FDTD Based Numerical Green's Function for S-parameter Measurement in Inverse Scattering Problems

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We present a numerical Green's function that serves as the kernel for volume integral equation (VIE) in inverse scattering problems. The primary motivation for this research is to address the lack of full antenna modeling in the VIE when solving inverse scattering problems. The numerical Green's function introduced here directly links the total field in the object domain and the object's dielectric properties to the measured scattered S parameters in the presence of the antennas and a presumed imaging cavity.

The computation of the numerical Green's function is based on the Finite Difference Time Domain (FDTD) method with several custom features and modifications. To ensure its accuracy and efficiency, we developed a GPU accelerated FDTD solver, which includes a conformal sub-cell modeling technique. The sub-cell modeling technique uses a re-derived Faraday curl equation to create a conformal boundary between the PEC and dielectric material. This technique enables accurate modeling of the coaxial feed and patch antenna with a minimum number of Yee cells.

To obtain the numerical Green's function for a specific observation plane in the coaxial feed, a voltage source is excited at that plane and the total field inside the imaging domain is recorded. After normalizing the total field with the exciting voltage source, we acquire the impulse response function between the observation point and imaging domain in the presence of the imaging cavity. Due to reciprocity, this function serves as the numerical Green's function kernel, which links the total field in the object domain to the scattered field in the coaxial feed.

The numerical Green's function are computed for several examples, including an in-house built imaging cavity. S-parameter simulation of the cavity—a fluid filled cube consisting of 12 panels, each with three patch antennas operating at 915MHz and 2.1GHz—will be demonstrated. Initial validation of the method will be shown in comparison to synthetic scattered fields computed using the commercial software packages CST and HFSS. Finally, experimental validation of the scattered S parameter computed using our FDTD solver with numerical Green's function kernel will be shown for several object cases in the imaging cavity.