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Machine Learning Techniques for Terahertz Channel Estimation

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Terahertz (THz)-band has been envisioned for the sixth generation wireless networks thanks to its ultra-wide bandwidth and very narrow beamwidth. Nevertheless, THz-band transmission faces several unique challenges, one of which is *beam-split* which occurs due to the usage of subcarrier-independent analog beamformers and causes the generated beams at different subcarriers split, and point to different directions. In this work, we introduce machine learning techniques for THz channel estimation in the presence of beam-split.

Firstly, we introduce a federated multi-task learning (FMTL) approach, wherein the users transmit only the model parameters instead of the whole dataset, for THz channel and user direction-of-arrival (DoA) estimation to improve the communications-efficiency. We first propose a novel beamspace support alignment technique for channel estimation with beam-split correction. Then, the channel and DoA information are used as labels to train an FMTL model. By exploiting the sparsity of the THz channel, the proposed approach is implemented with fewer pilot signals than the traditional techniques. Compared to the previous works, our FMTL approach provides higher channel estimation accuracy (see Fig.1) as well as approximately 25 (32) times lower model (channel) training overhead, respectively.

Secondly, we examine the near-field scenario, which should be considered in THz communications since the signal wavefront becomes spherical in the near-field due to high frequency operations. Therefore, in addition to the conventional far-field models, the near-field signal model should be considered for channel acquisition in THz systems. Unlike prior works which mostly ignore the impact of *near-field beam-split* (NB) and consider either narrowband scenario or far-field models, this work introduces both a model-based and a model-free techniques for wideband THz channel estimation in the presence of NB. Thus, we propose an NB-aware (NBA) THz channel estimation technique based on orthogonal matching pursuit (OMP), henceforth called NBA-OMP. For the model-free approach, we devise an FL approach, which is more communication-efficient as compared to conventional CL-based methods. We design a novel NBA dictionary, whose columns are composed of near-field subcarrier-dependent steering vectors spanning the whole angular spectrum and the transmission ranges up to the Fraunhofer distance. Then, we introduce our proposed NBA-OMP approach for wideband THz channel estimation.

The key idea of the proposed approach is that the degree of beam-split is proportionally known prior to the direction-of-arrival (DoA)/range estimation while it depends on the unknown user location. Thus, we employ the OMP algorithm, which accounts for this deviation thereby *ipso facto* compensating the effect of NB. We have conducted several numerical experiments to demonstrate the effectiveness of the proposed approach in comparison with the existing THz channel-estimation-based methods

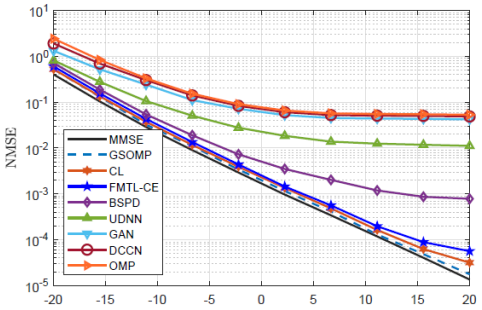

Figure 1. Channel estimation performance of the proposed FMTL approach in the presence of beam-split.