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RZ-4PAM Optical Access Signals with Pre-chirping Technology

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Abstract. In this paper, the generation and transmission of chirped return-to-zero 4-ary pulse amplitude modulation (CRZ-4PAM) signals in passive optical networks (PONs) is proposed and investigated. The optical spectra, eye-diagrams before and after transmission are also analyzed. We demonstrate that CRZ-4PAM signals after transmission over 20km single mode fiber (SMF) at 10Gb/s can be directly detected by using one photo detector, and the original data can also be restored by one M-ary threshold detector and one PAM sequence decoder. The results demonstrate that CRZ-4PAM downlink signals can be received effectively at the BER value of 10-6.

Keywords: PON, CRZ-4PAM ,optical spectra

1. Introduction

Next generation optical access system will provide advanced and customer-oriented network solutions and it can deliver higher data rates and better quality of services [1]. Advanced modulation format technique has been considered as an effective way to enhance the capacity of optical communication system [2-3]. Pulse amplitude modulation (PAM) has been studied for transmitting 100 Gb/s data signals over short distance [4-5], and carrier-less amplitude and phase modulation (CAP), orthogonal multi-pulse modulation (OMM) technologies are also adopted [6-8]. Among the above single carrier modulation schemes, 4PAM may be the most promising modulation way for short reach data access application [9]. 4PAM offers a simple and cost-efficient way to upgrade the already existing optical links performance, without increasing the system complexity and extra digital signal processing (DSP) in the transceiver [10-11]. Furthermore, the use of 4PAM modulation formats compatible with intensity modulation direct detection (IM/DD) is an attractive way to achieve higher spectral efficiency and faster bit rates without adopting costly coherent detection approaches [12-13]. On the other hand, through the regular introduction of chirp, the dispersion resistance performance of the signal can be enhanced[14], the in-band crosstalk can be reduced by the chirp induced using a RF tone with the RSOA in a PON where the non-return-to-zero(NRZ) format is adopted for the upstream transmission[15-16]. The RZ-4PAM instead of NRZ-4PAM format have been employed for the 20-km standard single mode fiber (SSMF) transmission due to its broad electrical spectrum [13]. As we know，high spectral efficiency RZ-4PAM optical signals with pre-chirping operation have not been reported in the study of others as the downstream optical signals in optical access systems. Hence, in this paper, RZ-4PAM optical signals with pre-chirping technology for 10-Gbit/s optical signals access application, is introduced. The simulation results show the reception performances of chirped return-to-zero 4-ary pulse amplitude modulation (CRZ-4PAM)signals after transmissions over 20km SMF are good. The results demonstrate that CRZ-4PAM downlink signals can be received effectively at the BER value of 10-6. Therefore, it is a competitive technology in the future access network.

2. System setup

Fig.1 depicts the system setup for the RZ-PAM downlink transmission performance with pre-chirping technology in passive optical access systems. A continuous wave signal emitted by a

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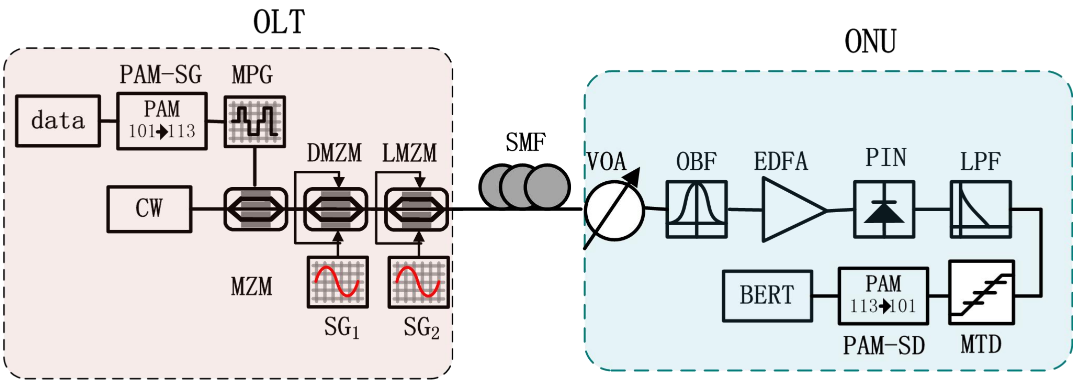

Fig.1 System setup for the CRZ-4PAM downlink transmission (CW: Continuous wave; PAM-SG:PAM sequence generator; MPG:M-ary pulse generator; DMZM: dual-arm Mach-Zehnder modulator; LMZM: LiNbo3 Mach-Zehnder modulator; SG: sine generator; SMF:single mode fiber; VOA: variable optical attenuator; OBF:Bessel Optical filter; EDFA:erbium-doped optical fiber amplifier; PIN:Photo detector; MZM: Mach-Zehnder Modulator; LPF: low pass filter; MTD: M-ary threshold detector; PAM-SD: PAM sequence decoder; BERT: bit error rate tester.)

continuous wave (CW) laser at frequencies mapped 193.1THz is launched with a linewidth of 0.1MHz into a Mach-Zehnder modulator (MZM). A PAM sequence generator (PAM-SG) module and a M-ary pulse generator (MPG) module are employed for generating the 10Gb/s electrical 4PAM signals. The modulator is externally driven by the electrical 4PAM signal, loaded with a 215−1 PRBS naturally encoded 4PAM sequence at 10Gbit/s. Two electrical clocks are amplified and input to the optical arms of dual-arm MZM (DMZM) and LiNb MZM (LMZM) for controlling the degree of interference at the output optical branch and therefore controls the output clock intensity. By adjusting the bias point, the difference voltage of the DMZM and regulating the sine generator(SG1) at the suitable point, the generated RZ-4PAM spreads to the LMZM for pre-chirping operation. The chirped RZ-4PAM optical signal is launched with a power of 3.7dBm into the single mode fiber (SMF). A variable optical attenuator (VOA) is placed after SMF to adjust the received optical power. We apply commonly used fiber parameters in this work: fiber chromatic dispersion (CD) of 16.1ps/nm/km, 0.2dB/km loss, and a nonlinear coefficient of 2.6×10-20m2/W. At the receiver, the generated noise signal is filtered out firstly by using a third-order optical Bessel filter (OBF). Then the received optical signal is amplified by one erbium-doped optical fiber amplifier (EDFA) for compensating the transmission attenuation and detected by a Photo detector (PIN) for optical to electrical conversion. A third-order Bessel low pass filters (LPF) with the cutoff frequency value of 5GHz for in-band noise suppressing. The original data is restored by one M-ary threshold detector (MTD) and one PAM sequence decoder (PAM-SD). One BER tester is applied for evaluating the system performance.

The LMZM modulated signal is accompanied by a phase modulation (chirp) given by (1):

$$E\_out\ (t)=E\_in\ (t)\exp(j\pi Vin/V\pi) \qquad (1)$$

Ein (t) ,Eout (t) are the input and output signals of the LMZM respectively, Vπ is the switching voltage required for the output signal intensity changed from the maximum to the minimum when the modulator works with a single arm, Vin is Modulated voltage signal, as in (2)

$$Vin=A.V\pi\sin\boxed{f_0}(wt) \qquad (2)$$

$$E\_out\ (t)=E\_in\ (t)\exp(jA\pi\sin\boxed{f_0}(wt)) \qquad (3)$$

When A changes, the phase shift also changes, thus inducing frequency chirp. This phase modulation depends on the gain variations induced by the intensity transitions in the LMZM driving signal, hence, in order to maximize the chirp on the modulated signal, we drive the LMZM with a RZ format instead of the NRZ. When the LMZM is driven by a NRZ signal, phase transitions occur only at 0-1 (or 1-0) transitions, whereas a constant symbol sequence (e.g., consecutive 1s) comes

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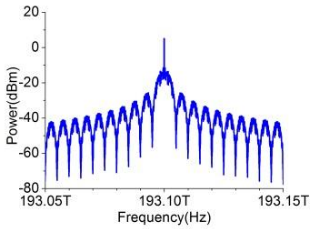
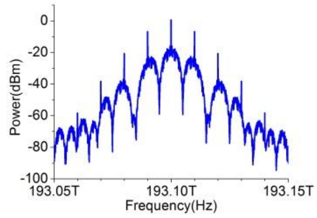
with no phase change. On the other hand, in the RZ signal, we have two opposite intensity transitions at every mark, therefore, the LMZM -modulated output is always highly chirped. In previous studies, the chirp change caused by the phase change has been analyzed.

3. Results and analysis

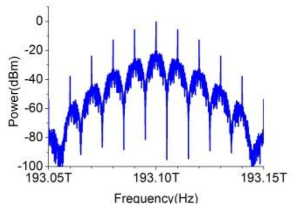
. The optical spectra diagrams of propagated signals at the output of MZM, DMZM and LMZM are shown in Fig. 2 respectively (taken with a 0.001nm resolution bandwidth optical spectrum analyzer). It is easy to see, they almost have the different sidelobe power decrease obviously. Most importantly, CRZ-4PAM signals at the output of LMZM have the wider spectrum width by the phase modulation, which will reduce the peak amplitude of any particular Fourier component. These reduced spectral peaks lowers nonlinear mixing between spectral components of other data signals or noise components [14].



a



b



c

Fig. 2. Optical spectra diagrams of propagated signals at the output of MZM(a), DMZM(b) and LMZM(c) respectively

The Fig. 3 are the received CRZ-4PAM signals eye diagram after 0km and 20km SMF transmission, CRZ-4PAM optical signals is 4-level amplitude modulation ， which can transmit more bit information than traditional digital signals. the eye diagrams after 20km SMF transmission open clearly and widely, just eyelids become thickened slightly. This indicates the transmission performance of CRZ-4PAM signals are good. Previous studies have also shown that CRZ-4PAM signals exhibits 2.4 dB receiver power penalty compared with the back to back case .This result is attributed to the regular introduction of chirp against the dispersion in the fiber transmission.

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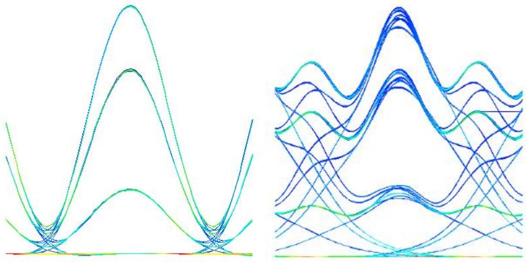

(a) **(b)**

Fig. 3. The eye diagrams before(a) and after(b) SMF transmission

4. Conclusions

In this paper, a novel scheme which can realize high-speed CRZ-4PAM optical signals transmission in 10Gb/s passive optical access systems, is introduced. Simulation results prove CRZ-4PAM downlink signals can be received effectively. This scheme exhibits compatibility with current optical network equipment with low cost budget. It is a promising scheme using CRZ-4PAM downlink signals for repressing dispersion in the transmission in the future optical access networks.

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