δ=0,05λ, a curve 2 – at δ=0,2λ, a curve 3 – at δ=0,8λ and a curve 4 – at δ=1,5λ, the curve 5 characterizes distribution of current along a single vertical conductor.

BSS in a semi-plane φ=0° of considered structure for the same angle of falling of a flat wave and distances between conductors are presented on Fig. 11. Designations of curves are similar to Fig. 10.

Conclusions

Basing on the method of auxiliary sources the numerical algorithm is built and the computer program for solution of problems of electromagnetic scattering on the structures made of finite number of uncrossed thin conductors is realized. Influence of a relative position of conductors on bistatic scattering sections of the considered structures, as well as on current distributions along conductors is investigated.

At inclined falling of a wave to an axis of the central conductor of structure the falling wave excites both the central conductor, and lateral conductors located near perpendicularly to it. In this case at small distances between conductors (δ<0,2λ) distributions of current on the central conductor depend on distance; however at distances $\delta\geq$0,8λ distributions of current on the central conductor of structure little differ from distribution of current along the same single conductor. It is shown, that bistatic scattering sections of considered structure differ from those for a single conductor.

Literature

1. Calculation methods in electrodynamics // Edition of R. Mitra Transl. from Engl. – M.: World, 1977. – 138 p.
2. Richmond J.H. Scattering by a Dielectric Cylinder of Arbitrary Cross Section Shape // IEEE Transactions on Antennas and Propagation. – 1965. – V. AP-13. – № 3. – P. 334–341.
3. Mei K.K. On the Integral Equations of Thin Wire Antennas // IEEE Transactions on Antennas and Propagation. – 1965. – V. AP-13. – № 3. – P. 374–378.
4. Lifanov I. K., nenashev A. S. New approach to the theory of Thin Wire Antennas // Electromagnetic waves and electronic systems. – 2003. – V. 8. – № 5. – P. 25–41.
5. Harrington R.F. Time-Harmonic Electromagnetic Fields. Ch. 3. – N.Y.: McGraw-Hill, 1961. – P. 358–359.

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INFLUENCE OF SPACE LIMITED OF THE DISPERSION MEDIUM ON IMAGE QUALITY CHARACTERISTICS

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Influence of space limited of the dispersion medium on radiation distribution and the quality characteristic of image obtained through dispersing medium of the finite sizes is investigated. The way of calculation of boundary function and contrast function of a light strip is determined. It is shown, that space limited of the dispersion medium and illumination conditions render significant influence on image quality characteristics.

Questions of calculation of radiation distribution are actual for problems of transfer of an image in the dispersion medium [1, 2]. However, the basic values describing the quality of image, obtained through dispersion medium, are determined only for medium, unlimited in a transverse direction (in relation to a direction of radiation distribution).

The radiation distribution on the output from space limited dispersion medium having the form of a parallelepiped is considered in the given work under various conditions of illumination of one of volume sides. Calculations are carried out using the method of repeated reflections [3] on which basis the way for definition of boundary function and contrast function of a light strip is obtained.

Let's consider volume of a dispersion medium in the form of a rectangular parallelepiped with the optical sizes τ_x, τ_y, τ_z, where x, y, z are axes of the Cartesian coordinate system, coinciding with parallelepiped edges. At normal illumination of one of volume sides by a parallel flow of monochromatic radiation the energy components of radiating balance of the given volume are defined by the method given in [3]. Depending on a direction of falling of radiation three variants of radiating balance are realized. At illumination on axis x – components of radiating balance are the following: I_x^+ is intensity of radiation passed through volume, I_x^- is intensity of radiation reflected in volume, $2(I_x^y+I_x^z)$ is intensity of radiation which has left through lateral sides; on axis the same components of balance are equal I_y^+, I_y^-, $2(I_y^x+I_y^z)$; on an axis components of radiating balance are – I_z^+, I_z^-, $2(I_z^x+I_z^y)$ accordingly.

At illumination of volume with a dispersion medium with radiation of intensity I_0=1 the normalizing conditions are the following: at illumination of side yz – $I_x^+ + I_x^- + 2I_x^y + 2I_x^z = 1$, at illumination of side xz – $I_y^+ + I_y^- + 2I_y^x + 2I_y^z = 1$, at illumination of side xy – $I_z^+ + I_z^- + 2I_z^x + 2I_z^y = 1$.

Let's apply the methods of calculation of radiation distribution on an output from a dispersion medium to define characteristics determining quality of the image, registered through the dispersion medium. Such characteristics are functions of dispersion of point $P(\tau)$, of dispersion of line $L(\tau)$, boundary $J(\tau)$, contrast of light strips $C(\tau)$ and contrast of dark $C'(\tau)$, transfers of modulation T.

A way to define a boundary function is presented below. It characterizes a distribution of illumination intensity in the image of luminous semi-surface and is formed at normal illumination of a flat layer of the dispersion medium by a parallel beam of light limited by semi-surface, the sum of line dispersion functions. The ratio

$$L(\tau) = -\frac{dJ(\tau)}{d\tau},$$

is true for boundary function, i.e., if boundary function is known, the plot of dependence of its derivative on τ defines function of line dispersion.

For the dispersion medium being infinite in a transverse direction (in relation to direction of falling of radiation) a boundary function is defined by microphysical parameters of medium in a unique manner. If a medium is space limited, a boundary function depends supplementary on the optical sizes of a medium and position of interface light/shadow relative to volume of the dispersion medium.

Let's consider contrast function of a light strip with width b which is bound up with function of line dispersion:

$$L(\tau) = -I^+ \frac{dC(b)}{db}.$$

Then $L(\tau)$ can be found, defining dependence of contrast function of a light strip on its width.

Contrast function of a dark strip is defined as follows. Let`s illuminate a dispersion medium with infinitely wide parallel light beam and close a part of falling radiation with the opaque screen in the form of infinitely long strip with width b. Then $C'(b) = 1 - C(b)$.

$$L'(\tau) = -I^+ \frac{dC'(b)}{db}.$$

At observation of the object through the dispersion space limited medium it is necessary to take into account optical sizes of medium and a position of a strip (light or dark) in relation to a medium border.

At normal falling of radiation on axis two variants of illumination of a side are possible: the straight line dividing illuminated and dark parts, passes in parallel to axes z, or in parallel to axes y. In the first case the output of radiation $I_1^{+1x}(\tau,\Lambda)$ from the illuminated layer and $I_2^{+1x}(\tau,\Lambda)$ from a dark layer in a direction $+x$ is equal

$$I_1^{+1x}(\tau,\Lambda) = I_{1x}^+ + \frac{I_{2y}^- I_{1x}^y I_{1y}^x}{1 - I_{1y}^- I_{2y}^-}; \quad I_2^{+1x}(\tau,\Lambda) = \frac{I_{1x}^y I_{2y}^x}{1 - I_{1y}^- I_{2y}^-}.$$

In the second case the output of radiation from $I_1^{+2x}(\tau,\Lambda)$ the illuminated layer and $I_2^{+2x}(\tau,\Lambda)$ from a dark layer in direction is equal

$$I_1^{+2x}(\tau,\Lambda) = I_{1x}^+ + \frac{I_{2z}^- I_{1x}^z I_{1z}^x}{1 - I_{1z}^- I_{2z}^-}; \quad I_2^{+2x}(\tau,\Lambda) = \frac{I_{1x}^z I_{2z}^x}{1 - I_{1z}^- I_{2z}^-}.$$

At illumination of side xy and falling of radiation on axis z the output $I_1^{+1z}(\tau,\Lambda)$ from the illuminated part and $I_2^{+1z}(\tau,\Lambda)$ from a dark part of a side in direction $+z$ is equal to

$$I_1^{+2z}(\tau,\Lambda) = I_{1z}^+ + \frac{I_{2x}^- I_{1z}^x I_{1x}^z}{1 - I_{1x}^- I_{2x}^-}; \quad I_2^{+1z}(\tau,\Lambda) = \frac{I_{1z}^x I_{2z}^z}{1 - I_{1x}^- I_{2x}^-}.$$

If the border a light / shadow is located in parallel to axis x the output of radiation $I_1^{+2z}(\tau,\Lambda)$ from the illuminated layer and $I_2^{+2z}(\tau,\Lambda)$ from a dark layer in direction $+z$ is equal to

$$I_1^{+2z}(\tau,\Lambda) = I_{1z}^+ + \frac{I_{2y}^- I_{1z}^y I_{1y}^z}{1 - I_{1y}^- I_{2y}^-}; \quad I_2^{+2z}(\tau,\Lambda) = \frac{I_{1z}^y I_{2y}^z}{1 - I_{1y}^- I_{2y}^-}.$$

At falling of radiation on axis the output $I_1^{+1y}(\tau,\Lambda)$ and $I_2^{+1y}(\tau,\Lambda)$ from the illuminated layer and $I_1^{+2y}(\tau,\Lambda)$ and $I_2^{+2y}(\tau,\Lambda)$ from a dark layer in direction $+y$, is equal to

$$I_1^{+1y}(\tau,\Lambda) = I_{1y}^+ + \frac{I_{2x}^- I_{1y}^x I_{1x}^y}{1 - I_{1x}^- I_{2x}^-}; \quad I_2^{+1y}(\tau,\Lambda) = \frac{I_{1y}^x I_{2x}^y}{1 - I_{1x}^- I_{2x}^-};$$

$$I_1^{+2y}(\tau,\Lambda) = I_{1y}^+ + \frac{I_{2z}^- I_{1y}^z I_{1z}^y}{1 - I_{1z}^- I_{2z}^-}; \quad I_2^{+2y}(\tau,\Lambda) = \frac{I_{1y}^z I_{2z}^y}{1 - I_{1z}^- I_{2z}^-}.$$

A technique of definition of contrast function of a light strip for space limited dispersion medium consists in the following. Let`s divide volume in the form of a parallelepiped into three parts, and illuminate the middle of them with normally falling parallel flow of radiation. Let`s designate the output in direction of falling radiation from the illuminated part $I_1^{1z}(\tau,\Lambda)$, from dark parts $I_2^{1z}(\tau,\Lambda)$ and $I_3^{1z}(\tau,\Lambda)$. Then

$$I_1^{1z}(\tau,\Lambda) = I_{1z}^+ + I_{1z}^x I_{1x}^z \left[\frac{I_{2x}^-}{1 - I_{1x}^- I_{2x}^-} + \frac{I_{3x}^-}{1 - I_{1x}^- I_{3x}^-} + \frac{I_{2x}^- + 2I_{1x}^+ I_{2x}^- I_{3x}^- + I_{3x}^-}{1 - (I_{1x}^+)^2 I_{2x}^- I_{3x}^-}\right];$$

$$I_2^{1z}(\tau,\Lambda) = I_{1z}^x I_{2x}^z \left[\frac{1}{1 - I_{1x}^- I_{2x}^-} + \frac{1 - I_{1x}^+ I_{3x}^-}{1 - (I_{1x}^+)^2 I_{2x}^- I_{3x}^-}\right];$$

$$I_3^{1z}(\tau,\Lambda) = I_{1z}^x I_{3x}^z \left[\frac{1}{1 - I_{1x}^- I_{3x}^-} + \frac{1 - I_{1x}^+ I_{2x}^-}{1 - (I_{1x}^+)^2 I_{2x}^- I_{3x}^-}\right].$$

These formulas are obtained in condition of falling of radiation on the side xy in direction z. The same formulas (just with other indexes) are obtained at other (perpendicular to previous) position of a light strip on the edge of volume with a dispersion medium in the form of a parallelepiped. At illumination of sides yz and xz the following 4 variants of formulas are obtained. Thus, at falling of radiation on space limited dispersion medium, six variants of form of contrast function of a light strip, and, hence, functions of modulation transfer are possible.

At consideration of function of modulation transfer a modulation depth characterizes contrast of the image of the cosine-form mira [1]. For any objects contrast of all images or their separate sides can be written as

$$K(\tau,\Lambda)=\frac{I_1^+(\tau,\Lambda)-I_2^+(\tau,\Lambda)}{I_1^+(\tau,\Lambda)+I_2^+(\tau,\Lambda)}.$$

Table. *Dependence between contrast parameters of medium and radiation*

Optical sizes of a part of volume of the dispersion medium τ_x, τ_y, τ_z		Albedo of single scattering, Λ	Degree of elongation of radiation phase function	Contrast, *K*
Illuminated	Dark			
4×3×4	4×1×4	1,0	0	0,750
4×2×4	4×2×4	1,0	0	0,510
4×1×4	4×3×4	1,0	0	0,283
4×3×4	4×1×4	0,5	0	0,932
4×2×4	4×2×4	0,5	0	0,870
4×1×4	4×3×4	0,5	0	0,796
4×3×4	4×1×4	1,0	0,86	0,997
4×2×4	4×2×4	1,0	0,86	0,992
4×1×4	4×3×4	1,0	0,86	0,977

The minimal or threshold contrast is defined by the optical sizes of the dispersion medium, radiation phase function and albedo of single scattering. Results of calculation of contrast value at various position of a light/shadow border on the edge of cubic volume with optical sizes of 4×4×4 are given in the table. From the data given in the table, it follows that contrast of light/shadow border, observable through the dispersion medium, to a large measure depends on relation of the illuminated and dark parts of volume, and this dependence is shown more strongly at less extended radiation phase function. The increase of absorption in the medium results in improvement of contrast at anyone phase function and the optical sizes of a dispersion medium.

Thus, the results obtained allow drawing the following conclusions. The account of space limited dispersive medium is necessary at calculation of characteristics of the image quality observed through dispersion medium, and conditions of illumination of space limited dispersion medium have determining influence. The increase of absorption in the medium improves the image quality, the same result gives increase in anisotropy of radiation phase function.

References

1. Zege E. P., Ivanov A. P., Katsev I. L. Transfer of image in a dispersion medium. [in Russian]. – Minsk: Nauka i tehnika, 1985. – 328 p.
2. Ivanov A. P., Loyko V. A. Optics of photographical layer. [in Russian] – Minsk: Nauka i tehnika, 1983. – 304 p.
3. Goryachev B.V., Mogilnitski S.B. Some features of transfer of radiation in space limited dispersion medium. [in Russian] // Izv. Tomsk Polytechnic Univ. – 2000. – V. 303. – № 3. – P. 91–104.