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Noise Measurement in Electronic-optic Transformers

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Abstract - **The transformation of the photoelectrons into photons by a electronic-optic transformer (EOT) is accompanied by a chain of processes which result in decrease in the relation signal/noise and also in worsening the characteristics of the EOT at lower levels of illumination. Such processes are the ion feed-back and diffusion of the amplification coefficient, and as a result of which scintillations appear with a different brightness and partly loss of photoelectrons. The decrease of the relation signal/noise of a real EOT in contrast with the theoretical value is characterized by a coefficient which is called noise-factor and which is a measure for the losses of information in EOT.**

The relation signal/noise is defined as a mean level of the brightness of a uniformly luminous screen, divided into the mean quadratic aberration of the brightness from this same mean level. When measuring the relation signal/noise of EOT, which is designed for visual devices, the analyzed area of the screen should correspond to the eye resolution and the noise is measured in the band of the eye frequency.

Keywords – **noise, measurement, electronic-optic transformer**

The transformation of photoelectrons into photons by an electronic-optic transformer (EOT) is accompanied by a number of processes resulting in decrease of the signal/noise ratio and worsening the characteristics of the EOT at low illumination levels. Such processes are ion feedback and gain factor dissipation, as a result of which scintillations of variable brightness appear on the EOT's screen, as well as partial loss of photoelectrons. The decrease of the signal/noise ratio of a real EOT, compared to the theoretical value, is characterized by the so-called noise factor which is also a measure of information losses in the EOT.

The signal/noise ratio is defined as the mean brightness level of a uniformly luminous screen, divided into the brightness's mean quadratic deviation from this mean level. When measuring the signal/noise ratio of an EOT intended for use in visual devices, the analyzed screen area should correspond to eye resolution and noise is measured in the eye frequency range.

The functional diagram of the signal/noise ratio measurement equipment is shown in fig. 1.

With the help of neutral filters, the input brightness of emission source 1 is adjusted in such a way as to make it equal to 3.10^{-5} cd/m^2. The size of diaphragm 2 is chosen so that its image on the photocathode of EOT 4 overlays the diameter of analyzing diaphragm 8, reflecting in the EOT's photocathode plane an element with diameter of 0,2 mm. From the EOT's screen, the image is transferred to the photocathode of a modular low-noise EOT amplifier of the image's brightness. The signal is recorded by a sensor–photoelectronic multiplier (PEM) 9, located behind diaphragm 8. The signal from the PEM passes through low-frequency filter 10 featuring range of 0-30 Hz. This factor, together with the amplification EOT, provides to harmonize the measurement circuit's frequency range with the eye frequency characteristic. The filter factor is equal to 10. The measurement is performed using two voltmeters: digital integrating voltmeter 11 featuring time constant of 10 s, which measures the signal's constant component, and static voltmeter 12, which measures the effective voltage of the signal's variable component. The ratio of the constant component to the mean quadratic deviation (MQD) is the signal/noise ratio. The measurement process involves a sequence of operations. To focus the system, emission source brightness is set at 3.10^{-4} cd/m^2, after which the brightness is reduced to 3.10^{-5} cd/m^2 and an automatic record is made of three values of the signal's constant component and three values of the MQD.

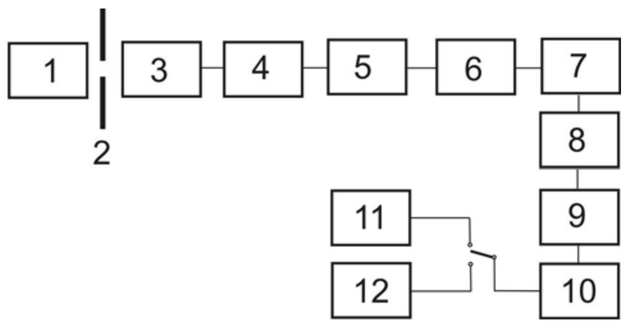

Fig. 1. Functional diagram of the signal/noise ratio measurement equipment: 1 – radiant energy source; 2 – diaphragm; 3, 5 – image transfer optic; 4 – the examined EOT; 6 – image amplifying EOT; 7 – microlens; 8 – analyzing diaphragm; 9 – sensor; 10 – low-frequency filter; 11 – statistical voltmeter; 12 – digital integrating voltmeter.

The averaged value of the constant component is divided into the averaged value of the MQD and is recorded as the signal/noise ratio. During the measurement process, the emission source voltage is controlled continuously and the luminance of the EOT's photocathode is checked from time to time. The dependence of the signal/noise ratio on the measurement tract's frequency characteristic and the luminance E_k of the EOT's photocathode are examined.

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The dependence of the signal/noise ratio on E_k is checked at constant frequency range of the measurement tract and changing luminance of the EOT's photocathode from 10^5 to 10^{-1} lx. It turns out that the dependence of the signal/noise ratio on E_k may be described by the expression:

$$\text{signal/noise} \approx E_k^{в} \qquad (1)$$

where $в = 0{,}42$.

The deviation of the theoretical value of $в = 0{,}5$ is explained by the available dark background, which affects materially the signal/noise ratio at low luminance levels of the EOT's photocathode.

The effect of the equivalent range frequency of the measurement tract's Δf_{ek} with respect to the signal/noise ratio of the examined EOT has been investigated, thereby confirming the theoretical reverse proportional dependence of the signal/noise ratio on $\sqrt{\Delta f_{ek}}$. The equivalent range frequency is determined based on the tract's amplitude-frequency characteristic $R(f)$, using the formula:

$$\Delta f_{ek} = \int_0^{\infty} R^2(f)df . \qquad (2)$$

The noise-factor F is a parameter determined by the ratio:

$$F = \frac{(signal\ /\ noise)_1^2}{(signal\ /\ noise)_2^2} \qquad (3)$$

where $(\text{signal/noise})_1$ and $(\text{signal/noise})_2$ are accordingly the signal/noise ratio at the EOT's input and output, determined at the same frequency Δf. Its effect on the EOT's characteristics is equivalent to the F-fold reduced sensitivity of the photocathode.

$$(signal\ /\ noise)_1^2 = \frac{1}{2e\Delta f} \qquad (4)$$

where e - electron's charge.

At operating voltage between the cathode and the microchannel plate (MCP), providing electron energy of 3-5 kV, the noise-factor's value varies between 4-5 and decreases when increasing the accelerating voltage, whereas the factors affecting this parameter are:

(5) $$F = \frac{1}{D}(1 + \nu)$$

where: D – the sum of electrons in the microchannel plate, determined as the ratio of the number of scintillations on the screen and the number of electrons falling onto the photocathode;

ν – relative variation of the scintillations' amplitude, comprising the effect of the microchannel plate's spatial noises.

$$\nu = \frac{\gamma^2}{E};$$

Here: E – mean scintillation energy;

γ – standard mean deviation.

According to formula (5), the noise-factor reducing means are mere reduction of ν, i.e. obtaining a more adequate amplitude distribution with small relative variations of the scintillations energy. When reducing ν, the plate's gain-factor increases. The optimum is reached at gain of 10^4, whereas further increase of the plate's gain up to 10^5 results in reverse ion relation and increase of the noise-factor.

Based on this, the amplitude distribution has been obtained, which can be used to determine the mean value of E and the standard deviation γ. The complete distribution of the scintillations by energy, which can be used to determine the mean value of the scintillations' energy E, the mean quadratic deviation γ and the electron total factor D, is shown in Fig. 2.

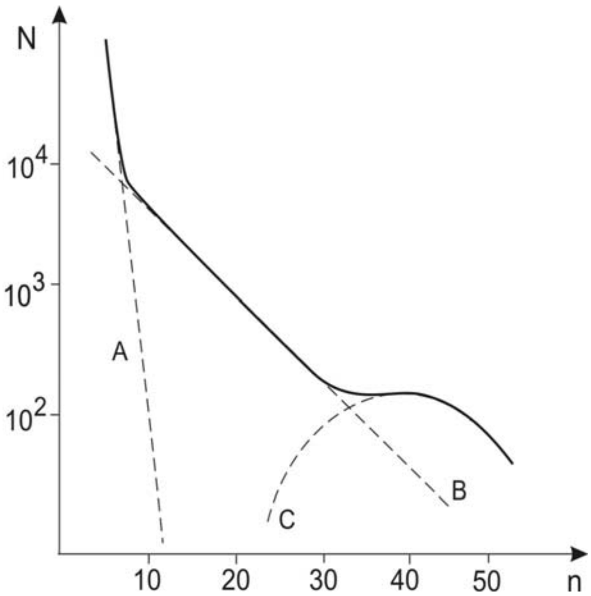

Fig. 2. Amplitude distribution of the examined EOT with MCP: along the x-axis – the scintillations' energy, along the y-axis – the scintillations' number; A – exponential distribution substantiated by the dissipation in the MCP's walls and low secondary electronic emission factor; B, C – distribution substantiated by the ion feedback mechanism.

In conclusion, it should be noted that the possibility to measure the EOT's noises provides for more efficient assessment of its technical characteristics and properties, using objective means. Unielectron amplitude distributions have been obtained, enabling to measure the signal/noise ratio and the noise-factor.

REFERENCES

[1] Zhekov Zh. Optical Techniques and Instrumentation for Identification of Remote Objects from the Board of Space Aircraft Doctor's Thesis. Space Research Institute - BAS, Sofia, 2006, 355 p.