Blind Adaptive Successive Interference Cancellation using Code-Constrained Constant Modulus Algorithms and Iterative Detection in Multipath Channels

Rodrigo C. de Lamare and Raimundo Sampaio-Neto

CETUC/PUC-RIO, 22453-900, Rio de Janeiro - Brazil

I. Introduction

In this work we propose blind adaptive successive interference cancellation (SIC) receivers with iterative detection for DS-CDMA systems in frequency selective channels. A code-constrained constant modulus (CCM) design criterion based on constrained optimization techniques is proposed for SIC detectors in scenarios subject to multipath. Computationally efficient blind adaptive stochastic gradient (SG) and recursive least squares (RLS) algorithms are described for estimating the parameters of SIC detectors. A novel iterative detection scheme that generates different cancellation orders and selects the most likely symbol estimate on the basis of the instantaneous minimum constant modulus (CM) criterion is also proposed.

II. DS-CDMA System Model

•Assuming synchronization of users, the *M x 1* discrete-time received signal at time instant *i* is

$$\mathbf{r}(i) = \sum_{k=1}^{K} A_k b_k(i) \mathbf{C}_k \mathbf{h}_k(i) + \boldsymbol{\eta}_k(i) + \mathbf{n}(i)$$

where $M=N+L_p+1$, *N* is the processing gain, L_p is the number of propagation paths, A_k is the amplitude of user *k*, b_k is the data symbol of user *k*, $\mathbf{C}_k$ is the $M \times L_p$ constraint matrix with one-chip shifter versions of the signature sequence of user *k*, $\mathbf{h}_k$ is the channel parameter vector of user *k*, $\eta_k(i)$ is the intersymbol interference, ***n(i)*** is the *M x 1* complex noise vector with $E[\mathbf{n}(i)\mathbf{n}^H(i)]$.

III. Linearly Constrained SIC Receivers

•Consider ***r(i)*** *and the constraint matrix* $\mathbf{C}_k$.

•Proposed SIC:

- blind linear receiver front-end
- detects users according to decreasing power order
- regenerates and cancels interference

• Symbol detection:

$$\hat{b}_k(i) = \text{sgn}\Big(\Re\Big[\mathbf{w}_k^H(i)\mathbf{r}_k(i)\Big]\Big)$$

where $\mathbf{w}_k(i)$ is the receiver parameter vector and $\mathbf{r}_k(i)$ is the received signal at the k^{th} stage.

•Receiver design: optimization criterion

$$J_{CM} = E\Big[(|\mathbf{w}_k^H \mathbf{r}_k|^2 - 1)^2\Big]$$

subject to $\mathbf{C}_k^H \mathbf{w}_k(i) = \nu \mathbf{h}_k(i)$

• Expression for the CCM receiver:

$$\mathbf{w}_k = \mathbf{R}_k^{-1}\Big[\mathbf{d}_k + \mathbf{T}_k\mathbf{f}_k - \mathbf{C}_k(\mathbf{C}_k^H\mathbf{R}_k^{-1}\mathbf{C}_k)^{-1} \Big(\mathbf{C}_k^H\mathbf{R}_k^{-1}\mathbf{T}_k\mathbf{f}_k + \mathbf{C}_k^H\mathbf{R}_k^{-1}\mathbf{d}_k - \nu\, \mathbf{h}_k\Big)\Big]$$

where

$$z_k = \mathbf{w}_k^H\mathbf{r}_k,\ \mathbf{R}_k = E[|z_k|^2\mathbf{r}_k\mathbf{r}_k^H],\ \mathbf{T}_k = E[|z_k|^2\mathbf{r}_k\hat{\mathbf{b}}],$$
$$\mathbf{d}_k = E[z_k^*\mathbf{r}_k]$$

•Received signal at at the *kth* stage:

$$\mathbf{r}_k(i) = \mathbf{r}(i) - \sum_{m=1}^{k-1} \hat{A}_m(i)\hat{b}_m(i)\hat{\mathbf{s}}_m(i)$$

where $\hat{\mathbf{s}}_m(i) = \mathbf{C}_m\hat{\mathbf{h}}_m(i)$

• Amplitude estimation:

$$\hat{A}_m(i+1) = \hat{A}_m(i) - \mu(\hat{A}_m(i)\hat{\mathbf{s}}_m^H(i)\hat{\mathbf{s}}_m(i) - \hat{b}_m^*(i)\mathbf{r}_m^H(i)\hat{\mathbf{s}}_m(i))$$

• Blind channel estimation:

$$\hat{\mathbf{h}}_k(i) = \arg\min_{\mathbf{h}_k} \mathbf{h}_k^T\mathbf{C}_k^T\mathbf{R}_k^{-1}\mathbf{C}_k\mathbf{h}_k$$

subject to || $\mathbf{h}_k$ *(i)* **|| = *1*,** where *p* is an integer and the solution is the eigenvector corresponding to the minimum eigenvalue of the *Lp x Lp* matrix

IV. Iterative SIC Detection based on Parallel Arbitration and Constant Modulus Criterion

• Proposed iterative (IT) detection:

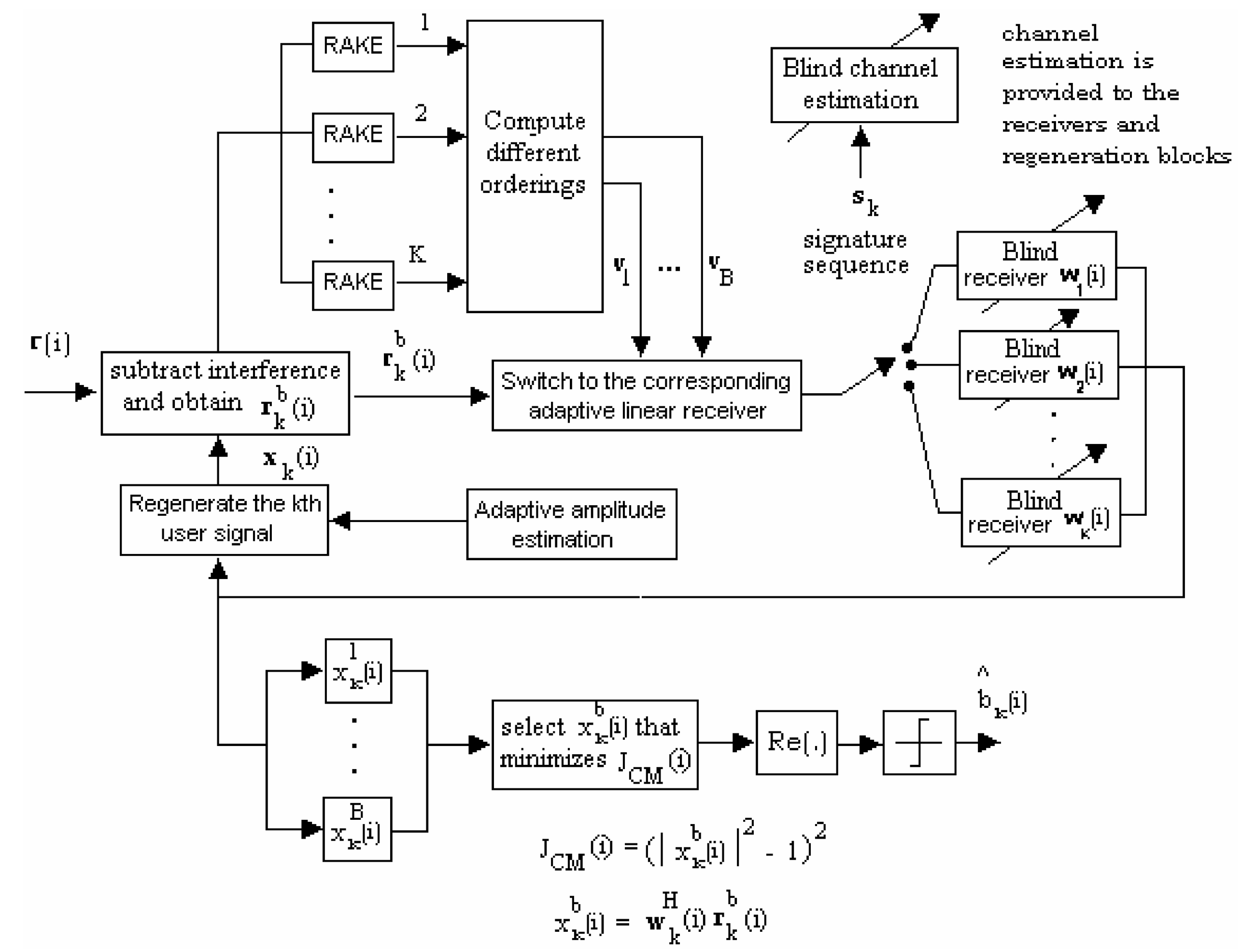
-Generation of *B* different user orderings.

-Ordering vector $\mathbf{v}_b$ with *K* elements contains ordering for branch *b*.

-For each $\mathbf{v}_b$ receiver scheme switches to corresponding linear receiver for interference suppression.

-Interference cancellation

-Generation of *B* candidates for each symbol and user



• Received signal for the IT detection scheme:

$$\mathbf{r}_k^b(i) = \mathbf{r}(i) - \sum_{m=1}^{k-1} \hat{A}_{\mathbf{v}_b(m)}(i)\hat{b}_{\mathbf{v}_b(m)}(i)\hat{\mathbf{s}}_{\mathbf{v}_b(m)}(i)$$

where $\mathbf{v}_b(m)$ is m^{th} index of ordering vector $\mathbf{v}_b$

• Proposed IT-SIC receiver chooses the best estimate of the *B* candidates according to:

$$\hat{b}_k^{(f)}(i) = sgn\Big[\Re\Big(\arg\min_{1\leq b\leq L} CM_k^b(i)\Big)\Big]$$

where the best estimate is the value $z_k^b(i) = \mathbf{w}_k^H(i)\mathbf{r}_k^b(i)$ that minimizes $CM_k^b(i) = (|z_k^b(i)|^2 - 1)^2$

V. Blind Adaptive Algorithms

• Blind SG and RLS channel estimation algorithms: Doukopoulos and Moustakides [1]

• Blind CCM-SG parameter estimation [2]:

$$\mathbf{w}_k(i+1) = \boldsymbol{\Pi}_k(\mathbf{w}_k(i) - \mu_w e_k(i) z_k^*(i)) + \mathbf{C}_k(\mathbf{C}_k^H\mathbf{C}_k)^{-1}\mathbf{h}_k(i)$$

where $e_k = (|z_k(i)|^2 - 1)$, $\boldsymbol{\Pi}_k = \mathbf{I} - \mathbf{C}_k(\mathbf{C}_k^H\mathbf{C}_k)^{-1}\mathbf{C}_k^H$.

•CCM-RLS parameter estimation [2]:

$$\hat{\mathbf{w}}_k(i) = \hat{\mathbf{R}}_k^{-1}(i)\Big[\hat{\mathbf{d}}_k(i) - \mathbf{C}_k\boldsymbol{\Gamma}_k^{-1}(i)\Big(\mathbf{C}_k^H\hat{\mathbf{R}}_k^{-1}(i)\hat{\mathbf{d}}_k(i) - \nu\,\hat{\mathbf{g}}(i)\Big)\Big]$$
$$\hat{\mathbf{d}}_k(i+1) = \alpha\hat{\mathbf{d}}_k(i) + (1-\alpha)z_k^*(i)\mathbf{r}_k(i)$$

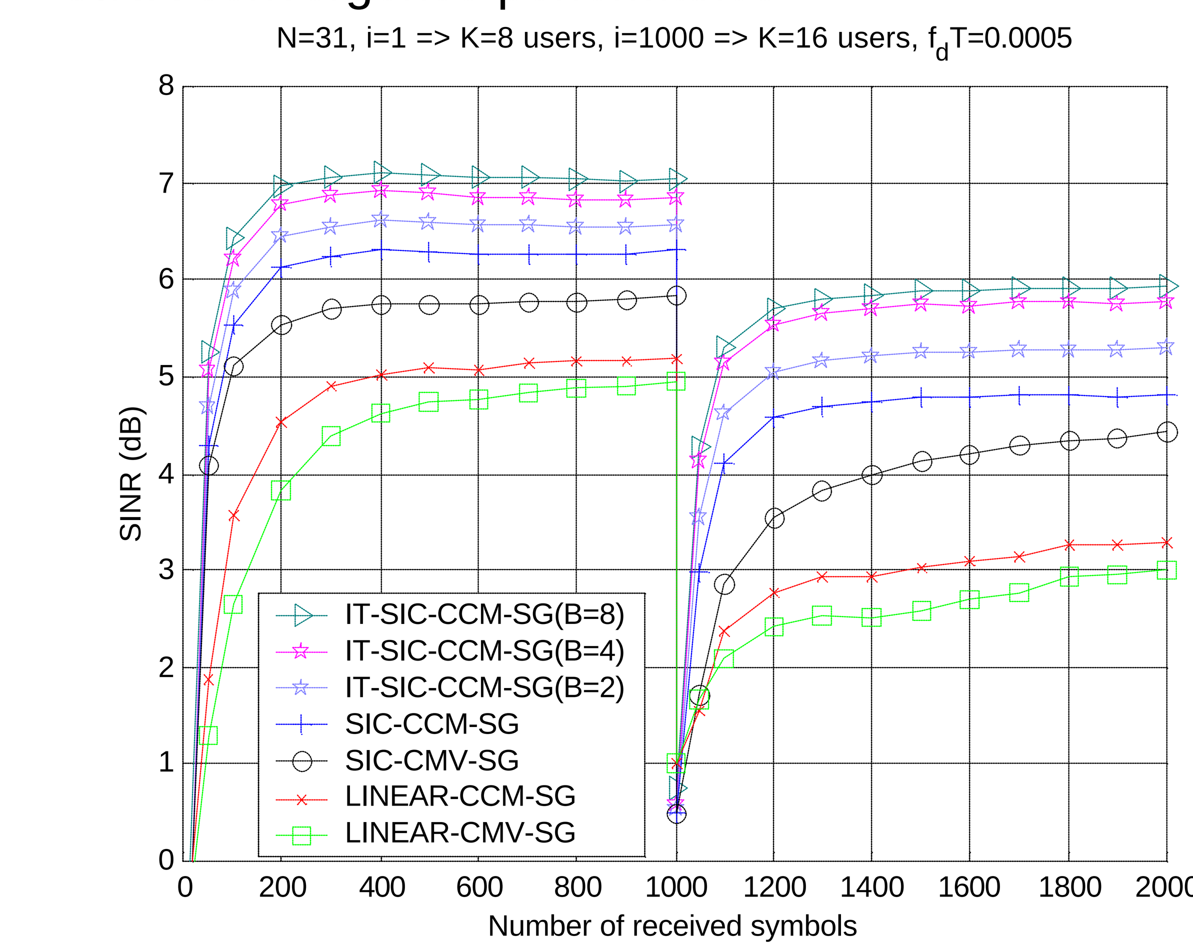
VI. Simulations

• We consider the uplink of a DS-CDMA system with BPSK modulation, K users, processing gain N=31 with Gold sequences.

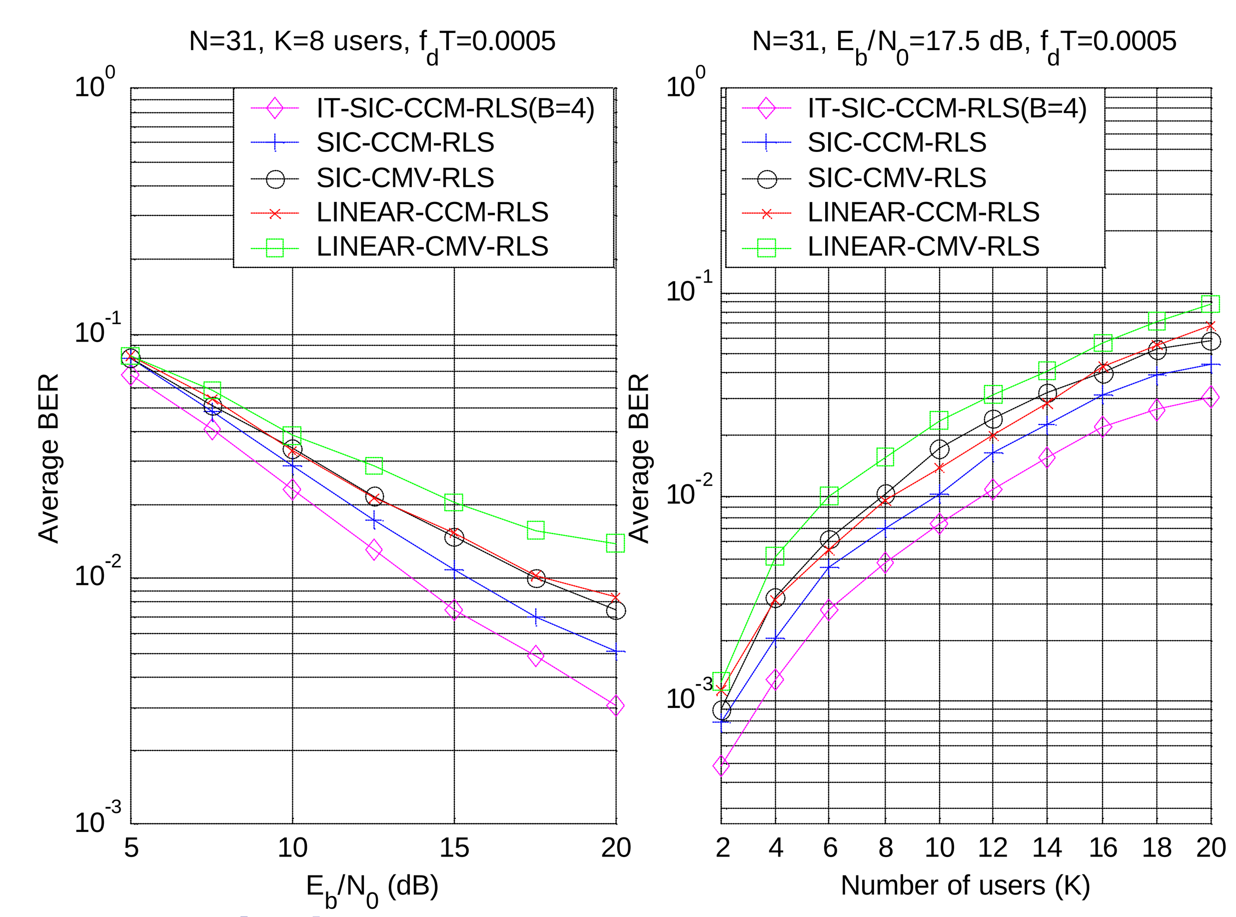
• Comparison with existing linear and SIC receivers and blind contrained minimum variance (CMV) SG and RLS techniques [3].

•Channels assume that *Lp* = 6 as an upper bound and have a profile with 3 paths with relative powers 0, -3 and -6 dB, where for each run and user the spacing between paths is taken from a discrete uniform random variable between 1 and 2 chips.

• SINR convergence performance



•BER performance versus E_b/N_0 and K



VI. Conclusions:

We proposed a blind adaptive iterative SIC receiver for DS-CDMA systems in multipath environments. The proposed IT detection scheme exploits user ordering and SIC to enhance channel and amplitude estimates, yielding significant BER performance improvements.

References:

[1] X. G. Doukopoulos and G. V. Moustakides, "Adaptive Power Techniques for Blind Channel Estimation in CDMA Systems", IEEE Trans. Signal Processing, vol. 53, No. 3, March, 2005.

[2] R. C. de Lamare and R. Sampaio Neto, "Blind Adaptive Code-Constrained Constant Modulus Algorithms for CDMA Interference Suppression in Multipath Channels", IEEE Communications Letters, vol 9. no. 4, April, 2005.

[3] Z. Xu and M.K. Tsatsanis, "Blind adaptive algorithms for minimum variance CDMA receivers," IEEE Trans. Communications, vol. 49, No. 1, January 2001.