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DISTRIBUTED COMPUTING OF INTERACTION OF ELECTROMAGNETIC RADIATION WITH A STRUCTURED SURFACE

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Abstract: The article deals with the problems of interaction of electromagnetic radiation with plates structured in a certain way (AIRES resonators). Radiation falls on the plate, and free electrons emerging on the plate, diffraction and mirroring generate converted radiation in the surrounding space, which is different from the radiation falling on the plate. A mathematical model has been built and estimations have been made using a cluster of highly productive parallel computations that showed that the resulting radiation differs significantly from the radiation falling on the plate, namely it has fractal self-similarity, and a powerful wave of radiation is generated above the central part of the plate. An AIRES resonator can be used for protection against surrounding electromagnetic radiation coming from, for instance, consumer devices, such as telephones, microwaves, refrigerators etc.

Keywords: electromagnetic radiation; interaction with matter; math modeling; distributed computing

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Abstract: The article deals with the problem of interaction of electromagnetic radiation with a certain way structured plates (resonators "AIRES"). The radiation incident on the plate and by forming the plate into the free electrons, diffraction and reflection mirror, in the surrounding space creates the converted radiation differs from that incident on the plate. A mathematical model and calculations on a cluster for high performance parallel computing, which showed that the resulting radiation is significantly different from the incident on the plate, in particular, it has a fractal self-similarity and the central part of the plate forms a powerful wave radiation. Resonator "AIRES" can be used for protection against electromagnetic radiation around us originating, for example, from household appliances, such as telephones, microwave - ovens, refrigerators and others.

Keywords: electromagnetic radiation; interaction with matter; math modeling; distributed computing

Introduction The surface of AIRES resonators is made in the shape of curvilinear slits (circular grooves), whose pattern adheres to the laws of self-similarity and scale invariance and is based on affine transformations. The AIRES resonator is made on a silicon substrate (7.5 mm in diameter and 1 mm thick), on whose surface there is a complex system of 1 mcm wide and 1.2 mcm deep circular grooves with a rectangular cross-section, which make up a regular self-affine structure. The substrate can be made of silicon as well as laminated fabric and other materials. The substrate can have any diameter and thickness, and the grooves any width and depth. Electric field interacting with the semiconductor causes the phenomenon of charge shift, and because the plate is thinner in the slit area, the concentration of charge carriers will be significantly higher in the slits than in the neighboring areas [1], [2], [3], [4], [5], [6], [7], [8], [9].

The electric charge distribution on the surface of a resonator with allowances for its relief, as well as electric field intensity above the resonator's surface were simulated. The simulation implied that charge carriers were concentrated in the slits. Moreover, it is supposed that if the charge density in two neighboring

slits is q_1 and q_2 accordingly, and the potentials are φ_1 and φ_2 , then as the potential reaches a certain critical value (φ_{kp}), a spark over the shortest distance between grooves (l) occurs.

Model Description. In simulation, the conservation law for electrons and holes can be written down as follows:

$$\frac{\partial}{\partial t}(n_e + a_e n_A y_e) = q - \text{div}[V_e (n_e + a_e n_A y_e) - D_e \text{grad}(n_e + a_e n_A y_e)] - b_e n_e n_p, \quad (1)$$

$$\frac{\partial}{\partial t}(n_p + a_p n_A y_p) = q - \text{div}[V_p (n_p + a_p n_A y_p) - D_p \text{grad}(n_p + a_p n_A y_p)] - b_p n_e n_p, \quad (2)$$

where n is free electron concentration, n_p is hole concentration, n_A is atom concentration, y_e is degree of saturation of atoms with electrons, y_p is degree of saturation of atoms with holes, V_e is velocity vector of active electron transport, V_p is velocity vector of active hole transport, D_e is electron diffusion constant, D_p is hole diffusion constant, q is the appearance rate of free electrons and holes, a_e , a_p , b_e , b_p are factors.

In the present case:

$$\frac{\partial n_e}{\partial t} = q - \mu_e \left(\frac{\partial E n_e}{\partial x} + \frac{\partial E n_e}{\partial y} + \frac{\partial E n_e}{\partial z} \right) + D_e \left(\frac{\partial^2 n_e}{\partial x^2} + \frac{\partial^2 n_e}{\partial y^2} + \frac{\partial^2 n_e}{\partial z^2} \right) - b_e n_e n_p, \quad (3)$$

$$\frac{\partial n_p}{\partial t} = q - \mu_p \left(\frac{\partial E n_p}{\partial x} + \frac{\partial E n_p}{\partial y} + \frac{\partial E n_p}{\partial z} \right) + D_p \left(\frac{\partial^2 n_p}{\partial x^2} + \frac{\partial^2 n_p}{\partial y^2} + \frac{\partial^2 n_p}{\partial z^2} \right) - b_p n_e n_p, \quad (4)$$

$$V_e = \mu_e E, \quad (5)$$

$$V_p = \mu_p E, \quad (6)$$

where μ_e is electron mobility, μ_p is hole mobility, E is electric field intensity.

Electron oscillation rate in an evenly charged plate

$$\omega_0 = \sqrt{\frac{4\pi k_0 e \rho}{m_e}}, \quad (7)$$

where $\rho = n_e e$ is charge of the plate unit volume, e is electron charge, m_e is electron mass,

$k_0 = 9 \cdot 10^9 \text{ H M}^2/\text{K}\mu^2$ is a constant [10].

If a wave falls on the plate:

$$E_{nao} = E_0 \cos \omega \left(t - \frac{z}{c} \right), \quad (8)$$

then

$$E = E_0 \cos \theta + \Delta E_0 \cos \left(\theta - \frac{\pi}{2} \right) = E_0 \left(\cos \omega \left(t - \frac{z}{c} \right) + \frac{2\pi k_0 n_e e^2 \omega}{cm_e (\omega_0^2 - \omega^2)} \Delta z \right), \quad (9)$$

$$\theta = \omega \left(t - \frac{z}{c} \right), \quad (10)$$

$$\Delta E_0 = \frac{2\pi k_0 n_e e^2 \omega}{cm_e (\omega_0^2 - \omega^2)} E_0 \Delta z, \quad (11)$$

where n_e is electron concentration, ω_0 is electron oscillation frequency, Δz is plate thickness, c is the speed of light, m_e is electron mass [10].

The first addend is due to reflection, the second one is due to free electrons. For holes, ΔE_0 can be estimated using a formula similar to that of electrons.

If there are narrow slits on the plate surface, the following diffraction has to be factored in:

$$\frac{I_\beta}{I_0} = \frac{\sin^2 \left(\frac{\pi b}{\lambda} \sin \beta \right)}{\left(\frac{\pi b}{\lambda} \sin \beta \right)^2}, \quad (12)$$

where I_β is the intensity of waves spreading at an angle of β , I_0 is the intensity of waves spreading at an angle of $\beta=0$, b is the width of a slit, β is the angle, λ is the wavelength.

Wave intensity is proportional to the amplitude squared [10], hence

$$\frac{I_{\beta}}{I_0} = \frac{E_{\beta}^2}{E_0^2} = \frac{\sin^2(\frac{\pi b}{\lambda} \sin \beta)}{(\frac{\pi b}{\lambda} \sin \beta)^2}, \quad (13)$$

$$E_{\beta} = E_0 \frac{\sin(\frac{\pi b}{\lambda} \sin \beta)}{\frac{\pi b}{\lambda} \sin \beta}. \quad (14)$$

Thus, as the general outcome, we have the vector

$$E = E_{\text{отражение}} + E_{\text{электроны}} + E_{\text{дырки}} + E_{\text{дифракция}}, \quad (15)$$

where $E_{\text{отражение}}$ is due to reflection, $E_{\text{электроны}}$ is due to free electrons, $E_{\text{дырки}}$ is due to holes, $E_{\text{дифракция}}$ is due to diffraction (if there are narrow slits).

In this case, if the influence of holes is ignored, the simultaneous equations are follows:

$$E = E_0 \cos \theta + \Delta E_0 \cos(\theta - \frac{\pi}{2}) + E_{\beta} = E_0 (\cos \omega(t - \frac{z}{c}) + \frac{2\pi k_0 n_e e^2 \omega}{cm(\omega_0^2 - \omega^2)} \Delta z + \frac{\sin(\frac{\pi b}{\lambda} \sin \beta)}{\frac{\pi b}{\lambda} \sin \beta}), \quad (16)$$

$$\frac{\partial n_e}{\partial t} = q - \mu_e (\frac{\partial E n_e}{\partial x} + \frac{\partial E n_e}{\partial y} + \frac{\partial E n_e}{\partial z}) + D_e (\frac{\partial^2 n_e}{\partial x^2} + \frac{\partial^2 n_e}{\partial y^2} + \frac{\partial^2 n_e}{\partial z^2}) - b n_e, \quad (17)$$

$$\omega_0 = \sqrt{\frac{4\pi k_0 e \rho}{m_e}}, \quad (18)$$

$$\rho = n_e e, \quad (19)$$

$$E_{\text{пад}} = E_0 \cos \omega(t - \frac{z}{c}), \quad (20)$$

$$\frac{I_{\beta}}{I_0} = \frac{E_{\beta}^2}{E_0^2} = \frac{\sin^2(\frac{\pi b}{\lambda} \sin \beta)}{(\frac{\pi b}{\lambda} \sin \beta)^2}, \quad (21)$$

where b is the factor,

Solving these simultaneous equations using numerical techniques, with relevant initial and boundary conditions, one can find distributions n_e (in the plate) and E (in space). Calculations were done on a cluster of highly productive parallel computations with different values of initial and boundary conditions. Thus, when calculations were done on a 201 by 201 mcm square matrix in a 200 mcm tall cube, it was assumed that there was no drain in the center and along the edges. In case of radiation with a frequency of $5 \cdot 10^{14}$ Hz (a wavelength of 0.6 mcm), radiation with a wavelength of approximately 40 mcm was generated above the central part of the plate, whose intensity value exceeded that of the incident radiation by several times (Figure 1).

Conclusion. There has been built a math model of interaction of electromagnetic radiation with a plate on which a pattern has been made in a certain way. The plate is a plate of thin silicon, laminated fabric or another material. The pattern on the plate is made by etching and has the form of rectangular grooves with a depth and width of approximately 1 mcm. The plate is exposed to electromagnetic radiation that causes the plate to emit radiation into the surrounding space; the structure of that radiation is different from that of the radiation falling on the plate. The difference is caused by the fact that, in the simulation, mirroring, free electrons generated in the plate during radiation, and diffraction on the slits were taken into account. Consideration of those parameters ensured distribution of electric field intensity in the surrounding space; the intensity changes regularly over time. The most significant changes are detected above the central part of the plate; they surpassed the characteristics of the incident radiation by several times. This can be

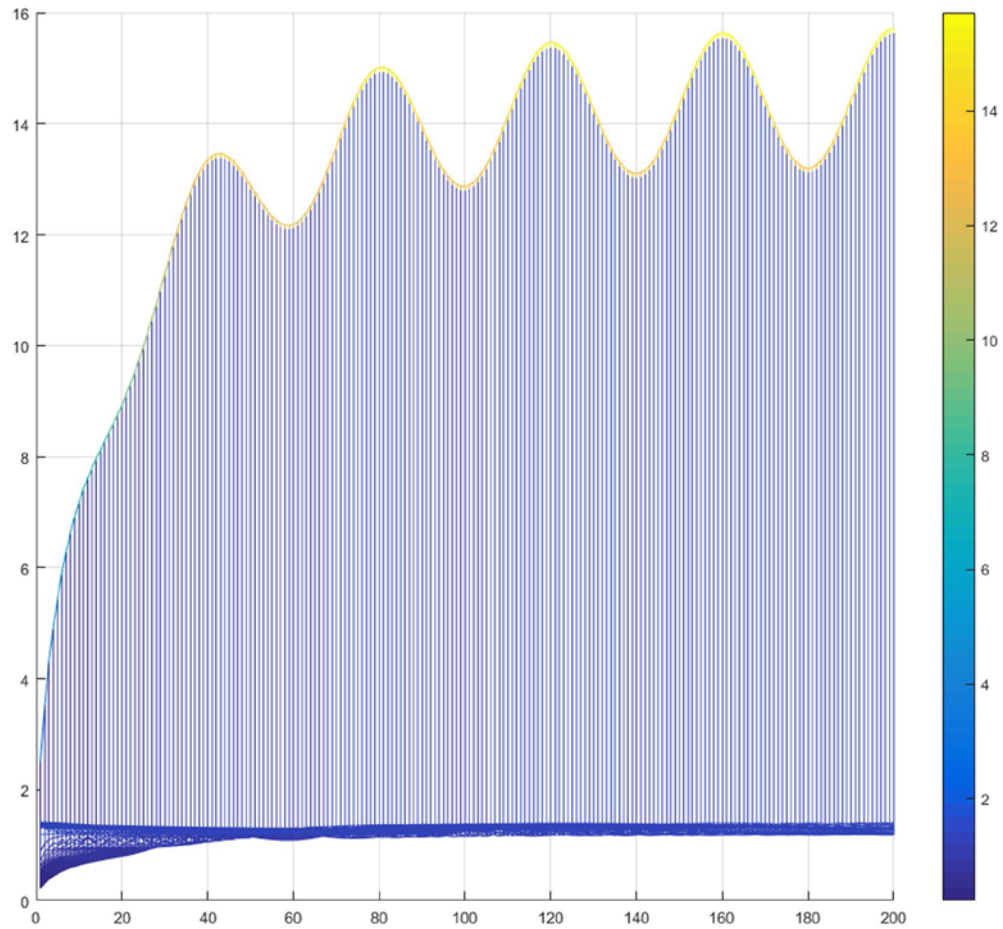


Figure 1. Change in the value of intensity (V/m) above the central part of the plate (mcm).

explained by the fact that the pattern on the surface of the plate is a set of circles located symmetrically in relation to the center of the plate and by the fact that the material of the plate is selected so that their own oscillation frequency of the intrinsic oscillation frequency of the electrons on the plate and the frequency of the incident radiation have close values. The radiation reflected from the plate has such a structure that offers a possibility to decrease the harmful effect of electromagnetic radiation coming from consumer devices, such as mobile phones, microwaves, refrigerators etc., on living organisms.

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