Workshop ISAE 2023 – Heterogeneous capsule-like structure

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Geometry of the case

The geometry is symmetric with respect to the z-axis. It consists of a PEC sphere-cylinder-sphere (each half-sphere is connected to the cylinder ensuring standard tangential constraints), of length $L = 0{,}25$ m and radius $R = 0{,}005$ m, covered by two layers of constant thicknesses: the inner layer, of thickness $e_1 = 0.016$ m, the outer layer, of thickness $e_2 = 0.004$ m. All geometry sizes are showed in the figures below.

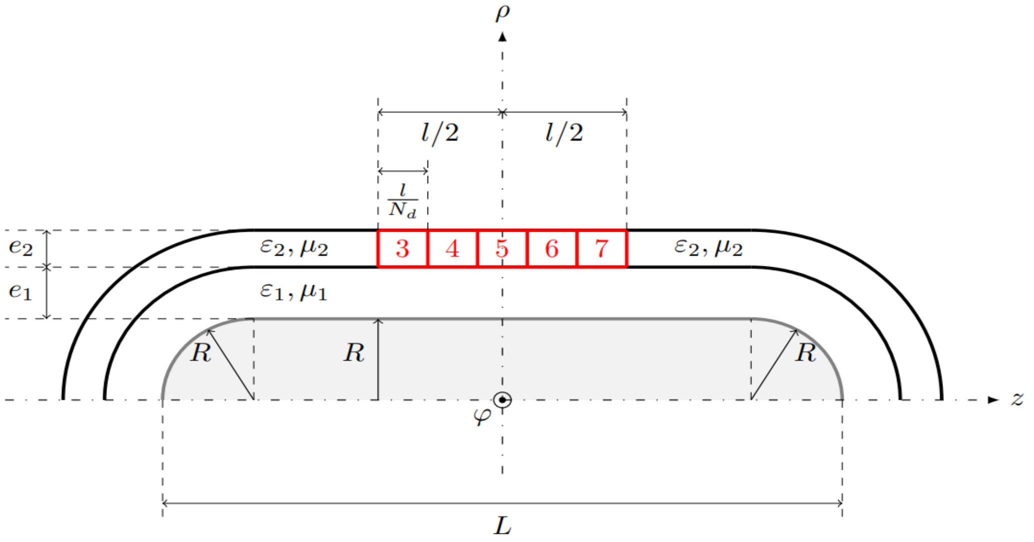
The inner and outer layers are filled by homogeneous, isotropic media with relative constitutive parameters $\varepsilon_1 = 1 - 0{,}397\,j,\ \mu_1 = 1 - 0{,}4$ j; $\varepsilon_2 = 1 - 0{,}143\,j$; $\mu_2 = 1$, respectively.

The aim is to analyze the electromagnetic scattering by this structure in air in **two configurations** as follows:

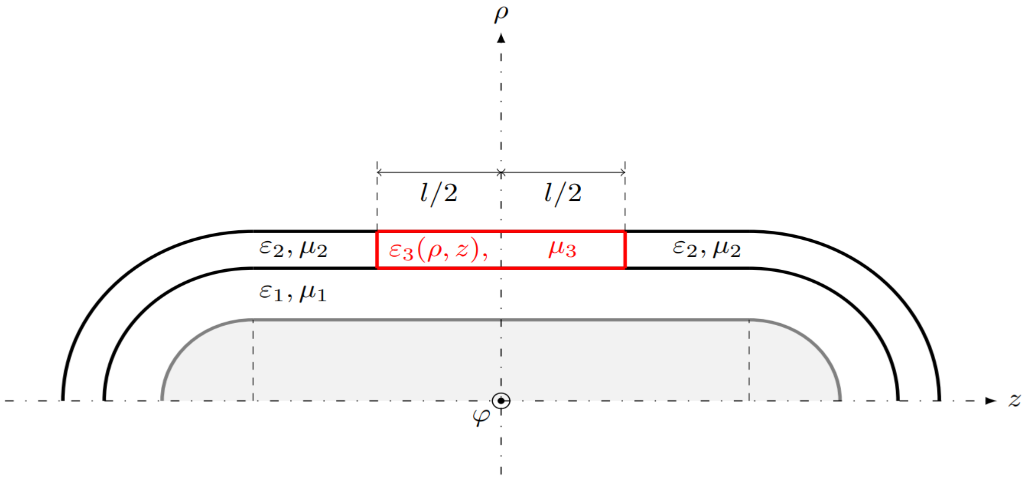
1. rectangle-section toroid filled by a medium with piecewise constant permittivity is prescribed in the outer layer;
2. rectangle-section toroid filled by a "heterogeneous" medium with non-constant permittivity is prescribed in the outer layer.

The time dependence is assumed to be $e^{j\omega t}$.

- **Configuration #1 :** piecewise constant transition



- **Configuration #2 :** heterogeneous transition

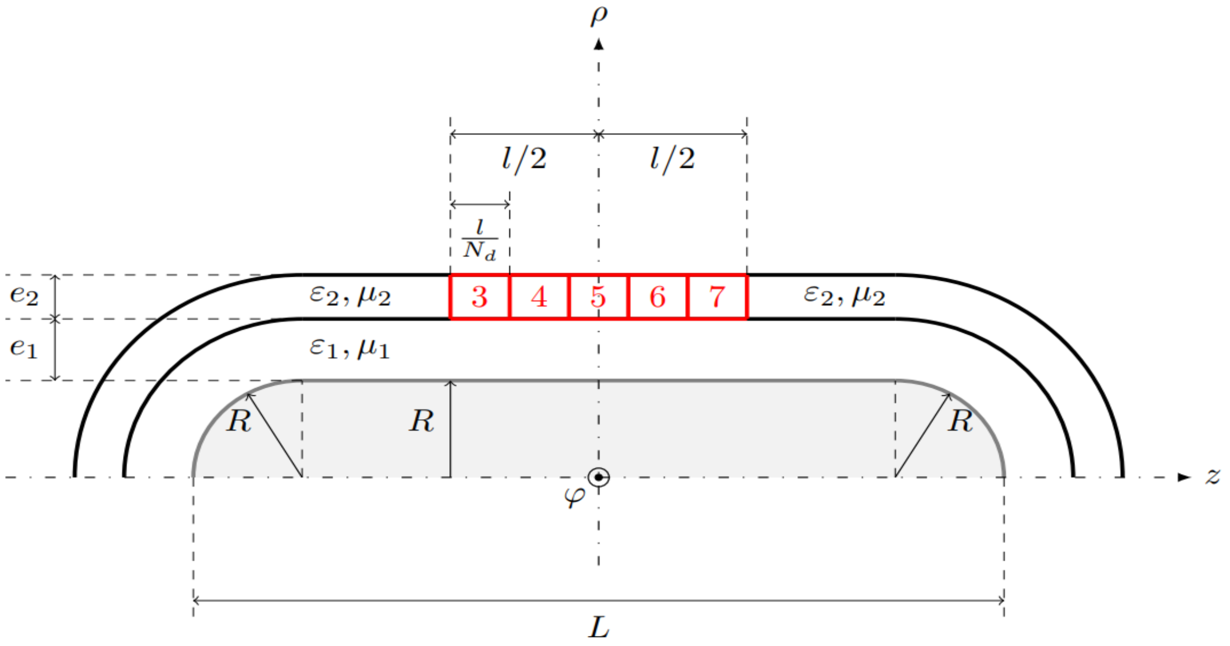


Configuration #1

In this configuration the scattering structure features a piecewise constant transition (the red area) in ε_2 of the homogenous medium in the outer layer, occurring along the z-axis over a distance $l = 0{,}06$ m and centered around the ρ-axis. The resulting transition toroid is partitioned into $N_d = 5$ non-overlapping sub-domains having the same shape. Each sub-domain, referred to as region $3, 4, 5, 6$ or 7 in the figure below, has a rectangle section of size e_2 and $l/N_d = 0{,}012$ m .

In the outer layer, the relative permeability is kept constant and equal to 1; i.e. $\boldsymbol{\mu_m = \mu_2 = 1}$ with $m \in [3,7]$; while the relative permittivity constants are defined as follows.

region #	ε_m
3	$\mathbf{1,6 - 0,115\,j}$
4	$\mathbf{2,8 - 0,059\,j}$
5	$\mathbf{3,7 - 0,017\,j}$
6	$\mathbf{2,8 - 0,059\,j}$
7	$\mathbf{1,6 - 0,115\,j}$

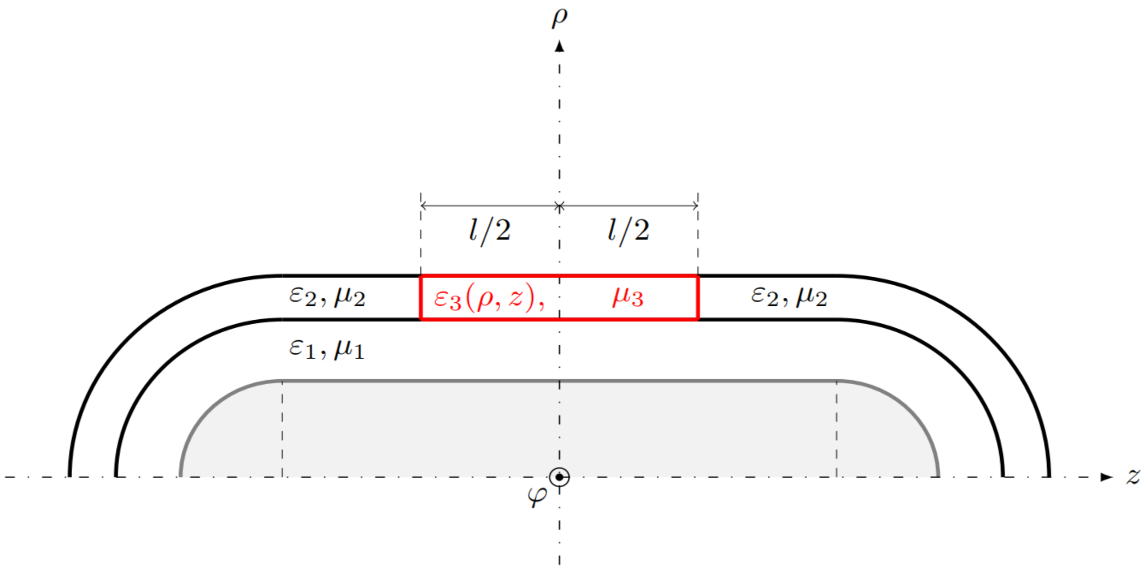


Configuration #2

In this configuration the scattering structure features a heterogeneous transition (the red area) in ε_2 of the homogenous medium in the outer layer, occurring on the $\rho - z$ plane within a rectangle-section region of size $\mathrm{l} = 0.06$ m and e_2 , centered around the ρ-axis.

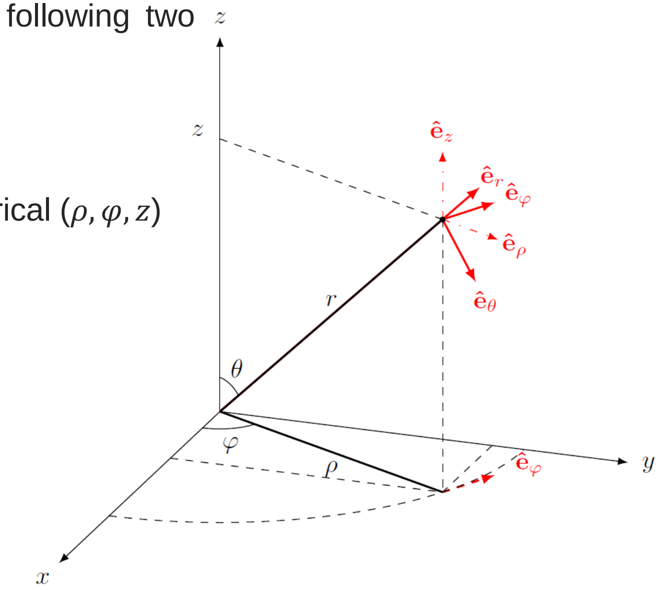
In the outer layer, the relative permeability is kept constant and equal to 1; i.e. $\boldsymbol{\mu_3} = \boldsymbol{\mu_2} = \mathbf{1}$; while the relative permittivity parameters are defined as follows :

- $\varepsilon_3(\rho, z) = \ \varepsilon_2 + 2{,}1634 \times \left[1 - \frac{\sqrt{\rho^2+z^2}}{\sqrt{(R+e1+e2)^2+\left(\frac{l}{2}\right)^2}}\right] \times (3 + 0{,}14\, j);$ if $\rho \in [R + e_1, R + e_1 + e_2]$; $\mathrm{z} \in \left[-\frac{l}{2}, \frac{l}{2}\right]$;
- $\varepsilon_2 = 1 - 0{,}143\, j;$ otherwise.



Results to be provided

- We are seeking the **monostatic RCS** (defined as $\mathrm{RCS} = \lim_{r\to\infty} 4\pi r^2 \frac{|\boldsymbol{E}^{scattered}(r)|^2}{|\boldsymbol{E}^{inc}|^2}$) in both configurations for the following two cases.
  - **Case "BANG"** :
    - $\begin{cases}\theta \in [0°, 90°] \\ \varphi = 0°\end{cases}$ in the standard spherical coordinate system (the figure shows spherical (r, θ, φ) and cylindrical (ρ, φ, z) coordinate systems), with angular step $\Delta\theta = 0.1°$ (i.e. 901 angles);
    - wave frequency $f = 5$ GHz;
    - $\theta\theta$ - and $\varphi\varphi$ – polarization;
  - **Case "BFRE"** :
    - $(\theta, \varphi) = (0°, 0°)$;
    - wave frequency ranging from 4 GHz to 6 GHz, with frequency step $\Delta f = 0{,}02$ GHz (i.e. 101 frequencies);
    - $\theta\theta$– and $\varphi\varphi$– polarization.



- <u>Nota Bene</u> : For results comparison, a **reference monostatic RCS**, for the two above cases, has to be also provided. In this case, the simulation is performed using the two-layer structure, only consisting of the two homogeneous, isotropic media without any permittivity transition region (see figure below).

- **Expected results** shall be stored in six ASCII files named `RCS_capsule_case_config.res`, with `case` being one of the keywords: `bang` or `bfre`; and `config` being one of the keywords: `pwconst`, `hetero` or `ref`.
- **Each file** shall have six columns :
  - angle θ in degrees (or frequency in GHz);
  - RCS in db.m^2 for $\theta\theta$ – polarization;
  - phase of the complex RCS in degrees for $\theta\theta$ – polarization;
  - RCS in db.m^2 for $\varphi\varphi$ – polarization;
  - phase of the complex RCS for $\varphi\varphi$ – polarization.