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The Electromagnetic Waves Scattering Evaluation on the Composite Material Fractal Structure with Radioisotope Elements

Semon Bohdan[1], Bondarchuk Andrii[2], Vyshnivskyi Viktor[3], Sierykh Serhii[4], Haidur Halyna[5], Kalashnyk-Rybalko Myroslava[6], Safarian Marat[7]

[1] Doctor of Technical Sciences , Full Professor ,Chief Researcher of the Science and Technology Management Centre, the National Defence University of Ukraine named after Ivan Cherniakhovskyi, generalsemon@.ukr.net

[2]Doctor of Technical Sciences, Pofessor of Software Ingeneering Department, State University of Telecommunications, Ukraine, dekan.it@ukr.net

[3]Doctor of Technical Sciences, Head of Department of Computer science, Professor, State University of Telecommunications, Ukraine, vish_vv@ukr.net

[4]Candidate of Technical Sciences, Associate Professor of Department of Computer Science, State University of Telecommunications, Ukraine, ssaanna888@gmail.com

[5]Doctor of Technical Sciences, Head of Information and Cybersecurity department, State University of Telecommunications, Ukraine, gaydurg@gmail.com

[6]Candidate of Technical Sciences, Senior Instructor of Aeronavigation Department of Flight Academy of National Aviation University, Ukraine kalashnik_miroslava2014@ukr.net

[7]Candidate of Technical Sciences, Deputy Head of International Relations of Flight Academy of National Aviation University, Ukraine, safmar@ukr.net

ABSTRACT

The studies results of the electromagnetic waves reflection and scattering incident on the composite materials surface with radioisotope inclusions (CMRI), which are materials with irregular and non-stationary homogeneity, are presented.

It is proposed to describe the radioisotope elements used to create non equilibrium states of the semiconductor matrix electronic subsystem, a model in which the conductivity distribution along one coordinate is a fractal function with a complex structure.

The representing CMRI source possibility as the secondary radiation in the fractal phased model of a antenna array (FMAA) is shown.

The influence of the secondary emitters non-stationary structure, which are a-particles tracks, on secondary radiation is estimated.

The CMRI non-stationary structure is taken into account in the FMAA model in the elementary emitters coherence violation form, which is accompanied by a variation in the material's conductivity fractal dimension.

The relations (ratios) are given for evaluating the electromagnetic waves (EMW) secondary radiation from the CMRI.

Numerical estimates of the electromagnetic waves scattering and reflection from the CMRI are performed. The reflected signal reducing possibility level in the emitter direction due to the only in homogeneous material structure is shown to be no less than a magnitude order (excluding absorption).

Key words: Composite materials, Radioisotope inclusions, α– particles tracks, electromagnetic waves, fractal structure.

1. INTRODUCTION

The research aimed at the technologies search and development to create small-sized and highly efficient materials suitable for the reflected signal lowering levels from the antenna systems structures, and for the military targets radar visibility reduction, led to the CMRI emergence [1-6].

A feature of these materials, along with the non equilibrium electronic subsystem of both the adjacent air layer and the semiconductor layers, is the radio-physical properties structure heterogeneity unsteadiness. This is caused by a change in the number of α particles tracks due to the radioisotope elements decay placed both on the surface and inside the semiconductor layers [1, 2, 5]. In [1–3, 6–7], the CMRI ensuring the required scattering and reflecting characteristics possibility due to the EMW non-stationary conductivity scattering influence, as well as the coating structure in homogeneous and irregular conductivity, was discussed.

1.1 Problem analysis

In well-known works devoted to the electrodynamics of composite materials [8], general relations are given that relate the scattering abilities of an individual particle to their collective behavior, which results in effective dielectric constant. The results of studies of EMW scattering on materials depending on the concentration of inclusions are presented. Moreover, inclusions in the matrix, regardless of the shape and size of the inclusions, are stationary. However, the results of these studies do not allow them to be directly used to evaluate the reflecting and scattering properties of the CMRI, primarily due to the irregularity and heterogeneity of the structure, as well as the unsteadiness of their radiophysical properties.

The aim of the article is to assess the scattering and reflection of EMW incident on the surface of CMRI, which are materials with irregular and non-stationary inhomogeneities.

2. MAIN MATERIAL

2.1 The composite materials fractal properties with radioisotope inclusions

Composite materials with radioisotope inclusions are the materials with irregular and non-stationary in-homogeneity, on which the EMW scattering occurs. Simplified secondary radiation in this case can be represented in the form shown in Figure 1.

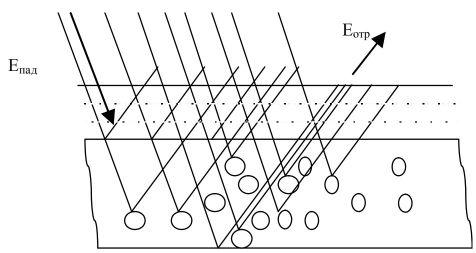

Figure 1: Secondary radiation from radioisotope inclusions CMRI

One of the most important tasks arising in the secondary radiation study from the CMRI is the electromagnetic waves study of the reflection processes from the radioisotope inclusions and α particles tracks, described on the fractal theory basis.

Let's show that the elementary emitters geometric self-similarity, which include radioisotope inclusions in a semiconductor matrix and deposited on its surface, induces a self-similar structure of the radiation energy spectrum and the spectral intensity is a self affine function [9]:

$$I(\lambda\omega) = \lambda^{-\alpha} I(\omega), \quad (1)$$

where λ – is the similarity coefficient;

α – the self-affinity function similarity degree.

The external signal exciting the CMRI forms radiation with a self-similar spectral structure localized in the coating center.

For analysis simplicity, without reducing the reasoning generality, we consider the conductive elements fractal structure radiation on a dielectric (Figure 2).

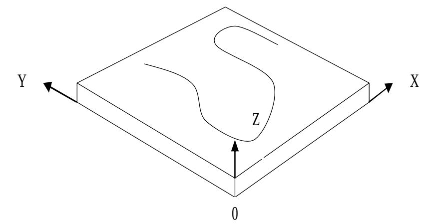

Figure 2: A radiating element on a dielectric

Secondary radiation can be represented as an integral sum over the elementary dipoles radiation into which a piece wise linear re-emitting circuit is naturally divided. To calculate the secondary radiation, it is assumed that the radiating element is excited by a potential pulse $U(t)$.

The fractal contour impedance has a power dependence on the form frequency [9]:

$$Z(\omega) \propto \omega^{D_f - 3},$$

where $1 < D_F < 2$ – where is the conductivity distribution.

The current amplitude in the radiating circuit is equal to:

$$I(\omega)=U(\omega)/Z(\omega). \quad (2)$$

The secondary radiation vector potential is determined by the expression [10]:

$$\vec{A}(\omega) = \frac{e^{i\vec{k}\vec{R}_0}}{R_0} \int e^{i(\vec{k}\ \vec{r} - \omega t)} I(\omega) dl; \quad (3)$$

$$\vec{R} = \vec{r} + \vec{R}_0. \quad (4)$$

It can be seen that the potential substantially depends on the fractal system geometry forming the secondary radiation. First of all, the expression for the electromagnetic field through the above power law impedance dependence on the frequency includes the fractal dimension. In addition, the radiating circuit geometry determines the phase term in the potential expression.

The current distribution along the circuit, necessary for the secondary radiation field calculation, can be determined, for example, by the moments method [10].

The integral equations that determine the radiation field are determined from the Maxwell's equations. By dividing the emitters system into a large number of rectilinear segments and approximating the distribution on each segment by a piece wise sinusoidal function and taking into account the boundary conditions from the integral equation, we can obtain a linear equations system for the approximation coefficients.

2.2 The ENW scattering assessment results on the CMRI

Numerical calculations for the above-described CMRI structure allow one to obtain the radiation spectrum simulating the secondary radiation from the complex CMRI structure, shown in Figure 3.

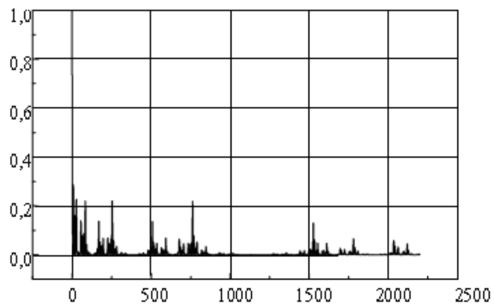

Figure 3 : The emitters system emission spectrum simulating the CMRI conductive elements with a fractal dimension of conductivity in homogeneity $D_f = 1.87$

Let us estimate the scattered field by conducting surface with a conductivity fractal distribution. To do this, we consider a fractal cluster elementary model as a square antenna array of nodes $N_p \times N_p$. *The above* structure, which is a secondary radiation source, can be modeled by a fractal phased array antenna (FMAA).

The FMAA arises when elementary radiators are located only in some lattice nodes and form the fractal conductive structure (cluster) shown in Figure 4. Blackened areas correspond to the elementary fractal emitters locations.

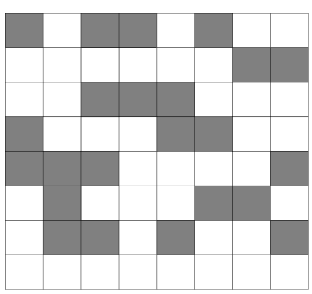

Figure 4: The elementary emitters location on the coating surface

The directional diagram $P(x, y)$ of such a lattice with the strict signal arriving coherence at the antenna is determined by the function:

$$P(x, y) = \left(\sum_{j=1}^{k} \exp[i(p_x(j)x + p_y(j)y] \right)^2 . (5)$$

In expression (5), the parameters represent the spatial coordinates, as well $p_x(j)$ and $p_y(j)$ as the antenna array cells integer coordinates, in which the elementary radiators are located.

In figure 5 the radiation pattern for the array flat antenna case consisting of 8×8 cells is presented. As elementary radiators, we can take the radiating element shown in Figure. 2.

The parameters that determine the radiation pattern quality are the grating size and the set fractal dimension formed by the cells in which the elementary emitters are located.

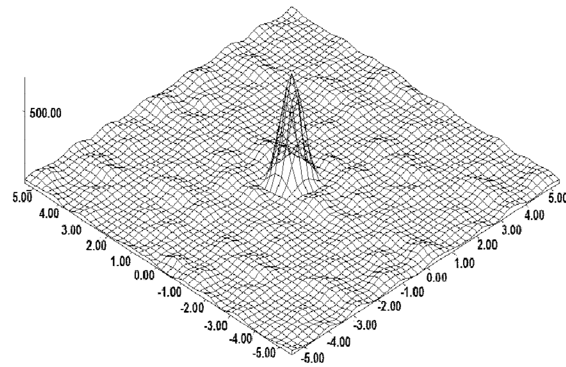

Figure 5: The FMAA directive pattern

Consider the interference case at the antenna array input when the strict phasing is violated and in the expression for the radiation pattern it is necessary to take into account a random phase incursion in each radiator of the antenna array.

Let us denote the phase shift normalized on 2π as a result of the interference through the φ action. For the case when φ = 0.9, the radiation pattern of the photo physical array is shown in figure 6.

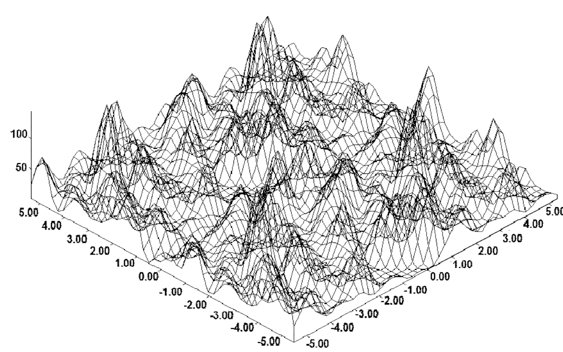

Figure 6: The FMAA radiation pattern under the phasing disturbance

Let us conduct a more detailed analysis of the CMRI in homogeneous structure influence on the scattered radiation properties.

We accept simplification and present the real CMRI surface structure with a simple one-dimensional model in which the conductivity distribution along one coordinate is described by a fractal function (for example, Weierstrass-Mandelbrot with a complex structure (fractal dimension $1 < D_F < 2$), then the scattered field can be estimated in accordance with the expression [9]:

$$E \approx \sum_{n=1}^{\infty} \varepsilon_u^{n(D_F-2)} \times \\ \times \cos\left(ka\varepsilon_u^{n} \cos\theta + \left(2+\varepsilon_u\right)\frac{ka}{\beta}\varepsilon_u^{n-1} \right). \quad (6)$$

In expression (6) $\varepsilon_u < 1$, $\beta < 1$ – are the the Weierstrass-Mandelbrot function parameters.

The scattered field intensity numerical estimates from the plane wave scattering angle in accordance with (6) are shown in figure 7.

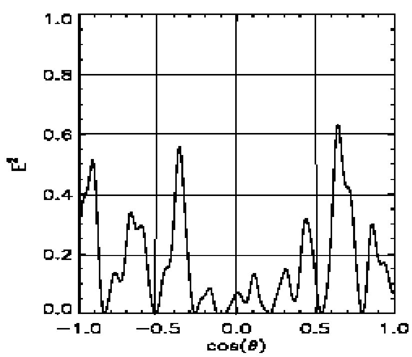

Figure 7: The scattered field intensity dependence on the plane wave scattering angle on the ideal scatters

The calculation results analysis shows that the EMW scattering diagram acquires an additional angular structure, which leads to a sharp decrease in back scattering, which is characteristic (common) to fractal objects scattering.

The CMRI secondary radiation is estimated by the elementary emitters radiation (inclusions and the charged particles tracks emitted from the radioactive inclusions) distributed in the material semiconductor layer. The calculating model for this radiation is actually an antenna array from the mentioned above emitters.

Let us evaluate the secondary emitters non-stationary structure effect, which are a-particles tracks on the secondary radiation. For this, the secondary emitters non-stationary structure will be taken into account in our model as a violation of the elementary emitters coherence. The elementary emitters coherence violation is accompanied by some variation in the fractal dimension of the material conductivity.

The EMW numerical estimation results scattering by the CMRI in homogeneous structure, taking into account its non-stationary properties, are presented in graphs in figures 8 - 9.

The EMW numerical estimates analysis scattering by the in homogeneous CMRI structure, taking into account non-stationary properties, shows that the level of the reflected signal decreases in the direction of the emitter by no less than a magnitude order(excluding absorption).

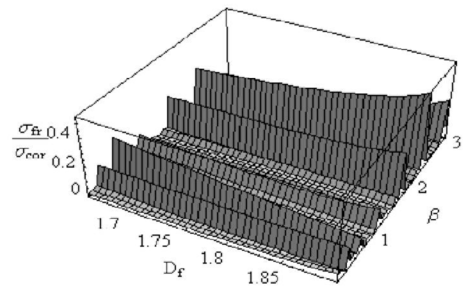

Figure 8 : The CMRI cross-section effective scattering ratio dependence with the coherence coefficient β and the CMRI with completely coherent inclusions on the inclusions fractal dimension D_f

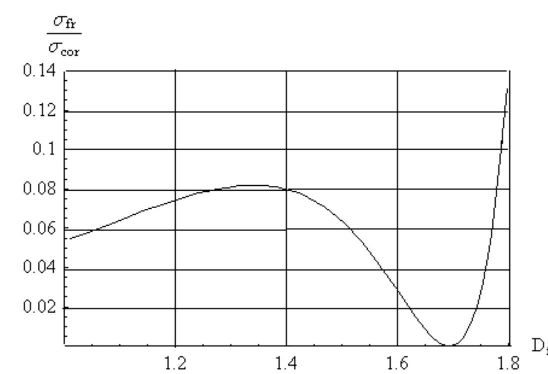

Figure 9 : The dependence of the EMW scattering amplitude in the direction of the emitter from the fractal dimension of inclusions D_f in the coherence absence $(\beta \approx 0{,}1)$

The study of the CMRI reflecting and scattering properties with the help of simple models showed that, as the combined action result of the physical mechanisms associated with the electronic subsystem non equilibrium state of the material various layers, as well as the heterogeneity and non-stationary conductivity, the level of reflected radiation is significantly reduced, and the back scattering is also significantly reduced. The obtained results completely coincide with the statistical theory results of the radio antennas and the optical wavelength ranges, which confirms the results correctness of the results.

3. CONCLUSION

As a result of the CMRI scattering and reflective properties studies associated with the presence of irregular and non-stationary in homogeneity in the material due to the radioisotope inclusions, it was found that:

- the radiation pattern of the secondary radiation acquires an additional angular structure due to the presence of the actual radioisotope elements;

- there is a sharp decrease in the EMW back scattering, common to the fractal objects scattering;

- there is a decrease in the reflected signal level in the emitter direction only due to the in homogeneous materiel structure non less than the magnitude magnitude.

The conductivity distribution representing possibility in the CMR model as a fractal function of a complex structure is shown. In this case, it is proposed to use a fractal phased antenna array as the CMRI secondary radiation model

REFERENCES

1. A.V. Krizny, O.M. Vorobyov, and O.M. Sotnikov. **Designing the structure of the material of the protective screens of radio-electronic means of arms and military equipment from the effects of powerful electromagnetic radiation pulse duration**. *Trudy Universitetu, 6 (120)*, 2013, pp. 187-191.

2. O. Vorobiov, V. Savchenko, A. Sotnikov, V. Tarshin, and T. Kurtseitov. **Development of radioisotopic-plasmatechnology for the protection of radio electronic means from powerful electromagnetic radiation**. *Eastern-European Journal of Enterprise Technologies*, *5(85)*, 2017, pp. 16-22. doi:10.15587/1729-4061.2017.91642.

3. A. Sotnikov, M. Iasechko. **Counteraction to the powerful electromagnetic radiation is for defence of radio electronic facilities**. *Information processing systems, 9(135),* Kharkiv, Ukraine, 2017, pp. 76–81.

4. M. Iasechko. **Plasma technologies for the protection of radio electronic means from exposure to high-power electromagnetic radiations with ultrashort pulse duration**, *Proceedings of the 1-st Annual Conference*, Tallinn, Estonia, 2017, pp. 18–21. doi: /10.21303/2585-6847.2017.00480.

5. M. Iasechko, V. Larin, S. Salkutsan, L. Mikhailova, O. Kozak, O. Ochkurenko **Formalized model descriptions of modified solid-state plasma-like materials to protect radio-electronic means from the effects of electromagnetic radiation,** *IJATCSE*, 8(3), 2019, pp.300-304. doi:/10.30534/ijatcse/2019/09832019.

6. A. Sotnikov, M. Iasechko. **Counteraction to the powerful electromagnetic radiation is for defence of radio electronic facilities**. *Information processing systems*, 9(135), Kharkiv, Ukraine, 2017, pp. 76–81.

7. M. Iasechko, A.Sotnikov, V. Tarshyn. **Impact of powerful electromagnetic radiation on radioelectronic means**, *International Journal of Advanced Trends in Computer Science and Engineering*, 8(3), May - June 2019, 393 - 398 Air Forces of the Armed Forces of Ukraine, 3, Kharkiv, Ukraine, 2017, pp. 86-91. https://doi.org/10.30748/nitps.2017.28.11

8. Landauer R. Proc.of AIP Conference, №. 40. N.Y.: *American Institute of Physics*, 1978.P.2.

9. Feder E. **Fractals.** - *M: Mir*, 1991. - 240 p.

10. Weinstein L.A. **Electromagnetic waves**.- 2nd ed., Rev. and DOP.–*M.: Sov. radio*, 1988.- 440 p.