# A Basic Study on Antenna Selection for Loose Beamforming in a Massive MIMO System

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***Abstract*—A study on multi-user massive multiple-input multiple-output (MIMO) systems has been done as one of the key technologies for the fifth generation mobile communication system. In massive MIMO systems, more than 100 antenna elements are often used at a base station, and large-dimensional beamforming as multi-user MIMO precoding is needed. Then, heavy computational complexity is a serious issue for multi-user massive MIMO systems. In this paper, we propose a loose beamforming method only using simple antenna selection focusing on desired signal power. In addition, we evaluate the sum-capacity of the loose beamforming using channel information obtained by a ray-tracing technique. Through the simulation, it has been shown that the performance of the simple antenna selection is better than random selection and show a possibility that the loose beamforming is effective when simple implementation is required.**

***Index Terms*—Multi-user MIMO, Ray-tracing technique, Antenna selection, Loose beamforming.**

## I. INTRODUCTION

Applications of a multi-user massive multiple-input multiple-output (MIMO) system have been considered in the fifth generation mobile communication systems. In a multi-user massive MIMO system, the number of elements greatly increases, so there is a problem that the amount of calculations required for beamforming increases. In order to cope with this problem, some methods of antenna selection in a transmission side have been proposed [1], [2]. The reference [1] clarified the possibility that it is not necessary to use all the antennas because the channels for antennas are different each other, and showed the effectiveness of applying antenna selection. In this paper, we consider a simple antenna selection method in a virtual indoor environment and evaluate the performances of the loose beamforming by the antenna selection.

The rest of this paper is organized as follows. In Section II, the loose beamforming method is explained. In Section III, a selection method is proposed. In Section IV, we described a simulation environment. After several performance evaluations in Section V, the paper is concluded in Section VI.

## II. LOOSE BEAMFORMING

On the assumption that the channel information is perfectly known at a base station (BS), $N_s$ antenna elements are selected out of $N_t$ total transmission antenna elements ($N_s \leq N_t$). Although the number of selected elements may differ for each user, for the sake of simplicity, it is assumed that the same number of antenna elements are selected in this paper. When there are $K$ user equipments (UEs) with one antenna element, an $N_t \times K$ selection matrix $\mathbf{W}_{\text{select}}$ is shown as follows:

$$\mathbf{W}_{\text{select}} = \frac{1}{\sqrt{N_s K}} \begin{pmatrix} w_{11} & w_{12} & \dots & w_{1K} \\ w_{21} & w_{22} & \dots & w_{2K} \\ \vdots & \vdots & \dots & \vdots \\ w_{N_t 1} & w_{N_t 2} & \dots & w_{N_t K} \end{pmatrix}. \quad (1)$$

Here, the element corresponding to the $n$th transmission antenna for the $k$th user has a value :

$$w_{nk} = \begin{cases} 1 \text{ when selected.} \\ 0 \text{ when not selected.} \end{cases}$$

Also, the $K \times N_t$ channel matrix $\mathbf{H}$ is expressed as follows:

$$\mathbf{H} = \begin{pmatrix} h_{11} & h_{12} & \dots & h_{1N_t} \\ h_{21} & h_{22} & \dots & h_{2N_t} \\ \vdots & \vdots & \dots & \vdots \\ h_{K1} & h_{K2} & \dots & h_{KN_t} \end{pmatrix}. \quad (2)$$

With a $K$ dimensional transmission signal vector $\mathbf{s}$ and a $K$ dimensional noise vector $\mathbf{z}$, a $K$ dimensional received signal vector $\mathbf{y}$ is written by

$$\mathbf{y} = \mathbf{H}\mathbf{W}_{\text{select}}\mathbf{s} + \mathbf{z}. \quad (3)$$

In (3), only antenna selection is performed and precoding such as spatial filtering is not used. Then, a formed beam can loosely emphasize a desired wave and reduce interference waves. When the number of antenna elements increases, the randomness of the channel responses will become high, and it is expected that an effective combination of antenna elements exists. However, to determine that, we need to examine $({}_{N_t}\mathrm{C}_{N_s})^K$ combinations for each element of $\mathbf{W}_{\text{select}}$. Therefore, in this paper, we discuss a simple antenna selection method based on desired signal power.

## III. ANTENNA SELECTION

In this section, we describe a selection method for loose beamforming. We select antennas by the following 5 steps based on desired signal power.

1) For each user, plot the channel response on the complex plane with amplitude and phase.
2) An arbitrary phase (45° in this paper) the complex plane is selected as the desired signal component, and $N_s$

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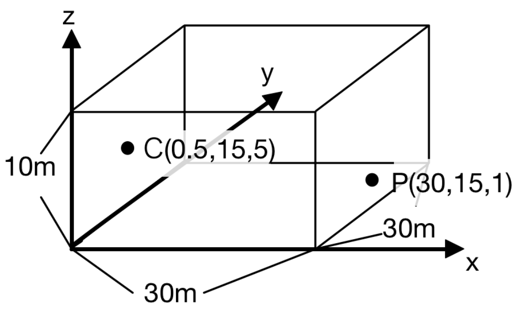


Fig. 1. Indoor model.

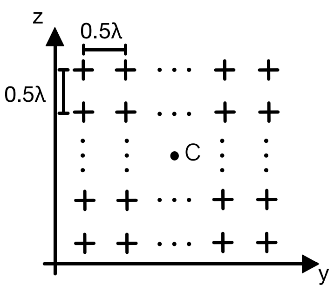


Fig. 2. Antenna arrangement

elements whose component is close to the desired one are selected.

3) Rotating the phase of the desired signal component by 90°, $N_s$ elements are selected by the same manner as 2).
4) Likewise, $N_s$ elements are selected by rotating the phase by 180° and 270°, respectively.
5) Among the four sets of $N_s$ elements, determine the set which gives the largest desired signal power.

We can form a loose beam by the decided set using the above selection method.

## IV. SIMULATIONS

### A. Simulation conditions

In this paper, we obtained channel matrices between the BS and UEs by RapLab [3], a software for radio propagation analysis using a ray-tracing technique. We assumed that the simulation model is an indoor environment such as a hall of 30 m long, 30 m wide, and 10 m high (as shown in Fig.1) surrounded by a concrete floor, a ceiling, and walls. In this simulation, we assumed that there is no furniture in the room. In addition, in this paper, we ignored shadowing by human. A BS antenna array is installed so that the center C of the square array shown in Fig.2 corresponds to the position C in Fig.1. In Fig.2, "+" represents the positions of a dipole antenna. As shown in Fig.2, a two-dimensional equally spaced array in which 100 dipole antennas are arranged at intervals of half wavelength with 10 elements vertically and horizontally around the point C is used as a transmitting base station. We assumed a vertically mounted dipole antenna with equal gain on the horizontal plane. We also assumed that all the UEs are distributed randomly in the whole room. We assumed that electrical properties of concrete employed in the simulations were: relative permittivity $\varepsilon_r = 6.76$, electrical conductivity $\sigma = 0.0023$ S/m, and permeability $\mu_r = 1$.

We defined the noise power at a UE in such a way that the signal-to-noise power ratio for the direct wave at P (30, 15, 1) was 20 dB in the case of SISO transmission from the point C (0.5, 15, 5) and used this noise power throughout all the simulations. TABLE I shows the simulation parameters. We ignored mutual coupling between antenna elements. We dealt with a downlink multi-user MIMO system from the BS to UEs and calculated the sum capacity.

TABLE I
SIMULATION PARAMETERS

| | |
|---|---|
| Number of BS antennas $N_t$ | 100 |
| Number of UE antennas | 1 |
| Number of UEs $K$ | 10 |
| UE Distribution $(x)$ | $0 \le x \le 30$ m |
| UE Distribution $(y)$ | $0 \le y \le 30$ m |
| UE Distribution $(z)$ | $0 \le z \le 2$ m |
| Antenna elements | Dipole |
| Carrier freqency | 5 GHz |
| Antenna spacing | $0.5\lambda$ |
| Maximum number of reflections | 2 |
| Material floor, ceiling and walls | Concrete |
| Number of trials | 1000 |

### B. Performance evaluation index of multiuser MIMO system

In this paper, we evaluated the signal-to-noise power ratio (SNR), interference-to-noise power ratio (INR), signal-to-interference power ratio (SIR), and channel capacity. We represent the effective channel after antenna selection in equation (3) by $\hat{\mathbf{H}}$,

$$\hat{\mathbf{H}} = \mathbf{H}\mathbf{W}_{\text{select}}. \tag{4}$$

We can see that $\hat{\mathbf{H}}$ is a $K \times K$ dimensional matrix. If we use the antenna selection described above, the instantaneous desired power $D_k$ for the $k$th user can be expressed as.

$$D_k = \overline{\left|\hat{h}_{kk} s_k\right|^2}. \tag{5}$$

The instantaneous interference power $J_k$, which the $k$th user receives from the other users,

$$J_k = \sum_{j=1, j\neq k}^{K} \overline{\left|\hat{h}_{jk} s_j\right|^2}. \tag{6}$$

Therefore, the signal-to-interference and noise power ratio (SINR) $\gamma_k$ for the $k$th user is calculated by using the noise power of $\sigma^2$ at each UE,

$$\gamma_k = \frac{D_k}{J_k + \sigma^2}. \tag{7}$$

Likewise, the SNR, INR, SIR for the $k$th user can be expressed as $D_k/\sigma^2$, $J_k/\sigma^2$, $D_k/J_k$, respectively. Furthermore, the

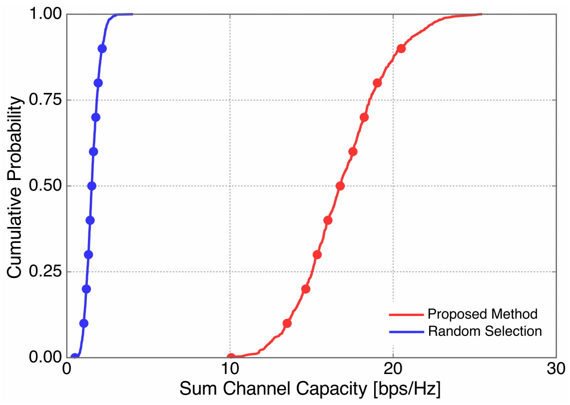


Fig. 3. CDF of Sum-capacity

channel capacity $C_k$ [bps / Hz] for the user $k$ can be expressed as follows:

$$C_k = \log_2(1 + \gamma_k). \tag{8}$$

Sum capacity of the whole room is given by

$$C_{\text{sum}} = \sum_{k=1}^{K} \log_2(1 + \gamma_k). \tag{9}$$

## V. Simulation Results

We describe the results of the antenna selection in this section. Figures 3, 4 and 5 show the cumulative distribution functions (CDFs) of the sum-capacity, SNR and INR, respectively for comparison, we evaluated the results using 40 randomly selected antennas. Both methods selected 40 antenna elements for each user. As shown in Fig. 3, it was confirmed that the proposed method can achieve higher sum-capacity than the random selection. To consider the reason of the result, we focus on the performance of SNR and INR. From Fig. 4, the proposed method improves the SNR performance. This result shows the proposed method can emphasize the desired signal power effectively. On the other hand, we can see from Fig. 5 that INR performance of the proposed method is slightly poorer than the random selection. It is considered that the selected antenna elements also emphasize the interference signal power. From these results, we find that the proposed method improves the sum-capacity by emphasizing the desired signal power and there is a possibility to improve the sum-capacity by reducing the interference signal power.

## VI. Conclusions

In this paper, we proposed loose beamforming by using simple antenna selection and evaluated the performances in the indoor multi-user massive MIMO environment through computer simulation. We showed that the antenna selection based on emphasis of the desired signal power is effective in loose beamforming. However, it was found that there is room for improvement in terms of INR performances. We will study an optimal antenna selection method to reduce interference for future work.

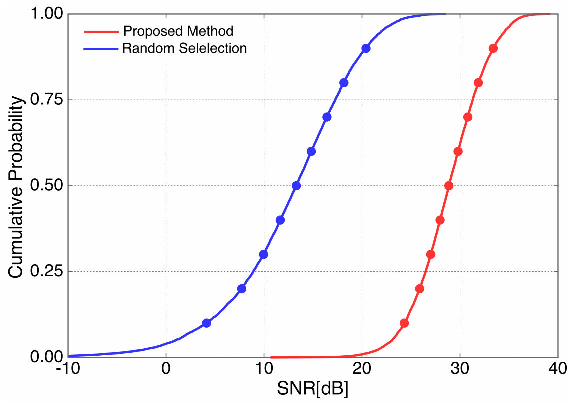


Fig. 4. CDF of SNR

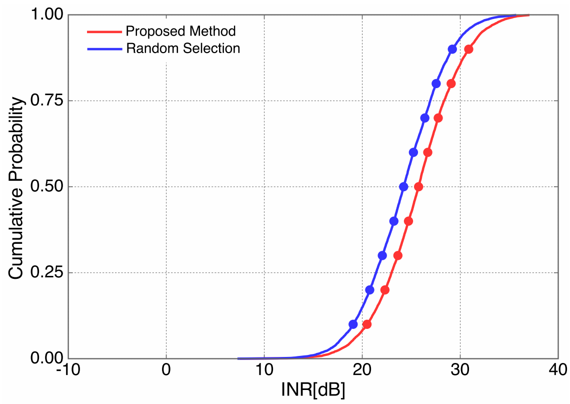


Fig. 5. CDF of INR

## Acknowledgment

This work was supported by JSPS KAKENHI Grant Number 17K06413.

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