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OPTIMIZATION OF PARAMETERS OF OPTICAL AND ELECTRONIC DEVICE IN THE PROCESS OF DETECTING DISTANT OBJECTS

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ABSTRACT: *The process of detecting distant objects through optical and electronic device along with optical device (visir) for preliminary rough targeting has been investigated. Methods of optimization and determination of the optimal values of the basic parameters of dev ices in detecting regime for distant objects hav e been suggested.*
KEYWORDS: *Detecting of distant objects*

It is expedient along with the precise accurate system of identification, the preliminary detection and determination of the coordinates of the object to be accomplished through optical device - visir [1,2,3]. in order to ensure increased noise protection, and to shorten the time interval for detecting the object.

In this way the probability of detecting a distant object in a definite direction is assumed as known and in most cases is equal to one. Figure 1 represents that part of the structural scheme of the optical and electronic device, which is necessary for detecting a distant object.

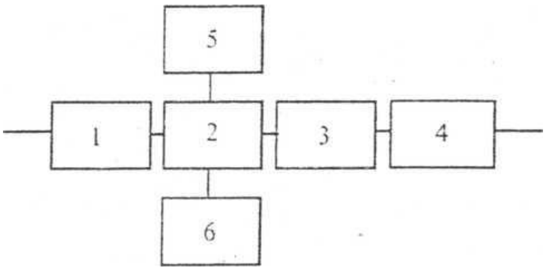

Fig. 1. Structural scheme of optical and electronic device in process of detecting distant objects: 1 - optical system; 2 - optic - electronic convertor; 3 - coordinating filter; 4 - signal - identifying device; 5 - block scanning; 6 - block power supply

Figure 2 represents the image of die object in the plane of photo-cathode of the optic - electronic convertor /dissector/.

The coordinate axes X and Y correspond to the axis of the optical visir, and its crossing point coincides with the center of the visible area, the scanning equipment has square shape with a face da, that moves with constant speed V, creating square raster with face h and overlapping factor $\delta = \chi/d\alpha$

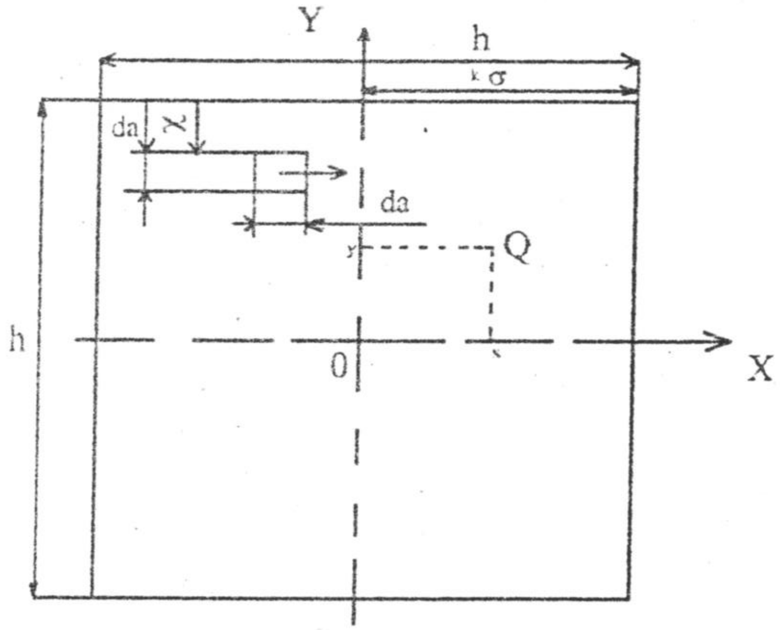

Fig. 2. Image of the object in the plane of the photo cathode of the dissector

Q identifies the projection of die image of the object with coordinates X and Y. The object will be discovered if the equipment crosses the projection of the image of the object and an impulse appears in the output of die threshold device. This event is marked with A. It appears only when, die projection of the image of the object is in the range of the raster (development event B), the speed of the object on axis Y doesn't exceed exact value Vo, in order the object not to be missed for the scanning period (event C), and the signal of the object exceeds the noise direshoid level of noise (event D).
When the time for detecting distant objects is undefined the events B and C are independent. In this case the probability of detecting an object will be (event A):

(1) $$P(A)=P(B)P(C)P(D/B,C),$$

where: *P(B).P(C)* – probabilities of events B and C respectively;

P(D/B,C) – probability of detecting the signal (event D) the signal (development D) in accordance with events B and C.

The probability of event B is equal to:

(2) $$P(B)=\int_{-k}^{k}\int_{-k}^{k}\frac{1}{2\pi\sigma^2}e^{-\frac{x^2+y^2}{2\sigma^2}dxdy}$$

where: *2k=h/s* - relative size of the dissector field $\sigma^2=\sigma_x^2=\sigma_y^2=\frac{1}{2\pi}\int_0^\infty S(\varpi)d\varpi$

Dispersion of the coordinates X and Y:

S(v) - spectral density of the process of alteration of the coordinates X or Y through time.

We have to know the speed of the object in order to find out the probability' of event C.

Since the coordinates of the object have normal distribution, the speed is distributed also according to the normal law and dispersion σ_y^2, which is equal to:

$$\sigma_v^2=\frac{1}{2\pi}\int_0^\infty S(\varpi)d\varpi$$

The probability *P(C)* is maximum, when the overlap is equal to $\delta=0{,}5$. Then:

(3) $$P(C)=\int_{-m}^{m}\frac{1}{\sqrt{2\pi\sigma v}}e^{-\frac{v^2}{2\sigma_v^2}dv}$$

where: $m=V_o/\sigma_v$ - relatively admissible speed of object's motion on axis Y The probability of detecting the signal is equal to:

(4) $$P(D/B,C)=\int_{\Delta H-\psi}^{\infty}\frac{1}{\sqrt{2\pi}}e^{-\frac{z^2}{2\sigma_v^2}dz}$$

where: $\Delta H=\frac{U_H}{U_M}$ = relative noise threshold :

U_M - average quadric value of noise in the output of the threshold device;

$\psi=\frac{U_C}{U_M}$ - ratio: signal amplitude/noise in the output of the threshold device when k and m have certain values;

$z=U/M_M$

The value of the relative (noise threshold) level of noise ΔH could be calculated with the help of Neiman-Pirson's, taking into account the probability of wrong signal

$$P' = \int_{\Delta H}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{z^3}{2\sigma_v^2}dz} \quad (5)$$

The most difficult case for detecting distant objects has been discussed in this article, when the background is highly lighted, and the contrast with the image is low. In this case the noise in the output of the dissector could be considered as stationary and normal. From formula (1) considering formulas (2), and (4) we observe, that the assigned value of the probability of detecting the object P(A) with fixed probability of receiving a wrong signal P' is suitable for the multiplicity of values of k, M and ψ.

To ensure maximum sensitivity of the system, i.e. minimum light on the object, it is necessary to fulfill the following condition:

$$\psi\sqrt{km} = \min \quad (6)$$

It is easy to see that the speed of scanning of the equipment V is related with the receiving of optimal value of m in ratio:

$$V \geq \frac{2h}{a_c d_c} M\sigma$$

where: a_c - relative time for one-way movement for scanning on axis X.

The period for scanning of a whole frame with calculated optimal values of k and m is defined by the formula:

$$T = \frac{2\sigma k}{a_c \sigma_v M}$$

The maximum value of the ratio signal/noise with optimal filtration is equal to:

$$y = \sqrt{\frac{2E}{N_O}} \quad (7)$$

where: E - energy of the signal;

N_O - spectral density of white noise.

The energy' of the signal is equal to:

$$E = \gamma I_o^2 \tau_i \quad (8)$$

where: I_o -maximum value of signal;

τ_1 - duration of signal;

γ - coefficient, describing the form of the signal (in this case it is rectangular - $\gamma = 1$).

Using the already known ratios of the signal I_o and the spectral density of the noise N_O in the output of the dissector, we have:

(9) $$N_O = \varepsilon.So.Eo.qn$$

(10) $$N_O = e.\varepsilon.Sa.E\frac{q^{2n+1}}{q-1}$$

where: ε - integral sensitivity of the photo cathode of the dissector:

So, Eo - surface of the object and the amount of light it receives in the plane of the photo cathode respectively:

q - coefficient of the secondary emission of the dynodes of the multiplier:

n - number of dynodes in the secondary - electronic multiplier in the dissector;

e - charge of the electron:

Sa, E' - surface of the scanning equipment and the amount of light of the background in the plane of the photo cathode respectively.

Duration of the impulse signal from object is equal to:

(11) $$t_1 = \beta\frac{da}{V}$$

where: β - coefficient, defining die size of the object and the speed of its movement V_O

Taking into consideration, that $S_a = d_a^2$, $V = \frac{2h}{a_c d_a}V_O$, $V_O = M\tau_v$, $h = 2k\tau$,

including formulae from (8) to (11), formula (7) acquires the following visualization

$$y = S_O E_O\sqrt{\frac{\varepsilon\gamma\beta(q-1)dc}{2eE'q\sigma\sigma_v km}}$$

or

$$E_O = y\sqrt{kMG}$$

where: $G = \frac{1}{S_O}\sqrt{\frac{2eE'q\sigma\sigma_v}{\varepsilon\gamma\beta(q-1)a_c}}$

In conclusion we can add that:

1. The optimal values of the main parameters of the optical and electronic sy stems in regime of detecting distant objects have been defined as follows: size of the field for detecting distant objects, speed of scanning according to a certain direction, period of frame scanning, thus securing maximum sensitivity.
2. It is proved that the probability of perceiving wrong signal does not in fact influence the optimal value of the size of the field for detecting distant objects.

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