Performance Enhancement of MIMO MC-CDMA System employing Cylically Rotated Complete Complementary Codes

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Abstract—Wireless communication needs very high data rate and throughput in order to meet increasing demand for multimedia applications. MC-CDMA technique along with multiple input multiple output (MIMO) technique is used to increase data rate and to reduce the channel impairments. Spreading code plays a major role in CDMA technique, Cyclically rotated complete complementary codes (CRCCCs) are used for spreading which have perfect auto-correlation and cross correlation properties. Bit error rate (BER) can be reduced and have other advantages like high data rate, high throughput, reduced inter symbol interference (ISI) and multiple access interference (MAI). MIMO MC-CDMA system employing CRCCCs is designed and simulation results are shown.

Keywords- *MC-CDMA, BER, CRCCCs, MIMO, throughput, MAI, ISI.*

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I. INTRODUCTION

The major demand for wireless communications is to achieve high data rate and better BER performance. MC-CDMA includes the advantages of both CDMA and OFDM, since it is the combination of both techniques. MIMO MC-CDMA [1],[7] system achieves high transmission rate, reliability, high capacity.

Orthogonal complete complementary (OCC) [3] codes are used to reduce the multiple access interference (MAI). A cyclical rotation scheme is applied to these codes to maximize the throughput, these extended codes are called CRCC codes.

Spreading codes plays a major role in CDMA technology. These spreading codes should be perfectly orthogonal and should have perfect auto-correlation and cross correlation properties. The proposed CRCCCs satisfies all these properties and achieves better BER performance than other spreading codes.

1.1 Methodology

The proposed work is performance analysis of MIMO MC-CDMA [1], [7] technique employing CRCC codes.

The first step is to study the fundamentals of MC-CDMA system, and then the MIMO technique is applied. Then gold codes are applied for spreading, the design is simulated in Rayleigh channel. This is done for 2x2 and 4x4 antennas.

The second step is to apply CRCC codes [1]-[4] for spreading and simulation is done. This is also done for 2x2 and 4x4 antennas. The results are compared with the gold code results.

Simulation results shows that the BER performance of CRCCC is better compared to gold codes and results also show that the BER performance is sensitive to length of spreading code. The performance is calculated in terms of Bit Error Rate (BER) versus Signal to Noise Ratio (SNR) using MATLAB.

This technology has applications in mobile multiple access infrastructures where receiver processing and power resources are limited.

The rest of the paper is organized as follows: Section II describes the transmitter, channel and receiver model for MIMO MC-CDMA system. Section III describes spreading codes. Simulation results are shown in section IV are results are analyzed in section V. Finally the conclusion will be given in section VI.

II. SYSTEM MODEL

2.1(a) MC-CDMA: MC-CDMA is the combination of CDMA and OFDM. Therefore it has the advantages of both the schemes. In MC-CDMA each data symbol is spreaded in frequency domain and transmitted on different subcarrier which achieves significant improvement in BER performance.

2.1(b) MIMO: In radio communications MIMO means multiple antennas both on transmitter and receiver side. Multiple antennas can be used to reduce the error rate and also increases the reliability and capacity of the system.

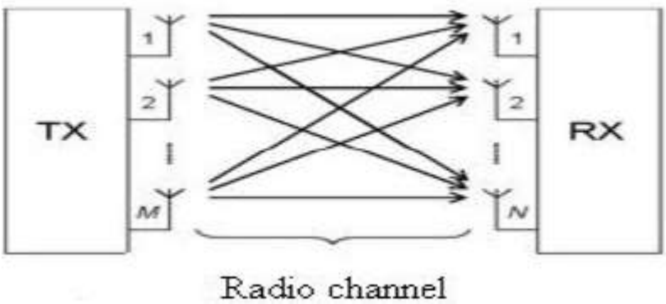

Figure 1: MIMO system with M transmit and N receive antennas

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Figure 1 shows the MIMO system with M transmit antennas and N receive antennas. Then the matrix of dimensions NxM with complex transfer factors can be given as

$$\begin{bmatrix} H_{1,1} & \cdots & H_{1,M} \\ \vdots & \ddots & \vdots \\ H_{N,1} & \cdots & H_{N,M} \end{bmatrix}. \quad \ldots\ldots\ldots\ldots (1)$$

2.2 MIMO MC-CDMA system

2.2(a) Transmitter: Figure 1(a) shows the transmitter block diagram. The binary data is modulated using quadrature phase shift keying (QPSK) generating a single stream of symbols. This single stream is then converted in to multiple parallel stream of symbols by serial to parallel converter. Then these parallel streams are spreaded by CRCCC which will be discussed in section III.

The spreaded streams are subsequently mapped onto multiple transmit antennas according to the OSTBC [5]. The number of parallel streams is equal to the number of transmit antennas.

The CRCC codes are composed of K flocks of sequences [1]. Each sequence will have M element codes each of length N, thus each flock will be of length KN. Then spreaded parallel streams are mapped to the multiple antennas.

The data rate and throughput will be increased as the number of antennas increases.

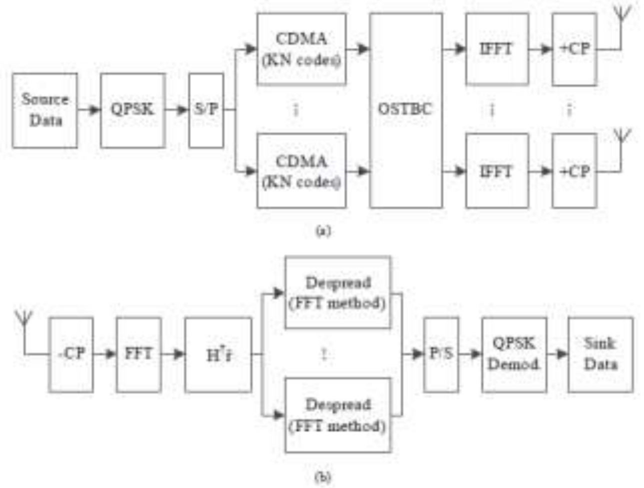

Figure 2: Block diagram of (a) transmitter, (b) receiver of MIMO MC-CDMA system.

Cyclic prefix (CP) is prepended to each stream before they are passed through the channel. Because of CP the there will be only small loss in sprectral efficiency.

The data will be passed through different channel models. Here Additive White Gaussian Noise (AWGN) and Rayleigh Flat fading are used.

2.2 (b) Receiver:

Figure 2 (b) represents the receiver of MIMO MC-CDMA system. The cyclic prefix is removed from the received signal.

Then the received signal r is conjugate transpose with the channel matrix H. then the resultant signal is despreaded by using the CRCC codes. The spreading codes which are used at the transmitter are used at the receiver to retrieve the data at the receiver side.

Then the parallel data streams are converted to serial data by using a serial to parallel converter. Then the data is decoded by QPSK demodulation technique.

The local correlators used at the receiver side correlates the received data from the channel with the flock of codes of particular user.

III. SREADING CODE

3.1 Gold code: These are PN sequences which are randomly generated by a linear shift register. Gold codes are produced from preferred pair of M-sequences. Gold codes have better auto correlation and cross correlation properties than Walsh codes and other PN sequences. Figure 3 gives the example of the gold sequence.

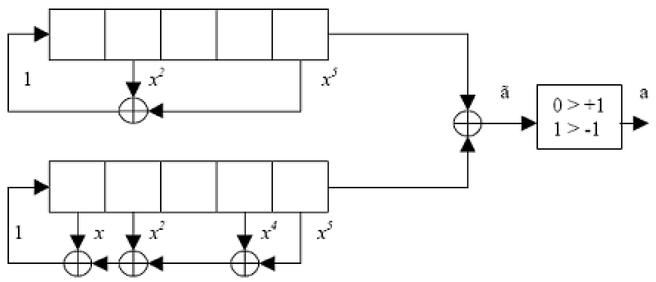

Figure 3:A Gold Sequence generator with $p1(x)=1+x^2+x^5$ and $p2(x)=1+x+x^2+x^4+x^5$

The system is simulated by using Gold sequences as spreading code and BER performance is analyzed. The BER performance is better compared to Walsh codes. The orthogonality of the Walsh codes reduces as the number of users increases.

But the disadvantage with gold sequence is the orthogonality of the spreading code reduces as the length of the code increases.

3.2 Cyclically Rotated Complete Complementary Codes

The selection of spreading code is important for CDMA type system. The spreading code should be orthogonal and should have perfect auto-correlation and cross correlation properties. If the spreading codes are not orthogonal the data will not be retrieved perfectly at the receiver. This results in reduction of throughput and increased BER.

The CRCC codes are produced by real environment adapted linearization (REAL) approach [2],[8]. The REAL approach generates interference free codes with perfect auto-correlation and cross correlation properties.

The procedure to generate the CRCC codes was shown in [2]. The OCC codes which are produced will have K “flock”. Flock is nothing but set of codes. Each flock will have

M element codes each of length N, thus KN codes will be produced.

$$C_1=\{C_{11},C_{12},C_{13,\ldots,}\ C_{1M}\}\ldots.(2)$$

$$C_2=\{C_{21},C_{22},C_{23},\ldots,C_{2M}\}\ldots.(3)$$

$$\ldots$$

$$C_K=\{C_{K1},C_{K2},C_{K3},\ldots,C_{KM}\}\ldots.(4)$$

Further these codes are rotated to maximize the throughput

$$C^{n=1}{}_1=\{C_{11}{}^1,C_{12}{}^1,C_{13}{}^1,C_{14}{}^1\}\ldots.(5)$$

$$C^{n=2}{}_1=\{C_{11}{}^2,C_{12}{}^2,C_{13}{}^2,C_{14}{}^2\}\ldots.\ (6)$$

$$\ldots.$$

$$C^{n=L}{}_1=\{C_{11}{}^L,C_{12}{}^L,C_{13}{}^L,C_{14}{}^L\}\ldots.\ (7)$$

Where L equals to the elementary code length. The orthogonality and perfect correlation properties of the codes are not destroyed the cyclic shifting operation. The cyclic rotation is possible because of the perfect auto correlation and cross correlation properties of OCC codes. Because of perfect orthogonality property of these codes MAI free operation is possible. The inter symbol interference will be reduced (ISI).

The advantages of CRCC codes over traditional CDMA codes are, the orthogonality depends on the set of codes called flock instead of single code. These codes have perfect correlation properties. The simulation results shows that CRCC codes achieves better BER performance and increased throughput than Gold and Walsh codes.

For a good system the Bit Error Rate should be low and should achieve high throughput. This system will be simulated by Gold codes and CRCC codes. The performance will be compared by increasing the antennas. The simulation results shows that the system

IV. RESULTS

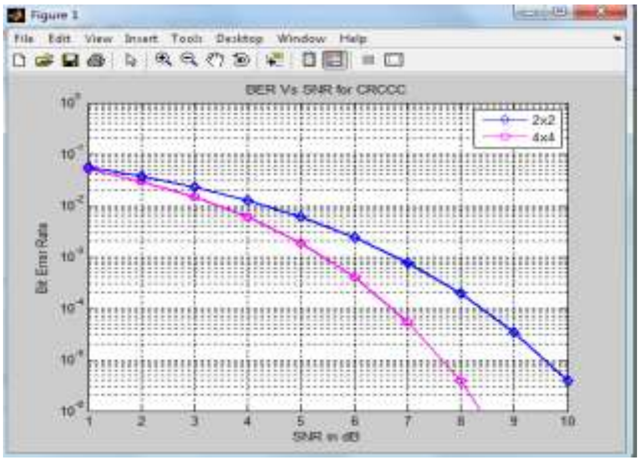

Figure 4: SNR Vs BER graph of CRCC codes

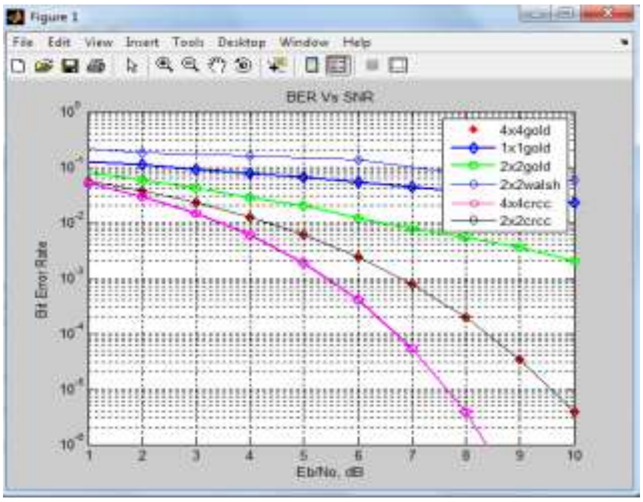

Figure 5: comparing the BER Vs SNR graphs of CRCC, Gold, and Walsh codes

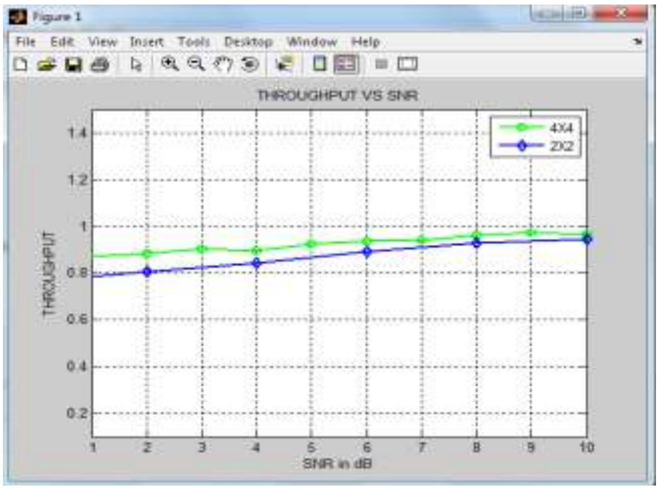

Figure 6: SNR Vs Throughput graph of gold code

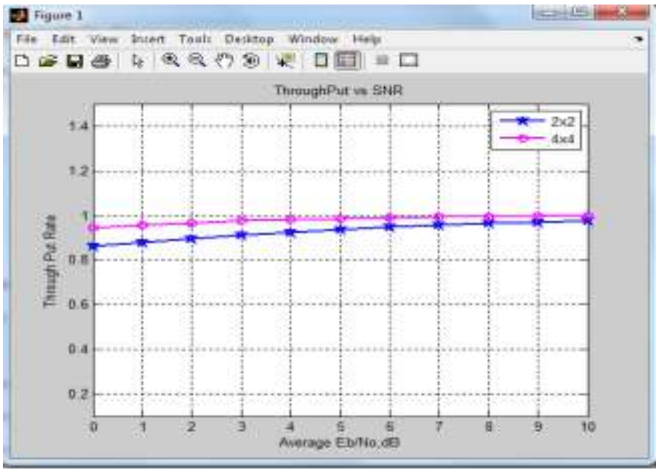

Figure 7: SNR Vs Throughput of CRCC codes

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V. RESULT ANALYSIS AND DISCUSSION

Spreading code	Number of antennas	SNR(dB)	Bit Error Rate	Throughput
Gold code	2x2	5	0.2	0.82
Gold code	4x4	5	0.05	0.95
CRCCC	2x2	5	0.04	0.96
CRCCC	4x4	5	0.01	0.99

Table1: Result analysis of CRCC codes and gold codes

From figures 4 and 5 we can conclude that the CRCC codes achieve better BER performance than Gold and Walsh codes. From figures 6 and 7 we can conclude that CRCC codes achieves high throughput than Gold codes. From figures 4,5,6,7 we can say that the system with 4x4 antenna performs better compared to system with 2x2 antenna.

VI. CONCLUSION

The implementation of MIMO MC-CDMA system employing CRCCCs has been presented. From the simulation results we can conclude that the systems using CRCCCs performs better than the systems using Gold codes.

BER performance of the system employing CRCCCs with 4x4 antennas is better than the system with 2x2 antennas.

The system employing CRCCCs with 4x4 antennas achieved better throughput compared to 2x2 antenna and other conventional techniques.

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