Application of the Random Coupling Model to the Hierarchical Modeling of Electromagnetic Coupling to Partially-Shielded Enclosures

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We report on the application of the Random Coupling Model (RCM) (S. Hemmady, et al, IEEE Trans. Electromagn. Compat., 54, 758-771, 2012) to the hierarchical modeling of electromagnetic field interaction with partially-shielded enclosures exhibiting multiscale material and geometric complexity. This study was motivated by recently reported experimental validation of the feasibility of the RCM as a computational tool for expedient statistical electromagnetic analysis of metallic cavities with apertures operating under conditions that support ray chaos behavior (J. G. Gil, et al, IEEE Trans. Electromagn. Compat., 58, 1535-1540, 2016).

This study had the following two primary objectives. First, to determine, for a partially shielded enclosure of a given size, and of geometric and material complexity supporting ray chaos conditions, the lower bound of the frequency range over which the RCM can be trusted to provide reliable results. Second, to explore the possibility of establishing a numerically-based approach for assessing the reliability conditions of the RCM for a given set of parameters defining the apertures and other related interruptions in the metallic shielding of the enclosure.

Toward these objectives, we treat the apertures in the enclosure as waveguide ports, which naturally leads to an impedance matrix description of the enclosure. Such description is consistent with the hierarchical approach to system-level electromagnetic coupling analysis. We focus on the interior electromagnetic boundary value problem, where the impedance matrix quantifies the interaction of the fields entering through apertures with interior objects. An electromagnetic field solver, together with either a brute-force Monte Carlo approach or stochastic collocation, will be used to calculate the impedance matrix of the interior of the enclosure. With the emphasis of the study on the electrical size of the enclosure and the properties of the apertures, the uncertainty and variability of the enclosure interior is defined in terms of a number of geometric and material features carefully selected to satisfy ray chaos conditions while at the same time containing the dimension of the random space. The result of such a simulation is a statistical description of the impedance matrix, which captures the impact of the material/geometrical statistical variability on the electromagnetic field behavior inside the enclosure. This result is used as the reference solution against which results from the impedance matrix predicted by the RCM are compared.