Created in COMSOL Multiphysics 5.6

Electric Sensor

Introduction

This example illustrates — in a simplified electrostatic setting — electric impedance tomography (EIT), a method used for imaging of the distribution of electrical permittivity in an object. The tomography is performed by measuring currents and voltages at the object's surface.

An application of this technique is medical diagnosis. Due to the different electrical properties of various organs and parts of the body, it is possible to obtain information on their position and movement in a non-invasive way.

This model shows how to determine from the outside the shape and the placement of small objects with different material properties inside a box. Applying a potential difference on the boundaries of the box creates a surface charge density that varies depending on the permittivity distribution 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. The different objects are made of materials with different values of the relative permittivity, ε_r: 1, 2, and 3.

To get a voltage difference, a ground condition ($V = 0$) is set on the bottom while the condition $V = 1$ is applied on the top of the box. On the side, the boundary condition used is electric insulation: $\mathbf{n} \cdot \mathbf{D} = 0$.

Results and Discussion

As seen in Figure 1, the surface charge density is higher in correspondence of materials with higher permittivity, as expected. An imaging of the figures inside the box is reproduced in the surface charge density plot.

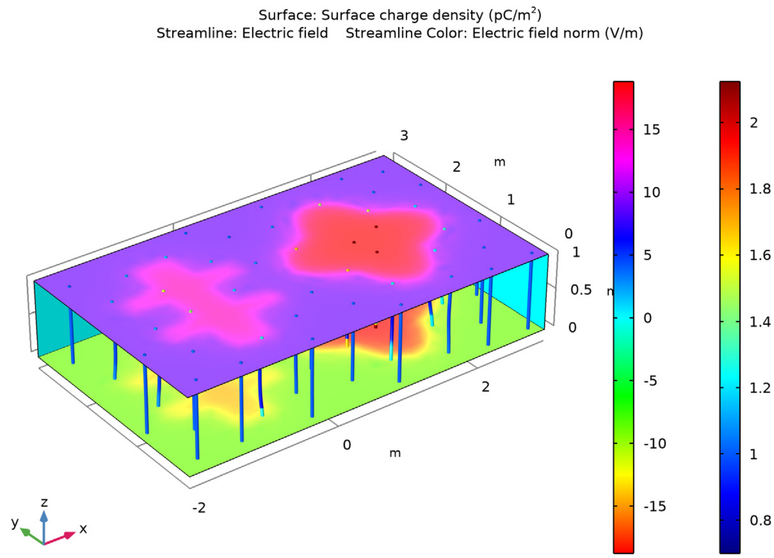


Figure 1: Surface charge density (boundary), electric field (streamline density), and electric potential (streamline color).

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

Application Library path: `COMSOL_Multiphysics/Electromagnetics/electric_sensor`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click  **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click  **3D**.

2 In the **Select Physics** tree, select **AC/DC>Electric Fields and Currents>Electrostatics (es)**.

3 Click **Add**.

4 Click **Study**.

5 In the **Select Study** tree, select **General Studies>Stationary**.

6 Click **Done**.

GEOMETRY 1

Work Plane 1 (wp1)

1 In the **Geometry** toolbar, click **Work Plane**.

2 In the **Settings** window for **Work Plane**, locate the **Plane Definition** section.

3 In the **z-coordinate** text field, type `0.1`.

4 Click **Show Work Plane**.

Work Plane 1 (wp1)>Rectangle 1 (r1)

1 In the **Work Plane** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `0.5`.

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

5 Locate the **Position** section. In the **xw** text field, type `-1`.

6 In the **yw** text field, type `0.5`.

7 Click **Build Selected**.

Work Plane 1 (wp1)>Rectangle 2 (r2)

1 In the **Work Plane** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `1.5`.

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

5 Locate the **Position** section. In the **xw** text field, type `-1.5`.

6 In the **yw** text field, type `1`.

7 Click **Build Selected**.

Work Plane 1 (wp1)>Rectangle 3 (r3)

1 In the **Work Plane** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `1.5`.
4 In the **Height** text field, type `0.25`.
5 Locate the **Position** section. In the **xw** text field, type `-1.5`.
6 In the **yw** text field, type `1.75`.
7 Click **Build Selected**.

Work Plane 1 (wp1)>Union 1 (uni1)

1 In the **Work Plane** toolbar, click **Booleans and Partitions** and choose **Union**.
2 Click in the **Graphics** window and then press Ctrl+A to select all objects.
3 In the **Settings** window for **Union**, locate the **Union** section.
4 Clear the **Keep interior boundaries** check box.
5 Click **Build Selected**.
6 Click the **Zoom Extents** button in the **Graphics** toolbar.

Work Plane 1 (wp1)>Ellipse 1 (e1)

1 In the **Work Plane** toolbar, click **Ellipse**.
2 In the **Settings** window for **Ellipse**, locate the **Size and Shape** section.
3 In the **a-semiaxis** text field, type `0.5`.
4 Locate the **Position** section. In the **xw** text field, type `1.5`.
5 In the **yw** text field, type `1.5`.
6 Click **Build Selected**.
7 Click the **Zoom Extents** button in the **Graphics** toolbar.

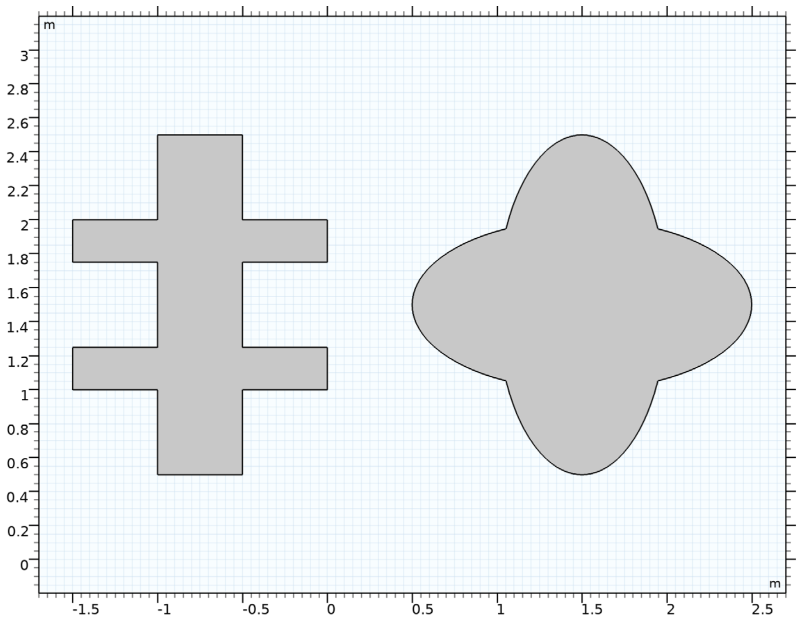
Work Plane 1 (wp1)>Ellipse 2 (e2)

1 In the **Work Plane** toolbar, click **Ellipse**.
2 In the **Settings** window for **Ellipse**, locate the **Size and Shape** section.
3 In the **b-semiaxis** text field, type `0.5`.
4 Locate the **Position** section. In the **xw** text field, type `1.5`.
5 In the **yw** text field, type `1.5`.
6 Click **Build Selected**.

Work Plane 1 (wp1)>Compose 1 (co1)

1 In the **Work Plane** toolbar, click **Booleans and Partitions** and choose **Compose**.
2 Select the objects **e1** and **e2** only.
3 In the **Settings** window for **Compose**, locate the **Compose** section.

4. Clear the **Keep interior boundaries** check box.
5. In the **Set formula** text field, type `e1+e2`.
6. Click **Build Selected**.
7. Click the **Zoom Extents** button in the **Graphics** toolbar.



Extrude 1 (ext1)

1. In the **Model Builder** window, under **Component 1 (comp1)>Geometry 1** right-click **Work Plane 1 (wp1)** and choose **Extrude**.
2. In the **Settings** window for **Extrude**, locate the **Distances** section.
3. In the table, enter the following settings:

Distances (m)
`0.8`

4. Click **Build Selected**.
5. Click the **Zoom Extents** button in the **Graphics** toolbar.

Block 1 (blk1)

1. In the **Geometry** toolbar, click **Block**.
2. In the **Settings** window for **Block**, locate the **Size and Shape** section.

3 In the **Width** text field, type `5`.

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

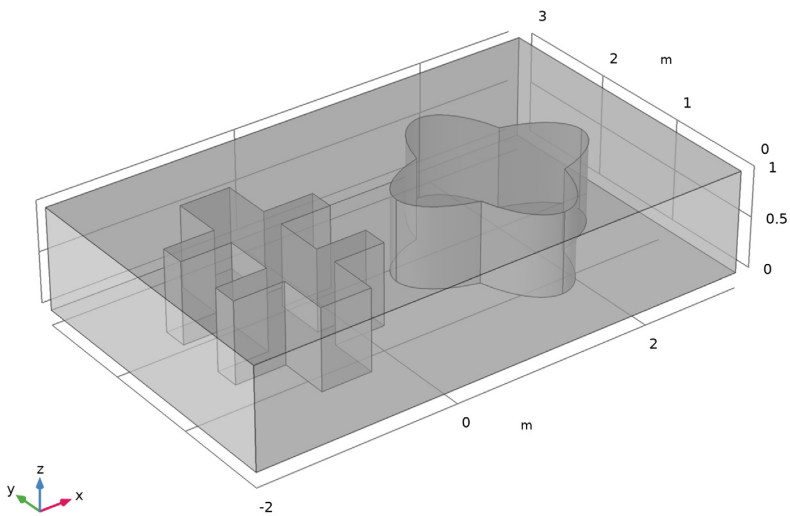
5 Locate the **Position** section. In the **x** text field, type `-2`.

6 Click **Build All Objects**.

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

8 Click the **Transparency** button in the **Graphics** toolbar.

This completes the model geometry.



ELECTROSTATICS (ES)

Ground 1

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Electrostatics (es)** and choose **Ground**.

2 Select Boundary 3 only.

Electric Potential 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Electric Potential**.

2 Select Boundary 4 only.

3 In the **Settings** window for **Electric Potential**, locate the **Electric Potential** section.

4 In the V_0 text field, type 1.

MATERIALS

Material 1 (mat1)

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Materials** and choose **Blank Material**.

2 In the **Settings** window for **Material**, locate the **Material Contents** section.

3 In the table, enter the following settings:

Property	Variable	Value	Unit	Property group
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	1	1	Basic

Material 2 (mat2)

1 Right-click **Materials** and choose **Blank Material**.

2 Select Domain 2 only.

3 In the **Settings** window for **Material**, locate the **Material Contents** section.

4 In the table, enter the following settings:

Property	Variable	Value	Unit	Property group
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	2	1	Basic

Material 3 (mat3)

1 Right-click **Materials** and choose **Blank Material**.

2 Select Domain 3 only.

3 In the **Settings** window for **Material**, locate the **Material Contents** section.

4 In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	3	1	Basic

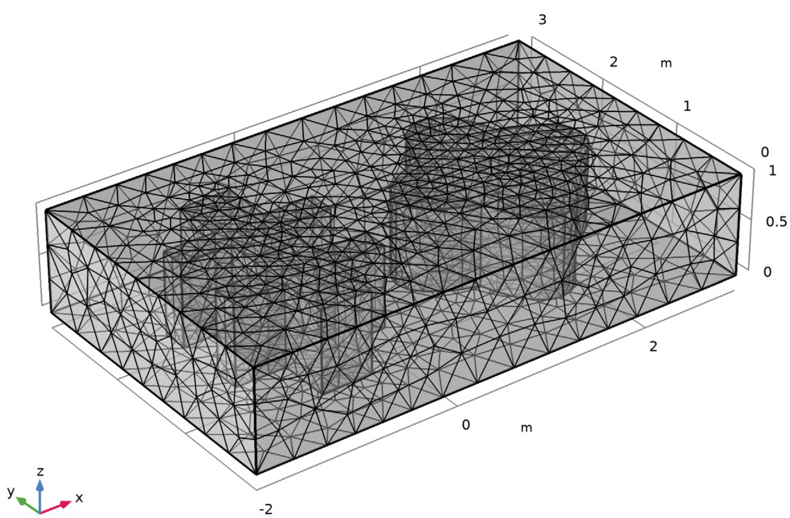
MESH 1

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Mesh 1**.

2 In the **Settings** window for **Mesh**, locate the **Physics-Controlled Mesh** section.

3 From the **Element size** list, choose **Fine**.

4 Click **Build All**.



STUDY 1

In the **Home** toolbar, click **Compute**.

RESULTS

Electric Potential (es)

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

Study 1/Solution 1 (sol1)

In the **Model Builder** window, expand the **Results>Datasets** node, then click **Study 1/ Solution 1 (sol1)**.

Selection

1 In the **Results** toolbar, click **Attributes** and choose **Selection**.

2 In the **Settings** window for **Selection**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 From the **Selection** list, choose **All boundaries**.

5 Select Boundaries 3–5 and 38 only.

6 Click the **Transparency** button in the **Graphics** toolbar.

Electric Potential (es)

Remove the default slice plot of the potential.

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

2 In the **Model Builder** window, click **Results**.

3 Click **Yes** to confirm.

3D Plot Group 1

In the **Results** toolbar, click **3D Plot Group**.

Surface 1

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

2 In the **Settings** window for **Surface**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)>Electrostatics> Currents and charge>es.nD - Surface charge density - C/m²**.

3 Locate the **Expression** section. In the **Unit** field, type `pC/m^2`.

4 Locate the **Coloring and Style** section. From the **Color table** list, choose **Cyclic**.

5 In the **3D Plot Group 1** toolbar, click **Plot**.

6 Click the **Zoom Extents** button in the **Graphics** toolbar.

Streamline 1

1 In the **Model Builder** window, right-click **3D Plot Group 1** and choose **Streamline**.
2 In the **Settings** window for **Streamline**, locate the **Streamline Positioning** section.
3 From the **Positioning** list, choose **Magnitude controlled**.
4 Locate the **Coloring and Style** section. Find the **Line style** subsection. From the **Type** list, choose **Tube**.

Color Expression 1

1 Right-click **Streamline 1** and choose **Color Expression**.
2 In the **Settings** window for **Color Expression**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)>Electrostatics>Electric>es.normE - Electric field norm - V/m**.
3 Click to expand the **Title** section. From the **Title type** list, choose **Automatic**.

   Compare the resulting plot with that in Figure 1.