Performance Analysis of Spatially Correlated QSTBC based Multi-Carrier CDMA System

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Abstract: Wireless communication has seen significant advancements over the last some years, with networking without using wires, mobile networking systems, and communication in person systems extensively utilizing modern wireless communication technologies. Multiple access techniques play a crucial role in enabling numerous mobile users to efficiently share the allocated spectrum. Among these techniques, Code Division Multiple Access (CDMA) stands out as a popular method for optimizing bandwidth usage. The traditional receiver for a CDMA system is a matched filter receiver. However, due to the multipath nature of mobile channels, the matched filter receiver often faces performance issues, including the near-far problem. In environments with frequency-selective fading, relying on a single carrier can result in poor performance. Conversely, transmitting the same data across multiple carriers allows for the combination of received data from each subcarrier, thereby enhancing performance. This method is known as the multicarrier (MC) CDMA scheme. Additionally, Multiple number of Input and Multiple number of Output (MIMO) technology is pivotal for current and future wireless communication systems. One of the features of MIMO is Space Time Block Coding (STBC). In that specified coding, the Quasi-orthogonal space-time block codes (QSTBC) have attracted interest for their potential to improve data rates, reliability, and coverage. However, the system's performance can be adversely affected by spatial correlation between MIMO channel coefficients. This paper implements an Q-STBC MC-CDMA system and analyzes its performance in the presence of spatial correlation effects.

Keywords: CDMA, MIMO, Spatial Correlation, Q-STBC Coding, Rayleigh Channel

1. INTRODUCTION

Multiple accessing with respect to signature codes is one of the most promising method in multiple accessing schemes. It is evolved in 2G and continued next generations also [1]. MC-CDMA is a robust mechanism that solves the channel issues in wireless system [2]. Multi-carrier code division multiple access (MC-CDMA) enables the several user communication while providing frequency diversity [3]. Multiple input multiple output is one of the most key technology in modern communication systems. Space time coding is one reliable approach, which sends the data in the form of blocks [4],[5]. QSTBCs are a sub class of STBCs. Complete data rates with reduction in the diversity is possible with these codes [6] [7]. Wireless systems are most difficult to design due to its channel attributes [8]. Rayleigh is one kind of channel, where there is no line of sight signals present, leads to fading and causes severe distortion at the receiving end [9].

Spatial correlation in wireless communication describes the connection amid the signal's spatial direction and the mean signal power of the received signal. Multi-antenna realizations improve the system performance. However, these gains are often limited, as the channels associated with individual antennas are typically correlated. To reduce spatial correlation, rich multipath propagation spreads the signal, enabling the reception of multipath components from various spatial directions. Conversely, antennas placed close to each other increase spatial correlation because they tend to get parallel elements of signal. Experiments have demonstrated the existence of spatial correlation. Many believe that it negatively affects the performance of several antenna based system and reduces the number of transmitter and receiving antennas that can be integrated into compact devices. While it seems reasonable to conclude that spatial correlation diminishes the individual channels number, the actual impact can depend on the specific environment and system design. Spatial correlation severely effects the performance of the system [10-13].

The paper is structured as follows: In this study the system model is introduced in Section 2. Proposed methodology detailed in Section 3. Performance evaluation illustrated in Section 4 and the Conclusions are mentioned in Section 5.

2. SYSTEM MODEL

The proposed system pictorial representation is shown in figures 1,2. In the transmitter side data is generated from data generation block then modulated and spread then transmitted through multiple carriers. The received data is despread and demodulated at receiver side to retrieve the data back.

2.1 Space Time Block Codes: STC is a MIMO function. In this data which is to be transmitted is converted into STBC matrix, where the rows represent spatial transmissions and columns signifies the time slots. Orthogonality is the main features of STBCs. These codes are developed using orthogonality concept, these codes use minimal extracting, which allows for the independent recovery of transmit symbols, is achievable through such an orthogonal design. However, a difficult design ensures both complete diversity and complete transmission rate cannot be realized with more than two transmit antennas.

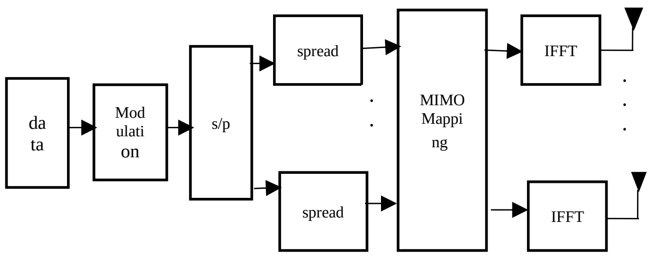

Fig. 1. Block diagram of MIMO MC-CDMA system (transmitter)

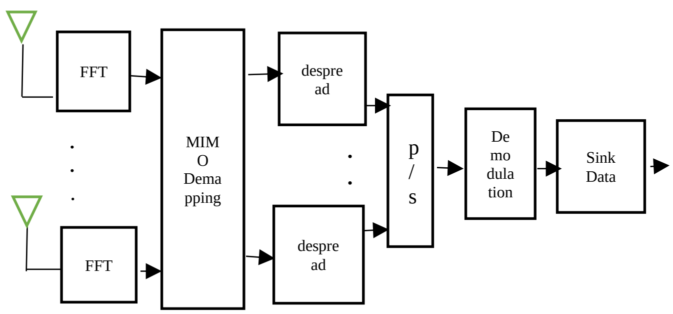

Fig. 2. Block diagram of MIMO MC-CDMA system (receiver)

2.2 Quasi-Orthogonal Space-Time Block Codes (QSTBC): The problem in OSTBCs is overcome by Quasi orthogonal codes. The transmission matrix is shown in equation 1. In this transmission, all the columns are not orthogonal like OSTBC. Group based orthogonality possible. That allows pair wise decoding and also supports less error rate.

$$U_J = \begin{bmatrix} u_1 & u_2 & u_3 & u_4 \\ -u_2^* & u_1^* & -u_4^* & u_3^* \\ -u_3 & -u_4^* & u_1^* & u_2^* \\ u_4 & -u_3 & -u_2 & u_1 \end{bmatrix} \qquad (1)$$

Spatial Correlation: The transmission channels amid the source and destination are typically identically distributed and independent. However, these channels are often correlated, which can lead to interference in the received signals. In spatially correlated channel the channel coefficient V can be modelled as shown in equation (2)

$$V = P_{rx}^{1/2} V_w P_{tx}^{1/2} \qquad (2)$$

where $P_{rx}^{1/2}, P_{tx}^{1/2}$ are the covariance matrices.

3. MIMO MC CDMA SYSTEM WITH SPATIALLY CORRELATED CHANNELS

Steps:

1. Data encoding: Data is randomly generated.
2. The generated data is modulated with BPSK scheme.
3. Then the data parallel converted and spread with spreading code.
4. Spread data is mapped with MIMO. The data is converted in to Q-STBC matrix and given to IFFT block for multi carrier transmission.
5. Data is transmitted through wireless channel.
6. At receiver, AWGN noise is added, maximum likelihood detection (MLD) is performed.
7. Then the data is despread and demodulated.

4. NUMERICAL RESULTS

The proposed system implemented using the following parameters. Simulation conditions and parameter are depicted in table 1.

4.1 Bit Error Rate (BER): The BER is a vital parameter for evaluating system performance. Fading effects the performance and also the spatial correlation. In the proposed system bit error rate is affected by the diversity order and also the correlation degree. The proposed Q-STBC system assists in improvement of BER at low signal to noise energy values but any how the performance reduces at increase SNR values.

4.2 Capacity: Capacity is the parameter that defines, the number of bits transmitted at given signal to noise ration and bandwidth.

Table. 1. Simulation parameters

Parameter	Value
Modulation	BPSK
No. of input bits	5000
Antenna Size	*Tx*=4 & *Rx* =4
Signature code	Walsh Code
Length of signature code	8
Channel	Rayleigh

The Figure 3, shows the is BER Vs Eb/No for the system with high and low correlation using. From the plot is clear that BER is low for low correlation and high for high correlation. The figure 4 depicts the capacity performance of low and high correlated system. From the plot it is conclusive that whenever the correlation impact is low then is increment in the capacity.

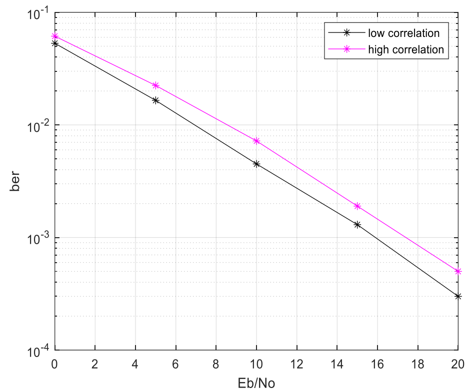

Fig. 3. BER for High and Low correlations

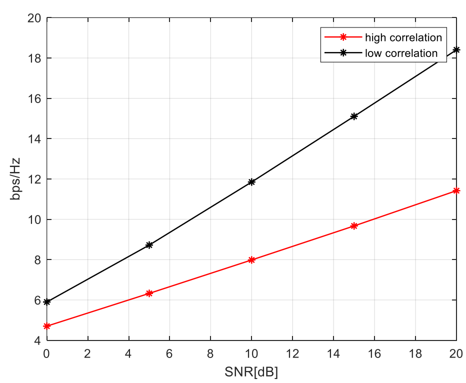

Fig. 4. Capacity graph for high and low correlations

5. CONCLUSIONS

Quasi-space time block coded MC CDMA is realized in this paper. When the system does not effect by spatial correlation then the performance is good. When the correlation present among the channels that reduces the overall output of the system. Because the MIMO transmission system performance highly depends on its channel attributes. The channel eigen values are very crucial in evaluating process of the MIMO transmission, absence of spatial correlation the SNR gain is increased. The challenges in the proposed system are resolved by correlation aware decoding mechanism and adaptive quasi space time block coded design. With these mechanisms the proposed system achieved high reliability and robust performance. The proposed system is implemented for smaller number of antennas at both transmission and receiving side of the system. Increased number of antenna based system will be implemented in the suitable for modern MIMO systems.

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