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Blind identification and synchronization of unequal power users in CDMA systems based on eigenvalues variations in slow flat fading channels

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Abstract

In this paper a new blind number of users estimation and sequences synchronization method in multi-user code division multiple access (CDMA) context with unequal power signals has been proposed. Instead of the traditional approach, based on the FROBENIUS square norm behavior (FSNB) and successive detection using serial interference canceler, which was proposed previously in Ghavami and Vakili [Blind SNR estimation on WCDMA systems with unequal power signals and without any prior knowledge. In: IEEE-IST2007; July 2007. p. 1–5; Joint blind users identification and synchronization in non-cooperative CDMA systems in slow flat fading channels. In: ICEE2008; May 2008], we develop a new blind method for joint identification and synchronization. This new method is based on the adaptive threshold and eigenvalues variations (EV) in terms of processing window shifts, number of active users estimation is performed using an adaptive threshold. Theoretical analysis shows that the EV-based criterion avoids the successive detection and non-overlapping synchronized peaks and hence improves the synchronization performance, and proves that it is a powerful tool for blind synchronization especially in unequal power scenario, which we face in eavesdropping case. We show that the improvement is mainly due to the suppression of delay and error propagation that occur with the successive detection in the previous method [Ghavami S, Vakili VT. Blind SNR estimation on WCDMA systems with unequal power signals and without any prior knowledge. In: IEEE-IST2007; July 2007. p. 1–5; Ghavami S, Vakili VT. Joint blind users identification and synchronization in non-cooperative CDMA systems in slow flat fading channels. In: ICEE2008; May 2008]. Simulation results confirm the performance of the identification and synchronization process using this new criterion, allows achieving very good performance at the receiver side in terms of chip error rate (CER) and bit error rate (BER), even at very low signal to noise ratios (SNRs) in unequal power scenarios.

Keywords: Blind identification; Blind synchronization; CDMA; Unequal power; Eigenvalue; Adaptive threshold

1. Introduction

Many blind schemes and algorithms have been devised to either improve the performance or reduce the complexity of a code division multiple access (CDMA) receiver in a multi-user context. Some prior knowledge of user in uplink or downlink scenarios, e.g. the signature waveform [3], the processing gain, the chip rate [4], is always assumed, but their parameters depend on the technique employed and applications may be unknown. Here, we propose a blind multi-user synchronization scheme with no prior knowledge about the transmitter and we assume there is no power control and the transmitted power of the signals may be different. Typically, it is the case of blind signal interception in the CDMA systems, military field or for spectrum surveillance, and generally non-cooperative scenarios.

Spread spectrum signals have been used in the military domain for a long time for secure communications [3].

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Nowadays their field of application includes civilian transmissions, especially CDMA transmissions [4].

In [5], maximum likelihood (ML) estimator, approximative maximum likelihood (AML) and multiple signal classification (MUSIC) algorithms are used for propagation delay estimation in multi-user asynchronous DS-CDMA systems. In this approach, ML estimator needs to test all possible transmitted bit sequences in order to perform a true ML estimation of the unknown parameter. AML algorithm finds estimations of all the delays simultaneously, but the AML cost function is highly nonlinear with many local minima and is therefore sensitive to incorrect initialization. Both ML and AML must know spreading sequences of all users for simultaneous delay estimation of active users. The MUSIC estimates delays one by one and requires knowledge of the spreading sequences of the users whose delays are to be estimated. Moreover, [6] proposes a subspace-based channel estimation for CDMA communication systems, it dose not need to know the spreading sequences of other users, but knowledge of desired user's spreading sequence is necessary.

Thanks to the properties of the pseudo-random sequences used, the CDMA technique allows to solve the problem of the increasing number of users in the same frequency band. Moreover, these signals are difficult to detect, especially in a non-cooperative context (e.g. spectrum surveillance), because they are often below the noise level, due to low signal to noise ratios (SNRs). Several blind approaches (i.e. the process of recovering data from multiple simultaneously transmitting users without access to training sequences) have been addressed in the literature [7,8]. In a different approach, many semi-blind multi-user schemes, that exploit some known channel properties, have been proposed [9,10]. But, all these methods are not blind in the sense used in our non-cooperative context. Indeed, they require some prior knowledge about parameters of users. This knowledge is not available in a eavesdropping receiver. Furthermore, in [11] an iterative blind synchronization algorithm based on Frobenius norm is proposed for synchronizing unequal power signals in multi-user scenario. Moreover, a blind estimation method without prior knowledge about spreading sequence of transmitted signal has been proposed in [12] for data detection of direct sequence spread spectrum signals in multipath channels. This paper investigates only single users scenario, and dose not consider multi-user scenario. Also, eavesdropping of synchronous CDMA systems based on expectation maximization has been proposed in [13] and same authors perform blind detection of synchronous CDMA systems in non-Gaussian channels in [14].

In [2] a method for synchronization and estimation of number of active user has been presented when difference between powers of received signals is low. Also in [1,11] successive or iterative methods for blind sequence synchronization and estimation of number of active users have been developed. This approach needs estimation of the spreading sequence of synchronized user, de-spreading it, bit stream estimation, re-spreading and eliminating it from received signal. This process has high computational complexity and imposes large delay time for detection process and prevents using of the successive method in real time applications. Moreover, in this method performance and accuracy of sequence synchronization in each step depend on that of the pervious steps. In [15] detection and synchronization of CDMA systems for equal power users with two active users have been considered. Multi-rate CDMA synchronization for equal power users and more number of active users have been considered in [16]. Moreover, in [17] a method is presented for synchronizing a multi-user system based on behavior of the maximum eigenvalues of received signal's estimated covariance matrix. But, in our paper, we will show, this method cannot synchronize signals of users in the unequal power scenario without any prior knowledge about both desired and interfering users' spreading sequences.

In this paper we suggest a method for joint sequence synchronization and estimation of number of active users with unequal transmitted signals powers, when SNR of the received signals are negative in dB. The proposed method supports the synchronization and number of active users estimation when difference between power of received signals is high (advantage over [2]). Synchronization for users is performed simultaneously and there is no need to successive or iterative detection (advantage over [1,11]). Scenario of unequal power users and low SNR signals occurs in eavesdropping of CDMA systems. Normally power control algorithms equalize transmit power of users relative to the base station place, however eavesdropping receiver for practical considerations is placed in a distance relative to the base station. Therefore powers of received signals are not equal. On the other hand no prior knowledge about spreading sequence of received signals causes received signal has low SNR (negative in dB) in receiving signals.

This article is organized as follows, Section 2 will introduce the system model and assumptions made. In Section 3 an adaptive threshold for discrimination of the desired signals eigenvalues from those of the noise will be introduced. In Section 4 synchronization based on FROBENIUS square norm behavior (FSNB) and successive detection will be reviewed briefly. Section 5 introduces and analyzes the new approach for joint sequence synchronization and user identification, which is based on the variations of the eigenvalues. The simulation results will be detailed in Section 6 and our conclusions will be drawn in Section 7.

2. System model

The received signal in eavesdropping receiver is a combination of mobile signals (uplink scenario) and base station signal (downlink scenario). This assumption has been considered as the worst cases, which both of the synchronized and asynchronized users exist in the environment. Although in CDMA systems transmission in up-link scenario and down-link scenario have different frequency band,