

## **A Hybrid Methodology for Efficient Electromagnetic Interference Modeling of High-Density Printed Circuit Boards**

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Electromagnetic modeling for the anticipation of both external and internal electromagnetic interference and compatibility difficulties in integrated electronic systems is rapidly emerging as one of the key enabling technologies in the quest for virtual prototyping of multi-functional, performance-driven electronic products. Despite their usefulness and versatility as point tools for RF/microwave component design and modeling of fairly small-size portions of an integrated electronic system, state-of-the-art electromagnetic field solvers today do not exhibit the computational efficiency required for tackling numerical electromagnetic modeling and simulation at the system level. Thus, in their current form they are not suitable for use as computer-aided design (CAD) tools for the EMI/EMC-related system level modeling and simulation studies discussed in the previous paragraph.

To address this shortcoming of state-of-the-art EM modeling CAD tools, the electrical modeling and simulation community has been exploring hybrid modeling and simulation methodologies that, through the use of physical model complexity reduction, attempt to blend together different electromagnetic models for different portions of the integrated system for the purpose of enabling system-level electromagnetic performance assessment. To date, these efforts have focused primarily on the so-called "signal integrity" portion of the intra-system EMI/EMC problem, where the emphasis is on the prediction of crosstalk-related signal degradation in the interconnect structure and the simultaneous switching noise effects associated with power distribution. However, no systematic approaches have been put forth toward the extension of such a hybrid modeling methodology to encompass radiated emissions and radiated susceptibility.

In this paper, an approach is described toward the establishment of an enhanced hybrid electromagnetic modeling framework that extends the aforementioned signal integrity-driven modeling and simulation methodology to a more comprehensive EMI/EMC-driven one. The proposed approach is capable of tackling the complexity of state-of-the-art integrated electronics while at the same time providing the accuracy needed to support and facilitate product design. The modeling versatility and computational efficiency of the proposed methodology are based on the introduction of reduced physical models for the shielded portion of the signal network as well as the power distribution network. The approximations used for the construction of the proposed reduced models are motivated by the geometric attributes of the printed circuit board environment. A careful development of the hybrid model leads to accurate electromagnetic analysis of printed circuit boards of complexity that cannot be handled by state-of-the-art electromagnetic field solvers.