UWB Millimeter Wave Propagation Model for Realistic Outdoor Environments: Dense Scatter by Trees and Non-specular Scattering Effects

Jean C. Silva and Emanoel Costa*
Centro de Estudos de Telecomunicações, Pontifícia Universidade Católica do Rio de Janeiro (CETUC PUC-Rio); Rua Marquês de São Vicente 225; 22451-900 Rio de Janeiro, RJ, Brazil; jean.carneiro.eng@gmail.com, epoc@cetuc.puc-rio.br

This contribution describes a 2½D ray-tracing model for outdoor propagation of ultra wideband (UWB) millimeter wave signals. The urban environment is specified by a combination of building blocks, trees, and poles (lighting, traffic and energy distribution) over a horizontal ground plane. Building blocks are represented by right prisms with convex polygonal bases with individual constitutive parameters (dielectric constant, conductivity, and roughness). Trees are modeled by canopies above associated trunks. Poles and trunks are modeled by smooth, right circular cylinders.

The ray-tracing model is based on the image method. The ground projections of the scattering centers of obstacles (canopies, tree trunks, poles, vertical block edges and centers of building faces) are treated as virtual sources, similar to that of the access point. Each generates its own set of multiple-order images with respect to the edges of the block bases. Using the sets of images, 2D rays are traced between the ground projections of the access and observation points. Aerial and ground-reflected 2½D rays are then obtained from each 2D ray, considering the heights of the end points. In addition to a possible direct ray, the following interactions with the environment are included: specular reflection by vertical block faces; diffraction by vertical edges of blocks, tree canopies, trunks, or poles; reflection by tree canopies, trunks, or poles; scattering by tree canopies; and diffuse scattering by vertical block faces. Up to eight interactions with the environment are allowed per ray, with at most one diffraction or scattering, at any order along it.

The contribution of each ray to the received signal is determined, combining its multiple interactions (reflection, diffraction, scattering) with the environment, for each of the two orthogonal linear polarizations and the central millimeter wave frequency of an UWB channel. The effects from specular reflections are determined by the product of a loss factor with the smooth-surface Fresnel coefficient. Appropriate Uniform Theory of Diffraction (UTD) models for wedges or cylinders are used to represent diffraction effects by vertical block edges, poles, trunks and canopies, respectively. Scattering effects by canopies and diffuse reflections by rough vertical faces are represented by proper models. Blocked rays by trunks or poles are eliminated and attenuation due to propagation through tree canopies are considered. The axes of the main lobes of the transmitting and receiving arrays are aligned with the directions of departure and arrival of the strongest ray so obtained, remaining fixed for calculations at other frequencies of the same channel. The complex amplitude of the field long each ray is then corrected for antenna array effects. The above 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 associated power-delay profile.

Finally, environments selected for measurement campaigns and described in the literature will be represented. The proposed model will then be applied to simulate propagation along routes with both line-of-sight and non-line-of-sight conditions. Results to be compared with the corresponding experimental data and discussed include variations in the power delay profile and the related mean delay and rms delay spread along the routes, for the co- and cross-polarized channels.