Fast Scan FEM Preconditioning for Infinite Periodic Structures

Dimitrios G. Makris and Marinos N. Vouvakis
Department of Electrical and Computer Engineering University of Massachusetts Amherst, MA,USA

An efficient and robust preconditioning scheme for the iterative solution of finite element method (FEM) for electromagnetic scattering and/or radiation of infinite periodic structures, is proposed. The preconditioning scheme aims at accelerating scan/incident angle sweeps.Unlike model order reduction methods or interpolation methods for fast sweeps, this method is exact and can be used in conjunction with such methods.The prediction of both the scan dependent gain and impedance constitutes an important requirement in the procedure of a successful phased array element design since reduces the development cost and time while provides an invaluable physical insight.

Over the past three decades a lot of work has been carried out on the development of the FEM for the analysis of three-dimensional doubly periodic phased arrays by imposing periodic boundary conditions(PBC) and Floquet boundaries.(D.T McGrath and Vittal P.Pyati, IEEE Trans on Antennas and Propagation, Vol.42 ,1994), (E.W.Lucas and T.P. Fontana IEEE Trans on Antennas and Propagation, Vol.42 ,1995). State of the art simulating packages have incorporated the most important of the achievements of this work.There are two approaches for the solution of the resulting system of equations:The first, requires the factorization(or precondition) of the FEM matrix and the forward/backward substitution(or iterative solution) to be performed at every scan angle.This inevitably increases the time requirements for the total system solution, which constitutes the main disantvantage of the conventional FEM solution methods for the infinite periodic arrays.The second approach is based on the requirement that the preconditioning of the FEM matrix is performed once at the broadside and it is reused at different scan angles.While the former approach is reliable and fast converging, it can be memory intensive or slow due to the repeated factorization or preconditioning, whereas the latter can be unreliable and slow.

Unlike the conventional approaches that factorize the FEM matrix at every scan angle, the proposed framework advocates an algebraic alternative of the second approach. It exploits the underlying physics of the PBCs in combination with linear algebra analytical calculations of the inverse of a matrix. Namely it is based on the observation that the change of the scan angle can be treated as a low rank perturbation of the broadside FEM matrix. This observation, can be exploited by using the Woodbury matrix inversion formula that relates the inverse of a matrix after a small rank perturbation to the inverse of the original matrix(in our case the FEM matrix at broadside)(W.Hager,SIAM Review, 221-239,1989). Under this regime an effective and efficient preconditioner will be available for an iterative solver at every scan angle. Results on scattering and radiation problems with 1D and 2D periodicity will be presented.