Using the Fast Multipole Method to Calculate the Fields inside a Motor Vehicle due to Communication Antennas

Johann J. van Tonder* and U Jakobus

EM Software & Systems-S.A., Stellenbosch, South Africa, jvtonder@emss.co.za

The multilevel fast multipole method (MLFMM) is used with the electric field integral equation (EFIE) to determine the near fields inside a motor vehicle. These near fields are calculated for communication devices in modern cars, with operating frequencies including TETRA (380-440MHz), GSM (876-915MHz, 1710-1910MHz) and Bluetooth (2400-2485MHz). The numerical calculation of near fields inside vehicles has two main practical applications: a) To assess human exposure to RF and microwave fields; b) predict electromagnetic compatability (EMC) and interference (EMI).

For efficient modeling of arbitrarily shaped 3-D geometries, the metallisation is discretised using the triangular patches of Rao, Wilton and Glisson, and the EFIE is solved with the Method of Moments (MoM). In the traditional MoM computer resources increase dramatically with the frequency (memory scales as N^2). For a standard passenger car at 915MHz we have approximately $N = 37,000$ unknowns (traditional MoM will require 20GB memory), at 1910MHz we have $N = 100,000$ (150GB with traditional MoM), and at 2485MHz we have $N = 200,000$ (610GB for traditional MoM). The MLFMM was therefore implemented that scales no worse than $N * log^2(N)$. The computational box is subdivided into eight equal boxes, and this subdivision continues until the smallest boxes are approximately half a wavelength. Only non-empty cubes are stored in a tree-like manner. Since the EFIE has a worse condition number than the combined field integral equation (CFIE), we must use a good preconditioner to ensure convergence in the interative solver (e.g. CGS). The CFIE cannot be used in this case, because the geometry under investigation is not closed (the windows of the car are modeled as free-space).

In the MLFMM (fast matrix-vector product) we compute a sparse near field matrix corresponding to the close interactions in the MoM impedance matrix. We will use an ILU(0) preconditioner with the same sparsity pattern as this near-field matrix (ILU preconditioning with fill-in will increase the convergence, but at the expense of memory). More implementation details, e.g. a fast spherical filter for the interpolation and filtering steps, will be discussed.

After implementation, the MLFMM was verified with the full MoM solution (out of core) at GSM 900MHz. In previous work the MLFMM was mainly used to predict far-field patterns (RCS) of closed structures for which the CFIE is better conditioned. In this paper we concentrate on the near fields inside geometries which are open structures. The near fields, human exposure levels and EMC/EMI implications for various communication antennas inside a motor vehicle will be presented up to Bluetooth frequencies.