A Blind Code Timing Estimator and Its Implementation for DS-CDMA Signals in Unknown Colored Noise

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***Abstract*—Commonly, the channel noise is assumed as temporally white when we estimate the PN code timing for direct-sequence code-division multiple-access (DS-CDMA) systems. However, it may be invalid in practice due to, for instance, the presence of some narrow-band interference or lumping the secondary users into the noise. In this paper, we introduce the matrix decomposition technique in a subspace-based code timing estimator. The new code timing estimator can robustly work in unknown colored noise. The Cramér–Rao bound for the code timing estimator is outlined. Furthermore, we propose a practical implementation method, which includes reducing the number of eigendecompositions and an adaptive eigendecomposition algorithm based on subspace tracking using the unconstrained gradient-descent technique. The performance of the new method is evaluated by computer simulation and compared with the MUSIC method. It is proved that the proposed code timing estimation algorithm outperforms the MUSIC method in colored noise or when the number of users is large.**

***Index Terms*—Adaptive algorithm, code-division multiple-access (CDMA), code timing estimation, colored noise, eigendecomposition, synchronization.**

I. Introduction

DIRECT-SEQUENCE code-division multiple access (DS-CDMA) is a crucial technology in third-generation (3G) wireless communication systems because of its many advantages compared with other technologies. However, most of these merits are based on the perfect solution to the near–far problem. Although the near–far problem can be alleviated by power control techniques, this is not an easy task. A few near–far resistant receivers (multiuser detectors) have been proposed under the assumption that the code timing of each user or the interested user is known. It is implied that the code timing estimation in the near–far environment is important. Several near–far resistant timing estimators have been presented [1]–[4], [6], [17]. The Multiple Signal Classification (MUSIC) estimator is a typical one [1]–[3], [6]. It is a blind method (no knowledge of the data sequence is required) and hence can be used as code acquisition or code tracking [2].

In the common MUSIC timing estimation for DS-CDMA signals, it is assumed that the channel noise is temporally white. However, such an assumption may be invalid in practice due to, for instance, the existence of some narrow-band interference. In addition, a disadvantage of the common MUSIC estimator for DS-CDMA code timing is that its performance is poor when the number of users is large [4]. Usually, a MUSIC estimator will not work when the number of signals is larger than half the dimensions of the observation vector [1], [2], [4].

To make the MUSIC method work well in an environment with a large number of users, we can increase the dimensions of the received signal vector by extending the observation interval to several symbol durations [6]. This kind of approach could also increase computation complexity due to the larger correlation matrix. Another method is to identify the most dominant users, include them in the signal subspace, and lump the remaining users into the noise [4]. In this case, the composite noise is not white [4]. In the presence of unknown colored noise, the common MUSIC method cannot precisely estimate the noise subspace, and its performance will degrade unless the signal-to-noise ratio is so high that the error about the channel noise model can be ignored. In fact, the white noise is just a special case of the colored noise. These facts motivate us to consider blind code timing estimation for DS-CDMA systems in colored noise.

In this paper, we introduce the matrix decomposition (MD) technique proposed in [5] in a subspace-based code timing estimator. The new code timing estimator can robustly work in unknown colored noise. We further propose an efficient implementation approach including the reduction of computation complexity and a recursive adaptive algorithm for obtaining and tracking the code timing.

The remainder of this paper is organized as follows. In Section II, the system model is described. In Section III, the principle of code timing estimation in unknown colored noise is presented. The derivation of the Cramér–Rao bound for the code timing estimation with colored noise is outlined in Appendix. In Section IV, we present how to reduce the computation complexity for the implementation of the blind code timing estimator. First, we derive how to use just one eigendecomposition to replace one Cholesky factorization plus two common and one generalized eigendecompositions in this special application. Then an adaptive eigendecomposition algorithm based on subspace tracking is proposed. In Section V, the performance of the proposed estimation method is evaluated by computer simula-

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