Electric Sensor

This is a model from electric impedance tomography, a method of imaging the interior permittivity distribution of an object by measuring current and voltage at the surface. The technique is used in, for example, medical diagnosis. Because different organs have different properties, you can "see" the organs and their movement from the outside.

The model shows how you can determine the shape and the placement of small objects with different material properties inside a closed box from the outside. Applying a potential difference on the boundaries of the box gives rise to a surface charge density that varies depending on the permittivity distribution inside the box. By looking at the surface charge density you can therefore see the shape of the different materials inside the box.

Model Definition

This model solves Gauss' law with $\rho = 0$.

$$-\nabla \cdot (\varepsilon_0 \varepsilon_r \nabla V) = \rho$$

The box contains air with ε_r equal to 1 and the different objects are made of material with different values of the relative permittivity, ε_r: 1, 2, and 3.

To get a voltage difference, set $V = 0$ on the bottom and $V = 1$ on top of the box. On all other boundaries, use an electric insulation condition: $\mathbf{n} \cdot \mathbf{D} = 0$.

Results and Discussion

The surface charge density is higher above material with higher permittivity as expected. You can clearly see the shape of the figures inside the box on the top surface in the following plot.

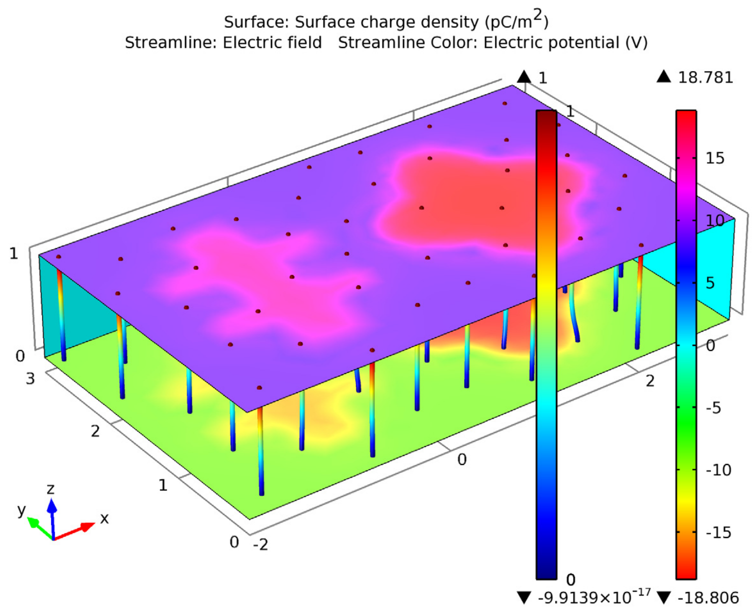


Figure 1: Surface charge density (boundary), electric field (streamline density), and electric potential (streamline color).

Inside the geometry the streamlines show how the electric field varies. The gradient of the electric field is lower in media with larger value of the permittivity.

Model Library path: `COMSOL_Multiphysics/Electromagnetics/electric_sensor`

Modeling Instructions

MODEL WIZARD

1. Go to the **Model Wizard** window.
2. Click **Next**.
3. In the **Add physics** tree, select **AC/DC>Electrostatics (es)**.
4. Click **Add Selected**.

5 Click **Next**.

6 In the **Studies** tree, select **Preset Studies>Stationary**.

7 Click **Finish**.

GEOMETRY 1

Work Plane 1

1 In the **Model Builder** window, right-click **Model 1>Geometry 1** and choose **Work Plane**.

2 Go to the **Settings** window for Work Plane.

3 Locate the **Work Plane** section. In the **z-coordinate** edit field, type `0.1`.

4 Click the **Build Selected** button.

Rectangle 1

1 In the **Model Builder** window, right-click **Geometry** and choose **Rectangle**.

2 Go to the **Settings** window for Rectangle.

3 Locate the **Size** section. In the **Width** edit field, type `0.5`.

4 In the **Height** edit field, type `2`.

5 Locate the **Position** section. In the **x** edit field, type `-1`.

6 In the **y** edit field, type `0.5`.

7 Click the **Build Selected** button.

Rectangle 2

1 In the **Model Builder** window, right-click **Work Plane 1>Geometry** and choose **Rectangle**.

2 Go to the **Settings** window for Rectangle.

3 Locate the **Size** section. In the **Width** edit field, type `1.5`.

4 In the **Height** edit field, type `0.25`.

5 Locate the **Position** section. In the **x** edit field, type `-1.5`.

6 In the **y** edit field, type `1`.

7 Click the **Build Selected** button.

Rectangle 3

1 In the **Model Builder** window, right-click **Work Plane 1>Geometry** and choose **Rectangle**.

2 Go to the **Settings** window for Rectangle.

3 Locate the **Size** section. In the **Width** edit field, type `1.5`.

4 In the **Height** edit field, type `0.25`.
5 Locate the **Position** section. In the **x** edit field, type `-1.5`.
6 In the **y** edit field, type `1.75`.
7 Click the **Build Selected** button.

Union 1

1 In the **Model Builder** window, right-click **Work Plane 1>Geometry** and choose **Boolean Operations>Union**.
2 Select the objects **r1**, **r2**, and **r3** only.
3 Go to the **Settings** window for Union.
4 Locate the **Union** section. Clear the **Keep interior boundaries** check box.
5 Click the **Build Selected** button.
6 Click the **Zoom Extents** button on the Graphics toolbar.

Ellipse 1

1 In the **Model Builder** window, right-click **Work Plane 1>Geometry** and choose **Ellipse**.
2 Go to the **Settings** window for Ellipse.
3 Locate the **Size and Shape** section. In the **a-semiaxis** edit field, type `0.5`.
4 Locate the **Position** section. In the **x** edit field, type `1.5`.
5 In the **y** edit field, type `1.5`.
6 Click the **Build Selected** button.
7 Click the **Zoom Extents** button on the Graphics toolbar.

Ellipse 2

1 In the **Model Builder** window, right-click **Work Plane 1>Geometry** and choose **Ellipse**.
2 Go to the **Settings** window for Ellipse.
3 Locate the **Size and Shape** section. In the **b-semiaxis** edit field, type `0.5`.
4 Locate the **Position** section. In the **x** edit field, type `1.5`.
5 In the **y** edit field, type `1.5`.
6 Click the **Build Selected** button.

Compose 1

1 In the **Model Builder** window, right-click **Work Plane 1>Geometry** and choose **Boolean Operations>Compose**.
2 Select the objects **e1** and **e2** only.

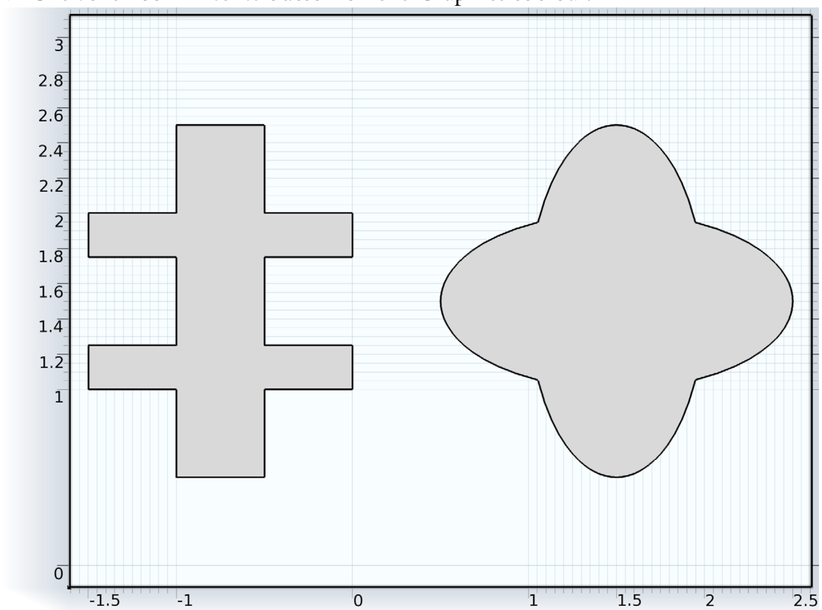
3 Go to the **Settings** window for Compose.

4 Locate the **Compose** section. Clear the **Keep interior boundaries** check box.

5 In the **Set formula** edit field, type `e1+e2`.

6 Click the **Build Selected** button.

7 Click the **Zoom Extents** button on the Graphics toolbar.



Extrude 1

1 In the **Model Builder** window, right-click **Work Plane 1** and choose **Extrude**.

2 Go to the **Settings** window for Extrude.

3 Locate the **Distances from Work Plane** section. In the associated table, enter the following settings:

DISTANCES (M)
0.8

4 Click the **Build Selected** button.

5 Click the **Zoom Extents** button on the Graphics toolbar.

Block 1

1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.

2 Go to the **Settings** window for Block.

3 Locate the **Size and Shape** section. In the **Width** edit field, type `5`.

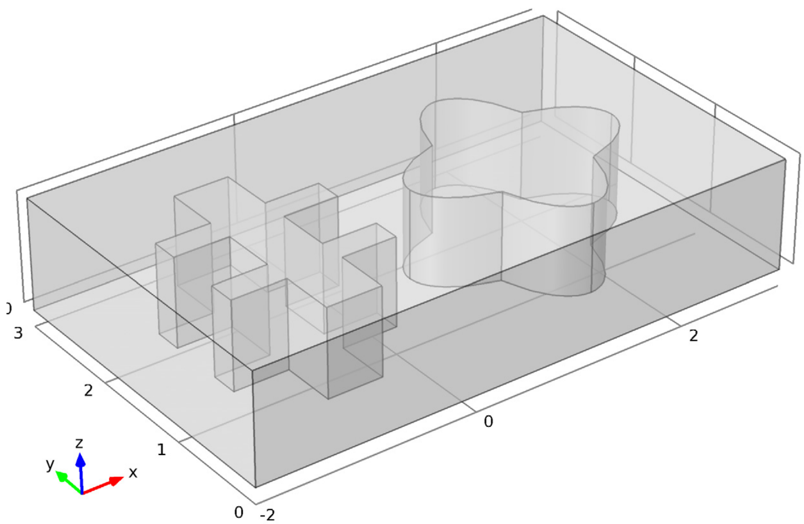
4 In the **Depth** edit field, type `3`.

5 Locate the **Position** section. In the **x** edit field, type `-2`.

6 Click the **Build All** button.

7 Click the **Transparency** button on the Graphics toolbar.

This completes the model geometry.



ELECTROSTATICS

Charge Conservation 1

1 In the **Model Builder** window, expand the **Model 1>Electrostatics** node, then click **Charge Conservation 1**.

2 Go to the **Settings** window for Charge Conservation.

3 Locate the **Electric Field** section. From the ε_r list, select **User defined**.

Charge Conservation 2

1 In the **Model Builder** window, right-click **Electrostatics** and choose **Charge Conservation**.

2 Select Domain 2 only.

3 Go to the **Settings** window for Charge Conservation.

4 Locate the **Electric Field** section. From the ε_r list, select **User defined**. In the associated edit field, type 2.

Charge Conservation 3

1 In the **Model Builder** window, right-click **Electrostatics** and choose **Charge Conservation**.

2 Select Domain 3 only.

3 Go to the **Settings** window for Charge Conservation.

4 Locate the **Electric Field** section. From the ε_r list, select **User defined**. In the associated edit field, type 3.

Ground 1

1 In the **Model Builder** window, right-click **Electrostatics** and choose **Ground**.

2 Select Boundary 3 only.

Electric Potential 1

1 In the **Model Builder** window, right-click **Electrostatics** and choose **Electric Potential**.

2 Select Boundary 4 only.

3 Go to the **Settings** window for Electric Potential.

4 Locate the **Electric Potential** section. In the V_0 edit field, type 1.

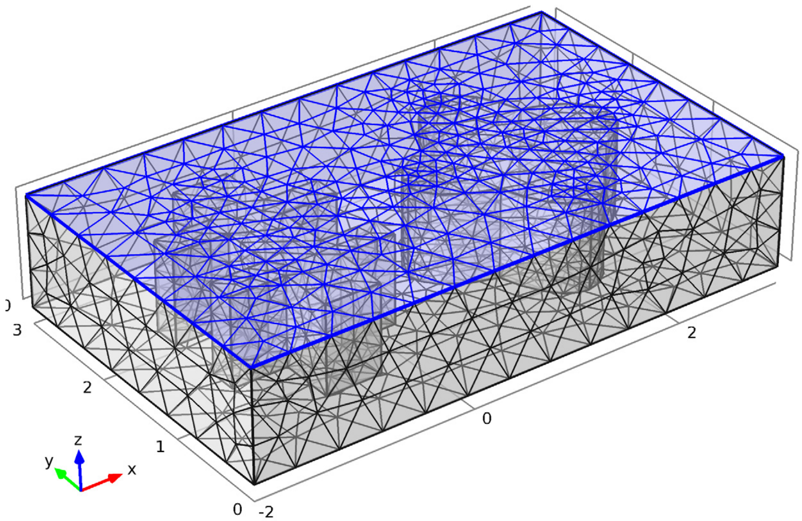
MESH 1

1 In the **Model Builder** window, click **Model 1>Mesh 1**.

2 Go to the **Settings** window for Mesh.

3 Locate the **Mesh Settings** section. From the **Element size** list, select **Fine**.

4 Click the **Build All** button.



STUDY 1

1 In the **Model Builder** window, right-click **Study 1** and choose **Compute**.

RESULTS

To reproduce the plot shown in Figure 1, begin by suppressing some boundaries so that the inside of the box becomes visible.

Data Sets

1 In the **Model Builder** window, expand the **Results>Data Sets** node.

2 Right-click **Solution 1** and choose **Add Selection**.

3 Go to the **Settings** window for Selection.

4 Locate the **Geometric Entity Selection** section. From the **Geometric entity level** list, select **Boundary**.

5 From the **Selection** list, select **All boundaries**.

6 Select Boundaries 3–5 and 38 only.

7 Click the **Transparency** button on the Graphics toolbar.

Remove the default slice plot of the potential.

Electric Potential (es)

1 In the **Model Builder** window, right-click **Results>Electric Potential (es)** and choose **Delete**.

2 Click **Yes** to confirm.

3D Plot Group 1

1 Right-click **Results** and choose **3D Plot Group**.

2 In the **Model Builder** window, right-click **Results>3D Plot Group 1** and choose **Surface**.

3 Go to the **Settings** window for Surface.

4 In the upper-right corner of the **Expression** section, click **Replace Expression**.

5 From the menu, choose **Electrostatics>Surface charge density (es.nD)**.

6 Locate the **Expression** section. From the **Unit** list, select **pC/m^2**.

7 Locate the **Coloring and Style** section. From the **Color table** list, select **Cyclic**.

8 Click the **Plot** button.

9 Click the **Zoom Extents** button on the Graphics toolbar.

10 In the **Model Builder** window, right-click **3D Plot Group 1** and choose **Streamline**.

11 Go to the **Settings** window for Streamline.

12 Locate the **Streamline Positioning** section. From the **Positioning** list, select **Magnitude controlled**.

13 Locate the **Coloring and Style** section. From the **Line type** list, select **Tube**.

14 Right-click **Streamline 1** and choose **Color Expression**.

Compare the resulting plot with that in Figure 1.