TEST CASE 3: Shielding Effectiveness of a finite conductivity sphere

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1. Abstract

We are interested in the computation of the shielding effectiveness of a hollow conducting shell as a function of frequency. In order to have a reference solution, in the this test case we consider a thin spherical shell of finite conductivity illuminated by a plane wave. We look for the total electromagnetic field at the centre of this sphere compared to the incident wave.

2. 2. Test object configuration

The test object is a hollow sphere of means radius $\boldsymbol{R} = \mathbf{1}\boldsymbol{m}$ and thickness $\boldsymbol{d} = \mathbf{0.25MM}$. The thin layer is characterised by electromagnetic coefficients $(\boldsymbol{\varepsilon_c} = \boldsymbol{\varepsilon_0}, \boldsymbol{\sigma_c}, \boldsymbol{\mu_c} = \boldsymbol{\mu_0})$, the interior domain $\boldsymbol{\Omega}^-$ and the exterior one $\boldsymbol{\Omega}^+$ by $(\boldsymbol{\varepsilon_0}, \boldsymbol{\mu_0})$. This object is illuminated by an incident plane wave $(\vec{\boldsymbol{E}}^{\boldsymbol{in}}, \vec{\boldsymbol{H}}^{\boldsymbol{in}})$

$$\vec{E}^{inc}(\mathbf{r}) = \vec{E}_0^{inc} e^{-ik\hat{\nu}\cdot\mathbf{r}} \vec{H}^{inc}(\mathbf{r}) = \vec{H}_0^{inc} e^{-ik\hat{\nu}\cdot\mathbf{r}}$$

The result does not dependent on the direction $\hat{\nu}$, nor the polarisation. One can take for example $\hat{\nu} = \hat{e}_z$ and

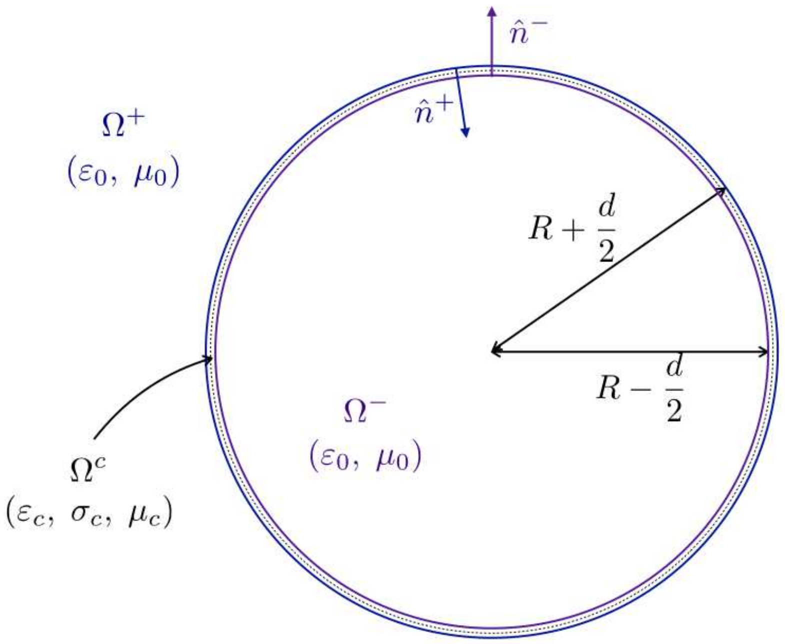

Fig1: Hollow sphere, layer of thickness = d very small compared to the mean radius R.

horizontal polarisation.
We denote by
Γ^+ the sphere of radius $R + \frac{d}{2}$,
Γ^0 the sphere of radius R,
Γ^- the sphere of radius $R - \frac{d}{2}$.

3. Modelling

Modelling of the thin layer could be done either in the time domain or the frequency domain. In the frequency domaine, using $e^{-i\omega t}$ convention, the thin layer is characterised by:

its wavenumber

$$k_c = \omega\sqrt{\left(\varepsilon + i\frac{\sigma}{\omega}\right)\mu}$$

and its specific impedance

$$Z_c = \sqrt{\frac{\mu}{\varepsilon + i\frac{\sigma}{\omega}}}$$

The thin layer could be modelled by the following impedance transmission condition on the sphere Γ^0 of radius R (*i.e.* neglecting the geometrical thickness):

$$\begin{bmatrix} \vec{E}_t^+ \\ \vec{E}_t^- \end{bmatrix} = \begin{bmatrix} z_d & z_n \\ z_n & z_d \end{bmatrix} \begin{bmatrix} \vec{H}^+ \wedge \vec{n}^+ \\ \vec{H}^- \wedge \vec{n}^- \end{bmatrix}$$

where

$$z_d = iZ_c\frac{\cos(k_c d)}{\sin(k_c d)} \qquad z_n = iZ_c\frac{1}{\sin(k_c d)}$$

and where $\hat{n}^-$ (resp. $\hat{n}^+$) is the outward unitary normal to Ω^-(resp. Ω^-) on Γ^0.

The transmission condition can also be given using the admittance relation:

$$\begin{bmatrix} \vec{H}_t^+ \\ \vec{H}_t^- \end{bmatrix} = \begin{bmatrix} y_d & y_n \\ y_n & y_d \end{bmatrix} \begin{bmatrix} \vec{n}^+ \wedge \vec{E}^+ \\ \vec{n}^- \wedge \vec{E}^- \end{bmatrix}$$

$$y_d = \frac{1}{iZ_c}\frac{\cos(k_c d)}{\sin(k_c d)} \qquad y_n = \frac{1}{iZ_c}\frac{1}{\sin(k_c d)}$$

4. Observable

We look for the electric and magnetic shielding effectiveness defined by

$$\mathrm{SE}_E = 20\log_{10}\left(\frac{|\vec{E}^{tot}(O)|}{|\vec{E}^{inc}(O)|}\right)$$

and

$$\mathrm{SE}_H = 20\log_{10}\left(\frac{|\vec{H}^{tot}(O)|}{|\vec{H}^{inc}(O)|}\right)$$

where O is the centre of the sphere. SE_E and SE_H shall be computed as a function of frequency. Frequency band : inside]0, 1GHz]. Smallest frequency shall be taken as small as possible. The choice of the frequencies is left up to the participants. Results will be compared both in logarithmic and linear frequency scale.

Three configurations will be considered:
case 4.1 : $\sigma = 10 S/m$,
case 4.2 : $\sigma = 10^5 S/m$,
case 4.3 : $\sigma = 10^7 S/m$.

Results will be stored in 3 ASCII files case31.txt, case32.txt and case33.txt, containing on each row 3 values : frequency SE_E SE_H (space will be used as separator).