Simulation of Near-Ground Radiowave Propagation over Terrain Using FMM-Accelerated Nyström Method with Phase Extraction Technique

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An investigation of radiowave propagation over irregular terrain profiles at near-grazing angles via an efficient numerical solver is described. For near-ground wireless sensor systems, accurate and efficient methods are needed in evaluating the propagation path loss and link budget. In supporting signal coverage prediction for such specialized systems in which the transmitter and receiver are in extreme proximity to the ground, available studies have been limited to the dependence upon site-specific, empirical-based models. The usefulness of these models is restricted as they cannot be applied to generalized propagation environments. Propagation over irregular terrain surfaces remains to be a challenging open problem demanding ongoing analysis; the unique properties, or complications, of near-earth propagation such as surface wave propagation, non-plane wave propagation, and higher order reflection and diffraction phenomena pose additional constraints that often beset the validity of classical analytical ray-tracing and physical optics techniques and their heuristic extensions. As such, when improved solution accuracy is required, full-wave simulation routines, despite their computational inefficiency, are employed to assess near-earth propagation parameters. A new 2D surface integral equation-based Nyström solver in which a phase extraction technique is utilized to reduce the number of surface unknowns is described. As forward scattering is the dominant mechanism at the near-ground region, the associated rapidly varying phase components of the integral equation kernel and solution unknowns are deduced and isolated in advance and subsequently built into the solver. It is shown that by applying this method, when combining with an adaptive surface segmentation routine, as few as one to two average unknowns per wavelength is adequate in obtaining accurate solutions. This significantly reduces the memory storage and computational expense for the simulation of long distance propagation effects. The efficiency of this method is further improved by incorporating it into the framework of the fast multipole scheme. The full details of the algorithm are discussed; comparisons with the regular Nyström solver for terrain surfaces (D. H. Liao, E. Michielssen, and K. Sarabandi, *IEEE Antennas and Propagat. Intl. Symp. Digest*, Honolulu, HI., June 2007) are made; and convergence studies are presented for both perfectly-conducting and dielectric surfaces with various scales of roughness.