Multi-beam Massive MIMO Using Analog Beamforming and DBF Based Blind Algorithm

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***Abstract*—Massive MIMO enables the improvement on the transmission rate without increasing the burden on the signal processing by employing a large number of antennas at a base station (BS). Channel state information (CSI) feedback scheme from terminal stations to BS gives a very large overhead when considering massive MIMO and implicit beamforming (IBF) with the calibration technique as the countermeasures are introduced. However, it is reported that CSI estimation itself has a large overhead when considering massive MIMO. In this paper, we propose analog-digital hybrid configuration using analog multi-beams with dielectric line array and lens and blind algorithm called Constant Modulus Algorithm (CMA) which does not need the CSI estimation. Via a computer simulation, the effectiveness of proposed configuration is verified.**

***Index Terms*—Massive MIMO, CSI estimation, multi-beam, dielectric line array, CMA**

I. Introduction

Recently, the concept of massive MIMO has been proposed [1], because massive MIMO realizes simple signal processing in Multi-user MIMO (MU-MIMO) transmission. However, when the Channel State Information (CSI) feedback is employed from the user terminals (UTs) to an access point (AP), this procedure gives a very large overhead compared with the communication data.

To solve this problem, an *implicit* beamforming method which eliminates the CSI feedback was proposed [3]. However, even if implicit beamforming is applied for the the massive MIMO system, the CSI estimation itself is still large overhead when considering the short packet communications such as Wireless LAN systems [4].

In this paper, we propose analog-digital hybrid configuration using analog multi-beams with dielectric line array and lens and blind algorithm called Constant Modulus Algorithm (CMA) [5] which does not need the CSI estimation. Via a computer simulation, the effectiveness of proposed configuration is verified.

II. Issues of CSI feedback and basic concept

Fig. 1 shows the frame format with CSI feedback. To initiate MU-MIMO transmission in the downlink channel, Period A is required as a negotiation time for user selection. As can be seen in Fig. 1, the CSI is estimated at the UTs by using the information in Period B, and the estimated CSI must be returned to the BS using Period C. When considering the MU-MIMO system, the number of transmit antennas (N) should be greater than or equal to the number of users (K). Therefore, Period B incurs a large overhead. Although user scheduling is effective in MU-MIMO transmission, as discussed in the previous section, Period C incurs a very large overhead when considering user scheduling.

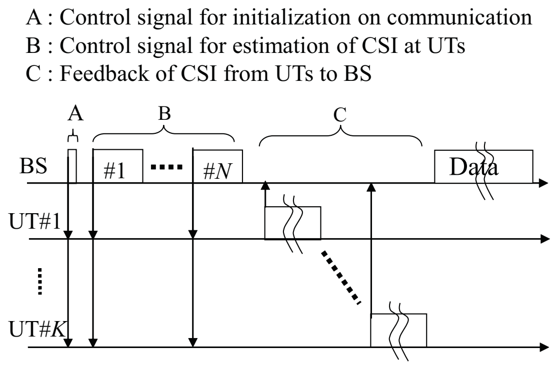

Fig. 1. Frame format for MU-MIMO transmission with CSI feedback.

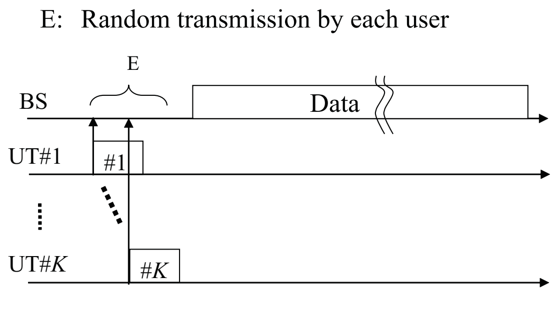

Fig. 2. Frame format without CSI estimation by proposed system.

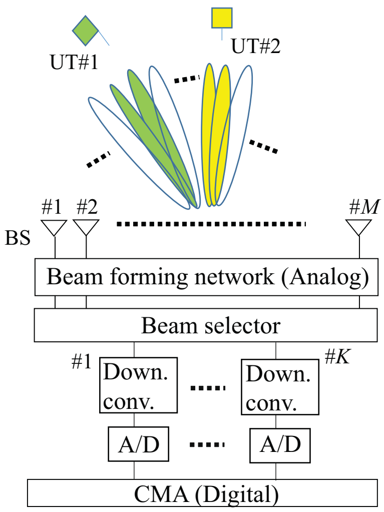

Fig. 3. Proposed configuration.

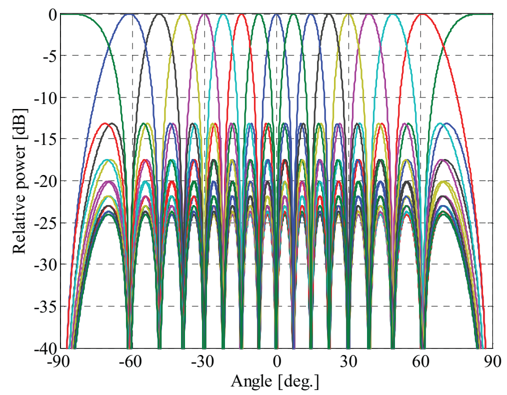

Fig. 4. Multi-beam patterns (16-beam).

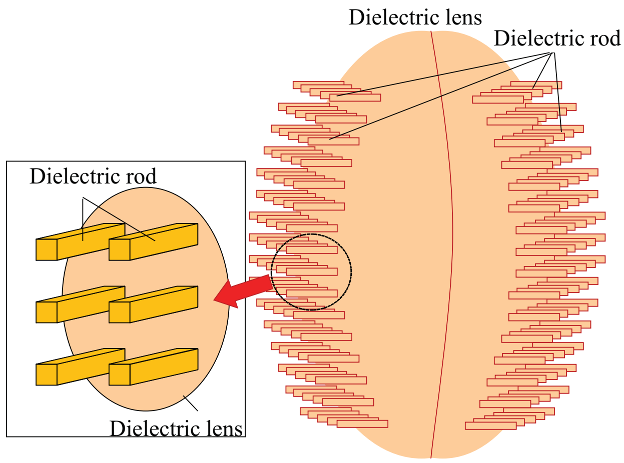

Fig. 5. Hardware configuration realizing multi-beam.

Fig. 2 shows the frame format which can eliminate the CSI estimation itself. We utilize narrow beam pattern for each user in massive MIMO system. Key point is *multi beamforming network*. When the CSI estimation is not required for multi-user transmission, the BS assigns the period of CSI estimation to the reception of uplink signals as shown in Fig. 2. Moreover, because multiple users are discriminated by multi beam-forming network, simultaneous transmission among multiple users in uplink is not needed. Therefore, asynchronous MU-MIMO transmission is realized without negotiation between the BS and users and overhead which gives low transmission efficiency does not ideally exist.

III. Proposed Method and Configuration

Fig.3 shows the configuration by the proposed method. In the proposed method, M orthogonal multiple beams are prepared at analog part. Fig. 4 shows an example of multi-beam patterns. The received powers for all the users are measured at the output of multiple beams. Selected number of beams is less than number of users (K). The user tracking is realized by the beam selection without CSI estimation.

Key question is how to realize the hardware of multi-beamforing network in the analog part. It is well known that butler matrix realizes multi-beam pattern [6][7]. Fig.5 shows an example which realizes multiple beams in the analog part. Because this configuration consists of dielectric line array and lens, multi-beam forming with low loss is expected. Moreover, because reduction effect in the antenna and circuit size due to dielectric is obtained, this circuit can be applicable for not only high frequency band but also micro frequency bands which are used in latest wireless communication systems. In addition, feeder circuit and antenna can be combined inside one circuit, because the production is possible by an injection molding.

The MU-MIMO transmission without CSI estimation for each user is realized by the circuit in Fig.5. However, when direction of arrivals (DoAs) are closed among users, same beam must be utilized for each user. Moreover, the signals by users except intended user are actually received at side lobe and the interference cannot be realized by only multi-beamforing network. In order to realize the perfect interference rejection, digital beam forming (DBF) based blind adaptive array is introduced at the output of selected multi beams. In this paper, constant modulus algorithm (CMA) is used as the blind adaptive algorithm [5]. The CMA works only received signals and does not need CSI. In addition, CMA reduce the interference with environment where carrier and timing offset exist. Hence, hybrid configuration with multi beams in the analog part and blind algorithm in the digital part is suitable for efficient transmission in massive MIMO system.

IV. SINR Characteristics by Proposed Method

To verify the basic performance of proposed method, the computer simulation is carried out. When two user exist in multi-path environment, the signal to interference plus noise power ratio (SINR) is evaluated. In this simulation, single cluster model is assumed and angular spread at the BS assumed to be 10. The signal to noise power ratio (SNR) per

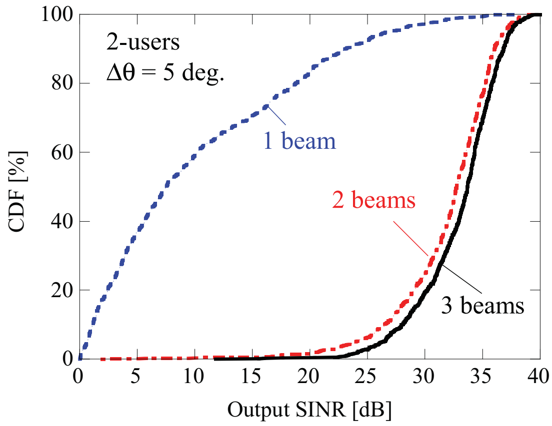

Fig. 6. CDF of SINR ($\Delta\theta = 5°$).

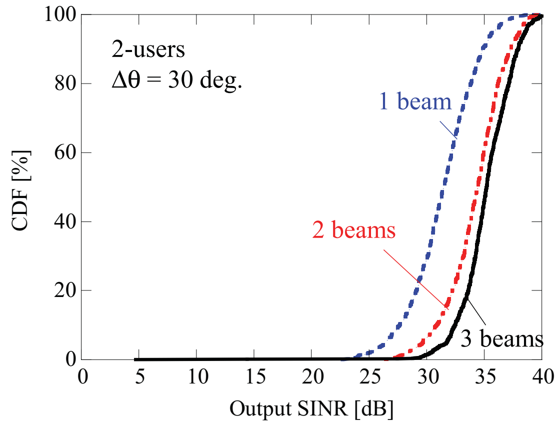

Fig. 7. CDF of SINR ($\Delta\theta = 30°$).

antenna at the BS is 20 dB. The number of multi beams is 64. Least square method is adopted as the optimization algorithm regarding the CMA [5]. The propagation condition is changed and the number of trials is 10,000.

Cummulative Density Function (CDF) of SINR is plotted in Figs. 6 and 7 when the difference of DoA ($\Delta\theta$) is set to be 5° and 30°. Selected number of beams for each user is changed from one to three. As can be seen in Fig. 6, the SINR is almost 0 dB with CDF=1% when $\Delta\theta = 5°$. On the other hand, the SINR with 2 beams is greater than 20 dB even in CDF=1%. As shown in in Fig. 7, although the SINR by only 1 beam without CMA is greater than 20 dB with CDF=1% when $\Delta\theta = 30°$, the further improvement in the SINR is observed thanks to the combination of CMA.

The SINR versus difference of DoAs between two users ($\Delta\theta$) with CDF=10% is plotted in Fig. 8. Selected number of beams for each user is changed from one to three. As can be seen in Fig. 8, the SINR is greatly decreased when $\Delta\theta$ is less than 10°. On the other hand, it is observed that the SINR is greater than 25 dB when the number of beams is greater equal to two. Although the results are not plotted in this figure, we confirmed that the SINR is not improved even if the number of beams is greater than three. From these results, it is shown that our multi-beam massive MIMO is effective for high transmission quality.

V. Conclusion

In this paper, we have proposed analog-digital hybrid configuration using analog multi-beams with dielectric line array and lens and blind algorithm called Constant Modulus Algorithm (CMA) which does not need the CSI estimation. Via computer simulation, although the SINR is almost 0 dB with CDF=1% when the difference of DoAs is 5°, the SINR with 2 beams is greater than 20 dB even in CDF=1%.

Acknowledgments

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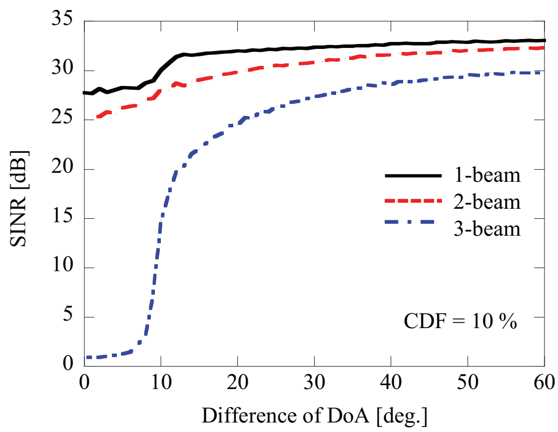

Fig. 8. SINR Characteristics versus DoA of interference.

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