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Efficient Signal Detection Using QRD-M Based On Channel Condition in MIMO-OFDM System

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***Abstract*—**In this paper, we propose an efficient signal detector that switches M parameter of QRD-M detection scheme is proposed for MIMO-OFDM system. The proposed detection scheme calculates the threshold by 1-norm condition number and then switches M parameter of QRD-M detection scheme according to channel information. If channel condition is bad, the parameter M is set to high value to increase the accuracy of detection. If channel condition is good, the parameter M is set to low value to reduce complexity of detection. Therefore, the proposed detection scheme has better tradeoff between BER performance and complexity than the conventional detection scheme. The simulation result shows that the complexity of proposed detection scheme is lower than QRD-M detection scheme with similar BER performance.

***Keywords*—**MIMO-OFDM, QRD-M, Channel condition.

I. Introduction

MULTIPLE input multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) system is considered for future wireless communication because it has high capacity and high data rate [1]. Therefore, the MIMO-OFDM signal detection scheme is key point and a lot of signal detection schemes have been proposed [2]-[5].

In the MIMO-OFDM detection schemes, maximum likelihood (ML) detection scheme provides the minimum bit error rate (BER) [3]. However, the complexity of ML detection scheme is exponentially increased by the number of transmit antennas and modulation order. Hence, MIMO signal detection scheme with a low complexity and high BER performance have been proposed.

Among the various MIMO signal detection schemes, a QRD-M detection scheme achieves near-MLD performance, while it demands considerably low complexity in comparison with MLD scheme [2]. The QRD-M detection scheme has tree structure similar to MLD scheme. In the QRD-M detection scheme, the parameter M limits the number of survived branches in tree structure. But the complexity of QRD-M detection scheme is still highly increased by the number of transmit antennas, modulation order and M parameter of QRD-M detection scheme. If the parameter M is set high value, the complexity of the QRD-M detection scheme is highly increased. On the other hand, the parameter M is set low value, the complexity of the QRD-M detection scheme is decreased.

In this paper, a switching technique for the parameter M of QRD-M for low complexity based on channel state is proposed. A threshold of the proposed detection scheme calculates the channel condition. The parameter M is selected by the threshold. The simulation results show that the complexity of the proposed detection scheme is lower than the conventional QRD-M detection scheme. Moreover, the proposed detection scheme has similar BER performance with the conventional QRD-M detection scheme.

The structure of this paper is as follows. Section II provides the MIMO-OFDM system model. A description of the related works is described in Section III. The proposed detection scheme is explained in Section IV, while the simulation results are showed in Section V. Final conclusion is summarized in Section VI.

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II. System Model

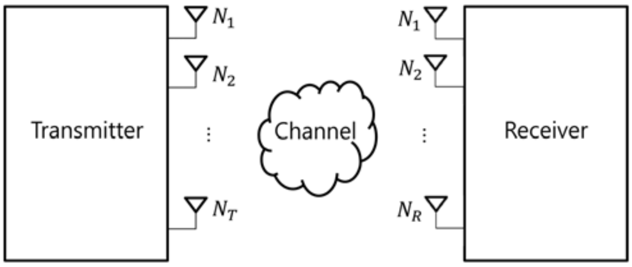

Fig. 1 MIMO-OFDM system model

Fig. 1 shows the MIMO-OFDM system considered in this paper. N_T is the number of transmit antennas and N_R is the number of receive antenna, denoted by $N_T \times N_R$. If $k$is the number of subcarriers, the received signal at the k-th subcarrier is given as

$$\mathbf{Y} = \sum_{i=1}^{N_T}\sum_{j=1}^{N_R} H_{i,j}{}^{k} X_j{}^{k} + N_i{}^{k} = \mathbf{HX} + \mathbf{N} \tag{1}$$

where j is transmit antenna index, i is receive antenna index, $\mathbf{N}$ is the $N_R \times 1$ complex Gaussian white noise and $\mathbf{H}$ is $N_R \times \mathrm{N}_T$ Rayleigh fading channel. Each element of $H_{i,j}{}^{k}$ is an independent and identically distributed (i.i.d).

III. Conventional Detection Scheme

The QRD-M detection scheme combines $\mathbf{M}$ algorithm with QR-decomposition. The channel matrix $\mathbf{H}$ is divided by $\mathbf{Q}$ matrix and $\mathbf{R}$ matrix like $\mathbf{H} = \mathbf{QR}$. The $\mathbf{R}$ matrix is an upper triangular matrix and the $\mathbf{Q}$ matrix is satisfied $\mathbf{Q^H Q} = \mathbf{I}$orthonormal matrix. Multiplying the received signal by $\mathbf{Q^H}$,the $\mathbf{W}$is represented as

$$W = Q^H Y = Q^H HX + N = RX + N' \quad (2)$$

(2) is expressed by matrix as (3),

$$\begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_N \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1N} \\ 0 & r_{22} & \cdots & r_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & r_{NN} \end{bmatrix} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix} + \begin{bmatrix} n_1' \\ n_2' \\ \vdots \\ n_N' \end{bmatrix}. \quad (3)$$

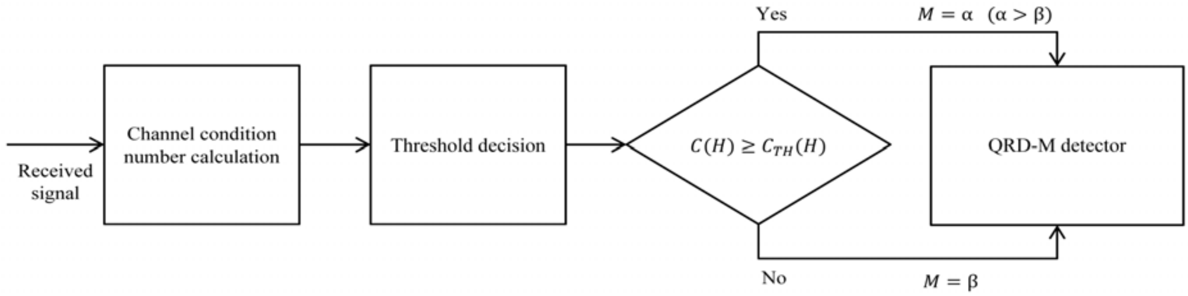

Fig. 2 The proposed detection scheme

At the first detection step, the all symbols of T-QAM modulation, $\mathbf{c} = [c(1), c(2), \cdots, c(T)]$, are considered.Using$\mathbf{c}$, the metric values of the first layer is calculated as follows,

$$d_1^t = \|w_N - r_{NN} \cdot c(t)\|^2. \quad (4)$$

$d_1^t$is the squared Euclidian distance vector and is memorized. (4) is calculated as many as modulation order of the received signal. $\mathbf{d}_1 = [\mathbf{d}_1^1, \mathbf{d}_1^2, \cdots, \mathbf{d}_1^T]$ is all metric values of the final of the first layer. Then, minimum squared Euclidian distance vector at $\mathbf{d}_1$ is selected up to M symbols. The selected symbols are represented as follows,

$$\hat{\mathbf{X}}_{1,c} = [x_1^1, x_1^2, \cdots, x_1^M]. \quad (5)$$

Equation (5) is used at the second detection step. In the *k*-th step, the stored path metrics are updated for all $M \cdot T$ combinations of *M* survival candidate symbols. The metric of path for *n*-th survival candidate symbols is$[\hat{x}_1^n,\ \hat{x}_2^n, \cdots, \hat{x}_{n-1}^n]$ and *l*-th candidate symbol is calculated as follows,

$$d_k^{n,l} = \left\| w_k - \left[r_{nn} \cdot c(l) + \left(\sum_{i=1}^{k-1} r_{ki} \cdot \hat{x}_i^n \right) \right] \right\|^2 + D_{k-1}^n \quad (6)$$

where D_{k-1}^n is the path metric of *n*-th survival candidate symbols of $(k-1)$-th step. The minimum path metric of the survival candidate symbols is selected up to *M* candidate symbols, along with their stored path metrics. The same process runs to the last step. At the last step, the minimum stored path metric is selected. The selected path metric is estimated symbol.

IV. Proposed Detection Scheme

The proposed detection scheme is the switching technique for parameter *M* based on channel condition as Fig. 2. The channel condition number means effect of channel. If channel condition is bad, the channel condition number has high value.

$$C_k(\mathrm{H}) = \sum_{i=1}^{N_T} h_i \cdot \sum_{i=1}^{N_T} h_i^{-1} \quad (7)$$

Equation (7) is calculation formula of the channel condition number. $h_i$is the *i*-th column vector of channel matrix **H**.

The threshold $C_{TH}(H)$ is decided average of the channel condition number of all channel matrixes. The threshold $C_{TH}(H)$ is calculated as follows,

$$C_{TH}(H) = \frac{1}{n} \sum_{i=1}^{n} C_i(H). \quad (8)$$

The threshold uses decision parameter *M* of the QRD-M detection scheme. If the channel condition is bad, the channel condition number is higher than the threshold. Then, the parameter *M* is set $\alpha(\alpha > \beta)$. When the channel condition number is lower than threshold, the channel condition is good and the parameter *M* is set β. This parameter is set in consideration of complexity of the system. If the parameter *M* is set to high value, the QRD-M detection scheme has high BER performance with high complexity. If the parameter *M* is set to low value, the QRD-M detection scheme has low BER performance with low complexity. After setting the parameter, the QRD-M detection scheme is run.

V. Simulation Results

In this section, BER performance of the proposed and conventional detection scheme is shown. Moreover, the complexity of each detection scheme is shown. In this simulation, system model is considered of MIMO-OFDM system which the number of subcarrier is 128. The channel assumes quasi-static Rayleigh fading channel model and the channel path length is 7.

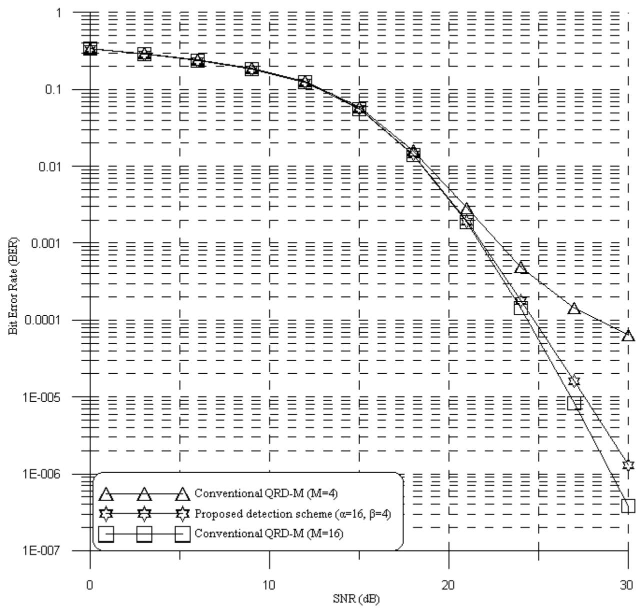

Fig. 3 BER performance of the proposed and the conventional detection scheme with $N_T = N_R = 4$ and 16-QAM modulation

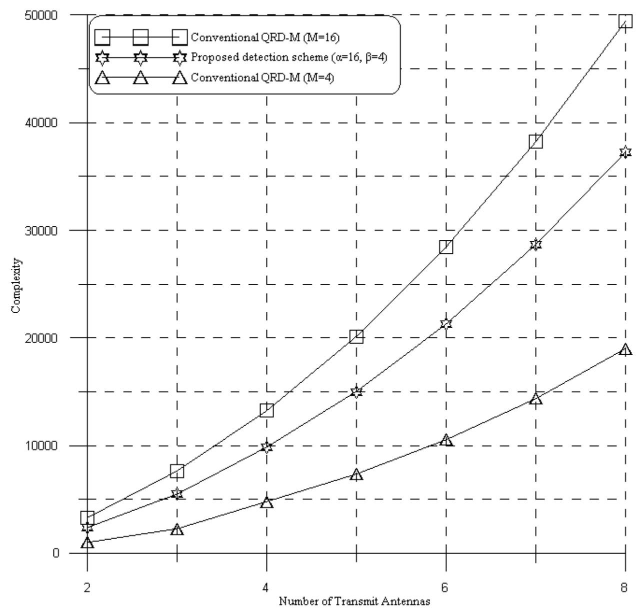

Fig. 4 The complexity of the proposed and the conventional detection scheme

Fig. 3 shows the BER performance of the proposed and conventional detection. The parameters α and β of proposed detection scheme are set by 16 and 4. The proposed detection scheme has better BER performance than the conventional QRD-M detection scheme with $M = 4$. The proposed detection scheme has almost similar performance with the conventional QRD-M detection scheme with $M = 16$. But complexity of the proposed detection scheme is less than the conventional QRD-M detection scheme.

Fig. 4 shows the complexity of proposed and conventional detection scheme. The complexity is calculated by the number of multiplication of the detection scheme. The proposed detection scheme has high complexity than the conventional QRD-M ($M = 4$) detection scheme but has low complexity than the conventional QRD-M detection scheme ($M = 16$). The proposed detection scheme is less about 37.3% than the conventional QRD-M ($M = 16$) detection scheme in $N_T = 4$.

VI. Conclusion

In this paper, the proposed detection scheme sets the parameter M in accordance with channel condition. If channel condition is good, the parameter M of the QRD-M detection scheme sets low value because it has low complexity. If channel condition is bad, the parameter M of the QRD-M detection scheme sets high value because it has high BER performance.

As a result, the proposed detection scheme has similar with BER performance of the conventional QRD-M ($M = 16$) detection scheme. Nevertheless, the proposed detection scheme has lower complexity than the conventional detection scheme. Therefore, the proposed detection scheme has lower complexity than the conventional detection scheme with similar BER performance.

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