Mitigation of Reflection-induced Crosstalk in a WDM Access Network
P. J. Urban, A. M. J. Koonen, G. D. Khoe, H. de Waardt
COBRA Research Institute, Eindhoven University of Technology, Den Dolech 2, 5600 MB Eindhoven, The Netherlands
p.j.urban@tue.nl

Abstract: Reduction of reflection-induced crosstalk in a link employing Reflective Semiconductor Optical Amplifier achieved by applying Bias Dithering at RSOA and Phase Modulation at the source gives 6dB and 7dB improvement in power penalty, respectively.

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1. Reflection-induced crosstalk in RSOA-based WDM access network

One of the key issues in Fiber-To-The-Home (FTTH) networks development is cost-efficiency. A Reflective Semiconductor Optical Amplifier (RSOA) represents a promising solution as a cost-efficient colorless transmitter for the Optical Network Unit (ONU).

Next to the advantage of having no wavelength-specific source at the ONU (which is very attractive in WDM-PON architectures), a drawback is the high sensitivity to reflected power coming from e.g. a fiber splice with insufficient return loss, or from a neighboring device. The highly-reflective facet of the RSOA may form a cavity with these reflection points in the network. This cavity introduces interferometric effects and power instabilities, which result in SNR degradation. Thus, power penalties may occur in the system’s upstream BER performance. The phase-induced amplitude variations are larger if the interference takes place within the coherence length.

There are some solutions to decrease the interferometric crosstalk [1], a.o. by external phase modulation, by polarization scrambling and by deploying a low coherence source. Recently, a powerful method for coherent crosstalk suppression based on bias dithering of the RSOA has been proposed in [2].

In this paper we present and compare complete measurements involving two techniques to combat the interferometric crosstalk: RSOA bias dithering and phase modulation at the source. The results are followed by a discussion on pros and cons of both techniques.

2. RSOA bias dithering

In order to reduce the coherent crosstalk noise the coherence of the interfering beams should be disrupted by decreasing the coherence length of the source or of the light reflected by RSOA. The coherence is reduced by broadening the optical spectrum of either the output or the input signal of the RSOA. Broadening the output signal spectrum is done by dithering the bias of the RSOA. Broadening the input signal spectrum is applied by means of phase modulation at the CW laser in the Central Office (CO).

The first technique, spectral broadening in RSOA, is based on the amplitude-to-phase coupling in the active material of RSOA and it is described by the linewidth enhancement factor ($\alpha$ factor). Due to the change in carrier density caused by a variable current applied to the device, the refractive index of the active material also changes and so does the phase of the signal. In long-distance transmission links this phenomenon (chirp) can have a destructive influence on the system performance due to dispersion. However, in access networks, assuming much shorter range, chirping can be used as an advantage to reduce the coherent noise.

In this experiment we apply single-tone bias dithering at RSOA with a frequency outside the data bandwidth and with appropriate amplitude. As a result in the electrical spectrum, the noise from baseband is moved to the higher harmonics out of the receiver bandwidth [3]. Thus, the influence of interferometric crosstalk is reduced.

The experimental setup is given in Fig. 1a. The commercially available RSOA is fed with a CW laser via a variable attenuator, a circulator, a polarization controller and a 3dB coupler. The light in the RSOA is intensity modulated according to current variations composed with the data signal ($2^{31}-1$ PRBS at 1.25Gbit/s) and the dithering (2GHz sine-wave signal). Part of the RSOA output power goes through the polarization controller into the variable reflector, where the return loss can be adjusted for different values of signal-to-crosstalk ratio. The reflected power is coupled back into the same fiber where the CW input signal is transmitted. The two beams interfere introducing interferometric (coherent) noise. The final modulated signal reaches the circulator where it is directed to the ASE filter. The received optical power is adjusted for BER measurements and detected by a 1.25Gbit/s receiver.
The influence of the coherent crosstalk is more visible when an O-E lightwave converter (15GHz bandwidth) is applied, which in contrast to the previously mentioned receiver (800MHz bandwidth) does not reshape the signal. The dithering frequency is 2GHz, which is sufficiently far beyond the data bandwidth, and the applied low-pass filter shows the best suppression at that frequency (31dB).

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3. External phase modulation at a source

The second method, spectral broadening at the CO’s CW source, is realized by applying phase modulation on the CW laser. It enables much larger linewidth enhancement than the first method.

In this experiment the same modulation frequency is applied as in the previous experiment. The only difference in the experimental setup (Fig. 1b) with respect to the previous one is that instead of adding the phase modulation signal to the bias of the RSOA it is provided to the phase modulator inserted between the attenuator and the circulator. In this setup one has to incorporate additional insertion loss introduced by the phase modulator (3-5dB) in the power budget, which can result in e.g. lower amount of users (passive splits) in PON architecture.

4. Measurement and discussion

The eye diagrams distorted by different levels of interferometric crosstalk are shown in Fig. 2 together with the example eye diagrams with noise suppressed by bias dithering of the RSOA. The dither amplitude is varied from the data amplitude (1.0V) to the double of the data amplitude (2.0V). The maximum total value of dither and data amplitude is limited by the maximum rating of the RSOA’s RF input. The required amplitude of the dithering is high due to the low linewidth enhancement factor (around 2-3 for the applied MQW-RSOA). For bulk materials this parameter is higher, up to 8-10, thus the dither amplitude may be much lower.

From the eye diagrams above it can be seen that the best results are achieved for the largest dithering. Therefore, the same dithering is applied for BER measurements, whereas the signal-to-crosstalk ratio is set to values which are more likely to happen in the optical link. Power penalties concerning the scheme with/without bias dithering are given in Fig. 3a and show the improvement of over 6dB for the highest level of crosstalk. At that point the signal-to-crosstalk ratio is 18.5dB and without bias dithering such signal is received with -log_{10} BER=8.5.
In the second method (Fig. 3b) for the same signal-to-crosstalk ratio an improvement of 7dB is achieved when 2-4V of driving voltage is applied to the phase modulator at the laser.

The phase modulator is more efficient in spectral broadening than bias dithering in terms of required voltage. Applying 2V-dithering to RSOA does not bring as good results as around 2V-driving voltage applied to the phase modulator (1.6dB difference in power penalty at 18.5dB signal-to-crosstalk ratio). It is clearly visible on the spectrum of the signals given in Fig. 4 (11dB signal-to-crosstalk ratio). Here, due to a limited resolution of the Optical Spectrum Analyzer (OSA) the difference in spectral broadening between the two methods is estimated as the difference in linewidth at -10dBm and equals $2.5\text{GHz}$.

Enhancing the linewidth is accompanied with reduction of spectral efficiency, regardless where the spectral broadening is applied. Nevertheless, bias dithering seems to have some basic advantages over phase modulation at source. It is an easy-to-implement method (only local oscillator at RSOA is required) and it does not introduce any additional loss, since no extra component in the optical path is inserted.

5. Conclusions
We have shown measurements involving RSOA bias dithering and phase modulation at the source to reduce the coherent crosstalk. The methods have been compared in terms of power penalty reduction and spectral broadening.

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7. References