Semi-Blind Beamspace-Time Interference Cancellation for a Multi-Code WCDMA System

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***Resumo*–Neste artigo, é investigado o desempenho de um formatador de feixe espaço-temporal semi-cego para um sistema assíncrono de múltiplo acesso por divisão de código de banda-larga por seqüência direta (DS-WCDMA) utilizando um esquema de códigos múltiplos num ambiente microcelular. O receptor proposto utiliza a identificação do canal para realizar conjuntamente equalização, combinação da energia dos multipercursos e cancelamento da interferência. Os resultados de simulação mostram uma melhora significativa de desempenho e uma redução dos símbolos de treinamento requeridos quando comparados a um formatador de feixe espaço-temporal de mínimos quadrados recursivo (RLS) baseado em treinamento.**

***Abstract*–In this paper, we investigate the performance of a semi-blind space-time beamformer for an asynchronous direct sequence wideband code division multiple access (DS-WCDMA) system employing multi-code scheme in a microcellular environment. The presented receiver uses channel identification to perform joint channel equalization, multipath energy combination and interference cancellation. The simulation results show a significant performance improvement and reduction of required training symbols when compared against a receiver employing a training-based space-time recursive least squares (RLS) beamformer.**

I. INTRODUCTION

Third generation cellular systems (3G) have been developed to offer a wide range of services as high quality voice, high data rate and new multimedia applications. Multi-code WCDMA (MC-WCDMA) has been introduced as a new transmission scheme for high speed and flexible data rate communications over wireless channels [1, 2]. MC-WCDMA provides data services for multimedia applications without decreasing the processing gain or increasing the spreading bandwidth. In such a scheme several code channels are assigned to a single user. High-rate data stream is split into a number of parallel low-rate streams that are spread by different orthogonal sequences and added together before transmission. As described in 3G standards [3], MC-WCDMA, together with the orthogonal variable spreading factor (OVSF) method, can provide data service up to the rate of 2 Mbps.

However, the introduction of multi-code causes several problems as high envelope variations, which result from a linear sum of multi-code signals, self-interference caused by the different delays of multi-code signals in a multipath environment and small number of supported users when using multi-code for high-speed data transmission with high transmit power. An efficient method to combat the high envelope variations is employing complex spreading [4] and a solution to recover the orthogonality among the multi-channels and increase the number of supported users is employing spatial-temporal beamforming. If the desired signal and interference have different temporal or spatial signatures, space-time processing can improve significantly the signal-to-interference ratio (SIR).

The hierarchical microcell-macrocell architecture has also been proposed to offer different services for 3G systems in different environments. Macrocells provide continuous umbrella coverage to high mobility users in a wide area while microcells can offer high spectrum efficiency and achieve strategic coverage to low mobility users in areas with high traffic capacity using low elevation antennas with low transmit power [5]. However, due to the frequency reuse factor equal to one, the use of the hierarchical architecture brings some problems as cross-layer interference.

The use of spatial-temporal antenna array receivers in the microcells can also mitigate this problem, offering efficient handover, capacity enhancement, and reduction of near-far effect between layers of the hierarchical cellular architectures [6]. In [7], a semi-blind spatial-temporal beamforming receiver based on the SBCMACI (semi-blind constant modulus algorithm with channel identification) [8] was initially presented. The algorithm uses the constant modulus property of the transmitted signal and performs semi-blind subspace channel identification as a precursor to semi-blind equalization. The resulting receiver allows for coherent combination of the desired signal multipath, cancellation of the interfering users, removal of phase ambiguities present in blind algorithms and significant reduction of the required number of training symbols.

Due to these observations, we investigate in this paper the performance of the SBCMACI spatial-temporal beamformer (BST-SBCMACI) for multi-code transmission in a microcell with low mobility and high data rate users. In section VII, comparison against a receiver employing the training-based RLS spatial-temporal beamformer (BST-RLS) is performed to verify the advantages of the presented semi-blind receiver.

The paper is organized as follows: system model is presented in section II; channel model is described in section III; LS optimization and semi-blind subspace channel identification are given in section IV; BST-SBCMACI and BST-RLS algorithms are given in sections V and VI, respectively; simulation results are provided in section VII and conclusions are presented in section VIII.

II. SYSTEM MODEL

We consider the reverse link of an asynchronous multi-code DS-WCDMA system employing complex spreading and QPSK data modulation to reduce peak-average ratio and achieve better bandwidth occupation. There are M users in the system and each user may transmit N_w multi-channels in parallel with N_b data symbols per packet over assumed stationary conditions. The receiver employs an antenna array consisting of A identical elements equally-spaced by $\lambda_{ant}/2$, where λ_{ant} is the carrier frequency wavelength. Considering that the inverse signal bandwidth is large compared to the travel time across the array, the complex envelopes of the signals received by different antenna elements from a given path are the same except for phase and amplitude differences [9]. The angle of arrival (AOA) of the lth multipath signal from the mth user is θ_m^l and $\mathbf{a}(\theta_m^l)$ is the array response vector (spatial signature vector) to the multipath signal arriving from the direction θ_m^l, with $\mathbf{a}(\theta_m^l) = \left[a_1(\theta_m^l), \cdots, a_A(\theta_m^l)\right]^T$.

Assuming that the total multi-channel information symbol of the mth user at the time n is given by:

$$b_m(n)=\sum_{w=0}^{N_w-1}\sum_{k=0}^{N_b-1} d_m^w(k)\cdot W_m^w(n-kG),\ n=0,\ldots,GN_b-1 \tag{1}$$

Where $d_m^w(k)=d_{m,w}^I(k)+jd_{m,w}^Q(k)$ is the kth information symbol in the wth code channel of the mth user with $d_{m,w}^I(n), d_{m,w}^Q(n)\in\{+1,-1\}$; $W_m^w(n)$ is the wth channelization code of the mth user at time n (nth element of the wth row of the Hadamard matrix of order G) with $W_m^w(n)\in\{+1,-1\}$; and G is the processing gain defined here by the symbol interval to chip interval ratio (T_s/T_c).

We can represent the discrete-time baseband received signal in the following vector form:

$$\mathbf{r}(n) = \sum_{m=1}^{M}\sqrt{\gamma_m}\sum_{k=0}^{N_b-1} b_m(k)\cdot\mathbf{h}_m(n-kG) + \mathbf{v}(n) \tag{2}$$

Where $\mathbf{r}(n)=\left[r_1(n),\cdots,r_A(n)\right]^T$; γ_m is the transmitted signal power of the mth user; $\mathbf{v}(n)=\left[v^1(n),\cdots,v^A(n)\right]^T$ is a complex white Gaussian noise vector with variance σ^2 and $\mathbf{h}_m(n)=\left[h_m^1(n),\cdots,h_m^A(n)\right]^T$ is the complex signature waveform vector of the mth user, described by:

$$\mathbf{h}_m(n)=\sum_{g=0}^{G-1} c_m(g)\cdot\mathbf{p}_m(n-g)$$

Where $c_m(n)=\upsilon_{m,n}^I + j\upsilon_{m,n}^Q$ is the complex scrambling code of the mth user at time n with $\upsilon_{m,n}^I,\upsilon_{m,n}^Q\in\{+1,-1\}$ and $\mathbf{p}_m(n)=\left[p_m^1(n),\cdots,p_m^A(n)\right]^T$ is the chip waveform vector of the mth user that has been filtered at the transmitter and at the receiver and distorted by the multipath channel. We can model $\mathbf{p}_m(t)$ as:

$$\mathbf{p}_m(n)=\sum_{l=0}^{L_m-1}\beta_m^l\cdot\mathbf{a}(\theta_m^l)\cdot\psi(n-\tau_m^l)$$

Where L_m is the number of multipath components for the mth user; β_m^l and τ_m^l are the complex gain and time delay of the lth path of the mth user; and $\psi(t)$ is the filtered chip waveform, which includes the effect of the transmitter and receiver filter.

We consider that the receiver is in perfect synchronization with the strongest multipath component, l_m, of the desired user m ($\tau_m^{l_m}=0$) and that each of the A stacked impulse responses of $\mathbf{p}_m(n)$ is FIR with order q_m such that $\lceil\tau_m^{\max}/T_c\rceil\le q_m\le(L-1)\cdot G$, where $\tau_m^{\max}$ is the maximum delay spread experienced by the mth user and L is some integer. So, we can write the discrete-time received signal, $\mathbf{r}_\mu(k)$, corresponding to the kth symbol as:

$$\mathbf{r}_\mu(k)=\left[\mathbf{H}(L-1),\cdots,\mathbf{H}(0)\right]\cdot\left[\mathbf{b}(k-L+1)^T,\cdots,\mathbf{b}(k)^T\right]^T+\mathbf{v}_\mu(k) \tag{3}$$

Where

$$\mathbf{r}_\mu(k)=\left[\mathbf{r}(k\cdot G)^T,\cdots,\mathbf{r}((k+1)\cdot G-1)^T\right]^T$$

$$\mathbf{H}(l)=\begin{bmatrix}\mathbf{h}_1(l\cdot G) & \cdots & \mathbf{h}_M(l\cdot G)\\ \vdots & & \vdots\\ \mathbf{h}_1((l+1)\cdot G-1) & \cdots & \mathbf{h}_M((l+1)\cdot G-1)\end{bmatrix}$$

$$\mathbf{b}(k)=\left[b_1(k),\cdots,b_M(k)\right]^T$$

$$\mathbf{v}_\mu(k)=\left[\mathbf{v}(k\cdot G)^T,\cdots,\mathbf{v}((k+1)\cdot G-1)^T\right]^T$$

III. CHANNEL MODEL

In this paper, we represent the microcellular multipath propagation channel for each user by the geometrically based single bounced elliptical model (GBSBEM) [10]. In the GBSBEM, it is assumed that the scatterers between the base-station and each user are uniformly distributed within an ellipse. This model is suitable to microcell and picocell environments where antenna heights are low and multipath scattering can occur near the base station or near the mobile with same probability [10]. We can obtain β_m^l, τ_m^l and θ_m^l of section II, using the procedure presented in [10]. The resulting joint probability density function of AOA and TOA (time of arrival) is given by:

$$f_{\tau,\theta}(\tau_m^l,\theta_m^l)=\begin{cases}\dfrac{\left(d_m^2-\tau_m^{l\,2}c_v^2\right)\cdot\left(d_m^2c_v-2\tau_m^lc_v^2d_m\cos(\theta_m^l)+\tau_m^{l\,2}c_v^3\right)}{4\pi a_m^{\max}b_m^{\max}\left(d_m\cos(\theta_m^l)-\tau_m^lc_v\right)^3}, & d_m^2/c_v<\tau_m^l\le\tau_m^{\max}\\ 0, & otherwise\end{cases} \tag{4}$$

Where c_v is the speed of light, d_m is the distance of the mth user to the base-station, $a_m^{\max}=c_v\tau_m^{\max}/2$ and $b_m=\sqrt{c_m^2\tau_m^{\max\,2}-d_m^2}$ are the major and minor axes of the ellipse containing the scatterers for the mth user.

In Fig.1, we present the joint AOA-TOA probability density function obtained by evaluating 100.000 scatterers for $d_m = 500$ and $\tau_m^{\max} = 2\, d_m / c_v$ [10]. The plot shows that there is a high concentration of scatterers near the line of sight with relatively small delays.

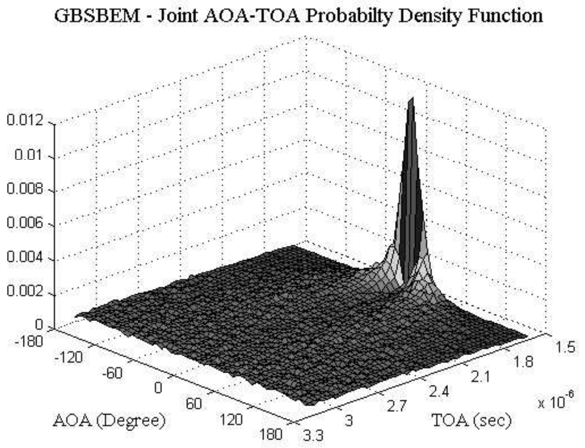


Fig.1. Join AOA-TOA Probability Density Function ($d_m = 500$ and $\tau_m^{\max} = 2\, d_m / c_v$)

IV. SEMI-BLIND SUBSPACE CHANNEL IDENTIFICATION

We can obtain an optimum spatial-temporal weight vector, $\hat{\mathbf{w}}_m$, in the LS sense that provides appropriate beam pattern to the desired user (user *m*) by [11]:

$$\hat{\mathbf{w}}_m = \underbrace{\left(\frac{1}{N_t} \sum_{k=0}^{N_t - 1} \mathbf{r}_\mu(k) \cdot \mathbf{r}_\mu^H(k) \right)^{-1}}_{\hat{\mathbf{R}}_{N_t}} \cdot \underbrace{\left(\frac{1}{N_t} \sum_{k=0}^{N_t - 1} b_m^*(k) \cdot \mathbf{r}_\mu(k) \right)}_{\hat{\mathbf{P}}_{N_t}^m} \tag{5}$$

Where $\hat{\mathbf{R}}_{N_t}$ and $\hat{\mathbf{P}}_{N_t}^m$ are the estimated autocorrelation matrix and crosscorrelation matrix using N_t training symbols, respectively.

It is also possible to determine $\hat{\mathbf{P}}_{N_t}^m$ by performing channel identification. This procedure allows to work at the chip level, increasing the amount of available training data and the estimation accuracy. As shown in [12], it is possible to perform channel identification based on eigendecomposition of the estimated autocorrelation matrix using N_b symbols, $\hat{\mathbf{R}}_{N_b}$, as follows:

$$\hat{\mathbf{R}}_{N_b} = \frac{1}{N_b} \sum_{k=0}^{N_b - 1} \mathbf{r}_\mu(k) \cdot \mathbf{r}_\mu^H(k) = \left[\hat{\mathbf{U}}_s \quad \hat{\mathbf{U}}_n \right] \begin{bmatrix} \hat{\mathbf{\Lambda}}_s & \\ & \hat{\mathbf{\Lambda}}_n \end{bmatrix} \cdot \left[\hat{\mathbf{U}}_s \quad \hat{\mathbf{U}}_n \right]^H \tag{6}$$

Where $\hat{\mathbf{U}}_s = \left[\hat{\mathbf{u}}_1, \cdots, \hat{\mathbf{u}}_\xi \right]$, $\hat{\mathbf{U}}_n = \left[\hat{\mathbf{u}}_{\xi+1}, \cdots, \hat{\mathbf{u}}_{AN\mu} \right]$, $\hat{\mathbf{\Lambda}}_s$ and $\hat{\mathbf{\Lambda}}_n$ contains the estimated signal space eigenvectors, the estimated noise space eigenvectors and the corresponding eigenvalues for the signal and noise space vectors respectively. ξ is the dimensionality of the signal space (rank of $\mathbf{H}_\mu$) which can be estimated using the MDL (minimum description length) criterion [13].

In DS-CDMA systems, we can use the spreading code for the desired user to perform channel classification. In [8], it was presented a semi-blind channel identification based on the following semi-blind regularized LS optimization:

$$\hat{\tilde{\mathbf{p}}}_m = \arg\min_{\mathbf{p}} \frac{1}{AGN_t} \underbrace{\left\| \mathbf{r}_{N_t} - \mathbf{X}_{N_t}^m \mathbf{p} \right\|^2}_{Training-based} + \alpha \cdot \underbrace{\left(\mathbf{p}^H \mathbf{\Pi}_m \mathbf{p} \right)}_{Blind-based} \tag{7}$$

Where α is some positive constant [8]

$$\hat{\tilde{\mathbf{p}}}_m = \left[\mathbf{p}_m(0)^T, \cdots, \mathbf{p}_m(q_m)^T \right]^T$$

$$\mathbf{r}_{N_t} = \left[\mathbf{r}(0)^T, \cdots, \mathbf{r}((N_t - 1)G)^T \right]^T$$

$$\mathbf{X}_{N_t}^m = \left[\tilde{\mathbf{X}}_{N_t}^m \otimes I_A \right]_{AGN_t \, x \, A(q_m + 1)};$$

$\mathbf{I}_{A \; (A\,x\,A)}$ is the identity matrix

$$\tilde{\mathbf{X}}_{N_t}^m = \begin{bmatrix} x_m(0) & 0 & \cdots & 0 \\ \vdots & x_m(0) & \cdots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ x_m((N_t - 1)G) & \vdots & \cdots & x_m((N_t - 1)G - q_m) \end{bmatrix}$$

$$x_m(n) = \sum_{k=0}^{N_b - 1} b_m(k) \cdot c_m(n - kG)$$

$$\mathbf{\Pi}_m = \mathbf{C}_m^H \cdot \tilde{\mathbf{\Xi}}^H \cdot \tilde{\mathbf{\Xi}} \cdot \mathbf{C}_m;$$

$$\mathbf{C}_m = \left[\tilde{\mathbf{C}}_m \otimes \mathbf{I}_A \right]_{ALG \, x \, A(q_m + 1)}$$

$$\tilde{\mathbf{C}}_m = \begin{bmatrix} c_m(0) & & & 0 \\ \vdots & c_m(0) & & \\ c_m(G-1) & \vdots & \ddots & \\ & c_m(G-1) & & c_m(0) \\ & & \ddots & \vdots \\ & & & c_m(G-1) \\ 0 & \cdots & \cdots & 0 \end{bmatrix}_{LG \, x (q_m + 1)}$$

$$\tilde{\mathbf{\Xi}} = \begin{bmatrix} \hat{\mathbf{\Xi}}_\mu & & \\ \vdots & \ddots & \hat{\mathbf{\Xi}}_\mu \\ \hat{\mathbf{\Xi}}_1 & & \vdots \\ & \ddots & \hat{\mathbf{\Xi}}_1 \end{bmatrix}_{(AG\mu - \xi)(\mu + L - 1)\, x \, AGL};$$

$$\hat{\mathbf{U}}_n^H = \left[\hat{\mathbf{\Xi}}_1, \cdots, \hat{\mathbf{\Xi}}_\mu \right]_{(AG\mu - \xi)\, x \, AG\mu}$$

Whose solution is given by [12]:

$$\hat{\tilde{\mathbf{p}}}_m = \left(\frac{1}{AGN_t} \mathbf{X}_{N_t}^{m\,H} \mathbf{X}_{N_t}^m + \alpha \mathbf{\Pi}_m \right)^{-1} \cdot \left(\frac{1}{AGN_t} \mathbf{X}_{N_t}^{m\,H} \mathbf{r}_{N_t} \right) \tag{8}$$

V. SEMI-BLIND CONSTANT MODULUS ALGORITHM WITH CHANNEL ESTIMATION

As presented in [8], SBCMACI first computes the subspace space-time beamforming weight vector for the *m*th user by:

$$\hat{\mathbf{w}}_{m,sub} = \hat{\mathbf{U}}_s \cdot \hat{\mathbf{\Lambda}}_s^{-1} \cdot \hat{\mathbf{U}}_s^H \cdot \mathbf{C}_m \cdot \hat{\hat{\mathbf{p}}}_m = \mathbf{\Gamma} \cdot \mathbf{C}_m \cdot \hat{\hat{\mathbf{p}}}_m \tag{9}$$

and then performs the following semi-blind regularized LS iterative procedure:

i. Initialize $\mathbf{w}_m^0 = \hat{\mathbf{w}}_{m,sub}$ (10)

ii. Generate $\tilde{b}_m^{(i)}$, a sequence that contains the N_t training symbols and the $N_b - N_t$ estimated data symbols:

$$\tilde{b}_m^{(i)} = \left\{ b_m(0), \cdots, b_m(N_t-1), \frac{\mathbf{w}_m^{(i)H} \cdot \mathbf{r}_\mu(N_t)}{\left|\mathbf{w}_m^{(i)H} \cdot \mathbf{r}_\mu(N_t)\right|}, \cdots \right.$$
$$\left. \cdots, \frac{\mathbf{w}_m^{(i)H} \cdot \mathbf{r}_\mu(N_b-1)}{\left|\mathbf{w}_m^{(i)H} \cdot \mathbf{r}_\mu(N_b-1)\right|} \right\} \tag{11}$$

iii. Compute

$$\mathbf{w}_m^{(i+1)} = \mathbf{\Gamma} \cdot \underbrace{\left(\frac{1}{N_b} \sum_{k=0}^{N_b-1} \tilde{b}_m^{(i)*}(k) \cdot \mathbf{r}_\mu(k) \right)}_{\tilde{\mathbf{P}}_{N_b}^{m\,(i)}} = \mathbf{\Gamma} \cdot \tilde{\mathbf{P}}_{N_b}^{m\,(i)} \tag{12}$$

iv. Determine $\varepsilon(i) = \left\|\mathbf{w}_m^{(i+1)} - \mathbf{w}_m^{(i)}\right\|^2 \Big/ \left\|\mathbf{w}_m^{(i)}\right\|^2$ (13)

v. Repeat ii. to iv until $\varepsilon(i) < \varepsilon_w$

Where ε_w is some small positive constant.

VI. RECURSIVE LEAST SQUARES ALGORITHM

RLS can also be used to obtain the spatial-temporal beamforming weight vector, $\hat{\mathbf{w}}_m$. In the following, we briefly describe the algorithm (for additional information, see [7]).

i. Initialize $\mathbf{w}_m^{(0)} = \mathbf{0}$ and $\hat{\mathbf{R}}_{N_t}^{-1} = \left(\sigma^2\right)^{-1} \cdot \mathbf{I}_{u \cdot A \cdot G_p}$ (14)

ii. Compute $\mathbf{K}_{gain}(k) = \dfrac{\lambda^{-1} \cdot \hat{\mathbf{R}}_{N_t}^{-1} \cdot \mathbf{r}_\mu(k)^*}{1 + \lambda^{-1} \cdot r_\mu(k)^T \cdot \hat{\mathbf{R}}_{N_t}^{-1} \cdot \mathbf{r}_\mu(k)^*}$ (15)

iii. Determine $\varepsilon(k) = b_m(k) - \mathbf{r}_\mu(k)^T \cdot \hat{\mathbf{w}}_m^{(k-1)}$ (16)

iv. Compute $\mathbf{w}_m^{(k)} = \mathbf{w}_m^{(k-1)} + \mathbf{K}_{gain}(k) \cdot \varepsilon(k)$ (17)

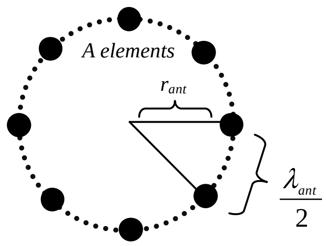
v. Update $\hat{\mathbf{R}}_{N_t}^{-1} = \lambda^{-1} \cdot \left\{ \hat{\mathbf{R}}_{N_t}^{-1} - \mathbf{K}_{gain}(k) \cdot \mathbf{r}_\mu(k)^T \cdot \hat{\mathbf{R}}_{N_t}^{-1} \right\}$ (18)

Where λ is the forgetting factor.

VII. SIMULATION RESULTS

In this section, we investigate the performance of the BST-SBCMACI receiver in a microcell scenario using the GBSBEM model for different training sequence lengths and different number of antennas and we compare the results with the training-based BST-RLS receiver.

For the simulations, we consider an asynchronous DS-WCDMA system with complex spreading operating at 2GHz. There are 5 QPSK modulated users (*M*=5) per cell, each one transmitting 4 code channels (N_w=4) composed by frames with 200 symbols (N_b=200). The chip rate is 3.84 Mcps, the symbol rate is 4x240 Ksps and the processing gain is 16 (*G*=16). The channelization codes are Walsh sequences and the scrambling codes are Gold-like sequences with one chip added at the end. It is considered that the frame duration is short compared with the coherence time of the channel. The cell ratio is 500 *m*, and the users are randomly positioned around the cell between 50 *m* and 500 *m* ($50 \le d_m \le 500$) and with angles between –180° and 180°. We assume for all the users that the maximum propagation delay is 3.33 μs (~13 chip) and L_m=4. The AOA of the strongest path of the desired signal is kept 150° ($\theta_m^{1_m} = 150^\circ$) for all the simulations. The base station employs a circular array antenna (see Fig.2) with equally spaced elements ($\lambda_{ant}/2$) and the SNR at bit level for each antenna element is 8dB (Fig.3 and Fig.4).



$$\mathbf{a}\left(\theta_m^l\right) = \left[\; e^{-j\frac{2\pi}{\lambda_{ant}} r_{ant} \cos\left(\theta_m^l\right)}, \ldots, e^{-j\frac{2\pi}{\lambda_{ant}} r_{ant} \cos\left(\theta_m^l - \frac{2\pi(A-1)}{A}\right)} \;\right]$$

Fig.2. Circular Antenna Array

The signal space is estimated by the MDL method [13]. Results are obtained computing 1000 frames. For all simulations, we consider μ=1, *L*=2, α=0.01, $\varepsilon_w = 10^{-5}$ (BST-SBCMACI) and λ=1 (BST-RLS).

In Fig.3, the bit error rate (BER) of the BST-SBCMACI receiver varying the number of antenna elements and the number of training symbols is presented. The results show that it is possible to reduce MAI and intersymbol interference (ISI) and explore multipath diversity with few training symbols. It also shows the performance degradation in overload scenarios (*A*<*M*) [9].

In Fig.4, a comparison between BST-SBCMACI and BST-RLS receivers for an 8 elements circular antenna array (*A*=8) varying the number of training symbols at *SNR* of 8 dB is presented. The result shows that the BST-SBCMACI receiver outperforms the BST- RLS receiver.

Finally, in Fig.5, we compare the performance of both receivers varying the number of antenna elements and *SNR* using a training sequence of 8 symbols (N_t=8). Again, the performance improvement of the BST-SBCMACI receiver is significant when compared against the BST-RLS receiver.

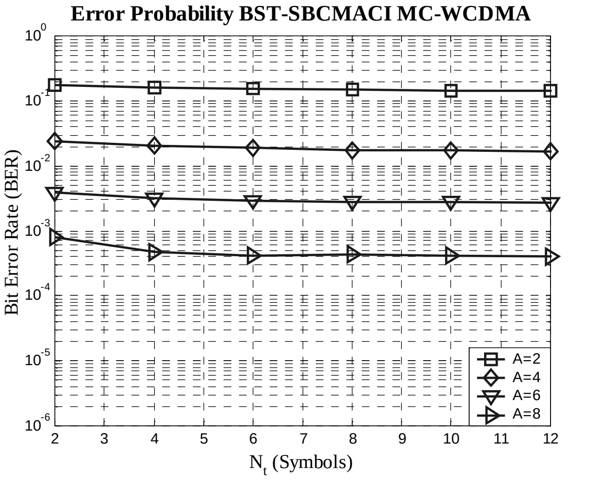


Fig.3. BER of BST-SBCMACI varying the number of training symbols and antennas elements (*SNR*= 8 dB and *M*=5)

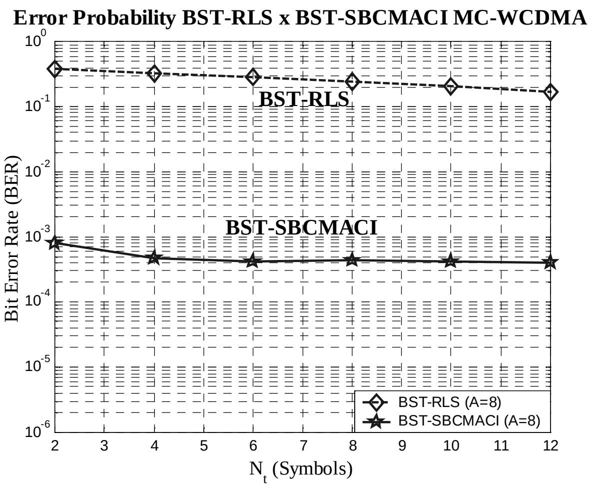


Fig.4. BER of BST-SBCMACI and BST-RLS varying number of training symbols (SNR=8, *M*=5 and *A*= 8)

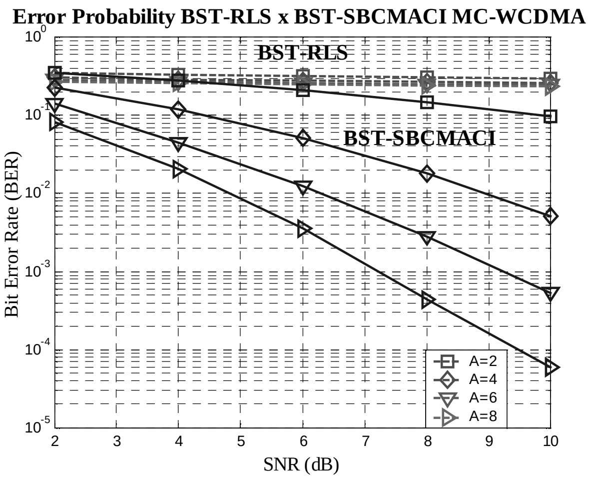


Fig.5. BER of BST-SBCMACI and BST-RLS varying SNR and the number of antennas elements (*M*=5 and N_t=8)

VIII. CONCLUSIONS

Third generation cellular systems will support a wide range of services in different environments, being necessary the use of multi-rate techniques and different type of cells to attend to such requirement. Multi-code is a multi-rate technique to provide high and variable data rates for multimedia applications and hierarchical cellular architecture is a promising technique to provide an efficient way to integrate different cell sites and attend the requirements of next cellular generation. In this architecture, microcells will be responsible to provide high spectrum efficiency and high traffic capacity to low mobility users.

The use of spatial-temporal antenna array receivers in microcellular environment can bring some benefits to multi-code systems as offering orthogonality among the multi-channels of a given user, increase of the number of supported users, efficient handover, capacity enhancement, and reduction of near-far effect between layers of the hierarchical cellular architectures.

In this paper, we have investigated the performance of a BST-SBCMACI receiver in a microcell with low mobility and high data rate users. We have performed simulations considering an asynchronous high data rate MC-WCDMA system employing complex spreading and a circular antenna array. The results show that BST-SBCMACI is suitable for multi-rate wireless applications employing multi-code scheme and that it can offer a significant performance improvement and a reduction of required training symbols when compared against BST-RLS.

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