BER Performance Evaluation by Antenna Selections Suitable for Two-Stream MIMO Systems

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Abstract

This paper presents a MIMO antenna selection for two-stream MIMO systems in LOS scenarios. We reveal that the selection criterion based on the determinant of the channel matrix is effective for low BER, which are confirmed by the ray-tracing propagation analysis and measurement in an indoor environment.

Keywords : MIMO Antenna selection Eigenvalue BER

1. Introduction

Many studies have been conducted for antenna selection in multiple-input multiple-output (MIMO) systems, and the BER performances have been evaluated. As antenna selection criteria, the signal to noise ratio (SNR) [1], minimum eigenvalue of spatial correlation matrix [1], [2], and determinant of channel matrix [3] have been examined. However, the performance evaluations were mainly conducted in the Rayleigh fading channel, and evaluations in line-of-sight (LOS) scenarios are few. Then, the variations in SNR depending on the selected antenna combinations were not considered accurately. In [4], we analyzed the BER performance by antenna selections for two-stream MIMO systems, and revealed that the criterion based on the determinant of the channel matrix is effective in the view of performance and calculation amount. However, the analysis was conducted under the specific environment, and it assumed the perfect channel state information (CSI). In this paper, we show that the determinant based criterion is also applicable in the various scenarios, and demonstrated measured BER performances considering the channel estimation.

2. Focused Selection Criteria

In 2 x 2 MIMO-space division multiplexing (SDM) systems, the channel matrix **H** is given by

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \quad (1)$$

where h_{ij} is the transmission function. The first and second eigenvalue of the spatial correlation matrix $\mathbf{HH}^H$ ($\{\cdot\}^H$ represents the complex conjugate transpose.) denoted by λ_1 and λ_2 are approximated as follows [5]:

$$\lambda_1 \approx |h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2 - \frac{|h_{11}h_{22} - h_{12}h_{21}|^2}{|h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2} = P - \frac{|\det(\mathbf{H})|^2}{P} \quad (2)$$

$$\lambda_2 \approx \frac{|h_{11}h_{22} - h_{12}h_{21}|^2}{|h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2} = \frac{|\det(\mathbf{H})|^2}{P} \quad (3)$$

where P indicates the total received power in MIMO-SDM. In [4], we showed that second eigenvalue was an important factor in an indoor LOS scenario. Then, we clarified the antenna selections maximizing λ_2 ($\lambda_{2,\max}$) and maximizing $|\det(\mathbf{H})|^2$ ($|\det(\mathbf{H})|^2_{\max}$), which was the numerator of λ_2, were effective to achieve low BER, compared to the other criteria. In this paper, we only focus on $\lambda_{2,\max}$ and $|\det(\mathbf{H})|^2_{\max}$ and compare between those BER performances and the minimum value by the antenna selection (*Opt*).

3. Analysis Based Performance Evaluation in Various Scenarios

We investigate the analytical BER performance of 2 x 2 MIMO-SDM with antenna selection by using ray-tracing propagation analysis. The basic simulated scenario and simulation parameters are shown in Fig. 1 and Table 1, respectively. Dipole radiation patterns are considered at Tx and Rx elements. The details of the simulation processes are described in [4]. Here, to select two elements from four elements at Tx, the channel matrices are derived for the six ($_4C_2$) combinations. Then, $|\det(\mathbf{H})|^2$ and λ_2 are calculated in each combination, and selected antenna combinations are decided by $|\det(\mathbf{H})|^2_{max}$ and $\lambda_{2,max}$.

As shown in Fig. 2(a), $|\det(\mathbf{H})|^2_{max}$ and $\lambda_{2,max}$ are almost identical to *Opt* in the basic scenario. Next, we evaluate the BER performance by changing several parameters from the basic (Fig. 2(a)-(d)). For the systems, when the transmitting power is reduced, 16QAM and minimum mean square error (MMSE) algorithm are used as a modulation scheme and a signal detection scheme at Rx, respectively, $|\det(\mathbf{H})|^2_{max}$ and $\lambda_{2,max}$ are also effective although the distributions of the BER are changed. For the simulated environments, the same is true regardless of the Rx array arrangement, the height and the location of Tx and the size of the room.

4. Measurement Based BER Performance Evaluation

In the room of 8.76 x 6.31 x 2.7 m shown in Fig. 3(a), we evaluate the BER performance empirically. For Tx and Rx antennas, four-element rectangular and two-element linear sleeve arrays are used, respectively (Fig. 3(b)). For the Tx, the number of the elements fed simultaneously is two. The feeding elements are switched manually, and non-fed elements are terminated. The location of Tx is fixed, and the signals are received at plural Rx positions (8 positions). Here, the heights of the Tx and Rx antennas are 1.15 m. The measured environment is quasi-static, and all the Rx positions are in the LOS from Tx. In the measurement, the transmitting frame format is constituted by header of 50 symbol/ch and data of 400 symbol/ch. The maximum-length sequences (M-sequences) are applied to the header of the transmitting signals, and the channels are estimated by complex sliding correlation using reference signals [6]. Then, the signals are detected by zero-forcing (ZF) algorithm. In this measurement, error-correcting code is not used for simplicity. The detail measurement systems are described in [6], [7]. Here, although the room size, the height of Tx and transmitting power are different from Fig. 1 and Table 1, we can evaluate the effect of $|\det(\mathbf{H})|^2_{max}$ and $\lambda_{2,max}$ in this scenario from the results of Section 3.

Figure 4 shows the cumulative distribution function (CDF) of the measured BER. Here, the numbers of *i-j* correspond to the element number in Fig. 3(b). Figure 4 indicates that the BERs obtained by the antenna selection outperform those obtained by all the fixed (non-selected) antenna combinations. In this measurement scenario, high λ_2 is effective to obtain low BER since BER for $\lambda_{2,max}$ is almost identical to that for *Opt* except for the regime in the vicinity of 10^{-1}. From eq. (3), since $|\det(\mathbf{H})|^2$ is related to λ_2, $|\det(\mathbf{H})|^2_{max}$ also leads to good BER performance.

Subsequently, BER at each Rx position obtained by each selection criterion is shown in Fig. 5. For the variations depending on the positions, since λ_2s at the Rx positions close to the wall (#5, #6, #7) are less than those at the other positions, those BER performances are degraded. For the effect of the antenna selection, BERs for *Opt*, $\lambda_{2,max}$ and $|\det(\mathbf{H})|^2_{max}$ are almost identical at #3-#8. At #2, although there is a difference between $\lambda_{2,max}$ or $|\det(\mathbf{H})|^2_{max}$ and *Opt*, there are no problems since those BERs are low sufficiently. The differences of BER for each selection criterion at #1 cause the difference of CDF in the vicinity of 10^{-2} in Fig. 4. Figure 6 shows the difference of eigenvalues between $\lambda_{2,max}$ or $|\det(\mathbf{H})|^2_{max}$ and *Opt* ($\lambda_{i,opt}$), that is, normalized eigenvalues (λ_1', λ_2') of $\lambda_{2,max}$ and $|\det(\mathbf{H})|^2_{max}$. At #1, λ_2' for $|\det(\mathbf{H})|^2_{max}$ is small and is less than 0. This is because of large *P* in eq. (3), and therefore λ_1' (eq. (2)) for $|\det(\mathbf{H})|^2_{max}$ is larger than that for $\lambda_{2,max}$ and is more than 0. At this position, for $|\det(\mathbf{H})|^2_{max}$, such large difference between λ_1 and λ_2 cause the degradation of BER, compared to $\lambda_{2,max}$ and *Opt*. However, at the other positions, λ_2s for $|\det(\mathbf{H})|^2_{max}$ are more than 0 in Fig. 6(b), and then the level of BER degradation is low.

Table 2 shows the number of arithmetic calculation required to derive λ_2 and $|\det(\mathbf{H})|^2$. Here, each component of the channel matrix h_{ij} is considered as a complex value. All the arithmetic calculations for $|\det(\mathbf{H})|^2$ are smaller than those for λ_2. As a result, $|\det(\mathbf{H})|^2_{\max}$ is an effective selection criterion leading to low BER and having low calculation amount.

5. Conclusion

In this paper, we revealed that $|\det(\mathbf{H})|^2_{\max}$ was an effective criterion for low BER and low calculation amount in two-stream MIMO systems with antenna selection. The analytical results showed that the criterion was applicable to the various conditions. Then, we demonstrated empirically that the criterion led to low BER.

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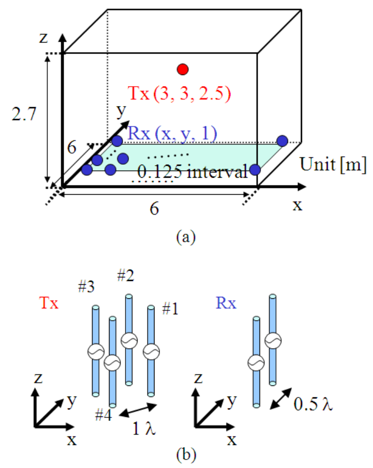

Figure 1: Basic (a) simulation scenario and (b) array arrangements of Tx and Rx.

Table 1: Basic simulation parameters.

Carrier frequency	5 GHz
Transmitting power	-15 dBm/ch
Noise level	-85 dBm
Modulation scheme	QPSK
Channel estimation	Perfect CSI
Signal detection scheme	ZF (Zero-Forcing)

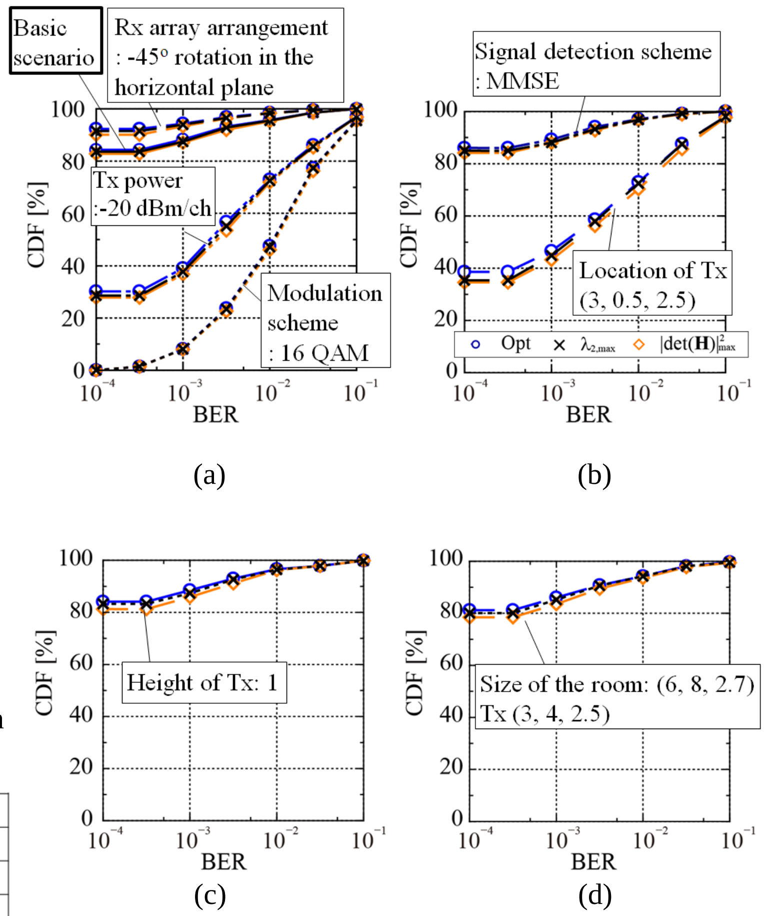

Figure 2: Cumulative distribution functions (CDFs) of BER obtained when several parameters are changed.

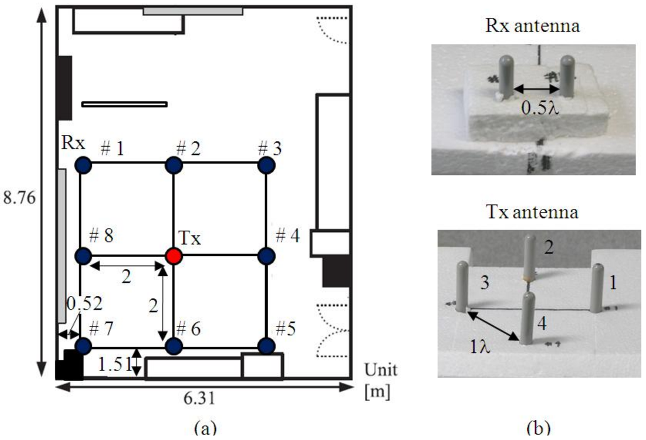

Figure 3: (a) Measurement environment and (b) array arrangements.

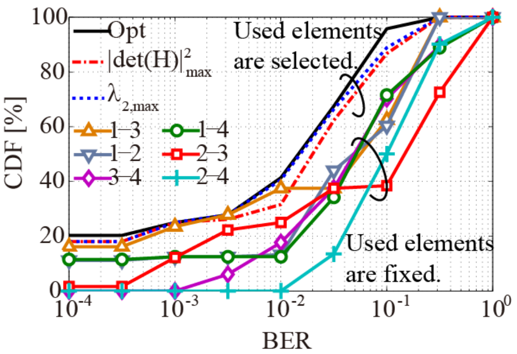

Figure 4: Cumulative distribution functions (CDFs) of BER by each antenna selection and fixed antenna combinations.

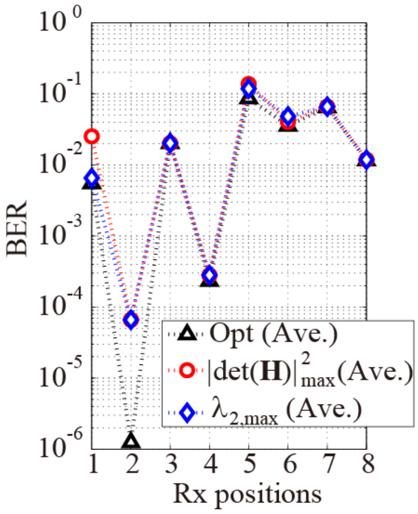

Figure 5: Averaged BER performances at each Rx position.

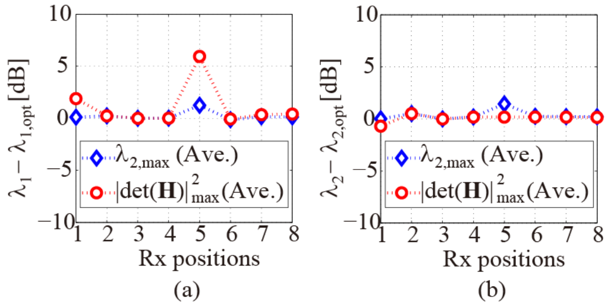

Figure 6: (a) 1st and (b) 2nd eigenvalues normalized by the eigenvalues for *Opt*.

Table 2: The number of arithmetic calculations required to derive λ_2 and $|\det(\mathbf{H})|^2$.

Parameters	Addition / Subtraction	Multiplication	Division
λ_2(eq. (3))	14	18	5
$|\det(\mathbf{H})|^2$	7	10	1

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