Throughput performance on IEEE802.11ac based massive MIMO considering calibration errors

Kentaro Nishimori†, Takefumi Hiraguri*, Toshiyuki Ogawa*, and Hiroyoshi Yamada†
† Faculty of Engineering, Niigata University
Ikarashi 2-nocho 8050, Nishi-ku Niigata-shi, 950-2181 Japan
*Department of Electrical and Electronics Engineering, Nippon Institute of Technology
4-1 Gakuendai,Miyashiro-machi, Minamisaitama-gun, Saitama Pref., 345-8501 Japan
Email : nishimori@m.ieice.org

***Abstract*—This paper describes the effectiveness of calibration technique for *implicit* beamforming which enables the transmission without the channel state information (CSI) feedback in massive MIMO system. First, we address the calibration technique using the circulation of self transmit signal. The effectiveness of calibration method is next verified by using 16-element testbed for the massive MIMO system. Finally, the throughput performance by the IEEE802.11ac based massive MIMO transmission with and without CSI feedback is verified when considering calibration errors which are obtained by the testbed.**

***Index Terms*—massive MIMO, channel state information, calibration, implicit beamforming, IEEE802.11ac**

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]. In this paper, we address the calibration technique which is essential for the implicit beamforming. The effectiveness of calibration method is next verified by using 16-element testbed. Finally, the effectiveness of implicit beamforming method considering the calibration errors (phase and amplitude) is verified by the throughput evaluation using IEEE802.11ac based massive MIMO transmission.

II. Principle of Calibration Method and Testbed

Fig. 1 shows the configuration of the basic calibration circuit [4]. The transmitted signals from Tx1 and 2 are divided by the directional coupler and these signals are received by Rx2 and 1, respectively. The ratio of the complex amplitudes at k-th transmitter and receiver (T_k and R_k, $k = 1 \sim N$), T_k/R_k, is the calibration value [4]. Here, N is the number of array antennas. Actually, $(T_k/R_k)/(T_1/R_1)$ is obtained by the two loops in Fig. 1.

Fig. 2 shows the configuration of the testbed to realize the calibration scheme. The main target of this testbed is to clarify

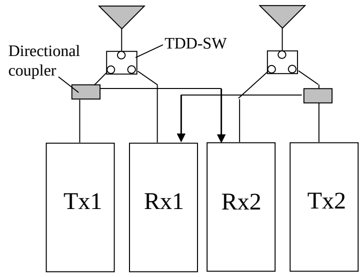

Fig. 1. Basic principle of calibration method.

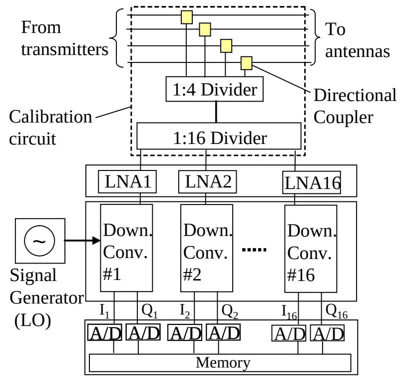

Fig. 2. 16-element receivers and calibration circuit.

the characteristics of amplitude and phase errors between 16-element receiving system. T_iR_j ($i = 1 \sim 4$, $j = 1 \sim 16$) can be obtained by using the directional coupler and divider, where T_i and R_j are the complex amplitude for transmitter and receiver, respectively. The number of transmitters is four and 4-user multiuser transmission is assumed. The radio frequency is 2.5 GHz and bandwidth is 50 MHz.

III. Throughput Performance Considering Calibration Error

In order to verify the effectiveness of the implicit beamforming method with the calibration error, we conducted the simulation when considering IEEE802.11ac signal format. The main simulation parameters are shown in Table I. The path loss by the ITU-R model [5] and i.i.d. Rayleigh fading are assumed in this simulation. The Block Diagonalization is employed

TABLE I
SIMULATION PARAMETER

Number of transmit antennas (N_T)	16
Number of receive antennas (N_R)	1
Number of users (N_U)	4
Frequency (f_c)	5200 MHz
Bandwidth	40 MHz
Transmit distance (d)	1 $\sim$ 50 m
Transmit power	19 dBm
Antenna gain	2 dBi
NPDA (Null Data Packet Announcement)	60μs
NDP (Null Data Packet)	100μs
NDP (for Implicit beamforming)	40 μs
BR (Beamforming Report)	1400 μs (Max.)
BA (Beamforming Report Polling)	52μs
BA (Beamforming ACK)	64μs
BAR (Beamforming ACK Request)	56μs
Frame aggregation	5000 $\sim$ 40000 Byte

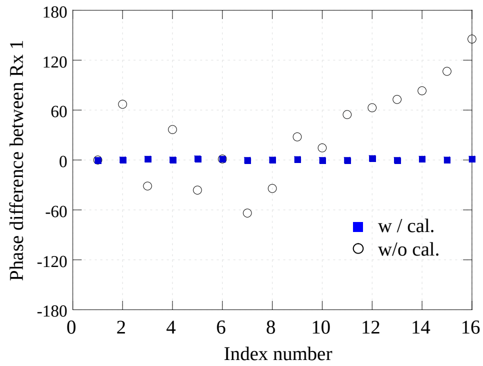

Fig. 3. Phase differences before and after calibration.

as the algorithm for MU-MIMO transmission [2]. We used a transmission rate that is calculated from the modulation scheme in IEEE 802.11ac standard.

Fig. 3 shows the phase errors on receivers by the testbed in Fig. 2 before and after calibration. Fig. 3 shows the relative phase errors of Rxk against to Rx1. As can be seen in Fig. 3, phase errors varies for each receivers and these values range from –60 to 150 degrees. On the other hand, when applying the calibration circuit in Fig. 2, phase errors can be eliminated, and these values are reduced to less than 1.5 degrees.

Fig. 4 shows the average transmission rate (TR) versus the transmit distance between the AP and UT, d, when considering the calibration errors in Fig. 3. As can be seen in this figure, the transmission rate is greatly decreased: the TR without calibration is 240 Mbps lower than the ideal TR at $d = 6$ m. On the other hand, the TR by the calibration is almost same with the ideal TR.

Fig. 5 shows the average throughput when considering the control signals in Table I. The results with and without the CSI feedback are shown in this figure. When the calibration is adopted, the throughput is higher than that with the CSI feedback regardless of the transmit distance : the effect by the implicit beamforming is ideally obtained. On the other hand, the throughput without calibration is lower than that

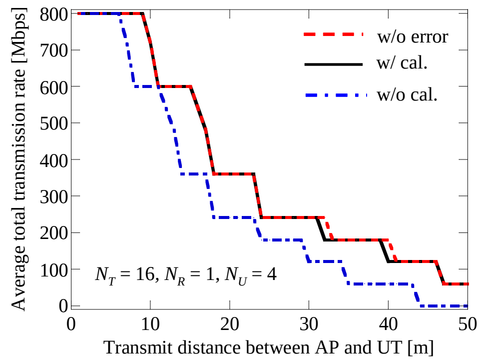

Fig. 4. Throughput versus data size.

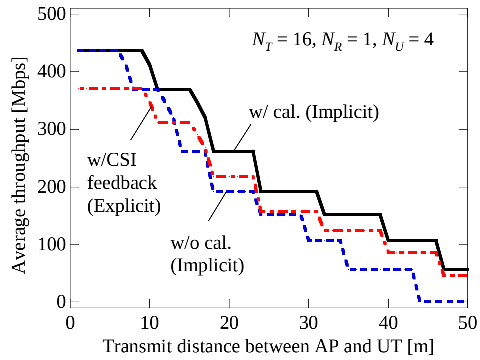

Fig. 5. Throughput versus transmit distance.

with the CSI feedback when d is greater than 13 m. Therefore, it is essential to apply the implicit beamforming with the calibration technique for the massive MIMO transmission.

IV. CONCLUSION

In this paper, the effectiveness of implicit beamforming method considering the calibration errors (phase and amplitude) is verified by the throughput evaluation using IEEE802.11ac based massive MIMO transmission. It is found that the implicit beamforming with the calibration technique is essential for the massive MIMO transmission when considering both physical and medium access control layers.

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