Computers and Electrical Engineering 55 (2016) 1–11

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Semi-blind simplified mean value channel estimator for MC-IDMA systems

Adeola Adisa[a], Stanley H. Mneney[a], Olutayo O. Oyerinde[b,*]

[a] Electrical, Electronics and Computer Engineering, University of KwaZulu-Natal, Durban, South Africa
[b] School of Electrical and Information Engineering, University of the Witwatersrand, Johannesburg, South Africa

ARTICLE INFO

Article history:
Received 25 January 2016
Revised 31 August 2016
Accepted 31 August 2016

Keywords :
Channel state information
MC-IDMA
Linear estimation
Semi-blind channel estimation
Eigenvalue
Eigenvector decomposition

ABSTRACT

The Multi-Carrier Interleave Division Multiple Access (MC-IDMA) scheme combines Orthogonal Frequency Division Multiplexing and IDMA. The scheme combats both Inter-Symbol Interference (ISI) and Multiple Access Interference (MAI). For coherent detection of the transmitted signals at the receiver, Channel State Information (CSI) is crucial. There are several schemes that can be used to obtain CSI at the receiver, such as pilot-based schemes and decision directed scheme, semi-blind and as blind channel estimation schemes. This paper focuses on developing semi-blind channel estimation scheme for the MC-IDMA systems. The developed scheme is based on Minimum Mean Square Error (MMSE) algorithm. The estimator employs applications of the eigenvalue and eigenvector decomposition (EVD) techniques to simplify the MMSE algorithm, and is named Simplified Mean Value Estimator (SMVE). Simulation results show that the proposed SMVE-based estimator outperforms Least Mean Square (LMS) algorithm-based estimator, Modified Minimized Mean Value Estimator (MMMVE), and the Minimized Mean Value-MMSE Estimator (MMVE).

1. Introduction

Wireless communication has been facing various inherent challenges based on the near unpredictable nature of the wireless environment. These challenges include multipath fading, co-channel interference and Doppler effects among others. Also, with the plethora of applications and users, there is high demand for data transmission at high speeds. The future wireless communication system is, therefore, faced with challenges, example of which is its ability to guarantee broadband mobile data access at high speed. This must be addressed for effective transmission and reception of data. Different methods have been considered in a bid to propose solutions to the various challenges of wireless communication. Inter Symbol Interference (ISI) which is a result of delayed signal interfering with the direct signal, causes degradation of network performance and limits the performance of single carriers systems because of wireless channels frequency selectivity. Multicarrier systems on the other hand circumvent ISI by propagating data over parallel narrowband sub-channels [1]. The multicarrier systems mitigate most of the problem associated with single carrier systems. They exhibit exceptional behaviour in multipath channels, immunity to impulse interference and high spectral efficiency. A combination of Orthogonal Frequency Division Multiplexing (OFDM) and Code Division Multiple Access (CDMA) tagged Multicarrier-CDMA (MC-CDMA) is a technique commonly used in multiuser based multicarrier systems [2]. The MC-CDMA scheme [1,2] uses the combined effort of OFDM and CDMA transmission methods to meet the demand and challenges inherent with the wireless communication

* Corresponding author.
E-mail address: Olutayo.Oyerinde@wits.ac.za (O.O. Oyerinde).

http://dx.doi.org/10.1016/j.compeleceng.2016.08.024
0045-7906/

systems. It is attractive due to its high spectra efficiency, transmission of signal over a wide bandwidth and radio resource management flexibility, thereby making MC-CDMA robust against multipath and interference such as ISI and inter-cell Multiple Access Interference (MAI). However, at the receiver, Inter-cell Multiple Access interference (MAI) is resolved using the multicarrier CDMA scheme but with the introduction of intra-cell MAI, as well as Inter-Symbol Interference (ISI). This is due to the high complexity of the interference cancellation processes performed at the receiver. In a bid to address this challenge in multiuser CDMA, the use of Multi-User Detector (MUD) presented the immediate solution to the problem of MAI. However, the additional cost and computational complexity associated with MUD used in MC-CDMA systems compromises the inherent attractive advantages of the system. This motivated research into multi-user-multi carrier schemes using multiuser detection (MUD) methods with low overall computational complexity [3–6]. The outcome of these studies is the Multicarrier Interleave Division Multiple Access (MC-IDMA) that was developed as a new multiuser access scheme. This scheme provides an alternative solution to the inherent problems associated with MC-CDMA scheme.

The MC-IDMA scheme was proposed in 2006 [7] and is based on the previous works and principles of IDMA developed in 2002 [8,9]. The IDMA scheme, on its own, mitigates MAI and ISI with low complexity. It possesses a high degree of diversity order, relying only on unique interleavers as means of distinguishing signals of various users in the system in comparison with its predecessor CDMA scheme where different users are separated at the receiver with user spreading code that is specific to each user. Due to the combined advantages of the OFDM and the IDMA multiuser schemes [10], ISI is mitigated and the suppression of MAI is concurrently carried out in the MC-IDMA system by utilizing the individual advantages of both OFDM and IDMA schemes. This provides a better performance and higher bandwidth efficiency than the multicarrier CDMA scheme. According to the study in [11], the complexity for each user in an iterative MC-IDMA using MUD is independent of the channel length and the number of users. Therefore, MC-IDMA scheme can employ the function of an iterative MUD at the receiver with low computational complexity. However, the ability to produce accurate Channel State Information (CSI) is required for accurate signal detection and information retrieval at the receiver end of the system. The CSI is obtained through channel estimation process.

There are different types of channel estimation schemes in literature. These include the data-aided (Pilot-symbols) scheme, the non-data-aided (NDA) (or totally blind) scheme, the semi-blind scheme and the code-aided (CA) scheme.

In the case of MC-IDMA systems, there are just few works that have been reported in literature. In [12], pilot-symbol assisted channel estimation scheme was proposed where the authors employ concurrent transmission of both pilot and information symbols. Unfortunately, the use of pilot symbols is known for its wastage in the scarce communication bandwidth**.** Besides, such scheme makes use of interpolation techniques and the pilot symbols exclusively for its channel estimation, therefore, estimation of channel at data point cannot be hundred percent perfect. Consequently, the scheme introduces unresolved error into the estimation process. In [13], a channel estimation scheme that employs a combination of linear algorithm-based CIR estimation and adaptive algorithms-based CIR prediction is proposed for MC-IDMA systems. In the proposed scheme, the channel estimator exchanges soft information with the MUD only. However, the scheme possesses high complexity. Furthermore, in [14,15], a time domain channel impulse response (CIR)-based least square error (LMS) estimator that operates in a soft-based decision directed channel estimation mode is proposed for MC-IDMA systems. However, LMS algorithm is associated with the problems of slow and data dependence convergence and excess mean square error (MSE). The authors in [16] employ a recursive minimum mean square algorithm for the iterative channel estimation for OFDM-IDMA systems. Furthermore, two families of LMS algorithm, namely, Normalized Least Mean Square (NLMS) and Variable Step Size Normalized Least Mean Square (VSSNLMS) algorithms are employed in [17] for iterative soft-input based time-domain channel estimation for MC-IDMA systems. However, the adaptive algorithms-based channel estimators still show some traces of the disadvantages associated with the LMS-based channel estimator.

To the best of our knowledge, there have been no attempt made to investigate the use of semi-blind channel estimation for MC-IDMA systems except in [18,19] where we earlier proposed the use of modified MMVM and MMVE-based estimator for the system.

In this paper, novel semi-blind channel estimation for MC-IDMA system is developed. The semi-blind channel estimator is developed through the use of structured correlation learning process. The estimator is named Simplified Mean Value Estimator (SMVE)-based channel estimator and it is combined with an initialization estimator based on the Least Square (LS) algorithm for optimum performance. The various computer simulations for the combined estimators proved that the proposed semi-blind SMVE-based channel estimator outperforms some of the earlier proposed estimators in literature.

The rest of the paper is organized as follows. Section 2 presents MC-IDMA system model, the proposed semi-blind channel estimation algorithm is developed and presented in Section 3. Computer simulation results and discussion followed in Section 4. Section 5 elucidates on the comparative complexities of the proposed semi-blind channel estimator and other some other estimators in literature. Finally, the conclusion is given in Section 6.

2. MC-IDMA system model

The model for the MC-IDMA system employed in this article is presented in this section. Fig. 1 shows the transmitter structure of the MC-IDMA system, while the receiver structure is depicted in Fig. 2. Forward error correction code (FEC) is applied to the data at a very low rate.

The randomly generated user specific interleaver is used to interleave the encoded data from each user. The serial modulated data streams are changed to parallel and are modulated to OFDM symbols with aid of the Inverse Fast Fourier Trans-