Electromagnetic scattering in a discrete basis

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Abstract: In this dissertation, I use discrete eigenfunction expansions to study three electromagnetic scattering problems in the frequency domain. Chapter 2 describes an eddy-current coil interacting with a perfectly conducting wedge of arbitrary angle. A closed-form expression for the impedance of a tangential eddy-current coil in the presence of an infinite conducting wedge of arbitrary angle is derived. The truncated eigenfunction expansion (TREE) solution given here is valid in the quasi-static frequency regime. The theory was validated via comparison to an independent analytical expression for the impedance change of a horizontal coil over a conducting half-space due to Burke. I present results for three geometries: a conducting quarter-space, a conducting wedge of angle 225 degrees, and a semi-infinite conducting sheet. Our theory predicts a measurable change in the tangent coil reactance in the presence of all three geometries.

Chapter 3 discusses the control of electromagnetic edge effects in electrically-small rectangular plasma reactors. Expressions for the fields in an electrically-small rectangular reactor with plasma in the chamber are derived. Modal field decompositions are employed under the homogeneous plasma slab approximation. The amplitude of each mode is determined analytically. It is shown that that the field can be represented by the standing wave, evanescent waves tied to the edges, and an evanescent wave tied to the corners of the reactor. The impact of boundary conditions at the plasma edge on nonuniformity is quantified. Uniformity may be improved by placing a lossy magnetic layer on the reactor sidewalls. It is demonstrated that nonuniformity is a decreasing function of layer thickness.

Chapter 4 is a theoretical investigation of extraordinary optical transmission (EOT) through a silver film perforated by an infinite square array of circular holes. A mode-matching solution to plane wave scattering by a silver film perforated by an infinite array of circular holes is presented. Impedance boundary conditions are imposed on all surfaces. Theory predicts a peak transmission value that is in good agreement with experiment. Extraordinary optical transmission is studied as a function of film thickness, hole radius, and lattice constant. The transmission profile position, shape, and amplitude are strong functions of film thickness, hole radius, and lattice constant. The effect of film thickness on coupling between modes bound to the upper and lower surfaces is studied. It is demonstrated that transmission peaks occur for holes of a roughly constant electrical size. A relationship between the lattice constant and the transmission-to-area efficiency is quantified.