Higher Order Diakoptic FEM-MoM Analysis of Electrically Large and Complex Periodic Electromagnetic Scatterers

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Electrically large and complex periodic electromagnetic (EM) scatterers of finite extent in all dimensions are frequently encountered in many conventional and emerging areas of applied electromagnetics, and most notably in analysis and design of EM materials, including metamaterials, propagation through complex media, EM band-gap materials, etc., and in analysis and design of all sorts of antenna arrays, including reflectarrays. Given the large range of applications and technological advancements in these areas and associated increases in complexities and electrical dimensions of EM structures involved, there is a continuing and growing demand for computational EM (CEM) tools that can handle full-wave simulations of such problems. One of the most promising approaches to tackle this challenge is the class of novel domain decomposition (DD) algorithms, which constitute the mainstream of recent research efforts in CEM. In general, these algorithms allow splitting of the original, large and/or complex, problem into a number of smaller ones, which can be analyzed independently, and then stitched together by some sort of local or integral boundary conditions. This way, the computational burden can be tremendously reduced. Among a variety of possible and existing DD algorithms, we apply here the diakoptic approach coupled to the higher-order hybrid of the finite-element method (FEM) and the method of moments (MoM) (D. I. Olćan, M. M. Ilić, B. M. Notaroš, B. M. Kolundžija, and A. R. Djordjević, 2010 IEEE APS International Symposium Digest, July 2010) to the analysis of periodic EM scatterers, which can contain arbitrarily inhomogeneous media.

According to the diakoptic approach, we wrap each scatterer with a closed surface (diakoptic surface) and place equivalent electric and magnetic surface currents on the diakoptic surfaces. Each scatterer, together with the associated equivalent surface currents, is analyzed completely independently, using the higher order FEM-MoM, with the objective to find linear relations between coefficients of the equivalent current expansions (diakoptic coefficients). The relations for all scatterers are combined into a system of linear equations (diakoptic system), whose solution are diakoptic coefficients, which, once known, are then used to obtain EM fields in all domains, as well as various parameters of interest for the original system.

The numerical results to be presented demonstrate high accuracy and efficiency of the new technique, as well as its advantages and areas of future improvements when compared to other suitable techniques. Examples include a variety of 2-D and 3-D finite arrays of lossless and lossy scatterers of various geometries and material compositions (e.g., metallic scatterers with multilayer dielectric coatings), and both far-field (e.g., radar cross section) and near-field (e.g., field penetration into materials) simulation results. Some examples are aimed at demonstrating the effectiveness of the technique in treating curved and continuously inhomogeneous scatterers, using large finite elements that allow continuous change of medium parameters throughout their volumes, instead of conventional piecewise-homogeneous approximate models (e.g., with many thin layers).