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RESEARCH ON THE BACKGROUND INFLUENCE ON THE RESOLUTION AND DEFINININITION OF THE VARIATIONS OF THE BACKGROUND LUMINANCE OF ELECTRONIC-OPTIC CONVERTERS

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ABSTRACT: *The urrent research refers to electronic-optical devices working in conditions of different levels of background luminance. The aim of the research is to define the influence of the background luminance upon the resolution of different types of electronic-optical converters. The aim is achieved by experimental research and dispersion analysis when mathematically processing the received data. A possibility to select the converters has been created according to the direct aspect of their usage. Four types of electronic-optical converters are used for official use and this is the reason why their technical characteristics are not presented.*

KEY WORDS: *visual observation, electronic-optical converters, distant objects, resolution, background luminance*

The research is about electronic-optical devices which work at different background luminance and which are used in machines for the defense and military technics [1], as well as in aerospace research [2,3,4].

The task is to choose an optimum electronic-optical converter (EOC) for identification of distant objects and for this reason it is necessary to define what influence has the background luminance over the resolution of the converters.

The resolution of four different types of EOC (for official use) at three levels of background luminance at contrast equal to 0,5. Devices for objective evaluation of the characteristics of electronic-optical converters have been used [5].

At level I:

$N_1(B_1)$ – maximum resolution of EOC at optimum luminance for observation of the test object;

At level II:

$N_2(B_2)$ – normal resolution of EOC at background luminance 2,6 cd/m^2;

At level III:

$N_3(B_3)$ – normal resolution of EOC at background luminance 0,024 cd/m^2;

The registered values for $N_1(B_1)$, $N_2(B_2)$ and $N_3(B_3)$ for the respective types of EOCs are presented in Table 1.

Table 1. Values of $N_1(B_1)$, $N_2(B_2)$ and $N_3(B_3)$ for different types of EOC

EOC / N	EOC 1				2				EOC 3				EOC 4				
	j			$\overline{x}_{1e}$	j			$\overline{x}_{2e}$	j			$\overline{x}_{3e}$	j			$\overline{x}_{4e}$	$\overline{x}_{0e}$
	I	II	III		I	II	III		I	II	III		I	II	III		
$N_1(B_1)$	35	33	34	34	36	37	38	37	27	28	29	28	29	30	28	29	32
$N_2(B_2)$	32	30	31	31	33	33	33	33	25	23	24	24	25	27	26	26	28,5
$N_3(B_3)$	25	27	26	26	28	29	30	29	22	23	21	22	23	23	23	23	28
$\overline{x}_{ie}$	33,33				33,36				24,66				26,0				28,5

When the calculated results are mathematically processed, a two factor dispersion analysis is used.

The basic equation of the dispersion analysis of two factors – the researched EOCs and the levels of the background luminance is: [6,7]

(1)
$$Q = Q_E + Q_B + Q_V + Q_R$$

where Q – sum of squares total;

Q_E – sum of squares of EOCs;

Q_B – sum of squares of background luminance;

Q_V – sum of squares between the variants of interaction between the EOCs and the background luminance;

Q_R – sufficient sum of the squares.

The number of degrees of freedom r of these sums of squares is respectively:

(2)
$$r = N - 1 = nkq - 1 = 3.4.3 - 1 = 35$$

where n – number of the experiments;

k – number of the researched EOCs;

q	–	number of the researched background luminance;

(3)
$$r_E = k-1 = 4-1 = 3$$
$$r_B = q-1 = 3-1 = 2$$
$$r_V = (k-1)(q-1) = 6$$
$$r_R = kq(n-1) = 24$$

where	r_E	–	degree of freedom of EOC;
	r_B	–	degree of freedom of the levels of background luminance;
	r_V	–	degree of freedom of the variants of interaction between EOC and the background luminance;
	r_R	–	degree of freedom of residual sum of squares.

Evaluation of the dispersion S is obtained when dividing the sums of the squares Q, Q_E, Q_B, Q_V and Q_R into the respective degrees of freedom $r, r_E, r_B r_V$ and r_R. The quotients are presented in Table 2.

Table 2. Values of the dispersion

Sum of squares	Degrees of freedom	Evaluation of the dispersion
$Q = \sum_{i=1}^{k} \sum_{l=1}^{q} \sum_{j=1} \left(\overline{x}_{ilj} - x\right)^2 = 1604{,}09$	$r = 35$	$S^2 = \frac{Q}{r} = 45{,}8$
$Q_E = nq \sum_{i=1} \left(\overline{x}_{io} - \overline{x}\right)^2 = 638{,}37$	$r_E = 3$	$S_E^2 = \frac{Q_E}{r_E} = 212{,}8$
$Q_B = nk \sum_{l=1}^{q} \left(\overline{x}_{lo} - \overline{x}\right)^2 = 147$	$r_B = 2$	$S_B^2 = \frac{Q_B}{r_B} = 73{,}5$
$Q_V = \sum_{i=1}^{k} \sum_{l=1}^{q} \left(\overline{x}_{ie} - \overline{x}_{io} - \overline{x}_{lo} + x\right)^2 = 798{,}72$	$r_V = 6$	$S_V^2 = \frac{Q_V}{r_V} = 133{,}12$
$Q_R = \sum_{i=1}^{k} \sum_{l=1}^{q} \sum_{j=1} \left(x_{ilj} - x_{il}\right)^2 = 20$	$r_R = 24$	$S_R^2 = \frac{Q_R}{r_R} = 0{,}83$

In order to check the validity of the null hypothesis H_0 for the different types of EOC and for the background luminance influence, the dispersion relations are calculated:

(4)
$$F' = \frac{S_E^2}{S^2} = 156{,}1$$

$$F'' = \frac{S_B^2}{S_R^2} = 88{,}5$$

$$F''' = \frac{S_E^2}{S_R} = 161{,}5$$

The table values of the dispersion relation F, (taken from Tables 5 and Table 6 [6]) are respectively 5% and 1% significance levels α at number of degrees of freedom $r_E = 3$, $r_B = 2$, $r_V = 6$ and $r_R = 24$ are:

for α=0,05	for α=0,01
$F_T' = \frac{r_E}{r_B} = 3{,}01$	$F_T' = 4{,}72$
$F_T'' = \frac{r_B}{r_R} = 3{,}40$	$F_T'' = 5{,}61$
$F_T''' = \frac{r_V}{r_R} = 2{,}51$	$F_T''' = 3{,}67$

Consequently the null hypothesis that the resolution of the different type of EOC is not influenced by the value of the background luminance cannot be taken as valid because $F' >> F_T', F'' >> F_T''$ и $F''' >> F_T'''$ for the two levels of significance, i.e. the influence of the background influences significantly the value of the resolution of the researched EOC.

Defining the numbers which characterize the change of the information signal depending on the dark current is performed in order to define the possibility to register weak signals. The mutual dependence of the information signal by the dark current is taken into account. It is known that when there is lack of information signal, the dark current is minimal. Consequently, there are variations of the dark current. Its identification is performed when we accept that the dark current is a random variable. The reason to accept this is the data from experimental measuring performed by devices for evaluation of the characteristics of EOC [5] and the data from the 100 measurements performed by ADC, DI and PO [9] when we use the dependence of dark current of this type:

(6)
$$i_{t_{cp}} = \sum_{i=1}^{n} i_{t_i} \frac{n_i}{N} = \sum_{i=1}^{n} i_{t_i} P_i^* = 2{,}34$$

where P_i^* – frequency of appearance of i_{t_i} values of the dark current;

N – number of the measured values of the dark current.

The fixed in (6) value of the dark current is the average value from the measurements. And because every random variable has a basic characteristic its average value [7,10], so this characteristic will be a basic one for the dark current. If we interpret from a physical point of view, this means that all the possible values of the scintillations in the central zone of the EOC are grouped.

A characteristic of the random variable is the expected value. In this case it is described as:

(7)
$$M(I_t) = \sum_{i=1}^{n} i_{t_i} P_i = 2{,}3$$

where i_{t_i} – Possible values of the dark current;

P_i – Probability of the possible values of the dark current to appear.

The received numbers of expected value, however close to the average value of the dark current, is enough to define fully its variations. In order to do this, we use another characteristics of the random variable – the dispersion D(I).

If we describe it as an expected value:

(8)
$$D(I) = M(I_t^2) - M^2(I_t) = 0{,}218.$$

The dispersion defines the scattering of the possible values about the center.

Mean squared deviation σ_{i_t} allows us to compare the random values according to the level of their dispersion.

By the calculated values of D(I) from formula (8) we define mean squared deviation:

(9)
$$\sigma_{i_t} = \sqrt{D(I_t)} = 0{,}466.$$

Consequently, expected value, dispersion and mean squared value can be used as numerical characteristics which characterize every random variable and which define the change of the information signal depending on the dark current.

The numerical values allow us to draw a graphics depicting the law for distribution of the dark current. For this purpose we use Lopunov Limit Theorem. [8].

So, for the probability density for normal distribution of the dark current i_t the formula is:

(10)
$$f_{(i_t)} = \frac{1}{\sigma_{i_t}\sqrt{2n}} e^{\frac{(i_t - m_{i_t})}{2\sigma_{i_t}}}$$

where m_{i_t} and σ_{i_t} are parameters of the normal distribution and $m_{i_t} = M(i_t)$ is the expected value and σ_{i_t} is mean squared deviation.

The distribution law is normal. This is evidence that the dark current is a random variable with normal distribution. Besides this, the maximum of the function is received at:

$$f_{(i_t)\max} = 0{,}865$$

The following conclusions can be drawn:

1. The data from the experiment prove the credibility of the defined numerical values which characterize the change of the information signal depending on the dark current at given background luminance.
2. The performed dispersion analysis proves that the background luminance influences at a different degree the resolution of the respective types of EOC. At lower level of background luminance the best results for visual observation of distant objects are registered by means of EOC-2 and EOC-1, and at observation at dusk – EOC-3, EOC-4 and EOC-1. Combining the type of EOC with the conditions of the conducting the experiment is basis for creating optimum conditions for discovery and identification of objects at different degrees of background influence, when predicting of the probability by means of the calculated resolution of the researched EOC.

REFERENCES:

[1]. Getzov, P. Space, Ecology, security. New Bulgarian University,2002, 211 p.

[2]. Mardirossian, G. Aerospace Methods in the Ecology and Environmental Studies. Part I. Academic Publishing Marin Drinov, Sofia, 2003, 208 p.

[3]. Stoyanov, S. Mathematical Model of Optical Tract of Optical-Electronic Device. Papers from Anniversary Scientific Session “100 Years Since the Brothers Write Flight”, Aviation Faculty of National Military University “V. Levski”, Dolna Mitropoliya, 2003.

[4]. Eldering H. G. JOSA, 1998, vol. 31, N 12, p. 1211.

[5]. Zhekov, Zh. Devices and Methods for Objective Evaluation of the Characteristics of Optical-Electronic Converters. Second National Conference of Optics and Laser Technics, Optics-84, 1984
[6]. Davis, G. Simp. Photo Image Dev., London, 1992.
[7]. Rangarian L. M., V. R. Katti, G.K. Bridge. Pure and Appl. Phys., 1994, N 2, p. 12.
[8]. Korn G, T. Korn. Handbook of Mathematics for Scientific Workers and Engineers, Science, Moscow, 1977
[9]. Stoychev, V., K. Valchev, Zh. Zhekov. Analogue-Digital Converter, Digital Indicator and Printing Output (ADC, DI and PO), Scientific Session, Military University, Shumen, 1985, p. 6
[10]. Greene, J. Navigation, 2003, vol. 31, N 12, p. 1211.