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Efficient Iterative Detection Technique in Wireless Communication System

Hwan-Jun Choi, Sung-Bok Choi, Hyoung-Kyu Song

***Abstract*—**Recently, among the MIMO-OFDM detection techniques, a lot of papers suggested V-BLAST scheme which can achieve high data rate. Therefore, the signal detection of MIMO-OFDM system is important issue. In this paper, efficient iterative V-BLAST detection technique is proposed in wireless communication system. The proposed scheme adjusts the number of candidate symbol and iterative scheme based on channel state. According to the simulation result, the proposed scheme has better BER performance than conventional schemes and similar BER performance of the QRD-M with iterative scheme. Moreover complexity of proposed scheme has 50.6% less than complexity of QRD-M detection with iterative scheme. Therefore the proposed detection scheme can be efficiently used in wireless communication..

***Keywords*—**MIMO-OFDM, V-BLAST, QR-decomposition, QRD-M, DFE, Iterative scheme, Channel condition.

I. INTRODUCTION

RECENTLY,wireless digital communication system has received extensive attention because of increasing demand for high data communication. Therefore various wireless digital communication techniques have been proposed and used for current life and many services using wireless communication are becoming common. To satisfy these demands for wireless multimedia services, high-speed wireless communication and higher network capacity are required.

The MIMO-OFDM system which is a combination of advantages of MIMO and OFDM is currently being considered as a strong candidate for the physical layer transmission scheme of next generation wireless communication systems [1]. The Vertical Bell Laboratories layered space-time (V-BLAST) which is an important branch of BLAST has been very attractive in recent years for its simple implementation structure and high frequency efficiency [2]. The V-BLAST causes performance degradation when the data rate is high. Therefore many detection techniques for V-BLAST have been suggested to develop the traditional transmit technique [3]-[6].

During the detection procedure, later detected symbol is detected through decision feedbacks from prior detected symbols. If no error exists in the prior detected symbol, the diversity degree of the next detected symbol is supposed to increase by on after each cancellation. Therefore addition of receive antennas attains more spatial diversity and improves diversity degree. However if error exists in the prior detected symbol, the decision feedbacks result in a great negative effect on the detection of the later detected symbols. In order to overcome these problems, iterative detection algorithm can be used in detection process. Iterative algorithms are those that repeatedly refine a current solution to a computational problem until an optimal or suitable solution is yielded. Iterative algorithms have a long history and are widely used. However complexity of iterative detection algorithm is increased by iteration time and the number of transmit antennas.

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In this paper, efficient iterative V-BLAST detection technique is proposed in wireless communication system. The proposed scheme has better BER performance than conventional schemes and similar BER performance of the QRD-M with iterative scheme. Moreover complexity of proposed scheme is less than complexity of QRD-M detection with iterative scheme.

II. MIMO-OFDM SYSTEM MODEL

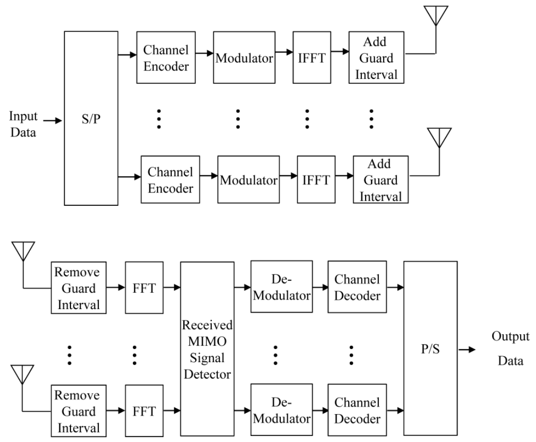

Fig. 1 Block diagram of MIMO-OFDM system

We consider MIMO-OFDM system with T_x transmit, R_x receive antennas and K subcarriers. The V-BLAST encoder takes a single stream of binary input data and transforms it into T_x parallel streams of baseband constellation symbols. Each stream is broken into OFDM sequences with the j -th stream denoted by $X_j^{k^*}$, $k = 0,...,K-1$. Each OFDM sequence of constellation symbol is transformed using an inverse fast Fourier transform (IFFT) and simultaneously transmitted by the antenna for its corresponding stream. The average energy of the signals transmitted from each antenna is normalized to one. The received signals at each antenna are similarly broken into sequences and processed using a fast Fourier transform (FFT). After FFT processing, the received signal of the k -th subcarrier at receiving antenna j can be expressed as follows

$$\mathbf{Y}^{k^*} = \sum_{i=1}^{R_x}\sum_{j=1}^{T_x} H_{i,j}^{k^*} X_j^{k^*} + N_i^{k^*} = \mathbf{H}^{k^*}\mathbf{X}^{k^*} + \mathbf{N}^{k^*} \tag{1}$$

where $\mathbf{Y}^{k^*}$ denotes received symbol, $\mathbf{N}^{k^*}$ denotes $N \times 1$ zero mean additive white Gaussian noise and $\mathbf{H}^{k^*}$ is independent and identically distributed(i.i.d.) random complex matrix of multipath channel. Fig. 1 shows MIMO-OFDM system.

III. Conventional Detection Scheme

A. DFE Detection Scheme

In order to reduce the computational complexity of the OSIC(Ordered Successive Interference Cancellation) detection, the DFE(Decision Feedback Equalization) detection is proposed. The DFE detection is based on QR-decomposition. Therefore channel matrix $\mathbf{H}^{k^*}$ can be expressed as $\mathbf{H}^{k^*} = \mathbf{Q}^{k^*}\mathbf{R}^{k^*}$, where $\mathbf{R}^{k^*}$ is an upper triangular matrix and $\mathbf{Q}^{k^*}$ is an orthonomal matrix. Therefore the received signal can be expressed as

$$\mathbf{Z}^{k^*} = (\mathbf{Q}^{k^*})^H \mathbf{Y}^{k^*} = \mathbf{R}^{k^*}\mathbf{X}^{k^*} + \widetilde{\mathbf{N}}^{k^*} \tag{2}$$

$$\begin{bmatrix} Z_{T_x}^{k^*} \\ Z_{T_x-1}^{k^*} \\ \vdots \\ Z_1^{k^*} \end{bmatrix} = \begin{bmatrix} r_{T_x,T_x}^{k^*} & r_{T_x,T_x-1}^{k^*} & \cdots & r_{T_x,1}^{k^*} \\ 0 & r_{T_x-1,T_x-1}^{k^*} & \cdots & r_{T_x-1,1}^{k^*} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & r_{1,1}^{k^*} \end{bmatrix} \cdot \begin{bmatrix} X_{T_x}^{k^*} \\ X_{T_x-1}^{k^*} \\ \vdots \\ X_1^{k^*} \end{bmatrix} + \begin{bmatrix} \tilde{N}_{T_x}^{k^*} \\ \tilde{N}_{T_x-1}^{k^*} \\ \vdots \\ \tilde{N}_1^{k^*} \end{bmatrix}. \tag{3}$$

The first detection order of DFE detection can be expressed as

$$\hat{X}_1^{k^*} = Q[Z_1^{k^*} / r_{1,1}^{k^*}] = Q[(r_{1,1}^{k^*} X_1^{k^*} + \tilde{N}_1^{k^*}) / r_{1,1}^{k^*}]. \tag{4}$$

After the first detection process, the remaining signal can be detected as follows

$$\hat{X}_m^{k^*} = Q[Z_m^{k^*} - \sum_{i=1}^{m-1} r_{m,i}^{k^*} \cdot \hat{X}_i^{k^*} / r_{m,m}^{k^*}]. \tag{5}$$

In (5), The signal is consecutively detected from $\hat{X}_1^{k^*}$ to $\hat{X}_{T_x}^{k^*}$.

B. QRD-M Detection Scheme

In order to increase the BER performance of DFE detection, the QRD-M detection is proposed. The QRD-M detection increases the candidate symbol in DFE detection and is based on QR-decomposition.

In the first step of QRD-M detection, the system considers all L symbols, $\mathbf{c} = [c(1), \cdots, c(L)]$ of L-QAM. $\mathbf{c}$ is candidates of transmit symbol. The system uses the squared Euclidean distance between $\mathbf{Z}_1^{k^*}$ and $\mathbf{c}$ in order to determine the transmit symbol and can be expressed as

$$e_1^{k^*}(l) = \left\| Z_1^{k^*} - r_{1,1}^{k^*} c(l) \right\|^2 . \tag{6}$$

$$\mathbf{e}_1^{k^*} = [e_1^{k^*}(1), \cdots, e_1^{k^*}(l), \cdots, e_1^{k^*}(L)]. \tag{7}$$

The L candidate symbols $(\mathbf{c})$ are calculated by the squared Euclidian distance vector($\mathbf{e}_1^{k^*}$), the $M_1 (M_1 \le L)$ symbols are selected from smallest to M_1 value for Euclidian distance and each symbol is the minimum branch metric. The selected symbols, $\widehat{\mathbf{X}}_1^{k^*} = [\hat{X}_1^{k^*}(1), \hat{X}_1^{k^*}(2), \cdots, \hat{X}_1^{k^*}(M_1)]$,are transferred to the next step. In the m-th stage, the branch metrics accumulated from the first to the m-1 step are updated to consider next candidate symbols.

Therefore, the path metric for h -th survived symbol candidates $[\hat{X}_1^{k^*}(h), \hat{X}_2^{k^*}(h), \cdots, \hat{X}_{m-1}^{k^*}(h)]$ and l -th candidate of symbol ($c(l)$) are calculated as follows

$$e_m^{k^*}(h,l) = \left\| Z_1^{k^*} - \left[r_{m,m}^{k^*} c(l) + \left(\sum_{i=1}^{m-1} r_{m,i}^{k^*} \hat{X}_i^{k^*}(h) \right) \right] \right\|^2 + E_{m-1}^{k^*}(h) \tag{8}$$

where $E_{m-1}^{k^*}(h)$ is the path metric of the h-th survived candidate symbols of the (m-1)-th stage. In(8) the $M_m (M_m \le L)$ symbols are selected from smallest to M_1 value for Euclidian distance. This step is repeated up to the T_x -th stage. At the T_x -th stage, the candidate symbol which has the smallest path metric is selected among M_{T_x} survived candidate symbols and the selected candidate symbol is decided to final detected symbols.

IV. Proposed Detection Scheme

In this section, the proposed detection scheme is described. The proposed scheme uses iterative detection algorithm, the number of candidate symbol and channel state. Detailed analysis is as follows.

The iterative scheme is the way to get the diversity gain and improves the BER performance. Iterative scheme uses the final detection symbol and the final detection symbol is used again to refine the remaining decision. Fig. 2 shows the algorithm of the iterative scheme.

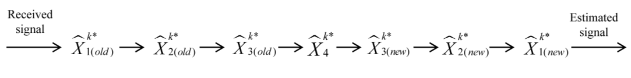

Fig. 2 Algorithm of the iterative scheme

The proposed scheme adjusts the number of candidate symbol and iterative scheme based on channel state. When channel state is good, the DFE detection which allocates only one candidate symbol is used for detection. However, when channel state is bad, the number of candidate symbol is increased and the iterative scheme is used for detection. The channel state ($C_i(H)$) is calculated by 1-norm condition number and threshold value is calculated as follows

$$C_{avg}(H) = \frac{1}{n}\sum_{i=1}^{n} C_i(H). \quad (9)$$

Fig. 3 shows the procedure of the proposed detection scheme.

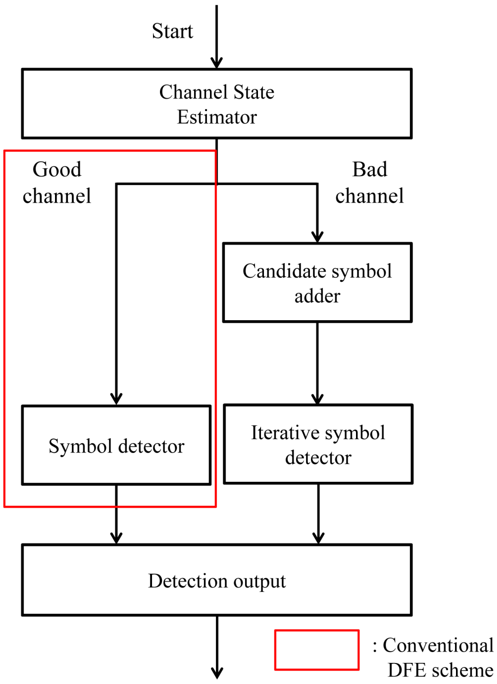

Fig. 3 The procedure of proposed detection scheme

V. Simulation Result

In this section, we demonstrate the BER performance of proposed detection scheme and compare with conventional detection schemes via simulation. Next, we demonstrate the complexity of proposed detection scheme and compare with conventional detection schemes.

The simulation considers MIMO-OFDM system and 16-QAM modulation is used. The number of subcarrier is 256 and the channel is Rayleigh fading channel and the number of channel path is 7. It is supposed that the channel is frequency flat fading during one MIMO-OFDM symbol period.

Fig. 4 shows the BER performance of the proposed detection with 8×8 MIMO-OFDM system and M is set to 2. In order to compare the BER performance of proposed scheme, ZF(Zero Forcing) detection, MMSE(Minimum Mean Square Error) detection, DFE detection, QRD-M detection and QRD-M detection with iterative scheme are shown. Simulation result shows that the proposed detection scheme has better BER performance than conventional ZF, MMSE and DFE detection. The proposed detection scheme has similar BER performance as the QRD-M(M =4) and iterative QRD-M(M =2). In high SNR environment, the proposed scheme has better performance than QRD-M(M =4) scheme.

Fig. 5 shows the BER performance of the proposed detection with 8×8 MIMO-OFDM system and M is set to 3. In order to compare the BER performance of proposed scheme, ZF(Zero Forcing) detection, MMSE(Minimum Mean Square Error) detection, DFE detection, QRD-M detection and QRD-M detection with iterative scheme are shown. Simulation result shows that the proposed detection scheme has better BER performance than conventional ZF, MMSE and DFE detection. The proposed detection scheme has similar BER performance as the QRD-M(M =6) and iterative QRD-M(M =3). In high SNR environment, the proposed scheme has better performance than QRD-M(M =6) scheme.

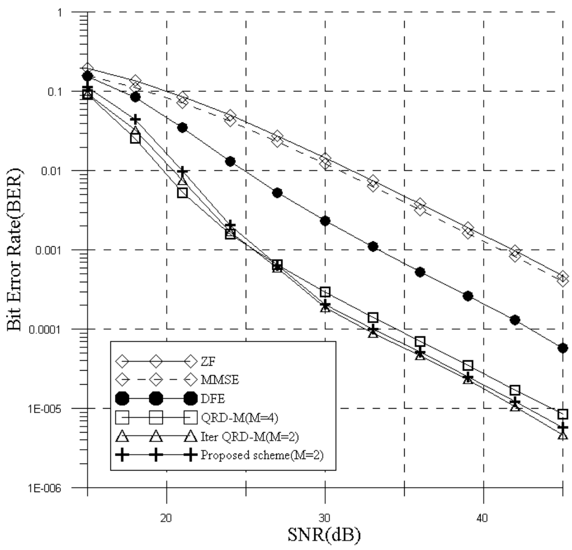

Fig. 4 BER performance of proposed detection with 8×8 MIMO-OFDM system using 16-QAM(M =2)

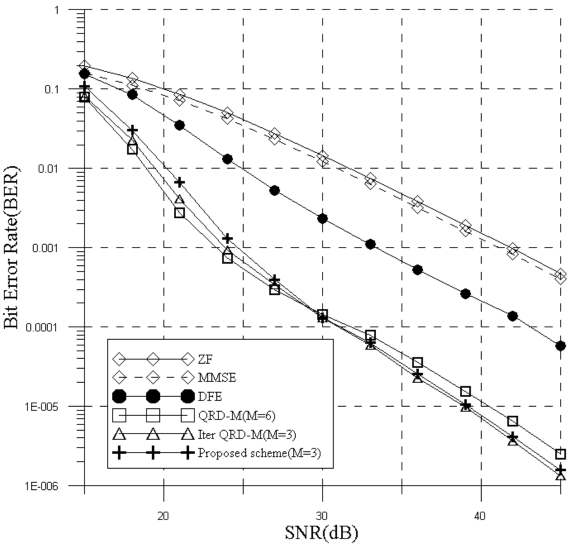

Fig. 5 BER performance of proposed detection with 8×8 MIMO-OFDM system using 16-QAM(M =2)

Because proposed detection scheme uses channel condition, complexity of proposed detection scheme is less than complexity of QRD-M with iterative scheme. In order to compare the complexity of detection scheme, the number of all candidates is used. The complexity of the proposed scheme, QRD-M and iterative QRD-M is as follows

$$T_{qr} = M\cdot T_x \quad (10)$$

$$T_{itqr} = M\cdot(2\cdot T_x - 1) \quad (11)$$

$$T_{pro} = w\cdot T_x + (1-w)\cdot(M\cdot(2\cdot T_x - 1)) \quad (12)$$

where w is weighting factor of proposed scheme. According to (10)-(12), the proposed scheme is about 50.6 % of QRD-M with iterative scheme. Therefore proposed detection scheme is more efficient than conventional detection schemes.

VI. Conclusion

In this paper, efficient iterative V-BLAST detection technique is proposed in wireless communication system. The proposed scheme adjusts the number of candidate symbol and iterative scheme based on channel state. When channel state is good, the DFE detection which allocates only one candidate symbol is used for detection. However, when channel state is bad, the number of candidate symbol is increased and the iterative scheme is used for detection. Therefore the proposed detection scheme can be efficiently used in wireless communication.

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References

[1] G. J. Foschini, "Layered space-time architecture for wireless communication in a fading environment using multi-element antennas," *Bell Labs Tech J.*, vol. 1, no.2, pp 41–59, 1996.

[2] P.W. Wolniansky, G.J. Foschini, G.D Golden and R.A. Valenzuela, "V-BLAST: An architecture for realizing very high data rates over the rich-scattering wireless channel," *in Proc. ISSSE'98*, pp 295–300, 1998.

[3] A. Benjebbour, H. Murata, and S. Yoshida, "Performance of iterative successive detection algorithm with space-time transmission," *IEEE Vehicular Technology Conference VTC 2001 Spring*, vol. 2,pp1287–1291, 2001.

[4] D. Li, L. Cai and H. Yang, "New iterative detection algorithm for V-BLAST," *in Proc. VTC'04*, vol. 4,pp2444–2448, 2004.

[5] M. -S. Baek, Y. -H. You and H. -K. Song,"Combined QRD-M and DFE detection technique for simple and efficient signal detection in MIMO-OFDM systems," *IEEE Trans. Wireless Communication*, vol. 8, no.4, pp1632–1638, 2009.

[6] J. -K. Ahn, S. -J. Yu and H. -K. Song, "Channel Condition Number Based Switching Detection Scheme in MIMO-OFDM System," *IEICE Trans. Fundamentals*, vol. E96-A, no.1, pp387–390, 2013.

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