PROBABILITY METHOD OF ANALYZING THE TIME CHARACTERISTICS OF THE ELECTROENCEPHALOGRAM

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The probability methods of analysis are of considerable interest for the theory and practice of electroencephalography [2]. The probability characteristics of the EEG can be studied both with respect to intensity [1, 2] and time. The instants of the transition of the EEG signals to the time axis are the carriers of information with respect to the time characteristics [4]. The amount of information obtained can be increased appreciably if the amplitude points and points of inflection of the EEG signal are also investigated [5]. In this work a method and computer are described for determining the average frequencies of intersection of various levels of analysis by the main signal of the EEG and its derivatives.

The basic diagram of the computer is shown in Fig. 1. Since amplitude points and the points of inflection are characterized by the first and second derivatives of the main EEG signal, it is first subjected to double differentiation. The input signal from the electroencephalograph or infrasonic magnetic recorder is fed through the buffer amplifier Y1 to the differentiating unit D1. The signal at the output of amplifier Y2 is proportional to the first derivative of the main EEG signal. The second derivative is obtained by similar methods using differentiating circuit D2. The signal at the output of amplifier Y3 is proportional to the second derivative of the main EEG signal. Further, through the method-of-operation switch, one of the signals—the main EEG signal, its first derivative, or the second derivative—is fed to the level selector (CY). The level selector makes it possible to select the level of analysis X, at which the points of intersection of the investigated signal and the time axis are determined (Fig. 1 B).

The obtained sequence of pulses of random shape and amplitudes from the output of the selector are fed to the pulse shaper (PS). The task of the pulse shaper is to transform the sequence of pulses of random shape and amplitude into square pulses which maintain the position of the points of intersection of the signal and selected level of analysis. The action of this pulse shaper corresponds to the maximal bilateral limitation of the investigated signal at the selected level of analysis at 60 db.

The amplitude-limited square pulses are further passed through differentiating unit (D3) with a time constant of 0.01 sec. Upon differentiation a sequence of short voltage pulses are formed whose time positions determine the useful information. The signal at the output of the differentiating unit is shown in Fig. 1B.

The sequence of pulses is fed to the PS-5m conversion unit which is triggered at a certain time of analysis Θ. Both pulses of the same polarity (positive or negative) and pulses of both polarities are recorded by means of it. As a result the converting unit shows the total number of intersections of the signal with each of the selected levels of analysis during time Θ. Based on these data the average number of intersections per second is calculated. The measurement error of the number of intersections on this device is ± 1 intersection.

An important characteristic of the analyzer is the accuracy of measuring the average frequency of transitions of the signal through the level of analysis X. The computer is calibrated with respect to a ZG-10 sound generator in the frequency range from 10 to 1,000 cps. The average number of transitions of the signal through the time axis is determined at various levels of the input signal $U_{in} = 1$ V. As the result it was established that the measurement error does not exceed ± 1 intersection in the range up to 1,000 cps.

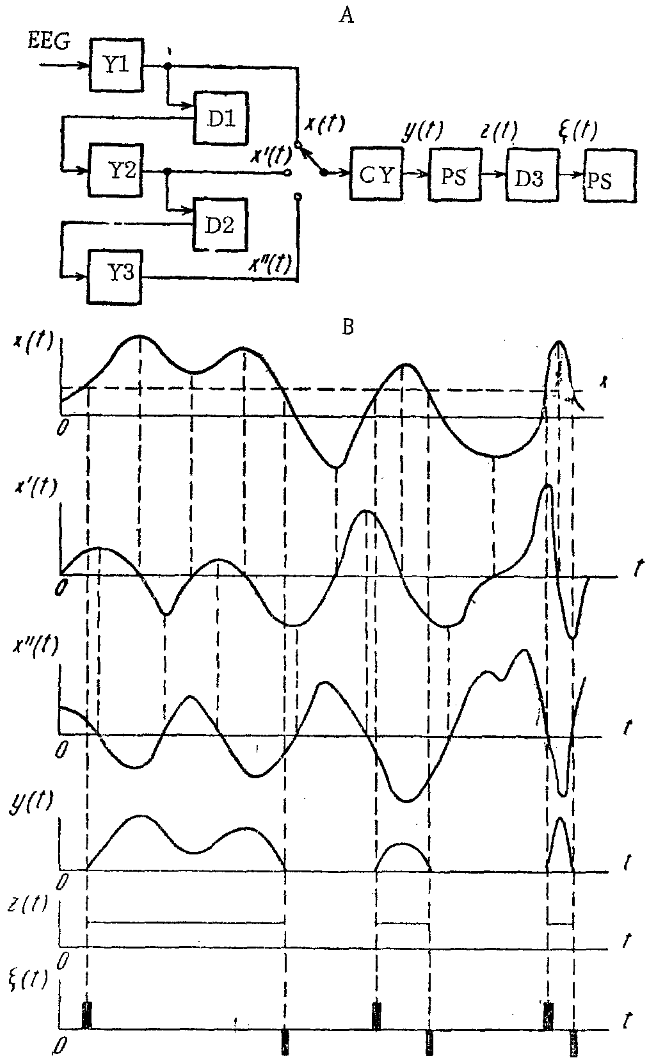

Fig. 1. Basic diagram of the computer for analyzing the time characteristics of an EEG (A) and voltage diagrams at various points of the circuit (B).

To study the dynamic characteristics of the device a voltage with a variable frequency from an AN-1-50 oscillatory-frequency generator was used. The change of voltage frequency occurred according to a linear law. In this case a reading accuracy was obtained which was not lower than under static conditions when calibrating with respect to the sound generator.

For an analysis of the EEG the bioelectric potentials are simultaneously recorded on paper and magnetic tape. The signal is read from the magnetic tape and fed into the computer. As an example we will give the results obtained on analysis of the EEG of a rabbit in a resting state and under the effect of discontinuous sound (Fig. 2 A).

Figure 2 B shows the graph of the dependence of the average number of intersections N on the level of analysis X/σ during time of analysis $\Theta = 10$ sec. It follows from the graph that the maximal number of intersections shifts from one level of analysis to another (toward negative polarity) under the effect of sound. Furthermore, we can see that the maximum of intersections and, consequently, the greatest information, is associated not with the zero level (the middle line of the EEG) but with other levels of analysis. The proposed method of analysis and the computer make it possible to distinguish the levels and to measure accurately the number of intersections under various conditions of recording the EEG.

Such an analysis has important advantages over other time methods of analysis, in particular the periodometric method [1,5]. We note that even in the most developed systems of this type the analysis of the intersections of EEG signal with the time axis was done only at one zero level.

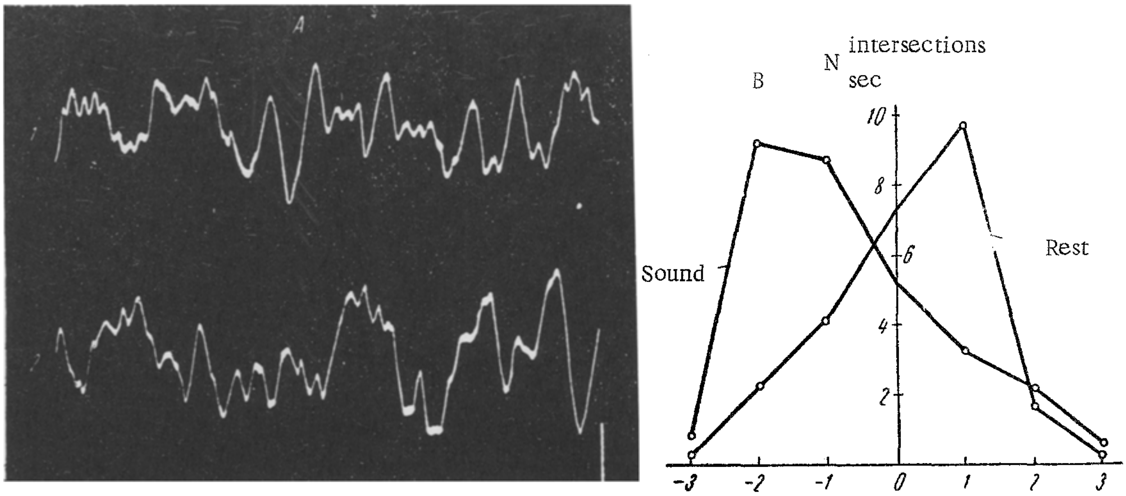

Fig. 2. EEG of rabbit during rest (1) and under the effect of sound (2). Calibration: 1 sec 50 μV (A); graph of the dependence of the average number of intersections on the analysis level (B) (explanation in text).

This method of analysis can also be used for measuring the average frequency of the EEG and its derivatives. In this case the average number of transitions of the signal through the time axis at the zero level ($X = 0$) corresponds to the doubled frequency of oscillations averaged during time Θ. Attempts to determine the average frequency of the EEG by determination of the zeroes were made earlier [3]. Although these measurements were made with a low accuracy by the graphic method, the possibility of the successful use of the method in practice was noted.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. ***Some or all of this periodical literature may well be available in English translation.*** **A complete list of the cover-to-cover English translations appears at the back of this issue.**