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DYNAMIC CHARACTERISTICS OF OPERATOR`S "VISUAL CHANNEL" WHILE WORKING WITH TFT MONITOR

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Abstract. *Experimental models of the dynamics of the human-operators "visual channel" are constructed while operators working with thin-film transistor monitor and stochastic information processing.*

Keywords: dynamic model; remnant; spectral density; structural identification; thin-film transistor monitor; transfer function; visual channel.

1. Introduction

Despite the increasing trend toward automation, robotics and artificial intelligence in many environments, the human operator will probably continue for some time to be integrally involved in the control and regulation of various machines (e.g., spacecrafts, helicopters, jet fighters, etc.).

A typical manual control task is the task in which the control of these machines is accomplished by manipulation of the hands or fingers [3].

The important part of operator activity is a detection of visual random signals and their tracking.

In the last two decades technical improvement of video monitors has largely changed their physical and technical parameters.

The appearance of liquid crystal displays which uses Thin-film Transistor (TFT) technology is based on active matrix has a new step in the evolution of displays, but cannot be seen as an opportunity to eliminate the negative impact on the organ of sight. New video monitors suffer from unchanging of sweep mode, spectral imperfection and a special type of the pixel that ultimately forms the so-called discrete image.

Thus actual problem is to estimate the influence of TFT monitor on a human-operator.

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. Its assessment is time of information passing through the closed loop of "human-machine" [1, 3].

2. Analysis of researches and publications

The number of computer users is growing every year. At the same time the amount of computer and electrical equipment in our work places, at home and everywhere is also increasing.

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 on the work of the organs of vision [2, 4]. But quantitatively the influence of the type of monitor on the professional activities of the operator is not sufficiently studied.

Purpose of work is to use quasilinear analytical models to estimate the influence of the TFT monitor on human-operator activities.

2. Experimental determination of the dynamic models of human-operators "visual channel"

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

Human operators are known to be nonlinear, adaptive, time varying and intelligent controllers. In some cases, the human operator may or may not be well trained or an expert, showing different dynamics from operator to operator.

Therefore, it is very difficult to obtain mathematical models of human operators in a human-in-the-loop-manual control tasks. But in these practical cases human characteristics can be presented as quasilinear model.

Principals of defining of human's linear model, which perform an operation of input signal tracking in open control circuit, are described on the block diagram Fig. 1.

Human represented on it by the transfer function W and so-called source of remnant, or remnant $r(t)$.

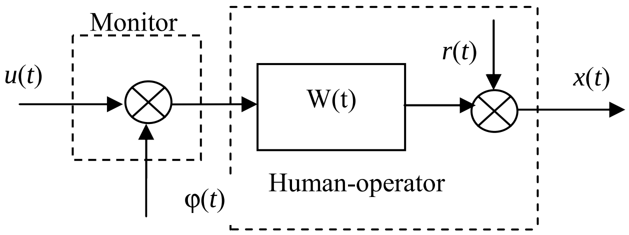

Fig. 1. Operator's block diagram in the control loop:
$u(t)$ — input visual signal;
$x(t)$ –output signal;
$\varphi(t)$ — is an error processing of the input signal

Human represented on it by the transfer function W and so-called source of remnant, or remnant $r(t)$.

We consider remnant as 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 the remnant:

— operator reacts not only on the signal, which requires reaction, but also on the another signal (for example, it reacts during two-coordinates observation, 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's transfer function.

Of course the transfer function of operator's "visual channel" describes the average for this observation or series of observations result. For short periods of time, and also for single observations the deviations from average values can take place.

Caused by this deviation of linear reaction around average reaction can be contained in the observation error.

Therefore to carry out only one observation and to reduce these errors stochastic input and output signals are used.

A computer-based experiment has been designed using the system identification theory to collect data from human operators.

The purpose of this work is to estimate an influence of TFT monitor on the structure and parameters of operator's "visual channel" dynamic model on the basis of the experimental data.

Processing of the input and output signals in the system of the "visual channel" research of a human was performed on a basis of the structural identification algorithm with a help of the applications package, which were specially designed in National Aviation University and are based on a spectral analysis method of a random ergodic processes.

4. Structural identification algorithm of the dynamic system model

We use well-known algorithm [1]. Let the experiments determine arrays of input u (t) and output x (t) signals of the object (Fig. 2).

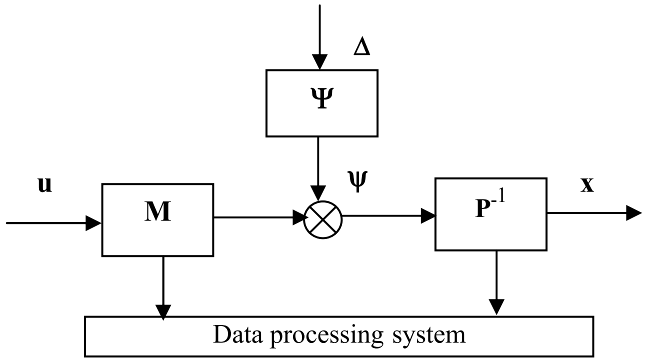

Fig. 2. Block diagram of the identification of the dynamics of the object

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

$$\mathbf{Px} = \mathbf{Mu} + \psi \qquad (1)$$

where **P** and **M** — polynomial matrix argument: $s=j\omega$;

x and **u** — vectors of the input and output signals of the object,

ψ — vector signal uncontrolled disturbances, which is a stationary random process, uncorrelated with the input **u**.

The problem is to find the matrix of transfer functions of the identified object and the matrix spectral density 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

$$\psi = \Psi\Delta,$$

where Ψ — the matrix of transfer functions of the filter, which forms the vector $\psi(s)$.

Fourier images of disturbing signals on the basis of "white" noise vector $\Delta(s)$, equation (1) can be rewritten as follows

$$x = P^{-1}Mu + P^{-1}\Psi\Delta.$$

Assuming that the measurement signals u and r are "ideal", we form the structural identification algorithm as follows:

— the matrix of transfer functions of the identification object

$$W = P^{-1}M = S_{ux}^{T}\ (S_{uu}^{T})^{-1}, \qquad (2)$$

— the matrix spectral density perturbation acting on an object

$$S_{\mathrm{rr}}^{T} = P^{-1}\Psi S_{\Delta\Delta}\Psi_{*}P_{*}^{-1} = S_{xx}^{T} - S_{ux}^{T}(S_{uu}^{T})^{-1}S_{xu}^{T}, \qquad (3)$$

where “*T*” — the sign of transposition;

“$*$” — a symbol of the Hermitian conjugation.

Model of operator`s “visual channel” while working with TFT monitor.

The experiment was carried out with the participation of 27 operators (16 men, 11 women, at the age of 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 — to repeat an input signal as precise as possible, 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 consider the steps of the structural identification for one of the operators group.

First step is to find spectral density input (Fig.3,*a*), the output (Fig.3,*b*) signals and their mutual spectral density (Fig. 4) and to approximate these characteristics by mathematical expression.

MatLab has been used for all these operation.

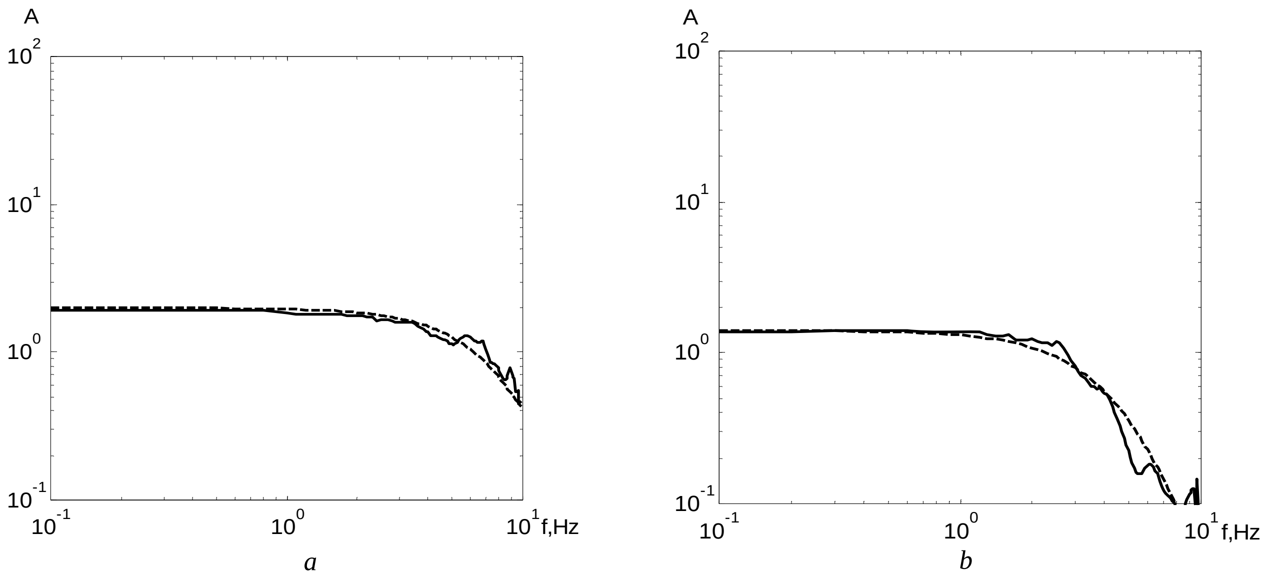

Fig. 3. Input (*a*) and output (*b*)signal spectral density (—) and its approximation (---)

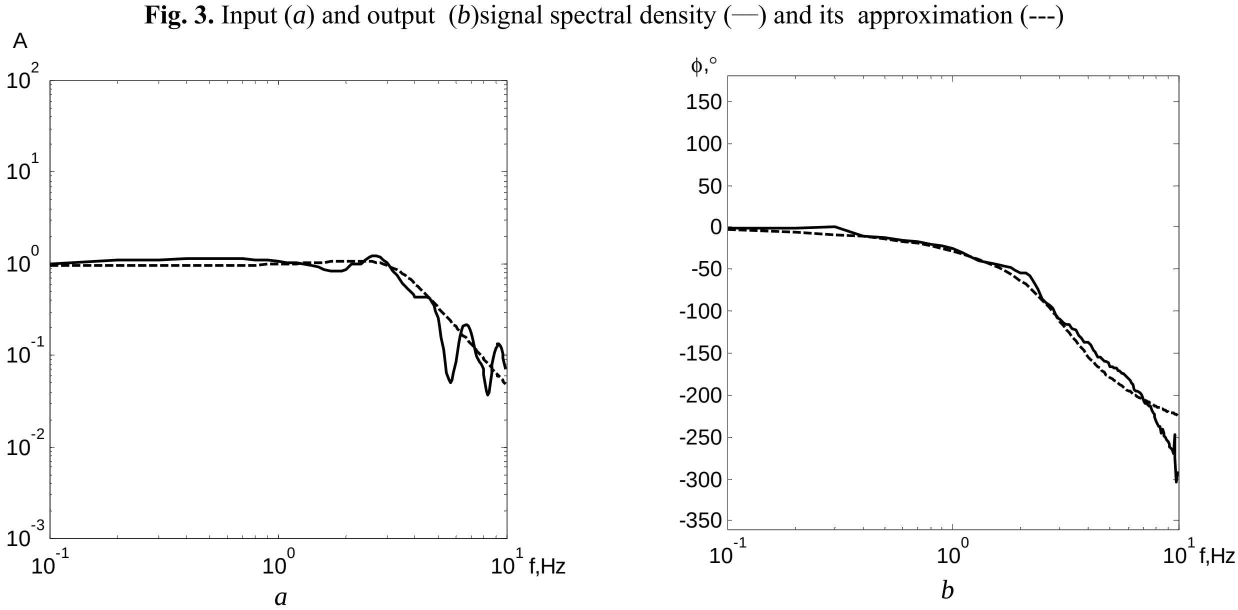

Fig. 4. Amplitude-frequency (*a*) and phase-frequency (*b*) characteristic of the mutual spectral density of the input and output signals (—) and its approximation (---)

Approximation of graphical dependencies analytical expressions is as follows:

— input test signal

$$S_{uu}(s) = \frac{(2,5)^2}{\pi}\left|\frac{1}{(0.018s+1)}\right|^2, \qquad (4)$$

— operator reaction

$$S_{xx}(s) = \frac{(2,1)^2}{\pi}\left|\frac{1}{(0.05s+1)(0.03s+1)}\right|^2, \qquad (5)$$

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

$$S_{ux} = 0.7\frac{1}{(0.05^2 s^2 + 2\cdot 0.45\cdot 0.05s+1)}\times$$

$$\times\frac{1}{(0.03s+1)}\cdot e^{-0.21s}. \qquad (6)$$

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.5.

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

$$W(s) = 0.73\frac{1}{(0.045^2 s^2 + 2\cdot 0.5\cdot 0.045s+1)}\times$$

$$\times\frac{1}{(0.03s+1)}\cdot e^{-0.21s}.$$

Fig. 6 shows the spectral density of the remnant that operator makes while working in the open-loop control system and its analytical expression:

$$S_{rr} = \frac{1.6^2}{\pi}\left|\frac{1}{(0.33^2 s^2 + 2\cdot 0.7\cdot 0.33s+1)}\right|^2.$$

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`s “visual channel” is showed what parameters can be used for estimation of influence of TFT monitor on the work of the operator.

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.

Statistical analysis
of the mathematical models parameters

Parameter	Average value	Root mean square deviation
K	0,71	0,006
τ	-0,2	0,003
f	2,81	0,16
R	1,14	0,083

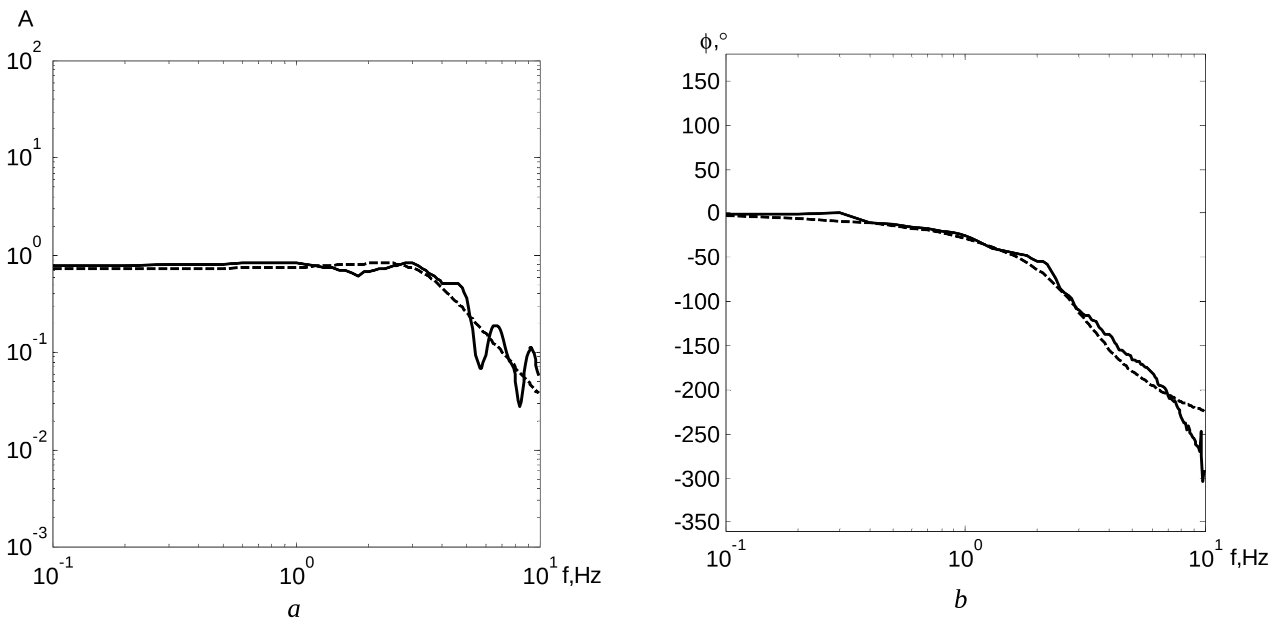

Fig. 5. Amplitude-frequency (*a*) and phase-frequency (*b*) characteristic of the transfer function of operator “visual channel” (—) and its approximation (---)

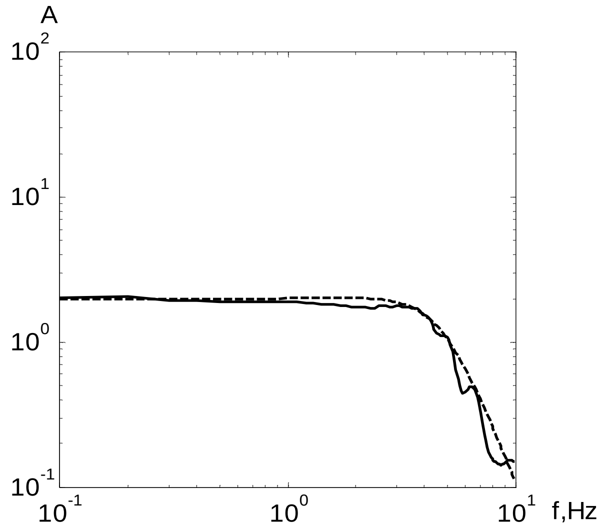

Fig. 6. Spectral density of operator remnant (—) and its approximation(---)

5. Conclusions

The transfer functions and spectral density of remnant of the operators group are found on the basis of the structural identification of experimental data.

Parameters for estimation of influence of TFT 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`s "visual channel" when operator working with cathode-ray tube monitor.

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Ю. В. Петрова. Динамічні характеристики «зорового каналу» оператора під час його роботи з TFT монітором

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Розглянуто вплив моніторів на оператора та органи зору, а також електромагнітного випромінювання на організм людини. Зазначено, що кількісно вплив типу монітора на професійну діяльність оператора недостатньо вивчений. Для кількісної оцінки впливу TFT монітору на діяльність людини-оператора використано квазілінійні аналітичні моделі. Знайдено передавальні функції та спектральні щільності ремнанти групи операторів на основі структурної ідентифікації експериментальних даних. Вибрано параметри для оцінки впливу TFT монітора. Проведено статистичний аналіз цих параметрів.

Ключові слова: динамічна модель; зоровий канал; передавальна функція; ремнанта; спектральна щільність; структурна ідентифікація; TFT монітор.

Ю. В. Петрова. Динамические характеристики «зрительного канала» оператора во время его работы с TFT монитором

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Рассмотрено влияние мониторов на оператора и органы зрения, а также электромагнитного излучения на организм человека. Отмечено, что количественно влияние типа монитора на профессиональную деятельность оператора изучено недостаточно. Для количественной оценки влияния TFT монитора на деятельность человека-оператора использованы аналитические квазилинейные модели. Найдены передаточные функции и спектральные плотности ремнанты группы операторов на основе структурной идентификации экспериментальных данных. Выбраны параметры для оценки влияния TFT монитора. Проведен статистический анализ этих параметров.

Ключевые слова: динамическая модель; зрительный канал; передаточная функция; ремнанта; спектральная плотность; структурная идентификация; TFT монитор.

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