Network Methods in Electromagnetic Field Computation *

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With increasing bandwidths and data rates of modern electronic circuits and systems, electromagnetic wave phenomena that in the past were in the domain of the microwave engineer, are now becoming pivotal in the design of analog and digital systems. Design, modeling and optimization of high-speed analog and digital electronic circuits and systems, photonic devices and systems, of antenna, radar, imaging and communications systems, among other applications, require the application of advanced tools in computational electromagnetics.

Network-oriented methods applied to electromagnetic field problems may contribute significantly to the problem formulation and solution methodology. Whereas in field theory the three-dimensional geometric structure of the electromagnetic field has to be considered, a network model exhibits a plain topological structure. In network theory systematic approaches for circuit analysis are based on the separation of the circuit into the connection circuit and the circuit elements. The connection circuit represents the topological structure of the circuit and contains only interconnects, including ideal transformers.

Applying a network description electromagnetic structures can be segmented into substructures. These substructures define the circuit elements and the set of boundary surfaces between the substructures define the interconnection network. Canonical Foster equivalent circuits can represent lossless structures in sub-domains. Canonical Cauer networks can describe radiation modes. The lumped element models can be obtained by analytic methods, i.e. via Green's function or mode matching approaches or by numerical methods techniques (Transmission Line Matrix Method or Transverse Wave Formulation) in connection with system identification techniques.

By applying time discretization using Richards transformation a time-discrete *transmission line segment circuit* (TLSC) algorithm for efficient time-domain modeling of electromagnetic structures is formulated. The TLM scheme is a special case of the TLSC scheme and can be easily incorporated into the TLSC scheme yielding a powerful hybrid method. The application of wave digital filter (WDF) methods for time-discrete modeling and their relation to TLSC and TLM schemes is discussed. The network approach allows a systematic introduction of hybrid methods. Furthermore, network formulations are well suited for the application of model order reduction methods.

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