

Bayesian and Non-Bayesian Methods for Iterative Joint Decoding and Detection in the Presence of Phase Noise

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We review some known schemes and propose new algorithms for joint iterative decoding and parameter estimation in the Bayesian and non-Bayesian frameworks. In particular, we focus on low-density parity-check (LDPC) codes in the presence of phase noise. The proposed algorithms can be also applied to turbo codes.

We consider a coded transmission system where codewords $\mathbf{c} = \{c_k\}_{k=0}^{K-1} \in \mathcal{C}$ are transmitted over a channel affected by additive white Gaussian noise (AWGN), with one-sided power spectral density N_0 , and by a random time-varying carrier phase (phase noise). The phase noise process $\{\theta_k\}$ is modeled as a discrete-time Wiener process with Gaussian increments of variance σ_Δ^2 . To avoid phase ambiguity problems, pilot symbols may be also inserted in the transmitted sequence.

The most popular non-Bayesian algorithm for an unknown phase channel is based on the application of the expectation-maximization (EM) algorithm [1]. Non-Bayesian estimation methods are suited to parameter estimation, but not to random signal estimation. In order to adapt the algorithm to a time-varying channel phase, a modified sliding window (SW) version of the algorithm (EM-SW) with an optimized window is considered. Another possibility is to find an efficient parameterization of the phase noise process such that an arbitrary realization of the phase $\{\theta_k\}$ can be expressed through a small number of deterministically unknown variables. A solution based on the Karhunen-Loeve expansion combined with the EM algorithm (EM-KL) is considered in this paper.

The proposed Bayesian algorithms are obtained as an application of the sum-product algorithm [2] to the factor graph representing the joint a posteriori distribution of the information bits and channel parameters given the channel output. Since the SPA for continuous random variables involves integration and computation of continuous pdfs, we advocate the method of *canonical distributions* [3] to overcome this problem. For several choices of canonical distributions, namely a discretization of the parameter space (by L values), a Fourier (by N harmonics), a Tikhonov, and a Gaussian parameterization, we derive the corresponding iterative decoding algorithms and compare their performance by computer simulation [4]. Since the algorithm based on a discretization of the parameter space becomes “optimal” (in the sense that it approaches the performance of the exact SPA) for a sufficiently large number of quantization levels, even if at the expenses of

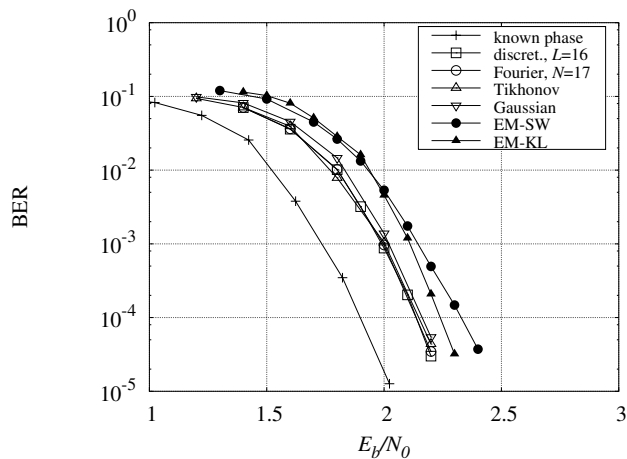


Figure 1: Performance of the proposed algorithms.

an increased computational complexity, it can be considered as a performance benchmark.

Comparing the performance of the considered algorithms (see Fig. 1) in the case of a (3,6)-regular LDPC code with codewords of length 4000, BPSK modulation, and 1 pilot every 20 bits, we may observe that the EM-KL algorithm performs better than EM-SW algorithm: the more accurate a priori knowledge of the phase time variations allows to obtain a performance improvement. For the same reason, all the proposed Bayesian algorithms perform better than their non-Bayesian counterparts. Among all considered schemes, the novel algorithm based on Tikhonov parameterization exhibits practically optimal performance and very low complexity, and represents an attractive solution for systems where powerful LDPC-coded modulations are transmitted in the presence of phase noise, such as in next-generation satellite Digital Video Broadcasting.

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