Spectral-Efficient Near-Field Rainbow Beam Training

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Abstract

Near-field beam training is essential for acquiring channel state information in 6G extremely large-scale massive MIMO systems. While existing approaches exploit the beam split effect of wideband signals to reduce time-domain pilot overhead [1], utilizing the full bandwidth for training imposes spectral resource consumption and reduces data throughput. To address this, we propose a spectral-efficient beam training scheme utilizing sparse subcarriers to minimize frequency overhead while ensuring robust beam alignment.

Ⅰ. Introduction

Existing research has leveraged the beam split capability of wideband signals to achieve rapid beam alignment [1]. However, these methods occupy the entire bandwidth for beam training, resulting in low spectral efficiency. By ensuring that the spacing between beams generated by active subcarriers remains within the null-to-null beamwidth, we maintain full spatial coverage with significantly reduced frequency resource consumption. Leveraging this property, we propose both on-grid and off-grid beam training methods to achieve efficient and accurate beam alignment.

Ⅱ. Method

On-grid method: For efficient scanning, we sparsely activate subcarriers subject to near-field beamwidth constraints, ensuring that the spacing between adjacent beams remains strictly within the null-to-null beamwidth to maintain seamless spatial coverage.

Off-grid method: We construct an offline array gain dictionary. During the online phase, by matching the measured gain distribution against this dictionary, we identify the best-fitting grid point. we mitigate quantization errors and enhance off-grid accuracy.

Ⅲ. Conclusion

Fig. 1 presents the impact of SNR on different beam training schemes.

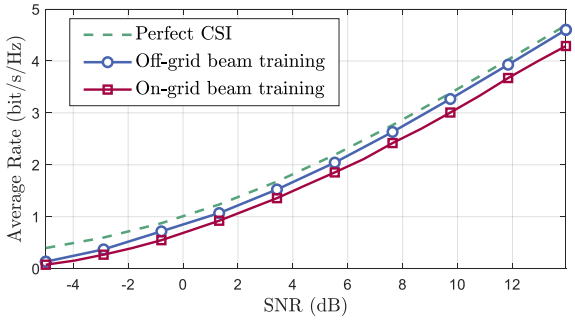

Fig. 1. Average rate performance vs. SNR.

ACKNOWLEDGMENT

This research was supported by Brain Pool program funded by the Ministry of Science and ICT through the National Research Foundation of Korea (RS2025-25456394).

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