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Progress on Potential-Based Time Domain Integral Equations for Low Frequency and Multiscale Electromagnetic Analysis

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The growth in electromagnetic applications that involve subwavelength or multiscale structures has necessitated the development of computational electromagnetics methods that can efficiently analyze these systems. Unfortunately, many of the traditional computational approaches experience various forms of numerical breakdowns when attempting to analyze the challenging structures involved in emerging applications. Potential-based integral equations are being explored to develop numerical methods that avoid the low-frequency breakdown that is inherent in many traditional field-based integral equation solvers. In this work, we review the recent progress on potential-based time domain integral equation solvers for the analysis of multiscale structures. We begin with the development of the first potential-based time domain integral equation solvers for perfectly conducting regions. We further comment on the importance of using an appropriate functional framework to analyze the stability of the integral equations to develop numerically stable marching-on-in-time discretizations. Following this, we discuss how potential-based time domain integral equations that are free from interior resonances can be developed. These methods allow for the accurate analysis of deeply multiscale structures of practical importance that contain significantly subwavelength- and wavelength-sized geometric features simultaneously. As a third example, we discuss the development of potential-based time domain integral equations for the analysis of penetrable regions. As with the original potential-based time domain integral equations, we see that the functional analysis results play a crucial role in developing discretization schemes that lead to stable numerical results for these newer potential-based time domain integral equations. Throughout each example of potential-based time domain integral equation, we comment on future research directions that are needed to continue maturing these new computational electromagnetics methods.