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복잡도 감소와 전송시간이 덜 소요되는 블록 층의 준 직교 시공간코드 설계

(Complexity Reduction of Block-Layered QOSTC with Less Transmission Time)

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요 약

ML디코딩이 복잡도와 전송시간이 덜 소요되는 고차 안테나의 시공간코드를 제안한다. 이 때 제안한 것이 부분간섭제거 알고리즘이다. 제안된 알고리즘은 심벌을 층(Layered)으로 구분하고 동등한 채널행렬을 만들고 그룹으로 디코딩한다. 이렇게 했을 때 전송시간과 디코딩 복잡도가 줄어들었고 성능이 비직교에 비해 좋아졌다.

Abstract

Because of increasing complexity in maximum-likelihood (ML) decoding of four of higher antenna scenario, Partial InterferenceCancellation (PIC) group decoding could be the perfect solution to reduce the decoding complexity occurs in ML decoding. In this paper, we separate the symbols the users in the layered basis and find the equivalent channel matrix. Based on the equivalent channel matrix we provide the grouping scheme. In our paper, we construct a block wise transmission technique which will achieve the desired code rate and reduce the complexity and provide less transmission time. Finally we show the different grouping performance.

Keywords: 3GPP LTE; TBH; MIMO; Multi-user MIMO; QOSTBC;

Ⅰ. Introduction

Increasing demand of mobile usages, the users want to transmit data faster. Since wireless communication technologies have been seen a remarkable fast evolution in the pasttwo and half decades. The data rates, battery life and network connectivity has increase highly. In the age of YouTube and iPhones, the reliability of networking and data speed, and battery power will increase ever more rapidly in the coming years. As a platform for high-speed wireless connectivity and networking, we need a reliable high data transmission rate. Thus, the transmit diversity requires more than one antenna at the transmitter side. Our proposed scheme is based on 8 transmit antennas. There are so may work has be done on transmit diversity.

A space-time block coding (STBC)-oriented diversity scheme has been widely adopted in future

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wireless communication standards, such as 3GPP LTE, WiMax, etc. The STBC scheme, originally proposed by Alamouti in [1], achieves transmit diversity without channel knowledge. Even though Alamouti's STBC was originally designed for two transmit antennas and one receive antenna, this scheme has been generalized by Tarokh in [2] and extended to a system for four transmit antennas. There is also a lot of research to make STBC system work in the multi-user environment[2~4]. The Multiple-input-multiple-output(MIMO) system, multiple antennas can be used for increasing the diversity order. The first orthogonal STBC (OSTBC) which has symbol-wise decoding is Alamouti code [1]. However, OSTBC suffers from the reduced symbol rate with an increased number of transmit antennas. In order to achieve a high data rate, layered OSTBC(LOSTBC) is proposed in the literature by partitioning the transmit antennas into different groups and coding information symbols in each group with an independent OSTBC. Considering the high complexity of the maximum-likelihood (ML) decoding, group interference suppression methods are proposed in [3] to perform the detection of the information symbols encoded with a layered space-time code. In [5] develops a different group decoding method for an layered STBC (LSTBC), where it treats the symbols coming from one STBC block as a group, and decodes them with ML decoding after cancelling the interferences from the other groups. A similar interference cancellation method called partial interference cancellation (PIC) group decoding is proposed in [6] for the design of full-diversity space-time codes with low decoding complexity.

In this letter, we investigate the performances of the PIC group decoding with orthogonal and non-orthogonal grouping schemes, where the PIC is performed by using theZF operator. Taking the Alamouti structure, we prove the PIC group decoding in an interleaved Quasi orthogonal STBC with four layered dividing the four blocks. We construct a block wise transmission technique which will achieve the desired code rate and reduce the complexity and provide less transmission time.

This work is organized as follows. In Section II, the system model is described. In Section III, the PIC decoding is described. A criterion for the optimal adaptive grouping scheme is also proposed. In Section IV, simulation results are shown and the conclusion is given in the following section.

Ⅱ. System Model

We consider a wireless system with Multiple Input and Multiple Output (MIMO) model. Where we assume, four users are transmitted data to a single receiver simultaneously. We consider the users have multiple antennas and the receiver has single antenna, the channels are flat fading channels. Here we consider the Alamouti STBC to construct for high order code coordinate interleaved code.

As it describe well known Alamouti STBC in [1] is written as

$$\mathbf{M}=\begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \tag{1}$$

The Alamouti matrix in (1) is based on two transmit antenna. For four transmit antenna we use the co-ordinate interleaved criterion proposed in [7] we have

$$\mathbf{M}_A=\begin{bmatrix} \mathbf{M} & 0 \\ 0 & \mathbf{M}' \end{bmatrix}=\begin{bmatrix} \tilde{s}_1 & \tilde{s}_2 & 0 & 0 \\ -\tilde{s}_2^* & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & \tilde{s}_4 \\ 0 & 0 & -\tilde{s}_4^* & \tilde{s}_3^* \end{bmatrix} \tag{2}$$

where, $\mathbf{M}'=\begin{bmatrix} \tilde{s}_3 & \tilde{s}_4 \\ -\tilde{s}_4^* & \tilde{s}_3^* \end{bmatrix}$. Similar way we can define,

$$\mathbf{M}_B=\begin{bmatrix} \tilde{s}_5 & \tilde{s}_6 & 0 & 0 \\ -\tilde{s}_6^* & \tilde{s}_5^* & 0 & 0 \\ 0 & 0 & \tilde{s}_7 & \tilde{s}_8 \\ 0 & 0 & -\tilde{s}_8^* & \tilde{s}_7^* \end{bmatrix} \tag{3}$$

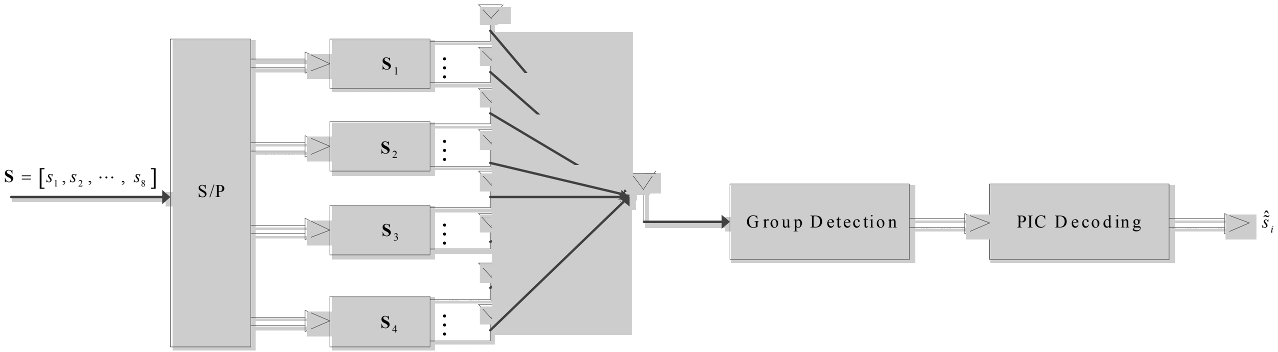

그림 1. 블록 심볼 전송 다이어그램
Fig. 1. Block-wise Symbol Transmission Diagram.

where $\tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_8$ are the information symbols ($\tilde{s}_i \in \mathrm{A}$, $i = 1,2,3,\cdots,8$, and A is a signal constellation) which is based on the interleaved orthogonal structure propose in [7~8]. From (2) and (3), we can say those are the *block-diagonal* matrices. Consider the ABBA Space-time Block Code over the complex-valued square matrices, $\mathbf{M}_A, \mathbf{M}_B \in \mathbb{C}^{K\times K}$.

$$\mathbf{S}(\mathbf{M}_A, \mathbf{M}_B) \triangleq \begin{bmatrix} \mathbf{M}_A & \mathbf{M}_B \\ \mathbf{M}_B & \mathbf{M}_A \end{bmatrix} \tag{4}$$

Then we can write $S_{8\times 8}$ matrix as follows,

$$\mathbf{S} = \begin{bmatrix} \tilde{s}_1 & \tilde{s}_2 & 0 & 0 & \tilde{s}_5 & \tilde{s}_6 & 0 & 0 \\ -s_2^* & s_1^* & 0 & 0 & -\tilde{s}_6^* & \tilde{s}_5^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & \tilde{s}_4 & 0 & 0 & \tilde{s}_7 & \tilde{s}_8 \\ 0 & 0 & -\tilde{s}_4^* & \tilde{s}_3^* & 0 & 0 & -\tilde{s}_8^* & \tilde{s}_7^* \\ \tilde{s}_5 & \tilde{s}_6 & 0 & 0 & \tilde{s}_1 & \tilde{s}_2 & 0 & 0 \\ -\tilde{s}_6^* & \tilde{s}_5^* & 0 & 0 & -s_2^* & s_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_7 & \tilde{s}_8 & 0 & 0 & \tilde{s}_3 & \tilde{s}_4 \\ 0 & 0 & -\tilde{s}_8^* & \tilde{s}_7^* & 0 & 0 & -\tilde{s}_4^* & \tilde{s}_3^* \end{bmatrix} \tag{5}$$

The information symbols $\tilde{s}_i, i = 1,2,\cdots,8$ at four transmitters are encode block-wise separately as follows,

$$\mathbf{S}_1 = \begin{bmatrix} \tilde{s}_1 & \tilde{s}_2 \\ -\tilde{s}_2^* & \tilde{s}_1^* \end{bmatrix}, \quad \mathbf{S}_2 = \begin{bmatrix} \tilde{s}_5 & \tilde{s}_6 \\ -\tilde{s}_6^* & \tilde{s}_5^* \end{bmatrix},$$

$$\mathbf{S}_3 = \begin{bmatrix} \tilde{s}_3 & \tilde{s}_4 \\ -\tilde{s}_4^* & \tilde{s}_3^* \end{bmatrix}, \text{ and } \mathbf{S}_4 = \begin{bmatrix} \tilde{s}_7 & \tilde{s}_8 \\ -\tilde{s}_8^* & \tilde{s}_7^* \end{bmatrix}$$

Now the S becomes,

$$\mathbf{S} = \begin{bmatrix} \mathbf{S}_1 & 0 & \mathbf{S}_2 & 0 \\ 0 & \mathbf{S}_3 & 0 & \mathbf{S}_4 \\ \mathbf{S}_2 & 0 & \mathbf{S}_1 & 0 \\ 0 & \mathbf{S}_4 & 0 & \mathbf{S}_3 \end{bmatrix} \tag{6}$$

Now the receive signal can be written as

$$\mathbf{Y} = \sqrt{\frac{\rho}{8}}\mathbf{S}\mathbf{H} + \mathbf{N} \tag{7}$$

$$\begin{bmatrix} \mathbf{Y}_1 \\ \mathbf{Y}_2 \\ \mathbf{Y}_3 \\ \mathbf{Y}_4 \end{bmatrix} = \sqrt{\frac{\rho}{8}} \begin{bmatrix} \mathbf{S}_1 & 0 & \mathbf{S}_2 & 0 \\ 0 & \mathbf{S}_3 & 0 & \mathbf{S}_4 \\ \mathbf{S}_2 & 0 & \mathbf{S}_1 & 0 \\ 0 & \mathbf{S}_4 & 0 & \mathbf{S}_3 \end{bmatrix} \begin{bmatrix} \mathbf{H}_1 \\ \mathbf{H}_2 \\ \mathbf{H}_3 \\ \mathbf{H}_4 \end{bmatrix} + \begin{bmatrix} \mathbf{N}_1 \\ \mathbf{N}_2 \\ \mathbf{N}_3 \\ \mathbf{N}_4 \end{bmatrix} \tag{8}$$

where, $\mathbf{Y}_1 = [y_1 \quad y_2]^T$, $\mathbf{Y}_2 = [y_3 \quad y_4]^T$, $\mathbf{Y}_3 = [y_5 \quad y_6]^T$, and $\mathbf{Y}_4 = [y_7 \quad y_8]^T$ are the receive signals in four-time slots, ρ is the average signal-to-noise-ration (SNR) at the receiver, $\mathbf{H} \in \mathbb{C}^{1\times 4}$ channel matrix assumed complex-valued Gaussian distributed with zero mean and unit variance. Where, $\mathbf{H} = [\mathbf{H}_1 \quad \mathbf{H}_2 \quad \mathbf{H}_3 \quad \mathbf{H}_4]^T$, where, we define $\mathbf{H}_1 = [h_1 \quad h_2]^T$, $\mathbf{H}_2 = [h_3 \quad h_4]^T$, $\mathbf{H}_3 = [h_5 \quad h_6]^T$, and $\mathbf{H}_4 = [h_7 \quad h_8]^T$, $(.)^T$ denotes the transpose operation. $\mathbf{N} \in \mathbb{C}^{4\times 1}$ is the complex-valued additive white Gaussian noise with zero-mean and unit variance. Now the receive signals at the 4-time slots are given by

$$\mathbf{Y}_1 = \sqrt{\frac{\rho}{8}}(\mathbf{S}_1\mathbf{H}_1 + \mathbf{S}_2\mathbf{H}_3) + \mathbf{N}_1 \tag{9}$$

$$\mathbf{Y}_3 = \sqrt{\frac{\rho}{8}}(\mathbf{S}_2\mathbf{H}_1 + \mathbf{S}_1\mathbf{H}_3) + \mathbf{N}_3 \tag{10}$$

$$\mathbf{Y}_3 = \sqrt{\frac{\rho}{8}}(\mathbf{S}_2\mathbf{H}_1 + \mathbf{S}_1\mathbf{H}_3) + \mathbf{N}_3 \tag{11}$$

$$\mathbf{Y}_4 = \sqrt{\frac{\rho}{8}}(\mathbf{S}_4\mathbf{H}_2 + \mathbf{S}_3\mathbf{H}_4) + \mathbf{N}_4 \tag{12}$$

Now from (9), we have,

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \sqrt{\frac{\rho}{8}}\begin{bmatrix} \tilde{s}_1 & \tilde{s}_2 \\ -\tilde{s}_2^* & \tilde{s}_1^* \end{bmatrix}\begin{bmatrix} h_1 \\ h_2 \end{bmatrix} + \sqrt{\frac{\rho}{8}}\begin{bmatrix} \tilde{s}_5 & \tilde{s}_6 \\ -\tilde{s}_6^* & \tilde{s}_5^* \end{bmatrix}\begin{bmatrix} h_5 \\ h_6 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2^* \end{bmatrix} = \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}\begin{bmatrix} \tilde{s}_1 \\ \tilde{s}_2 \end{bmatrix} + \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_5 & h_6 \\ h_6^* & -h_5^* \end{bmatrix}\begin{bmatrix} \tilde{s}_5 \\ \tilde{s}_6 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \end{bmatrix} \tag{13}$$

Similarly from (10), (11), and (12) we have the followingrespectively,

$$\begin{bmatrix} y_3 \\ y_4^* \end{bmatrix} = \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_3 & h_4 \\ h_4^* & -h_3^* \end{bmatrix}\begin{bmatrix} \tilde{s}_3 \\ \tilde{s}_4 \end{bmatrix} + \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_7 & h_8 \\ h_8^* & -h_7^* \end{bmatrix}\begin{bmatrix} \tilde{s}_7 \\ \tilde{s}_8 \end{bmatrix} + \begin{bmatrix} n_3 \\ n_4^* \end{bmatrix} \tag{14}$$

$$\begin{bmatrix} y_5 \\ y_6^* \end{bmatrix} = \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}\begin{bmatrix} \tilde{s}_5 \\ \tilde{s}_6 \end{bmatrix} + \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_5 & h_6 \\ h_6^* & -h_5^* \end{bmatrix}\begin{bmatrix} \tilde{s}_1 \\ \tilde{s}_2 \end{bmatrix} + \begin{bmatrix} n_5 \\ n_6^* \end{bmatrix} \tag{15}$$

and,

$$\begin{bmatrix} y_7 \\ y_8^* \end{bmatrix} = \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_3 & h_4 \\ h_3^* & -h_4^* \end{bmatrix}\begin{bmatrix} \tilde{s}_7 \\ \tilde{s}_8 \end{bmatrix} + \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_7 & h_8 \\ h_8^* & -h_7^* \end{bmatrix}\begin{bmatrix} \tilde{s}_3 \\ \tilde{s}_4 \end{bmatrix} + \begin{bmatrix} n_7 \\ n_8^* \end{bmatrix} \tag{16}$$

Now from (7), (13), (14), (15), and (16), we have,

$$\begin{bmatrix} y_1 \\ y_2^* \\ y_3 \\ y_4^* \\ y_5 \\ y_6^* \\ y_7 \\ y_8^* \end{bmatrix} = \sqrt{\frac{\rho}{8}}\begin{bmatrix} h_1 & h_2 & 0 & 0 & h_5 & h_6 & 0 & 0 \\ h_2^* & -h_1^* & 0 & 0 & h_6^* & -h_5^* & 0 & 0 \\ 0 & 0 & h_3 & h_4 & 0 & 0 & h_7 & h_8 \\ 0 & 0 & h_4^* & -h_3^* & 0 & 0 & h_8^* & -h_7^* \\ h_5 & h_6 & 0 & 0 & h_1 & h_2 & 0 & 0 \\ h_6^* & -h_5^* & 0 & 0 & h_2^* & -h_1^* & 0 & 0 \\ 0 & 0 & h_7 & h_8 & 0 & 0 & h_3 & h_4 \\ 0 & 0 & h_8^* & -h_7^* & 0 & 0 & h_4^* & -h_3^* \end{bmatrix}\begin{bmatrix} \tilde{s}_1 \\ \tilde{s}_2 \\ \tilde{s}_3 \\ \tilde{s}_4 \\ \tilde{s}_5 \\ \tilde{s}_6 \\ \tilde{s}_7 \\ \tilde{s}_8 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \\ n_3 \\ n_4^* \\ n_5 \\ n_6^* \\ n_7 \\ n_8^* \end{bmatrix} \tag{17}$$

The model in (17) is easy to be rewritten as an equivalent form as in [6],

$$\mathbf{y} = \sqrt{\frac{\rho}{8}}\mathbf{G}\mathbf{s} + \mathbf{n} \tag{18}$$

where, $\mathbf{y} \in \mathbb{C}^{8\times1}$ is the receive signal vectors, $\mathbf{s} = [\tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_8]^T$, $\mathbf{n} \in \mathbb{C}^{8\times1}$ is the noise vector, $\mathbf{G} \in \mathbb{C}^{8\times8}$ is the equivalent channel matrix, where,

$$\mathbf{G} = [c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8],$$

where

$$c_1 = \left[h_1, h_2^*, 0, 0, h_5, h_6^*, 0, 0\right]^T,$$

$$c_2 = \left[h_2, -h_1^*, 0, 0, h_6, -h_5^*, 0, 0\right]^T,$$

$$c_3 = \left[0, 0, h_3, h_4^*, 0, 0, h_7, h_8^*\right]^T,$$

$$c_4 = \left[0, 0, h_4, -h_3^*, 0, 0, h_8, -h_7^*\right]^T,$$

$$c_5 = \left[h_5, h_6^*, 0, 0, h_1, h_2^*, 0, 0\right]^T,$$

$$c_5 = \left[h_6, -h_5^*, 0, 0, h_2, -h_1^*, 0, 0\right]^T,$$

$$c_7 = \left[0, 0, h_7, h_8^*, 0, 0, h_3, h_4^*\right]^T,$$

and

$$c_4 = \left[0, 0, h_8, -h_7^*, 0, 0, h_4, -h_3^*\right]^T.$$

We can easily check that the column vectors of the equivalent channel matrix meet the following conditions,

$$\begin{aligned} c_1^H c_1 &= c_2^H c_2 = c_5^H c_5 = c_6^H c_6 \\ c_3^H c_3 &= c_4^H c_4 = c_7^H c_7 = c_8^H c_8 \end{aligned} \tag{19}$$

where, we can see,

$$\begin{aligned} c_1^H c_1 &= \left(\left[h_1, h_2^*, 0, 0, h_5, h_6^*, 0, 0\right]^T\right)^H \left[h_1, h_2^*, 0, 0, h_5, h_6^*, 0, 0\right]^T \\ &= h_1^* h_1 + h_2^* h_2 + h_5^* h_5 + h_6^* h_6 \\ &= \| h_1 \|^2 + \| h_2 \|^2 + \| h_5 \|^2 + \| h_6 \|^2 \end{aligned} \tag{20}$$

and

$$\begin{aligned} c_3^H c_3 &= \left(\left[0, 0, h_4, -h_3^*, 0, 0, h_8, -h_7^*\right]^T\right)^H \left[0, 0, h_4, -h_3^*, 0, 0, h_8, -h_7^*\right]^T \\ &= h_4^* h_4 + h_3^* h_3 + h_8^* h_8 + h_7^* h_7 \\ &= \| h_3 \|^2 + \| h_4 \|^2 + \| h_7 \|^2 + \| h_8 \|^2 \end{aligned} \tag{21}$$

Ⅲ. PIC Group Decoding Scheme

A. PIC group decoding

The ML Decoding of eight symbols with four blocks making the decoding more complex. PIC group decoding reduces the decoding complexity. As a result, the performance also degrades. In this section we present some preliminaries of the Partial Interference Cancellation (PIC) group decoding. From the equivalent channel matrix represent in (18) we can represent the vectors as a general form as

$$G_{I_k} = \begin{bmatrix} c_{I_{k,1}} & c_{I_{k,2}} & \cdots & c_{I_{k,n-kk}} \end{bmatrix} \tag{22}$$

Now we can write from (18) as,

$$\mathbf{y} = \sqrt{\frac{\rho}{8}} \sum_{i=1}^{N-1} \mathbf{G}_{I_k} \mathbf{s}_{I_k} + \mathbf{n}. \tag{23}$$

The projection matrix we define as $\mathbf{Q}_{I_k}$ can be represent as

$$\mathbf{Q}_{I_k} = \mathbf{C}_j \left(\left(\mathbf{C}_j \right)^H \mathbf{C}_j \right)^{-1} \left(\mathbf{C}_j \right)^H \tag{24}$$

where, the column vectors in the equivalent channel matrix G into four groups as we called C_1, C_2, C_3, and C_4. Denotethe projection matrices for the corresponding groups; we have the projection matrix as[6],

$$\mathbf{P}_i = \mathbf{I}_8 - \mathbf{C}_j \left(\left(\mathbf{C}_j \right)^H \mathbf{C}_j \right)^{-1} \left(\mathbf{C}_j \right)^H \tag{25}$$

In this section, considering that grouping of the symbols is needed before the PIC decoding, we first show that different grouping schemes may have different performances.

B. PIC groupign based on orthogonal column vectors

Based on the equivalent channel matrix in (17), by taking the column vectors which are orthogonal to each other, we have the possible orthogonal grouping schemes are,

Scheme 1:

$C_1 = [c_1, c_3],\ C_2 = [c_2, c_4],\ C_3 = [c_5, c_7],\ C_4 = [c_6, c_8],$

Scheme 2:

$C_1 = [c_1, c_4],\ C_2 = [c_2, c_3],\ C_3 = [c_5, c_8],\ C_4 = [c_6, c_7],$

Scheme 3:

$C_1 = [c_1, c_7],\ C_2 = [c_2, c_8],\ C_3 = [c_3, c_5],\ C_4 = [c_4, c_8],$

Scheme 4:

$C_1 = [c_1, c_8],\ C_2 = [c_2, c_7],\ C_3 = [c_4, c_5],\ C_4 = [c_3, c_6],$

Now normalizing the signal power from the (24) we have,

$$\begin{aligned} Q_{I_1} &= \frac{1}{8}\left[h_1, h_2^*, 0, 0, h_5, h_6^*, 0, 0\right]^T \times \\ &\quad \left(\frac{1}{8}\left(\| h_1 \|^2 + \| h_2 \|^2 + \| h_5 \|^2 + \| h_6 \|^2\right)\right)^{-1} \times \\ &\quad \left(\left[h_1, h_2^*, 0, 0, h_5, h_6^*, 0, 0\right]^T\right)^H \\ &= \frac{1}{c_1^H c_1}\left[h_1, h_2^*, 0, 0, h_5, h_6^*, 0, 0\right]^T \times \\ &\quad \left(\left[h_1, h_2^*, 0, 0, h_5, h_6^*, 0, 0\right]^T\right)^H \end{aligned} \tag{26}$$

Therefore, the orthogonal projection can be found by combining (25) and (26) as follows

$$\begin{aligned} P_1 c_1 &= \frac{1}{c_1^H c_1}\begin{bmatrix} |h_1|^2 & h_1 h_2 & 0 & 0 & h_1 h_5^* & h_1 h_6 & 0 & 0 \\ h_1^* h_2^* & |h_2|^2 & 0 & 0 & h_2^* h_5^* & h_2^* h_6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ h_1^* h_5 & h_5 h_2 & 0 & 0 & |h_5|^2 & h_5 h_6 & 0 & 0 \\ h_6^* h_1^* & h_6^* h_2 & 0 & 0 & h_6^* h_5^* & |h_6|^2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} h_1 \\ h_2^* \\ 0 \\ 0 \\ h_5 \\ h_6^* \\ 0 \\ 0 \end{bmatrix} \\ &= \frac{1}{2\sqrt{2}} \cdot \frac{1}{c_1^H c_1}\begin{bmatrix} h_1\left(|h_1|^2{}_1 + |h_2|^2 + |h_5|^2 + |h_6|^2\right) \\ h_2^*\left(|h_1|^2{}_1 + |h_2|^2 + |h_5|^2 + |h_6|^2\right) \\ 0 \\ 0 \\ h_5\left(|h_1|^2{}_1 + |h_2|^2 + |h_5|^2 + |h_6|^2\right) \\ h_6^*\left(|h_1|^2{}_1 + |h_2|^2 + |h_5|^2 + |h_6|^2\right) \\ 0 \\ 0 \end{bmatrix} \\ &= \frac{1}{2\sqrt{2}c_1^H c_1}\left[h_1(c_1^H c_1), h_2^*(c_1^H c_1), 0, 0, h_5(c_1^H c_1), h_6^*(c_1^H c_1), 0, 0\right]^T \\ &= \frac{1}{2\sqrt{2}} \times c_1 \end{aligned} \tag{27}$$

Similarly we have,

$$Q_{I_2} = \frac{1}{8}\left[0,0,h_3,h_4^*,0,0,h_7,h_8^*\right]^T \times \left(\frac{1}{8}\left(\| h_3 \|^2 + \| h_4 \|^2 + \| h_7 \|^2 + \| h_8 \|^2\right)\right)^{-1} \times \left(\left[0,0,h_3,h_4^*,0,0,h_7,h_8^*\right]^T\right)^H$$

$$= \frac{1}{c_3^H c_3}\left[0,0,h_3,h_4^*,0,0,h_7,h_8^*\right]^T \times \left(\left[0,0,h_3,h_4^*,0,0,h_7,h_8^*\right]^T\right)^H$$

$$P_{I_2} = \frac{1}{\sqrt{8}}\frac{1}{c_3^H c_3}\begin{bmatrix} 0 \\ 0 \\ h_3\left(|h_3|^2+|h_4|^2+|h_7|^2+|h_8|^2\right) \\ h_4^*\left(|h_3|^2+|h_4|^2+|h_7|^2+|h_8|^2\right) \\ 0 \\ 0 \\ h_7\left(|h_3|^2+|h_4|^2+|h_7|^2+|h_8|^2\right) \\ h_6^*\left(|h_3|^2+|h_4|^2+|h_7|^2+|h_8|^2\right) \end{bmatrix}$$

Since the column we take here are orthogonal to each other, we can verify that the $\boldsymbol{P}_{I_1}\boldsymbol{G}_{I_0} = 0$, for the grouping scheme $C_1 = \{1,3\}$, $C_2 = \{2,4\}$, $C_4 = \{5,7\}$ $C_4 = \{6,8\}$ the optimal decision can be written as,

$$\hat{s}_1 = \arg\min_{\tilde{s}_1 \in A} \| \boldsymbol{P}_{I_1}\boldsymbol{y} - \sqrt{SNR}P_{I_1}G_{I_1}\tilde{s}_1 \| \tag{28}$$

Which,

$$\hat{s}_1 = \arg\min_{\tilde{s}_1 \in A}\left\|\left(h_1^* y_1 + h_2 y_2 + h_5^* y_5 + h_6 y_6\right) - \sqrt{\frac{SNR}{8}}c_1^H c_1 \tilde{s}_1\right\|$$

Similarly we could find the other symbols as well.

C. PIC grouping based on non-orthogonal column vectors

For the non-orthogonal PIC grouping, we choose the columns which are not orthogonal to each other. We choose the grouping scheme as $C_1 = [c_1, c_2]$, $C_2 = [c_3, c_4]$, $C_3 = [c_5, c_6]$, $C_4 = [c_7, c_8]$. There could have the others combination of non-orthogonal grouping of the by doing those we can calculate the followings as follows,

$$P_{I_1} = I_8 - \frac{1}{c_4^H c_4}(c_3 c_3^H + c_4 c_4^H), \tag{29}$$

$$P_{I_2} = I_8 - \frac{1}{c_6^H c_6}(c_5 c_5^H + c_6 c_6^H), \tag{30}$$

$$P_{I_3} = I_8 - \frac{1}{c_8^H c_8}(c_7 c_7^H + c_8 c_8^H), \tag{31}$$

$$P_{I_4} = I_8 - \frac{1}{c_2^H c_2}(c_1 c_1^H + c_2 c_2^H), \tag{32}$$

Therefore the power gain for the eight symbol can be calculate after PIC group decoding applying in receiver are

$$\mathbf{W}_i = \| P_{I_1} g_i \|^2 = g_i^H g_i - \frac{1}{c_4^H c_4}(g_i^H c_3 c_3^H g_i + g_i^H c_4 c_4^H g_i), \tag{33}$$

$$\mathbf{W}_j = \| P_{I_2} g_j \|^2 = g_j^H g_j - \frac{1}{c_6^H c_6}(g_j^H c_5 c_5^H g_j + g_j^H c_6 c_6^H g_j), \tag{34}$$

$$\mathbf{W}_k = \| P_{I_3} g_k \|^2 = g_k^H g_k - \frac{1}{c_8^H c_8}(g_k^H c_7 c_7^H g_k + g_k^H c_8 c_8^H g_k), \tag{35}$$

and,

$$\mathbf{W}_l = \| P_{I_4} g_l \|^2 = g_l^H g_l - \frac{1}{c_8^H c_8}(g_l^H c_7 c_7^H g_l + g_l^H c_8 c_8^H g_l), \tag{36}$$

After the PIC, the two pairs of vectors in the equivalent channel matrix are still orthogonal.

Ⅳ. Simulation Analysis

In this section, we present some simulation results to show the performances of the PIC group decoding with orthogonal and non-orthogonal grouping schemes. Figure 2 shows the SER performance of 8 antenna layered PIC group decoding scheme.

Where we can see the ML is still achieve better SER then that of PIC decoding. In our system we reduce the transmission time. The channel model follows what is described above and it is quasi-static

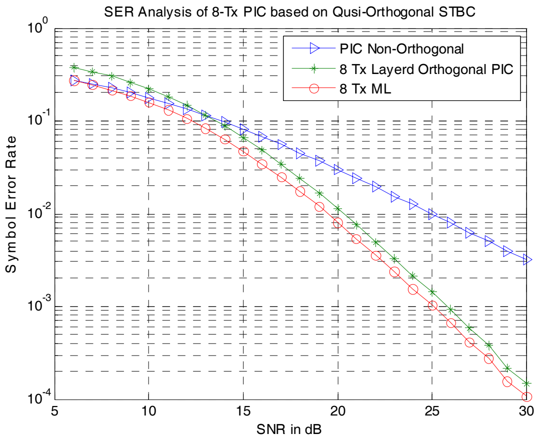

그림 2. 비직교와 직교 부분간섭 그루핑에 대한 심볼오류

Fig. 2. SER analysis of Non-orthogonal vs Orthogonal PIC grouping scheme.

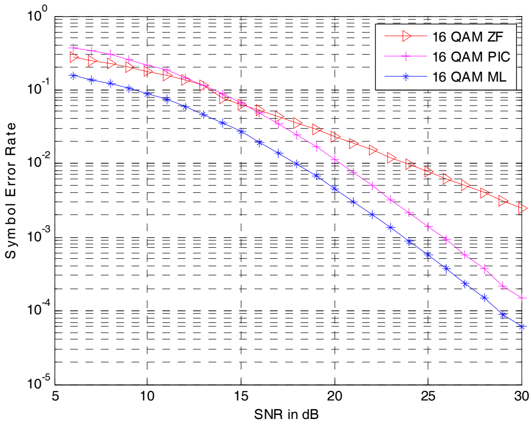

그림 3. 부분간섭제거와 제로포싱 그리고 ML디코딩 비교

Fig. 3. PIC, ZF and ML decoding comparison.

Rayleigh fading. QAM modulation is employed in the simulation. From the figure, one can see that the symbol-error-rate (SER) performance with the adaptive grouping scheme. SER performance with orthogonal grouping is improved than that of the Non-orthogonal scheme. Figure 3 shows the SER comparison of ML, PIC, and ZF decoding.

Ⅴ. Conclusion

In this letter, we applied the PIC group decoding into the detection of four-user layered Quasi-orthogonal Spacetime-Block code. Our QOSTBC scheme achieves full diversity when they are decoded with the PIC. Taking the Alamouti structure, we prove the PIC group decoding in an interleaved Quasi orthogonal STBC with four layered dividing the four blocks. We construct a block wise transmission technique which will achieve the desired code rate and reduce the complexity and provide less transmission time.

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