A novel methodology for measuring coherent homowavelength crosstalk in an Optical Signal Supervisory System

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Fault and degradation detection in a Transparent All-Optical Network Node is an important function that has to be implemented in a Signal Supervisory System [1]. Homowavelength Crosstalk (HOC), that has its origin in the same signal that previously has taken a spurious path (Coherent HOC), is the most harmful kind of linear crosstalk since it cannot be avoided and it can cause a burst of errors if it adds in counterphase when main signal and crosstalk are marks or adds in phase when main signal is a space and crosstalk signal is a mark [2]. It can occur due to MUX and DMUX leakage or to internal switch multipath interaction [3]. Although the leakage may be small, it accumulates through a cascade of nodes thus being potentially a serious limitation to performance.

For measuring the level of the C-HOC the proposed measurement method uses a cw optical signal from a Test Signal Generator which should be a block of the Supervisory System [4]. The summation of this signal with a delayed and attenuated version of itself (C-HOC) produces a phase-induced intensity noise whose power spectral density (psd) equation, without the dc term, is given by

$$\begin{aligned} S_I(f) = \frac{4R}{\pi} c P_0^2 e^{-2\pi \tau/\tau_c} \Bigg\{ & \cos^2 \omega_0 \tau \left[\frac{f \, sin 2\pi\tau f}{f^2 + 1/\tau_c^2} - \frac{sin 2\pi\tau f}{f} \right] + \\ & + \frac{1}{2}\left(e^{2\pi \tau/\tau_c} - e^{-2\pi \tau/\tau_c} \cos 2\omega_0 \tau \right) - sin^2 \omega_0 \tau \frac{\cos 2\pi\tau f}{\tau_c\left(f^2 + 1/\tau_c^2 \right)} \Bigg\} A_{eff}^2 / Hz \end{aligned} \qquad (1)$$

where P_0 is the optical power of the main signal, c is the crosstalk level, τ_c is the source coherence time (i.e. the inverse of the source linewidth), τ is the optical flight delay, ω_0 the optical angular frequency and R the photodetector responsivity.

The main dependences of equation (1) are the time delay τ and the crosstalk level c. In the range where $\tau<\tau_c$ the time delay is given by the inverse of the first relative minimum of the curve drawn by expression (1), and crosstalk level can be derived from the maximum value of the curve without the dc term (psd at dc or low frequencies). When $\tau>>\tau_c$ the phase noise of the two signals (main and crosstalk) are decorrelated and the power spectral density is strictly Lorentzian. When the crosstalk level is very low (below the thermal and ASE noise), the induced intensity noise is no longer detectable and thereby we can only see a dc component in the spectrum analyzer.

We have carried out an experiment with the layout shown schematically in figure 1 corresponding to the main and a spurious path.

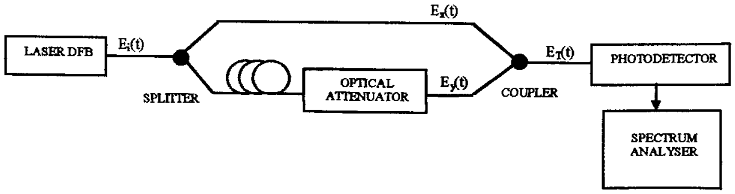

Figure 1. Experiment layout.

In our experiment we have used a DFB laser with a linewidth of 25MHz (τ_c=40ns), and have measured the maximum of the detected psd (without taking into account the dc component) for different crosstalk time delays and crosstalk levels. An example of the obtained psd for three different crosstalk levels is shown in figure 2.

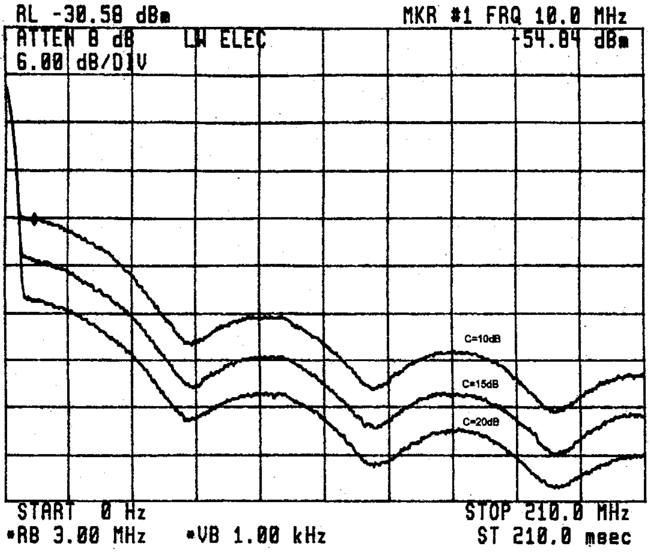

Figure 2. Detected psd for three different crosstalk levels (c=10dB, 15dB and 20dB) with a delay of 16.13nsec.

The measured levels are shown in figure 3 (lines with circles) in comparison with the analytic results from (1). It can be seen from figure 3 that good agreement is achieved between calculations and measures. Errors are lower than 1dB and are caused because, in the real measured psd, we cannot get rid of the dc term, so the measure has to be made not in the origin but onto an offset frequency where there is a level difference which is larger as higher is the time delay. The best agreement is achieved when the time delay is near half the source coherent time. It is worth noting the dependence of (1) with the factor $\omega_0\tau$ which is an uniform random variable caused by the system instability. The expected psd is obtained for $\omega_0\tau=\pi/4$ and it is equivalent to performing the measure through some averages. With a measured electrical signal-to-noise ratio of 28dB we were able to measure a crosstalk level as low as 27dB.

For best performance of this measurement methodology, the length of every internal link of the optical node should differ from each other in some distance so we can detect the C-HOC. Although this condition implies a restriction on the optical node architecture, it allows for an easy and cost effective methodology of detecting, isolating and measuring the Coherent Homowavelength Crosstalk, which is a high potential degrading effect. It also enables the possibility of detecting its origin what is also an important feature in a Supervisory system.

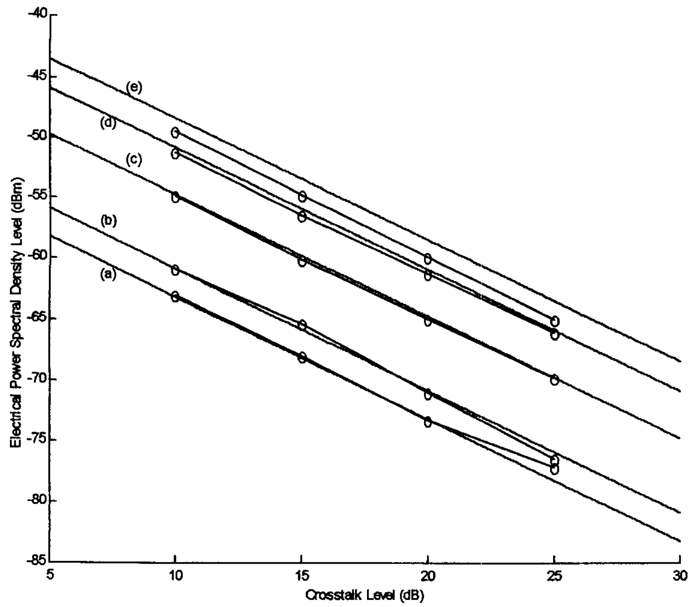

Figure 3. Maximum psd detected level measures (lines with circles) and calculations (solid lines) for different crosstalk delays: a)τ=5.71nsec, b)τ=7.56nsec, c)τ=16.13nsec, d)τ=27.02nsec and e)τ=38.46nsec.

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References

[1] A.Amrani, J.Roldan, J.Prat, A.Rafel and G.Junyent, "Degradation Surveillance Module for Optical Transport Networks", accepted for presentation at IEEE LEOS'98, Orlando, Florida, (1998).

[2] Y.Jin and M.Kavehrad, "An Optical Cross-Connect System as a High-Speed Switching Core and Its Performance Analysis", IEEE J. Lightwave Technol., Vol.14, No.6, 1183-1197, (1996).

[3] J.Zhou, R.Cadeddu, E.Casaccia, C.Cavazzoni and M.J.O'Mahony, "Crosstalk in Multiwavelength Optical Cross-Connect Networks", IEEE J. Lightwave Technol., Vol.14, No.6, 1423-1435, (1996).

[4] C.S.Li and R.Ramaswami, "Automatic Fault Detection, Isolation, and Recovery in Transparent All-Optical Networks", IEEE J. Lightwave Technol., Vol.15, No.10, 1784-1793, (1997).