Simple Selection Method by the Second Eigenvalue in Indoor 2×2 MIMO System

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1. Introduction

There are two kinds of MIMO systems [1], such as spatial multiplexing method and diversity method. To enhance the channel capacity, the space multiplexing method is effective in high SNR environment, while the diversity method is effective in low SNR environment. The channel capacity improvement combining two transmission methods is expected by selecting on appropriate methods depending on the propagation situation. This paper presents the simple selection method to improve the channel capacity by switching two transmission methods.

2. Channel capacity comparison and selection threshold

In this paper, a simple selection method is carried out by using channel capacity characteristics. Two kinds of MIMO systems in this paper are MIMO-SDM (Spatial Division Multiplexing) of spatial multiplexing method and MIMO-MRC (Maximum Ratio Combing) of diversity method. Each channel capacity is formulated by eqs. (1) and (2), respectively,

$$C_{SDM} = \sum_{j=1}^{N_t} \log_2(\lambda_j \frac{\gamma_0}{M} + 1) \quad (1) \qquad C_{MRC} = \log_2(\lambda_1 \gamma_0 + 1) \quad (2)$$

where, λ_j is calculated by channel propagation matrix H, M is number of transmitting antenna, and γ_0 is the ratio of all transmitting power to noise. If transmitting and receiving position for these transmission methods are the same, the difference of channel capacity characteristics C_{dif} is given as follows.

$$C_{dif} = C_{SDM} - C_{MRC} \geq 0 \quad (3) \qquad \lambda_2 \geq \frac{2}{\gamma_0 + 2/\lambda_1} \quad (4)$$

When the threshold is formulated by using eq. (3), a proper transmission method is selected by eq. (4) using eigenvalues and the ratio of all transmitting power to noise. Eqs. (4) and (5) are approximated as,

$$\log_2(\lambda_1\gamma_0 + 2) - \log_2(\lambda_1\gamma_0 + 1) \approx 0 \quad (5) \qquad \lambda_2 \geq \frac{2}{\gamma_0} \quad (6)$$

when the second eigenvalue satisfies the condition of eq. (6), the MIMO-SDM is effective. The calculation complexity is shown in Table 1, which shows that the eq. (6) reduces the computation time.

3. Simulation and experiment

Proposed method by eq. (6) is compared with the method by eq. (4) under indoor propagation environment. The room size of simulation model is 12×12t×2.7[m], where 4 different aspect ratios (t), and 2 transmitting and 55 receiving positions are examined as shown in Fig. 1. Simulation parameters are shown in Table 2. Each eigenvalue is calculated by the channel propagation matrix H, and the eigenvalue distributions are shown in Fig. 2. The area enclosed by eqs. (4), (6), and $\lambda_1 \geq \lambda_2$ is error region between eqs. (4) and (6). Therefore, the selection of transmission method is wrong, for the eigenvalue plotted this area. 13 points are in this error area, then the channel capacity is decreased by 0~1.5% as shown in Table 3.

Next, the channel propagation matrix H is measured in indoor environment. The experimental environment is shown in Fig. 3. The standard monopole antennas with resonance frequency of 5 GHz are used as the transmitting and receiving antennas. Experimental details are given in refs. [2] and [3]. The receiving system is moved to each receiving position (Rx1~Rx16), and it is moved by hand to the next measurement position after data acquired at one position. It is confirmed that proposed threshold by eq. (6) is effective at each receiving position in this experimental environment.

The channel capacity is compared between MIMO-SDM and MIMO-MRC by channel propagation matrices H at each receiving position as shown in Fig. 4, where each channel capacity is calculated by eqs. (1) and (2). The solid line in Fig. 4 takes large channel capacity at each receiving position, and Fig. 5 shows the eigenvalue at each receiving position. The value of the first eigenvalue depends on the distance between transmitter and receiver as shown in Fig. 5. On the other hand, the second eigenvalue depends on not the distance but the receiving position and the indoor environment. Considering the characteristic of each transmission method, proper transmission method is dominated by the value of the second eigenvalue. If the second eigenvalue exceeds certain value by eq. (6), proper transmission method is MIMO-SDM.

Secondly, the increasing rate of channel capacity at each receiving position is shown in Fig. 6. The increasing rate of the proposed method by eq. (6) is compared with the single transmission method. Fig. 6 shows the increasing rate for the 2 cases such as the transmission method changes from MIMO-SDM or MIMO-MRC to proposed method. The proposed threshold by eq. (6) selects the transmission method providing large channel capacity at each receiving position, then this threshold improves channel capacity more than the single transmission method. For example, there are many receiving positions providing large channel capacity by the MIMO-MRC in this environment as shown in Fig. 4. Thus, the selection of MIMO-MRC or MIMO-SDM by eq. (6) increases channel capacity more than the single MIMO-SDM as shown in Fig. 6.

The improvement by the proposed method is shown in Table 4, where C_s is the channel capacity of the transmission method selected by eq. (6). The channel capacity C_s is increased about 20% compared with the single MIMO-MRC at 5 receiving positions, and about 10% compared with the single MIMO-SDM at 11 receiving positions. Furthermore, wrong selections by eq. (6) are not observed in this experiment. There is no decreasing channel capacity by the wrong selection, then the proposed threshold are effective to select proper transmission method.

4. Conclusion

In this paper, the simple selection of the transmission method using the threshold by the second eigenvalue was proposed and experimentally demonstrated. As a result, using the threshold by eq. (6) improves the channel capacity more than single transmission method by about 10%. In addition, when some error selections are observed, there is little difference of channel capacity between MIMO-SDM and MIMO-MRC, and little influence of decreasing channel capacity. Therefore, it is confirmed that proposed threshold by using second eigenvalue is effective to select properly transmission method.

References

[1] G. J. Foschini and M. J. Gans, "On limits of wireless communications in a fading environment when using multiple antennas," Wireless Personal Commun., vol. 6, pp. 311-335, 1998.

[2] Y. Inoue, N. Ito, H. Arai, "4×4 MIMO prototype system and measurement of indoor environment," in Proc. 2005 Int. Symp. On Antennas Propag., WA3-4, pp. 59-62, Aug. 2005

[3] D. Uchida, H. Arai, Y. Inoue, K. Cho, "Experimental assessment of the channel capacity in indoor MIMO systems using dual-polarization," in Proc. IEEE VTC-Spring, April 2009.

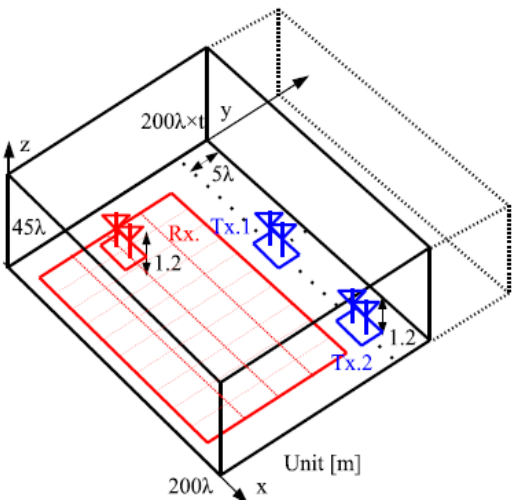

Fig. 1: Simulation environment

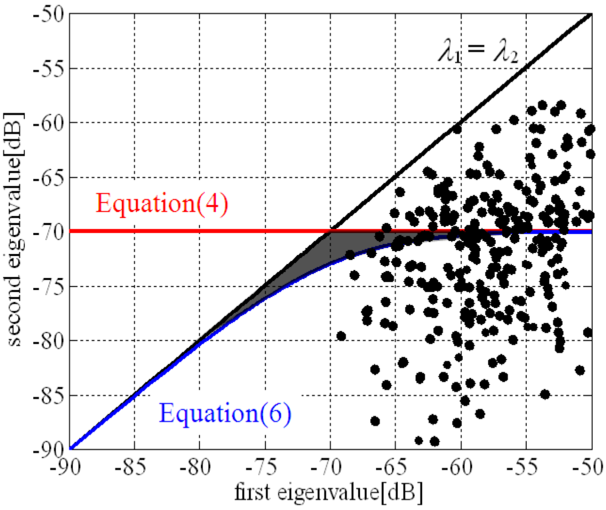

Fig. 2: Eigenvalue distribution

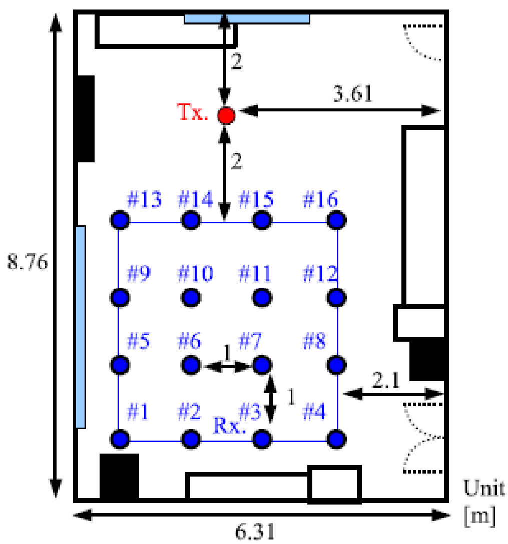

Fig. 3: Experimental environment

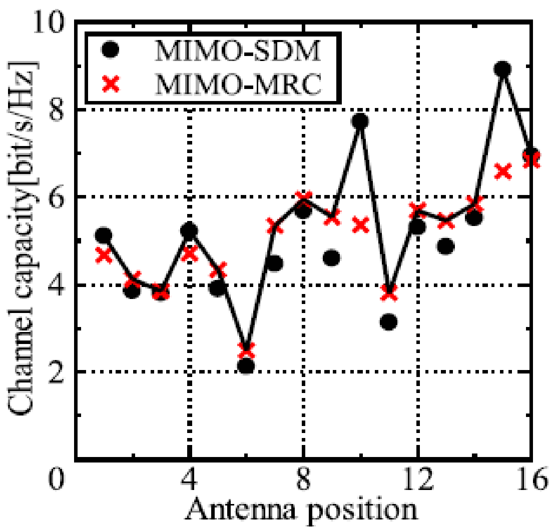

Fig. 4: Channel capacity at each receiving position

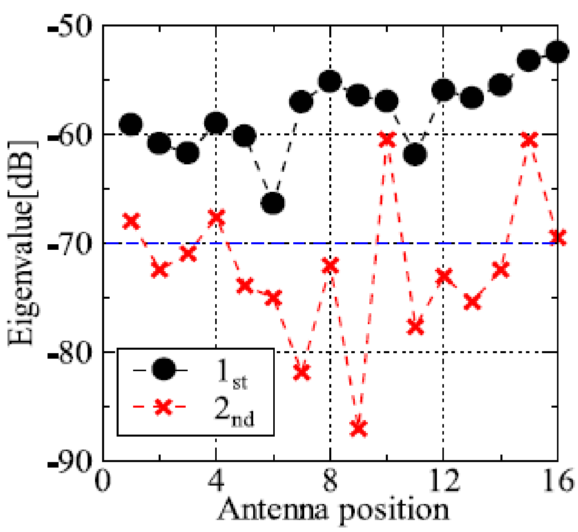

Fig. 5: Eigenvalue at each receiving position

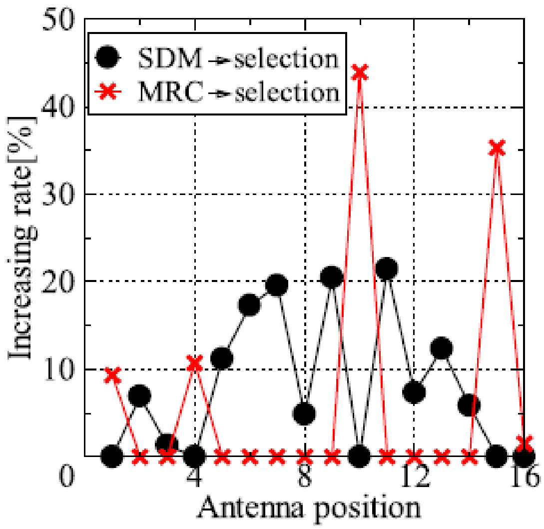

Fig. 6: Channel capacity increasing rate at each receiving position

Table 1: Comparison of calculation amount

Selection criterion	Four arithmetic operations	Comparison	Calculation amount
Equation (4)	3	1	4
Equation (6)	1	1	2

Table 2: Simulation parameters

Carrier frequency	5 [GHz]	Material of wall	concrete	Number of reflection	5 times
Noise power	-85 [dBm]	Transmitter power	-15 [dBm/h]	ε_r / σ	6.76 / 0.0023

Table 3: Average decreasing rate of channel capacity by error selection

Aspect ratio: t	0.5	1	1.5	2
Decreasing rate(Tx1) [%]	0	0	0.87	1.31
Decreasing rate(Tx2) [%]	0	0.75	0	1.38

Table 4: Improvement factor compared to single transmission method

	Number of receiving point	Average channel capacity increasing rate
$C_{MAC} \rightarrow C_s$	5 points	+20.15%
$C_{SDM} \rightarrow C_s$	11 points	+11.67%