systems using enhanced double weight code*, Journal of Engineering Science and Technology **1**(2), 2006, pp. 192–202.

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