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Performance Analysis of Parallel Interference Cancellation in Cyclic-prefix CDMA

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Abstract. Code division multiple access with cyclic prefix (CP-CDMA) is regarded as one of the best candidates for the broadband wireless communication system. This paper proposes a parallel interference cancellation (PIC) in CP-CDMA system. With less complexity, the PIC can achieve better bit error rate (BER) performance than the conventional interference cancellation. The simulation results are provided in both additive white Gaussian noise channel and inter-symbol interference (multipath fading channel). According to the simulation result, it is found that the performance is confirmed.

Keywords: CP-CDMA, PIC

1. Introduction

The next generation mobile communication systems are required to support much higher variable data rate services with high quality. In direct sequence code division multiple access (DS-CDMA) mobile communication systems with time-varying multipath channels and additive white Gaussian noise (AWGN), both inter-symbol interference (ISI) and multiple access interference (MAI) must be considered [1]. The equalization is carried out in the frequency domain instead of in the time domain, which has less implementation complexity in the rich multipath environments. Furthermore, direct sequence code division multiple access, with higher capacity than other multiple access techniques, can be combined with single-carrier frequency domain equalization (SC-FDE) not only to solve the difficult multipath environment problem but also to achieve good frequency efficiency [2]. This system, called as cyclic-prefix (CP)-CDMA.

CP-CDMA is a novel type of single-carrier DS-CDMA that combines the use of OFDM-style cyclic prefixes with frequency-domain equalization, for use in high performance broadband CDMA cellular systems. The CP-CDMA technique enables, in principle, the single carrier broadband DS-CDMA system to support full code usage with a good BER performance. The cyclic-prefix (CP) of CP-CDMA system is known to be useful for removing IBI (Inter-Block Interference) and then CP-CDMA has been applied to uplink. The CP-CDMA system for uplink is useful for reducing complexity or processing delay of multiuser detection algorithm [3][4].

Multiuser interference cancellation techniques exploit the structured nature of MAI and offer significant gains in system capacity resistance over the conventional DS-CDMA receiver [5]. A significant amount of work has been done in the simulation and analysis of Parallel Interference Cancellation (PIC) techniques in reducing MAI for CP-CDMA system, however, concentrated on the improvement in bit-error-rate (BER) performance of the system after PIC [6].

In this paper, we propose performance of parallel interference cancellation (PIC) receiver in CP-CDMA multi-user communication systems in multipath fading channel. The simulation results show that the performances of the proposed receiver are better than the PIC receiver in DS-CDMA and lower BER.

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The paper is organized as follows. In Section 2, the system model for CP-CDMA forward link. Section 3 introduces the PIC receiver scheme. Simulation results are discussed in Section 4. Finally, a conclusion is given in Section 5.

2. System Model

This section describes the simple system model of single carrier CP-CDMA system with K user. We assume that the signals of the users arrive at the receiver. The transmitter structure for CP-CDMA forward link is described in Fig. 2. After binary phase shift keying (BPSK) modulation, each user's data symbols are multiplied by m-sequence code and summed up, then divided into non-overlapping blocks. In each block, there are M symbols per user. For simplicity notation, only one data block is considered in the context. The chip-level sequence in one data block can be expressed as

$$p(i) = \sum_{k=1}^{K} p_k(i) = \sum_{k=1}^{K} A_k \sum_{m=0}^{M-1} d_k(m) c_k(i - mN), \qquad i = 0,1, \dots MN - 1 \tag{1}$$

where $\boldsymbol{p_k(i)}$ is the $\boldsymbol{k}$th user's chip-level sequence, $\boldsymbol{A_k}$ is the average amplitude of the $\boldsymbol{k}$th user, and $\boldsymbol{d_k(m)}$ denotes the $\boldsymbol{m}$th symbol of the $\boldsymbol{k}$th user. The $\boldsymbol{k}$th user's spreading sequence $\boldsymbol{c_k(i)}, \boldsymbol{0 \le i \le N-1}$ is selected from a set of m-sequence code of size $\boldsymbol{N}$, where $\boldsymbol{N}$ is the spreading factor. Thus, the length of one data block is $\boldsymbol{MN}$ chip.

Before transmission, a cyclic prefix (CP), which is a repetition of the last $\boldsymbol{N_{cp}}$ chips in the block, is inserted at the beginning of the data block, as shown in Fig. 1. Note that the length of CP should be no less than the maximum delay spread of the channel to absorb the inter-block interference (IBI). The transmitted chip sequence in one CP-extended data block is define as[7]

$$\boldsymbol{r(i)} = \begin{cases} \boldsymbol{p(i + MN - N_{cp})}, & \boldsymbol{0 \le i \le N_{cp} - 1} \\ \boldsymbol{p(i - N_{cp})}, & \boldsymbol{N_{cp} \le i \le MN + N_{cp} - 1} \end{cases} \tag{2}$$

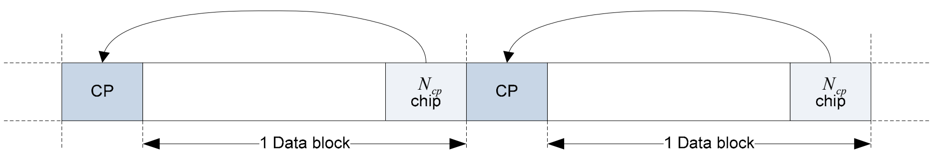

Fig. 1: Structure of the transmitted data block for CP-CDMA

Then, the transmitted data block passes through a fading channel, where the discrete channel impulse response can be expressed as:

$$\boldsymbol{h_i(t)} = \sum_{\boldsymbol{k=0}}^{\boldsymbol{L-1}} \boldsymbol{a_i^k \delta(t - kT_c)} \tag{3}$$

The path attenuation a_i^k is complex Guassian random process with zero mean, where a_i^k can be written by [8]

$$a_i^k = \begin{cases} 0.5\left\{1 + \cos\left(\frac{2\pi}{G}(m-2)\right)\right\}, & m = 1,2,3, \dots \\ 0 & , \quad otherwish \end{cases} \tag{4}$$

where the factor G is introduced to allow scaling to customize the simulated ISI.

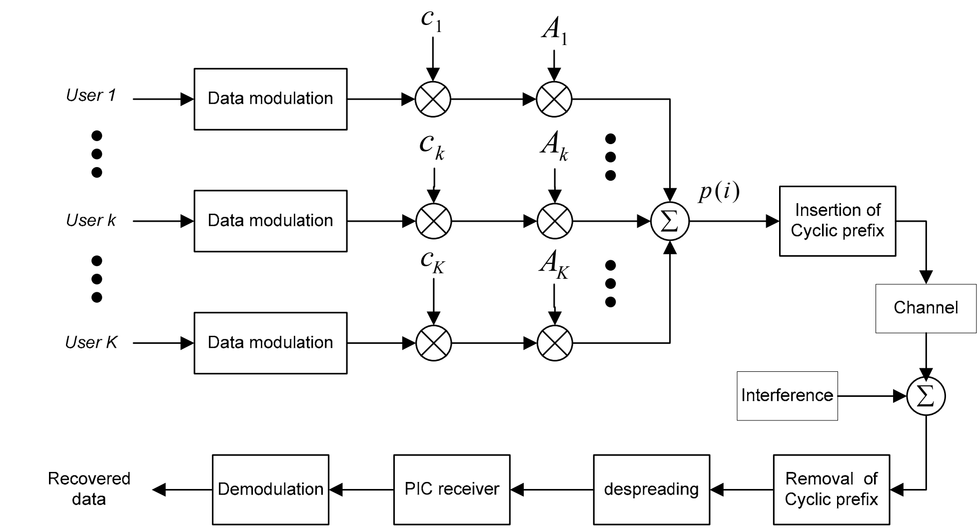

Fig. 2: CP-CDMA block diagram.

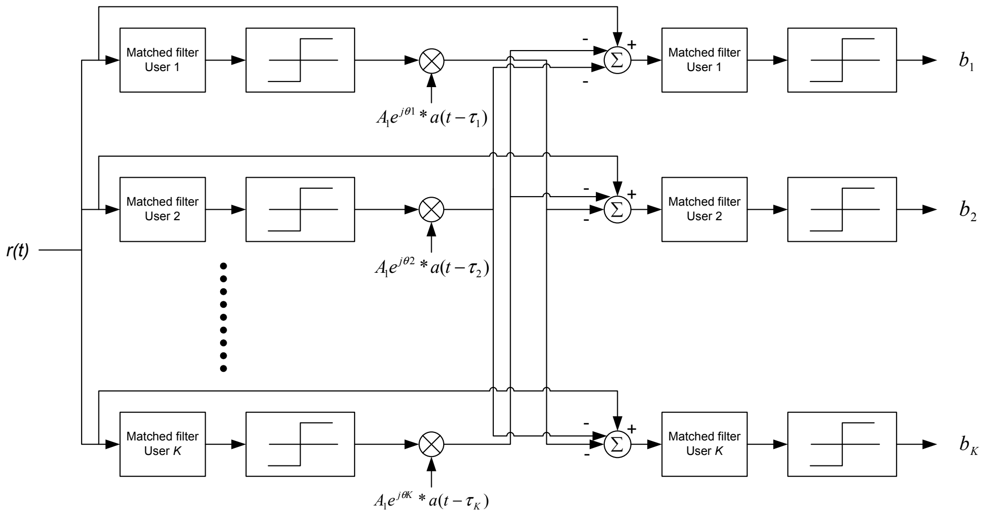

Fig. 3: Parallel Interference Cancellation (PIC) receiver

3. Parallel Interference Cancellation (PIC) Receiver Scheme

The proposed parallel interference cancellation (PIC) receiver scheme for CP-CDMA forward link, PIC detectors use matched filter to estimate the data from all signals in parallel. The estimates for each user can then be used to reduce the interference to and from the other signals by subtracting the estimate of each interferer from the desired user's signal. Ideally, this would allow the elimination of all interference from the desired user. Formally,

$$\hat{b}_k = sgn\left[y_k - \sum_{i\neq k} A_i \hat{b}_i \rho_{i,k}\right] \tag{5}$$

Where again we have assumed perfect channel knowledge (i.e., A_i). Of course, in practice, this must also be estimated. Additionally, during this development we have assumed equal phase between users for notational simplicity. However, in practice there are clearly phase differences between users. This must also be estimated and used in the cancellation process. In such a case, we can consider A_i to be complex containing both amplitude and phase. Further, the final decision statistic would have to be phase rotated prior to making a decision.

According to Eq.(2) assumes the implementation of cancellation directly on the matched filter outputs. Since cancellation and dispreading are linear operations, we can perform cancellation prior to despreading with no change in performance. If cancellation is performed on the signal prior to despreading, we have

$$\hat{b}_k = sgn\left[\frac{1}{T_b}\int_0^{T_b}\left[r(t) - \sum_{i\neq K} 2A_i\hat{b}_i a_i(t)\cos(\omega_c t)\right] a_k(t)\cos(\omega_c t)dt\right] \qquad (6)$$

which is demonstrated in complex baseband form (i.e., after demodulation) in Fig. 3

4. Simulation Results

In this section, the performance of the proposed PIC receiver scheme is evaluated by computer simulation. The main system parameters are defined as follows: support 4 users, each user transmits 4,096 bits, spreading factor = 7. We assume each block size is 14 chips excluding the cyclic prefix 2 chips for multipath fading 2 paths and block size 14 chips excluding the cyclic prefix 4 chips for multipath fading 4 paths when compared to DS-CDMA and CP-CDMA in matched filter receiver and PIC receiver.

Fig. 4 and Fig. 5 show the PIC and MF receiver performance comparison between DS-CDMA system and CP-CDMA system with 2 and 4 multipath fading. From the simulation results can be observed in this case, the PIC and MF receiver in CP-CDMA system has lowest BER when compared to the PIC and MF receiver in DS-CDMA.

5. Conclusion

In this paper proposes the performance of PIC in CP-CDMA system. This cyclic prefix can effectively decrease ISI. Moreover it can be decrease MAI better than DS-CDMA, as shown in the lower of bit-error-rate. However CP-CDMA has to use bandwidth for transmitting the data more than DS-CDMA.

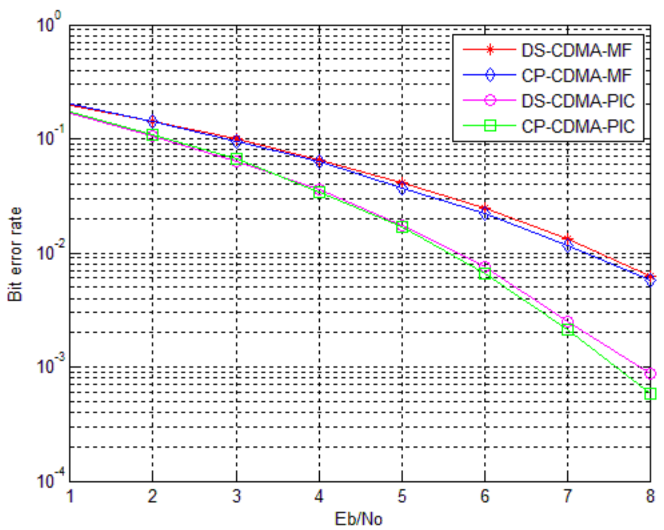

Fig. 4: The PIC and MF performance comparison between DS-CDMA system and CP-CDMA system with adding 2 multipath fading.

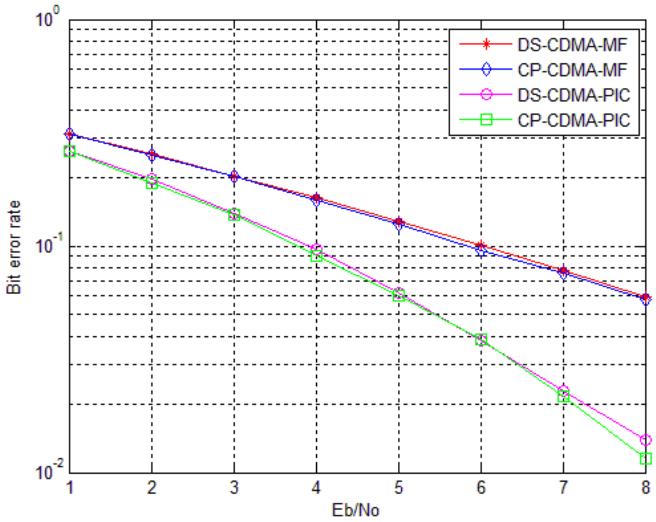

Fig. 5: The PIC and MF performance comparison between DS-CDMA system and CP-CDMA system with adding 4 multipath fading

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