Operator Index Reduction in Electromagnetism

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Electromagnetic disturbances among elements in an electrical circuit and their influences on dynamics of the circuit, the so-called crosstalk phenomenon, can be modeled by bilateral coupling of the set of partial differential equations (PDEs), namely the Maxwell equations, with the set of differential-algebraic equations (DAEs), the so-called circuit equations. Our approach to numerically treating such a model is by semi-discretization of the Maxwell equations in space, where the circuit equations are incorporating into the boundary conditions via the coupling relations. This allows us to obtain a set of DAEs corresponding to the original PDEs, which in turn leads to a large DAE system as a model equation for the crosstalk. Semi-discretization of the Maxwell equations by finite element method results in a system of high index DAEs. On the other hand, the high index may create instabilities and inconsistencies in the numerical treatment of DAEs, and therefore it is necessary to regularize the system by an index reduction technique before the time integration.
In this talk, we introduce the operator based Maxwell equations and show that with the certain choice of spaces for the operators, the semi-discretized Maxwell equations has index 1.