# A Parametric Foliage Path-Loss Model

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Estimation of coherent and incoherent radio frequency (RF) signal attenuation through foliage is of great importance for a number of radar and communication problems. At UHF band and higher frequencies foliage presents a complex environment for electromagnetic waves in terms of scattering and wave propagation. For most applications, dealing with complex foliage models that account for single and multiple scattering in such environment is cumbersome and time consuming in practice. Accurate but simple-to-use foliage path-loss models can act as a surrogate for many engineering practitioners. Existing empirical foliage channel models, e.g. the Weissberger model, are constructed from measured data under specific environmental and system conditions, and do not include important foliage parameters which differentiate various foliages and significantly affect the path-loss. On the other hand, commonly used analytical foliage models, e.g. a ray-optics-based model treating the foliage medium as dielectric slab(s) with constant permittivity and conductivity, are generally oversimplified and have very limited regions of validity. Recently, a physics-based foliage propagation model using wave theory has been developed at the University of Michigan. This model computes the field propagation through a foliage environment consisting of realistic-looking fractal trees by accounting for attenuation and the scattering from all individual constituents (trunks, branches, and leaves) coherently. Monte-Carlo simulations are employed to provide wave propagation statistics. Based on this fractal-based coherent scattering model (FCSM), a statistical wave propagation (SWAP) model is also developed that allows for computation of path-loss over long propagation distances within foliage. This model significantly reduces the computation time by confining the extensive computation to representative short block of foliage. In addition the SWAP model improves path-loss prediction accuracy by taking into account the multiple-scattering components between scatterers inside different foliage blocks.

Successful though these models have proven to be, the implementation of both FCSM and SWAP models is still rather complicated. The existing codes are developed in such a researcher-oriented way, that ordinary users without enough knowledge on the subject find them too difficult to use. Therefore, a macro-model with simple mathematical expressions, while maintaining the accuracy of the original FCSM/SWAP model, is in great need. In this paper, a macro-model, referred to as the Michigan Foliage Attenuation Model (MiFAM), based on SWAP and expected physical behavior of path-loss in a lossy and scattering environment is developed. First, a physics-based parametric formulation of the foliage path-loss, capable of predicting the dual-slope path-loss behavior, is selected. Then, the most influential foliage and radio system attributes and their effects on the parameters of the parametric model are determined through a sensitivity analysis using a large number of SWAP simulations. Next, a multiple linear regression is conducted to relate the parametric model parameters to the foliage and radio system parameters quantitatively. Finally, some out-sample test is performed to verify the established macro-model. In this paper, specific MiFAM macro-models up to L-band are generated for two popular tree species in Northern America, the red maple and red pine, each representing the deciduous and coniferous tree category respectively.