Electrode Positions at a Dielectric Interface for Uniform Electric Field

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This paper considers the placement of four electrodes at a dielectric interface (e.g., skin surface) to produce a nearly uniform electric field at a near-surface target (e.g., a tumor).

In some biomedical applications one desires to put a large electric field on a target near a skin surface. One can do this with two electrodes (needles) stradling the target, but the electric field near the target has significant nonuniformity. One may wish for a more uniform electric-field exposure of the target. So let us consider a 4- electrode system.

One approach is that of four wires as discussed in [C. E. Baum, "Impedances and Field Distributions for Symmetrical Two Wire and Four Wire Transmission Line Simulators", Sensor and Simulation Note 27, October 1966]. Let the four wires be parallel to the z axis with equal radii r_e and with

$$(x, y) = (\pm a, \pm b) \text{ (all combinations of + and -)}$$

These wires are considered infinitely long for the moment. With voltages $\pm V$ on the wires we find that if we choose (for small r_e)

$$a/b = \frac{1}{\sqrt{3}} \cong 0.577, \Psi = 60°$$

the electric field near *(x, y)* = (0, 0) is oriented in the y direction. By symmetry all odd derivatives are zero, and also the second derivative is zero. This is a two-dimensional analog of a Helmholtz coil which is useful in EMP simulator design.

The two-dimensional case, while giving a simple answer, is not the same as the three dimensional case.

Consider a three-dimensional geometry using spherical (or hemispherical) electrodes of small radius r_e . There are now two uniform, isotropic media separated by the $z = 0$ plane which forms a symmetry plane, the electric field on this plane being parallel to the plane. This simplifies the analysis, allowing us to calculate the fields as though the electrodes were in a uniform medium. The target is situated in medium 1 near $\vec{r}$. This medium may be a conducting dielectric, but we can analyze this as an electrostatic problem. Medium two might be air, or some other medium one chooses to apply.