Optimization of Blind Adaptive Decorrelating PIC Detector Performance in DS-CDMA System

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Abstract: In this paper, the new algorithm for blind adaptive decorrelating parallel interference canceller detector in direct-sequence code division multiple access (DS-CDMA) synchronous communication systems is proposed. The goal of this paper is to improve the performance of the blind adaptive decorrelating parallel interference cancellation detector (BAD/PIC). The proposed blind adaptive decorrelating detector is using optimum step-size technique bootstrap algorithm as an initial stage of PIC, which does not require a training sequence. Therefore, this algorithm has a superior view of utilizing bandwidth and reduces the complexity of computation of inversion cross-correlation matrix. The computer simulation results show that the bit error rate performance of the proposed algorithm for the new structure of detector is better than that of the other detectors such as matched filters, the conventional PIC, and the blind adaptive decorrelating PIC detector.

Keywords: DS-CDMA, PIC, decorrelating detector, blind adaptive, bootstrap algorithm.

1. INTRODUCTION

Direct-sequence code division multiple access (DS-CDMA) is well known as interference limited air interface in wireless communication where each user is affected by the Multiple Access Interference (MAI) originating from other active users that transmit their data simultaneously.

Performance of DS-CDMA system is severely degraded by MAI and near-far effect. Furthermore, the difference of transmitted power between users makes the situation worse in the multi-rate DS-CDMA system with the multiple modulation. The matched filter (MF) receiver cannot eliminate MAI.

As a result, many sub-optimal receivers have been developed [1,2] and these include the linear multiuser detectors and interference cancellation detectors. The latter can be further classified as parallel interference cancellation (PIC) and successive interference cancellation (SIC). In this paper, we interests in blind adaptive decorrelating detector [3] using bootstrap algorithm as an initial stage of PIC (BAD/PIC) [5-7] that this detector provides better performance than that of the standard PIC.

This paper aims to improve the performance of the PIC detector . First, the DS-CDMA model is presented. In section 3 and 4 present the usefulness previous detector such as the standard parallel interference cancellation and the blind adaptive bootstrap algorithm respectively. Section 5, the proposed blind adaptive decorrelating parallel interference cancellation detector using optimum adaptation technique is presented. Computer simulations for several situations to demonstrate the performance of the detectors and conclusions are given in section 6 and 7, respectively.

2. DS-CDMA MODEL [4]

The DS-CDMA model considered here is a synchronous K users system with long spreading codes (also called random codes) over the interval [0,T]. In this, the received signal at the base-station can be written as:

$$r(t) = \sum_{k=1}^{K} b_k a_k s_k(t) + n(t) \tag{1}$$

where $b_k \in \{-1,1\}$ is the information bit sequence, a_k is the received amplitude, and $s_k(t)$ is the time-varying pseudo-random signature code for *k-th* user. Here in, $n(t)$ is assumed to be additive white Gaussian noise (AWGN).

The correlator-receiver for detection of *k-th* user in this model is given by matched filtering with the received pulse wave form.

$$y_k = \int_0^T r(t) s_k(t) dt \qquad ; k = 1, 2,\ldots, K \tag{2}$$

This can be written in the matrix-vector form as:

$$\boldsymbol{y} = \Gamma \Lambda \boldsymbol{b} + \boldsymbol{n} \tag{3}$$

where $\boldsymbol{y} = [y_1, y_2, ..., y_K]^T$

$\boldsymbol{b} = [b_1, b_2, ..., b_K]^T$

$\boldsymbol{n} = [n_1, n_2, ..., n_K]^T$

$\Lambda = diag[a_1, a_2, ..., a_K]$

and Γ is the cross-correlation matrix is defined as:

$$\Gamma_{j,k} = \int_0^T s_j(t) s_k(t) dt \quad ; \quad j,k \in (1,2,...,K) \tag{4}$$

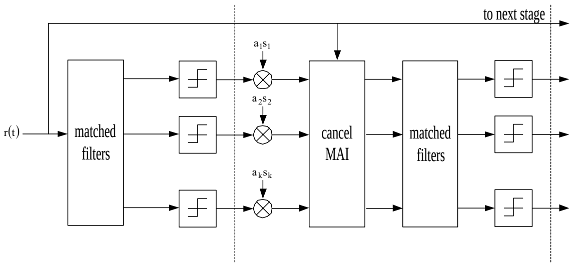

Fig. 1 Structure of the standard PIC detector.

3. THE STANDARD PARALLEL INTERFERENCE CANCELLATION [4]

The structure of the receiver is shown in Fig. 1. The received signal of the *k-th* user's PIC stage after subtracting MAI is given by:

$$\hat{r}_k(t) = r(t) - \sum_{\substack{j=1 \\ \neq k}}^{K} \hat{x}_j(t) \tag{5}$$

where $\hat{x}_j(t) = \hat{b}_j a_j s_j$, $\hat{b}_j$ is the decision bit of the *j-th* user's an initial stage of PIC.

The output of the *k-th* user's matched filters at PIC stage can be written as:

$$y_k = \int_0^T \hat{r}_k(t) s_k(t) dt \tag{6}$$

The decision bit of PIC is given as:

$$\hat{b}_k = \mathrm{sgn}(y_k) \tag{7}$$

4. THE BOOTSTRAP ALGORITHM

The inverse cross-correlation matrix to be generated with a blind adaptive bootstrap algorithm [5-7], as shown in Fig. 2.

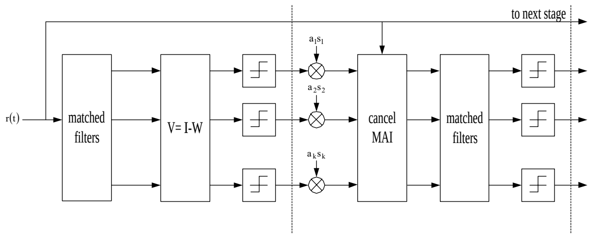

Fig. 2 Structure of BAD/PIC detector.

In the limit performance. Let,

$$\boldsymbol{z} = \boldsymbol{V}\boldsymbol{y} = \boldsymbol{V}\Gamma\Lambda\boldsymbol{b} + \hat{\boldsymbol{n}} \tag{8}$$

For the transformation the bootstrap decorrelator has the form

$$\boldsymbol{V} = \boldsymbol{I} - \boldsymbol{W} \tag{9}$$

where $\boldsymbol{I}$ is an identity matrix and

$$\boldsymbol{W}^T = \begin{bmatrix} 0 & w_{1,2} & \cdots & w_{1,K-1} & w_{1,K} \\ w_{2,1} & 0 & \cdots & w_{2,K-1} & w_{2,K} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ w_{K-1,1} & w_{K-1,2} & \cdots & 0 & w_{K-1,K} \\ w_{K,1} & w_{K,2} & \cdots & w_{K,K-1} & 0 \end{bmatrix} \tag{10}$$

$\boldsymbol{W}$ is not necessarily a symmetric matrix, then the output of detector is given as follow:

$$z_k = y_k - \boldsymbol{w}_k^T \boldsymbol{y}_k \tag{11}$$

where $\boldsymbol{w}_k$ is the *k-th* column of $\boldsymbol{W}$ without w_{kk}

$\boldsymbol{y}_k$ is the vector $\boldsymbol{y}$ with y_k taken out

The update formula of the bootstrap algorithm can be written as:

$$\boldsymbol{w}_k(i+1) = \boldsymbol{w}_k(i) + \mu z_k \,\mathrm{sgn}(\boldsymbol{z}_k) \tag{12}$$

where μ is a fix step-size parameter.

5. THE PROPOSED ALGORITHM

In the blind adaptive decorrelating detector using bootstrap algorithm that using a fix step-size parameter μ. In this section, we propose the blind adaptive decorrelating PIC detector using optimum adaptation technique.

The optimum adaptation technique is modified from the bootstrap algorithm by adjusting the step-size parameter μ, as shown in Fig. 3.

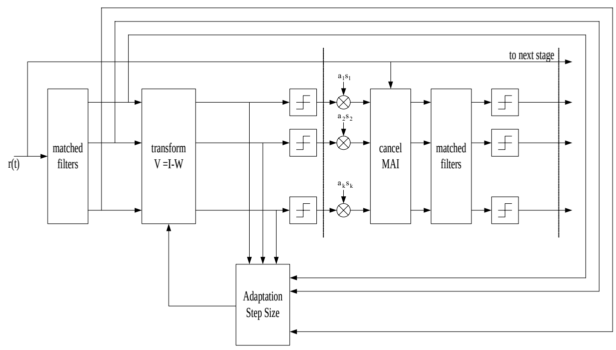

Fig. 3 Structure of proposed detector

The parameter of update recursion of the adaptive algorithm is given by:

$$\boldsymbol{w}_k(i+1) = \boldsymbol{w}_k(i) + \mu(i) z_k \,\mathrm{sgn}(\boldsymbol{z}_k) \tag{13}$$

where $\mu(i)$ is variable step-size parameter.

The adaptation step-size algorithm that uses to approach the optimum step-size. The performance of the system can improve when step-size has the optimum value. For the first stage, must define the parameters , K is number of user, N is number of bit for sample (odd number), S_{max} is boundary of maximum step-size value and S_{min} is boundary of minimum step-size value.

The step-size parameter $\mu(i)$ can be adjustment by equations (14) and (15), respectively.

$$\varsigma(j) = \frac{s_{max}(j) - s_{min}(j)}{N-1} \tag{14}$$

$$\mu(i) = s_{min}(j) + n\varsigma(j) \tag{15}$$

where i = number of bit
$j = (i - 1)$ divide by N (j = 0,1,2,…)
$n = (i - 1)$ modulus by N (n = 0,1,2,…,N-1)

The initial value of $s_{max}(0)$, $s_{min}(0)$ and $s_{mid}(0)$ are

$$s_{\max}(0) = s_{\max} \tag{16}$$

$$s_{\min}(0) = s_{\min} \tag{17}$$

$$s_{mid}(0) = s_{\min} + \left(\frac{N+1}{2}\right)\left(\frac{s_{\max} - s_{\min}}{N-1}\right) \tag{18}$$

The values of $s_{max}(j)$, and $s_{min}(j)$ have variation by the mean of comparison between input and output of bootstrap.

$$Mn(i) = \left\{ \frac{\sum_{k=1}^{K} N_k(i) - 1}{K-1} \right\} \tag{19}$$

$$N_k(i) = \frac{\Delta_k(i)}{\Delta_{\max}(i)} \tag{20}$$

$$\Delta_{\max}(i) = \max\{|\Delta_1(i)|, |\Delta_2(i)|, \ldots, |\Delta_k(i)|\} \tag{21}$$

$$\Delta_k(i) = z_k(i) - y_k(i) \tag{22}$$

The one of comparison use N bit each. The boundary of summation defined as $Mid = \frac{N+1}{2}$ and $Max = N$. The condition of comparison is defined as:

$$\sum_{n=1}^{Mid} Mn(jN+n) > \sum_{n=Mid}^{Max} Mn(jN+n) \tag{23}$$

Let: $s_{max}(j+1) = s_{mid}(j)$
$s_{min}(j+1) = s_{min}(j)$

$$\sum_{n=1}^{Mid} Mn(jN+n) < \sum_{n=Mid}^{Max} Mn(jN+n) \tag{24}$$

Let: $s_{max}(j+1) = s_{max}(j)$
$s_{min}(j+1) = s_{mid}(j)$

After the value of $s_{max}(j)$ and $s_{min}(j)$ have changed by equation (23) or (24) must check condition as:

if $s_{min}(j+1) = s_{min}(j-1)$ and $s_{min}(j+1) > s_{min}$

then $s_{min}(j+1) = s_{min}(j+1) - \left[\varsigma(j)\left(\frac{N-1}{2}\right)\right]$

or if $s_{max}(j+1) = s_{max}(j-1)$ and $s_{max}(j+1) < s_{max}$

then $s_{max}(j+1) = s_{max}(j+1) + \left[\varsigma(j)\left(\frac{N-1}{2}\right)\right]$

6. SIMULATION RESULTS

Consider DS-CDMA system, which support 4 users. Each user transmits 10,000 bits. The spreading codes are the fixed binary codes of length 7 (Gold code) and the random generated binary codes of length 15. The constant parameters of this simulation for the proposed detector structure are defined as follows: N = 11, S_{max} = 0.03 and S_{min} =0.001.

Fig. 4 and Fig. 7 show the perfect power control, the average BER of 4 users over 30 ensembles versus E_b/N_0. The power of each user is 1 dB. From these Figures, the simulation results can be observed the proposed detector has lower bit error rate (BER) than that of the BAD/PIC for every E_b/N_o values.

For the near-far effect, the power of each users are 1, 1, 8 and 8 dB respectively. In Fig. 5, Fig. 8 show the average BER of the lowest-power and in Fig. 6, Fig. 9 show the average BER of the highest-power user over 30 ensembles versus the E_b/N_o, respectively. From the results show that the performance of the proposed detector has better than that of the BAD/PIC for every E_b/N_o values in both cases.

7. CONCLUSION

An optimum adaptation technique for blind adaptive decorrelating PIC detector is proposed. It has better performance than that of the other detectors such as matched filters, the conventional PIC, and the blind adaptive decorrelating PIC detector for every E_b/N_o values in both cases of the perfect power control, lowest-power and highest-power user in near-far situation.

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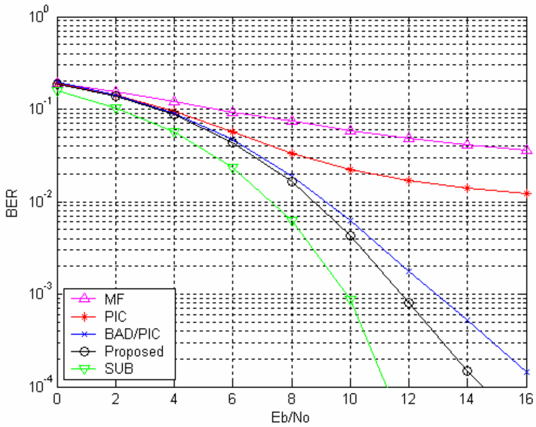

Fig. 4 BER in perfect power control using Gold Code.

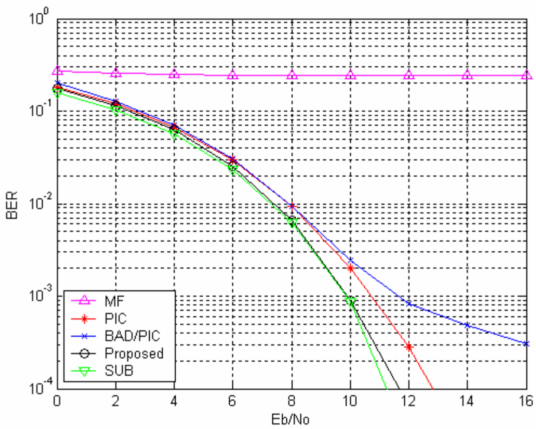

Fig. 5 BER of the lowest-power user in near-far situation using Gold Code.

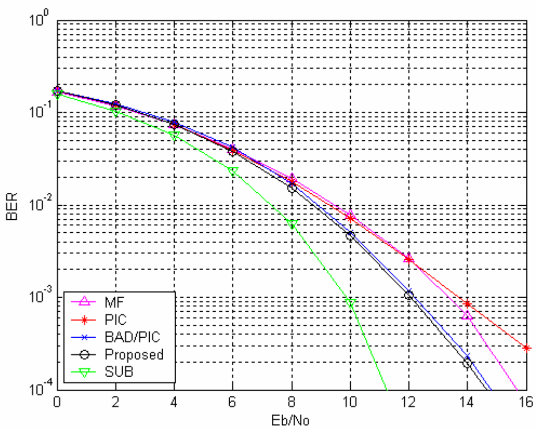

Fig. 6 BER of the highest-power user in near-far situation using Gold Code.

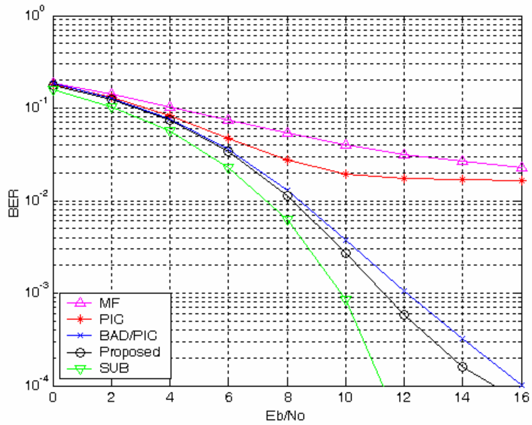

Fig. 7 BER in perfect power control using random code.

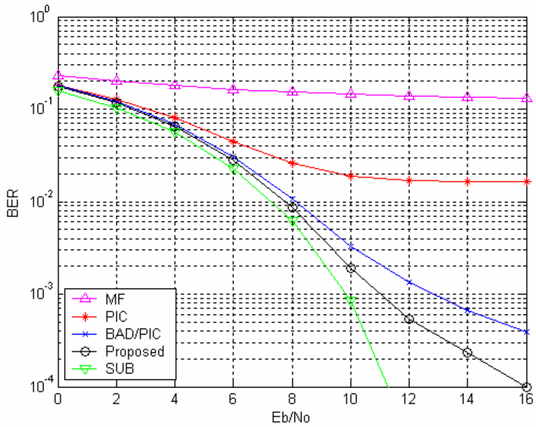

Fig. 8 BER of the lowest-power user in near-far situation using random code.

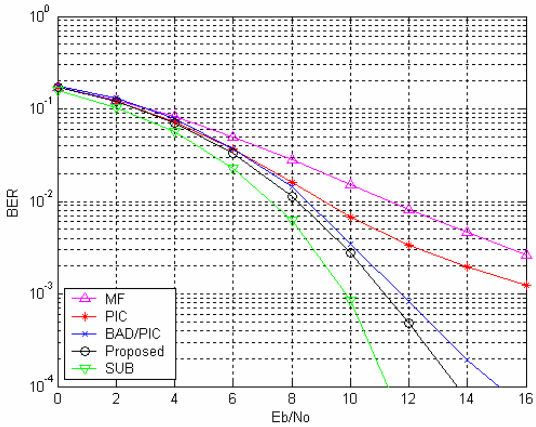

Fig. 9 BER of the highest-power user in near-far situation using random code.