Implicit handling of multilayered material substrates in full-wave SCUFF-EM calculations

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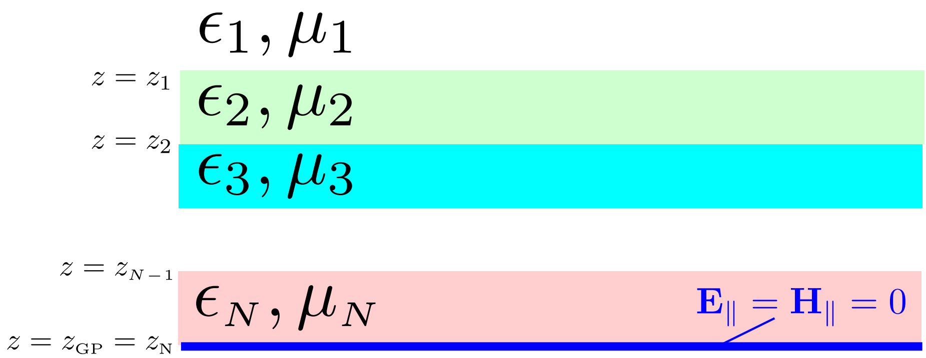

Figure 1: Geometry of the layered substrate. The nth layer has relative permittivity and permeability ϵ_n, μ_n, and its lower surface lies at $z = z_n$. The ground plane, if present, lies at $z = z_{\rm GP}$.

1 Overview

In a previous memo[1] I considered SCUFF-STATIC electrostatics calculations in the presence of a multilayered dielectric substrate. In this memo I extend that discussion to the case of *full-wave* (i.e. nonzero frequencies beyond the quasistatic regime) scattering calculations in the SCUFF-EM core library.

Substrate geometry

As shown in Figure 1, I consider a multilayered substrate consisting of N material layers possibly terminated by a perfectly-conducting ground plane. The uppermost layer (layer 1) is the infinite half-space above the substrate. The nth layer has relative permittivity and permeability ϵ_n, μ_n, and its lower surface lies at $z = z_n$. The ground plane, if present, lies at $z \equiv z_{\rm N} \equiv z_{\rm GP}$. If the ground plane is absent, layer N is an infinite half-space[2] ($z_{\rm N} = -\infty$).

Mechanics of implementation in SCUFF-EM

The full-wave substrate implementation in SCUFF-EM involves multiple working parts.

[1] "Implicit handling of multilayered dielectric substrates in SCUFF-STATIC"

[2] As in the electrostatic case, this means that a finite-thickness substrate consisting of N material layers is described as a stack of $N + 1$ layers in which the bottommost layer is an infinite vacuum half-space.

2 Computation of Fourier-space DGF

3 Reduction of 2D integrals over q to 1D integrals over q

4 Evaluation of 1D integrals

5 Substrate contributions to panel and panel-panel integrals

$$\begin{aligned}\boldsymbol{\mathcal{G}}^{\text{PQ}}(\rho,\theta,z_{\text{D}},z_{\text{S}}) &= \sum_{\nu p} g^{\text{PQ}\nu p}(\rho,z_{\text{D}},z_{\text{S}})\boldsymbol{\Lambda}^{\text{PQ}\nu p}(\theta) \\ g^{\text{PQ}\nu p}(\rho) &= \int \frac{qdq}{(2\pi)}\widetilde{g}^{\text{PQ}\nu p}(q)J_\nu(q\rho)e^{i\alpha(q,z_{\text{D}},z_{\text{S}})}\boldsymbol{\Lambda}^{\text{PQ}\nu p}(\theta)\end{aligned}$$

$$\Big\langle \mathbf{b}_\alpha \Big| \boldsymbol{\mathcal{G}}^{PQ} \Big| \mathbf{b}_\beta \Big\rangle$$