Linearized Semiconductor Optical Amplifiers impairments in dynamic optical networks

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Abstract: Transmission impairments due to the cross-gain modulation effect in Linearized Semiconductor Optical Amplifiers have been evaluated in a dynamic network environment. Results demonstrate the arising of power penalizations when the amplifier is operated in saturation.

Keywords: Dynamic networks, optical amplification, XGM

Introduction

Amplification is a key issue in next-generation optical networks even when short distances are to be covered. The transfer of routing and switching functionalities to the optical layer in such networks involves an increase of losses that need to be compensated for. Traditionally optical amplification has been performed by Erbium-doped fiber amplifiers (EDFAs). These show good performance in point-to-point links but introduce serious impairments when dealing with dynamic traffic [1]. On the other hand, semiconductor optical amplifiers (SOAs) are good candidates for amplification in cost-sensitive networks, such as those for access or metropolitan areas. The drawback of this kind of amplifiers is their non-linear behaviour which leads to the arising of interchannel crosstalk due to cross-gain modulation (XGM) effects. In the last years a linearized SOA (LOA) intended for amplification in optical networks has been proposed and commercialized [2]. LOAs have been demonstrated to be the ideal candidates for amplification purposes in cost-sensitive dynamic networks [3, 4]. However, degradations related to both add/drop events and amplification of multiple data channels are present.

In this work we assess the power penalties associated with the operation of LOAs in WDM dynamic networks with add/drop events of channels, bursts or packets. For this purpose, we have measured the transmission performance at reception in terms of bit error rate (BER).

2. Experimental setup and results

The experimental setup shown in Figure 1 emulates the operation of the LOA in a dynamic network environment. Two lasers (*A*, *B*) represent the data channels to be amplified. One of them is operated in continuous mode, while the other is operated in burst mode (*CW* and *bursts* in the Figure). The relative power between the CW and bursts channels is controlled by variable optical attenuators (VOA), so that the number of channels, bursts or packets added/dropped can be modified. The burst or packet length is set to 5 μs and channel burst-mode operation is performed by an optical switch that truly adds or drops the bursts channel to/from the link. At the receiver end the CW channel is monitored and its BER measured. Data from

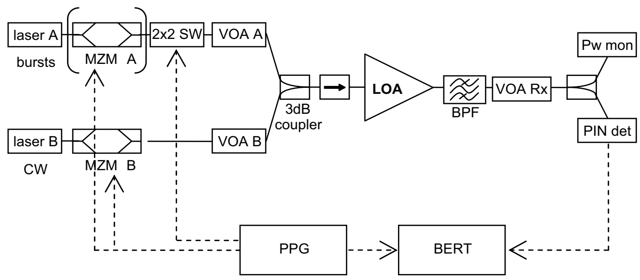

Figure 1: Experimental setup for the assessment of LOA impairments in dynamic networks

pulse pattern generator (PPG) is PRBS 2^{15}-1 at 10 Gb/s and CW and bursts wavelengths are 1556.5 and 1558 nm. Optical powers considered are -7 dBm for CW channel and -7, -1, +5 dBm for bursts channel, associated with scenarios where 1, 4 and 16 bursts are added/dropped.

2.1 XGM by add/drop events

Figure 2 shows BER curves for the above-described scenarios when only the XGM effect associated with add/drop events is taken into account (i.e. no data is conveyed by bursts channel, MZM A inactive in Figure 1).

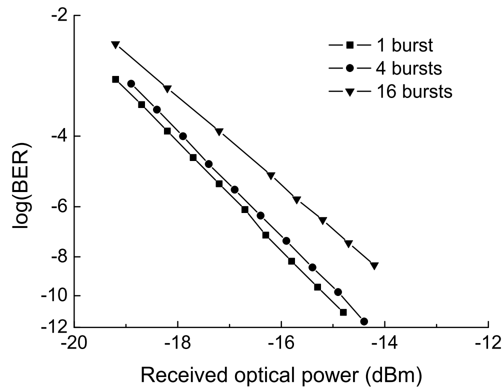

Figure 2: BER vs. received optical power as a function of the number of bursts added/dropped

As it can be observed from the Figure, the number of channels, bursts or packets simultaneously added/dropped has a direct influence over the transmission performance in the amplified link. Power penalties (at 10^{-6} BER) are 0.2 and 1.1 dB for the cases of 4 and 16 bursts add/drop with respect to the scenario with just 1 burst added/dropped.

2.2 XGM by data bit pattern

In order to account for the XGM associated to the bit pattern of data conveyed by channels present in the link, both CW and bursts channels were modulated (MZM A in Figure 1 active). Extinction ratio (ER) of both modulations was varied from 5.6 dB (low ER) to 9 dB (high ER). Figure 3 shows the BER curves in the scenarios where no bursts (grey) and 16 bursts (black) are added/dropped.

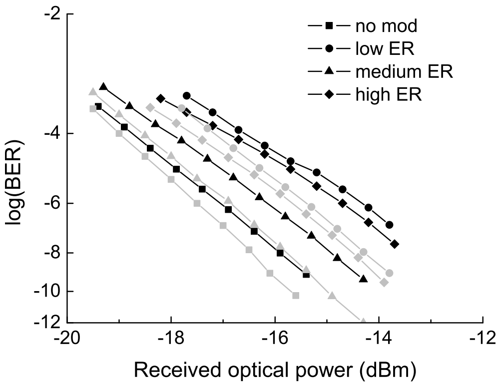

Figure 3: BER vs. received optical power for different ERs

Results show the intra and interchannel effects of data bit patterns. As it can be seen the best performance corresponds to the medium ER case. Regarding the low ER case, performance degradation is mainly caused by noise in the transmission link and at the detector, which is especially deleterious due to the reduced eye opening. On the other hand, when high ER modulation is applied to CW and burst channels, the first one suffers most from both self- and cross-gain modulation of the amplifier gain.

The XGM phenomenon at the amplifier has been further characterized by measuring the modulation index of the CW channel after amplification when it conveys no data (MZM B inactive). For this experiment no add/drop events were introduced in the link so that both channels (*CW* and *bursts* in Figure 1) were operated in continuous mode.

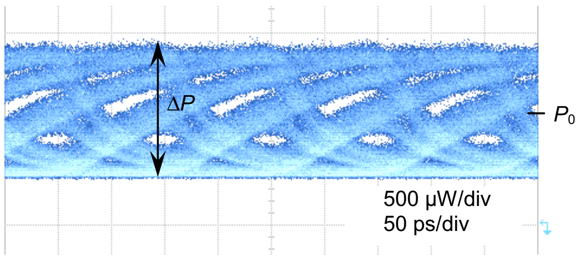

Figure 4: Eye diagram of the CW channel at the output of the LOA (+3 and +12 dBm CW and bursts powers)

Figure 4 shows the eye diagram of the CW channel at the output of the LOA induced by the 10 Gb/s modulated bursts channel in the case the amplifier is operated under deep saturation. As it can be observed, the gain of the amplifier is modulated, which in turn involves an amplitude modulation of the CW channel through XGM. The eye diagram also reflects the gain time response of the LOA, which is of 300 ps for the device used in the experiments.

By measuring the CW channel power levels after amplification, the modulation index m can be calculated as

$$m = \frac{1}{2}\frac{\Delta P}{P_0} \qquad (1)$$

where ΔP is the level power difference and P_0 is the mean power (see Figure 4). Modulation index of the CW channel after amplification is represented against ER of the interfering channel for different relative power values. CW channel power is set to +3 dBm, while interfering channel power is varied from +3 to +12 dBm (1 to 8 interfering bursts). Figure 5 shows the results.

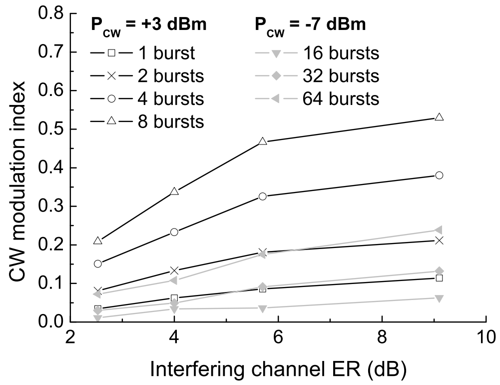

Figure 5: XGM characterisation at 10 Gb/s

Results associated with lower and more realistic power values (P_{CW} = -7 dBm) are also included (grey curves in the Figure). As it can be seen, although minimized, bit pattern XGM can play an important role in WDM amplification by LOAs when the number of channels is high or in general when the amplifier is operated in saturation.

3. Conclusions

In this work we have evaluated the degradation induced by the use of LOAs in WDM dynamic optical networks. Two main XGM contributions have been identified, one associated with add/drop events and another associated with the data modulation of the channels, which additionally has two terms related to self- and cross-gain modulation, respectively. Low penalizations have been observed, which demonstrate the suitability of such devices. XGM impairments, however, need to be accounted for because of the decrease of the link power budget they involve.

4. Aknowledgment

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5. References

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