HOFEM-AIRBUS Transmission/Reflection

Group of Radiofrequency, Electromagnetism, Microwaves and Antennas (GREMA)
http://grema.webs.tsc.uc3m.es/

Departamento de Teoría de la Señal y Comunicaciones (TSC)
Universidad Carlos III de Madrid, Spain

Contact: Luis Emilio García-Castillo legcasti@ing.uc3m.es,
Adrián Amor aamor@ing.uc3m.es, Sergio Llorente sllorent@ing.uc3m.es

uc3m | Universidad **Carlos III** de Madrid

Outline

1. On the FEM Implementation of TX/RX Conditions in HOFEM
   - Existing FEM Formulation in HOFEM
   - Two-Port Network Parameters
2. $[Z]/[Y]$ Approach
   - FEM Formulation
   - Testing
   - HOFEM Implementation

Outline

1. On the FEM Implementation of TX/RX Conditions in HOFEM
   - Existing FEM Formulation in HOFEM
   - Two-Port Network Parameters

2. $[Z]/[Y]$ Approach
   - FEM Formulation
   - Testing
   - HOFEM Implementation

We start considering different alternatives to implement the TX/RX conditions in the context of the present FEM formulation coded in HOFEM

Outline

TITULO

Hola

Outline

TITULO

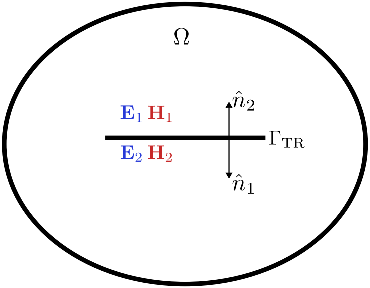
Hola

Outline

We describe the implementation of the TX/RX conditions uisng the characterization of the material sheet in terms of its immittance (impedance/admittance) matrix

Outline

Formulation



$$\hat{n}_1 \times (\mu_r^{-1} \nabla \times \mathbf{E}_1) - \frac{jk_0}{\eta} y_{11} \hat{n}_1 \times (\hat{n}_1 \times \mathbf{E}_1) - \\ - \frac{jk_0}{\eta} y_{12} \hat{n}_2 \times (\hat{n}_2 \times \mathbf{E}_2) = 0,$$

$$\hat{n}_2 \times (\mu_r^{-1} \nabla \times \mathbf{E}_2) - \frac{jk_0}{\eta} y_{21} \hat{n}_1 \times (\hat{n}_1 \times \mathbf{E}_1) - \\ - \frac{jk_0}{\eta} y_{22} \hat{n}_2 \times (\hat{n}_2 \times \mathbf{E}_2) = 0,$$

Note that y_{xx} are relative to the vacuum admittance.

Formulation (cont.)

Find $\mathbf{E} \in \mathbf{H}_0(\text{curl}, \Omega)$ such that

$$\Big(\nabla \times \mathbf{w}, \mu_r^{-1} \nabla \times \mathbf{E}\Big)_\Omega - k_0^2 \Big(\mathbf{w}, \varepsilon_r \mathbf{E}\Big)_\Omega + jk_0 \Big\langle \hat{n} \times \mathbf{w}, \hat{n} \times \mathbf{w} \Big\rangle_{\Gamma_\mathrm{C}} =$$
$$\Big(\mathbf{w}, \mathbf{F}\Big)_\Omega - \Big\langle \hat{n} \times (\mathbf{w} \times \hat{n}), \mathbf{\Psi}_\mathrm{N} \Big\rangle_{\Gamma_\mathrm{N}} - \Big\langle \hat{n} \times (\mathbf{w} \times \hat{n}), \mathbf{\Psi}_\mathrm{C} \Big\rangle_{\Gamma_\mathrm{C}} \quad \forall\, \mathbf{w} \in \mathbf{H}_0(\text{curl}, \Omega).$$

with

$$\Big(\mathbf{w}, \mathbf{v}\Big)_\Omega = \int_\Omega \mathbf{w}^* \cdot \mathbf{v} \, d\Omega,$$
$$\Big\langle \mathbf{w}, \mathbf{v} \Big\rangle_\Gamma = \int_\Gamma \mathbf{w}^* \cdot \mathbf{v} \, d\Gamma.$$

Formulation (cont.)

For *upper* elements on Γ_{TR} (side 1), we have

$$\begin{aligned}&\mathrm{LHS}_1\\&+j\frac{k_0}{\eta}\left\langle \hat{n}\times(\mathbf{w}_1\times\hat{n}), y_{11}\hat{n}\times(\mathbf{w}_1\times\hat{n})\right\rangle_{\Gamma_{\mathrm{TR}}}+j\frac{k_0}{\eta}\left\langle \hat{n}\times(\mathbf{w}_1\times\hat{n}), y_{12}\hat{n}\times(\mathbf{w}_2\times\hat{n})\right\rangle_{\Gamma_{\mathrm{TR}}}=\\&\mathrm{RHS}_1,\end{aligned}$$

whereas for *lower* elements (side 2), we get

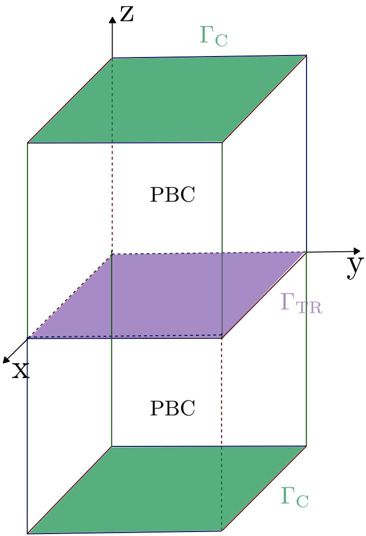
$$\begin{aligned}&\mathrm{LHS}_2\\&+j\frac{k_0}{\eta}\left\langle \hat{n}\times(\mathbf{w}_2\times\hat{n}), y_{21}\hat{n}\times(\mathbf{w}_1\times\hat{n})\right\rangle_{\Gamma_{\mathrm{TR}}}+j\frac{k_0}{\eta}\left\langle \hat{n}\times(\mathbf{w}_2\times\hat{n}), y_{22}\hat{n}\times(\mathbf{w}_2\times\hat{n})\right\rangle_{\Gamma_{\mathrm{TR}}}=\\&\mathrm{RHS}_2,\end{aligned}$$

FEM implementation

- The DOFs will be doubled for the faces and the interior edges.
- The exterior edges of Γ_{TR} are not doubled.
  - Identified by code: the edges associated to two faces are interior.
  - If the boundaries of the sheet belong to PBC, the edges of Γ_{TR} are also doubled.

Outline

Problem to be solved



Simulation of an infinite medium with transmission/reflection sheet that divides the space into two halves.

- Γ_{TR}: Transmission/reflection sheet defined with

$$\mathbf{Y} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}.$$

- Γ_C: ABC with excitation with polarization E_y
- The vertical faces are set to PBC

Testbench

- $\mathbf{Y} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$: sanity check, we should get same result as the two halves with a PMC.
- $\mathbf{Y} = \mathbb{I}$: sanity check, we should get same result as the two halves with an ABC.
- Change lower Γ_C by PEC and solve analytic problem with four media: final test.
  - Obtain parameters for $\mathbf{Y}$ of the equivalent problem.
  - Get same solutions for the electric field.
  - Transparent? Puede ser que aproximar con $1e6$. Quizás con ABCD.

Outline

HOFEM implementation

- New boundary condition: `TRBC`.
  - We define a normal, $\hat{n}_{\mathrm{TRBC}}$ to detect lower and upper side. Upper side is the closer to $\hat{n}_{\mathrm{TRBC}}$.
  - Definition of y_{11}, y_{12}, y_{21}, and y_{22} as relative values with respect to vacuum admittance.
- Two options for implementation
  - Integers defined in `tetrahedra_element`.
  - Allocatable array of $1 \times N_{\mathrm{elem,TR}}$ where the two positions (stored in boundary conditions module, accessible from `mesh_reordering_module` and `elementary_terms_3D`):
    1. $10\times$ Neighbor element identifier (to couple $\mathbf{w}_2$ and $\mathbf{w}_1$).
    2. Integer 1,2 (side) (to extract the values of y_{11},y_{12},y_{21}, and y_{22}).
- Significant methods involved:
  - Postprocessing over `reordering_DOF_algorithm_3D`.
  - `calc_boundary_3D_nxNi_nxNi_term_of_this_element`.
  - Construction of the MUMPS-related matrix: different number of non-zeros per element, assembly of coupled elements (now single-element assembly).