Modeling EMI in Complex and Electrically Large Systems

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With the advent of high-power sources and increased usage of the communication spectrum, digital devices have become increasingly susceptible to both deliberate and unintentional sources of electromagnetic interference (EMI). The sizes of enclosing structures in which the devices typically appear make them particularly sensitive in the 300 MHz – 3 GHz frequency range. Though specific digital devices may appear to be confined within several layers of shielding protection, signals may couple to such systems through various complex coupling paths. For example, consider coupling to a digital device on a chip within an aircraft avionics system. The coupling might occur through a path starting from induced currents on the aircraft skin that interact with hydraulic lines or cables, then proceeding along a network of cable bundles through multiple compartments and equipment bays, finally entering the equipment chassis through an external cable that couples through internal wiring to the traces on a printed circuit board, ultimately affecting a semiconductor component inside the digital device.

In the past, topological decompositions have been very useful in estimating the shielding between individual levels. Now, despite the complexities involved, computational methods are being used to provide more rigorous estimates of coupling across the hierarchy of shielding levels. A significant simplification in such modeling is the extensive use of multi-conductor transmission line codes generalized to model field coupling, and the use of BLT and scattering matrix formulations to describe lines, junctions, and terminations.

To model bulk equipment enclosures and coupling to devices within complex geometries, various computational approaches involving traditional finite element, boundary element, FDTD, and ray-optic methods may be used. Fast methods are usually needed to significantly speed up frequency domain computations. Computational efficiency may be further improved by using approximate domain-decomposition strategies. For example, for problems where wires penetrate apertures and couple to devices within cavities, suitable interior and exterior problems may be solved separately and then combined in an appropriate manner. It is also convenient to identify ports (e.g., at the inputs of a device) where Thevenin circuit models may be constructed. For resonant responses, simple CAD formulas that reproduce the response with a minimum number of calculation points may also be beneficial. This presentation will focus on the use of these tools and strategies for EMI computation.