Nonlinear Successive Interference Cancellation for Turbo-CDMA

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***Abstract*—This article presents a novel iterative technique for joint detection and decoding of Direct Sequence-Code Division Multiple Access (DS-CDMA) systems. A turbo-CDMA successive interference cancellation structure is proposed with complexity in $O(K)$, where K is the number of users. The structure can be implemented easily and converges rapidly to the single user bound.**

keywords: Turbo decoding, successive interference cancellation, multiuser detection, Coded CDMA, SISO.

I. Introduction

In [1], the turbo-CDMA approach is applied to MIMO systems in a structure with linear complexity $O(K)$, but weak performance. In [2] a very efficient algorithm, involving MMSE based interference removal, with complexity in $O(K^2)$ is proposed. In [3] an algorithm with closely related structure and linear complexity in the case of fixed signatures is presented. In the event of signatures changing continuously, the complexity becomes $O(K^2)$.

In this article, we propose an iterative turbo-CDMA algorithm for DS-CDMA communications, with complexity in $O(K)$ even in the presence of time user's signatures.

II. Signal model

In this article, the convolution turbo code is composed of two recursive systematic convolution (RSC) codes separated by a random interleaver π. Let Π_k denote the channel interleaver at transmission level for k^{th} user's, the code-bit interleavers help to reduce the influence of the error bursts at the each input channel decoder. This turbo code is represented in Figure 1.

To simplify, the k^{th} user's information $\mathbf{d}_k$ in the channel, where $\mathbf{d}_k = (d_k^{(1)}, \ldots, d_k^{(P)}) \in \{-1, +1\}^P$, P being the length frame, are sent into the encoder. Then the output coded data is interleaved; the corresponding bit stream will be noted as $\mathbf{b_k} = (b_k^{(1)}, \ldots, b_k^{(N)}) \in \{-1, +1\}^N$, where $N = P/R$, R being the code rate. The modulation is (BPSK).
The bipolar data symbols are multiplied by channelization codes denoted $\bar{\mathbf{s}}_{[k]}$. The channelization codes are Gold sequence, waveform $\bar{\mathbf{s}}_k = [s_1, s_2, \ldots, s_K]$; $s_k \in \{-1/\sqrt{N_c}, +1/\sqrt{N_c}\}^{N_c}$; N_c are length of Gold sequence. The received base band signal can be expressed as

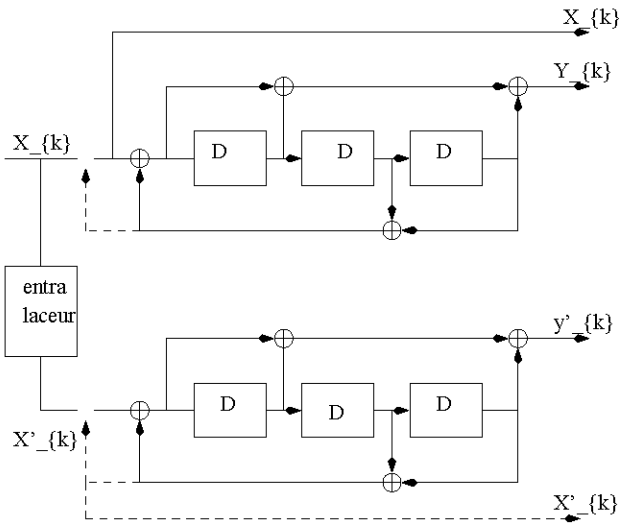


Fig. 1. Structure of the turbo-coder (R=1/3; dotted lines apply for treillis termination only)

$$\bar{\mathbf{r}} = \sum_{i=1}^{N} \bar{\mathbf{r}}^{(i)}, \tag{1}$$

where $\bar{\mathbf{r}}^{(i)} = \sum_{k=1}^{K} A_k b_k(i) \bar{\mathbf{s}}_k + \bar{\mathbf{n}}$. A_k denotes amplitude of the k^{th} user; $\bar{\mathbf{n}}$ is a vector chip zero-mean white Gaussian noise process with unit power spectral density; and σ^2 is the power spectral density of the ambient channel noise. The transmitter is represented in figure 2

III. Receiver

The k^{th} Interference Cancellation Unit of the m^{th} iteration ($ICU_k^{(m)}$) is presented in figure 4. The input is the residual error $\bar{\mathbf{e}}_{m,k}$, we applied a Filter Adapter followed are desinterleaver and added with estimation with preceding iteration $m-1$. These symbols are then passed through a decoding channel, which allows us to estmate the symbols transmitted by k^{th} user $\tilde{\mathbf{b}}_{m,k}$, $\tilde{\mathbf{b}}_{m,k}$ being the vector estimated

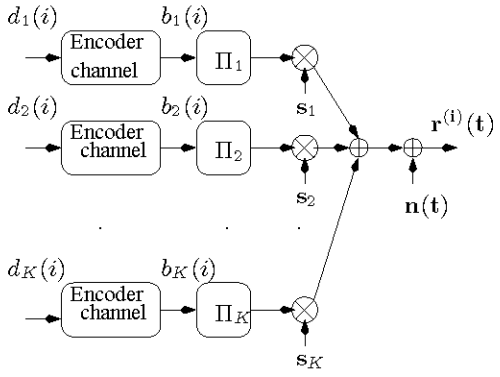


Fig. 2. The CDMA transmitter with K synchronous users.

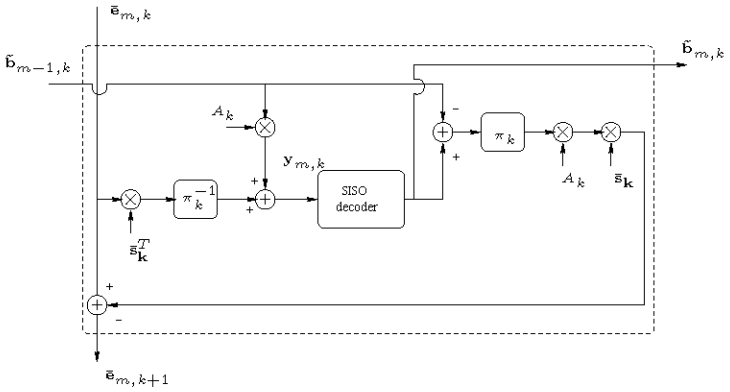


Fig. 4. The Interference Cancellation Unit for k^{th} of m^{th} iteration.

[2].
We retrenched the estimation with preceding iteration m-1 for estimation M, these symbols are interleaved and multiplied by amplitude followed by channelization. The resultant symbol is the contribution for the k^{th} user.

The contribution is retrenched by residual $\bar{e}_{m,k}$ to give the residual $\bar{e}_{m,k+1}$ for the next ICU.
The equations of the $ICU_k^{(m)}$:

$$\begin{aligned} \mathbf{y}_{m,k} &= [\bar{\mathbf{s}}_k^T \bar{\mathbf{e}}_{m-1,k}]_{\text{desin[k]}} \\ &+ A_k \tilde{\mathbf{b}}_{m-1,k}, \\ \bar{\mathbf{e}}_{m,k+1} &= \bar{\mathbf{e}}_{k,m} - A_k[\tilde{\mathbf{b}}_{m,k} - \\ &\tilde{\mathbf{b}}_{m-1,k}]_{\text{int[k]}} \bar{\mathbf{s}}_k, \end{aligned} \tag{2}$$

where $int[k]$,$desin[k]$ are interleaved and desinterleaver respectively.

The structure of the receiver is described in figure 3. The iteration of structure is made up of constituted of K blocs ICU. With each iteration, one ritualizes estimated symbols transmitted information and one withdraws their contributions to the residual signal. The decision on the symbols is made with the last iteration M. We assume the amplitudes A_k knows. The treatments carried out within each unit ICU allow us to discover what makes algorithm flexible.

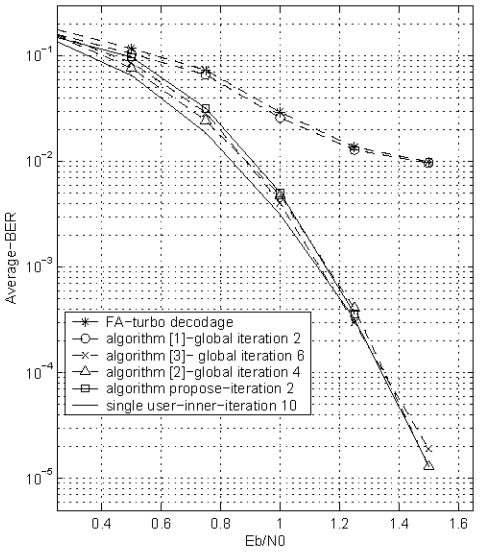


Fig. 5. Average BER: $K = 31$,$N_c = 31$

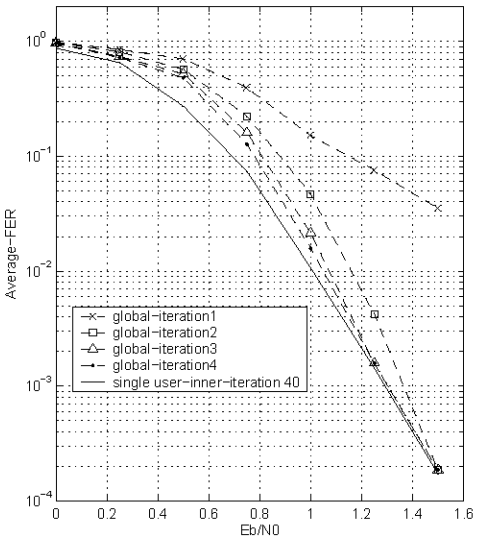


Fig. 6. Average FER: performance of algorithm in synchronous case ($N_c = 31$ et $K = 31$

IV. Simulations

To investigate the accuracy of the proposed analysis, simulations were carried out. The perequisibe system is DS-CDMA system with $K = 31$. The spreading sequences are length $N_c = 31$ Gold sequences. Furthermore, the system uses BPSK modulation and we have AWGN on the channel. A turbo code with rate $R = 1/3$ is used [4]. In simulations, several global turbo-CDMA iterations are performed and in each global iteration, 10 turbo-decoding inner iterations are performed.

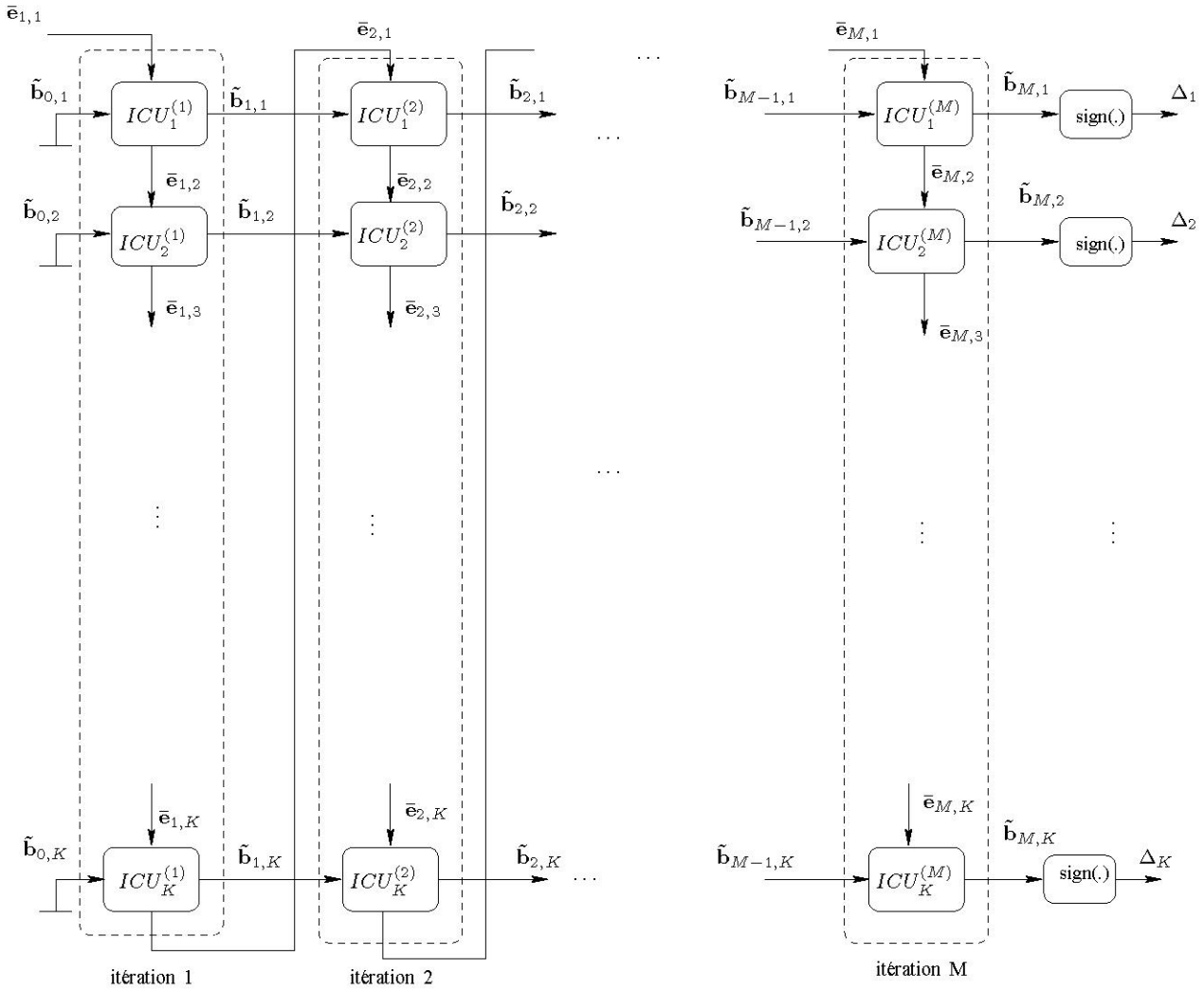


Fig. 3. Structure of the proposed receptor.

In Figure5, we initialized the extrinsic information to zero each global iteration, the results in terms of BER (Binary Error Rate). We notice the algorithms converge fast and close after two global iteration for single user (inner iteration 10) and the algorithm is more performance to [2] and [1]. The structure with linear complexity of [3] appears to perform poorly.

In Figure 6. From the second global iteration, the extrinsic information at the decoder input is initialized with the value supplied at the output of the last inner decoding iteration in the previous global iteration [5] the results in terms of FER (Frame Error Rate) are given on Figure 4.
It appears that after two global iterations, the performance of the proposed algorithm is closed to the single user bound with 40 turbo-decoding iterations.

V. Conclusion

The algorithm converges at the end of some iterations and its complexity is linear with respect the number of user. This algorithm is flexible enough to br used in the UMTS system. small

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