# ELECTRIC FIELD STRUCTURE IN CERTAIN CASES OF AXIAL AND PLANE SYMMETRY

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This paper presents results of calculations made on a BÉSM-6 computer of the electric field of a rod and a plate, and also, of the distortion in an external field produced by a rod antenna.

The problem often arises of calculating the axial and plane electric fields produced by a cylindrical rod of finite size with a certain potential distribution along its length or by plates, disks, and strip lines. This class of problem also includes the calculation of the fields from an exploding wire [1] and from a rheostat potential divider used to measure high pulse voltages, the determination of the distortion in an external field produced by a test antenna or in the atmospheric field by a lightning conductor, and finally the question of creating a uniform field in a restricted volume for simulating the action of a uniform external field [2]. In this last case, it is important to be able to calculate the distortion produced by the introduction of a test object.

In the quasistatic approximation, the field calculation reduces to the integration of the Laplace equation with the given boundary conditions. An analytical solution is difficult in the particular cases we are considering. However, the difficulty can be resolved by a simplification of the problem. In [3], for example, an analysis of the field of a linear dipole is carried through on the assumption that the antenna is thin.

A whole class of problems, including those specified above, can be solved by the method described in [4].

As an example, we consider the electric field of a rod and a plate inside a grounded envelope (the external boundary). The details of the problem are as follows: length of rod 4 m, radius 0.1 m; the potential varies linearly along the rod with a unit gradient ($u_m = 4$); grid step $h = l = 0.2$ m; envelope radius $a = 10.7$ m, height $b = 16.2$ m. The dimensions in the plane cases are the same as in the axial case.

Figures 1a and 1b show the equipotentials for the rod and plate, respectively, at intervals of $\Delta u = 0.4$. In the

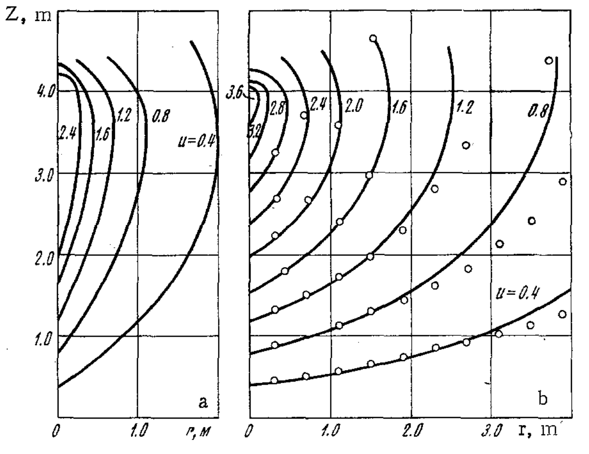


Fig. 1

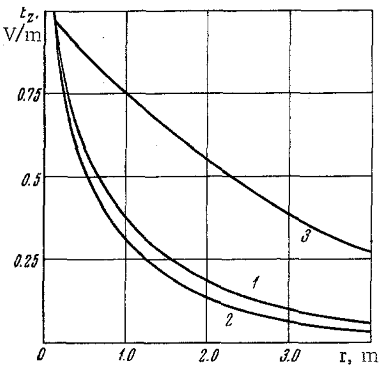


Fig. 2

Chelyabinsk. Translated from Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, No. 3, pp. 173–175, May-June, 1972. Original article submitted June 30, 1971.

TABLE 1

| $r_r$, m | Z, m | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.4 | 0.8 | 1.2 | 1.6 | 2.0 | 2.4 | 2.8 | 3.2 | 3.6 | 4.0 |
| 0.1 | 0.85 | 1.71 | 2.58 | 3.48 | 4.42 | 5.42 | 6.53 | 7.85 | 9.74 | 15.2 |
| 0.025 | 1.69 | 3.40 | 5.12 | 6.89 | 8.71 | 10.0 | 12.7 | 15.0 | 18.2 | 25.9 |
| 0.01 | 3.84 | 7.70 | 11.6 | 15.4 | 19.5 | 23.5 | 27.9 | 32.7 | 38.7 | 52.9 |

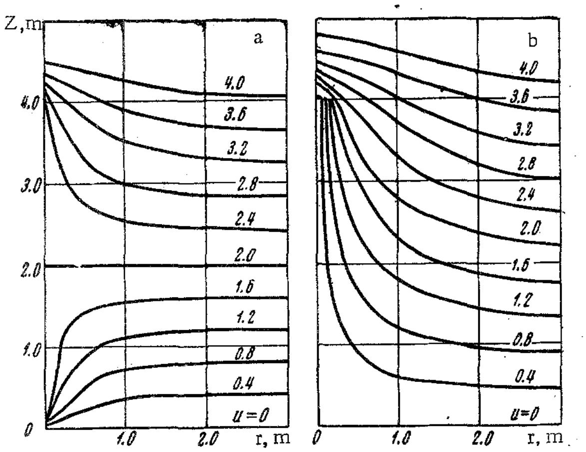


Fig. 3

case of the plate, Fig. 1b also shows the equipotential points that have been derived for the equivalent problem with an infinitely distant boundary [5]. It can be seen that the two field patterns are in close agreement for distances r < 3 m from the plate. Further out, the effect of the boundary (chamber walls) becomes important. This effect would be less noticeable in the axially symmetric case.

We now consider the case of the rod in more detail. Figure 2 shows a plot of $E_z = E_z(r)$ for z = 0.2 m (curves 1 and 2). Curve 3 corresponds to the field from the plates at a height of z = 0. It can be seen that with increasing distance from the rod the vertical field component falls off rapidly. Naturally, in the case of the plate, the field in the surrounding space is greater and the decrease with distance is slower. The maximum value of $E_z$ occurs at the ground surface (z = 0). The value then falls off and changes polarity at a level roughly equal to the height of the end of the rod.

The field component $E_r$ increases as $E_r \sim z$ near the rod, and then decreases ($E_r \sim 1/r$) as the radial distance gets greater. The magnitude of $E_r$ can be several times bigger than that of $E_z$ on the rod.

The field calculations were made for different values of the rod radius $r_r$. The values of $E_r$ at the rod surface are given in Table 1.

As a rule, a decrease in $r_r$ produces a drop in $E_z$ near the rod, and an increase in $E_r$ at the surface. Calculations show that $E_r$ might be some tens of times bigger than $E_z$. These large values of $E_r$ have been confirmed in [4] on a simplified model of a two-wire coaxial system.

There is an obvious possibility of large radial field gradients appearing in the electric explosion of a wire. These could produce ionization in the surrounding air and lead to a broadening of the discharge track; the ionization is most likely to occur high up the wire. The process might in fact affect the potential distribution along the wire, depending on the magnitude of the dynamic resistance, so that it becomes nonlinear.

These ideas also apply to the measurement of large voltage pulses by means of rheostat potential dividers.

Figure 3a and 3b show the distortion in a uniform external field produced by the introduction of an electrically short rod antenna; in Fig. 3a the antenna is unloaded, and in 3b, it is short circuited. It follows from the figure that the distortion is greatest when the loading is greatest—as is physically reasonable.

The field pattern in Fig. 3b also gives an idea of the distortion in the atmospheric electric field which would occur near a lightning conductor. The results could be useful for determining the region over which discharge occurs in such a conductor.

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