Incorporation of Multiport Lumped Circuit Networks into DGFETD Method

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In this paper, a hybrid field-circuit simulation method is introduced based on the discontinuous Galerkin finite element time domain (DGFETD) method and the circuit network parameters. Due to the discontinuous property of DGFETD, it allows solutions to be discontinuous across boundaries of adjacent mesh cells. The communication between neighboring elements are achieved by the numerical flux which is derived from the Rankine-Hugoniot condition. Hence, all operations of DGFETD are local. This local property enables the coupled field-circuit matrix system also local. To solve the hybrid field-circuit system, the whole computational domain is split into two subsystems. One is electromagnetic (EM) subsystem that is analyzed by the field solver DGFETD, another is circuit subsystem which is represented by its admittance matrix $[\mathbf{Y}(s)]$ in the Laplace domain. The coupling between these two subsystems happens at a rectangular lumped port where an external voltage source and a port current are introduced. The EM-to-circuit coupling is facilitated by this voltage source calculated by the field solver, and the circuit-to-EM coupling is realized by the port current provided by the circuit solver. However, there are situations that the circuit details are unavailable or too complex to derive its admittance matrix while only measured or simulated frequency domain S-parameters are known. In this case, the discrete frequency domain admittance matrix elements are firstly derived from the S-parameters based on the basic microwave network theory, then vector-fitting method is employed to approximate each of the admittance matrix elements by a rational function. With this method, the proposed solver is more flexible in regarding to without resorting to circuit details. Since current circuit systems usually involve multiscale structure, the generated mesh cells are highly disparity. For time-domain method, the minimum time-step size will be very small. To increase the efficiency and reduce the computational cost, the local time-stepping method is integrated into the proposed algorithm. This strategy regroups the elements according to the local time step size. For the k-th group, its time step size is $\delta t_k = (2m+1)^{k-1}\delta t_{min}$ with $\delta t_{min} = \min(\delta t_i)$ denoting the minimum global time-stepping size.