A Novel Re-modulation Method in a WDM-PON with Enhanced Extinction Ratio

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Abstract

We propose and experimentally demonstrate a novel coding scheme for a WDM-PON system using ASK/DPSK re-modulation corresponding to downstream/upstream signals respectively to enhance the toleration of injection signal extinction ratio.

Introduction

Wavelength-division-multiplexed passive optical network (WDM-PON) is a promising technology for future broadband access network, since it can offer advantages including high capacity, large coverage range, upgradeability, and cost-effective configuration [1]. Recently the re-modulation scheme was proposed to achieve high speed centralized light source (CLS) WDM-PON. Several orthogonal modulation formats for downlink and uplink transmission have been deployed in access network, including downstream differential phase shift keying (DPSK) and upstream on-off keying (OOK), downstream frequency shift keying (FSK) and upstream OOK, downstream inverse return-to-zero (IRZ) and upstream OOK, and both downstream and upstream DPSK [2-5]. In addition, downstream amplitude shift keying (ASK) and upstream DPSK is also an alternative scheme due to the support of a colorless WDM-PON of 30-km distance, which reduces the implementation cost, maintenance complexity, and power consumption [6]. However, the scheme has an inherent limitation of ASK downstream extinction ratio (ER) in order to satisfy DPSK upstream detection.

In this paper, we propose a novel encoding method based on inserting marks in the signal sequence uniformly. Experimentally results show that the tolerable ER can be improved from 6dB to 13dB for a 40Gb/s RZ-ASK downstream and a 622Mb/s DPSK upstream with less than 1dB penalty.

Principle

In the proposed orthogonal ASK/DPSK re-modulation scheme, the downstream data is carried by a ASK signal and the upstream data is re-modulated directly on the downstream signal to a DPSK format, which has the following advantages:

- The ASK downstream signal can be easily detected without frequency discrimination or phase demodulation so that simplifying the architecture in ONU.
- The DPSK upstream helps for the burst mode receiving because of the fixed threshold at zero level in differential receiver independent of the power distinction from different ONUs.

Since the sensitivity of the DPSK signal deteriorates with an increasing value of ER due to the reduced signal power when an ASK '0' is transmitted, a limited value of ER has to be used for the ASK signal. To eliminate the limitation to the ER, we propose a new coding method realized in the time domain, hereafter referred to mark insertion coding. The principle of this scheme is depicted in Fig 1. We insert m-bits of 'marks' for every N bit-stream of the ASK signal. The delay of the DPSK demodulator is equal to 1/m times the ASK bit-duration. Because the inserted marks ensure the DPSK demodulation even when continuous zero of the ASK signal are transmitted, the requirement on the ER is thereby alleviated.

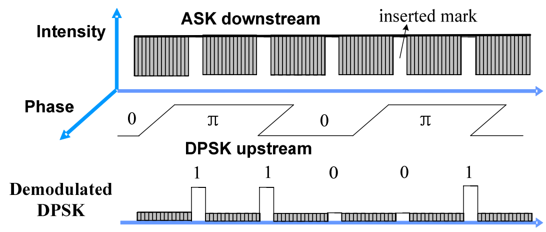

Figure 1: Principle of the mark insertion coding for ASK/DPSK re-modulation and demodulation

Experimental Setup and Results

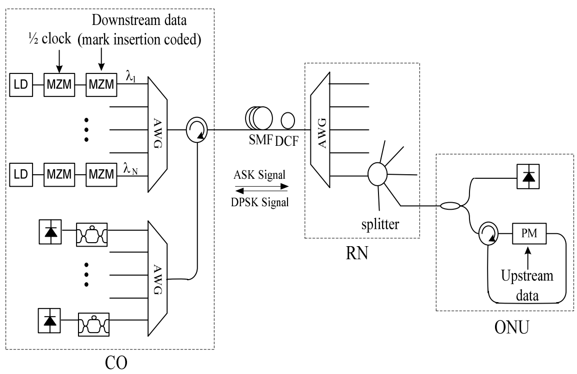

Figure 2: Experimental setup for orthogonal ASK/DPSK modulation in WDM-PON using mark insertion coding

Fig. 2 shows the experimental setup for ASK/DPSK modulation in WDM-PON using mark insertion coding scheme. In the central office (CO), the signal source is a wavelength tunable external cavity laser (ECL) working at 1550 nm. The downstream RZ-ASK signal is generated by two cascaded Mach-Zehnder modulator (MZM). The data sequence is a 2^7-1 PRBS pre-encoded by mark insertion method at 40 Gb/s. In our experiment we insert one mark for every 15 bits of the downlink data. The arrayed waveguide grating (AWG) performs wavelength multiplexer/demultiplexer functions as a remote network (RN). The downstream signal through a 40-km feeder standard single mode fiber (SMF) and a matching 6-km spool of dispersion compensation fiber (DCF) is divided by the 3-dB coupler in optical network unit (ONU). A portion of the downstream source is detected directly by a photodiode. The residue of the downstream source is injected in a $LiNbO_3$ phase modulator (PM) as a seeding source and re-modulated at 2.5 Gb/s or 622 Mb/s by PM with the digital signal for upstream. In CO the DPSK upstream signal is demodulated by a Mach-Zehnder delay interferometer (MZDI), received by a followed photodiode and synchronized with the time slot of the inserted marks. The MZDI has a delay of approximately 8 cm corresponding to 1-bit duration (400 ps) of the DPSK signal at 2.5 Gb/s. A 1.8 GHz electrical low pass filter is used to suppress high frequency noise.

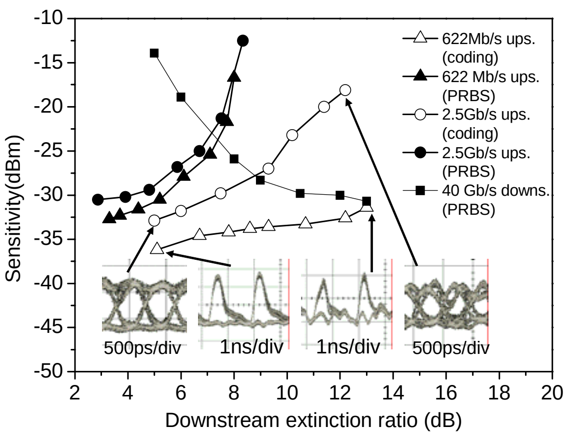

Figure 3: Measured receiver sensitivity of DPSK upstream signal versus ASK downstream signal ER

The measured receiver sensitivity of the DPSK upstream as a function of the ASK downstream ER is shown in Fig. 3. The eye diagrams of the DPSK upstream signal is shown in the inset figures of Fig. 3. As expected, we observe a trade off between the ER requirements for the ASK downstream and DPSK upstream. A degraded ER is known to result in a penalty for the ASK downstream, whereas an increase in the ER leads to a receiver penalty on the DPSK upstream. For the downstream data coded with a 2^7-1 PRBS, an optimum value of 7 dB ER is obtained where the ASK and DPSK signal share the same sensitivity. This optimum value is enhanced to larger than 9 dB when the mark insertion coding is applied to the downstream PRBS. For the upstream at 2.5 Gb/s, the optimum ER is around 9 dB. The enhancement on the sensitivity is about 6 dB. It is found that an optimum ER value as high as 13 dB can be achieved for the upstream at 622 Mb/s, which results in around 10 dB enhancement of the sensitivity compared to the PRBS case.

The measured BER curves for the downstream and the upstream are shown in Fig.4. The penalty for both signals is less than 1dB.

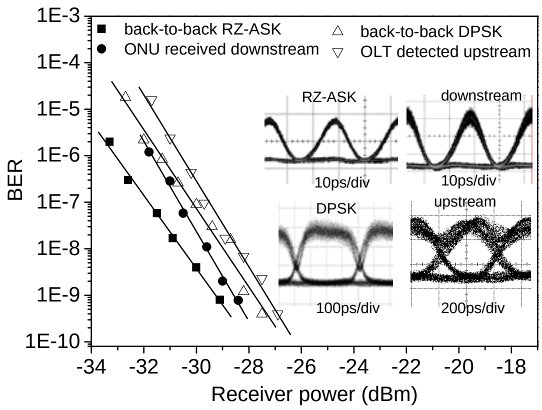

Figure 4: Measured BER curves for the received RZ-ASK downstream and DPSK upstream.

Conclusions

The ER limitation deteriorates the performance of the orthogonal ASK/DPSK re-modulation in WDM-PON. We propose and demonstrate that adopting a new mark insertion coding technique can efficiently overcome such a limitation. In the experiment, we compare the curve of the DPSK upstream receiver sensitivity vs. the ASK downstream ER with and without mark insertion coding to the PRBS. It is testified that mark insertion coding helps to alleviate the requirement on the ER when the ASK/DPSK re-modulation using in a WDM-PON. This work is supported by National Natural Science Foundation of China (No. 60777010), Hi-Tech Research and Development Program of China (No. 2007AA01Z260, No.2006AA01Z251) and Program for New Century Excellent Talents.

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