# Near-Field Preconditioning for Envelope-Tracking Electromagnetic-Circuit Simulators

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In integral-equation based Fourier-envelope electromagnetic-circuit (EM-CKT) solvers, all fields, voltages, currents (signals) of interest are represented using $N_{\mathrm{H}}$ harmonic sinusoids (carriers) with complex-valued time varying coefficients (envelopes). The envelopes are sampled in time at a rate proportional to the bandwidth of the excitation. Then, the method of moments solution of the integral equation, the modified nodal analysis solution of the CKT equations, and the EM-CKT coupling are formulated in terms of these envelope samples. This gives rise to a nonlinear system of equations, which is solved by a marching-on-in-time scheme that uses a multidimensional Newton-Raphson algorithm at each time step (V. Subramanian and A. E. Yilmaz, Proc. Appl. Comp. Electromagnetics Symp., 2012). For narrowband excitations, Fourier-envelope EM-CKT solvers are more efficient than their time-domain counterparts because they can use a larger time-step size (V. Subramanian and A. E. Yilmaz, Proc. Appl. Comp. Electromagnetics Symp., 2012 , Proc. USNC/URSI Rad. Sci. Meet, 2012). The larger time step size also leads to denser and less diagonally dominant matrices in the EM solver component. This, in turn, renders simple diagonal and block-diagonal preconditioners, which are often satisfactory for time-domain EM-CKT solvers, to be ineffective for Fourier-envelope EM-CKT solvers.

In this article, sparse near-field preconditioners are proposed for improving the performance of Fourier-envelope EM-CKT solvers. At each Newton iteration, the Jacobian equation for finding the Newton step is implicitly preconditioned, i.e., an inner-outer iterative solution strategy is used. Specifically, the Jacobian equation is preconditioned using a block-diagonal matrix composed of $N_{\mathrm{H}}$ blocks. As a result, the inner iterative solution is simplified to $N_{\mathrm{H}}$ different iterative solutions, each of which solves a smaller matrix equation for $N_{\mathrm{H}}$ times fewer unknowns than the Jacobian equation. Each of these $N_{\mathrm{H}}$ blocks has four sub-blocks: One EM, one CKT, and two coupling sub-blocks. The CKT and coupling sub-blocks are identical to those in the Jacobian equation, whereas the EM sub-block is formed by filtering. The filtering schemes represent a tradeoff between the number of iterations needed for convergence and the number of operations per iteration. Here, proximity based filtering and algebraic filtering are used. Proximity based filtering chooses those EM entries for which the source and observer basis functions are separated by less than a predefined distance; algebraic filtering removes the entries with less than a predefined value (T. Malas, and A. E. Yilmaz, URSI 2011). Analysis of various microwave circuits and antennas demonstrating the features of the proposed near-field preconditioners will be presented at the conference.