Two Layers Dielectric Cylinder in a Homogeneous Field

Description

In this validation example, the calculation of electrostatic field strength in two layers dielectric cylinder is considered. The inner cylinder has radius, a = 5mm, and a relative permittivity, ε_{r2} = 2. The outer cylinder has radius, b =10mm, and a relative permittivity, ε_{r1} = 5. The whole system is placed in a homogeneous transverse electrostatic field, $E_0 = E_0\hat{x}$, as illustrated in Figure 1. We wish to validate the results of EMS against the published data [1].
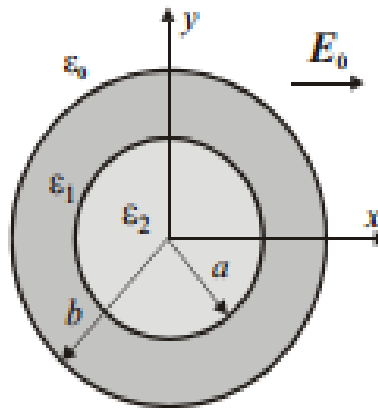

Figure 1: Two layers dielectric cylinder

In the published article, the authors simply modeled it as a 2-Dimensional structure. EMS is a fully 3-dimensional field simulator. Even though the cylinder is uniform along its axis, a small depth must be considered. Furthermore, the air around the cylinder must be also included in the model.
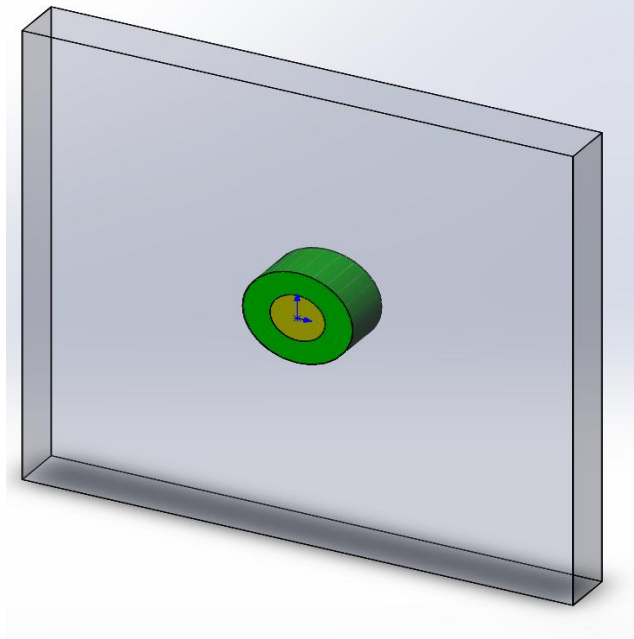
Figure 2: SolidWorks model of the dielectric cylinder

The study

The Electrostatic module of EMS is used to compute the electric field strength and the potential distribution in the dielectric cylinders and the surrounding air region. After creating the Electrostatic study, or the design scenario, in EMS, three important steps shall always be followed. That is, apply the proper material for all solid bodies, apply the necessary boundary conditions, or the so called Loads/Restraints in EMS, and mesh the entire model.

Materials

In this example, there are only 3 materials to apply. The Table 1 illustrates these materials

Component/Body	Relative Permittivity
Air box	1.0
Inner cylinder	2.0
Outer cylinder	5.0

Table 1: Materials of all solid bodies in the Electrostatic study

The application of materials is straight forward. Just right-click on the component icon and apply the material.

Loads/Restraints

Loads and restraints are necessary to define the electric and magnetic environment of the model. The results of analysis directly depend on the specified loads and restraints. Loads and restraints are applied to geometric entities as features that are fully associative to geometry and automatically adjusted to geometric changes.

The only applicable boundary condition in this study is the external electrostatic field. To mimic the external electrostatic field, a voltage difference of 10 V is applied across the 100mm air region, i.e. E0 = 10V/0.1m = 100 V/m.

Meshing

Meshing is a very crucial step in the design analysis.   EMS estimates a global element size for the model taking into consideration its volume, surface area, and other geometric details. The size of the generated mesh (number of nodes and elements) depends on the geometry and dimensions of the model, element size, mesh tolerance, and mesh control. In the early stages of design analysis where approximate results may suffice, you can specify a larger element size for a faster solution. For a more accurate solution, a smaller element size may be required.

In this particular benchmark, the meshing is rather straightforward since the geometry does entail small regions and gaps. Thus, the global element size is set to 10 mm with a mesh tolerance of 0.01 mm. To achieve a good accuracy without increasing the total number of mesh elements, it is recommended to apply a mesh control to the regions where a large field or variation is expected. A local mesh control of 1 mm is applied to the dielectric cylinders. Figure 3 shows the resulting mesh.
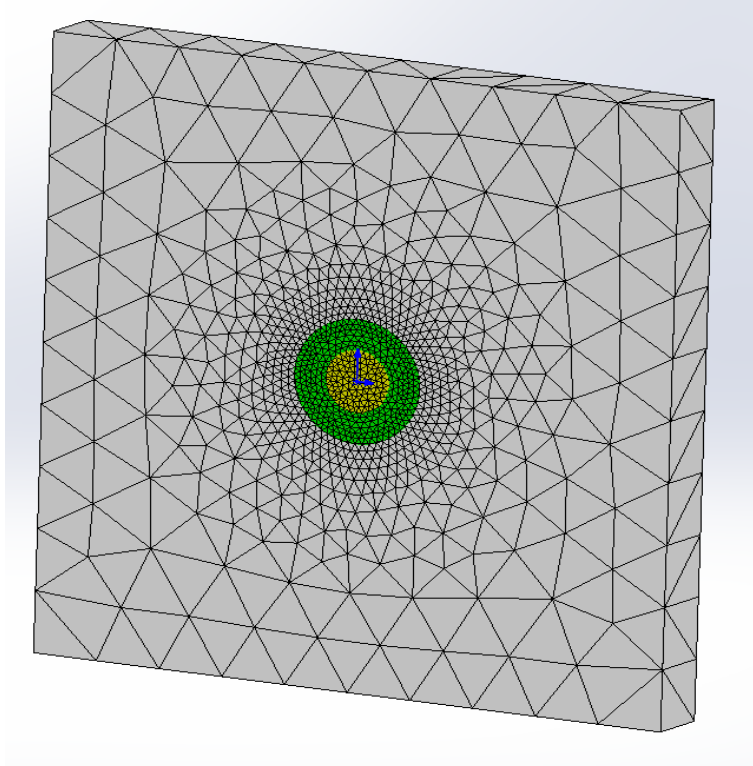
Figure 3: Mesh of the structure

Results

After a successful run, the Electrostatic module produces three result folders and a result table. The folders contain the electric field **E**, the electric displacement **D**, the potential distribution **V**, respectively. The result table contains the electrostatic stored energy and the capacitance matrix if applicable. Furthermore, all of the results can be visualized in various formats such as fringe, vector, contour, section, line, and, clipping plots. The results can easily be zoomed-in, exported, and dissected.

For this particular benchmark, the fringe plot of the electric field distribution in the dielectric cylinders and the surrounding air is compared against the reported results in [1]. In addition, the line plot feature of EMS is used to compare the electric field at two points with coordinates (0.0, 0.0, 0.0) and (0.75cm, 0.0, 0.0). As Figures 4-6 indicate, the results of EMS match those reported by the authors of [1].
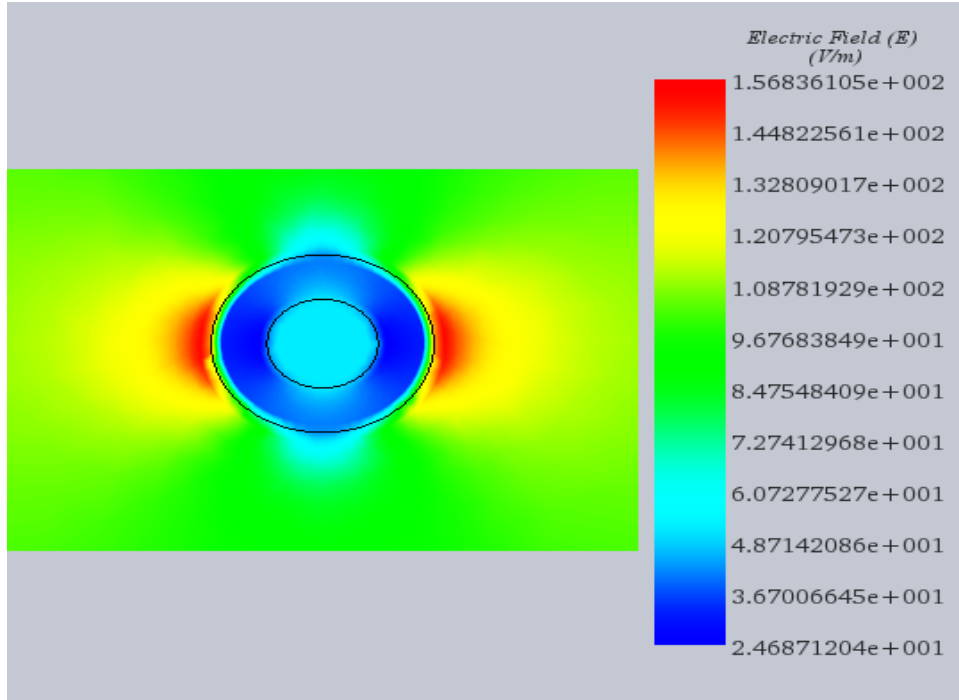
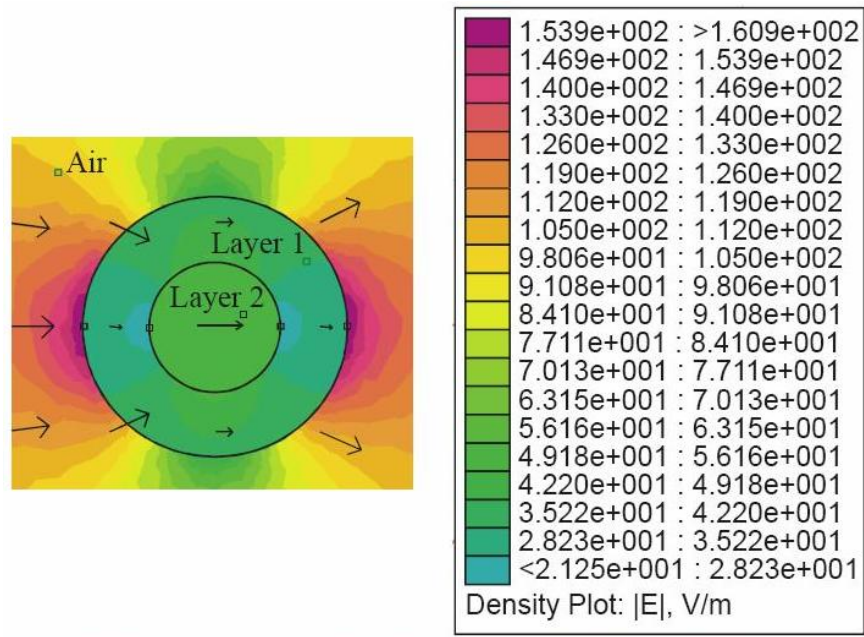Figure 4: Electrostatic field distribution obtained by EMS

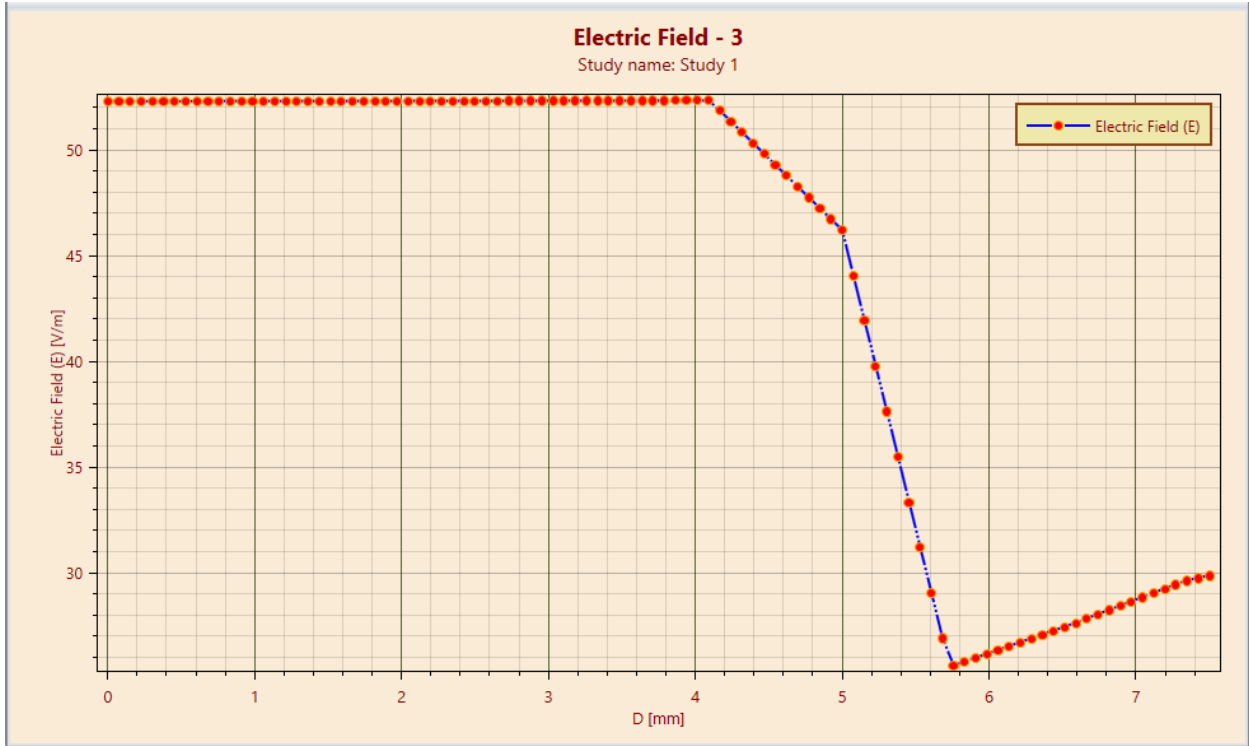Figure 5: Electrostatic field distribution as reported in [1]

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Figure 6: Line plot of electrostatic field between **(0.0, 0.0) and (0.75cm, 0.0)** obtained by EMS

Applied method	E/E_0 $(x/b, y/b)$	
	$(0,0)$	$(0.75,0)$
Analytical method	0.512820	0.290598
Charge simulation method	0.512820	0.290605
Finite element method (femm 4.0)	0.523663	0.297639
Finite element method (FEMLAB)	0.522716	0.298253

Table 2: Electrostatic field at **(0.0, 0.0) and (0.75cm, 0.0)** as reported in [1]

Conclusion

This benchmark demonstrates the high accuracy achieved by the Electrostatic module of EMS compared to published results. Hence, in addition of being fully integrated in SolidWorks and easy to use, EMS is also very accurate.

References

[1] Peric, M.T; Cvetkovic, Z.Z; Aleksic, S.R., "Two Layers Dielectric Cylinder in Homogeneous Field," Proceedings of the European Conference on Antennas and Propagation: EuCAP (ESA SP-626). 6-10 November 2006, Nice, France. Editors: H. Lacoste & L. Ouwehand. Published on CDROM, p.396.1