A Novel architecture of an optical high-speed access network WDM-PON using NRZ-DQPSK/ASK modulation.

A.CHENIKA[1], *A.TEMMAR*[2]
Laboratory of Applied Research in TIC,
INT&TIC,
Oran, ALGERIA.
[1]achenika@ito.dz; [2]a_temmar @hotmail.com.

O.SEDDIKI
Department of Electrical Engineering,
Abu-Bakr Belkaïd University,
Tlemcen, ALGERIA.
omar_seddiki@yahoo.fr.

Abstract—**The work presented in this paper treats the feasibility to transmit 40 Gbps data both in the Downlink direction (OLT-ONU) and 10Gbps in the Uplink direction (ONU-OLT) using an optical access network WDM-PON of a 30 km standard single-mode fiber (SSMF-28). The proposed method is based on the comparison between two systems with the same characteristics, using two different format of modulation in OLTs. In the first system, we used the NRZ-ASK modulation in the downlink and the re-modulation NRZ-ASK/ASK in the uplink, while in the second; we used the NRZ-DQPSK in the downstream transmission and re-modulation NRZ- DQPSK/ASK in the opposite direction.**

Keywords: Single-mode fiber (SMF), Passive Optical Network (PON), Wavelength Division Multiplexing (WDM), No Return-to-Zero (NRZ), Amplitude Shift Keying (ASK), Differential Quadrature Phase Shift Keying (DQPSK), Differential Detection, Bidirectional fiber.

I. INTRODUCTION

The use of the optical fiber in access networks constitutes a major advance in order to satisfy the ever increasing demand for higher throughput among users. Currently, the passive optical networks can offer high speed broadband at speeds of up to 100Mbps for customers and provide advanced voice and multimedia services simultaneously [1]. It exploits two different wavelengths for both downloading and uploading.

The Wavelength Multiplexing Division (WDM) technology appears gradually in optical communication systems and seems to be a technique adopted in the medium term. This is because it has great potential to enhance system design and flexibility. The association of the two technologies WDM and PON, seems inevitable to accompany the increase flow at the subscriber [2]. 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 [3].

In order to increase the data rates in the optical links, a number of advanced modulation formats were adopted for their effectiveness and their capacity to fight against the effects of chromatic dispersions (DC), polarization mode dispersions (PMD) and the nonlinear effects [4].

In optical access network, several orthogonal modulation formats have been deployed in the downlink and uplink transmission, such as the DPSK (Differential Phase Keying Shift) in downstream and OOK (One-Off keying) in upstream, the FSK (Frequency Shift Keying) in down direction and ASK (Amplitude Shift Keying) in the opposite direction, thus the use of DPSK in both directions [5-8]. Moreover, the use of DQPSK in downstream and ASK in upstream is an alternative solution which makes possible to reduce the implementation cost, the maintenance complexity and power consumption [9]. Recently, the optical re-modulation scheme is proposed to achieve high speed centralized light source where we use only one source of light in order to reduce the cost of the customer transmitter [10].

In this document, our work consists of proposing a new architecture of a WDM-PON system which transmits 40 Gb/s of data through 30 km of SSMF using NRZ-DQPSK modulation in downlink and 10 Gb/s of data using the re-modulation DQPSK/ASK in uplink. In order to assess our system, we compare it with another WDM-PON system having the same characteristics but use the ASK/ASK modulation. Let us note that simulations are made by OptSim 4.0 tools. In deferent simulations we have considered the effects of the Rayleigh and Brillouin backscattering presented in bidirectional fiber.

II. DESCRIPTION OF SIMULATIONS

We present below some results of simulation modeling an optical access network WDM-PON supported with Optsim (simulator of the optical systems) to test the feasibility of the network structure and the improvement brought by using DQPSK modulation in downlink and Re-modulation DQPSK/ASK in uplink. Indeed, the work carried out in this paper allows to make a comparison between two WDM-PON with the same characteristics, the difference is located in the type of modulation used on downstream of systems, where the first uses the traditional modulation NRZ-ASK and the second uses NRZ-DQPSK.

Figure 1 presents the general structure of the simulated system, including Optical Line Terminal (OLT) and the Optical Network Unit (ONU), connected between them by a standard bidirectional fiber (SMF-28) with 30 km of length. The downstream signal is generated at OLT, sent through optical fiber at ONU which represents customer side, and re-modulated to the ASK format to load the upstream data which is received at OLT. In our simulations, the attenuation coefficient in fiber is 0.2 dB/km, the effect of the chromatic dispersion is not simulated because its compensation is controlled perfectly by several methods dedicated to that. All nonlinear effects are taken into account in this study. It is also considered the effects of the Rayleigh and Brillouin backscattering presented in bidirectional fiber.

The 40 Gb/s NRZ-DQPSK transmitter is composed of a CW laser source works at 1550 nm with output power Po = 0 dBm. The data is generated by a pseudo-random generator of 512 bits of length. After differential pre-coding the data are

modulated optically through two parallel Mach-Zehnder modulators MZM. Each of the two modulators must function at its null polarization mode [11],one of the two modulators is followed by a phase modulator PM in order to create a dephasing of π/2 between the two beams of light [12].

The downstream signal is received by ONU and demodulated by a differential detector using two MZDI (Mach-Zehnder Dual-arm Interfero-meter) each followed by two photodiodes [13]. Each MZDI has a delay of 50 ps (2Tb) as the symbol rate of DQPSK is 20GSym / s.

The ONU transmitter uses the re-modulation DQPSK/ASK, by recovering part of the optical signal to modulate the upstream data by an MZM.

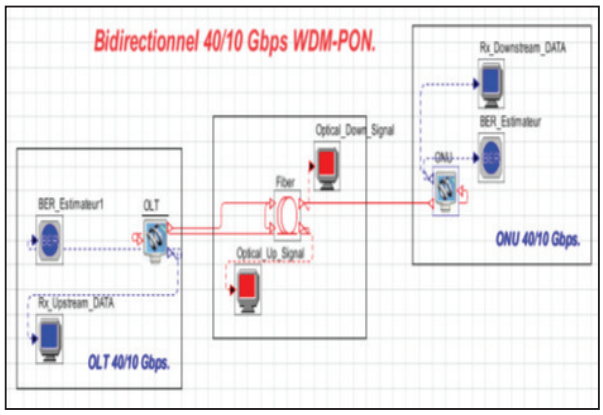

Figure 1. Architecture of the simulated system.

III. DISCUSSION OF RESULTS

Figure 2 shows the curve of BER vs. the OSNR (Optical Signal-to-Noise Ratio) measured at the receiver of ASK/ASK system. It is clear that when the noise level increases the performance of the system is mediocre, the signal is submerged in the noise and therefore the decision is difficult because the signal is modulated in amplitude and the noise acts on the amplitude therefore the level detection signal becomes difficult. The Degradation system when we simulate the Rayleigh and Brillouin scattering is almost zero in the downlink, but we measure a penalty of 0.5 dB in the uplink.

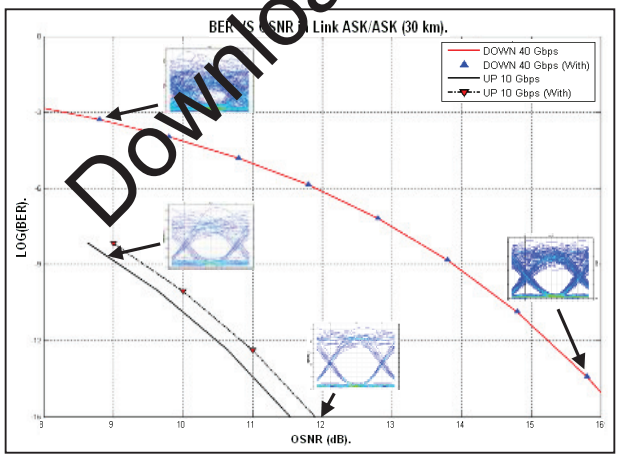

Figure 2. BER vs OSNR for NRZ-ASK system.

Figure 3 shows the BER performance with varied OSNR for down/upstream transmission with Rayleigh and Brillouin scattering in DQPSK/ASK system. The influence of Rayleigh and Brillouin scattering is transparent to the system; this is due to the non-variation of the optical power in the downlink signal that affects the uplink signal.

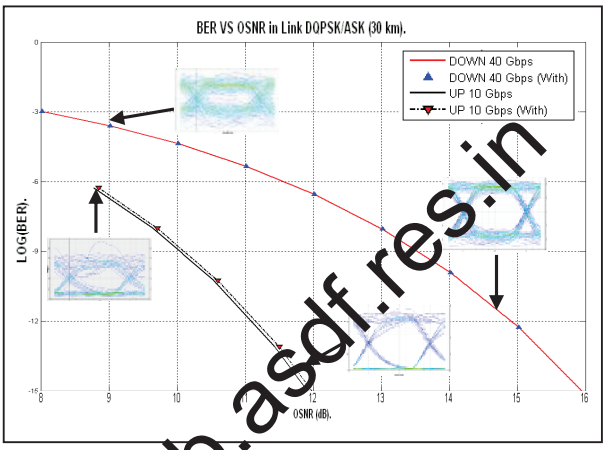

Figure 3. BER vs OSNR for NRZ-DQPSK system.

Comparing the two figures, it can be noticed that the 2nd system exhibits a gain of 0.5 dB in downstream which promotes the use of the DQPSK modulation in high speed WDM-PON systems.

IV. CONCLUSION

In this work we made a comparison between two high speed WDM-PON systems using two deferent formats of modulations (NRZ-ASK/ASK and NRZ-DQPSK/ASK). The transmission distance is 30km at a bit rate of 40 Gb/s for downstream transmission. For upstream transmission, the ONU directly modulates its information on the received optical carrier without using another wavelength.

This architecture may be viewed as a highly attractive candidate for the next generation optical access networks. This work was carried out at the Laboratory of Optoelectronics in the National Institute of Telecommunications and Information Technologies and Communication of Oran, ALGERIA.

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