Investigations of Optimal Geometrical and Field/Current Modeling Parameters for Higher Order FEM, MoM, and Hybrid CEM Techniques

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In terms of the particulars of the numerical discretization, traditional computational electromagnetic (CEM) tools are low-order (also referred to as small-domain or subdomain) techniques – the electromagnetic structure is modeled by volume and/or surface geometrical elements that are electrically very small and with planar sides, and the fields and/or currents within the elements are approximated by low-order basis functions, which results in very large requirements in computational resources. An alternative which can greatly reduce the number of unknowns for a given problem and enhance the accuracy and efficiency of the CEM analysis is the higher order (also known as the large-domain or entire-domain) computational approach, which utilizes higher order basis functions defined in large geometrical elements (B. M. Notaroš, "Higher Order Frequency-Domain Computational Electromagnetics," IEEE Transactions on Antennas and Propagation, Vol. 56, August 2008, pp. 2251-2276).

However, the principal advantage of higher order techniques, their flexibility in terms of the size and shape of elements and spans of approximation functions, is also their greatest shortcoming – in terms of dilemmas, uncertainties, and so many open, equally attractive, options and decisions to be made on how to actually use them. We demonstrate this in the context of higher order techniques based on using generalized curved parametric hexahedral and quadrilateral elements to model the geometry of the structure in conjunction with curl and divergence-conforming hierarchical polynomial vector basis functions to model fields and currents, in the framework of the finite element method (FEM) and the method of moments (MoM) and various hybrid techniques. Parameters that can be varied and are systematically studied in this work toward optimal choices are geometrical orders of elements, approximation orders of field/current basis and testing functions, and orders of the corresponding Gauss-Legendre integration formulas, which all can, theoretically, be arbitrary. In addition, decisions have to be made on electrical dimensions of elements in the model, jointly with decisions on other parameters. Generally, field/current polynomial approximation orders for a given level of accuracy of the results are directly proportional to the corresponding electrical dimensions of elements, but often not in a linear fashion. In addition, being able to specify the level of desired accuracy – or, equivalently, the acceptable uncertainty – of the results being computed is extremely important, so this work also investigates tradeoffs between accuracy and efficiency, i.e., the cost of getting the results. Through very extensive numerical experiments and theoretical studies, some of which are to be presented, as precise as possible quantitative "recipes" for adoptions of higher order and large-domain parameters are developed. The ultimate goal of this work in progress and a quite ambitious and challenging endeavor is to establish and validate general guidelines and instructions in order for the higher order CEM modeling methodology, at least within the class of approaches and techniques developed in our group, to be an easily used analysis and design tool, with a minimum of expert interaction required to produce valuable results in practical applications.