



# The adaptive path selective decorrelating detector: performance analysis with channel estimation errors

Ali Hakan Ulusoy<sup>a,\*</sup>, Ahmet Rizaner<sup>a</sup>, Kadri Hacıoğlu<sup>b</sup>, Hasan Amca<sup>a</sup>

<sup>a</sup>Department of Electrical and Electronic Engineering, Eastern Mediterranean University, Via Mersin 10, Magosa—KIBRIS, Turkey

<sup>b</sup>Center For Spoken Language Research, University of Colorado at Boulder, Boulder, CO 80309, USA

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## Abstract

In this paper, the multipath decorrelating (MD) detector which is used in code division multiple access (CDMA) systems to eliminate multiple access interference (MAI) is considered. The MD detector requires the inversion of a signature sequence correlation matrix. This process is computationally expensive and it also enhances the channel noise. Recently, an adaptive path selective decorrelating (APSD) detector has been proposed to reduce both the computational complexity and noise enhancement at a marginal increase in residual MAI due to unselected paths. The APSD detector requires the channel knowledge. In practice, the channel coefficients are not known and must be estimated. Although several channel estimation methods exist for CDMA systems, a maximum-likelihood approach using short preamble sequences is adopted in this paper. The estimation process has an impact on the overall system performance by introducing estimation errors in actual channel coefficients. Therefore, this paper proposes a semi-analytic method to analyze the performance of the APSD detector in the presence of those channel estimation errors. Extensive simulations are carried out and reported to show tradeoffs for different system parameter settings.

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## 1. Introduction

With the ever-increasing requirements for more flexibility, higher capacity and resistance to

propagation impairments, direct sequence code division multiple access (DS-CDMA) has become one of the favorite candidates for future mobile radio systems. Although CDMA-based systems provide high power efficiency and moderate error rates, multiple access interference (MAI) and intersymbol interference due to multipath propagation are two most significant factors limiting the performance of the wireless CDMA systems.

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\*Corresponding author. Tel.: +90-392-6301301; fax: +90-392-3650240.

E-mail address: alihakan.ulusoy@emu.edu.tr  
(A.H. Ulusoy).

Multipath fading is a result of transmission through a multipath channel, whereas MAI is a result of multiple users sharing the same channel. A receiver structure that consists of the RAKE receiver [9] followed by a decorrelating detector [23,25] and multipath combiner can be used, first, to separate the resolved paths of the channel, next, to eliminate MAI and, finally, to combine all the paths using channel knowledge [23,25]. That structure, known as the multipath decorrelating (MD) detector, is computationally demanding and has noise enhancement problem. Recently, a path selective scheme called adaptive path selective decorrelating (APSD) detector has been proposed [16,17] to reduce complexity of the MD detector and improve system performance by decreasing noise enhancement, with the price of a small increase in MAI due to unselected paths. A similar path selective method has been investigated for the RAKE receiver in [20] to transform the physical RAKE paths into virtual path domain. The channel coefficients are already needed in the MD detector at the combining of the paths for the maximal ratio combining and the APSD detector also uses these channel coefficients for path selection and, in [16,17], they are assumed to be known. In this paper, we address this unrealistic assumption by introducing a channel estimator into the system and analyzing the impact of channel estimation errors on the system's overall performance.

Traditionally, channel estimation is achieved by sending preamble sequences or using a pilot channel. These approaches rely on periodic transmission of long preamble sequences [5], making the identification of channel impulse response feasible since both input and output signals are known during the transmission of these sequences. Generally, for better estimation accuracy, more preamble bits or higher power for pilot channel shall be required. Consequently, one must pay the price of using long preamble sequences with a significant reduction of channel efficiency. Recently, some preamble-based channel estimation algorithms are proposed for CDMA systems [14,22]. Although, the method proposed in [22] is computationally complex; it only requires the short preamble sequences of the desired users for

the estimation. Alternatively, subspace-based algorithms have been successfully developed for different CDMA systems, which eliminate the use of preamble sequences [2,7,18]. The method presented in [2] is only applicable when the system is underloaded or when a few users are active. In [7], a subspace-based method, which can estimate the channel responses of overloaded systems, is proposed. However, the computational complexity of this method is quite high due to complicated matrix manipulations.

Although, preamble-based channel estimation has the advantage of being used in any radio communications system quite easily, it is wasteful on bandwidth since long preamble sequences are used. In [11], a multiuser maximum-likelihood channel estimation method that estimates the channel responses successfully with a relatively small number of preamble bits at high channel efficiency was proposed. In this paper, we used this maximum-likelihood estimator that uses the knowledge of short training sequences and users' spreading codes. The algorithm is suitable for use in, for instance, slotted system where each user transmits a data burst with a short preamble sequence. The suggested channel estimation method can also be iteratively implemented by using an iterative algorithm such as gradient descent method to provide a reasonable simpler complexity [10].

The effect of the channel estimation errors on bit error rate (BER) performance of the multiuser detectors has been analyzed by several researchers [13,21,24]. It is also important to obtain performance of the APSD detector with channel estimation errors when channel is not perfectly known. After obtaining the channel coefficients successfully, we derive an expression for the channel estimation error and incorporate it into performance analysis of the APSD detector. We provide semi-analytical results that help to make a reasonable choice of system parameters (e.g., length of the preamble bit, threshold values for path selection) with insignificant loss in performance compared to the actual channel case.

The paper is organized as follows. In the next section, the assumed communication system model is presented. Section 3 describes the channel

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