Computationally-Efficient Algorithms for Multiuser Detection in Short Code Wideband CDMA TDD Systems

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Abstract: **This paper derives and analyzes a novel block fast Fourier transform (FFT) based joint detection algorithm. The paper compares the performance and complexity of the novel block-FFT based joint detector to that of the Cholesky based joint detector and single user detection algorithms. The novel algorithm can operate at chip rate sampling, as well as higher sampling rates. For the performance/complexity analysis, the time division duplex (TDD) mode of a wideband code division multiplex access (WCDMA) is considered. The results indicate that the performance of the fast FFT based joint detector is comparable to that of the Cholesky based joint detector, and much superior to that of single user detection algorithms. On the other hand, the complexity of the fast FFT based joint detector is significantly lower than that of the Cholesky based joint detector and less than that of the single user detection algorithms. For the Cholesky based joint detector, the approximate Cholesky decomposition is applied. Moreover, the novel method can also be applied to any generic multiple-input-multiple-output (MIMO) system.**

Index Terms: **Code division multiple access (CDMA), inter-symbol interference (ISI), minimum mean squared error (MMSE) equalizers, multiuser detection, zero-forcing.**

I. INTRODUCTION

In some communication systems, such as frequency division duplex code division multiple access (FDD-CDMA) and time division duplex CDMA (TDD-CDMA), multiple communications are sent over the same frequency spectrum. These communications are differentiated by their channelization (spreading) codes. TDD-CDMA communication systems use repeating frames divided into timeslots for communication. A single communication sent in such a system will have one or multiple associated codes and timeslots assigned to it. However for wideband code division multiple access (WCDMA) systems [1], [2], conventional RAKE receivers suffer from severe degradation in frequency selective fading channels because of significant multi-access interference and inter-symbol interference. For such systems, minimum mean squared error (MMSE) based multiuser detectors [3]–[10] and joint detectors [11]–[19], which jointly removes multi-access interference (MAI) and inter-symbol interference (ISI), have attracted attention. Joint detector algorithms are characterized by good performance with high complexity. However, for short-code TDD-CDMA systems, codes have a length equal to the symbol period, which allows the development of joint detectors. However, spreading codes, called long spreading or scrambling codes, used in FDD-CDMA systems have a period much longer than the symbol period, for which it is difficult to design multiuser detectors, as stated in [19], [20].

Another approach to removing multi-access and inter symbol interference is single user detection [11], [12], [16], [21]–[25]. This is an approach based on channel equalization and is applicable to the downlink of a CDMA system, without any transmit diversity. In single user detection, the received signal is passed through an equalization stage, followed by de-spreading for recovering the data of a single mobile. The equalization stage can be implemented using an approximate Cholesky decomposition described in this paper. Single user detection also has recent practical significance, as in recent references [21] for impulse radio ultra wideband (IR-UWB) systems, and [22] for a multiuser interference channel with multi-antenna transmitters and single antenna receivers, restricting each transmitter to a Gaussian input and each receiver to a single-user detector, all boundary points of the achievable rate region can be achieved.

An earlier fast Fourier transform (FFT) based implementation of the joint detector was indicated in [4], [5]. However the prior approach is for chip rate sampling and can be extended to oversampling or multiple chip rate sampling, although needing some adjustments. Also, it is not clear as to how the channel matrix based methods in [4], [5], with addition of block columns and block rows, would perform, in single chip rate or oversampled case. No analysis has been done on the degradation in [4], [5], whereas an analysis of the degradation in the novel algorithm is undertaken in our paper. This paper provides a novel fast joint detector algorithm that is applicable at any sampling rate. Practical receivers typically operate at twice the chip rate or higher rates. The fast implementation is achieved through a block circulant approximation of the correlation matrix, unlike prior approaches. Research in joint detectors still has recent relevance as witnessed in [11]–[17], particularly [[12], page 57], where advanced, computationally efficient joint detectors, like the one proposed in this paper, will play very crucial role in future TDD systems, like evolution of time division synchronous code division multiple access (TD-SCDMA) to TD-SCDMA to future terrestrial universal radio environment (FuTURE) TDD, including long-term evolution TDD and FuTURE Beyond 3G TDD.

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