

Fast and Accurate Computation of the EM Effect of Small Defects

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Aircraft and vehicles frequently exhibit minor surface irregularities and imperfections, which can occur either accidentally or intentionally. These include features such as gaps, grooves, rivets, holes, cracks, joints, and attachments. Although these features may be small compared to the wavelength, their presence can number in the hundreds or even thousands on a single platform. This abundance can undermine internal region isolation or substantially affect scattering behavior, particularly for platforms geared toward low radar cross-section (RCS) (D. C. Jenn, *Radar and Laser Cross Section Engineering*, 2nd ed. VA, USA: Amer. Inst. Aeronaut. Astronaut., 2005, pp. 324–327). Full wave simulation that accurately accounts for both the entire platform and local defects at once poses a multiscale challenge. This significantly increases the computational demands of electromagnetic simulation and mesh generation. Efficiently analyzing objects with these defects is vital, not only for compatibility considerations but also for the accurate prediction of scattering reduction.

The investigation of defects has been a long-standing area of interest. Initially, researchers concentrated on understanding the scattering mechanism by simplifying it into 2-D problems and deriving analytical or quasi-analytical expressions for the scattered field (T. B. A. Senior and J. L. Volakis, “Scattering by gaps and cracks,” *IEEE Trans. Antennas Propag.*, vol. 37, no. 6, pp. 744–750, Jun. 1989). More recently, with advancements in numerical methods in computational electromagnetics, several approaches have been suggested for analyzing the scattering of complex objects with small-scale structures. These approaches also allow for evaluating the field transmitted through defects on a screen and coupled with shielded devices. These methods include hybrid methods that combine shooting and bouncing rays with the finite-element method, ray theory-based methods, fast finite-element boundary integral (FE-BI) methods, methods of moments (MoM) utilizing domain decomposition, and methods using special basis functions. In this paper, we propose to simplify the approach by replacing each defect with a small patch of four RWGs that allows us to describe the small hole/protrusion with equivalent magnetic currents whose solenoidal and irrotational components can be related a priori with the MoM currents through the defect's polarizability. The process is designed to be user-friendly and does not require the use of a denser mesh to model each defect. Essentially, the object under analysis will be discretized as if the defects are absent, and their presence will be directly considered in the Method of Moments impedance matrix. This approach ensures an accurate and efficient evaluation of the impact caused by the presence of defects.

As an example, we have considered a metallic box where a rectangular slot is cut on its smaller face and a plane wave impinges orthogonally on it (M. P. Robinson, et al., “Analytical formulation for the shielding effectiveness of enclosures with apertures,” *IEEE Trans. Electromagn. Compat.*, vol. 40, no. 3, pp. 240–248, Aug. 1998). With a standard MoM, to get the correct frequency response of the electric field that penetrates the box, not only a dense mesh on the aperture is required, but it must also be nonuniform and denser on the aperture edges. On the contrary, when the proposed formulation is adopted, and the box is discretized everywhere with a uniform mesh, we obtain a perfect match with the reference solution because the slot is accurately taken into account through an equivalent “patch” discretized with four RWGs which effect is directly included in the MoM matrix. The details of the procedure and several cases of study will be shown at the time of the conference.