Effective Amplification of Real WDM Burst Traffic Using Optical Gain Clamping

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Abstract: Experimental studies of real optical burst traffic in WDM systems are performed with optical gain clamping for stabilizing the EDFA amplification. Impairments of power variation due to burst are shown to be negligible.

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1. Introduction

Optical burst has been shown to be an effective way for transmitting IP traffic over WDM systems [1]. However the optical amplifier saturates when several WDM burst channels arrive simultaneously. As consequence the output power signals present fluctuations that accumulate in a cascaded amplifier network. One way of minimizing these impairments is to stabilize the optical amplifier (OA) gain. Electronic techniques have been used to minimize the burst channel degradation and simultaneous burst traveling through cascaded amplifiers. Reported results show strong gain transients due to burst interaction [2]. In addition, no typical traffic data were used which limited the understanding of the efficiency of the method. Here we focus on the optical gain clamping (OGC) technique due to its simplicity and all optical passive components used. Recently we have studied the OGC amplifier to stabilize its gain under burst traffic. We have found excellent performance but we have also observed that strong gain oscillations may be generated when the burst arrival time interplays with natural device relaxation oscillation frequencies [3,4]. This behavior therefore requires the verification of amplifier performance under real burst data.

In this paper the performance and the dynamic behavior of an OGC-OA in a real burst traffic are investigated. For this purpose, the experiments use real burst data obtained from a tailor made testbed and a commercial Erbium-doped Fiber amplifier. A 16 WDM burst transmission is used to characterize the amplifier performance.

2. Optical Burst Amplification

For obtaining relevant results, the burst data used here is obtained from a pair of Full-Duplex Gigabit Ethernet links, which connects the Catalan R&D network (around 50 Universities and Research Centers) with the Spanish R&D RedIris network and to the internet [5]. An optical burst switching (OBS) node performs packets aggregation and burst generation [6]. A tailor made measurement platform, designed to operate at gigabit speed without packet losses, captures the packet traces with ns precision. A 14-seconds trace composed by 95k bursts is obtained from the testbed. The WDM burst stream is built by taking uncorrelated data in different time slot to generate a 1-second long trace to be introduced into the amplifier. Each burst is in the order of tens of microseconds.

We used a standard commercial OA and a simple laser ring configuration to provide optical feedback. The lasing wavelength is set to 1548 nm by means of a narrowband tunable filter placed in the feedback loop. The tunable filter permits to set the lasing wavelength to minimize the spectral-hole-burning offset [7]. The cavity passive length outside the amplifier is ~5m and the gain is set to 17 dB for -3 dBm input power. The OA operation can be described as a laser perturbed by the varying input signal power [7]. The pump power is increased by a factor $x = 1.30$ as opposed to the unclamped EDFA and this power is described as a function of the threshold pump power as $P_{Pump} = x.P_{Pump,\ th}$[7]. The maximum total input power of the 16 channels is -3 dBm over C-band, while a cw-probe at 1555 nm with -19 dBm is used to monitor the gain excursion. Fig. 1 illustrates a schematic of the experiment set-up.

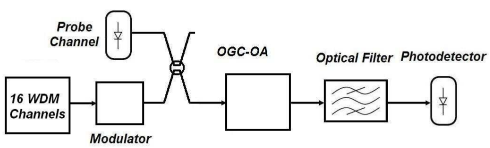

Fig. 1. Schematic of experimental set up

The behavior of the OGC-OA is first observed in extreme situations, when all channels are on and off. This allows us to evaluate the maximum gain variation in case of sudden failure and network restoration. Fig. 2 shows that the gain excursion is lower than 0.25 dB and the relaxation oscillation frequency (ROF) for both full channel load and no channel are 17 kHz and 45 kHz, respectively. As previously observed, this implies that burst sequence with arrival time separated by ~10 μs about hundred of μs [3,4] may generate string gain oscillations. The used burst data have several burst sequences in this range. Fig. 3A shows a part of the burst data trace used in the experiment to appreciate details, similar results were found within 1s transmission. Fig.3B and Fig.3C depict the gain variations for the clamped and non-clamped amplifier, respectively. We notice that the peak-to-peak transients of the OGC-OA is four fold reduced compared to non-clamped case which demonstrates that optical gain clamping technique reduces considerably the transients. The random burst overlapping does not affect significantly the OGC-OA and an almost negligible interplay between ROFs and burst sequences can be observed. A further improvement will be achieved by reducing the laser cavity length using waveguide devices [7].

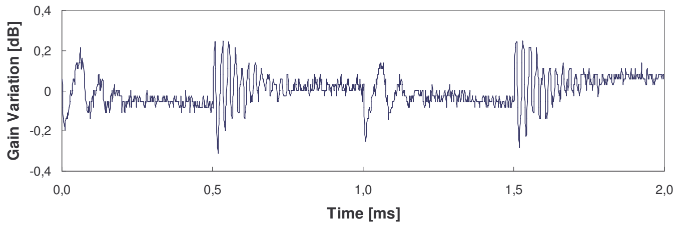

Fig. 2. Gain variation under on / off of all channels

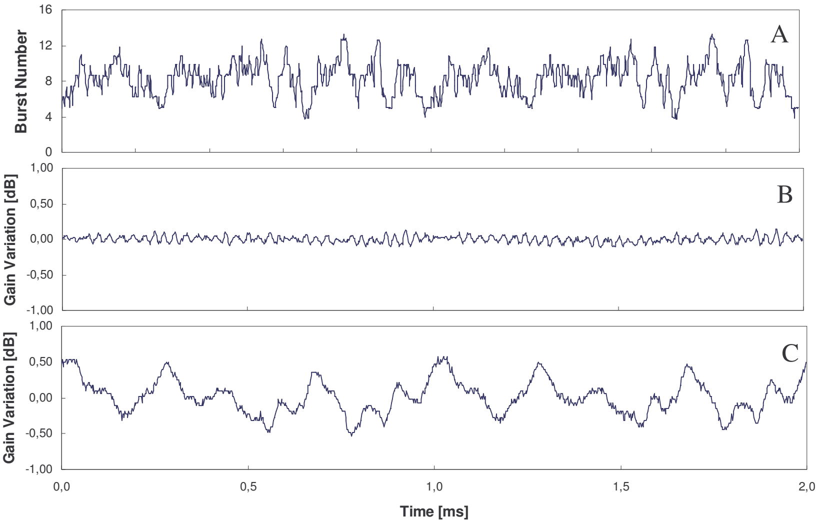

Fig. 3. (A) Optical burst data at the amplifier input; (B) Gain variation with clamped amplifier and (C) non-clamped amplifier.

3. Conclusions

We have experimentally investigated the OGC-OA under real burst traffic. The interaction between bursts generate a very limited excursion. The experimental results demonstrate that the behavior of the OGC-OA is suitable for optical burst transmission over WDM systems.

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4. References

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