# Numerical Study of Scalar and Vector Potential Integral Equations for Electromagnetic Scattering

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In the past several decades, an extensive amount of efforts by the computational electromagnetics community have been invested in seeking stable integral equations for electromagnetic scattering problems. Most of available approaches are based on electric field and/or magnetic field descriptions of electromagnetic problems. Integral operators in those equations would typically involve surface current densities and/or charges as sources (hence unknowns). In certain scenarios, the sources, like current, charge or potential, could be even nonphysical. In practice, equivalence theorem is mostly used to represent both electric and magnetic fields. However, widely used EFIE or its related formulation suffers from stability issues: the so-called low-frequency breakdown due to unbalanced dependence of two components on frequency. Problematic formulations either use EFIE operator directly or employ it for post-processing that suffers from catastrophic cancellation. Besides the EFIE operator related low frequency instability, electric/magnetic field based formulation may not be ideal in some multiphysics like quantum simulations(W.C. Chew, PIER, 149, 69-84, 2014). Research into new formulations for better stability and flexibility of coupling other physics would certainly benefit the community.

Quite recently, two vector and scalar potential based integral equations have been proposed independently to study electromagnetic scattering (Vico et al, Comm. Pure Appl. Math., 69, 771-812, 2016 and Liu et al, IEEE-APS, 2015). In those works, two potential terms that satisfy the Lorentz gauge are used to construct integral equation based formulation, both offering advantages like low-frequency stability. The former work by Vico et al., does result in two sets of second kind IEs for both potentials. In this work, a new well-conditioned potential based formulation for dielectrics will be studied. The new system features (1) the second kind integral equations, (2)frequency stability and (3) decoupling between vector potential and scalar potential. Furthermore, interestingly, the formulation can be reduced into several formulations for PEC case, and that means the new formulation is related with previous known formulations. In this work, numerical studies will be carried out around the new formulation. At the conference, we will present: (1) a new well-conditioned decoupled potential formulation for dielectric problems, (2) demonstration of the spectral identities for the formulation and its reduced versions for PEC, (3) numerical verification of the accuracy and efficacy of the decoupled potential formulation, and (4) discussions of the discretization and testing schemes.