technische universität dortmund

Faculty EE/IT
Communication Networks Institute (CNI)
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Master Thesis

Characterization of mmWave Reflecting Surfaces for Rapid Intelligent Cellular Coverage Enhancements

Motivation and Problem Statement

With the recent move of 5G networks to incorporate millimeter-wave (mmWave) spectrum, scalability of both network capacity and peak data rate is achieved. However, increased free-space path loss, penetration loss, and diffraction reduce cell coverage, and further, make it particularly prone to shadow regions. Despite the use of beamforming antenna arrays, network operators will perceive outage regions in the intended coverage of the mmWave network, or alternative, regions where there are too few multipath opportunities such that the connection may be easily blocked. Therefore, on-going discussions about 6G mmWave networking focus heavily on reconfigurable intelligent surfaces (RISs) and metasurfaces which, for example, may be mounted on building facades. These active reflectors allow for tuning of the reflection angle of impinging electro-magnetic (EM) waves such that the mmWave coverage can be steered to where it is required, see Fig. 1. As a result, mmWave connectivity can be enhanced significantly [1]. However, the proposed technology is an active concept which requires a power supply for the phase shifters, and moreover, a signaling link to the network which is not compatible with current 5G networks. Future scalability in terms of size and price are yet unclear.

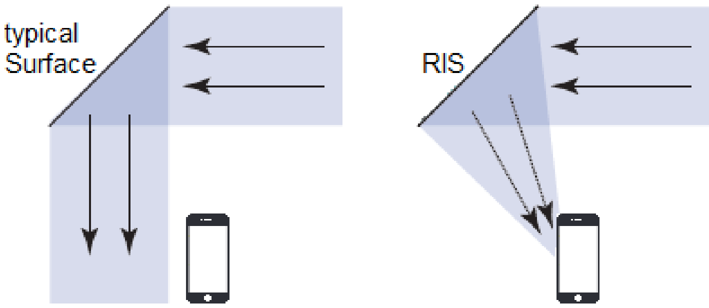

Figure 1: Changing the reflection characteristics for a better connectivity.

In literature, passive reflectors have been studied using reflective materials such as copper plates or aluminum foil wrapped geometries [2, 3]. By varying the mounting position and the geometry, RIS-equivalent coverage enhancements can be achieved, however, the reflection characteristics cannot be adapted after the deployment [4]. Yet the primary needs of network operators can nonetheless be fulfilled as further reflectors can be mounted to serve other regions. For network planning purposes, mmWave operators will thus require a model on the reflection channel similar to existing ones for RISs [5]. This thesis aims to provide such a model based on EM simulations and to confirm it via mmWave lab measurements.

Potential Goals

This master thesis brings together several interesting topics such as the 5G standard, reflecting surfaces, and future 6G mmWave networking with a particular focus on optimizing mmWave propagation. Expect to dive into current RIS/metasurface literature and become an expert on reflector-based channels and according EM tooling. Afterwards you will build up your own passive reflection model and evaluate it via measurements and simulations.

Potential topics your master thesis will address:

- *Survey:* Research state-of-the-art reflecting surfaces and channel models.
- *Modeling*: Characterize the reflection of passive reflectors in regards to main reflection lobe gain and half-power beamwidth. Derive the expected signal strength at the intended UE positions using the reflector-based channel. Consider the impacts of adapting both the reflector geometry and modular constellation. Investigate the effect of the carrier frequency.
- *Verification*: Investigate the validity of the model using our mmWave channel sounder. Using ray-tracing, you may further study the gains in real environments such as a city center or a manufacturing floor.

Requirements

- Interest in 5G standard and mmWave communications
- Participation in MRN 1+2 lectures (Grade: *excellent/good*); other CNI lectures are a plus
- Excellent English skills; highly desirable: Willingness to write thesis in English
- Basic MATLAB/Python and LaTeX/TikZ skills

References

[1] K. Heimann, B. Sliwa, M. Patchou, and C. Wietfeld, “Modeling and simulation of reconfigurable intelligent surfaces for hybrid aerial and ground-based vehicular communications,” in *24th ACM Int. Conf. on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM)*, Dec. 2021.

[2] W. Khawaja, O. Ozdemir, Y. Yapici, F. Erden, and I. Güvenc, “Coverage enhancement for NLOS mmWave links using passive reflectors,” *IEEE Open Journal of the Communications Society*, vol. 1, pp. 263-281, Jan. 2020.

[3] N. A. Abbasi, J. Gomez-Ponce, S. M. Shaikbepari, S. Rao, R. Kondaveti, S. Abu-Surra, G. Xu, C. Zhang, and A. F. Molisch, “Ultra-wideband double directional channel measurements for THz communications in urban environments,” in *IEEE Int. Conf. on Communications (ICC)*, Jun. 2021.

[4] J. S. Romero-Pena and N. Cardona, “Irregular multifocal reflector for efficient mmWave propagation in indoor environments,” in *14th European Conf. on Antennas and Propagation (EuCAP)*, Mar. 2020.

[5] Ö. Özdogan, E. Björnson and E. G. Larsson, "Intelligent Reflecting Surfaces: Physics, Propagation, and Pathloss Modeling," in *IEEE Wireless Communications Letters*, vol. 9, no. 5, pp. 581-585, May 2020.

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