A Resonant-Free Integral Formulation for EM Scattering from Electrically Large High-Q Cavities

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Numerical simulation of electromagnetic (EM) scattering from a large cavity with a very high Q factor is extremely challenging. Due to multiple reflections of EM waves inside the cavity and the very low energy loss-to-storage ratio, the high-Q cavity is highly resonant. When formulated by an integral equation in the frequency domain, the physical resonance makes the formulation extremely ill-conditioned, which is very difficult to converge when solved with an iterative solver. It is also impossible to design an effective preconditioner to improve the conditioning of the formulation. As a result, a direct solver has to be applied, which limits the size of the problem that can be solved. A similar difficulty is encountered when formulating the problem in the time domain, where the strong resonance and multiple wave reflection result in an extremely long simulation time with a very large number of time steps for the time-domain solution to complete. Although various numerical methods have been developed in the past (P. Li, *J. Comput. Math.*, 36(1), 1–16, 2018), the scattering from electrically large high-Q cavities remains an open problem.

Recently, the generalized reciprocity theorem has been applied to formulate EM scattering from closed PEC objects to eliminate spurious internal resonance (J. L. Tsalamengas, *IEEE Trans. Antennas Propag.*, 64(11), 4745–4752, 2016). In this formulation, the object is first removed and its interior region is filled with null fields. To account for the scattering from the object, an equivalent surface electric current is introduced on the surface of the object, according to the surface equivalence principle. An artificial lossy material is then placed in the interior region. Doing so, the original scattering problem can be described as a radiation problem, where the equivalent current is radiating in front of a lossy material. This radiation field, together with the incident field in the presence of the lossy material, satisfies the original PEC boundary condition, which results in a new integral formulation. Due to the introduction of the lossy material, this formulation removes the spurious internal resonance successfully, resulting in resonant-free electric and magnetic field integral formulations that are well-conditioned and can be solved iteratively with a fast convergence rate.

This formulation, unfortunately, cannot be applied to model open cavity scattering, since the lossy material has to be placed in the null-field region in order not to interfere with the EM fields in the equivalent problem. To formulate an integral equation that is applicable to open cavity scattering problems, we first close the cavity aperture with the introduction of equivalent electric and magnetic currents on the aperture. An artificial lossy material is then introduced into the closed cavity body to formulate the electric and magnetic field integral equations. In this talk, we introduce the formulation of the resonant-free electric and magnetic field integral equations for open cavity scattering problems. Several numerical examples are given to demonstrate the accuracy and convergence of the proposed formulation in simulating EM scattering from electrically large cavities with high-Q factors.