

THEORY AND METHODS OF SIGNAL PROCESSING

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CORRELATION METHOD FOR VERIFICATION OF HUMAN ORGANISM PSYCHOPHYSIOLOGICAL STATE

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Abstract—*This article presents correlation method of human's organism psychophysiological state checking. Authors propose the structural scheme for estimation of humans biologically active points characteristics and clarifying calculations.*

Index Terms—Psychophysiological state; acupuncture points; correlation.

I. INTRODUCTION

Modern society can't be imagined without aviation. It represents the universal cargo, passenger carrier, and despite all complexity of the flight carrying out, it is still one of the safest mode of transport. This is related to the constant monitoring of the equipment capacity, and also to the physical and psychological state of the craft's crew.

According to the civil aviation rule, every crew member has to be tested by the special medical certification directly before sortie and get the medical cerebrum from duty doctor in any airport health center. Health examination must be passed neither less an hour before sortie, nor more than 2 hours before the flight. Doctor reads the blood pressure, takes pulse rate, assesses pilot's state. If there are any suspicions, additional tests may be passed.

However, after long hours' flight performing pilot's vital factors can change. For catastrophic consequences prevention, namely for safety instructions observing during flight carrying out, it's necessary to perform permanent survey of the pilot's psychophysiological state.

It is well-known fact that the human organism as an organic whole, can exist only at a certain ratio of various oscillatory processes in cells, tissues, organs and functional systems and their synchronization with environmental conditions [1].

The most famous examples of oscillatory processes manifestations are the so-called biorhythms, three of which the physical, emotional and intellectual – are widely used to predict the human state in a certain period of time. Generally, biological rhythms are a complicated sequence of multistage processes of biochemical and biophysical changes in the human organism. Scientists think [2], that the source of biorhythms is a molecule of RNA and DNA. Ratio of

interdependent chemical reactions rates that run simultaneously, can be consider as a regulatory mechanism of the body biological hours, synchronization of which is provided by central and vegetative nervous systems. Perhaps, parameters of physiological functions rhythms are set by some genetic program, but in any case they are implemented by changing of the metabolic processes under influence of a resonance-energy of external and internal factors. Resonance-energy interactions are very important for implementation of development processes and existing of living organisms. These energy interactions determine the synchronization systems, self-organization and self-sustaining of complex systems generally and living one especially [3].

Violation of resonance rhythms and synchronization of physiological processes regime is a key indicator of deviation from the norm. Therefore, the degree of process synchronization at the cellular level, in particular, the synchronization process of opening and closing the gates of ion channels, charge and discharge of cell membranes, potential changes of nerve fibers, etc., objectively shows human psycho physiological state.

Electrophysiological characteristics of the human body acupuncture points (AP), which include conduction, current potential, bioelectric current, the level of electrical noises, etc., shows the intensity of physiological and information-energy processes both occurring as in a whole organism as in its different systems. Because of thermodynamic equilibrium of electric current carriers (electrons and ions) in AP arise thermal power fixed-ratio fluctuations that cause current and voltage noises. Along with equilibrium thermal noise in the body biological noise also occurs caused by non-equilibrium electrophysiological processes. These processes include opening and closing the gates of ion channels,

charge and discharge of cell membranes, changes potentials of rest and activity of nerve fibers, changes in receptor potential and others. The result is the presence in AP thermal and biological noise with different spectral energy characteristics.

II. PROBLEM STATEMENT

However, the determination of an electric couple between different AP is connected with great difficulties because of small values of electrical noise and lack of proper equipment.

For estimation of level of extremely small electrical noise signals, traditional methods of measurements with direct amplification of the investigated signal can't be used. This is due to the fact that electronics apparatus circuits have own inherent electrical noises, the level of which may be greater than the level of useful signal. In such conditions, there a certain prospects gives usage of correlation methods of noise signals processing [4].

Correlation between AP current noise signals characterizes the degree of synchronization of electrophysiological processes proceeding in cells and intercellular body space.

Determination of the body AP electrical connection [2] is carried out by using two metal electrodes, one of which is covered with oxide membrane and sensitive device for DC measuring. Electrodes due to potential difference induce directed current through AP of the body, the values of which gives a possibility to make conclusion about corresponding reaction of the functional-energy system. However, DC using has difficult to evaluate relaxation and oscillation processes occurring in the cells of living organisms. For an objective estimation

of AP electrical connections, it is appropriate to take into account resonance-energy properties of the human body.

III. PROBLEM SOLUTION

Figure 1 illustrates a functional scheme of the device for psychophysical state estimation. Needle electrodes 1 and 2 connect with selected AP, electrical connection between which is the subject of research. Electrode-clamp 15 is connected to the hand or foot of the investigated human depending on location of comparable AP along the trajectory of chosen energy meridian. As a result, the skin cover 17 in the selected zone begins to be connected to a common grounded bus 16 of device. Electrical signals, read by needle electrodes 1 and 2 from comparable AP, are an additive mix of thermal and biological noise, which is inherent for living organisms. Biological noise intensity is determined by a random set of singular electro-physical reactions (opening and closing the gates of ion channels, charge and discharge of cell membranes, energy transitions of neurons from active to inactive state and so on.). Matching amplifiers 3, 4 which are connected to the needle electrodes 1, 2 in the form of high-resistance probes that are easy moves across the skin surface relative to the electrode-clamp 15. The output signal from matched amplifier 3 receives the direct input of the differential amplifier 6, and on its inverse input through automatic switch 5 each after each heteropolar signals from symmetrical outputs of the matched amplifier 4 come. Frequency of switching signals is determined by the frequency of low frequency generator 14, which voltage controls the operation of the automatic switch 5 and synchronous detector 11.

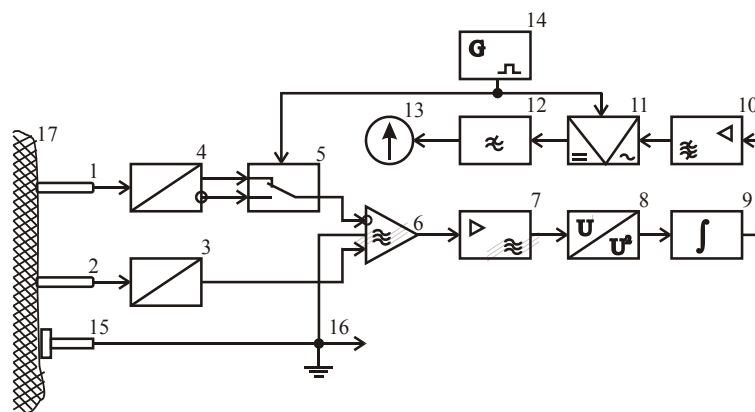


Fig. 1. Functional scheme of the device for evaluation of psycho-physiological state

Let's introduce noise signals from AP as a complex \dot{U}_1 and \dot{U}_2 . Then at the top position of automatically switch 5 at the output of the differential amplifier 6 a complex differential voltage is formed

$$\dot{U}_3 = K_1(\dot{U}_2 - \dot{U}_1 + \dot{U}_{A1}), \quad (1)$$

where K_1 is the amplifying coefficient of an differential amplifier 6; \dot{U}_{A1} is the internal voltage noise of differential amplifier 6.

At the bottom position of automatically switch 5, considering polar change of the matching amplifier 4 output voltage the summary complex voltage is formed:

$$\dot{U}_4 = K_1(\dot{U}_2 + \dot{U}_1 + \dot{U}_{A1}). \quad (2)$$

Packages of noise voltages \dot{U}_3 and \dot{U}_4 are amplified in turn by wideband amplifier 7. In the squarer 8 instantaneous values of the amplified voltages are squared and then averaged in the integrator 9. As the result of represented operations, under one position of the automatically switch on the output of integrator 9 the averaged voltage appears

$$U_5 = K_2^2 S_1 K_3 \overline{(\dot{U}_3 + \dot{U}_{A2})^2}, \quad (3)$$

where K_2 is the coefficient of the wideband amplifier 7 gain; S_1 is the escarpment of squarer 8 transformation; K_3 is the integrator 9 transfer coefficient; \dot{U}_{A2} is the voltage of the wideband amplifier 7 proper noises, and symbol “ $\overline{\quad}$ ” means time average.

In another position of the automatically switch 5 the averaged voltage appears

$$U_6 = K_2^2 S_1 K_3 \overline{(\dot{U}_4 + \dot{U}_{A2})^2}. \quad (4)$$

As we may see in expressions (1) and (2), voltages \dot{U}_3 and \dot{U}_4 represent the difference and the sum of the comparing voltages. Their squaring as in (3) and (4) together with proper noises voltages \dot{U}_{A1} and \dot{U}_{A2} leads to appearance of voltages, which are proportional to product of the noise voltages as of comparing AP, as of the proper noise voltages of amplifiers among themselves and AP voltage. It's necessary to consider that the amplifiers noises are not correlated with AP noises because their sources are statically independent. Thus the noises of the differential 6 and wideband 7 amplifiers are not correlated together. As we know, averaged products of the noise non-correlated voltages are equal to zero:

$$\overline{\dot{U}_1 \dot{U}_{A1}} = 0; \quad \overline{\dot{U}_1 \dot{U}_{A2}} = 0; \quad \overline{\dot{U}_{A1} \dot{U}_{A2}} = 0; \quad (5)$$

$$\overline{\dot{U}_2 \dot{U}_{A1}} = 0; \quad \overline{\dot{U}_2 \dot{U}_{A2}} = 0. \quad (6)$$

Noise voltages of the comparing AP are correlated together due to synchronism of the electro-physiological processes, determined by the regulation effect of the electromagnetic frame of the living organism. That's why averaged product of the AP biocurrents

$$\overline{\dot{U}_1 \dot{U}_2} = \rho_{12} \bar{U}_1 \bar{U}_2, \quad (7)$$

where ρ_{12} - coefficient of the mutual correlation of the electrodes 1 and 2 noise voltage; \bar{U}_1 and \bar{U}_2 are mean squared values of this noise voltages.

Mean square of the complex noise voltage gives the value of this voltage variance (\bar{U}_2) in the period of the amplifying voltages frequencies. Considering ratios (5), (6) and (7) the averaged voltage looks like

$$\bar{U}_5 = K_1^2 K_2^2 S_1 K_3 \left(\bar{U}_1^2 + \bar{U}_2^2 + \bar{U}_{A1}^2 + \frac{\bar{U}_{A2}^2}{K_1^2} - 2\rho_{12} \bar{U}_1 \bar{U}_2 \right). \quad (8)$$

Similarly the averaged voltage (4) is expressed

$$\bar{U}_6 = K_1^2 K_2^2 S_1 K_3 \left(\bar{U}_1^2 + \bar{U}_2^2 + \bar{U}_{A1}^2 + \frac{\bar{U}_{A2}^2}{K_1^2} + 2\rho_{12} \bar{U}_1 \bar{U}_2 \right). \quad (9)$$

Presence in the expressions (8) and (9) of the correlated part of the noise signals with different signs determines inequality of this voltages. Voltages U_5 and U_6 are formed on the output of the integrator 9 in tern an in time with the automatically switch 5 working, therefore, in their time sequence variable part, proportional to their half difference, exists:

$$U_7(t) = \frac{1}{2}(\bar{U}_6 - \bar{U}_5) \text{sign} \sin 2\pi Ft + U_{A3}(t), \quad (10)$$

where F is the frequency of automatically switch 5 switches; $\text{sign} \sin 2\pi Ft$ is the rectangular voltage rounded the voltage U_5 and U_6 package; $U_{A3}(t)$ is the low-frequency noise voltage of the integrator 9.

Variable voltage of the low frequency F is amplified by selective amplifier 10 of the low frequency, set on the frequency F , and straightened by the synchronous detector 11, controlled by the generator 14 voltage. Synchronously detected voltage together with low frequency noises is smoothed by the low frequencies filter 12. As the result constant voltage is emitted

$$U_8 = \frac{K_4 S_2 K_5}{2} (\bar{U}_6 - \bar{U}_5) + U_{A4}(t), \quad (11)$$

where K_4 is the coefficient of selective amplifier 10 gain; S_2 is the escarpment of the synchronous detector 11 transformation; K_5 is the coefficient of low frequencies filter 12 transfer; U_{A4} is the fluctuating part of the voltage.

Considering voltages U_5 and U_6 values with (3), (4), constant voltage measured by voltmeter 13 looks like

$$U_9 = K_1^2 K_2^2 S_1 K_3 K_4 S_2 K_5 \rho_{12} \bar{U}_1 \bar{U}_2. \quad (12)$$

Presence of the fluctuating part of measured voltage because of noise effect determines fluctuating threshold of the device. Increasing time constant of the low frequencies filter 12 to 3...5 s, determines fluctuating threshold can be decreased to permissible value (less than 0.1...0.2 units of voltmeter scale).

For obtaining the coefficient of mutual correlation ρ_{12} needle electrodes 1 and 2 are connected and, firstly, touch one of the comparing AP. In this case voltmeter 13 indications will be calculated by the product of only one noise voltage, for instance, \dot{U}_1 , i.e. its variance

$$U_{10} = K_1^2 K_2^2 S_1 K_3 K_4 S_2 K_5 \rho_{12} \bar{U}_1^2. \quad (13)$$

Then by connected together needle electrodes 1 and 2 touch another AP. In this case voltmeter 13 indications will be determined by another AP noises variance

$$U_{11} = K_1^2 K_2^2 S_1 K_3 K_4 S_2 K_5 \rho_{12} \bar{U}_2^2. \quad (14)$$

Then number N is calculated as the ratio of measured voltage U_9 to square root of the measured voltages U_{10} and U_{11} product:

$$N = \frac{U_9}{\sqrt{U_{10} U_{11}}}. \quad (15)$$

Substitute in formula (15) values of the measured voltages (12), (13) and (14), get

$$N = \rho_{12}. \quad (16)$$

Thus, a value of the mutual correlation coefficient is defined by three values of the measured noise voltages.

IV. CONCLUSION

The result of psychophysiological state evaluation doesn't depend on the parameters of the measuring scheme, and also on the level of proper

amplifying-transfer path noises. It allows to use the wideband, although unstable enough, amplifiers with the high amplifying coefficient and other active elements of the device and in this way provides high responsiveness to the biological noises of investigated human, what allows more objectively evaluate psychophysiological state.

Experiments showed that under the mutual correlation coefficient between AP, located on the paired meridians, in limits 0.5...0.6, human can act with maximum return, what in pilot's case can appear in ability to provide the maximum reliability of the airplane trouble-free control. Under depressed state, anxiety or disease this indicator decreases to 0.15...0.25, relatively the ability of adequate evaluation of flight situation decreases as the adequate reaction on its change. So, suggested device allows objectively evaluate psychophysical state of the human by the instrumental means and predict the ability of trouble-free airplane control.

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К. Л. Шевченко, Є. С. Щербина, Т. А. Єремєєва. Кореляційний метод оцінювання психофізіологічного стану організму людини

Представлено кореляційний метод перевірки психофізіологічного стану організму людини. Запропоновано структурну схему оцінювання характеристик біологічноактивних точок людини і висвітлено розрахунки.

Ключові слова: психофізіологічний стан; точки акупунктури; кореляція.

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К. Л. Шевченко, Е. С. Щербина, Т. А. Еремеева. Корреляционный метод оценки психофизиологического состояния организма человека

Представлен корреляционный метод проверки психофизиологического состояния организма человека. Предложена структурная схема оценивания характеристик биологически активных точек человека и высветлено результаты.

Ключевые слова: психофизиологическое состояние; точки акупунктуры; корреляция.

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