Performance of Quadrature Amplitude Modulation Under Gaussian and Laplacian Noises

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I. Summary and Critical Analysis of the Reference Article

THE paper ”Exact Symbol Error Probability of Square M-QAM Signaling over Generalized Fading Channels subject to Additive Generalized Gaussian Noise” presents a performance evaluation study of square M-ary quadrature amplitude modulation (MQAM) in terms of average symbol error rate (SER) over flat fading channels contaminated by generalized Gaussian noise. The authors also derived closed-form expressions for the case of extended generalized-K (EGK) fading. Special attention is given to performance analysis under Gaussian and Laplacian noise.

The importance of evaluating the performance of systems under pure AWGN is well-recognized. However, in certain environments, other forms of interference and noise may arise that are not adequately modeled by the conventional Gaussian distribution. Therefore, using a generalized form of the Gaussian distribution, which encompasses not only the Gaussian case but also the Laplacian and Uniform cases, becomes highly attractive.

The primary objective of this work is to derive general expressions for the SER of square MQAM systems and to adapt these expressions for specific cases. The structure of the paper is well-organized and maintains a clear progression of the topics discussed. However, it lacks a systematic literature review that would highlight related studies in the field.

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In Section II, the authors present the theoretical framework for calculating the average SER of MQAM modulations, specifically under AWGN conditions. This serves as the reference curve for calibrating simulations and other cases. In Section III, they derive a general expression for the SER in the presence of EGK fading contaminated by additive white generalized Gaussian noise (AWGGN). The mathematical approach is relatively complex but detailed, allowing for thorough understanding.

In Section IV, the authors present adaptations and necessary simplifications of the general SER expression for the following cases: EGK fading with additive Laplacian noise, GK fading with AWGN, Rayleigh fading with additive Laplacian noise, and Rayleigh fading with AWGN. A significant contribution of this work is that Section IV not only provides simplifications but also offers expressions with reduced computational complexity.

In the performance evaluation presented in Section V, three graphs are shown:

- The first graph depicts SER as a function of average SNR in dB, with curves representing different parameters. Special attention is given to scenarios with flat fading subjected to AWGN and additive Laplacian noise. Notably, the theoretical curves previously derived align well with the computational simulations;
- The second graph illustrates Rayleigh fading under AWGGN, with various parameters tailored to specific cases;
- The third graph displays Nakagami-m fading subjected to AWGGN, with parameters also varied for specific cases.

The reproduced results correspond to a section of Figure 1 from the reference article, associated with the performance evaluation of 16QAM modulation in a flat fading channel with Gaussian and Laplacian noise. These reproduced results show conformity with the proposed theoretical results and, consequently, with the original simulations.

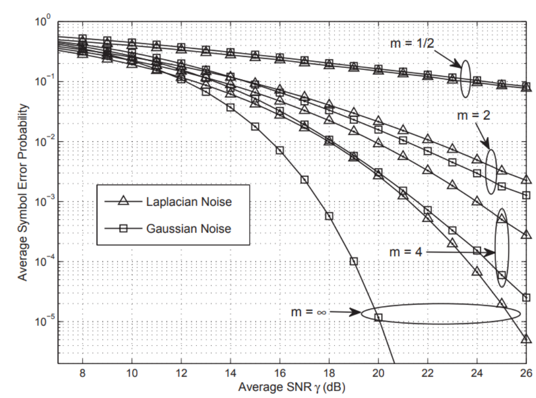

Fig. 1. SER vs average SNR: 16QAM under AWGN and Laplacian noise (reference figure).

The following figure shows both theoretical and simulated curves of a 16QAM system operating under AWGN channel (flat fading and Gaussian noise contaminating the signal). If we set SNR to 10dB in Fig.1, it is possible to reach an average SER equals to 2×10^{-1}. In Fig. 2, this result is possible to see not only in the theoretical curve but also in the simulated curve.

The last figure depicts the simulated curve of a 16QAM system operating under Laplacian noise (flat fading and additive Laplacian noise). If we analyze the SER for an SNR of 15dB in Fig.1, we find a value of 4×10^{-2}, whereas in Fig3, it is

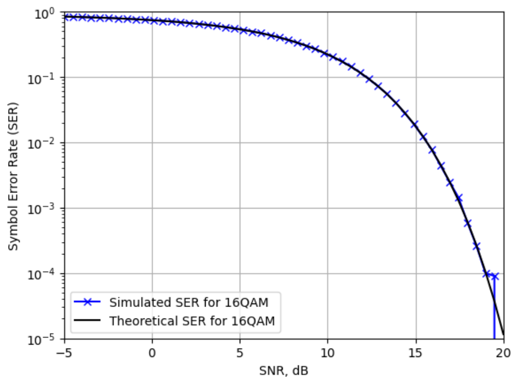

Fig. 2. SER vs average SNR: 16QAM under AWGN.

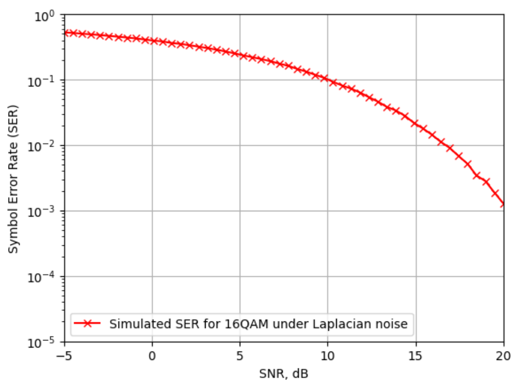

Fig. 3. SER vs average SNR: 16QAM under Laplacian noise.

2×10^{-2}. This difference can be justified by some statistical fluctuation between the simulations.