Energy Dispersion Index for Finite-Length Probabilistic Shaping by 4D Signaling

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1 Abstract

Probabilistic shaping (PS) is a key enabler to realize near capacity-achieving transmission for the additive white Gaussian noise (AWGN) channel. In the context of fiber optical communications, the shaping gains provided by AWGN-optimal PS are undermined by the nonlinear interference (NLI), as fiber Kerr nonlinearities are enhanced by the Maxwell–Boltzmann distribution of amplitudes. To combat this NLI penalty, a straightforward approach is simply using short shaping blocklengths [1], which induces less NLI thanks to highly-correlated transmitted symbols. The effects of shaping blocklength on the NLI were investigated in [2]. A precise metric that quantifies such effects was missing, until recently we proposed energy dispersion index (EDI) [3]. The numerical results of coherent optical communications in [3] showed a strong association between EDI and effective signal-to-noise ratio (SNR). However, only 2D symbols using single polarization were considered in [3] for the sake of simplicity. By contrast, dual-polarization offers four carriers and, hence, naturally leads to 4D symbols. Besides shaping blocklength, mapping strategy also plays an important role in the temporal structure of 4D symbols and subsequently affects the NLI [4].

This work is a follow-up study of [3]. The performance of EDI in predicting effective SNR of constant-composition distribution matcher (CCDM) shaped 4D symbols is evaluated at different distances, as shown in Fig. 1. Generation of 4D symbols is realized at various shaping blocklengths and with different symbol mapping strategies. We first generalize the EDI definition to 4D symbols. Then we analyze the EDI of 4D symbol sequences and also provide the corresponding analytical expressions for the EDI. The numerical results show that EDI performs well, in particular for the single-span links.

References

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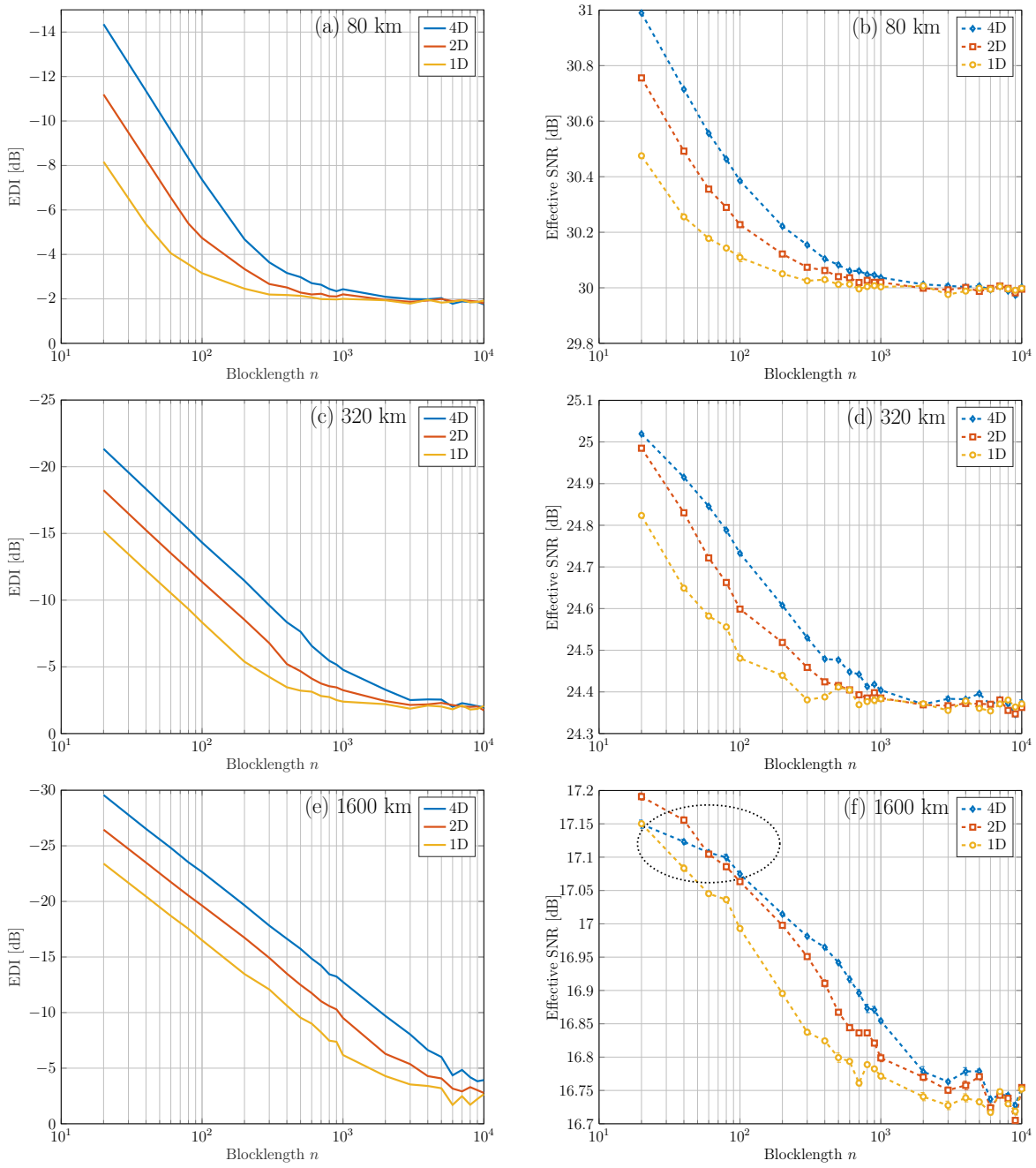

Figure 1: EDI (left column) and effective SNR (right column) vs. blocklength n after CCDM-shaped 64QAM WDM fiber transmission at various distances. The simulation setup is the same as in [3], except that dual-polarization is used here. The EDI is shown in dB and inverted for convenience of comparison. 1D, 2D and 4D (see [4, Fig. 3]) symbol mapping strategies are compared. Window lengths of 30, 150 and 1000 are used for the EDI calculation at distances of 80 km, 320 km and 1600 km, respectively. The dashed circle in (f) indicates the discrepancy between EDI and effective SNR for 4D symbol mapping, which could be due to the coupling effect between the two polarization components.