# Performance Evaluation of Multi-beam Massive MIMO Using Multi-level Modulation

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*Abstract* – **Massive MIMO transmission has been attracted much attention as one of key technologies in next-generation mobile communication system, because it enables improvement in service area and interference mitigation by simple signal processing. Multi-beam massive MIMO configuration has proposed that utilizes the beam selection with high power in analog part and blind algorithm such as constant modulus algorithm (CMA) which does not need channel sate information (CSI) is applied in digital part. In this paper, in order to achieve the further higher transmission rate, the amplitude and phase compensation scheme is proposed when using the CMA with amplitude and phase modulation scheme.**

*Index Terms* — **Massive MIMO, Multi-beam, constant modulus algorithm, quadrature amplitude and phase modulation**

## 1. Introduction

Recently, the concept of massive MIMO has been proposed, because massive MIMO realizes simple signal processing in multi-user MIMO (MU-MIMO) transmission [1]. However, when the Channel State Information (CSI) feedback is employed from the user terminals (UTs) to base station (BS), this procedure gives a very large overhead compared with the communication data [2]. Analog and digital hybrid configuration in massive MIMO, which realizes both simple signal processing and low power consumption, has been proposed [2]. However, because beam-scan with analog phase shifters for the desired users is required in this configuration, overhead arises due to initial user tracking.

Multi-beam massive MIMO configuration has proposed that utilizes the beam selection with blind algorithm such as constant modulus algorithm (CMA) which does not need channel sate information (CSI) is applied in digital part [3]. We have evaluated QPSK signals, because the CMA basically focuses on the constant amplitude modulation [4].

In this paper, the amplitude and phase compensation scheme is proposed when using the CMA with amplitude and phase modulation scheme such as quadrature amplitude and phase modulation (QAM) for multi-beam massive MIMO configuration without CSI estimation. The effectiveness of proposed method is verified by the computer simulation.
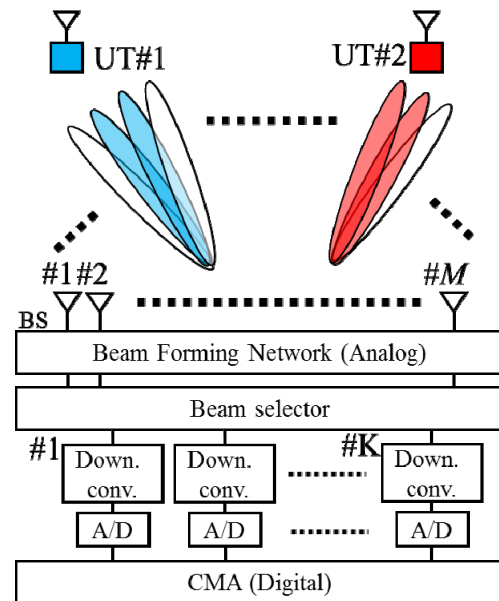
## 2. Proposed method



Fig. 1. Configuration by using multi-beam massive MIMO and CMA.

Fig.1 shows the configuration by using multi-beam massive MIMO and CMA. In this configuration, $M$ orthogonal multiple beams are prepared at analog part. 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.

In order to realize the perfect interference rejection after beam-forming network in the analog part, 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 [3]. The CMA works only received signals and does not need CSI.

Fig.2 shows an example of constellation on 16QAM when applying the CMA in Rayleigh fading environment. Because the CMA does not control the phase, the signals are rotated and amplitude is changed due to fading channel. Although the differential detection, which does not need amplitude and phase offset compensation, can be applicable for QPSK, the coherent detection is essential for QAM. In this paper, the amplitude and phase compensation method is introduced as the processing after the CMA by using training signal used for terminal's identification. When $P_k$
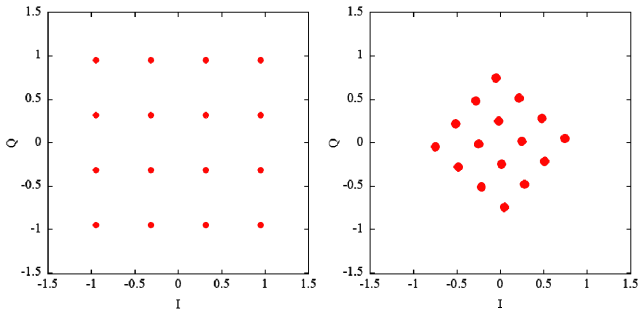
(a) 16QAM signals     (b) Signals after CMA

Fig. 2. Example of constellation.

and $P'_k$ are $k$-th transmit signal and receive signal after the CMA, respectively, compensated amplitude, $A$ and phase, $\theta$ is denoted as

$$A = \frac{1}{n}\sum_{k=1}^{n}\frac{|P'_k|}{|P_k|},\qquad(1)$$

$$\theta = \frac{1}{n}\sum_{k=1}^{n}(\tan(P_k)-\tan(P'_k)),\qquad(2)$$

where $n$ is number of training bits. The received signal can be compensated by using $A$ and $\theta$.

## 3. Effectiveness of proposed method by computer simulation

The effectiveness of proposed method is verified by using QAM signals when considering Rayleigh fading environment. The numbers of the receiving antennas and beams are set to be 64. The number of UTs is two. The angular spread is 10 degrees for each UT. The number of waves is eleven for each UT. The data length is 1,024. The data smoothing size for weight update CMA is 16. The trial number is 10,000 times. The training bits for the compensation of amplitude and phase errors after the CMA are 5.

Fig.3 shows the selection probability of modulation scheme versus the signal to noise power ratio (SNR) by multi-beam processing, CMA, and proposed amplitude and phase compensation method. The difference of angle of arrival (AoA) between two users is 60 degree. As can be seen in Fig.3, the higher level QAM can be selected, when the SNR is increased.

Fig.4 shows bit rate versus the SNR. In Fig.4, the modulation scheme with maximum bit rate is selected to when a bit error rate (BER) is less than $10^{-3}$. The difference of AoA between two users is set to be 0 to 60 degrees. As can be seen in Fig.4, the bit rate is improved when the AoA is wider and the performance is saturated when the AoA is greater than 30 degree. From these result, it is shown that QAM signals can be applicable for the multi-beam Massive MIMO system by using the proposed amplitude and phase compensation method.
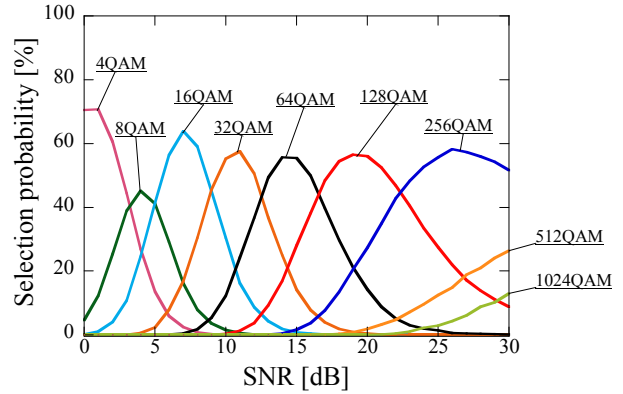


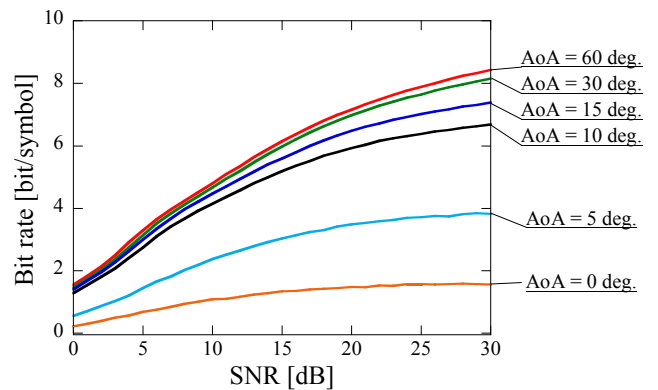Fig. 3. Selection probability versus the SNR.



Fig. 4. Bit rate versus the SNR

## 4. Conclusion

In this paper, we have proposed the amplitude and phase compensation scheme is proposed when using the CMA with QAM for multi-beam massive MIMO configuration without CSI estimation. From computer simulation, the higher level QAM can be selected and bit rate is improved, when the SNR is increased by the proposed method.

## References

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