# Iterative Correction of ISI via Equalization and Decoding with Priors

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*Abstract* — **An iterative algorithm is presented for joint equalization and decoding of data that has been transmitted over intersymbol interference (ISI) channels. This differs from well-known "turbo equalization" (TEQ) methods, in that the ISI is removed with a soft-input soft-output (SISO) equalizer via linear or decision feedback equalization (DFE). The data is encoded with a convolutional code and interleaved prior to transmission over the channel. At the receiver, symbol estimates are successively refined by passing extrinsic information, in the form of priors over the symbols, between the SISO equalizer and a SISO decoder based on maximum-aposteriori-probability (MAP) symbol estimation. The low complexity of this algorithm make it a practical alternative to existing methods, without sacrificing bit error rate (BER) performance.**

## I. Introduction

Data transmission over ISI channels is a classical problem in communication scenarios. Conventional approaches implement an equalizer to remove ISI or use MAP or maximum likelihood (ML) detection. Data reliability can be enhanced using coding, where the data is encoded in the transmitter prior to transmission. For reasons of complexity, the receiver then typically performs separate equalization and decoding of the data. Significant performance gains can be achieved through joint equalization and decoding at the cost of added complexity. A recent approach that significantly reduces the complexity of joint equalization and decoding is the so-called "turbo equalization" algorithm, where MAP/ML detection and decoding are performed iteratively on the same set of received data [4, 5]. It has recently been shown that passing soft information, the use of interleaving, and the controlled feedback of soft information are essential requirements to achieve performance gains with an iterative system [1]. Various algorithms similar to TEQ have been proposed to overcome the complexity of the MAP/ML algorithms, especially in the detector, where complexity is exponential in the channel delay spread [2, 3].

An algorithm that is a practical alternative to turbo equalization is presented in this paper. In an approach similar to that of Wang and Poor [2], the MAP/ML detector in the TEQ setup is replaced by a linear equalizer (LE) or DFE. The filter coefficients are selected according to a minimum mean squared error criterion (MMSE), taken over both the statistics of the noise and the prior over the symbols.

## II. Concepts

A block diagram of the data transmission system is shown in Figure 1. In the receiver, the SISO equalizer and SISO decoder exchange priors over the possible values of each code symbol $c_n$. The SISO equalizer consists of an estimator, providing

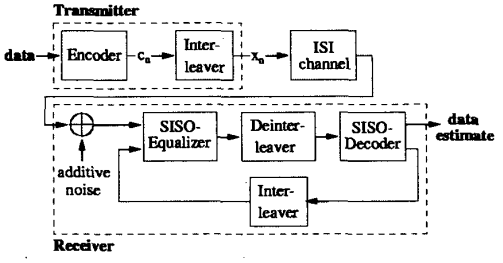


Figure 1: *Data Transmission System*

the estimates $\hat{x}_n$ of the transmitted symbols $x_n$, followed by a mapping that transforms $\hat{x}_n$ to a prior over the transmitted symbol at time $n$. The SISO decoder uses this soft information to decode the data and produce an additional prior over the symbols, which can be interpreted as soft feedback information for the equalizer. The SISO equalizer minimizes the MMSE cost function $E\{|x_n - \hat{x}_n|^2\}$ using the time varying statistics $E\{x_n\}$ and $Cov\{x_n x_m^*\}$, which are computed for each received symbol using the soft feedback information [1].

For the SISO equalizer, a time-recursive update algorithm with $O(N^2+M^2)$ (exact implementation) and $O(N+M)$ (approximate) complexity per received symbol and iteration was developed [1], where $M$ is the ISI channel length and $N$ the length of the equalization filter. Both implementations yield significant savings in the computational complexity compared to MAP/ML-based detectors with $O(q^M)$ complexity, where $q$ is the size of the alphabet of the transmitted symbols $x_n$.

## III. Results

From the set of possible equalizer implementations, the exact implementation of the LE-based SISO equalizer performs best in terms of BER and can match or beat the performance of the approach in [3] and even the MAP-based TEQU approach in [5]. The DFE-based solutions are shown to perform worse than LE-based solutions [1]. The performance improvements of the proposed algorithm over that of the TEQ approach, for certain ISI channels and data block lengths, demonstrates that BER-optimum SISO receiver elements (detector, decoder) are not necessarily optimum in an iterative setup [1].

## References

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