Performance analysis of low complexity multiuser STBC MC-CDMA system

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Abstract. In this paper, a low complexity and efficient multi-user Space Time Block Code Multi-Carrier Code Division Multiple Access (STBC MC-CDMA) for downlink wireless communication system is proposed. STBC MC-CDMA provides diversity gain to improve transmission efficiency of mobile wireless systems where both STBC encoder and decoder are in time domain thus reducing the complexity at the receiver side. Proposed STBC MC-CDMA scheme achieves a diversity order of 2 without Channel State Information (CSI) at the transmitter under flat fading conditions without bandwidth expansion. In this paper the STBC MC-CDMA is compared with the STBC OFDM scheme under Rayleigh fading channel and AWGN channel using Zero Forcing (ZF) linear detection scheme and as anticipated the proposed STBC MC-CDMA outperforms STBC OFDM. Simulation results verify this.

Keywords: STBC, MC-CDMA, CSI, Linear detection schemes, Rayleigh fading channel

1 Introduction

Multi Carrier Code Division Multiple Access (MC-CDMA) also known as OFDM-CDMA is a promising technology for 4G wireless communication systems [1, 2]. MC-CDMA spreads the data in frequency direction, thus increasing the frequency diversity gain [1]. Since the symbol rate is lower than the original rate the effect of ISI is eliminated [3], thus making the complex equalizer design much easier. So MC-CDMA provides a flexible system design, since the Spreading Factor (SF) is not necessarily to be taken equal to the no of subcarriers [1, 2].

Space Time Block Code (STBC) is a special form of MIMO and originally employed for 2 transmit and 1 receive antenna by Alamouti [4]. Since STBCs are originally proposed only for flat fading channels, application of this scheme to frequency selective channel is challenging. Hence, integration with multi-carrier techniques such as OFDM and MC-CDMA is essential which convert frequency selective channel to several flat fading channels eliminating ISI. In [5], STBC OFDM is explained in

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which both STBC encoders and decoders are in time domain. In this proposed STBC MC-CDMA, the equalization is carried out in time domain. Time domain equalization is preferred over frequency domain equalization because it is simple to implement and less complex.

This paper is organized as follows. Following this section, mathematical model of STBC MC-CDMA is explained. The communication system model is discussed in section 3. Section 4 contains the simulation results and section 5 presents the concluding remarks.

Notation: $(\cdot)^T, (\cdot)^*, (\cdot)^H$ represent transpose, complex conjugate, Hermitian operation respectively.

2 Mathematical Model

In this section, a brief description about the STBC encoding scheme for two transmitting antennas and one receive antenna is given.

2.1 STBC Encoding Scheme

In the first time instant, antenna 1 transmits $X_1$and antenna 2 transmits X_2 simultaneously, while in second time instant antenna 1 transmits$-X_2^*$ and antenna 2 transmits X_1^* [4]. The coding rate of this STBC is one since in two symbol periods only two signals are transmitted. Since the STBC codes are orthogonal, the symbols from different antennas can be distinguished at the receiver by simple zero forcing (ZF) equalization [1]. At the receiver we can mathematically model the received signals as follows:

Received signal at 1st time slot:

$$y(1) = [h_1 \quad h_2] \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + n(1) \tag{1}$$

Received signal at 2nd time slot:

$$y(2) = [h_1 \quad h_2] \begin{bmatrix} -X_2^* \\ X_1^* \end{bmatrix} + n(2) \tag{2}$$

where $h_1\ and\ h_2$ are flat fading channel coefficients and $n(1)$ and $n(2)$ are noise components which is generally additive white Gaussian noise (AWGN). In this paper, we have assumed that the channel is assumed to be constant over the two time slots.

3 Communication System Model

The baseband processing at the transmitter is presented at Fig.1. The information bits of different users are digitally modulated and then spreaded using orthogonal Walsh-Hadamard (W-H) codes. All the spreaded signals are summed up to produce the CDMA signal and then passed through STBC encoder. Each of these STBC encoded outputs are passed through individual OFDM modulators. After IFFT operation, the cyclic prefixes (CP) are added and then transmitted through channel.

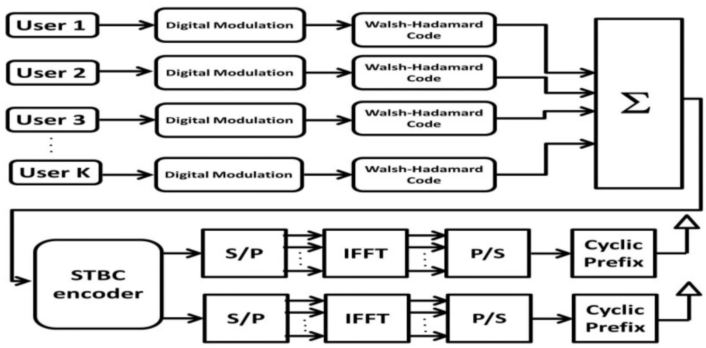

Fig. 1. Transmitter block diagram of STBC MC-CDMA system

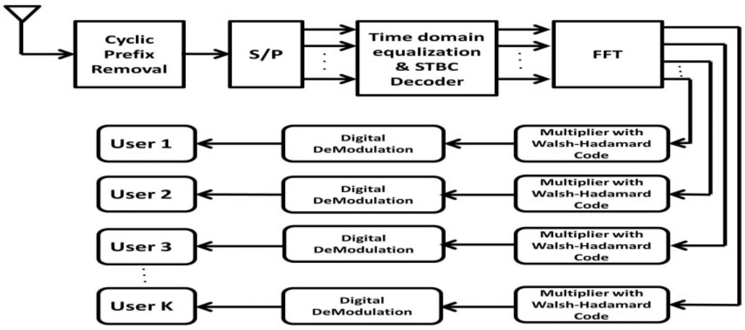

Fig. 2. Receiver block diagram of STBC MC-CDMA system

3.1 STBC Decoding Scheme

At the receiver first the CP is removed and then the channel equalization is carried out in time domain as shown in Fig. 2. In the conventional STBC MC-CDMA [6, 7] equalization is implemented in frequency domain which increases the complexity by processing the channel coefficients which are already present in time domain into frequency domain. For detection of signal, simple ZF equalizer can be used. Now, the received signal vectors from (1) and (2) as

$$\begin{bmatrix} y(1) \\ y(2)^* \end{bmatrix} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} n(1) \\ n(2)^* \end{bmatrix} \tag{3}$$

For detection of signals $X_1$and X_2 zero forcing receiver is employed as under

Let, $H = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}$ and $\bar{Y} = \begin{bmatrix} y(1) \\ y(2)^* \end{bmatrix}$, then we can define $W = (H^H H)^{-1} H^H$

To estimate the transmitted symbols we can employ

$$\tilde{X} = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = W\bar{Y} = (H^H H)^{-1} H^H \begin{bmatrix} y(1) \\ y(2)^* \end{bmatrix} \qquad (4)$$

After the channel effects are nullified according to above equations the data are sent to the FFT block and the signals are despreaded by using the same W-H code assigned to the specified user followed by the detection of the signals to retrieve all the user information bits.

4 Results and Discussion

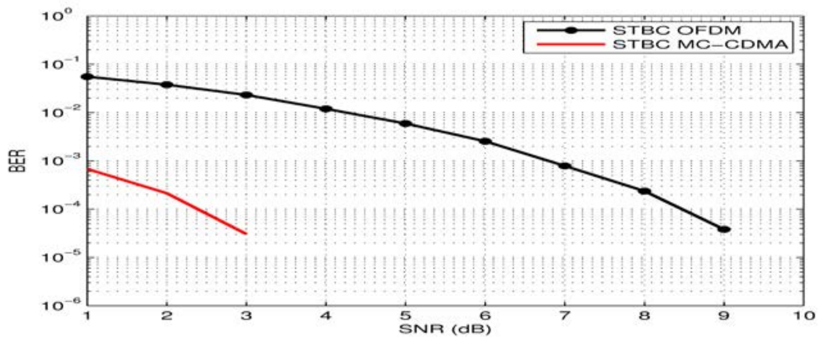

Fig. 3. BER performance of STBC OFDM and STBC MC-CDMA under AWGN channel for single user

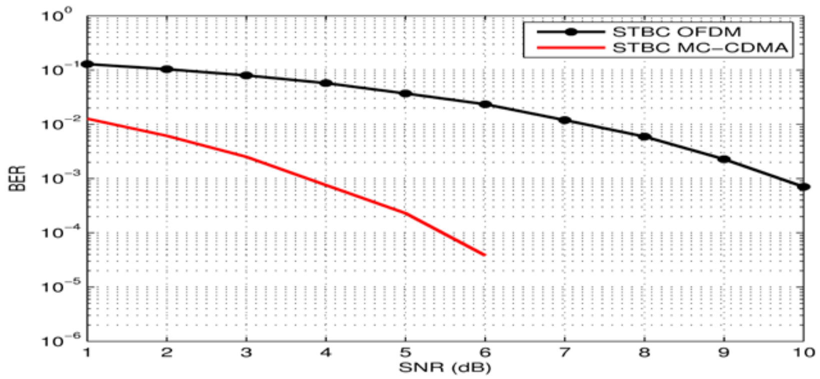

Fig. 4. BER performance of STBC OFDM and STBC MC-CDMA under Rayleigh fading channel for single user

Fig. 3 and Fig. 4 present that the STBC MC-CDMA performs better than STBC OFDM under AWGN and Rayleigh channel. For BER of 10^{-3}, STBC MC-CDMA achieves a SNR gain of around 6 dB in AWGN and Rayleigh fading channel.

In Fig.5, it is observed that as the no of users increase the BER performance degrades.

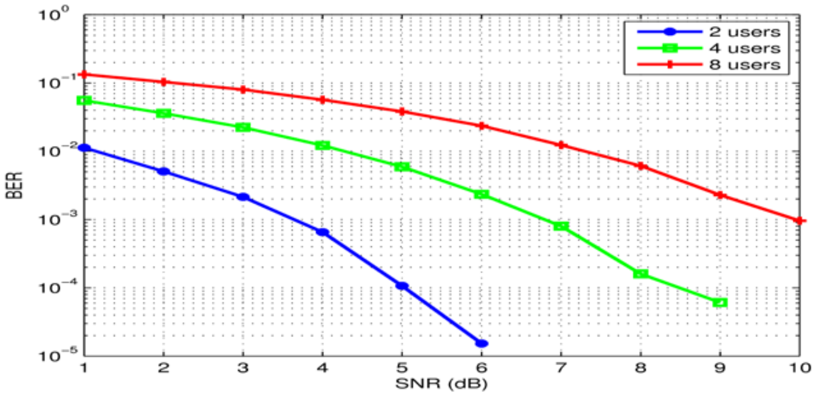

Fig. 5. BER performance for 2, 4 and 8 users for SF=4 of STBC MC-CDMA under Rayleigh fading channel

5 Conclusions

In this paper, a low complexity multiuser STBC MC-CDMA scheme is proposed. The proposed scheme is compared with STBC OFDM. Also the simulation results for different users for STBC MC-CDMA are presented. Multiuser BER performances are also given which ensures that BER performance degrades as the no of users increase. It is observed that STBC MC-CDMA performs better than STBC OFDM under AWGN and Rayleigh fading channel.

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