Gain Transient Mitigation in Remote Erbium Doped Fibre Amplifiers by Burst Packet Carving at the ONU for Extended Power Budget PONs

F. Bonada[(1)], B. Schrenk[(1)], J. A. Lazaro[(1)], V. Polo[(1)], P. Chanclou[(2)], J. Prat[(1)]

[(1)] Universitat Politècnica de Catalunya, Jordi Girona 1-3, 08034 Barcelona, Spain, francesc2b@tsc.upc.edu
[(2)] Orange Labs, 2 Avenue Pierre Marzin, 22300 Lannion, France

Abstract *We present a new approach to mitigate the gain transients in remote Erbium Doped Fibre Amplifiers by means of pre-distortion of data packets at the ONU, allowing a strong reduction (30%) of the packet overshoot.*

Introduction

Access networks have became an important research line in optical communications, for serving high bandwidth services. Passive Optical Networks (PON) present some important advantages for operators, since no active components are deployed in the fibre plant. Combining WDM and TDM techniques in hybrid ring+tree topologies, the number of users and the network reach can be increased[1,2]. Long reach and high splitting ratios to serve a large number of users will require amplification between the Optical Line Terminal (OLT) and the Optical Network Unit (ONU). Remotely pumped Erbium Doped Fibre (EDF) appears as an optimal solution to compensate the transmission losses while keeping the network completely passive.

Amplification of the burst mode traffic seems to be one of the main challenges for remote amplification using EDFAs, due to the variations in the EDF's population inversion caused by the burst pattern. These changes in the population inversion can cause gain variations degrading the network performance. Different techniques have been presented to mitigate this undesired effect, such as Automatic Gain Control[3] and all-Optical Automatic Gain Control[4] (OAGC). While these techniques are shown to be appropriate for some applications, they present some drawbacks for access networks and PONs, since no active devices can be deployed in the fibre plant and no gain should be wasted amplifying a lasing signal, for pump power economy.

In this paper, we present a novel technique for EDF gain transients mitigation, by means of a packet-carving performed at the ONU, in order to pre-compensate the EDF gain overshoot.

Packet-Carving technique

Due to the direct relation between gain of the Reflective Semiconductor Optical Amplifier (RSOA) and its bias current, the desired pre-distortion of the data packet can be applied by simple electrical filtering of the burst enable signal that is provided to the bias input of the RSOA, Fig. 1b. A first order lowpass was used as the distorting element, whereby a part of the burst signal was left unaffected. The time constant of the lowpass was adjusted according to the given conditions of the desired duty cycle and the expected overshoot of the EDF. In a real network, means of signalling would have to be integrated into a higher layer for optimization of the packet-carving. The risetime of the packet at its begin was monitored at the output of the RSOA not to loose the first bits due to too strong distortions. This imposes a limit to the performance. A disadvantage of this technique might be that the gain of the RSOA has to be partially reduced to mitigate the later EDF-induced overshoot, increasing the noise figure. Hence, it is necessary to keep track of the OSNR at the OLT receiver. The RSOA used in the experiments provides a small signal gain of 21.7 dB, an optical 3 dB bandwidth of 54 nm centred at 1550 nm, and has been biased at 70 mA as an average value for the carved packet. The small signal noise figure of the RSOA is 9 dB.

Set-up description

At the OLT transmitter, a Laser Diode (LD1) generates a CW downstream signal at 1551.32 nm with a launched power of 0 dBm. For testing this technique, a PON architecture based in ring+tree Sardana network is used[2]. A spool of 50 km of Standard Single Mode Fibre (SSMF) is used as

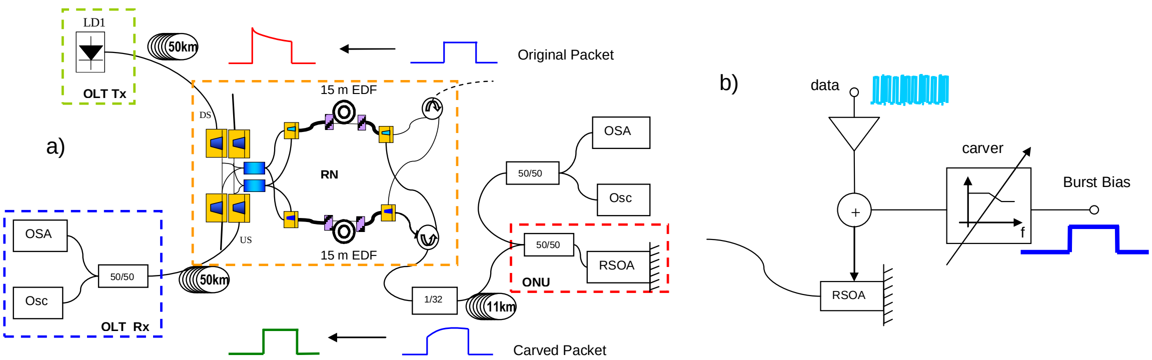

Fig. 1: a) Experimental set-up, b) Packet Carving circuitry

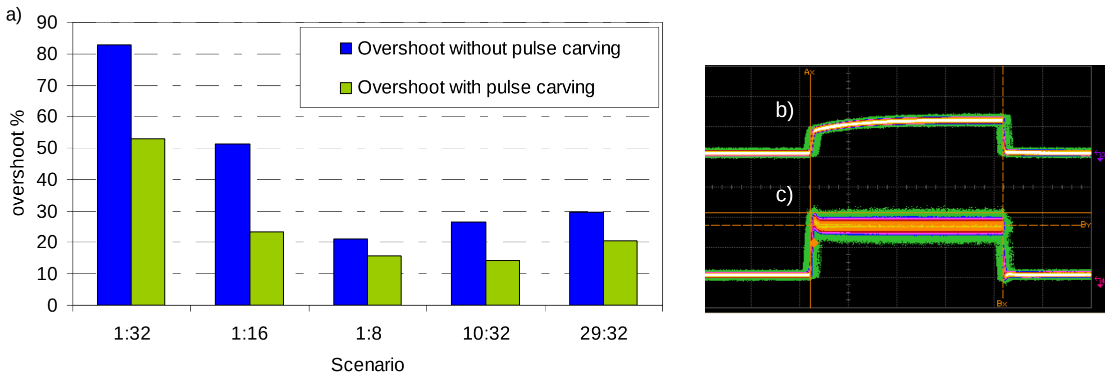

Fig. 2: a) Gain transient overshoot, b) carved packet at ONU output, c) received packet at the OLT

downstream ring fibre to reach the RN that drops the selected wavelength using thin film add&drops. Remotely pumped amplification in the RN is performed by 15 m of HE980 EDF, to compensate the losses due to signal transmission and covering a typical PON budget. The tree section of the PON is composed by 11 km of feeder fibre preceded by a 1/32 splitter. A RSOA acts as the ONU transmitter, generating the burst mode upstream pattern. Upstream burst traffic is then amplified in another 15 m of remotely pumped HE980 EDF in the RN, generating the gain transients under analysis. A second 50 km SSMF spool is used as upstream ring fibre. At the OLT receiver, a 50/50 coupler splits the signal to the Optical Spectrum Analyzer (OSA) and to the Oscilloscope (Osc) characterizing the OSNR and the gain transients. A PIN diode with a bandwidth of 20 GHz was used in order to avoid the suppression of any fast overshoot. The pump power was 16 dBm at 1480 nm at each EDF. The input power at the RSOA was fixed to -20.4 dBm, according to the given power budget. The input OSNR at the RSOA was 39.3 dB.

Experimental results

To analyze the proposed technique, different packet lengths over a 125 μs frame have characterized. The different duty cycles under study were: 3.125%, 6.25%, 12.5%, 30% and 90%, corresponding to relative activity of: 1:32, 1:16, 1:8, 10:32 and 29:32 respectively. For each case, packet characterization with and without packet-carving technique has been carried out, comparing the reduction of the gain transients in terms of overshoot, defined as: $P_{out}(0)/P_{out}(\Delta t)$, where $P_{out}(0)$ is the output power at the start of the packet (overshoot) and $P_{out}(\Delta t)$ is the output power at the end of the packet. The overshoot with and without packet-carving at the RSOA can be seen in Fig. 2a. For the case of the most significant overshoots (85% and 50%) corresponding to the smaller packet/duty cycle (1:32 and 1:16), a reduction of 30% of the overshoot can be measured. For longer packets there is still a strong reduction of the overshoot, but smaller since long packets show less overshoot even without packet-carving. It is important to note that packets with intermediate lengths seem to show less improvement when using pulse carving in the ONU than shorter or longer ones.

Another important parameter to analyze is the OSNR at the OLT receiver, after the upstream EDF amplification. As can be seen in Fig. 3, the use of the pulse carving technique in the ONU, to mitigate the EDF gain transients, only represents a degradation of less than 0.2 dB in the OSNR when comparing with the OSNR without using packet-carving. The input power at the OLT receiver only presents a small decrease of less than 1-1.5 dB compared to the case when the packet-carving technique is not used.

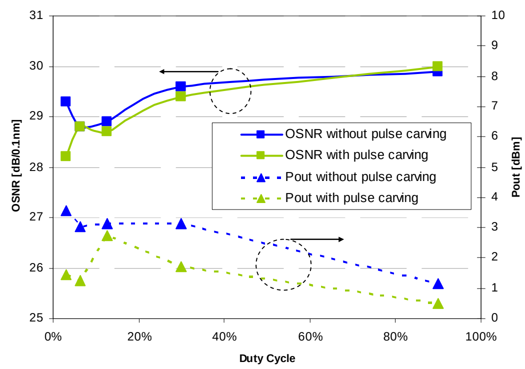

Fig. 3: OSNR and output power measurements

Conclusions

We have presented a novel electronical, easy to integrate and cost effective technique to mitigate EDF gain transients, by using packet-carving performed at the ONU transmitter. Different duty cycles have been analyzed, showing a strong reduction of the gain transient (30%) especially for the cases of most significant overshoot, without any significant degradation in the signal OSNR (<0.2 dB).

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