# MIMO MC-CDMA System Advanced using Coding Techniques

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*Abstract*—**Industry communications systems without thread has grown tremendous over the last few years, these systems have evolved significantly in terms of services offered, the wireless communication suffers of the Multiple Access Interference (MAI) and computational complexity. We propose a new technique of coding applies to the downlink of Multi input Multi output Multi-Carrier Code Division Multiple Access (MIMO MC-CDMA) systems. Theoretical analysis and comparative simulations show that significant performance improvement and computational complexity can be attained with the proposed technique.**

***Keywords—MIMO MC-CDMA; precoding; multiple acces interference;Bit Error Rate***

## I. INTRODUCTION

Wireless communications become more and more popular in these years. The requirement of data transmission through mobile radio interface also increases rapidly [2].The traditional systems of transmission for the information which should be issued successively over time were put in competition with new approaches in which the information is transmitted simultaneously. These new approaches, permit a better exploitation of the propagation channel (OFDM) [3], and can, in the context of multi users access (CDMA), facilitates the extraction of transmission resources [3]. Currently these methods tend to merge MC-CDMA to obtain the best efficiencies possible transmission [3]. The MC-CDMA [5, 6, 7] has become one of the attractive candidates for next-generation mobile communications [8]. Meanwhile, another promising approach is to exploit spatial diversity or spatial multiplexing using multiple antennas at the transmitter and the receiver, this approach is called MIMO systems.

In the MIMO channel, consider a scenario where there are $N_u$ users communicating synchronously with a common base station. Each user station (mobile station) has $M$ transmit antennas and the base station has $N$ receive antennas [14, 1, 15].

Pre-coding techniques are gaining a prominent role in modern wireless communications as they offer the best potential for the simplification of Mobile Unites' (MU) receivers. In Multi Input Multi Output Multiple Carrier Code Division Multiple Access (MIMO MC-CDMA) these techniques are made more complexity-efficient since by use of guard intervals and Inter Symbol Interference (ISI) elimination there is no need for block wise processing. A variety of pre-decorrelating techniques for Direct Sequence CDMA (DS-CDMA) has been introduced but their application to MIMO MC-CDMA has not yet been thoroughly investigated. In [8] the authors propose transferring the channel equalization processing to the Base Station (BS) which yields the pre-equalization technique. This technique's main advantage is that the equalization processing is removed from the MU. However, without the use of Multi-User Detection (MUD) performance is poor in a multiuser scenario. The authors in [10] propose a system similar to the conventional receiver-based decorellator detector where the decorrelation procedure happens at the BS prior to transmission.

On a system using pre-equalization while TP would utilize post-equalization. Both decorrelating methods introduced in [10, 11] involve the inversion of a square matrix which imposes a significant computational burden when block wise processing is required. Evidently, these techniques could benefit in MIMO MC-CDMA from the fact that ISI and consequently MAI from symbols of adjacent symbol periods is eliminated and there is no need for block wise decorrelation.

In the next section, we present the system model of MIMO MC-CDMA. In Section 3, a description of Joint Transmission is presented; in section 4 analyses of pre-coding methods is presented. Section 5 proposed new pre-coding methods. Section 6 provides some simulation results on the performance comparison of different pre-coding methods. The summary of the findings is given in conclusions in section 7.

## II. SYSTEM MODEL

Figure 1 and Figure 2 show the simple model of MIMO-MC-CDMA transmitter and receiver respectively. The transmitter of MIMO-MC-CDMA consists of direct sequence spreader and OFDM modulator. In these schemes the pilot sequence are very important for the performance. After modulating, the data stream is multiplied by a spreading sequence. The length of this spreading code is usually identical to the number of sub carrier. The pilot signals are multiplexed to the data streams, after OFDM modulation the signals are transmitted through multiple antennas.

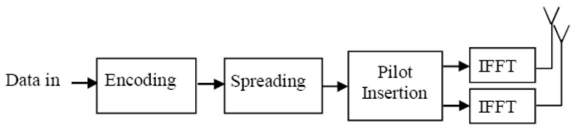


Figure 1. Simple Model of MIMO MC-CDMA Transmitter

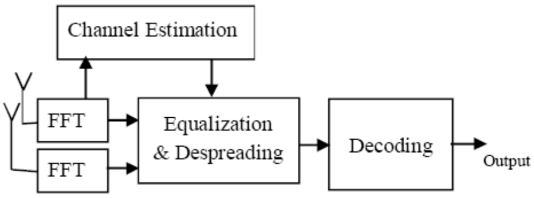


Figure 2. Simple Model of MIMO MC-CDMA Receiver

The received signal is demodulated using Fast Fourier transform (FFT). After OFDM demodulation the user data symbols and pilot symbols are recovered by despreading with corresponding spreading codes. The required transfer function for channel estimation and equalization is recovered from pilot sequence. Finally the original data stream is recovered by dividing the received signal by channel response. At the receiver end, the demodulator process the channel equalized waveform and reduces each waveform to a scalar (or) a vector that represents an estimation of the transmitted data symbol. The detector, which follows the demodulator, decides whether the transmitted bit is a 0 or 1.

Consider a MC-CDMA system having $N_c$ subcarrier and $N_T$ x $N_R$ MIMO system, the transmitted signal after modulation can be expressed as

$$s(t)=\sum_{i=-\infty}^{\infty}\sqrt{\frac{2E_b}{N_cT_s}}\sum_{k=1}^{N_T}\sum_{n=1}^{N_c} b_k(i)c_n\,\mu_{T_s}(t-iT_s)\cos(\omega_n t) \tag{1}$$

where $E_b$ and $T_s$ are the bit energy and symbol duration respectively, $u_{Ts}(t)$ represents a rectangular waveform with amplitude 1 and pulse duration $T_s$, $b_k(i)$ is the i[th] transmitted data bit $c_n$ is the spreading code, $N_T$ is the transmitting antenna, $\omega_n = 2\pi f_0 + 2\pi(n - 1)\Delta f$ is the radian frequency of the nth subcarrier, and the frequency spacing is $\Delta f = 1/T_s$. The received signal $r(t)$ through receiving antenna $N_R$ is given by

$$r(t)=\eta(t)+\sum_{i=-\infty}^{\infty}\sqrt{\frac{2E_b}{N_cT_s}}\sum_{k=1}^{N_R}\sum_{n=1}^{N_c} h_n b_k(i)c_n\cdot u_{T_s}(t-iT_s)\cos(\omega_n t+\varphi_n) \tag{2}$$

Where $h_n$ is the subcarrier flat fading gain, $\varphi_n$ is the subcarrier fading phase and $\eta(t)$ is AWGN with single-sided power spectral density $N_0$. After phase compensation, the receiver performs amplitude correction using equalizer coefficient. The received signal after FFT is given by

$$Y(k)=X(k)H(k)+W(k),\ k=0,1,..,N_c-1 \tag{3}$$

The received pilot signals $Y_p(k)$ is extracted from $Y(k)$ , the channel transfer function $H(k)$ can be obtained from the information carried by $H_p(k)$ . With the knowledge of the channel responses $H(k)$ , The transmitted data samples signal $X(k)$ can be recovered by simply dividing the received signal by channel response

$$X(k)=\frac{Y(k)}{H(k)} \tag{4}$$

The equalizer co-efficient is expresses as [15]

$$\acute{\alpha}=R_{yy}^{-1}R_{by} \tag{5}$$

$R_{by}$ is the constructive cross correlation matrix that contains the $\rho_{uk}$ elements of $R_{yy}$.

$R_{yy}$ is the cross correlation matrix of modulated signature waveform.

## III. JOINT TRANSMISSION

Joint Transmission (JT) as an example of downlink Coordinated Multi-Point (CoMP) transmission can improve the overall system performance, particularly the coverage of high throughput and cell-edge throughput. Many studies are related to JT in homogeneous network and based on full buffer traffic which is not a practical scenario. An improvement is attained by applying the JT decorrelating procedure. This optimization again presented for DS-CDMA leads to the use of a decorrelation scheme that also employs Pre-Rake processing. This method offers both the benefits of pre-decorrelation as well as the advantages of Pre-Rake over the Rake technique. Equivalently, in MIMO MC-CDMA, JT would apply pre decorrelation processing on a system using pre-equalization while TP would utilize post-equalization. The joint transmission are used to produce a vector of K-users' energies that will be multiplied by the inverse of *KxK* signatures' codes cross-correlation matrix [16].

## IV. PRE-CODING METHOD ANALYSIS

Pre-coding techniques are gaining a prominent role in the downlink transmission of modern wireless communications as they offer an improved potential for the simplification of MU receivers. This type of processing at the transmitter requires the Channel State Information (CSI) at the transmitter. In order to be able to obtain CSI at the transmitter, the channel should be fixed (non-mobile) or approximately constant over a reasonably large time period. If CSI is available at the transmitter, the transmitted symbols, either for a single-user or for multiple users, can be partially separated by means of pre-equalization at the transmitter. In MIMO MC-CDMA these techniques are made more complexity-efficient since by use of guard intervals and ISI elimination there is no need for block wise processing. By means of pre-coding, the multiuser detection problem is reduced to decoupled single user detection problems. Normally, in synchronous multipath channels that are frequency non selective in nature, orthogonal signals can be employed. However, this requires code (signature waveform) management via a signaling channel [9].

## V. PROPOSED SELECTIVE PRE-CODING METHODS

It should be clear so far, that the system can benefit from the existence of constructive interference. Consequently, there is no need for it to be removed by applying full pre-decorrelation. This is the main principle of the proposed system.

Using CSI, knowledge of all users' codes and data, readily available at the BS, and with the help of the interference to each user can be estimated at the BS prior to transmission.

### *A. Proposed selective pre-coding A*

The simplest method would be to fully orthogonalized the users that experience destructive cumulative MAI and leave the users that expect constructive cumulative MAI correlated to interference.

$$R_{by}=\begin{pmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} \\ 0 & 1 & \rho_{23} & \rho_{24} \\ 0 & \rho_{23} & 1 & \rho_{34} \\ 0 & \rho_{24} & \rho_{34} & 1 \end{pmatrix} \quad (6)$$

which provides a noiseless matched filter output as

$$X_{R_{by}}=\left[x_1x_2+\rho_{12}x_1+\rho_{23}x_3+\rho_{24}x_4x_3+\rho_{13}x_1+\rho_{23}x_2+\rho_{34}x_4x_4+\rho_{14}x_1+\rho_{24}x_2+\rho_{34}x_3\right] \quad (7)$$

### *B. Proposed selective pre-coding B*

An alternative to the preceding method would be to orthogonalize every user but only users that impose destructive interference to the useful signal at each symbol period. This would completely remove all destructive interference while allowing all constructive interference.

$$R_{by}=\begin{pmatrix} 1 & 0 & 0 & \rho_{14} \\ 0 & 1 & \rho_{23} & 0 \\ 0 & \rho_{23} & 1 & \rho_{34} \\ \rho_{14} & 0 & \rho_{34} & 1 \end{pmatrix} \quad (8)$$

which provides a noiseless matched filter output as

$$X_{R_{by}}=\left[x_1+\rho_{14}x_4x_2+\rho_{23}x_3+\rho_{23}x_2+\rho_{34}x_4x_4+\rho_{14}x_1+\rho_{34}x_3\right] \quad (9)$$

### *C. Proposed selective pre-coding C*

Here, an optimization between the required scaling, the constructive interference held in the system, and complexity is attempted. This is done by orthogonalizing the users experiencing destructive cumulative MAI only to the users that impose destructive MAI on them while leaving the remaining users completely un-decorrelated

$$R_{by}=\begin{pmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} \\ 0 & 1 & \rho_{23} & \rho_{24} \\ 0 & \rho_{23} & 1 & \rho_{34} \\ \rho_{14} & \rho_{24} & \rho_{34} & 1 \end{pmatrix} \quad (10)$$

which provides a noiseless matched filter output as

$$X_{R_{by}}=\left[x_1+\rho_{14}x_4x_2+\rho_{12}x_1+\rho_{23}x_3+\rho_{24}x_4x_3+\rho_{13}x_1+\rho_{23}x_2+\rho_{24}x_4x_3+\rho_{13}x_1+\rho_{23}x_2+\rho_{34}x_4x_4+\rho_{14}x_1+\rho_{24}x_2+\rho_{34}x_3\right] \quad (11)$$

It should be noted that, in the following, it is assumed that the codes and channel are normalized to unit energy so that $\rho_{uu}$ =1. Evidently, orthogonality between users cannot be preserved using Walsh codes, as the resulting cross correlation of the codes viewed at the receiver is nonzero due to the channel distortion.

## VI. SIMULATION RESULTS

In this work, we are using MATLAB tool. BPSK, 16QAM, and 64QAM modulations have been employed to investigate performance with the parameters given in Table 1; the proposed scheme provides performance benefits. However, since Selective Precoding (SP) mainly applies to high-interference scenarios where transmission is problematic and lower order modulation is commonly used to reduce the error rates.

TABLE I. SIMULATION PARAME[AT] TERS

| | |
|---|---|
| Spreading Codes | Walsh-Hadamard Code |
| Channel | Rayleigh fading |
| Modulation | BPSK/16 QAM/64QAM |
| Antennas | 2x2 |
| Equalization/Estimation | MMSE/Pilot |

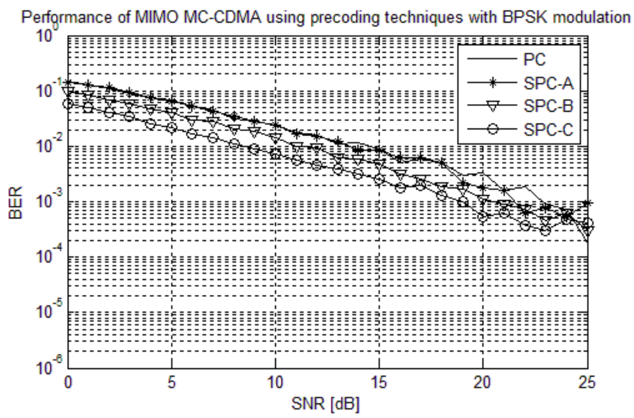


Figure 3. BER versus SNR performance of the three proposed SPC precoding methods in a Rayleigh fading channel; with BPSK modulation.

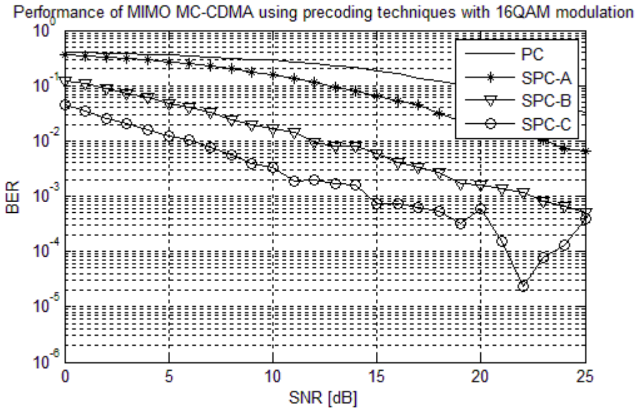


Figure 4. BER versus SNR performance of the three proposed SPC precoding methods in a Rayleigh fading channel; with 16QAM modulation.

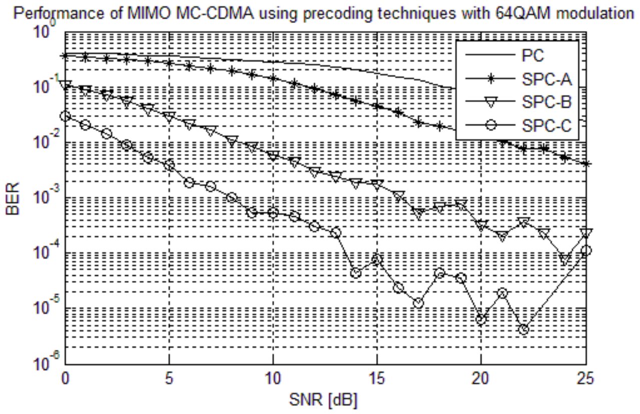


Figure 5. BER versus SNR performance of the three proposed SPC precoding methods in a Rayleigh fading channel; with 64QAM modulation.

The diversity technique uses 2 antennas for both transmitter and receiver. In Figure 3 the BER versus SNR performance for the precoding (PC) method applied in MIMO MC-CDMA and the three proposed selective precoding (SPC) techniques. It can be seen that all three SPC methods outperform conventional precoding; due to the benefit from the existence of constructive MAI. In figure 4 BER versus SNR performance for the same case is shown with 16QAM modulation is shown. In figure 5 BER versus SNR performance for the same case is shown with 64QAM modulation. In all the performances of the MIMO MC-CDMA system SPC-C method is the best technique.

## VII. CONCLUSION

A novel scheme joint transmission (JT) and SPC is proposed, which utilizes the knowledge of the channel impulse responses at the BS transmitter in such a way that at the receivers of the MS's channel estimators are no longer required. Consequently, the computational expense of the data detection is dramatically reduced. Three SP techniques have been introduced in the aim of optimizing between performance enhancement and complexity increase according to the requirements of the specific communication system. SNR improvement is attained with no need for additional power-per-user investment at the transmitter since energy that is inherent in the CDMA system is utilized.The scheme introduced in this paper applies to the downlink of cellular phase-shift keying (PSK)-based CDMA systems. Theoretical analysis and comparative simulations show that significant performance improvement can be attained with the proposed technique.

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