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Editorial

Advances in Propagation Modeling for Wireless Systems

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Advanced wireless systems face an ever-increasing number of challenges, such as the limited availability of the radio frequency spectrum and the demand for faster data transmissions, better quality of service, and higher network capacity. Yet, the true challenge faced by new communication technologies is to achieve the expected performance in real-world wireless channels. System designers classically focus on the impact of the radio channel on the received signals and use propagation models for testing and evaluating receiver designs and transmission schemes. The needs for such models evolve as new applications emerge with different bandwidths, terminal mobility, higher carrier frequencies, new antennas, and so forth. Furthermore, channel characterization also yields the fundamental ties to classical electromagnetics and physics as well as the answers to some crucial questions in communication and information theory. In particular, it is of outstanding importance for designing transmission schemes which are efficient in terms of power or spectrum management. Advanced channel modeling is also recognized as a major topic by two on-going research programs in Europe: the Network of Excellence in Communications NEWCOM++ and the European COST 2100 Action "Pervasive Mobile & Ambient Wireless Communications." While the former only includes a number of European partners (see http://www.newcom-project.eu/), the latter is a large network of coordinated national research projects in the fields of interest to participants coming from different EU and non-EU countries (see http://www.cost2100.org/).

The objective of this special issue, published following an initiative by NEWCOM++ and COST 2100 partners, is to highlight the most recent advances in the area of propagation measurement and modeling. We received 25 high-quality submissions, which were peer-reviewed by experts in the field, and we selected 9 papers for inclusion in this special issue. These articles cover the gamut from electromagnetic models to experimental characterizations of complex environments as well as the measurement-based parameterization and analysis of geometry-based stochastic models.

Three papers deal with the modeling of complex media or environments. One of the challenges of emerging or future technologies is indeed the large variety of application scenarios, for which classical models might not apply. Furthermore, more and more techniques rely on adaptive and/or multiple antenna signal processing, so that the dynamic and spatial behaviors of the propagation channel should be covered as well.

The paper by Molina-Garcia-Pardo et al. proposes the experimental characterization and modeling of propagation in tunnels, at various frequencies in the 2.8–5 GHz band. Path loss, large-scale correlation, and fading statistics are derived from measurements conducted by means of a vector network analyzer. It is shown that the tunnel behaves as a low-loss waveguide, and the fading is strongly dependent on the distance. An extension to a multiple-input multiple-output (MIMO) channel model is also presented.

The paper by Moraitis et al. presents experimental results related to the propagation inside a passenger aircraft, at various frequencies between 1.8 and 2.45 GHz. Empirical formulas are inferred for the path loss, slow- and fast-fading, and interference modeling. A comparison with a physical-optics-based ray-tracing model is also successfully conducted.

The paper by Cheffena and Ekman combines fading measurements from 2.45 up to 60 GHz with wind speed data to study the dynamic effects of swaying vegetation on radiowave propagation. A simulation model based on a multiple mass-spring system is developed and empirically validated. The outputs of the model are the fading first- and second-order statistics.

Two papers cover the area of physical models. Physical models traditionally consist of electromagnetic theory combined with engineering expertise that allows making reasonable assumptions about the propagation mechanisms involved. Provided that the correct propagation phenomena are identified, such theoretical models are capable of making very accurate predictions in a deterministic manner. The output being specific to particular locations rather than being an average value, the model can be applied to very wide ranges of system and environment parameters, certainly well beyond the range within which measurements have been made. The two drawbacks of such models are the computational effort and the required accuracy of the geometrical and electrical properties of the environment. These two issues are dealt with by the following papers.

The paper by Jemai and Kürner investigates the performance boundaries of a calibrated ray-tracing model in indoor scenarios. It is indeed well known that the precision of ray-tracing tools is limited by the accuracy of the environmental description. The proposed approach improves the prediction accuracy by means of a calibration procedure, whose sensitivity is further analyzed in the paper.

The paper by Valcarce et al. applies a finite-difference time-domain (FDTD) method in the framework of WiMAX femtocells. Two optimization methods are proposed to tackle the issue of computational complexity. Calibration is also carried out. The paper eventually presents mobile WiMAX system-level simulations that make use of the developed model.

Finally, the last set of papers deals with geometry-based models for MIMO systems. In geometrical channel models, the channel impulse response is related to the location of scatterers, the location of which is chosen stochastically. A further important generalization is the existence of multiple clusters of scatterers. Geometry-based models emulate the physical reality and thus reproduce many effects implicitly: small-scale fading, correlation of the signals at different antenna elements, and even large-scale changes of delays and directions. Due to the close relationship with physical reality, it is also relatively easy to parameterize that model, for example, from measurement results. In a first step, the matrix impulse responses are measured with a channel sounder. High-resolution algorithms are then employed to extract the required information.

Two papers deal with multipath clustering. The paper by Czink et al. presents the so-called Random-Cluster Model, which is a stochastic time-variant frequency-selective MIMO channel model directly parameterized from experimental data. A fully automated clustering algorithm is used to identify multipath clusters which define the model. The approach is then validated based on different metrics applied to indoor data.

The paper by Materum et al. presents a methodology to identify multipath clusters in an automatic way. The approach is then applied to the clustering at the mobile station in small urban macrocell at 4.5 GHz. Each identified cluster is manually confronted with its physical counterpart, and conclusive results are drawn on the various propagation mechanisms.

The last paper on geometry-based modeling by Zhang et al. investigates several possible simplifications of geometry-based models in view of reducing their complexity without compromising their accuracy. The analysis relies on simulation and experimental results and a number of metrics.

Finally, the paper by Sivasondhivat et al. focuses on the modeling of the double-directional power spectrum in urban macrocells when considering dual-polarized MIMO transmissions. In particular, the separability of the power spectrum between the base station and the mobile is investigated, and a model is proposed and validated, based on the sum of polarization pairwise Kronecker product approximation.

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