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Electric Field in the Ovoid-Shaped Dielectric

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Abstract: In nature are quite present ovoid-shaped of the dielectric. Using the method of fictitious sources we can determine the electric field inside the ovoid-shaped dielectric.

Keywords: Ovoid-shaped dielectric, Method of fictitious sources.

1 Introduction

A variety of dielectric forms for storing different resources, such as water, gas, fuel, etc. are commonly used in external environment, e.g. in industry. These sphere-, helicoid-, torus-, or ovoid-shaped forms are exposed to electric field effects. High frequency waves that create significant value of the electric field can be the source of the fields above [1, 2]. As for the sphere-shaped dielectric, it is not the dielectric size that determines the value of the field inside the dielectric, but the value of the dielectric constant [3], which implies that the field is the same in both micro and macro spherical shape, provided that the value of the dielectric constant is the same. In all other geometric forms of dielectric, the field within it is correlated with its dimensions.

In this study, the value of the field in an ovoid-shaped dielectric will be determined, whereby the method of fictitious sources [4, 5] is employed to determine the fields and potentials.

2 Dielectric Model and Formulation of the Problem

To ensure the ovoid shape of the dielectric, an approximation of the outer surface of the dielectric was done using the equation in (1).

$$r = a + b\cos\theta, \quad a > b > 0, \quad 0 \le \theta \le 2\pi . \qquad (1)$$

It is assumed that the form is independent and filled with dielectric $\varepsilon = \varepsilon_0 \varepsilon_r$ and subjected to the effect of the electric field $\vec{\boldsymbol{E}}_0 = E_0 \vec{\boldsymbol{x}}$, where ε_r stands for relative dielectric constant of the dielectric inside the ovoid-shaped form. The electric field and the potential both inside and outside of the ovoid-shaped electrodes cannot be accurately determined therefore the method of fictitious sources will be used for approximate workout of this problem.

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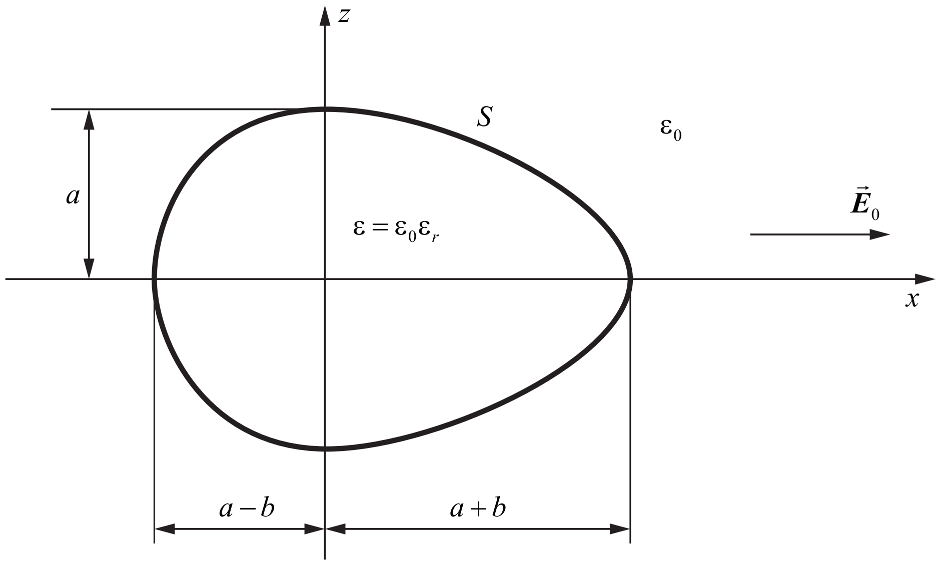

Fig. 1 – *Ovoid shape dielectric.*

For simplicity reasons, still maintaining the generality, in this particular case, the external field is axial relatively to the dielectric form, which allows the fictitious sources to be located along the axis of symmetry (x-axis). In terms of creating fields outside the dielectric ovoid-shaped form, N_1, point loads located on the axis of the ovoid shape inside, is established.

As for the formation of the field inside the ovoid-shaped form, fictitious point loads, located on the x-axis, but outside of the ovoid-shaped form, are established, whereby N_2 and N_3 are set on the left and right of the electrode, respectively.

The potential within φ_i and outside of the ovoid-shaped form (electrode) φ_e, can be presented as

$$\varphi_i = \sum_{n=1}^{N} q_n G(\vec{r}, \vec{r}_n), \quad N = N_2 + N_3, \tag{2}$$

$$\varphi_e = \sum_{n=1}^{N_1} Q_n G(\vec{r}, \vec{r}_n) - E_0 x, \tag{3}$$

where $G(r, r_n) = \dfrac{1}{4\pi\varepsilon_0 |\vec{\boldsymbol{r}} - \vec{\boldsymbol{r}}_n|}$ is Green's function for the potential of independent spot load.

The intensity of fictituous sources q_n and Q_n need to be chosen in such a way as to ensure that the boundary conditions on the electrode surface are met

$$\varphi_i = \varphi_e \tag{4}$$

at S surface

$$\frac{\partial \varphi_i}{\partial n} = \varepsilon_r \frac{\partial \varphi_e}{\partial n}, \tag{5}$$

which shows that the potential and the normal component of electric induction on bubbles surface are unchanging sizes.

To determine the intensity of fictitious sources, a functional is formed:

$$F = t_1 \sum_{i=1}^{I_1} \left(\varphi_i - \varphi_e \right)^2 + t_2 \sum_{i=1}^{I_2} \left(\frac{\partial \varphi_i}{\partial n} - \varepsilon_r \frac{\partial \varphi_e}{\partial n} \right)^2 + t_3 \sum_{i=1}^{I_3} \left(\frac{\partial \varphi_i}{\partial t} - \frac{\partial \varphi_e}{\partial t} \right)^2 . \tag{6}$$

At the S surface, where t_1, t_2, t_3 stand for the weight factors which characterize the presence of particular boundary condition, whereas I_1, I_2 and I_3 are adjustment points on the surface of the ovoid-shaped electrode.

Minimizing the functional (6) allows for the system of linear equations which in the final outcome enable the determination of intensity of fictitious sources.

3 Numerical Example and Conclusion

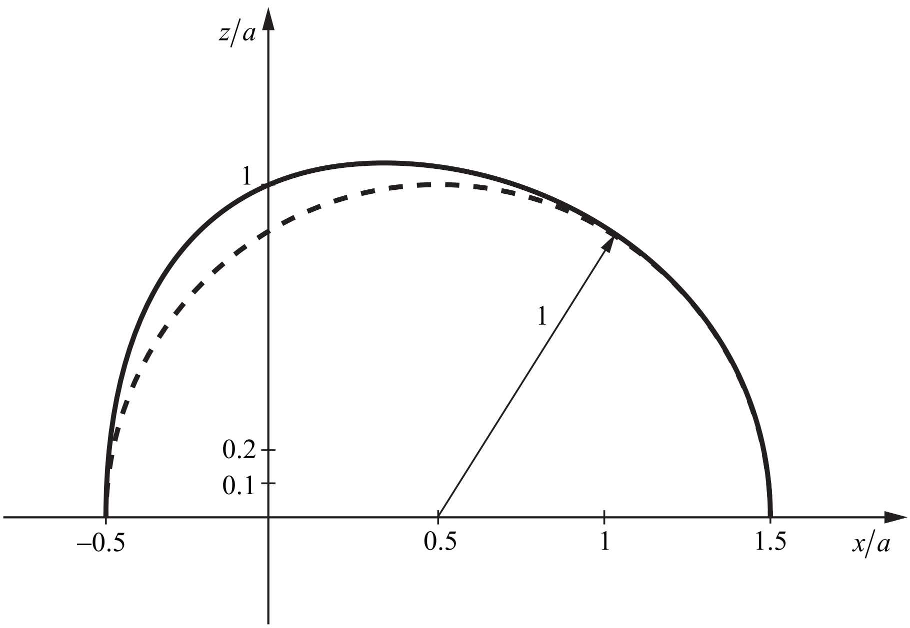

Fig. 2 – *Ovoid-shaped electrode spherical approximation.*

In order to illustrate the given procedure, the ovoid-shaped electrode where $b/a = 0.5$ is presented. In Fig. 2, the solid line shows the ovoid-shaped electrode while the broken line represents its spherical approximation.

Fig. 3 shows the dependence of the electric field strength on the ovoid shape axis (the E/E_0 ratio), whereby it is assumed that $\varepsilon_r = 2.5$, and the calculation resulted in $N_1 = N_2 = N_3 = 12$ and $I_1 = I_2 = I_3 = 100$. The weight factors are assumed to be equal.

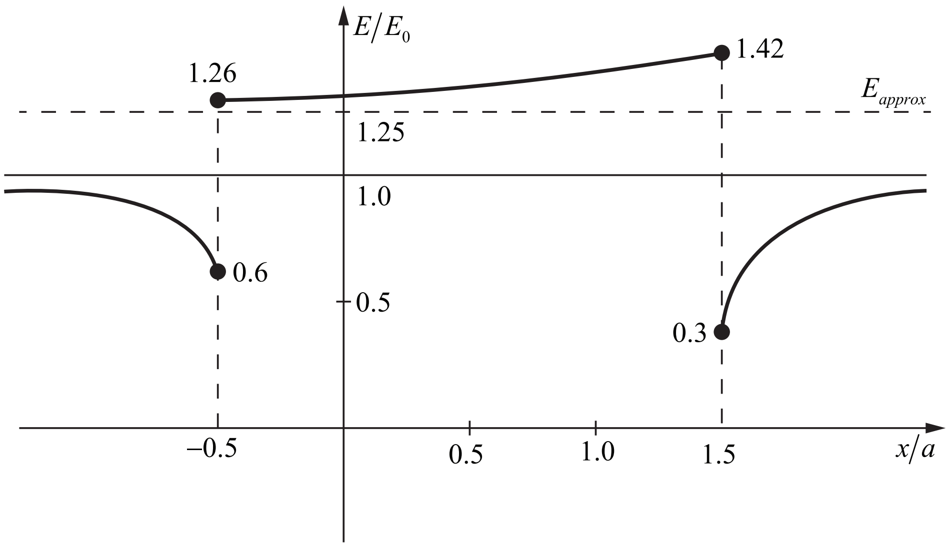

Fig. 3 – *Dependence of the electric field strength on the ovoid shape axis.*

If the dielectric (electrode) were assumed as a sphere, the inside strength of the field would be $E_{approx} = \dfrac{3\varepsilon_r E_0}{(1+\varepsilon_r)} = 1.25$. Compared to approximate value, more accurately determined field is larger by some $0.17E_0$, or by about 13% relative to an approximate value.

This actually shows that the deformation of the electrode relative to the sphere increases the value of the field inside the deformed, ovoid-shaped, form.

The developed numerical procedure enables also the examination of the influence of the field on the human head, which can be spherical, ovoid or elliptical in shape.

Scientific papers published so far already present analyses of the influence of the electric or magnetic fields on the head (animal or human) [6, 7, 8], however the further work of the authors of this paper is about to include analyses of the impact of potential and fields relative to the geometric shape of the human head.

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