A Ray-Tracing Model for Millimeter-Wave Radio Propagation in Dense-Scatter Outdoor Environments

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Extended Abstract

There is great expectation about the characteristics of the future 5G wireless standard, which has led to intensive research in several collaborating areas. An important part of this effort is aimed at the development of proper propagation channel models. For the previous mobile technologies, ray tracing methods were able to characterize the outdoor channel with good accuracy, by mainly using building representations [1, 2]. However, the small wavelength associated with millimeter waves that are considered by 5G wireless applications impose the need to analyze the effects from a wide range of smaller obstacles (trees, poles, etc.) that are present in the outdoor environments, blocking or scattering the transmitted signals.

This contribution describes a model for millimeter wave propagation of ultra wideband signals (UWB) based on a 2½ D ray-tracing algorithm over a realistic urban environment. City blocks are represented by right prisms with arbitrary convex polygonal bases. The blocks are tall enough for propagation over them to be neglected. The city blocks, as well as the horizontal plane representing the ground, have their own constitutive properties (permeability, conductivity, dimensions and roughness). Trees, modeled by canopy and trunk, as well as light and traffic poles are located near the curbs. The canopies have a scattering pattern proposed by Ulaby et al. [3]. Scattering by tree trunks and poles modeled with basis on the Uniform Diffraction Theory (UTD) for right circular cylinders [4].

The ray-tracing model is based on the image method [2]. The projections of the scattering centers of obstacles (canopies, tree trunks, poles, and vertical block edges) onto the ground are treated as virtual sources, each generating its own set of two-dimensional images with respect to the edges of the block bases, in addition to that of the actual source. These sets of images interact to define two-dimensional rays representing up to eight reflections on edges of the block bases and a single diffraction or scattering (in arbitrary order). Corresponding aerial and ground reflected rays are then obtained from each two-dimensional ray, considering the heights of the source and observation point, as well as the lengths of the above obstacles.

The transmitter and receiver are modeled by planar and linear arrays, respectively. For each channel, the direction of departure of the strongest ray is used to steer the main lobe of the transmitting array. Considering the interaction (reflection, diffraction, scattering) of each ray with the environment, its contribution to the received signal is determined, for each of the two orthogonal linear polarizations and a single millimeter wave frequency. This procedure is repeated for closely and equally spaced frequencies over an ultra-wide frequency band to determine the channel transfer function. An inverse Fourier Transform then provides the corresponding power-delay profile. Routes with both line-of-sight and non line-of-sight conditions were simulated, considering the obstacles characterized above. Results to be discussed include variations in the power delay profile and the corresponding mean delay and delay spread along the routes, for the co- and cross-polarized channels.

References

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