WQ44 Power penalty due to a laser's mode partition noise in a fiber-optic system

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We present the newly defined parameter S to quantify the power penalty due to a laser's mode partition noise (MPN) for a fiber-optic system by assuming the system has a raised cosine pulse shape, an exponential probability distribution for the power of each mode in the laser source, and a negligible sum of the power covariance between each mode for the laser. These assumptions are different from the previous assumptions that a laser has a Gaussian spectrum shape and a constant output power from which the k factor can be defined to characterize MPN and from which the link limited length due to MPN is obtained.[1,2] Like the k factor, the parameter S can be used to estimate a laser's MPN.[2] Unlike the k factor, S can be easily measured because of the approximation made of the exponential distribution for the power of each mode.

For a system operating with a multilongitudinal mode laser, by incorporating the parameter S, which is an indicator of MPN for a laser, the power penalty due to the laser's MPN is found as

$$PP_{MPN} = -5 \log[1 - AQ^2(RDl)^4 S], \tag{1}$$

where

$$S = \sum_i (\lambda_i - \lambda_t)^4 (\overline{a_i})^2, \tag{2}$$

and where A is the parameter that governs the noise bandwidth and noise level in a receiver, Q is the signal-to-noise ratio (for white Gaussian noise, $Q \approx 6$ for a bit error rate (BER) $= 10^{-9}$), R is the system line rate, D is the dispersion coefficient of the fiber, l is the link length, λ_i is the wavelength for the ith mode, λ_t is the statistical central wavelength which is a power weighted mean of spectrum, and a_i is the normalized average power of the ith mode.

It has been shown that the probability distribution of the side modes, in which spontaneous emission dominates the output power, can be well approximated by an exponential distribution.[3,4] For those central modes (high peaks) in which stimulated emission dominates, the error from using an exponential distribution is negligible because of the small wavelength difference [see Eq. (2)].

For a single-longitudinal-mode laser, the MPN can be presented by the side mode suppression ratio (SSR). The power penalty caused by MPN for a system using a single-longitudinal-mode laser then becomes

$$PP_{MPN} = -5 \log\left[1 - \frac{AQ^2(RDl\,\Delta\lambda)^4}{(1 + SSR)^2}\right], \tag{3}$$

where $\Delta\lambda$ is the wavelength difference between the peak mode and side mode.

Figure 1 shows the BER vs received power for a fiber-optic system operating at 560 Mbit/s ($\lambda = 13\ \mu$m). A dispersion-shifted fiber is used to generate high dispersion (22 ps/nm/km at $\lambda = 1.3\ \mu$m) so that a BER floor can be found by using a short fiber link. The measured data are matched by the curves obtained from Eq. (1) with $A \approx 175$. Using Eq. (2), S is estimated as 0.73 nm^4 from the spectrum of the laser used in the 560-Mbit/s system (Fig. 2). The power penalty caused by various amounts of MPN for a 1-Gbit/s system operating at a BER $= 10^{-9}$ is predicted in Fig. 3. This prediction is similar to the power penalty predicted by the k factor model.[5] Hence the parameter S can be used to characterize MPN; furthermore, it can be obtained easily from the measured spectrum. **(Poster paper)**

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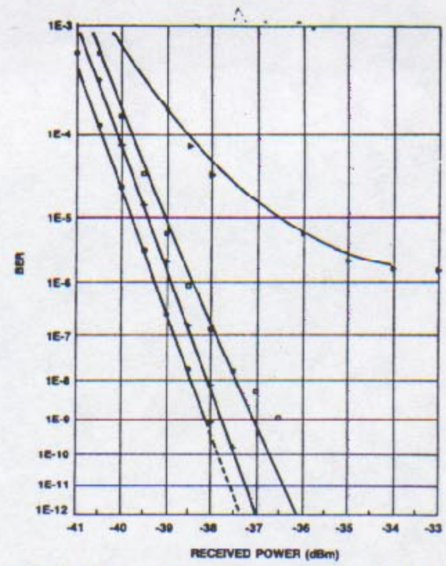
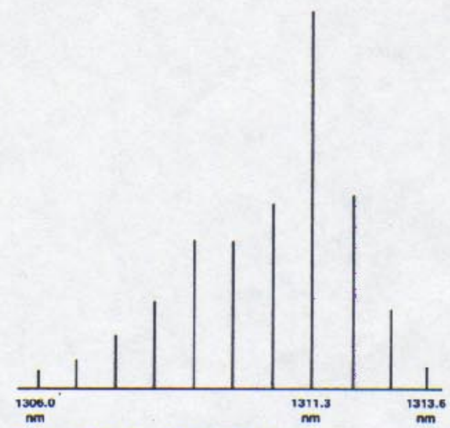
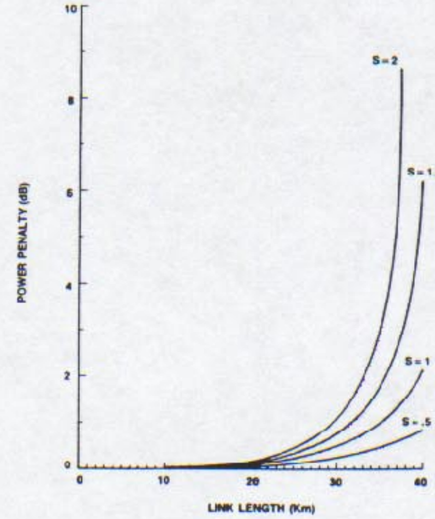


WQ44 Fig. 1. Measured BER for a 560-Mbit/s system operating with 0-km (●), 3-km (+), 7-km (□), and 11-km (Δ) links.



WQ44 Fig. 2. Spectrum of the laser used in the 560-Mbit/s fiber-optic system.



WQ44 Fig. 3. Predicted power penalty for a 1-Gbit/s fiber-optic system operating at a BER $= 10^{-9}$ with $A = 175$ and $D = 2.5$ ps/nm/km.