ELECTRIC POLARIZATION, AS A BASIS OF CONSTRUCTION OF THE STABLE FIELD STRUCTURES ON THE SELF-AFFINE SURFACE

Alexander Kopyltsov
Department of Computer Science
The Herzen State Pedagogical University of Russia
St. Petersburg, Russia
Moyka Emb., 48, St. Petersburg, 191186
kopyl2001@mail.ru

Gennady Lukyanov
Department of Physical Engineering
National Research University of Information Technologies, Mechanics and Optics
St. Petersburg, Russia
Kronverkski Pr. 49, St. Petersburg, 197101
gnluk@rambler.ru, gen-lukjanow@yandex.ru

Abstract
The mathematical model simulating interaction of electromagnetic radiation with a self-affine surface is developed. The model is described by system of the differential equations in partial derivatives in complex area. Changes of the field structure formed on a surface, depending on model parameters are analyzed. It is shown that at certain values of parameters of model there is a formation of stable field structures.

Keywords
Self-organization, self-affine, electric polarization, complex time, electric charge, field structures.

1. Introduction

Development of nanotechnologies and research of new principles of construction of electronic and optical devices puts a problem of creation of the physical models adequately describing their functioning. The big possibilities represent the regular structures generated on a surface of a semi-conductor material. Surface special characteristics are caused by infringements in one of directions of strict periodicity of a crystal lattice. Its properties differ from properties of a volume crystal. Formation on a surface of any topological features can open unexpected possibilities for creation of solid-state elements of essentially new type. For example, difractional lattices, difractional optical elements, etc. [Brillouin, 1970; Gulyaev, Nikitov, Potapov and Davydov, 2005]. Numerous studies, including computer simulation, are the base of contemporary radar, computer optics and holography. Experimental and computer studies have shown that it is necessary to develop researches in complex area. Such modeling has been spent by authors earlier [Kopyltsov, Lukyanov and Serov, 2007; Kopyltsov, Lukyanov, 2008; Kopyltsov, Lukyanov, 2009]. The received results show that the most interesting results turn out at a variation of parameters. Therefore calculations have been carried out at various values of parameters of model. Interaction of the self-affine structure of a surface with electromagnetic radiation which was generated on a surface of the semiconductor, considered earlier, in particular,

1. A surface with a self-affine bas-relief formed circles (Fig. 1) [Kopyltsov, Lukyanov and Serov, 2007].
2. A surface with the carpet Sierpinski relief [Kopyltsov, Lukyanov, 2008].
3. A casual surface [Kopyltsov, Lukyanov, 2008].
4. A complex area [Kopyltsov, Lukyanov, 2009].

It is earlier shown that the self-affine surface at interaction with radiation generates coherent structure of electromagnetic radiation [Kopyltsov, Lukyanov and Serov, 2007; Kopyltsov, Lukyanov, 2008; Kopyltsov, Lukyanov, 2009] and therefore it is necessary to study this phenomenon both in real, and in complex area at various values of modeling parameters.

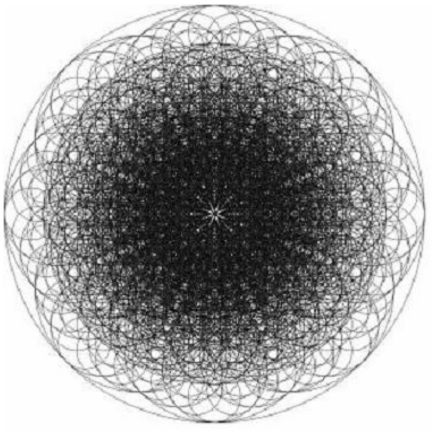

Fig.1. Surface with a self-affine relief.

2. The description of model

Interaction of electromagnetic radiation with a silicon plate with the drawing put on it definitely was modeled. As basis for construction of mathematical model following results served. Electric field which influences a semi-conductor plate is at the bottom of displacement of charges and the raised concentration of charges in the field of flutes (Fig. 2). Therefore with the simulation it was assumed that the concentration of charge carriers in the flutes is higher than in the surrounding regions. With the reaching by the potential of some critical value appears the breakdown on the shortest distance between the flutes (Fig. 3).

The mathematical model simulating this phenomenon can be written down in the form of system of the differential equations in partial derivatives.

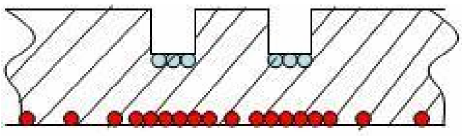

Fig. 2. Silicon plate with flutes and charges.

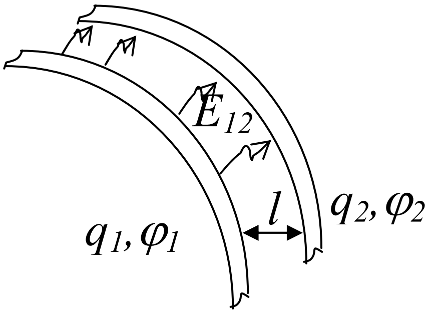

Fig. 3. Charges in the next flutes. l – distance between flutes, E_{12} - intensity of electric field between flutes, q_1, q_2 - density of charges in the next flutes, φ_1 , φ_2 - potentials.

The mathematical model is described by equation

$$\frac{\partial E}{\partial T} = D2\left(\frac{\partial^2 E}{\partial x^2} + \frac{\partial^2 E}{\partial y^2}\right) - A2\,E + B2$$

for 2-dimension surface (Fig. 1) and by equation

$$\frac{\partial^2 E}{\partial T^2} = D3\left(\frac{\partial^2 E}{\partial x^2} + \frac{\partial^2 E}{\partial y^2} + \frac{\partial^2 E}{\partial z^2}\right) + A3\,E$$

for 3-dimension space over the surface, where $E = E_1 + iE_2$ is electrical tension (E_1 is real and E_2 is imagine parts), $T = t + i\tau$ is time (t is real and τ is imagine parts), $D2$, $A2$, $B2$, $D3$ and $A3$ are constants. The calculations were considered in a limited area of the circular cylinder in Cartesian coordinates (x, y, z) (Fig. 4).

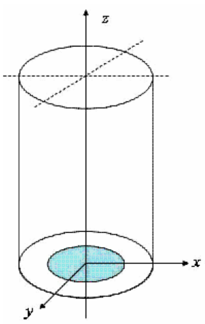

Fig. 4. The cylinder in Cartesian coordinates (x, y, z).

It is assumed that at the border of the cylinder there is not flow. The beginning conditions are following:

1) $E_1(x, y, z = 0, t = 0, \tau = 0)$ is determined by the values of E_1 on the surface (Fig. 1).

2) $E_1(x, y, z \neq 0, t = 0, \tau = 0) = 0$.

3) $E_2(x, y, z, t = 0, \tau = 0) = 0$.

The breakdown condition is realized as follows. If a difference between the next values E more than some Eb then its values at these points are equal to the arithmetic mean of E.

.It has been shown, that for a self-affine surface nonlinear transition of electric charges leads to formation of the steady coherent response to external radiation. Calculations have been spent for different values of parameter A2 in the range from 0,01 to 1200.

3. Results of calculations and discussion

The simulation showed that the numerical values of A2 less than 800 appear stable and orderly pattern of distribution of electric field on the surface. In this case the phase distribution on the surface and in an orderly and well formed geometric patterns as the Persian carpets. (Fig. 4, 5).

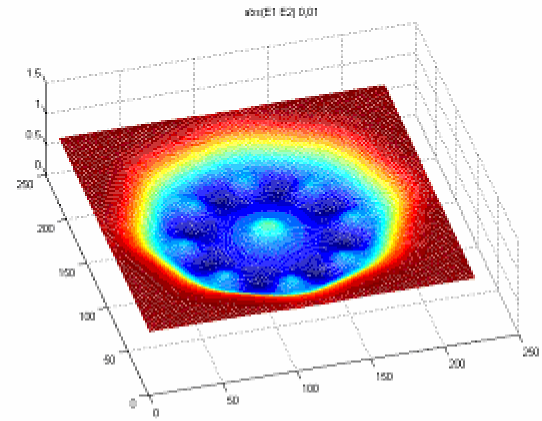

Fig. 4a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=0,01.

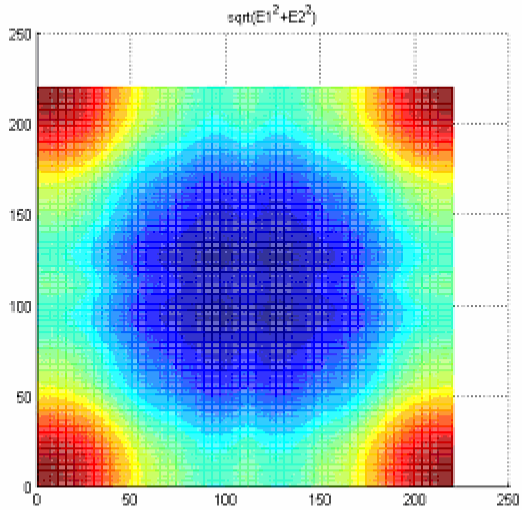

Fig. 4b. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=0,01. Projection on the plane (x, y).

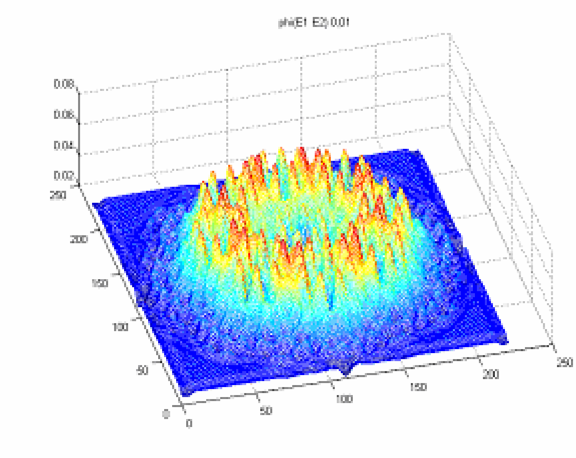

Fig. 4c. Component $\varphi = arctg\dfrac{E_2}{E_1}$ for A2=0,01.

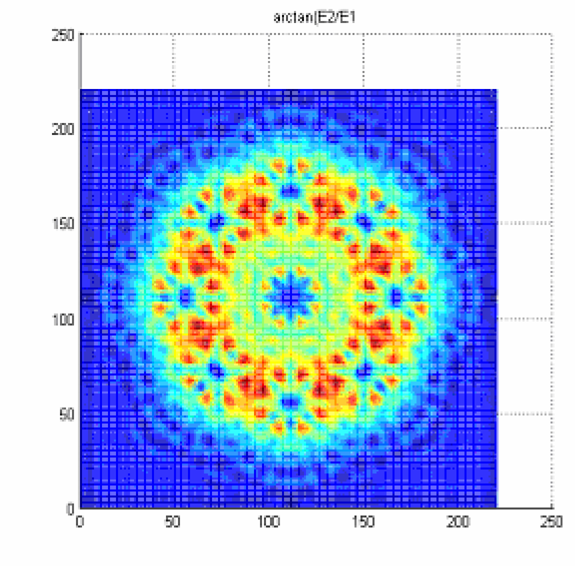

Fig. 4c. Component $\varphi = arctg\dfrac{E_2}{E_1}$ for A2=0,01.

Projection on the plane (x, y).

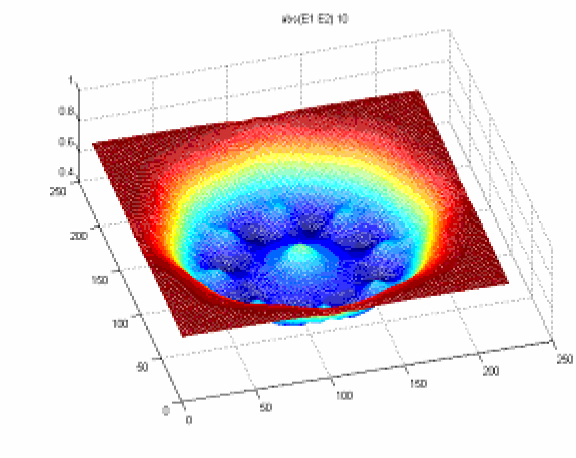

Fig. 5a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=10.

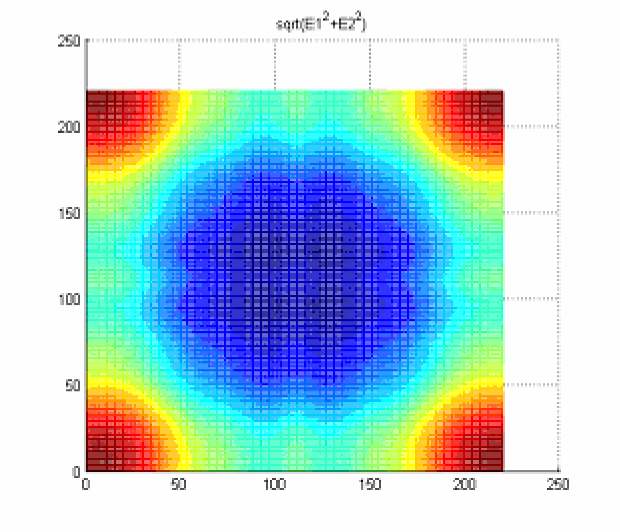

Fig. 5b. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=10.

Projection on the plane (x, y).

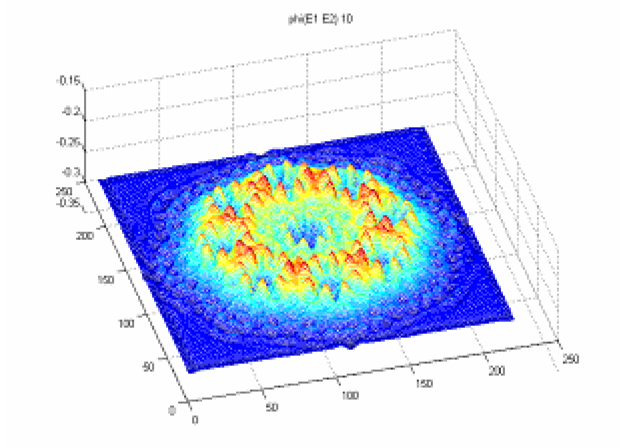

Fig. 5c. Component $\varphi = arctg\dfrac{E_2}{E_1}$ for A2=10.

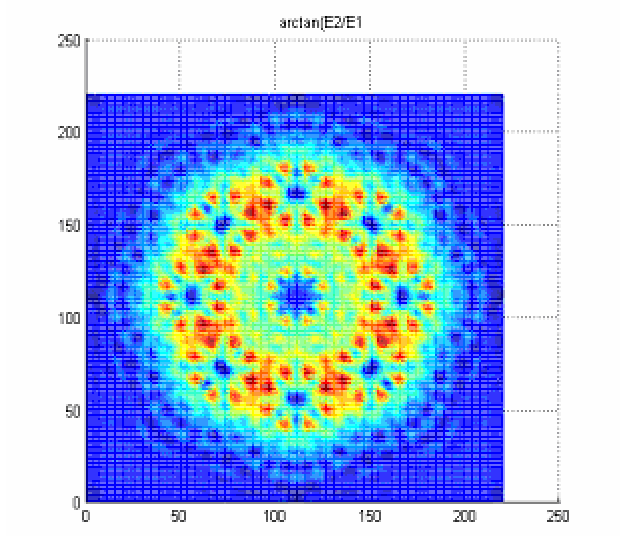

Fig. 5d. Component $\varphi = arctg\dfrac{E_2}{E_1}$ for A2=10.

Projection on the plane (x, y).

If the value of A2 is from 800 to 840 retained the ordering of the absolute value of the field, but it loses a clear ordering phase, at lower values of the coefficient A2. (Fig. 6, 7).

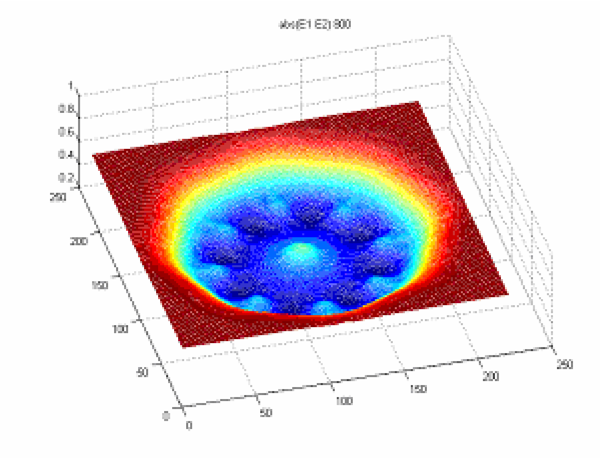

Fig. 6a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=800.

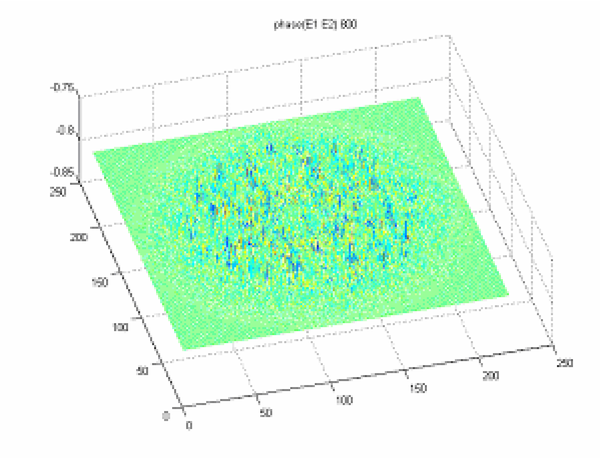

Fig. 6b. Component $\varphi = arctg\dfrac{E_2}{E_1}$ for A2=800.

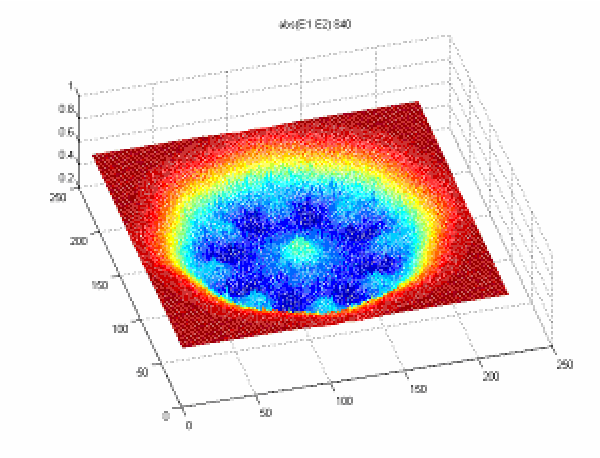

Fig. 7a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=840.

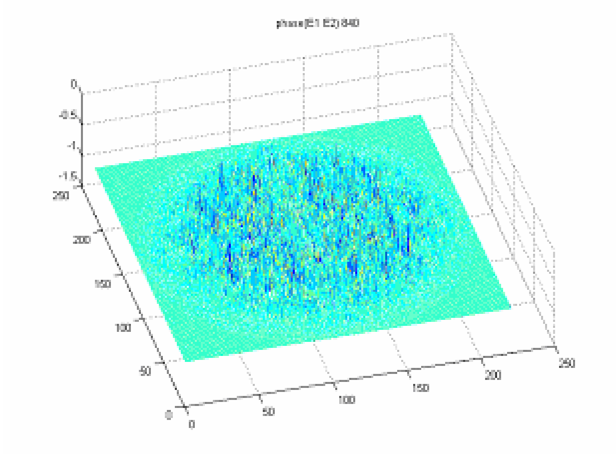

Fig. 7b. Component $\varphi = arctg\dfrac{E_2}{E_1}$ for A2=840.

With increasing parameter A2 of values higher than 840 sharply chaotization of distribution of electric field along the surface with increasing values of strength E. (Fig. 8-12).

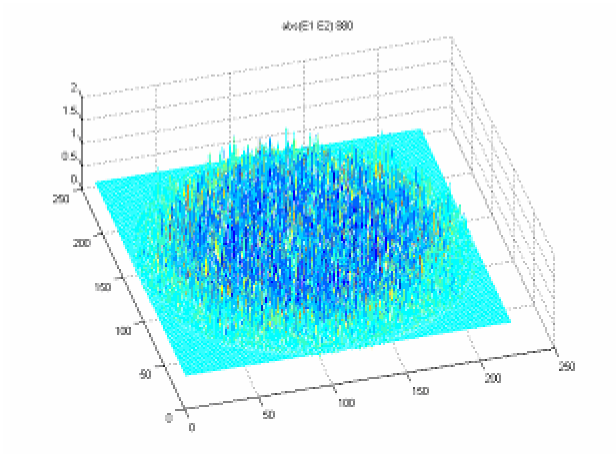

Fig. 8a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=880.

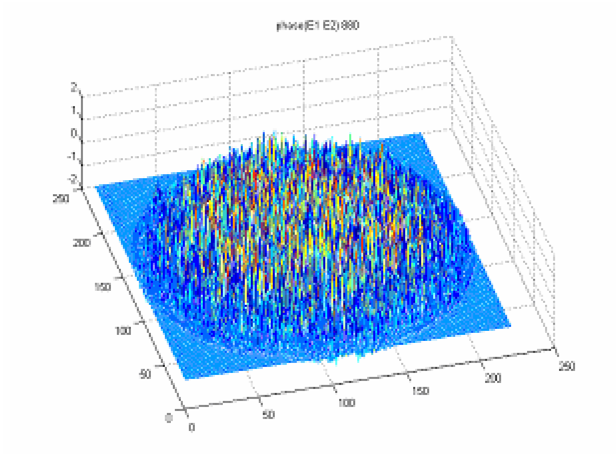

Fig. 8b. Component $\varphi = arctg\dfrac{E_2}{E_1}$ for A2=880.

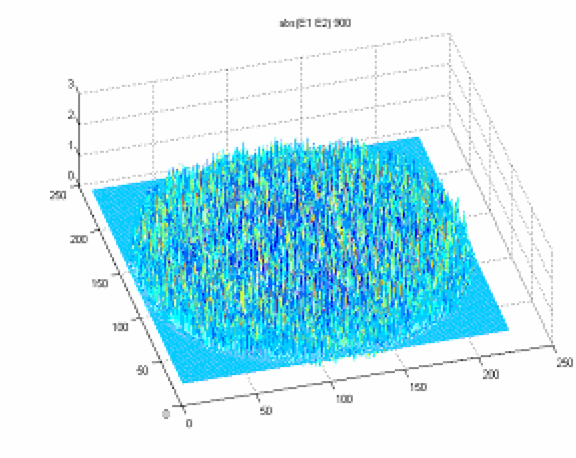

Fig. 9a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=900.

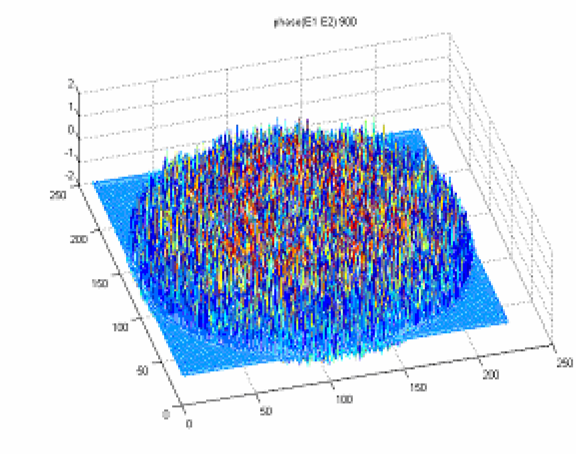

Fig. 9b. Component $\varphi = arctg\frac{E_2}{E_1}$ for A2=900.

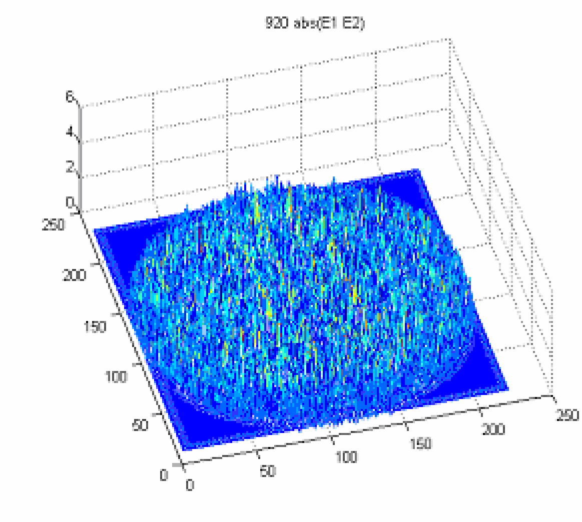

Fig.10a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=920.

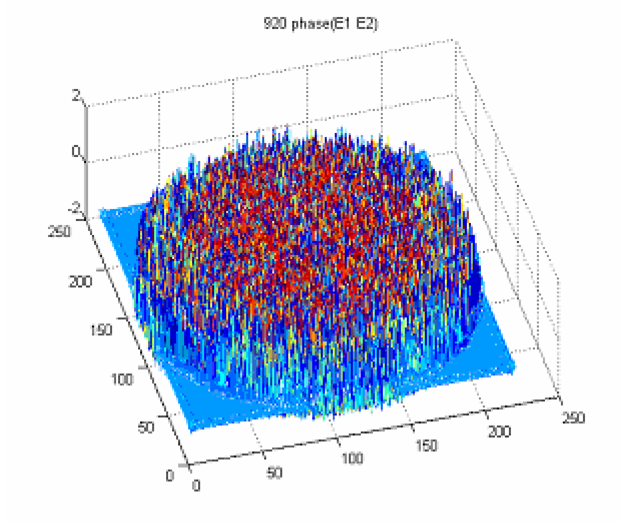

Fig. 10b. Component $\varphi = arctg\frac{E_2}{E_1}$ for A2=920.

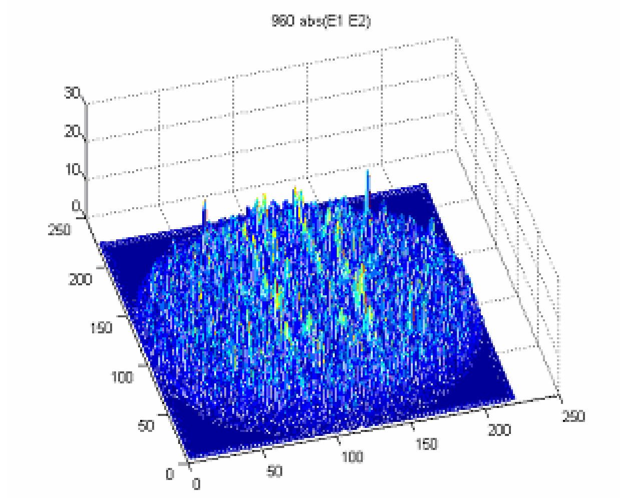

Fig. 11a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=960.

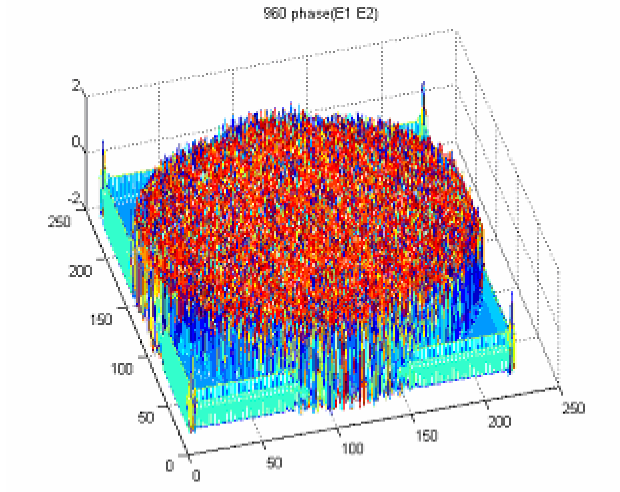

Fig. 11b. Component $\varphi = arctg\frac{E_2}{E_1}$ for A2=960.

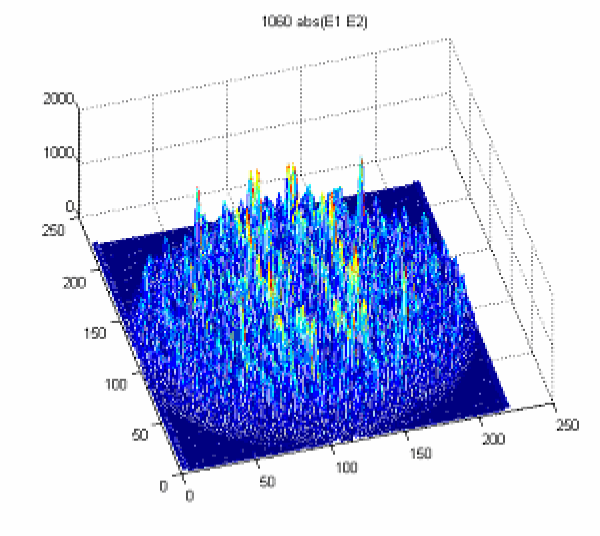

Fig.12a. Component $|E| = \sqrt{E_1^2 + E_2^2}$ for A2=1060.

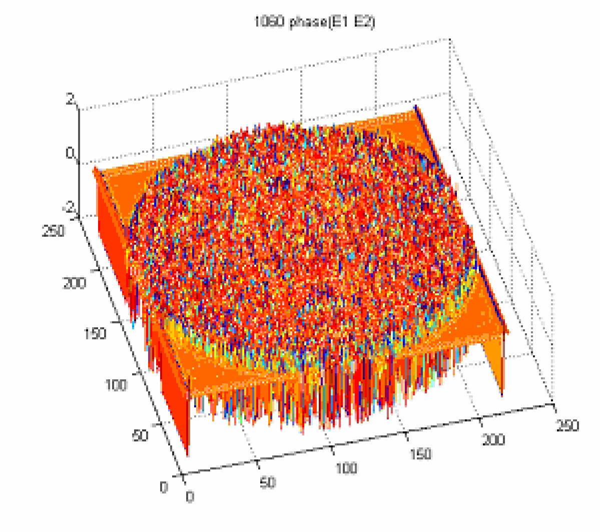

Fig. 12b. Component $\varphi = arctg\frac{E_2}{E_1}$ for A2=1060.

The above results showed that changing the properties of the substrate material without changing its geometrical characteristics strongly influence the characteristics of the field generated by it. With increasing values of A2 = 800 and above is the failure of sustainable and stable field, its enhancement in cross areas of the plate, with simultaneous loss of definition of the field forms, to its chaotization.

3. Conclusions

Application of a model based on the polarization of the semiconductor substrate with self-affine surface relief in an electric field, allowed to establish the fact of forming a stable secondary field on the surface of the plate. This field is formed due to resonant phenomena caused by the shape of the surface relief. This is a phenomenon the authors observed in full-scale experimental [Kopyltsov, Lukyanov and Serov, 2007; Kopyltsov, Lukyanov, 2008; Kopyltsov, Lukyanov, 2009].

Comparison of the model calculations with the experimental data at different values of parameters shows that the computer calculations in the complex area permit to find new results in the area of interaction of electromagnetic radiation with the self-affine structures.

Thus

1. Coherence is observed in the wide range of the wave lengths (Fig. 4-12).
2. Strong infringement of the symmetry occurs to electromagnetic area only in case of a self-affine surface (Fig. 1).
3. If to assume that distinction of conditions of interaction of electromagnetic radiation with a surface, leads to various fields, in particular, electromagnetic E1 and gravitational E2 [Brillouin, 1970] then the gravitational component E2 sharply increases at the increase of parameter A2 from equation for 2-dimension surface (Fig. 1).
4. Increase of parameter A2 higher than 840 lead to the sharply chaotization of the distribution of the electric and gravitational fields on the surface.

References

Brillouin L. (1970). Relativity reexamined, NY: Academic Press.

Gulyaev Y., Nikitov S., Potapov A. and Davydov A. (2005). Design of fractal radio systems: numerical analysis of electromagnetic properties of the Sierpinski fractal antenna. Journal of Communications Technology and Electronics. Vol. 50, No. 9, September, pp. 988-993.

Kopyltsov A., Lukyanov G. (2008). Simulation of interaction of emission with the self-affine surface by system with the complex argument. Sixth EUROMECH Nonlinear Dynamics Conference. June 30 - July 4, St. Petersburg, Russia.

Kopyltsov A.V., Lukyanov G.N. (2009). Mathematical modeling of interaction of electromagnetic radiation with the surface having the self-affine bas-relief. The 5rd International IEEE Scientific Conference on Physics and Control (PhysCon 2009).

Kopyltsov A., Lukyanov G. and Serov I.(2007). Coherent emission of electromagnetic radiation from the surface of semiconductor plate with the self-affine relief. The 3rd International IEEE Scientific Conference on Physics and Control (PhysCon 2007). September, 3-7, Potsdam, Germany.

Kopyltsov A., Lukyanov G. and Serov I. (2007). Modeling of the interaction between electromagnetic radiation and semiconductor silicon surface having affine relief. HoloExpo-2007, Moscow, Russia. pp. 143-146.