ESTIMATION OF OUTAGE PROBABILITY IN PRESENCE OF POLARIZATION DEPENDENT LOSS

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We exploit a PDL-extended GN model to estimate the outage probability in ultra-long-haul optical links, focusing on the different impacts of PDL in the linear and nonlinear regime.
Keywords: Polarization-dependent loss, Gaussian noise model

1. Introduction

Polarization-dependent loss (PDL) is an energy loss depending on the polarization state of the electromagnetic wave. It manifests principally in lumped devices, e.g., Erbium-doped fiber amplifiers (EDFA) and wavelength-selective switch (WSS). The effect is particularly relevant in reconfigurable add and drop multiplexers (ROADM) where the signal may cross two WSS thus undergoing PDL of the order of 0.5-0.8 dB.
In optical communication systems, the PDL experienced by the signal can be equalized at the receiver through digital-signal processing. However, the PDL accumulated along the link in the amplified spontaneous emission (ASE) and the nonlinear interference (NLI) partially remains. The distributed generation of the two effects along distance results in different PDL impairments. As a result, the performance of the link expressed, for instance, in terms of the signal-to-noise ratio (SNR), is a random variable and may fall below the threshold of the forward error correcting (FEC) code thus inducing system outage.
The experimental or numerical investigation of PDL is extremely time-consuming since the effect is random and many propagation observations are necessary to build some statistics. A popular model in the literature, the reverse channel model (RCM) [1], decouples the effect of PDL and the NLI. In another model [2] we showed that the two effects can be included in the framework of the Gaussian noise (GN) model and validated it both numerically and experimentally.
In this work, we use the GN model to investigate the impact of PDL in linear and nonlinear regimes.

2. PDL impact

We estimated the probability density function (PDF) of the SNR by using the PDL-extended GN model. We focused on a 60x100 km uncompensated single mode fiber (SMF) link, with randomly oriented PDL inserted after each amplifier, each of value 0.5 dB. The signal under investigation was the central channel of a wavelength division multiplexing (WDM) comb made of 51 channels at symbol rate 49 Gbaud with channel spacing 50 GHz, modulated by polarization division multiplexing quadrature phase shift keying (PDM-QPSK).
We estimated the outage probability, i.e., the probability that the SNR is below the threshold of 6.25 dB, a typical value when using soft-decision FEC. Such an outage is showed in the inset of Fig. 1. We reported the PDF of the SNR at power 2 dBm where ASE and NLI, on average, have the same variance. Contrary to the RCM prediction, the results show that the estimation of the outage probability requires to account for the different PDL impacts on the linear and nonlinear noise.
More results will be discussed at the time of the presentation.

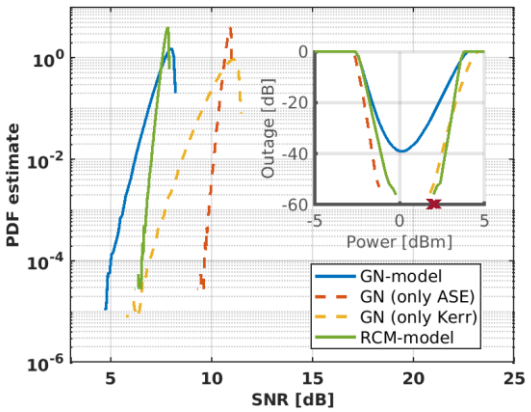

Fig. 1 PDF of the SNR at channel power 2 dBm (outage probability in the inset) 51 PDM-QPSK over 60x100 km of SMF.

3. Conclusions

We estimated the PDF of the SNR in the presence of PDL in ultra-long-haul optical links by using a PDL-extended GN model. Our results show that the PDL acts in different ways between the nonlinearly and the linearly dominated regime, having a more severe impact in the nonlinear regime.

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References

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