An Overloaded MIMO Receiver with Extended Rotation Matrices for Virtual Channels

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***Abstract*—This paper proposes a novel receiver with virtual channels for overloaded MIMO systems, where the number of spatial multiplexing streams is more than that of receive antennas. We propose extended rotation matrices used for the receiver in order to make the receiver performance flexible in terms of complexity and detection performance. A lot of the extended rotation matrices can be formed, even if the size of the rotation matrix is fixed. This paper proposes to select the optimum extended rotation matrix adaptive to the overloaded MIMO channel for further performance improvement. The performance of the proposed receiver with the extended rotation matrix is evaluated by computer simulation. It is shown that the the optimum extended rotation matrix selection attains $2\mathrm{dB}$ of a gain at BER of 10^{-3} in the proposed receiver.**

I. Introduction

Multiple-input multiple-output (MIMO) spatial multiplexing has bean intensively investigated because the spatial multiplexing can increase the link capacity without any additional spectrum. MIMO spatial multiplexing is one of the most promising techniques in future high speed wireless communications. In fact, MIMO spatial multiplexing has been applied in the cellular networks and the wireless local area networks. Many techniques have been introduced to the MIMO spatial multiplexing for capacity enhancement. It has been shown that multiuser MIMO enhances system throughput manly in downlinks of wireless networks. Collaborative wireless networks have a potential to increase system capacity avoiding mutual interference within the networks. In future wireless communication systems such as LTE-A, not only system capacity but also user throughput are requested to enhance. While terminals do not have enough space to install many antennas, base stations or access points have relatively large space to do. Unless the number of receive antenna on the terminals can increase, the above two techniques are not effective for enhancing the user throughput, although they are useful for increasing system throughput.

One straightforward approach to increase user throughput in such a situation is to send more streams than the number of receive antennas, e.g., "overloaded MIMO". Some receiver configurations have been proposed for the overloaded MIMO. Sphere decoding with a sophisticated detection technique has been proposed that achieves good performance [1], [2]. The maximum likelihood detection (MLD) with block codes has been theoretically analyzed to keep the same diversity order in spite of the number of spatial multiplexing streams [3], [4]. On the other hand, receivers with virtual channels have been proposed to achieve the MLD performance with relatively small computational complexity [5], [6]. However, the complexity only depends on the number of the spatially multiplexed streams as well as the transmission performance.

This paper proposes a new receiver configuration with the virtual channels for overloaded MIMO systems. Especially, we propose an extended rotation matrix used to generate the virtual channels. Because the extended rotation matrix can be designed flexibly, the extended rotation matrix makes the proposed receiver flexible in terms of complexity and performance. Moreover, this paper proposes to adaptively select the best extended rotation matrix for further performance improvement.

The remainder of the paper is organized as follows. The next section describes a system model. The proposed receiver is explained in Sec. III, and the performance of the proposed receiver is evaluated by computer simulation in Sec.IV. Finally, the conclusion is described in Sec.V .

II. System Model

We assume a MIMO spatial multiplexing system with N_{T} transmit antennas and N_{R} receive antennas where the number of spatial multiplexing signal streams is equal to N_{T}. Overloaded MIMO systems are characterized by the parameter set of $N_{\mathrm{T}} > N_{\mathrm{R}}$. The system model is drawn in Fig.1. Let $\Re[a]$ and $\Im[a]$ denote a real part and an imaginary part of a complex number a, a received signal vector $\mathbf{Y}$ at the terminal is defined as $\mathbf{Y} = (\Re[y_1], \Im[y_1], \cdots, \Re[y_{N_{\mathrm{R}}}], \Im[y_{N_{\mathrm{R}}}])^{\mathrm{T}} \in \mathbb{R}^{2N_{\mathrm{R}}\times 1}$, where where superscript T, $V \in \mathbb{R}^{N\times 1}$, and y_i, represent

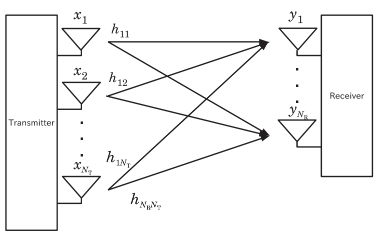

Fig. 1. System model

transpose of a vector, an N dimensional vector, a received signal at ith antenna. With the received signal vector $\mathbf{Y}$, the system model can be expressed as ,

$$\mathbf{Y} = \mathbf{HX} + \mathbf{N}. \quad (1)$$

$\mathbf{X} \in \mathbb{R}^{2N_\mathrm{T}\times 1}$ and $\mathbf{N} \in \mathbb{R}^{2N_\mathrm{R}\times 1}$ in (1) denote a transmission signal vector and the additive white Gaussian noise (AWGN) vector, which are defined as $\mathbf{X} = (\Re[x_1], \Im[x_1], \cdots, \Re[x_{N_\mathrm{T}}], \Im[x_{N_\mathrm{T}}])^\mathrm{T}$, $\mathbf{N} = (\Re[n_1], \Im[n_1], \cdots, \Re[n_{N_\mathrm{T}}], \Im[n_{N_\mathrm{T}}])^\mathrm{T}$. where x_i and n_i represent a transmission signal from ith transmit antenna and the AWGN at ith receive antenna, In addition, $\mathbf{H} \in \mathbb{R}^{2N_\mathrm{R}\times 2N_\mathrm{T}}$ represents a channel matrix defined as follows.

$$\mathbf{H} = \begin{pmatrix} \mathbf{H}_{1,1} & \cdots & \mathbf{H}_{1,N_\mathrm{T}} \\ \vdots & \ddots & \vdots \\ \mathbf{H}_{N_\mathrm{R},1} & \cdots & \mathbf{H}_{N_\mathrm{R},N_\mathrm{T}} \end{pmatrix} \quad (2)$$

In (2), $\mathbf{H}_{m,n}$ denotes a submatrix that contains a channel impulse response from nth transmit antenna to mth receive antenna. The submatrix is defined as,

$$\mathbf{H}_{m,n} = \begin{pmatrix} \Re[h_{m,n}] & -\Im[h_{m,n}] \\ \Re[h_{m.n}] & \Im[h_{m,n}] \end{pmatrix}. \quad (3)$$

In (3), $h_{m,n}$ represents a complex channel impulse response from nth transmit antenna to mth receive antenna.

A. Conventional Receiver With Virtual Channels

While performance of linear MIMO receivers such as the MMSE filter degrades by the overload of the spatial multiplexing streams, receivers with virtual channels achieve superior performance, even though the receivers are implemented with relatively low computational complexity. In conventional receivers with virtual channels, the transmission signal vector $\mathbf{X}$ is factorized as,

$$\mathbf{X} = \mathbf{\Omega}(\phi)\mathbf{D}(\phi). \quad (4)$$

$\mathbf{D}(\phi) \in \mathbb{R}^{N_\mathrm{T}\times 1}$ and $\mathbf{\Omega}(\phi) \in \mathbb{R}^{2N_\mathrm{T}\times N_\mathrm{T}}$ in (4) are called as the real transmit signal vector and the rotation matrix, respectively. When the Quaternary phase shift keying (QPSK) is applied to the system, the former is defined as $\mathbf{D}(\phi) = (d_1, \cdots, d_{N_\mathrm{T}})^\mathrm{T}$ where d_i is a scalar takes ± 1. The latter is defined as,

$$\mathbf{\Omega}(\phi) = \begin{pmatrix} \mathbf{C}_1(\phi) & 0 & \cdots & \\ 0 & \mathbf{C}_2(\phi) & 0 & \cdots \\ \vdots & 0 & \ddots & \\ 0 & \cdots & 0 & \mathbf{C}_{N_\mathrm{T}}(\phi) \end{pmatrix}. \quad (5)$$

In (5), $\mathbf{C}_i(\phi)$ denotes a 2-dimensional vector that is defined as,

$$\mathbf{C}_i(\phi) = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ c_i(\phi) \end{pmatrix}, \quad (6)$$

where $c_i(\phi)$ is a scalar taking ± 1. By substituting $\mathbf{X}$ in (4) for (1), the system model can be rewritten as,

$$\mathbf{Y} = \mathbf{\Phi}(\phi)\mathbf{D}(\phi) + \mathbf{N}. \quad (7)$$

In (7), $\mathbf{\Phi}(\phi) \in \mathbb{R}^{2N_\mathrm{R}\times N_\mathrm{R}}$ is called the "Virtual channel" matrix that is apparently written as follows.

$$\mathbf{\Phi}(\phi) = \mathbf{H\Omega}(\phi) = \begin{pmatrix} \mathbf{H}_{1,1}\mathbf{C}_1(\phi) & \cdots & \mathbf{H}_{1,N_\mathrm{T}}\mathbf{C}_{N_\mathrm{T}}(\phi) \\ \vdots & \ddots & \vdots \\ \mathbf{H}_{N_\mathrm{R},1}\mathbf{C}_1(\phi) & \cdots & \mathbf{H}_{N_\mathrm{R},N_\mathrm{T}}\mathbf{C}_{N_\mathrm{T}}(\phi) \end{pmatrix} \quad (8)$$

While the size of the channel matrix in the system model in (1) is $2N_\mathrm{R} \times 2N_\mathrm{T}$, that of the virtual channel matrix is $2N_\mathrm{R} \times N_\mathrm{T}$. In a word, the number of the spatial multiplexing streams in the channel model in (7) looks half of the actual number of the streams. This enables linear receivers to detect the vector $\mathbf{D}(\phi)$, a part to of the transmission signal vector. The other signals contained in the transmission vector $\mathbf{X}$ are detected by the exhaustive search in the receivers with the virtual channels. Because the linear receiver is used to detect a part of the signals, however, the complexity of the receivers is much less than that of the MLD.

The performance of the conventional receiver depends only on the number of the columns in the virtual channels matrix, e.g., the number of the spatial multiplexing streams in (7). Then, this paper proposes a receiver that achieves further complexity reduction or performance improvement in the following section.

III. Proposed flexible Receiver

Similar as the conventional receivers, the transmission signal vector $\mathbf{X}$ is factorized like (4) as,

$$\mathbf{X} = \mathbf{\Omega}_{\alpha,M}(\phi)\mathbf{D}_{\alpha,M}(\phi). \quad (9)$$

$\mathbf{\Omega}_{\alpha,M}(\phi) \in \mathbb{R}^{2N_\mathrm{T}\times M}$ and $\mathbf{D}_{\alpha,M}(\phi) \in \mathbb{R}^{M\times 1}$ are named as an extended rotation matrix and a real signal vector where α specifies a type of the extended rotation matrices. In other words, there are lots of types of the extended rotation matrices. For example, $\mathbf{\Omega}_{0,M}(\phi)$ can be expressed as,

$$\mathbf{\Omega}_{0,M}(\phi) = \begin{pmatrix} \mathbf{I}_{M\times M} \\ \mathbf{R}_{0,M}(\phi) \end{pmatrix} \quad (10)$$

In (10), $\mathbf{I}_{M\times M} \in \mathbb{R}^{M\times M}$ and $\mathbf{R}(\phi) \in \mathbb{R}^{(2N_\mathrm{T}-M)\times M}$ represent the M-dimensional identity matrix and a submatrix of the extended rotation matrix defined as,

$$\mathbf{R}_{0,M}(\phi) = \begin{pmatrix} \mathbf{0}_{(2N_\mathrm{T}-M)\times 2(N_\mathrm{T}-M)} & \tilde{\mathbf{R}}_{0,M}(\phi) \end{pmatrix}. \quad (11)$$

$\tilde{\mathbf{R}}(\phi) \in \mathbb{R}^{2(N_\mathrm{T}-M)\times 2(N_\mathrm{T}-M)}$ in (11) also denotes a submatrix in the extended rotation matrix $\mathbf{\Omega}_{0,M}(\phi)$. The submatrix $\tilde{\mathbf{R}}(\phi)$ is, for instance, defined as follows.

$$\tilde{\mathbf{R}}_{0,M}(\phi) = \mathrm{diag}\left[r_0(0)\ r_0(1)\ \cdots r_0(2N_\mathrm{T} - 2M)\right], \quad (12)$$

where $\mathrm{diag}[a_1 \cdots c_L] \in \mathbb{R}^{L\times L}$ denotes a diagonal matrix with $a_1 \cdots a_L$ in the diagonal positions. The channel matrix defined in (2) is rewritten as,

$$\mathbf{H} = \begin{pmatrix} \mathbf{H}_{1:M} & \mathbf{H}_{M+1:2N_\mathrm{T}} \end{pmatrix}. \quad (13)$$

where $\mathbf{H}_{m_1:m_2}$ represents a submatrix that consists of the column vectors in m_1th column to m_2th column of the channel matrix $\mathbf{H}$. By substituting $\mathbf{X}$ in (9) and $\mathbf{H}$ in (13) for (1), the

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system model can be rewritten with a new virtual channels $\mathbf{\Phi}_{0,M}(\phi) \in \mathbb{R}^{2N_\mathrm{R} \times M}$ as,

$$\begin{aligned}\mathbf{\Phi}_{0,M}(\phi) &= \mathbf{H}\mathbf{\Omega}_{0,M}(\phi) \\ &= \Big(\mathbf{H}_{1:M} \quad \mathbf{H}_{1:M} - \mathbf{H}_{M+1:2N_\mathrm{T}}\tilde{\mathbf{R}}_{0,M}(\phi)\Big). \end{aligned} \quad (14)$$

In contrast with the virtual channel $\mathbf{\Phi}(\phi)$ defined in (8), the new virtual channel matrix $\mathbf{\Phi}_{0,M}(\phi)$ has M columns. In a word, only M signal streams looks to be transmitted in the virtual channel with the virtual channel matrix $\mathbf{\Phi}_{0,M}(\phi)$. Because the value M can be changed arbitrary, the number of the spatial multiplexing streams in the virtual channel is altered from that in the channel model in (7) by the introduction of the extended rotation matrix. Since the performance of the receiver depends on the number of the spatial multiplexing streams in the virtual channel, hence, the performance of the receiver can be designed by changing the M value.

As the M value increases, the receiver becomes less complex and the transmission performance degrades. Hence, there is a trade off between the complexity and the transmission performance. In order to reduce the complexity with maintaining the transmission performance degradation as small as possible, the Lattice reduction is applied to the proposed receiver.

A. Lattice Reduction-Aided MMSE filter

The lattice reduction is applied for all the proposed virtual channels generated in the proposed receiver. Let $\mathbf{T}_{0,M}(\phi)$ denote a unimodular matrix for ϕth virtual channel with the extended rotation matrix $\mathbf{\Omega}_{0,M}(\phi)$ [1], the lattice reduction for the MMSE filter is expressed as [7], [8],

$$\underline{\mathbf{\Phi}}_{0,M}(\phi) = \begin{pmatrix} \mathbf{\Phi}_{0,M}(\phi) \\ \frac{\sigma^2}{\sigma_\mathrm{D}^2}\mathbf{I}_{M\times M} \end{pmatrix} \mathbf{T}_{0,M}(\phi). \quad (15)$$

In (15), σ^2 and σ_D^2 represent the power of the AWGN and that of the real signal $d_i(\phi)$ in the real signal vector $\mathbf{D}_{0,M}(\phi)$. By using the virtual channel matrix obtained in the above equation, the lattice reduction-aided MMSE filter can be written as follows.

$$\mathbf{W}_{0,M}(\phi) = \mathbf{\Phi}_{0,M}(\phi)\mathbf{T}_{0,M}(\phi)\left(\underline{\mathbf{\Phi}}_{0,M}(\phi)^\mathrm{T}\underline{\mathbf{\Phi}}_{0,M}(\phi)\right)^{-1} \quad (16)$$

$(A)^{-1}$ in (16) represents an inverse matrix of a matrix A. When the lattice reduction is applied in systems, in principle, the unimodular matrix is introduced in the system model. Moreover, when the virtual channel is used, the system model is rewritten with the unimodular matrix $\mathbf{T}_{0,M}(\phi)$ and the virtual channel matrix $\mathbf{\Phi}_{0,M}(\phi)$ in (14) as follows.

$$\mathbf{Y} = \mathbf{\Phi}_{0,M}(\phi)\mathbf{T}_{0,M}(\phi)\mathbf{Z}_{0,M}(\phi) + \mathbf{N}, \quad (17)$$

where

$$\mathbf{Z}_{0,M}(\phi) = \mathbf{T}_{0,M}(\phi)^{-1}\mathbf{D}_{0,M}(\phi). \quad (18)$$

The real signal vector $\mathbf{D}_{0,M}(\phi)$ can be estimated by the spatial filtering with the MMSE filter $\mathbf{W}_{0,M}(\phi)$ defined in (16) as,

$$\bar{\mathbf{D}}_{0,M}(\phi) = \mathrm{sgn}\left[\mathbf{T}_{0,M}(\phi)\lfloor\mathbf{W}_{0,M}(\phi)^\mathrm{T}\mathbf{Y}\rceil\right]. \quad (19)$$

[1]Unimodular matrices are defined as matrices that contain only inters as entries with the determinant of ± 1.

In (19), sgn[•] and ⌊•⌉ represent a function of the slicer and the floor function that outputs the nearest integer to the input value. As is defined in (9), the vector $\mathbf{D}_{0,M}(\phi)$ is a part of the transmission signal vector. As is previously described, the proposed receiver estimates the M signals in the transmission signal vector $\mathbf{X}$ with the MMSE filter. In other words, the $2N_\mathrm{T} - M$ signals in the transmission signal vector $\mathbf{X}$ is estimated by employing the exhaustive search in the proposed receiver. As the M value is set larger, the MMSE filter detects more signals, which reduces the complexity of the proposed receiver. Because more streams has to be detected by the MMSE filter, the transmission performance could be degraded even though the lattice reduction is used.

We propose a technique to improve the transmission performance in the following section. .

B. Optimum Rotation Matrix Selection

As is described at the beginning of Sec.III, a lot of the extended rotation matrices can be formed even if the matrix size is fixed. In this paper, we only consider extended rotation matrices defined in the following.

$$\mathbf{\Omega}_{\alpha,M}(\phi) = \begin{pmatrix} \mathbf{R}_{1:n_1-1}(\phi) & \vdots & \cdots & & \vdots \\ 1 & 0 & \cdots & & 0 \\ \mathbf{R}_{n_1+1:n_2-1}(\phi) & \vdots & \cdots & & \\ & 0 & & & \\ 0 & 1 & 0 & \cdots & \\ & & & & 0 \\ & 0 & & & \\ \mathbf{R}_{n_2+1:n_3-1}(\phi) & \vdots & \cdots & & \vdots \\ & & & & 0 \\ \vdots & & & \ddots & 0 \\ & & \cdots & 0 & 1 \\ & & & & 0 \\ \mathbf{R}_{n_M-1:2N_\mathrm{R}}(\phi) & \vdots & \cdots & & \vdots \\ & 0 & & & 0 \end{pmatrix} \quad (20)$$

In (20), $n_k, k = 1, \cdots, M$ denotes a position of the row where 1 is placed at the k column and the others are all zero. The row is called "W1-row"in this paper. In addition, $\mathbf{R}_{m_1:m_2}(\phi) \in \mathbb{R}^{m_2-m_1\times 1}$ denotes a vector defined as,

$$\mathbf{R}_{m_1:m_2}(\phi) \begin{cases} \emptyset & m_1 = m_2 \\ (r_{m_1} \cdots r_{m_2})^\mathrm{T} & m_1 \neq m_2 \end{cases}. \quad (21)$$

$\emptyset$ in (21) denotes the empty set. By swapping the W1-row with the non W1-row, many extended rotation matrices can be generated. When the extended rotation matrix defined in (20) is applied to the virtual channel, the virtual channel matrix $\mathbf{\Phi}_{\alpha,M}(\phi)$ is written as,

$$\begin{aligned}\mathbf{\Phi}_{\alpha,M}(\phi) &= \mathbf{H}\mathbf{\Omega}_{\alpha,M}(\phi) \\ &= \Big(h_{n_1} + \sum_{i\neq n_1,\cdots .n_M}^{2N_\mathrm{R}} h_i r_i \quad h_{n_2} \ldots h_{n_M}\Big). \end{aligned} \quad (22)$$

The virtual channel matrix defined in (22) is completely different from that in (14). Since performance depends on a channel matrix in principle, the performance of the proposed receiver depends on the selection of the extended rotation matrix.

This paper proposes to adaptively select the optimum rotation matrix in all the matrices in terms of the transmission performance. The error vector $\mathbf{e}_{\alpha,M}(\phi)$ between the MMSE filter output and the desired signal is defined for the selection.

$$\mathbf{e}_{\alpha,M}(\phi) = \mathbf{Z}_{\alpha,M}(\phi) - \mathbf{W}_{\alpha,M}(\phi)^{\mathrm{T}}\mathbf{Y} \tag{23}$$

By using the error vector $\mathbf{e}_{\alpha,M}(\phi)$, metric to select the optimum rotation matrix is defined as $\sigma_{\alpha,M}(\phi) = \mathrm{E}[\mathbf{e}_{\alpha,\mathrm{M}}(\phi)^{\mathrm{T}}\mathbf{e}_{\alpha,\mathrm{M}}(\phi)]$, where $\mathrm{E}[\beta]$ denotes an expectation of β. The optimum extended rotation matrix with index $\bar{\alpha}$ that is selected based on the following criterion, is selected in this paper.

$$\begin{aligned}\bar{\alpha} &= \arg\min_{\alpha}\left\{\max_{\phi}\mathrm{E}\left[\mathbf{e}_{\alpha,\mathrm{M}}(\phi)^{\mathrm{T}}\mathbf{e}_{\alpha,\mathrm{M}}(\phi)\right]\right\} \\ &= \arg\min_{\alpha}\left\{\max_{\phi}\{\mathrm{tr}\left[\mathbf{T}_{\alpha,M}(\phi)^{-1}\mathbf{T}_{\alpha,M}(\phi)^{-\mathrm{T}}\right.\right. \\ &\qquad \left.\left.\bullet\big(\mathbf{I} - \mathbf{T}_{\alpha,M}(\phi)^{\mathrm{T}}\mathbf{\Phi}_{\alpha,M}(\phi)^{\mathrm{T}}\mathbf{W}_{\alpha,M}(\phi)\big)\right]\right\}\end{aligned} \tag{24}$$

In (24), $\arg\min_{\alpha}[f(\alpha)]$ is a function to output α_{min} that minimizes $f(\alpha)$ and $\max_{\phi}[f(\phi)]$ is also a function to find the maximum value of $f(\phi)$ with respect to ϕ.

IV. Simulation

We assume an overloaded MIMO system where 6 streams are spatially multiplexed and 2 antennas are placed on the receiver, e.g., $N_{\mathrm{T}} = 6, N_{\mathrm{T}} = 2$. Single carrier transmission with the QPSK modulation is applied for simplicity. Rayleigh fading based on Jakes' model is used as the channel model. The M value is set to 10. Accordingly, the number of the virtual channels is only 4. The Lenstra-Lenstra-Lovás (LLL) algorithm is applied for the lattice reduction. Error control techniques are not applied for evaluating only the performance of the receiver.

Fig.2 shows the BER performance of the proposed flexible MIMO receiver without the adaptive selection. In the figure, the performance of the conventional receiver with the rotation matrix in (5) is added for a reference. The parameter δ in the LLL algorithm is set to 0.90 in order to verify the upper bound of the receivers. The proposed receiver has inferior performance to the conventional receiver by about 5dB at BER of 10^{-3}. Because the M value corresponds to 6 in the conventional receiver, however, the complexity of the conventional receiver is 2^4 times as much as that of the proposed receiver without the adaptive selection. In a word, the computational complexity is reduced in the proposed receiver in return of a little performance degradation.

As is described in Sec.III-B, lots of types of the extended rotation matrices can be formed even if the matrix size is fixed. In addition, many virtual channels are generated per one of the extended rotation matrices. Let N_{ex} and N_{vc} denote the number of the extended rotation matrices and that of the virtual channels per the rotation matrix, the number of the MMSE filters required in the receiver is $N_{\mathrm{ex}} \times N_{\mathrm{vc}}$. Because all

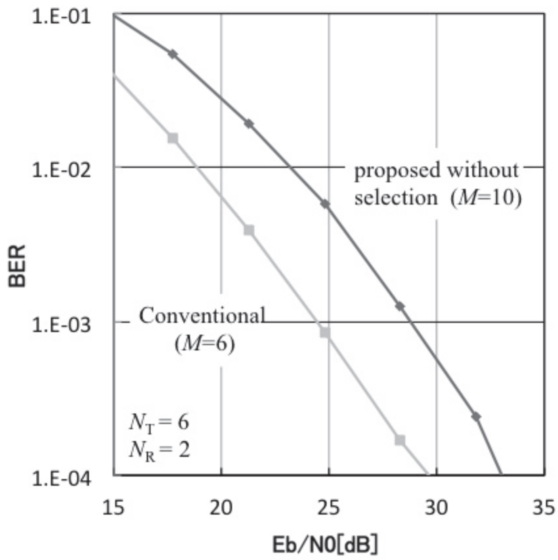

Fig. 2. BER performance of the proposed receiver without the selection

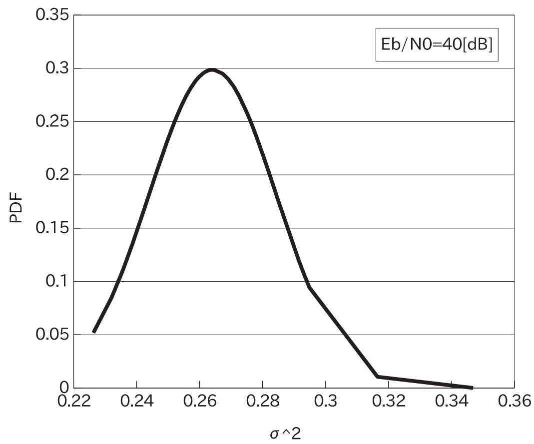

Fig. 3. PDF of error, $\sigma^2_{\alpha,M}(\phi)$

the MMSE filters are different from each other, the estimation performance of the MMSE filter is different from that of the other MMSE filters. Fig.2 draws a probability density function of the estimation errors of the MMSE filters. Actually, the horizontal axis means $\sigma^2_{\alpha,M}(\phi) = \mathrm{E}[\mathbf{e}_{\alpha,\mathrm{M}}(\phi)^{\mathrm{T}}\mathbf{e}_{\alpha,\mathrm{M}}(\phi)]$ in the figure. The estimation errors are distributed with some variance that is not negligible small. The rotation matrix with which the MMSE filter achieves the least estimation error can be regarded optimum in terms of the transmission performance. Hence, we can expect that the adaptive selection of the extended rotation matrices can improve the transmission performance. The BER performance of the proposed receiver with the adaptive selection is compared with that without the selection in Fig.4. As is expected from Fig.III-B, the adaptive selection of the extended rotation matrix improves the transmission performance by about 2dB at BER of 10^{-3}. Therefore, the adaptive selection reduces the performance degradation from

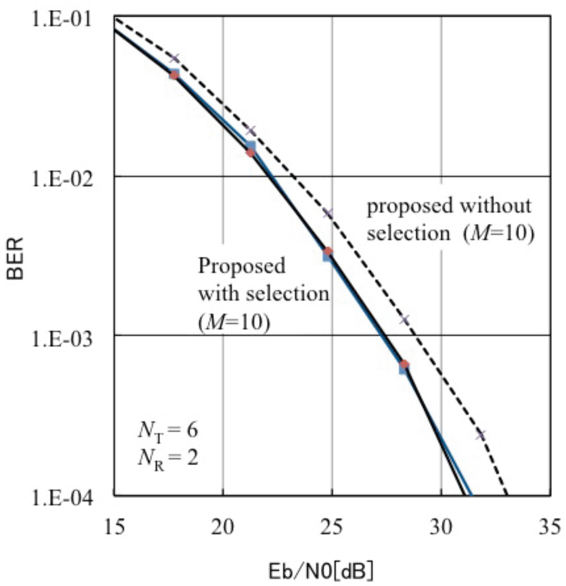

Fig. 4. BER performance of the proposed receiver with the adaptive selection

the conventional receiver to about 3dB. However, some computation is necessary for the adaptive selection. The complexity reduction of the selection is one of our future tasks.

V. Conclusion

This paper proposes a novel flexible receiver for overloaded MIMO systems. We propose extended rotation matrices for the proposed receiver for flexibility in terms of computational complexity and transmission performance. Moreover we propose an adaptive selection of the extended rotation matrix for transmission performance improvement based on “MINI-MAX” approach.

The performance of the proposed receiver is evaluated by computer simulation. As a result, it is confirmed that the computational complexity of the propose receiver without the selection is reduced to $\frac{1}{2^4}$ of that of the conventional receiver, while the performance of the proposed receiver without the selection has a little bit inferior performance. However, the adaptive selection enables the proposed receiver to attain about $2\mathrm{dB}$ of a gain at the BER of 10^{-3}.

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