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DYNAMIC CHARACTERISTICS OF OPERATOR'S "VISUAL CHANNEL" WITH USING CATHODE-RAY TUBE MONITOR

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Abstrakt. *Experimental models of the dynamics of the human-operators "visual channel" are constructed when operators are working with cathode-ray tube monitor and processing stochastic information.*

Keywords: visual channel, structural identification, dynamic model, remnant, spectral density, transfer function, CRT monitor.

Introduction. Among the various types of operator activity the important part takes such activity, as the detection of visual signals appeared randomly, often associated with the further definition of their characteristics (recognition) and their monitoring.

In the last two decades the extremely intensive introduction to virtually in all areas of modern society of information technologies has been seen, which in turn causes more and more increasing influence on the human operator. Possibilities of science and technology now allow us to create tools and methods to influence the functionality of the person, to change their activity as indirectly, and in real time, which is directly related to the safety and efficiency of operator work.

The term "human operator" means a person performing a labor activity, which was based on the interaction of the technical components of the machine and the environment indirectly, namely via the data model and controls.

The main characteristics of the human operator are speed, accuracy, and reliability. Assessment of high-speed performance of the operator is the time of the problem solving, mainly time from the appearing of the signal to the end of the control actions. Together with the indicators of the high-speed performance of the "human-machine", this indicator measures the performance of the entire system. His assessment is time of information passing through the closed loop of "human-machine"[1; 2].

Now the "human-machine" systems include different types of the monitors. Recently there have been only cathode-ray tube monitors (CRT monitor) and TV sets, used by people and produced by manufactures. So actual problem is to estimate the influence of CRT monitor on a human-operator.

Analysis of researches publications. Displays are being actively implemented in our lives, from home and school to a professional activity of any nature. Like any progressive innovation, displays, make life easier for people, but, on the other hand, create a new problem – "display disease". The influence of the display is determined by the age, the initial state of the visual system and the conditions of visual work.

When studying the influence of the monitors on the operator in the first place there is the question about the impact of electromagnetic radiation on the human body and monitor influence of on the work of the organs of vision [1]. But quantitatively the influence of the type of monitor on the professional activities of the operator is not sufficiently studied.

Formulation of the problem. The "visual channel" consists of the receptors, which receive information (human eyes), the central nervous system that processes this information and effector (in this case a human hand).

In general case human, as a complicated system, that organizes itself, presents nonlinear and not stationary system. For most of practical cases its characteristics can be presented as quasilinear model. The linear model of a human performing the operation of input signal tracking in open control loop, are described in the block diagram (fig. 1).

In fig. 1 $\varphi(t)$ is error of processing of the input signal. Human is represented on it by transfer function W and so-called source of remnant, or remnant $r(t)$. Under remnant we consider a part of output signal of the human-operator, which can't be obtained by the linear transformation of output signal. We can specify next sources, which reproduce remnant: operator reacts not only on the signal, that requires reaction, but also on some another signal (for example, during two-coordinates observation it reacts, working in the horizontal direction, on the vertical signal); nonlinear part of reaction on the input signal; own noise of operator; nonstationarity of parameters of the operator transfer function.

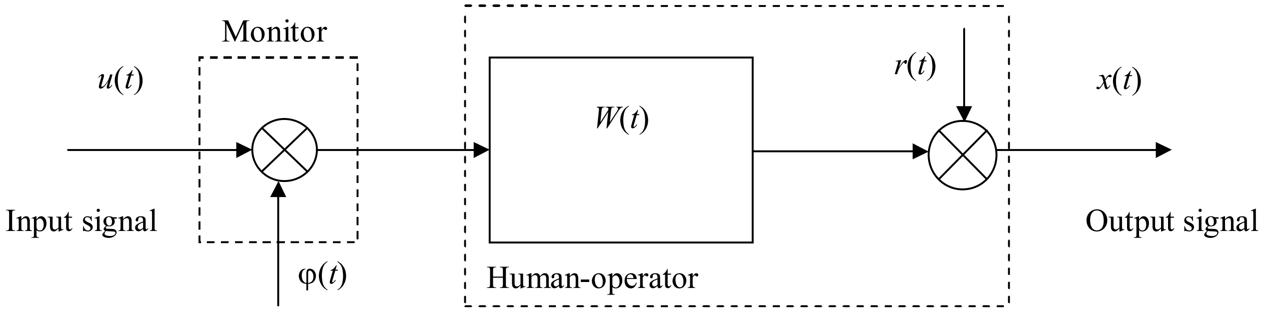

Fig. 1. Operator block diagram in the control loop

Of course transfer function of operator "visual channel" describes the average for this observation or result of series of observations. For short periods of time, and also for single observations deviations from average values can take place. Caused by this deviation of linear reaction around average the reaction can be contained in the observation error. Therefore to carry out only one observation and to reduce these error the stochastic input and output signals are used.

The purpose of this work is to estimate an influence of CRT monitor on the structure and parameters of operator "visual channel" dynamic model on the base of the experimental data. Processing of the input and output signals in the system of "visual channel" the research of a human was performed on the base of the structural identification algorithm with a help of the applications package, which specially designed in National Aviation University and is based on spectral analysis method of random ergodic processes.

Structural identification algorithm of the model of a dynamic system. We use the well-known algorithm [2]. Let the experiments determine arrays of input u (t) and output x (t) signals of the object (fig. 2).

Fig. 2. Block diagram of the identification of the object

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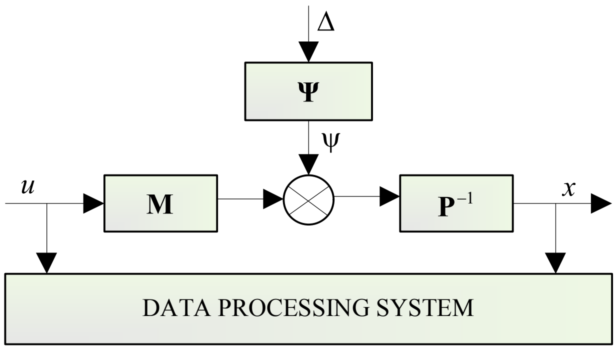

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The behavior of the researching object is described by a system of ordinary differential equations with constant coefficients

$$\mathbf{Px} = \mathbf{Mu} + \boldsymbol{\psi}, \tag{1}$$

where **x** and **u** – are vectors of the input and output signals of the object; $\boldsymbol{\psi}$ – is vector of signal uncontrolled disturbances, which is a stationary random process, uncorrelated with the input **u**; **P** and **M** are polynomial matrix of the argument $s = j\omega$. The problem is to find the matrix of transfer functions of the identified object and the matrix of spectral density of a disturbance vector.

The spectral matrix and mutual spectral density $\mathbf{S}_{uu}(s)$, $\mathbf{S}_{xx}(s)$, $\mathbf{S}_{ux}(s)$, and $\mathbf{S}_{xu}(s)$ are determined as a result of the primary signal processing.

Introducing the symbol $\boldsymbol{\psi} = \boldsymbol{\Psi} \cdot \boldsymbol{\Delta}$, where $\boldsymbol{\Psi}$ –is the matrix of transfer functions of the filter, which forms the vector $\boldsymbol{\psi}(s)$ Fourier images of disturbing signals on the base of "white" noise vector $\boldsymbol{\Delta}(s)$, equation (1) can be rewritten as

$$\mathbf{x} = \mathbf{P}^{-1}\mathbf{M}\mathbf{u} + \mathbf{P}^{-1}\boldsymbol{\Psi}\boldsymbol{\Delta}.$$

Assuming that the measurement signals **u** and **x** are «ideal», we form the structural identification algorithm as follows:

– the matrix of transfer functions of the identification object is

$$\mathbf{W} = \mathbf{P}^{-1}\mathbf{M} = \mathbf{S}_{ux}^{\mathrm{T}}\ (\mathbf{S}_{uu}^{\mathrm{T}})^{-1}, \tag{2}$$

– the matrix spectral density perturbation acting on an object is

$$\mathbf{S}_{\mathrm{rr}}^{\mathrm{T}} = \mathbf{P}^{-1}\boldsymbol{\Psi}\mathbf{S}_{\Delta\Delta}\boldsymbol{\Psi}_{*}\mathbf{P}_{*}^{-1} = \mathbf{S}_{xx}^{\mathrm{T}} - \mathbf{S}_{ux}^{\mathrm{T}}(\mathbf{S}_{uu}^{\mathrm{T}})^{-1}\mathbf{S}_{xu}^{\mathrm{T}}, \tag{3}$$

where "$^{\mathrm{T}}$" – the sign of transposition; "*" – a symbol of the Hermitian conjugation.

Investigation of the models of operator's "visual channel" dynamics working with CRT monitor (Samsung SyncMaster 753DFX, screen size – 15 inches, resolution 800×600, refresh rate 85 Hz, horizontal sweep 30-70kHz, vertical sweep 50-160Hz). The experiment was carried out with the participation of 16 operators (age 20–23 years).

Random signal is presented to the operator. Human-operator can see only a part of this signal (five points). Another points become invisible due to the convenience of performing the tracking task. The task of operator is – as precise as possible, to repeat an input signal, using a mouse cursor. The input signal and the vertical coordinate of the mouse were saved and late these signals were processed using the algorithm of structural identification.

For example let's consider the steps of the structural identification for the one of the operators group. First step is to find spectral density input (fig. 3), the output signals (fig. 4) and their mutual spectral density (fig. 5) and to approximate these characteristics by using MatLab.

Approximation of graphical dependencies by analytical expressions are:

– input test signal

$$S_{uu}(s) = \frac{(2,4)^2}{\pi} \cdot \left| \frac{1}{(0,05s+1)(0,025s+1)} \right|^2, \tag{4}$$

– operator reaction

$$S_{uu}(s) = \frac{(2,5)^2}{\pi} \cdot \left| \frac{1}{(0,044^2 s + 2 \cdot 0,35 \cdot 0,044s + 1)} \right|^2, \tag{5}$$

– mutual spectral density of the input signal and the reaction of the operator

$$S_{ux} = \frac{3,8}{\pi} \cdot \frac{(0,3s+1)}{(0,22^2 s^2 + 2 \cdot 0,5 \cdot 0,22s + 1)(0,08s+1)} e^{-0,35s}. \tag{6}$$

Second step is to substitute expressions (4), (5) and (6) into (2) and (3) and obtain transfer function and spectral density of remnant of human operator "visual channel". Amplitude and phase frequency characteristics of the operator are shown in fig. 6.

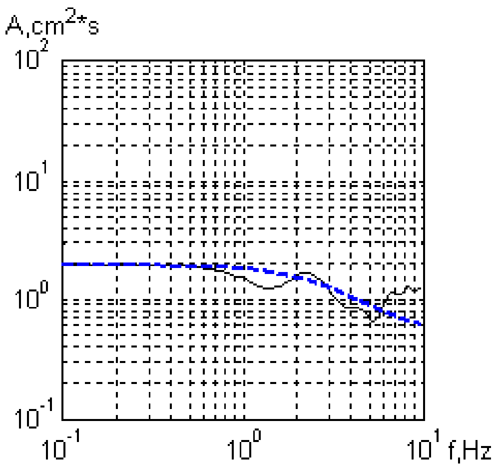

Fig. 3. Input signal spectral density (—) and its approximation (---)

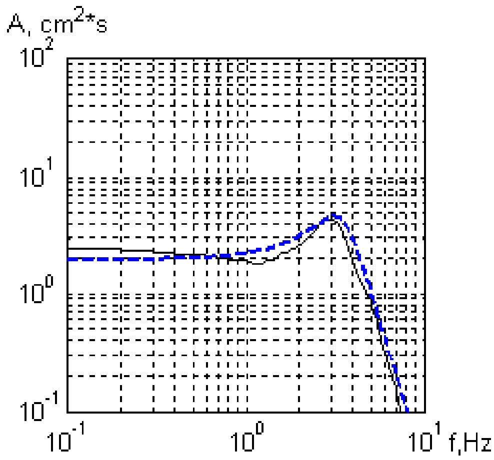

Fig. 4. Output signal spectral density (—) and its approximation (---)

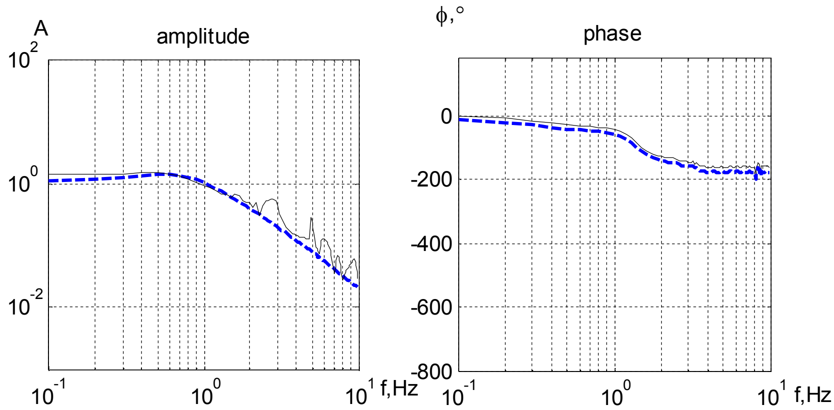

Fig. 5. Mutual spectral density of the input and output signals (—) and its approximation (---)

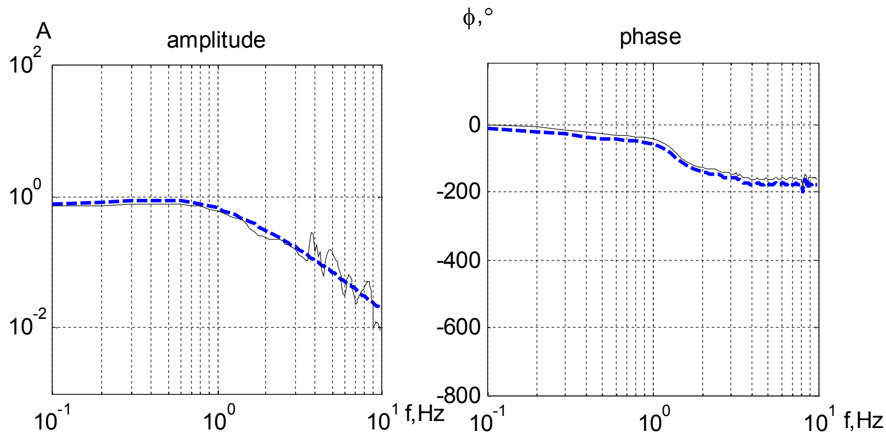

Fig. 6. The transfer function of operator "visual channel" (—) and its approximation (---)

Analytical expression for the transfer function of the operator has the form

$$W(s) = 0,78\frac{(0,3s+1)}{(0,22^2 s^2 + 2\cdot 0,6\cdot 0,22s+1)(0,06s+1)}e^{-0,35\cdot s}.$$

Figure 7 shows the spectral density of the remnant that operator makes working in the open-loop control system and its analytical expression:

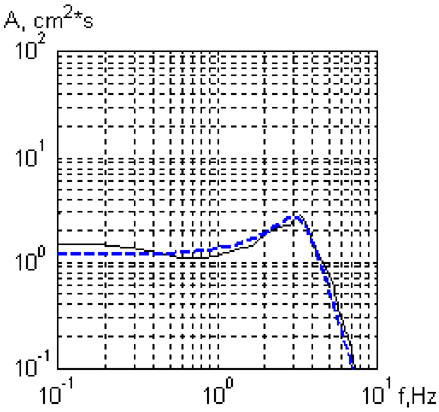

Fig. 7. Spectral density of operator remnant (—) and its approximation(---)

$$S_{rr} = \frac{1,95^2}{\pi}\left|\frac{1}{(0,045^2 s^2 + 2\cdot 0,36\cdot 0,045s + 1)}\right|^2.$$

The transfer functions and spectral density of remnant of all 16 operators are found in the same way.

Analysis of the dynamic characteristics of operator “visual channel” is showed which parameters can be used for estimation of influence of CRT monitor on the operator work. Therefore the gain (*K*) and time delay of operator reaction (τ), the bandwidth of the signal (*f*) and the signal intensity of remnant (*R*) are chosen. Then statistical analysis of each parameter was carried out. The table represents the average value and root mean square deviation of these parameters for researched group of operators.

Average value and root mean square deviation of the parameters of “visual channel” models

	K	τ	*f*	*R*
Average value	0,5775	-0,5726	2,7938	4,2394
Root mean square deviation	0,0083	0,0233	0,11	0,1667

Conclusion. The transfer functions and spectral density of remnant of the operators group are found on the base of the structural identification of experimental data. Parameters for estimation of influence of CRT monitor are chosen and statistical analysis of these parameters was carried out. In the future, these results will be compared with the results of structural identification of dynamic characteristics of operator “visual channel” when operator is working with TFT monitor.

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Динамічні характеристики «зорового каналу» оператора під час його роботи з монітором із електронно-променевою трубкою

Побудовано експериментальні моделі динаміки «зорового каналу» людини-оператора під час обробки стохастичної інформації під час роботи оператора із монітором на основі електронно-променевої трубки.

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Динамические характеристики «зрительного канала» оператора, во время его работы с электронно-лучевым монитором

Построены экспериментальные модели динамики «зрительного канала» человека-оператора, во время обработки стохастической информации при работе оператора с монитором на основе электронно-лучевой трубки.