Computationally Efficient Extension of a 2D Integral Equation Indoor Propagation Model to 3D

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The ability to accurately describe electromagnetic wave propagation underpins all radio channel modeling and base-station location optimization. The indoor environment presents some unique challenges due to the high potential for multipath and the variety of materials encountered. Thus, there is a growing demand for accurate propagation models which can include as much of the physics of the surrounding environment as is possible but yield a solution within a reasonable runtime. Significant research has been directed towards ray-tracing based models. The Geometrical Theory of Diffraction and Uniform Theory of Diffraction have been applied to ray-tracing models to include the diffraction phenomenon leading to enhanced accuracy. Diffuse reflection models are also increasingly being employed to further enhance the accuracy of ray-tracing models. This trend towards increasing complexity (and computation) for ray-tracing based models suggests that it may be beneficial to take a different approach – to start with a full-wave model and reduce its computation cost.

The full paper will outline some recent work which has resulted in the development of a very accurate full-wave model by applying the 3D Volume Electric Field Integral Equation (VEFIE) to the description of an indoor propagation problem. The Method of Moments is applied to discretize the VEFIE resulting in a linear system which can be solved by iterative means. The Fast Fourier Transform is applied to accelerate the matrix-vector product performed within each iteration. A method for concentrating the solver solely on unknowns situated in scattering material (as opposed to unknowns situated in free-space, which do not interact with other unknowns) is also applied in order to reduce the number of iterations required for the solver to converge.

The 2D VEFIE can be derived from the 3D VEFIE and solved for in a similar way. However, as the complexity for the 2D VEFIE is much less than that for 3D, $O(n^2)$ versus $O(n^3)$, a propagation model based on the 2D VEFIE can produce results in a much quicker runtime. There are inherent differences between the electric field in 2D and 3D which are shown in Fig. 1. Preliminary analysis of the 2D and 3D VEFIEs aided by knowledge of the underlying system has enabled us to apply simple correction methods to our 2D model to bring it more inline with that of our 3D model. One such method involves dividing the field strength by an additional $\frac{1}{\sqrt{r}}$ term to account for the difference between the 2D and 3D Green's functions. An example of this correction applied to the 2D model can be seen in Fig. 1 where we note the corrected 2D simulation shows good agreement with the full 3D results. The full paper will examine more fully our correction methods indicating the difference required for points with line of sight of the transmitter, those without and the improved accuracy achieved when fast fading has been removed from the results prior to correction.

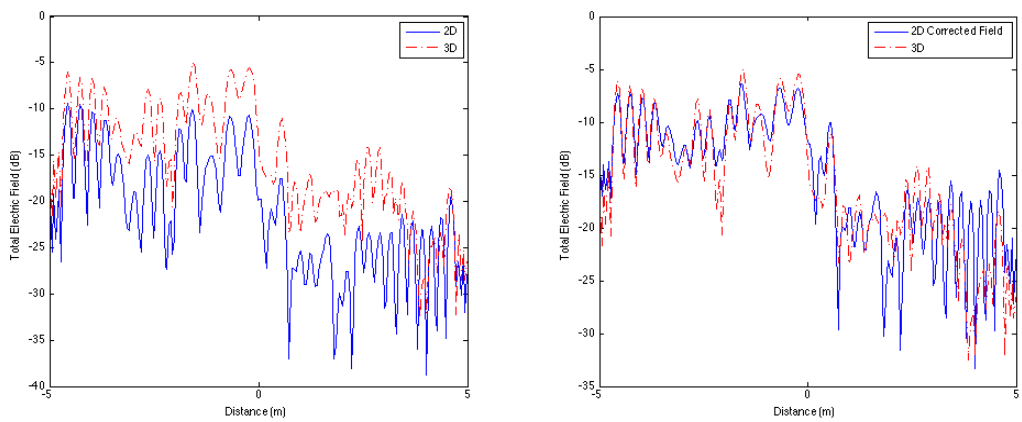

Fig. 1 Results show electric field strength along a test line in a 10m x 10m x 3m building at 700MHz.