Advanced Science and Technology Letters
Vol.51 (ITCS 2014), pp.264-267
http://dx.doi.org/10.14257/astl.2014.51.60

Efficient QRD-M Detection in the MIMO-OFDM System

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Abstract. In this paper, the improved QR-decomposition with M algorithm (QRD-M) for efficient signal detection is proposed. In order to improve efficiency in terms of complexity and detection performance, the proposed detection scheme adjusts the number of candidates according to the layer. Simulation results show that the proposed scheme has an improved detection performance compared to the conventional scheme with similar complexity.

Keywords: Detection, QRD-M, Layer

1 Introduction

The current communication systems demand high channel capacity in a band-limited environment. The orthogonal frequency division multiplexing (OFDM) [1] system and the multiple input multiple output (MIMO) system meet high channel capacity in a band-limited environment. Two systems are combined and the combined system is called as the MIMO-OFDM system.

The MIMO-OFDM system is mainly implemented by using the vertical Bell laboratories layered space time (V-BLAST) [2], [3] architecture. Many detection schemes based on the V-BLAST architecture have been proposed. The QRD-M [4] detection scheme is one of the schemes based on V-BLAST architecture. Although the QRD-M detection scheme has the good performance, it is difficult to apply to an actual system due to the high complexity.

2 MIMO-OFDM System Model

The antenna configuration with N_T transmitting antennas and N_R receiving antennas is expressed by $N_T \times N_R$. Signals are transmitted by each sub-carrier. The OFDM symbol of the i-th transmitting antenna is expressed as

$$\left[{X_{(0)}}^i {X_{(1)}}^i \cdots {X_{(k)}}^i \cdots {X_{(K-1)}}^i\right], \tag{1}$$

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ISSN: 2287-1233 ASTL

where ${X_{(k)}}^i$ is the signal at the k-th sub-carrier. OFDM symbols are simultaneously transmitted in parallel using the multiple transmitting antenna. In the MIMO-OFDM system, the transmitted symbol is expressed as

$$\mathbf{Y}(k) = \mathbf{H}(k)\mathbf{X}(k) + \mathbf{N}(k) = \sum_{i=1}^{N_T}\sum_{j=1}^{N_R} H_{i,j}(k)X_i(k) + N_j(k), \quad (2)$$

where $H_{i,j}(k)$ is a Rayleigh fading channel gain with multi-path from the i-th transmitting antenna to the j-th receiving antenna, $N_j(k)$ is an additive white Gaussian distribution noise vector of the j-th receiving antenna.

3 Proposed Detection Scheme

The proposed detection scheme uses the different number of candidates according to the layer. The method that uses the different number of candidates according to the layer is related to detection process of the QRD-M.

The QRD-M removes the interference signals of lower layer using detected signals of upper layers. Considering structure of QRD-M, $(X_{l-1}, X_{l-2}, \cdots, X_1)$ are interference signals for the signal of the l-th layer X_l. The number of interference signal of the l-th layer is $(l-1)$. Interference signals must be removed for signal detection.

If the channel state is not good in the upper layer, the signal detection at upper layer isn't correct. Because of the interference cancellation process, the error at the upper layer influences negative effects to all lower layers. Therefore, the detection at upper layer needs a lot of candidates. However, since different interference signals undergo each independent channel, if interfering signals are correctly removed, the detected signal has a higher diversity compared to signals of upper layers. For that reason, the detection at lower layer can correctly detect with small candidates compared to upper layer. However, if the channel condition is very poor, the detection can be inaccurate in case of small candidates. Based on the explained contents so far, the different number of candidates according to the layer should follow the three rules.

First, in order to guarantee detection performance, a lot of candidates must be used for the detection at upper layer. Next, the detection of lower layer should use a relatively small candidates in order to reduce the complexity. Finally, the minimum number of candidates is required.

4 Simulation Results and Conclusion

The computational complexity for the proposed detection scheme and the conventional QRD-M is only considered as multiplication since most of the complexity is multiplication. Table 1 shows the equations for complexity.

In the Table 1, M is the number of candidates for the conventional QRD-M, $\mathbf{P}$ is the number of candidates for proposed scheme and L is the modulation

Table 1. The formula for the complexity of the conventional QRD-M and the proposed scheme.

Operation	Detection Scheme	The required number of real multiplication per sub-carrier
Calculation of Moore-Penrose pseudo inverse matrix for QR decomposition	Conventional QRD-M & Proposed scheme	$8N_T^3$
QR decomposition		$4N_T^3$
Removal the Q component of the received signal matrix		$4N_T^2$
Calculation of the Euclidian distance	Conventional QRD-M	$4L+\sum_{n=2}^{N_T}(4MLn)+4L+\sum_{n=2}^{N_T}(4ML)$
	Proposed scheme	$4L+\sum_{n=2}^{N_T}(4\mathbf{P}_nLn)+4L+\sum_{n=2}^{N_T}(4\mathbf{P}_nL)$

order. How to assign the value of $\mathbf{P}$ complies with the described rules in the section 3.

Table 2 shows the complexity for two case of assigned $\mathbf{P}$ in the proposed scheme with 8×8 antenna and the conventional scheme with similar complexity.

Table 2. The assignment of the number of candidates for the proposed and the conventional scheme in the 8×8 MIMO-system

Schemes \ Layer	1	2	3	4	5	6	7	8	Complexity (The number of real multiplication per sub-carrier)
QRD-M with 16 candidates	16	16	16	16	16	16	16	16	49536
Case 1 (proposed scheme)	16	16	8	8	4	4	2	2	19712
QRD-M with similar complexity of case 1	5	5	5	5	5	5	5	5	19968
Case 2 (proposed scheme)	16	14	12	10	8	6	4	2	24448

To estimate the BER performance, MIMO-OFDM systems of 8×8 antenna with 256 sub-carriers are considered. The Rayleigh fading channel with multi-path 7 is considered for simulation. Fig.1 shows the simulation results.

In the 8×8 antenna system and case 1, considering the BER of 10^{-4}, the BER performance of the proposed scheme is 2.8dB better than the conventional scheme with similar complexity and 4.5dB better than the conventional scheme with similar complexity in the case 2. Simulation results show that the proposed scheme is efficient detection scheme in terms of complexity and detection performance compared to the conventional scheme.

The conventional QRD-M scheme is difficult to apply to an actual system due to high complexity. For this problem, the proposed scheme uses the different

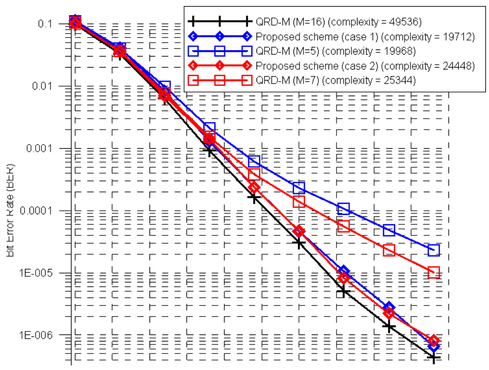

Fig. 1. BER performance of the conventional and the proposed detection schemes in the 8×8 antenna system.

number of candidates according to the layer. The assignment of the number of candidates according to the importance of each layer. From the simulation results, the proposed scheme is efficient in terms of complexity and detection performance compared to the conventional scheme.

Acknowledgments. This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT and future Planning(No. 2013R1A2A2A01067708) and this research was supported by the MSIP(Ministry of Science, ICT&Future Planning), Korea, under the C-ITRC(Convergence Information Technology Research Center) support program (NIPA-2014-H0401-14-1006) supervised by the NIPA(National IT Industry Promotion Agency).

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