Original Contribution

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RESEARCH OF FACTORS WHICH INFLUENCE THE QUALITY OF OPTIC TELESCOPIC DEVICES

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Abstract: *Defining of the information quantity as a function from the adaptation brightness. It has been found that there exists a correlation between the information quantity which is transferred by a telescopic appliance and the eye and the background brightness in which the object will be observed and this allows to define an informational criterion about the quality of the apparatus as a function from the background brightness.*

The given formulas are used to evaluate concrete apparatuses for observation, which are applied in distant objects discovery from the board of man-navigated spacecrafts and they are in fact used there.

Key words: *information quantity, adaptation brightness.*

In studies from orbital research stations it becomes necessary to take account of the amount of information [1 ... 9]. In studies [5] for evaluation of the quality of the optical telescopic apparatus is proposed an information criterion, defined as the ratio of the amount of information *H*, passed by an actual telescopic device together with the eye, to the amount of information H_0 which can be obtained through the eye in observation with ideal optical instrument. The studies were conducted using a table "Mira" with complete 100% contrast. At low brightness the resolution of the optical device is a function of the brightness in direct proportion to the diameter of the lens [10, 11]. Therefore, it is logical to assume that in the low brightness, the ideal device will have a resolution as many times higher than that of the eye, as the diameter D of its lens is larger than the diameter d_z of the pupil of the eye.

Calculations of limiting angle δ_z of the eye and the pupil diameter d_z are performed using the following formulas [5]:

(1) $$S_z = 0,45 + 0,64B^{-0,42},$$

(2) $$d_z = 5 - 1,23B,$$

where δ_z is expressed in angular minutes, d_z in *mm*, B in *cd/m*^{2}.

Diffraction limit angle φ is calculated using the formula

(3)
$$\varphi_d = \frac{a}{D},$$

where $a = 1{,}22\lambda$.

For the limit brightness B_p at which diffraction limit angle for the eye is equal to zero, when calculate using the formula (1), shall be obtained

$$\delta_z = \varphi_d \text{ и } d_z = D .$$

Solving equations (1) - (3) together we obtain B = 17 *cd/m*^{2}.

About ideal telescopic system (peep-sight) follows:

At B < 17 *cd/m*^{2}

(4)
$$\varphi = \delta_z \frac{d_z}{D},$$

(5)
$$H_0 = \frac{\pi\omega^2 D^2}{d_z^2 \delta_z^2}.$$

At B > 17 *cd/m*^{2}

(6)
$$\varphi = \frac{a}{D},$$

(7)
$$H_0 = \frac{\pi\omega^2 D^2}{a^2},$$

where 2ω - Angle of field of view expressed in angular minutes.

In a real optical system, the limiting angle φ is a function of the u - field angle. The amount of information *H* obtained from a real peep-sight will be

(8)
$$H = 2\pi \int_D^{\omega} \frac{udu}{\varphi^2(u)},$$

where $\varphi(u)$ for each particular optical instrument should be determined by direct measurements.

The studies were conducted at five different brightness within the range 5.10^{-2} ... 5.10^2 *cd/m*^{2} using the table "Mira" at contrast, close to hundred percent, and the brightness of the background is assumed to be equal to the brightness of the light bands.

The study was conducted with three optical instruments: Vizir - target 15K, Vizir B 3x4 and Pankratic vizir. The results are shown in Figure. 1. At each curve is indicated the brightness at which the measurement was performed.

Figure 2 presents the values of the limit angle φ for the center of the visual field of the optical instruments, derived from the results presented in Figure 1.

With dotted line is presented the curve of the limiting angle δ_z for unaided eye, derived by the formula (1).

The experimental correlations of $\varphi(u)$ enable the calculation of the quantity of information *H*, which is obtained by the eye at observation with a real optical device at various values of the brightness adaptation. The results are presented in Figure 3, where along the abscissa-axis is presented the brightness of B in cd/m^2, and along the ordinate-axis - the quantity of information *H* in bits. The quality of a real optical instrument is implemented compared to the ideal through the quality coefficient *K* using the formula

(9)
$$K = \frac{H}{H_0},$$

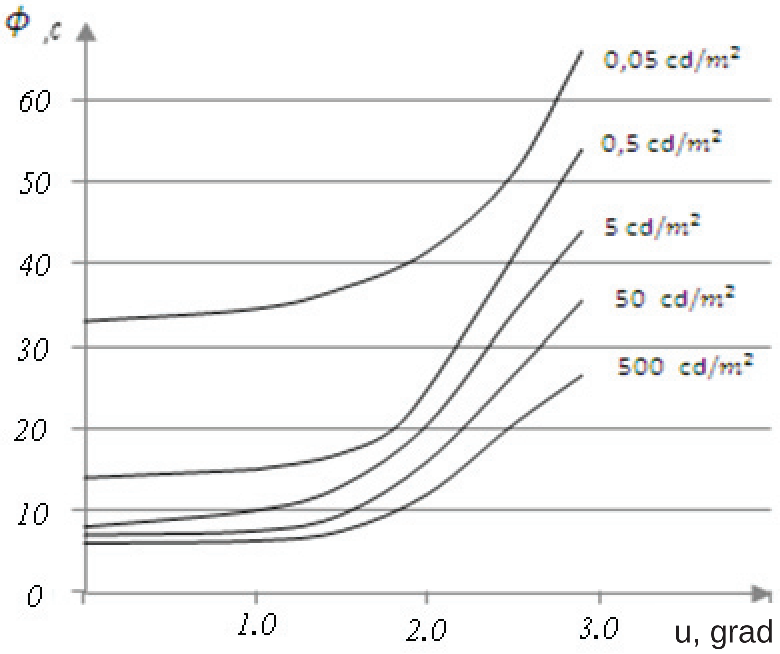

Figure 1. Limit angle φ in correlation to the field angle u for Vizir- target 15K

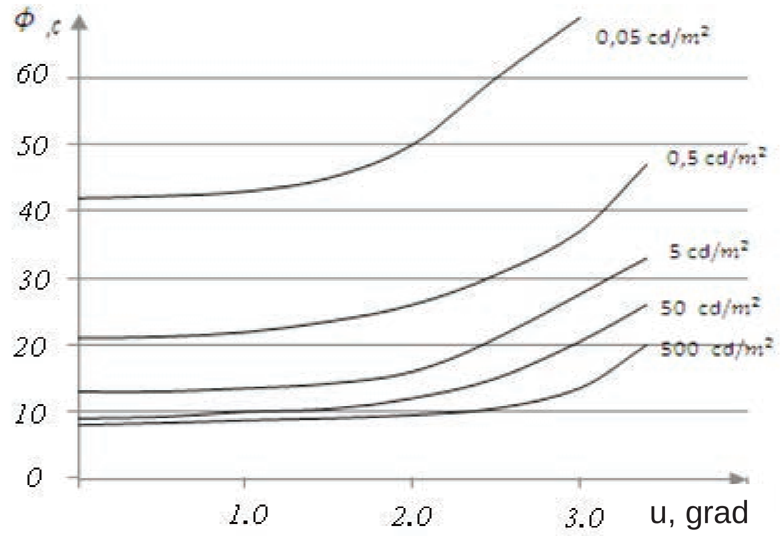

Figure 2. Limit angle φ in correlation to the field angle u for Vizir B 3x40

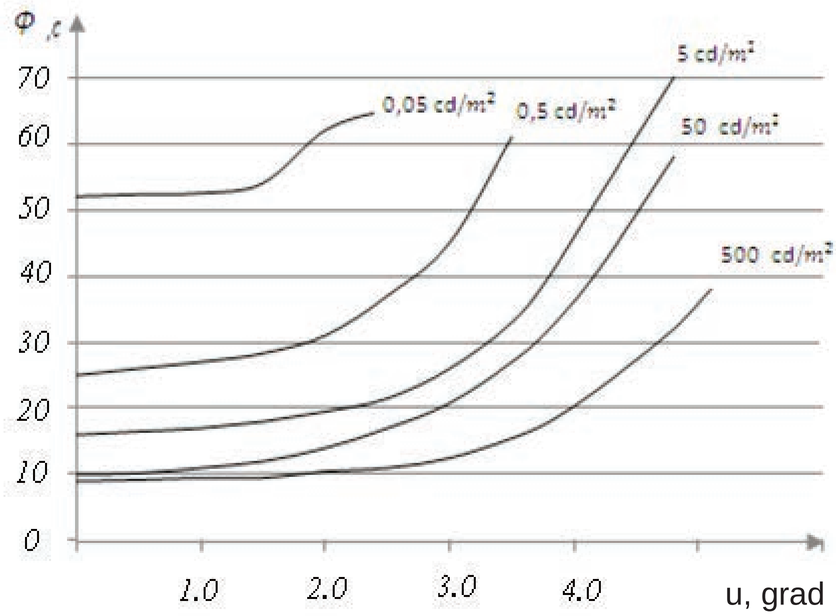

Figure 3. Limit angle φ in correlation to the field angle u for Pankratic vizir

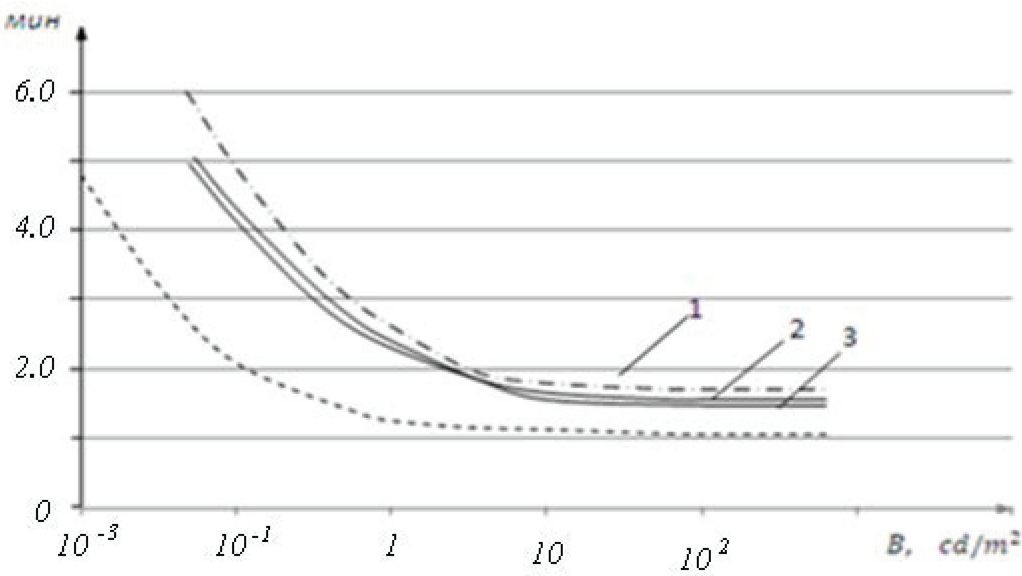

Figure 4. The limit angle depending on the brightness of the background: 1 - Vizir - target 15K, 2 – Vizir B 3x4 and 3 - Pankratic vizir

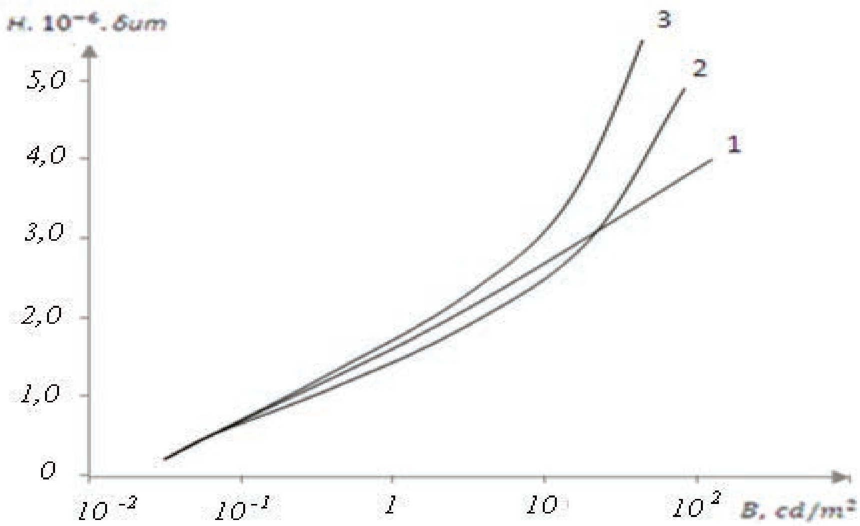

Figure 5. Quantity of information from real optical device at depending to the brightness of adaptation: 1 – Vizir – target 15K, 2 – Vizir B 3x4 and 3 – Pancratic vizir.

Fig. 4 presents the correlation between the coefficient of the quality and brightness adaptation, hence is observed that the quality factor increases rapidly with decreasing brightness, apparently due to the fact that with the lowering of the resolution ability of the eye, aberration defects of the image become not significant.

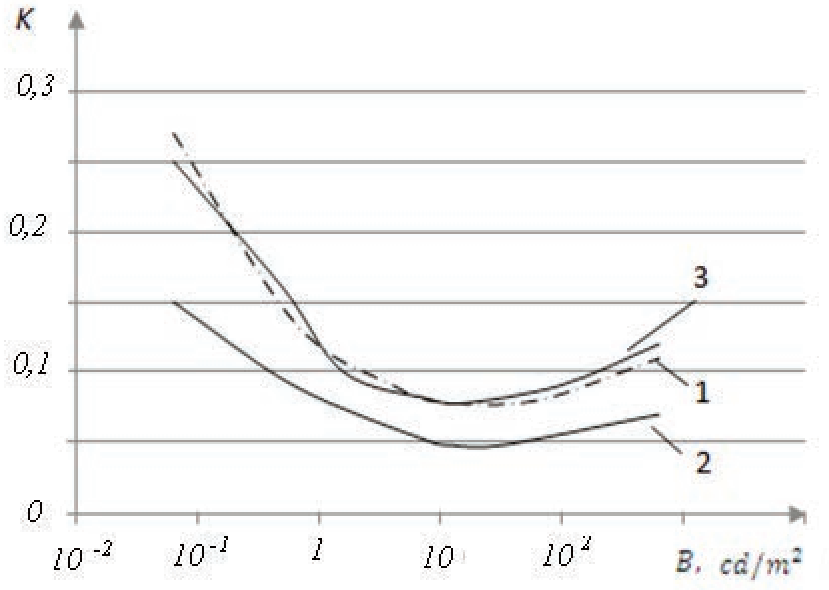

Figure 6. Correlation of the quality coefficient and the brightness adaptation: 1 – Vizir – target 15K, 2 – Vizir B 3x4 and 3 – Pancratic vizir.

When B = 17*cd/m*^{2}, K acquires a minimum value and with the increasing of the brightness it is growing again. Therefore, in formula (9), when B> 17*cd/m*^{2}, with increase of the brightness, the numerator increases, the denominator stays unchanged and K is increasing.

Finally, it should be noted that has been established a correlation between the amount of information transmitted from the optical device in combination with the eye and the brightness of the background behind the observed object, that allows determination of information criterion for the quality of the device as a function of the brightness adaptation.

The resulting formulas provide assessment of certain monitoring devices designed to detect distant objects from manned space stations, namely Vizir - target 15K - implemented to point the zonal spectroscopic equipment "Spektur"15, Vizir B 3x40 - implemented to point electro photometric equipment "Duga" and Pankratic vizir - implemented to point pulse photometric equipment "Terma".

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