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PRIMARY PROCESSING OF SIGNALS IN AN OPTO-ELECTRONIC DEVICES

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ABSTRACT:

The energy efficiency of systems for primary processing of signals in opto-electronic devices is analyzed for the case of identification and study of remote objects against a bright background and under low-contrast conditions. A criterion is determined for evaluating the energy efficiency of the major unit of the system for primary signal processing - the optic system, and some expressions are derived, relating the value of the signal-to-noise ratio at the device's input with these criteria (amplification factor) and other "ideal" or "real" optic systems' parameters. The specific thing here is the operation of the system for primary processing of signals when the value of recorded contrast equals 1 percent or less. As an evaluation criterion for the energy efficiency of this system, the signal-to-noise ratio is used.

Comparative evaluation of various systems for primary processing of signals operating under low-contrast conditions and specific values of the signal-to-noise ratio is performed.

The operation analysis for the system for primary processing of information (signals) under low-contrast conditions is performed accounting for the impact of the optic system.

The evaluation criterion for the energy efficiency of the major unit of the system for primary processing of information (the optic system) is the amplification factor, which determines the limit value for the signal-to-noise ratio at the output of the optic-electronic device. The assumption is made that the flow, which determines the circle's area, is uniformly distributed, which does not cause significant errors in evaluating the energy efficiency of the optic-electronic system.

KEY WORDS: *Energy, Low-contrast conditions Optic-electronic system, signal-to-noise.*

The system for primary processing of information is the major module of the opto-electronic device. This system consists of an optic block, an image analyzer, and an emission receiver. The operation of the system for primary processing of signals is quite specific when the registered contrast values equal one or even less than one. This is a matter of interest for space device construction and therefore, a subject of numerous studies [2, 4, 5].

In this study, the signal-to-noise ratio shall be used as an evaluation criterion for the energy efficiency of the system for primary processing of information. Accounting for the fact that the observed (studied) object emits during a certain time interval Δt. monochromatic flow of N_1 photons, while the background emits N_2 photons ($N_2 >> N_1$), and accounting as well for the fact that the emission receiver features generalized quantum efficiency Y_λ [1] based on the well-known expression [3], we can write for signal power N_λ^2 and quantum fluctuations ΔN_λ^2:

(1) $$N_\lambda{}^2 = N_1{}^2 \Delta t^2 Y_\lambda{}^2,$$

and

(2) $$\Delta N_\lambda{}^2 = (N_1 + N_2)\, \Delta t.\, Y_\lambda.$$

Then, the signal-to-noise ratio ψ at the output of the system for primary processing of information under low contrast conditions will be:

(3) $$\psi = \frac{N_1}{\sqrt{N_2}} \sqrt{Y_\lambda}\, \Delta t\ ,$$

consequently depending on the generalized quantum efficiency of the emission receiver and observation time. From the viewpoint of these two parameters we shall make the following analysis. As already known, quantum efficiency under external photoeffect is much smaller than one, amounting theoretically to $Y \leq 0{,}5$. The quantum efficiency of receivers with internal photoeffect is close to one. Therefore, from the viewpoint of the first parameter, it is expedient, in view of restricting photon fluctuations in the system for primary processing of information, to use emission receivers (single-component or multi-component) whose operation is based on internal photoeffect.

Concerning the optimization of the second parameter from expression (3), observation time Δt, it is most expedient to use accumulation receivers, such as mosaic receivers and the multi-component structures that have been used more and more often recently, each of whose components accumulates during the observation period [6].

Here, we shall make a comparative evaluation of various systems for primary processing of information operating under low-contrast conditions, depending on the specific value of the signal-to-noise ratio.

In the case of a system for primary processing of information with single-component emission receiver operating in object accompanying mode during time interval T, under conditions where the receiver's size is synchronized with the dissipation contour of the optic system, based on formula (3), we obtain:

$$\psi = \frac{N_1}{\sqrt{N_2}}\sqrt{TY_\lambda} \; . \tag{4}$$

In detection mode using image analyzer, the signal value is determined not over time T, but over the time during which the object is registered by the receiver, i.e. over time:

$$\tau = \frac{T}{n} \; ,$$

where n - the number of elements within the view field.

In this case, the signal-to-noise ratio is:

$$\psi_2 = \frac{N_1 \frac{T}{n} Y_\lambda}{\sqrt{N_2 T Y_\lambda}} = \frac{N_1}{n\sqrt{N_2}}\sqrt{TY_\lambda} \; . \tag{5}$$

In the same mode, in a system for primary processing of information with image analyzer of the "uniform grid" type, accounting for the feet that the signal over a time interval of one modulator revolution is accumulated over a time interval of half a period T/2 only, it may be written:

$$\psi_3 = \frac{N_1 \frac{T}{n} Y_\lambda}{\sqrt{n.\frac{N_2}{2} T Y_\lambda}} = \frac{N_1}{\sqrt{2n.N_2}}\sqrt{TY_\lambda} \; . \tag{6}$$

If the system for primary processing of information uses mosaic receiver as image analyzer, the signal from the object is actually registered by the receiver over the whole time interval T. The fluctuation noises are accumulated over the whole area of the mosaic receiver:

$$\psi_4 = \frac{N_1 T Y_\lambda}{\sqrt{n.N_2 T Y_\lambda}} = \frac{N_1}{\sqrt{n.N_2}}\sqrt{TY_\lambda} \; . \tag{7}$$

If the system for primary processing of information uses a receiver of the "electronic-optic convertor with accumulation" type or a set of microchannel plates, from each of the elements for which the signal and noise accumulated over the frame time T_k are downloaded, accounting for the background fluctuation noises of each area, it may be written:

(8) $$\psi_5 = \frac{N_1}{K\sqrt{N_2}}\sqrt{T_K Y_\lambda},$$

where k is the reserve factor accounting for the number of times the signal-to-noise ratio of the components of the electronic-optic convertor must be increased, so that the influence of background fluctuations be eliminated.

The operation analysis of the system for primary processing of information under the conditions of low contrast is made not taking into account the influence of the optic system. But, this influence on the energy efficiency of the system for primary processing of information is also of interest. Therefore, we shall determine the value of the signal-to-noise ratio at the output of the optic system, before the image analyzer and the emission receiver.

The area within which the radiation flow from a remote dot-like source is collected defines on the focal plane of the optic system a dissipation circular contour of diameter d_1. The exposure to radiation E' created by the dot-like source on the focal plane of the optic system is determined by the expression:

(9) $$E' = \frac{\frac{1}{4}\pi D^2 \varsigma E}{\frac{1}{4} n d_1^2} = \frac{\varsigma D^2}{d^2} E,$$

where D - diameter of the lens' inlet;
ς - effective admission factor of the optic system;
E - exposure to radiation created by dot-like source on the inlet plane.

The effective admission factor of the optic system ς is equal to

$$\varsigma = \varsigma_1 + \varsigma_2,$$

where: ς_1 - admission factor of the lens;
ς_2 - factor of energy concentration within the dissipation circular contour.
The amplification factor β of the optic system is determined by:

(10) $$\beta = \varsigma \frac{D}{d_1}.$$

The average number of photons N_n emitted by the dot-like source, which determines the area of the dissipation circle follows the normal distribution law and, for a certain observation time T is expressed by:

(11) $$N_n = a\frac{n}{4}\varsigma D^2 ET,$$

where a is the quantum number for 1 s.

The average number of photons emitted from a uniform background determined on the focal plane over observation time T is determined by the formula [4]:

(12) $$N' = aB\varsigma d_1 (\frac{n}{4}\frac{D}{f'})^2 T,$$

where: B - brightness of the uniform background;
f′ - focal distance of the optic system lens.

In practice, when the view field of the system has n elements, the average number of photons is calculated by the formula:

(13) $$N'' = naB\varsigma d_1 (\frac{n}{4}\frac{D}{f'})^2 T.$$

Based on expressions (11), (12), and (13), replacing the value of amplification factor β from (10), the value of the signal-to-noise ratio al the output of the optic system is obtained. For a single-element system with momentary view field:

(14) $$\varphi_1 = \frac{N_n}{\sqrt{nN'}} = \frac{E}{\sqrt{B}}\sqrt{\beta aTf'}.$$

while for a system of n elements

(15) $$\varphi_2 = \frac{N_n}{\sqrt{nN'}} = \frac{E}{\sqrt{nB}}\sqrt{\beta aTf'}.$$

In this form, with focal distances and view field unchanged, and with equal observation time, the value of the signal-to-noise ratio at the output of the optic system (not accounting for the losses in the image analyzer and the emission receiver) depends solely on the amplification factor β of the optic system.

The major conclusions from this study are:

- the energy efficiency of a system for primary processing of information in opto-electronic devices while detecting and studying remote objects against bright background under the conditions of low contrast has been analyzed; a, criterion has been specified for evaluation of energy efficiency, and expressions have been derived, relating the signal-to-noise ratio with some specific parameters of the opto-electronic device.
- the evaluation criterion for the energy efficiency of the major module of the system for primary processing of information, the optic system,

operating under the conditions of low contrast appears to be the amplification factor β determining the boundary value of the signal-to-noise ratio at the output of the opto-electronic device.

The results from this analysis have been used in developing systems for primary processing of information for the opto-electronic devices designed at the Space Research Institute - Bulgarian Academy of Sciences.

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