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VISUAL DETECTION OF DISTANT OBJECTS USING ELECTRONIC OPTICAL DEVICES AT IRREGULAR BACKGROUND LUMINANCE

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Abstract: *This research refers to detection of distant objects by using electronic optical devices in conditions of spatial noise. Irregular luminance of the visual field worsens the observation and the visual conditions of objects in comparison to visual conditions at uniform background. Therefore there appears the necessity to evaluate this disturbance.*

Keywords: *electronic optics, irregular background luminance*

The research is about finding distant objects by means of electronic-optical devices in conditions of spatial noise.
When we view the image through electronic-optical devices with electronic-optical converter (EOC) and when we want to find and identify objects, it is necessary to solve the problem in conditions of irregular distribution of the screen luminance which is caused by the specter of the system's noises. The irregular luminance in the vision field worsens the observation and the visibility conditions of the objects in comparison with the conditions of visibility at regular background. This is the reason why it is important to evaluate this worsening and to calculate the threshold difference between the luminance when finding the object and the irregular background luminance [1, 2, 3].

Mathematical calculations are performed in the process and the models of the background with irregular luminance are built as well as its relative auto correlation function, the spatial spectral density according to the theoretical values and according to the experimental results. The calculated and experimental relations are presented when finding a distant object depending on the mean square deviation of the luminance at irregular background. There is conformity between the calculated and the experimental values. The influence of the threshold luminance when finding distant objects is clearly seen by the elements of the irregularity of the luminance.

The electronic-optical devices are defined as an optimum system for finding distant objects in the infrared part of the optical specter and they are an efficient system when solving problems of visual detection of objects at irregular background luminance.

A model for optimum system for finding is offered which uses criteria for decision taking to find a distant object which is above the threshold values of the relation signal/noise.

The goal of the current research is to analyze the possibility of visual detection to find distant objects of background with irregular distribution of the screen luminance of the electronic-optical converter from an electronic-optical device.

The irregular background in the vision field of the observer is taken as a perturbation when finding the object which is independently summed with the internal and external photon noises. [4]. For the optimum system for finding distant objects μ we can present the square of the relationship signal/(perturbations+noise) as follows [5]:

(1) $$\mu^2 = \int \int_{-\infty}^{\infty} \frac{\left[S_0(\nu_x,\nu_y) H(\nu_x,\nu_y) H_c(\nu_x,\nu_y)\right]^2 d\nu_x d\nu_y}{(\nu_x,\nu_y) + R_\Phi(\nu_x,\nu_y)\left[H(\nu_x,\nu_y) H_c(\nu_x,\nu_y)\right]^2},$$

where $S_0(\nu_x,\nu_y)$ – is a spatial specter of the object

$g(\nu_x,\nu_y)$ – spectral density of the own and the reduced external photon noises

$R_\Phi(\nu_x,\nu_y)$ – Spatial spectral density of irregular background luminance;

$H(\nu_x,\nu_y)$ – spatial-frequency characteristics of the eye;

$H_c(\nu_x,\nu_y)$ – spatial-frequency characteristics of the retina.

If we present with

(2) $$G(\nu_x,\nu_y) = g(\nu_x,\nu_y)\left[H(\nu_x,\nu_y) H_c(\nu_x,\nu_y)\right]^{-2},$$

the spectral density of the strength of the spatial noises which are produced at the entrance of the system, then formula (1) can be presented as

(3) $$\mu^2 = \int \int_{-\infty}^{\infty} \frac{\left[S_0(\nu_x,\nu_y)\right]^2 d\nu_x d\nu_y}{G(\nu_x,\nu_y) + R_\Phi(\nu_x,\nu_y)}.$$

We can present its difference of the object luminance B_0 and B_Φ with the difference of their values

(4) $$\Delta B = |B_0| - |B_\Phi| .$$

And when we present the specter of the object like a multiplication of the amplitude $\Delta B'$ and the spatial constituent $S'_0(v_x, v_y)$ the formula is:

(5) $$S'_0(v_x, v_y) = \Delta B' S'(v_x, v_y)_0 = \Delta B' \int \int_{-\infty}^{\infty} B'_0(x, y) \exp[-j2\pi(v_x x + v_y y)] dx dy .$$

Where $B'_0(x, y)$ is distribution of the objects' luminance defined by means of formula (3).

For the exact threshold values of μ_p the following formula is presented for calculation of the threshold difference in the luminance ΔB when finding objects at background with irregular background distribution.

(6) $$\Delta B = \mu_p \left\{ \int \int_{-\infty}^{\infty} \frac{[S_0(v_x, v_y)]^2 dv_x dv_y}{G(v_x, v_y) + R_\Phi(v_x, v_y)} \right\}^{-\frac{1}{2}} .$$

The function $G(v_x, v_y)$ which comes to (6) is valid for a wide range of adaptation according to luminance of the observer's eye.
The function $R_\Phi(v_x, v_y)$ can be defined as Fourier transform of the autocorrelation function $R_\Phi(v_0, v_0)$ for a background with irregular luminance.

(7) $$R_\Phi(v_x, v_y) \int \int_{-\infty}^{\infty} R_\Phi(v_0, v_0) \exp[-j2\pi(v_x x + v_y y)] dx_0 dy_0 ,$$

(8) $$R_\Phi(v_0, v_0) = \left| [B_\Phi(x, y) - |B_\Phi|][B_\Phi(x - x_0, y - y_0) - |B_\Phi|] \right| ,$$

where $B_\Phi(x, y)$ – is a spatial distribution of the background luminance
x_0, y_0 – spatial displacement of the coordinates x and y.

The threshold value of μ_p in conditions of irregular distribution of the luminance of the object and the background can be defined on the basis of the following considerations. In real situations the observation of the objects is characterized by the value of the electricity impulses which impact upon the optic nerve of the brain (perception of the luminance changes) at threshold possibility to find the object.

When finding a distant object by means of electronic-optical device, there is a probability to miss it P_{pr} or to find the wrong object P_{po} and the following formulas are applied:

(9) $$P_{pr} = 1 - \frac{\Delta B}{\tau_{s+sn}} \text{ and } P_{pr} = \frac{\Delta B - \Delta B_0'}{\tau_{p+sn}},$$

where τ_{s+sn} – is dispersion of the distribution of the object luminance in the mixture signal and noise;

τ_{p+sn} – dispersion of the distribution of the background of the object in the mixture of perturbations and noise.

From formula (9) we define the threshold value of the relation signal/perturbation+noise when we P_{pr} and P_{po} are given

(10) $$\mu_p = (1 - P_{po}) - \frac{\tau_{s+sn}}{\tau_{p+sn}}(P_{pr}).$$

The relation $\frac{\tau_{s+sn}}{\tau_{p+sn}} = m$ in (10) characterizes the conditions of finding the object at irregular background luminance. It can be presented as:

(11) $$m = \frac{\tau_{s+sn}}{\tau_{p+sn}} = \frac{\sqrt{\tau_0^2 + \tau_{sn}^2}}{\sqrt{\tau_\phi^2 + \tau_{sn}^2}},$$

where τ_0^2 and τ_ϕ^2 – is dispersion of the distribution of the object and background luminance;

τ_{sn}^2 – dispersion of the spatial distribution of the luminance of the internal noises according to the object's space.

In case of the equation $\tau_0^2 = \tau_\phi^2$ which is typical for threshold discovery at adaptive luminance of the object and the background and also at conditions for finding objects at irregular background luminance $\mu \approx 1$

Using (5)…(8) and (10) when the functions $B_\phi(x, y)$ and $R_\phi(x_0, y_0)$ are given and values for P_{po} and P_{pr}, we can find the threshold difference of the luminance when finding distant objects with random form of irregular background luminance at adaptive object and background luminance.

To check the given method of calculation of ΔB When finding objects at irregular background luminance, experimental research is performed to find distant objects with positive contrast and size of the angles α_0=5º,20'and 1°.

The average background luminance is 10 cd/m^2 and the mean square deviation of the luminance:

$$\tau_{\phi}=0,1...0,2(1...2)cd/m^2.$$

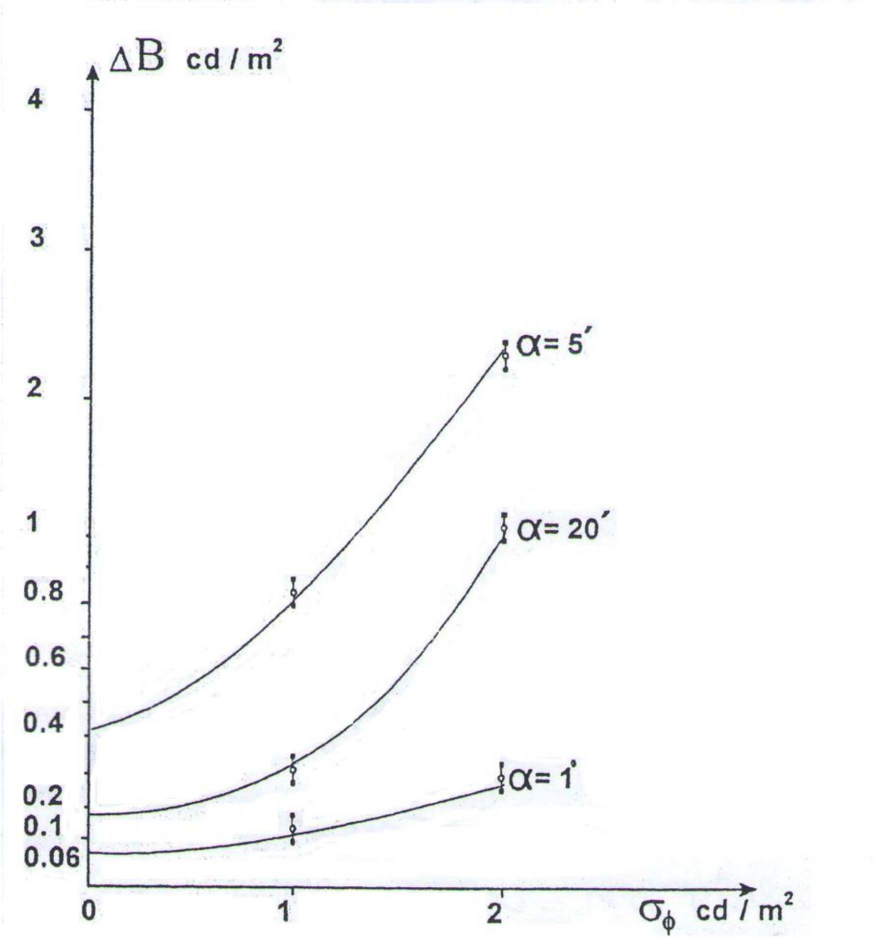

Fig. 1. Calculated values, shown as curves and experimental results in the presented intervals.

The experiment was conducted by means of devices and methods for objective evaluation of the characteristics of electronic-optical converters. The device is characterized by the possibility to gradually change the dispersion of the luminance of irregular background while keeping a constant value of the average background luminance of the screen which presents regular background luminance and decreasing of the screen luminance.

The test object appears in the vision field of the observer by means of gradual increasing of its luminance up to the moment when it is discovered. The average value of the luminance of the irregular background and its dispersion are constant. Every record is taken 100 times for every of the five observers who had been trained preliminarily. The results of the experiment are processed statistically.

The calculations of the values ΔB for the conditions which correspond to the experiment are done with formula (6).

The results from the calculations of the threshold difference when finding objects are presented in Fig. 1 as ΔB being dependent on the dispersion τ_ϕ

The values of ΔB in the figure are presented by means of a continuous curve and the experimental results – in the corresponding around the curve intervals. We can see on the figure that the calculated values and the experimental results are satisfactory and the errors from the two methods are comparable. The increased intervals from the experimental results come from the distraction of the individual indications of the observers.

Therefore, the electronic-optical device is an optimum system for discovery of distant objects in dusk and darkness and it is efficient for solving problems when visually discovering distant objects in background with irregular luminance.

References:

[1]. Getzov, P. Space, Ecology, security. New Bulgarian University, 2002, 211 p.
[2]. Getzov, P., National Aerospace System for Earth Remote Sensing and its Applicability to Monitoring and Prevention of Natural Disasters. Academic Publishing House “Prof. Marin Drinov”, 2013, p.
[3]. Getzov, P., National Aerospace System for Earth Remote Sensing and its Applicability to Monitoring and Prevention of Natural Disasters. Doctoral thesis, SRTI – BAS, 2012, 258 p.
[4]. Stoyanov St., Applied Optics, Publishing House Faber, 2009, pp. 234.
[5]. Zhekov, Zh., Optical Systems for Monitoring Distant Objects, Kosntantin Preslavski University Press, Shumen, 2007, p. 251.