

Low Complexity Estimator for Downlink MC-CDMA System

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Abstract — Multi-carrier code division multiple access (MC-CDMA) is a strong candidate for downlink of future mobile communication to obtain high data rates. Nevertheless, during transmission over fading channel, performance of MC-CDMA systems are highly degraded due to presence of multiple access interference(MAI).Therefore channel estimation play an important role in overcoming MAI and characterising the channel to correct the received signal. A low complexity estimator for downlink MC-CDMA is proposed and simulated by MATLAB over a frequency selective fading channel. Comparing with conventional MMSE this algorithm has advantages of low computational complexity. The simulation results demonstrate that MC-CDMA with proposed channel estimator outperforms the OFDM in the practical case of Rayleigh fading environment.

Index Terms—Code division multiple access, Inverse Fast Fourier Transform, Orthogonal Frequency Division multiplexing, channel estimation, frequency selective fading channel, Multicarrier Code Division Multiple Access.

I. INTRODUCTION

MC-CDMA is effective transmission scheme for frequency selective fading channel because of easy equalization. Multicarrier Code Division Multiple Access (MC-CDMA) is a multiple access technology that combines CDMA with OFDM modulation. It is one of the candidate technologies considered for 4G wireless communication systems [1].

In an MC-CDMA Systems, the total transmission bandwidth is divided into many narrow sub channels and each data symbol is spread in the frequency domain by transmitting all the chips simultaneously. Thus frequency diversity can be achieved. Furthermore, by inserting a cyclic prefix between adjacent OFDM symbols, inter symbol interference can be prevented. Since different users share the same bandwidth at the same time with separate data with these silent features, the MC-CDMA systems become an attracting technique to support both high data rate transmission and multiple accesses in a wireless communication environment [2]. The main features of MC-CDMA is its simple adaptability to variable bit rate transmissions making it suitable for users with different quality of service requirements.

In MC-CDMA System a synchronous downlink transmission is employed where the multiple access interference can be suppressed by using orthogonal spreading sequences over the AWGN channel. For wideband wireless communication, it is necessary to dynamically estimate the channel before demodulating the signals [3]. So far several channel estimation schemes have been proposed for multicarrier transmission schemes.

In [4], a new frequency averaged MMSE estimator has been discussed. The proposed estimator provides an accurate estimation using few pilot OFDM symbols without a priori knowledge of multipath channel statistics. The proposed estimator can achieve low complexity,

selecting a suitable number of averaged subcarriers. But the proposed estimator also worse as delay spread increases.

In [5], Q-Robust MMSE low complexity channel estimator and Generic low-rank channel estimator with fixed SNR has been demonstrated. In Q-Robust MMSE low complexity channel estimator the pilot tones are partitioned into reasonable size blocks and performs estimation in the blocks. In Generic low-rank channel estimator the computational complexity of pilot signal estimation based on MMSE criterion can be reduced by using a simplified MMSE estimator obtained with singular value decomposition and low rank approximation. However Generic low-rank channel estimation algorithm is less complex than Q-MMSE algorithm but originates an error flow for high values of SNR.

In [6], a reduced complexity minimum mean square sample spaced channel impulse response (RC-MMSE-SS-CIR) estimator has discussed. The performance of the proposed low complexity MMSE method is at least good as that of its high complexity counterpart. In [7], a new method to calculate equalizer coefficients for minimum mean square error (MMSE) combining scheme based on reduced size matrices has discussed. The complexity reduction is achieved by reducing matrix inversion size.

In [8], MMSE based estimator for downlink MC-CDMA systems has discussed. This can reduce computational complexity. In [9] a space generalized expectation maximization algorithm has discussed. This algorithm updates data sequences serially and channel parameters in parallel. This algorithm has excellent symbol error rate.

This paper is organized as follows. Section II introduces the downlink MC-CDMA transmission model. The channel estimator as discussed in section III and simulation results are presented in section IV for Rayleigh Fading channel. Also the behavior of MC-CDMA is compared with OFDM systems. Section V provides a conclusion of this paper

II. MC-CDMA SYSTEMS BLOCK-DIAGRAM

Fig. 1 represents the block diagram of downlink MC-CDMA transmitter system. At the transmitter where K active users share one common transmitter and K mobile terminals. The signals from different users arrive at one mobile terminal synchronously.

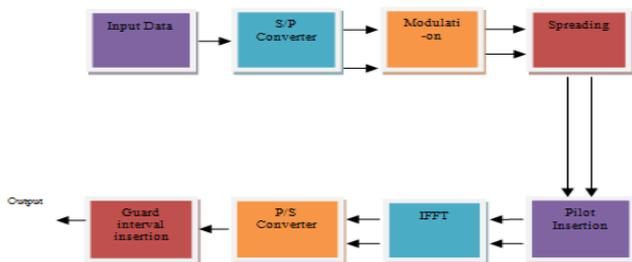


Fig 1 Transmitter

MC-CDMA systems uses L subcarriers supporting up to K users. At the transmitter side, a stream of QPSK symbols of kth user is first serial to parallel converted. Each D symbols of kth user spread by a same walsh spreading sequence C. Let D is the vector with transmitted data symbols of K active users [10].

$$D = (d^{(0)}, d^{(1)}, \dots, d^{(K-1)})^T \quad (1)$$

Let C is the user specific spreading code matrix.

$$C = (c^{(0)}, c^{(1)}, \dots, c^{(K-1)}) \quad (2)$$

The complex valued signal obtained after spreading is given as

$$\begin{aligned} s &= \sum_{k=0}^{K-1} s^k \\ &= (S_0, S_1, \dots, S_{L-1})^T \end{aligned} \quad (3)$$

An equivalent representation for s is

$$s = DC \quad (4)$$

The multicarrier downlink signal is obtained after processing the signal through OFDM block. A guard period is added to the start of each OFDM symbol. Which provide the immunity of signal to propagation delays, echoes, and reflections. The receiver block diagram is shown in Fig. 3 the receiver basically does the reverse operation to the transmitter. The received vector of transmitted sequence after inverse OFDM is given as

$$R = Hs + n = (R_0, R_1, \dots, R_{L-1})^T \quad (5)$$

Where H is the L X L channel matrix whose diagonal element is given as.

$$H = (H_{0,0}, H_{1,1}, \dots, H_{L-1,L-1})^T \quad (6)$$

and n is noise vector of length L. that is given as

$$n = (N_0, N_1, \dots, N_{L-1})^T \quad (7)$$

Similarly an equivalent representation of received vector R can be write as

$$R = AD + n = (R_0, R_1, \dots, R_{L-1})^T \quad (8)$$

Where A is the system matrix which is defined as

$$A = HC \quad (9)$$

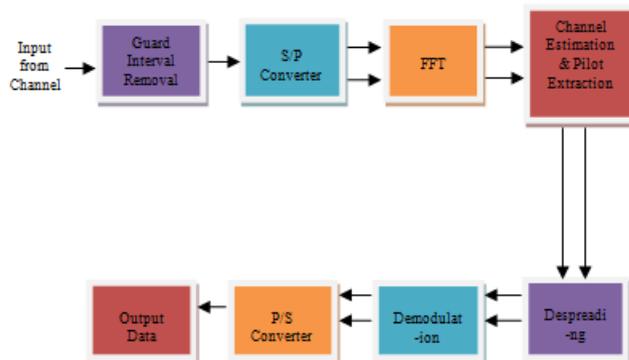


Fig 2 Receiver

After the pilot symbols removal the vector R is fed to channel estimator to estimate the channel properties and correct the received signal. The receiver despreading code is used to de-spread and recover the data. Now the recovered OFDM symbols subjected to demodulator. After that parallel data is converted to serial data.

III. LOW COMPLEXITY CHANNEL ESTIMATION

As per literature least square (LS) channel estimator is a simplest channel estimation method and has low complexity. But without using any knowledge of the statistics of the channels, it suffers from a high MSE. The mathematical equation of MMSE channel estimation from LS estimator is given as [8]

$$\hat{H}_{MMSE} = R_H (R_H + \sigma_n^2 (X X^H)^{-1})^{-1} \hat{H}_{LS} \quad (10)$$

Where σ_n^2 is the variance of noise and $R^H = E(HH^H)$ is the channel correlation matrix. The MMSE estimator in equation (10) is of high complexity since a matrix inversion is needed every time the data in X changes. The computational complexity of equation (8) can be reduced by replacing $(X X^H)^{-1}$ according to theory of diagonal matrix as in proposed [8] for OFDM.

$$\text{Let } X = P \Lambda_x P^{-1} \quad (11)$$

Where Λ_x is the diagonal matrix and P is the hermitian matrix then $(X X^H)^{-1}$ can be expressed as

$$\begin{aligned} (X X^H)^{-1} &= (P \Lambda_x P^{-1})^H (P \Lambda_x P^{-1})^{-1} \\ &= [(P \Lambda_x)^{-1}]^H (P \Lambda_x)^{-1} \end{aligned} \quad (12)$$

Now equation 8 becomes

$$\hat{H}' = R_H (R_H + \sigma_n^2 [(P \Lambda_x)^{-1}]^H (P \Lambda_x)^{-1})^{-1} \hat{H}_{LS} \quad (13)$$

$$= R^H R_Y^{-1} \hat{H}_{LS} \quad (14)$$

Using the SVD algorithm, R_Y can be described as

$$R_Y = R_H + \sigma_n^2 [(P \Lambda_x)^{-1}]^H (P \Lambda_x)^{-1} \quad (15)$$

$$= R_H + \sigma_n^2 U U^H \quad (16)$$

$$= U \Lambda U^H \quad (17)$$

Where $U = [(P\Lambda_x)^{-1}]^H$ is a unitary matrix and $\Lambda = \text{diag}(\lambda_1, \lambda_2 \dots \lambda_i \dots \lambda_k)$ then equation (14) can be rewritten as

$$\begin{aligned} \hat{H}' &= (R_y - \sigma_n^2 U U^H) R_y^{-1} \hat{H}_{LS} \\ &= U (\Lambda - \sigma_n^2 I) U^H (U \Lambda U^H)^{-1} \hat{H}_{LS} \\ &= U \left(\frac{\Lambda - \sigma_n^2 I}{\Lambda} \right) U^H \hat{H}_{LS} \end{aligned} \quad (18)$$

Where diagonal matrix $\frac{\Lambda - \sigma_n^2 I}{\Lambda}$ can be rewritten as $\text{diag}(\frac{\lambda_i - \sigma_n^2}{\lambda_i})$ thus, the calculating of finding the inverse matrix $R^H (R^H + \sigma_n^2 (X X^H)^{-1})^{-1}$ can be replaced in the form of SVD, through inverting the diagonal matrix $\frac{\Lambda - \sigma_n^2 I}{\Lambda}$ to reach the purpose of reducing computational complexity

IV. SIMULATION RESULTS

In this section simulation results for proposed low complexity channel estimator, mmse estimator in the context of both OFDM and MC-CDMA systems communicating over Rayleigh fading channel is shown. Figure 3 demonstrates the BER of proposed channel estimator, mmse estimator, conventional estimator in the context of both OFDM and MC-CDMA systems.

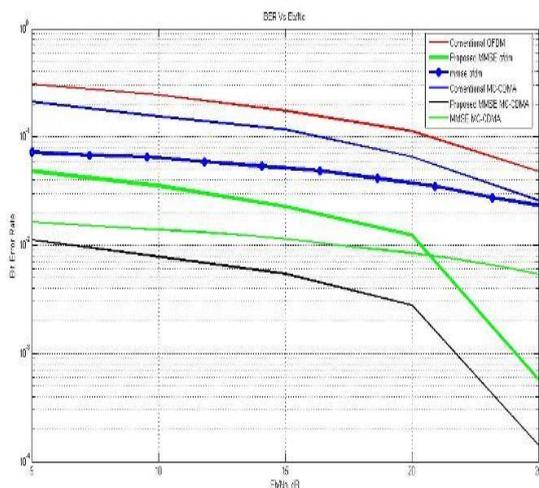


Fig. 3 BER of proposed channel estimator mmse estimator, conventional in the context of both OFDM and MC-CDMA systems.

The system being considered is pilot spacing = 16, No. of pilot per OFDM symbol = 128, No. of OFDM symbol = 2560, No. of bits per symbol = 164, size of FFT = 2048, spreading scheme is WH, data bits are QPSK modulated. It can be seen from figure 3 proposed estimator operating in the context of the MC-CDMA system outperforms its OFDM counterpart.

V. CONCLUSIONS

In this paper we have proposed a low complexity estimator which is suitable for both OFDM and MC-CDMA systems. The complexity reduction is achieved by reducing matrix inversion size according to theory of diagonal matrix. Furthermore, it was shown that MC-CDMA using low complexity estimator outperforms the corresponding OFDM based systems.

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