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Low Complexity QRD-S Using Channel State Information in MIMO-OFDM System

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Abstract. In this paper, an adaptive detection scheme is proposed to reduce the complexity. The QRD-S detection scheme reduces the complexity by reflecting the channel state information (CSI) directly.

Keywords: MIMO-OFDM, QRD-M, channel state information

1 Introduction

Orthogonal frequency division multiplexing (OFDM) system and Multiple input multiple output (MIMO) system are used in various fields recently. However, the problem is that the MIMO-OFDM signal detection process is difficult at the receiver side. The detector with the low complexity and the high performance is very important. So, various detection schemes in Vertical Bell Laboratories Layered Space Time (V-BLAST) [1] system have been proposed. The conventional QRD-M [3] - [4] detection scheme uses the M algorithm,which is directly linked with the performance-complexity trade-off. To obtain the good performance, the large M value is referred and the complexity of the QRD-M detector is increased.

Therefore, the QR decomposition with the switching M algorithm (QRD-S) is proposed in this paper. The QRD-S can reduce the complexity by using the CSI [2]. By using the CSI, an adaptive detector is generated.

2 System Model

In this section, the MIMO-OFDM system model is explained. The MIMO-OFDM symbols are expressed as follows:

$$\mathbf{Y}^{(k)} = \sum_{i=1}^{N_r} \sum_{j=1}^{N_t} H_{ij}^k X_j^k + N_i^k = \mathbf{H}^{(k)} \mathbf{X}^{(k)} + \mathbf{N}^{(k)} \tag{1}$$

where i is the index of the receiving antenna and j is the index of the transmitting antenna. H_{ij}^k is the channel distortion component and N_j^k is the noise

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distortion component. The property of the channel is independent and identically distributed (i.i.d.) random matrix. The noise is zero mean additive white gaussian noise (AWGN).

3 Conventional Schemes

The QRD-M detection scheme is implemented with the 7-steps. A new symbol vector which is based on the QR decomposition is obtained until the fourth step. From the fifth step, the M algorithm is implemented.

First, the pseudo inverse matrix of the channel $\mathbf{H}$ is calculated and the ordering number is defined. From the largest norm value to the smallest norm value, the ordering number is sorted. At the second step, the channel matrix is sorted with the ordering number which is calculated at the first step. The column vector of the $\mathbf{H}$ matrix is sorted with the ordering number. This means that the channel matrix is sorted with the ordering number which affects more to the transmitting symbols. As a result of this step, $\mathbf{H}_{sort}$ matrix is obtained. At the third step, the $\mathbf{H}_{sort}$ matrix which is calculated from the second step can be decomposed by using the QR decomposition scheme. In this equation, the $\mathbf{Q}$ matrix is an orthogonal matrix. And the $\mathbf{R}$ is an upper triangular matrix. At the fourth step, by multiplying the $\mathbf{Q}^H$, the components of the $\mathbf{Q}$ matrix are eliminated from the received vector $\mathbf{Y}$ and the components of the $\mathbf{R}$ matrix are remained only. The $\mathbf{Z}$ matrix can be obtained from the received vector $\mathbf{Y}$. Consequently, the $\mathbf{Z}$ matrix is denoted as follows:

$$\mathbf{Z} = \mathbf{Q}^H\mathbf{Y} = \mathbf{Q}^H\mathbf{Q}\mathbf{R}\mathbf{X} + \mathbf{Q}^H\mathbf{W} = \mathbf{R}\mathbf{X} + \mathbf{N}. \tag{2}$$

From the fifth step, the M algorithm is implemented. A symbol vector for L-QAM system can be generated by all available candidates. And next, the candidates are selected according to the M value. The candidate vector for the M-candidates is expressed as $\hat{\mathbf{X}}_1 = \left[\hat{X}_1^1, \hat{X}_1^2, \cdots, \hat{X}_1^M\right]$. This is based on the Euclidean distance between $\mathbf{c}$ and $\mathbf{z}$. The Euclidean distances are sorted and the M candidates based on the sorting index are selected. This process is continued to the N_t-th layer. At the end of the step, a path which has the smallest Euclidean distance is selected among the candidate vector components. Consequently, the maximum likelihood path among the candidates is selected.

4 Proposed Detection Scheme

In this section, the QR decomposition with the switching M algorithm (QRD-S) detection scheme is proposed. The switching M value can be expressed as the S value. The QRD-S detection scheme follows the steps which are same with the QRD-M until the fourth step.

From the fifth step, the proposed switching M algorithm is implemented. The switching M value can be expressed as the S value. At the sixth step, the number of the candidates for the first layer is defined as L to eliminate the error

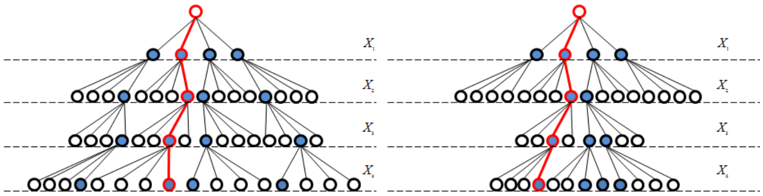

Fig. 1. Tree diagram example of the fixed QRD-M(M=4) and the QRD-S for QPSK modulation with 4 by 4 antenna system.

propagation. And from the next layer, the number of the candidates is selected on the basis of the channel state. The selected S value in each layer is expressed in Fig. 1. At the first process of the figure, the CSI can be expressed as the norm value of the **G** matrix. At the next stage, each norm value is normalized from 0 to 1. So the range of the normalized norm value is defined from 0 to 1 also. By using this normalized value, the S value is generated. The equation for the S value is denoted as follows:

$$S = \text{floor}\left(G_{norm} \times L\right). \tag{3}$$

As the result of this equation, the S value ranges from 1 to L. At the final step, the only one path which has the smallest Euclidean distance is selected.

5 Simulation Results

In this section, the BER performance and the comparison of the computational complexity are expressed. For the simulation, the 16-QAM modulation systems with the 4×4, 8×8 and 16×16 MIMO antenna are considered. The complexity of the proposed scheme is reduced by 28% of the conventional QRD-M. To compare the complexity, the number of the multiplication is counted. The BER performances of the conventional QRD-M and the QRD-S detection scheme are expressed in Fig. 2. The graph shows that the QRD-S scheme has almost same performance of the QRD-M scheme whose M value is 16.

6 Conclusion

In this paper, the QRD-S detection scheme is proposed to reduce the complexity. The proposed QRD-S and the conventional fixed QRD-M (M=16) detection scheme have almost same performance. Moreover, the complexity can be reduced almost by half in the case that the conventional fixed QRD-M (M=16) is changed to the QRD-S detection scheme for 16×16 MIMO system. The same performance and the almost half complexity of the fixed QRD-M (M=16) can be obtained if the QRD-S detection scheme is used. Therefore, the QRD-S detection scheme can be very efficient detection scheme for the MIMO-OFDM system.

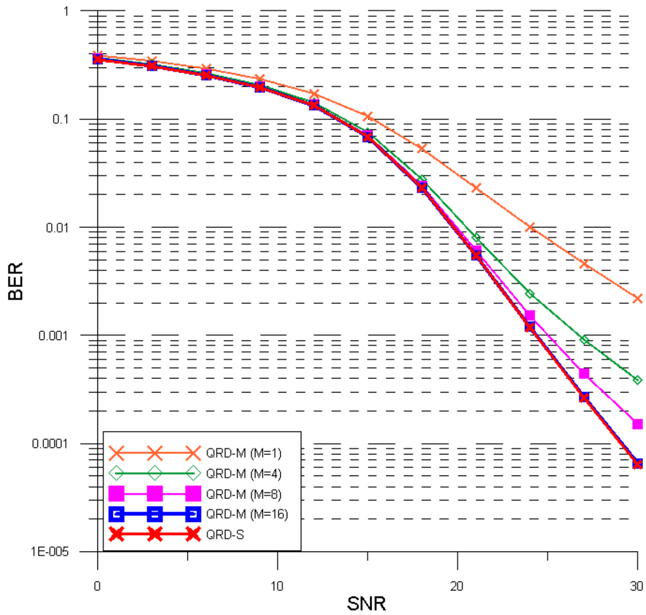

Fig. 2. The BER of the conventional QRD-M (M=1, 4, 8, 16) and the QRD-S detection scheme with 8 by 8 MIMO-OFDM with 16-QAM system.

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