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Research Paper

DESIGN AND ANALYSIS OF VARIOUS MULTIUSER DETECTION TECHNIQUES FOR SDMA-OFDM SYSTEMS

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SDMA (Space-Division Multiple Access) is a MIMO (Multiple-Input and Multiple-Output) based wireless communication network architecture which has the potential to significantly increase the spectral efficiency and the system performance. The maximum likelihood (ML) detection provides the optimal performance, but its complexity increases exponentially with the constellation size of modulation and number of users. The QR decomposition (QRD) MUD can be a substitute to ML detection due its low complexity and near optimal performance. The minimum mean-squared-error (MMSE) multiuser detection (MUD) minimises the mean square error (MSE), which may not give guarantee that the BER of the system is also minimum. But the minimum bit error rate (MBER) MUD performs better than the classic MMSE MUD in term of minimum probability of error by directly minimising the BER cost function. Also the MBER MUD is able to support more users than the number of receiving antennas, whereas the rest of MUDs fail in this scenario. In this paper the performance of various MUD techniques is verified for the correlated MIMO channel models based on IEEE 802.16n standard.

Keywords: Multiple input multiple output, Multiuser detection, Orthogonal frequency division multiplexing, Space division multiple access, Bit error rate

INTRODUCTION

The most popular SDMA structure in MIMO system is able to increase system capacity by supporting multiple users. SDMA exploits the unique, user-specific “spatial signature”, i.e. the channel impulse repose (CIR) of the individual users for differentiating amongst them. This allows the system to support multiple users within the same frequency band and/time slot, if their CIRs are sufficiently different and are accurately measured. SDMA architecture can be configured and deployed for most of the well-known mobile communication architectures such as CDMA (Code division Multiple Access), TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access). However,the space domain has not been exploited within a cell so far. Equipping base stations with antenna arrays

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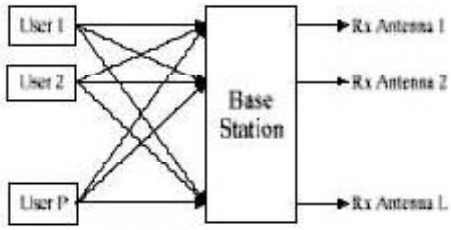
will enable beam steering in contrast to omnidirectional or sectorized single antenna systems. Thus, it becomes possible for base stations (BS) to radiate directed to specific users on the down-link as well as receive directed on the up-link. This can be done by reusing channels within a cell for user which are spatially separable by the antenna array mitigating the intersymbol interference (ISI) caused by multipath propagation (Ming Jiang and Hanzo L, 2007). Orthogonal frequency division multiplexing (OFDM) is effective in OFDM therefore is considered as an efficient modulation technique for broadband access in a very dispersive environment. Hence the combination of OFDM and SDMA is an efficient technique in high data rate transmission scenario (Nirmalendu Bikas Sinha *et al*., 2009; and Sheng Chan*et al*., 2001). Research in the development of efficient signal detection algorithms for SDMA-OFDM systems have generated much interest in recent years, and several detection algorithms have been proposed in the literatures (de Lamare R C and Sampaio-Neto R, 2003; Erceg V *et al.*, 2001; Vandenameele P*et al.*, 2000; Jin-Sung Kim*et al.*, 2010; Yeh C C and Barry J R, 2000; Alias M Y *et al.*, 2003). Among the various MUDs, the classical linear ZF and MMSE MUDs exhibit low complexity at the cost of a limited performance. The high-complexity optimum ML MUD provided here has capable of achieving the best performance with an exhaustive search. However, the complexity of nonlinear ML detector generally avoids its use in practical systems especially with many users and large constellations. QR decomposition using tree search is a most promising algorithm, which can be implement with low complexity and also provides near optimal solution.

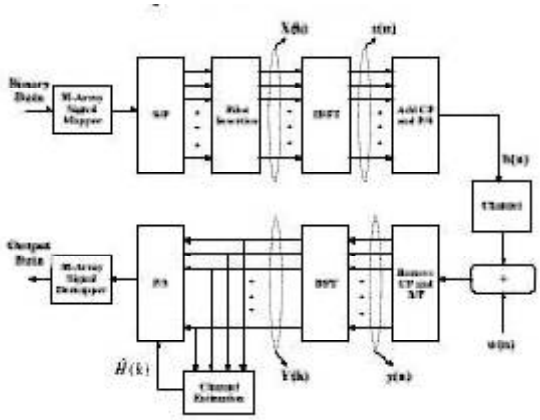
SDMA-OFDM SYSTEM MODEL

The SDMA system with P number of users each equipped with single antenna and L number of receiving antennas at BS was depicted in Figure 1. And each user Rx antenna pair undergoes OFDM modulation as shown in the below Figure 2.

Figue 1: Basic SDMA Structure



Figue 2: OFDM Modulation



MULTIUSER DETECTION TECHNIQUES

A. Zero Forcing (ZF) Detection This algorithm involves a linear transformation between the output signal and estimated channel, and the detected signal is given by (Nirmalendu Bikas Sinha *et al*., 2009).

where X is estimated user signal, H is the estimated channel response and Y is the received vector.

B. Minimum mean square error (MMSE) Detection MMSE detection scheme is also a linear process but it assumes a priori knowledge of noise variance and channel

covariance. Due to this it is a more accurate detection scheme compared to ZF MUD. This algorithm detects users as (Nirmalendu Bikas Sinha *et al*., 2009)

C. Maximum Likelihood detection (ML) The highest-complexity, highest performance optimum ML MUD uses an exhaustive search for finding the most likely transmitted users (Jehad I Ababneh *et al*., 2010). For a ML-MUD supporting P simultaneous transmitting users, a total of 2mP metric evaluations have to be invoked, where m denotes the number of bits per symbol, in order to detect the L user symbol vector X that consists of the most likely transmitted symbols of the L users at a specific subcarrier, which is given by

D. QRD-M Detection The QRD-M algorithm provides near ML detection performance with comparatively low complexity (Yeh C C and Barry J R (2000). It is basically a breadth first tree traversal algorithm. At each detection layer, QRD-M algorithm keeps M reliable nodes instead of deciding the symbol. Detection is done after processing all layers. The concept of QRD-M is to apply the tree search to detect the symbols in a sequential manner. Starting from the first layer i.e. i = P, the algorithm calculates the metrics for all possible values of Yˆ i from the constellation

SIMULATION ANALYSIS OF RESULTS

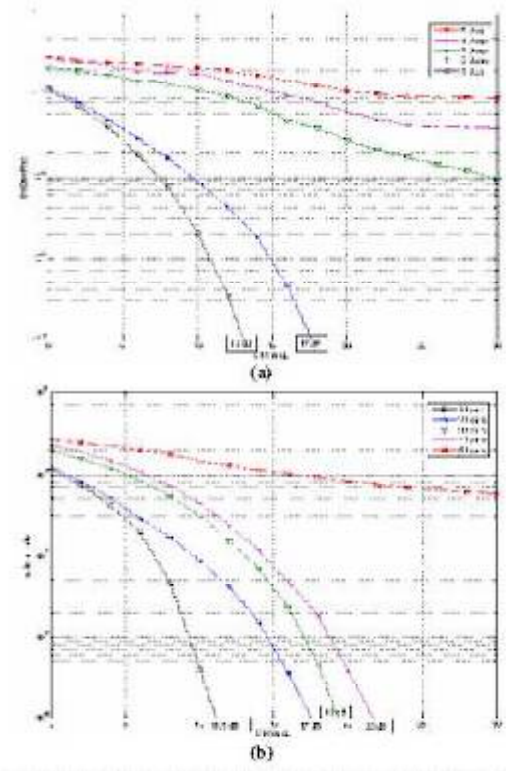
In this section, we have analyzed the performance of SDMA-OFDM system using the various multiuser detection techniques mentioned in previous section. In the simulation study a 2×2 SDMA OFDM system is considered. Further simulation parameters chosen are outlined in Table I. Performance carried through BER vs SNR in dB plots.

Parameters Used for Simulation

Channel impulse response Correlated MIMO Channel given in the below Table.

Parameters	Specification
No.of active Carriers	128
Guard Interval	32
No.ofFrames Parameters	1000
No. of Users	2
No. of Rx antennas	2
Modulation Technique	
BPSK OptimizationUsed Conjugate Gradient Step Size	0.0975

Figure 3: The BER Performance of User 1 Employing both MMSE and MBER MUDs in SDMA-OFDM System Equipped with Two Receiving Antennas for Different Number of Uses Over Dispersive Gaussian Channels Given in Table 3. (a) MMSE MUD (b) MBER MUD



Further a 2×5 SDMA-OFDM system is studied over Gaussian channels given in Figure 3. It is seen that as the number of users increases, the BER performance degrades due to the increased multiuser interference. The MMSE MUDs in Fig. 5(a) can only support a maximum number of users that is equal to the number of receiver antennas, which is two in this case. Once the number of users exceeds the number of receiver antennas, the MMSE MUD becomes incapable of differentiating the users, and performance detorates. Under such case the MBER MUD as shown in Figure 5(b) performs significantly better by supporting up to four users. Finally by comparing Figure 5(a) and (b) we may conclude that the MBER MUD is capable of supporting more users than the number of receiver antennas.

CONCLUSION

In this paper various multiuser detection schemes like ZF, MMSE, ML, QRD, and MBER have been elaborated and compared in a SDMA–OFDM system. The MMSE estimator assumes a priori knowledge of noise variance and channel covariance, so that MMSE detects users accurately than ZF detection. The ML detection scheme provides an optimal solution for MUD, but due to its complexity its application is rohibited in high load scenarios. The QRD detection algorithm performs close to the optimal ML detection and the computational complexity of QRD algorithm is less compared to ML detection and it eliminates exhaustive search. In this paper, it is shown that the conjugate gradient based MBER MUD is capable of achieving better performance than the conventional MMSE MUD. Unlike the MMSE MUD, the MBER MUD has compatible of supporting more users than the number of receiver antennas. The MUD simulations of SDMA-OFDM system are performed over the correlated MIMO channel for IEEE 802.16n standards, and those are studied through the BER plots.

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