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Improved signal fidelity at higher SNR using probabilistic constellation shaping with enhanced Gaussian noise model

Zahid G. Khaki[1,2] **· Gausia Qazi**[1]

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Abstract
The paper discusses the implementation of enhanced Gaussian noise (EGN) model-based probabilistic shaping (PS) in long-haul optical transmission systems to mitigate the effects of non-linearities that can occur when using different input distributions for constellation shaping. This approach aims to increase the achievable information rate (AIR) while maintaining a reasonable signal-to-noise ratio (SNR) at optimal launch power. The authors propose that this approach can improve the efficiency and reliability of long-haul optical transmission systems by reducing the impact of fiber non-linearities. The proposed method aims to maximize mutual information in a coherent optical system without relying on digital signal processors. This is achieved by optimizing PS using sequential quadratic programming in a back-to-back configuration with 16-Quadrature Amplitude Modulation. The objective function is set to minimize the second and fourth order moments of input, resulting in reduced higher order noise coefficients and minimal non-linear interference noise at higher values of SNR. The EGN model is used to optimize the PS, resulting in an SNR value of 14.52 dBm and a minimal SNR penalty of 0.15 dBm towards the uniform probability distribution. The optimized EGN model returns $\widehat{\mu}_4$ and $\widehat{\mu}_6$ values of 1.41 and 2.24 respectively, which further contribute to reducing the impact of higher order noise coefficients on the system.

Keywords Mutual information · Achievable information rate · Enhanced Gaussian noise model · Maxwell–Boltzmann distribution · Probabilistic shaping

1 Introduction

Non-linearity has consistently limited the required data rate in long-haul optical communication systems that are not repeated. (Saleem et al. 2022). This in turn limits the achievable effective signal-to-noise ratio (SNR) at receiver, thereby confining the maximum spectral

✉ Zahid G. Khaki
xahid.khaki@islamicuniversity.edu.in

Gausia Qazi
gausia.qazi@nitsri.net

[1] National Institute of Technology, Srinagar, Jammu and Kashmir 190006, India

[2] Islamic University of Science and Technology, Kashmir, India

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