AUTOMATIC UNIT FOR MEASURING THE DISTRIBUTION FUNCTIONS OF THE INSTANTANEOUS VALUES OF EEG SIGNALS

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The abundance of data obtained when studying the EEG show that the EEG signal should be treated as a random process. Multivariate distribution functions give the total characteristic of the random process, but by means of univariate distributions it is possible to obtain valuable information on the probable properties of the EEG signal[1].

We will describe a discrete electronic device for the automatic measurement of univariate distribution functions of the instantaneous values of the EEG. The frequency spectrum of the investigated signals is 0-5000 cps. The measurement error is less than 1.5%.

The device permits measuring integral and differential distribution functions of instantaneous values by a numerical method. It is almost completely assembled from ready-made laboratory instruments and consists of a gating device, AADO-1 amplitude analyzer, and two scaling instruments of the PST-100 type (from the PP-8 radiometer). The block diagram of the device is shown in Fig. 1.

The gating unit (see Fig. 1) is used to transform the continuous EEG signal into a series of discrete amplitude-modulated impulses. The input signal through the cathode follower on 6N1P tube L1a is sent to the diode modulator consisting of D105 type diodes D1 and D2. The diode modulator is operated by a 6N1P-tube pulse generator L1b. The control pulses from the generator block diode D1 and, thus, gate the diode-selector circuit for transmission of the next instantaneous value of the input signal. The obtained sequence of impulses through the cathode follower consisting of tube L2a and a 6N1P tube amplifier L2b is sent to the AADO-1 amplitude analyzer.

The AADO-1 analyzer measures the integral and differential distribution functions of the signals with an amplitude of 0.2-100 V. The discriminators of the instrument have a nonlinearity of the discrimination characteristic of not more than 1.5%. The resolving time of the differential discriminator is 1-2 μsec. The difference of the differential discriminator thresholds ("width of the window") can be varied stepwise from 1 to 20 V, and the thresholds

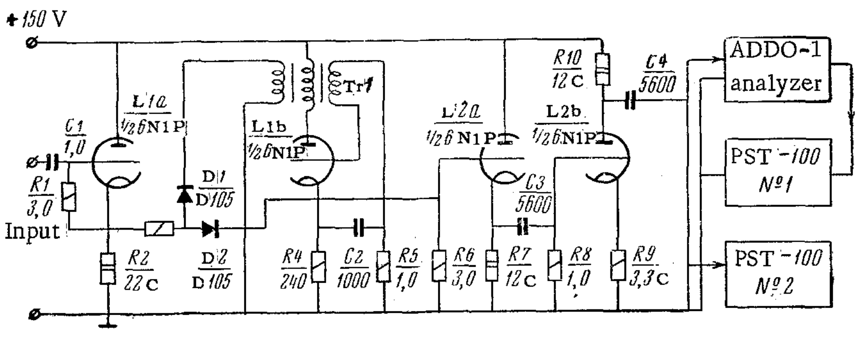

Fig. 1. Block diagram of the device for measuring the distribution functions and the basic circuit of the gating unit. Explanation in text.

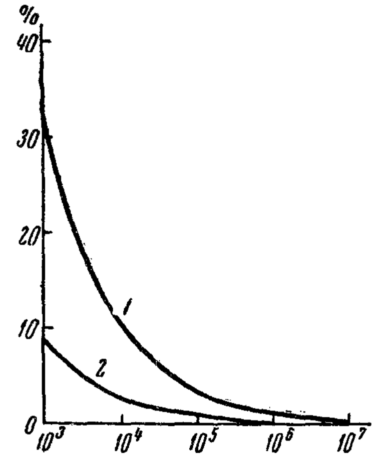

Fig. 2. Mean square error of measurements as a function of the number of accumulated impulses. The number of impulses is plotted on the x-axis and the error on the y-axis. Remaining explanations are in the text.

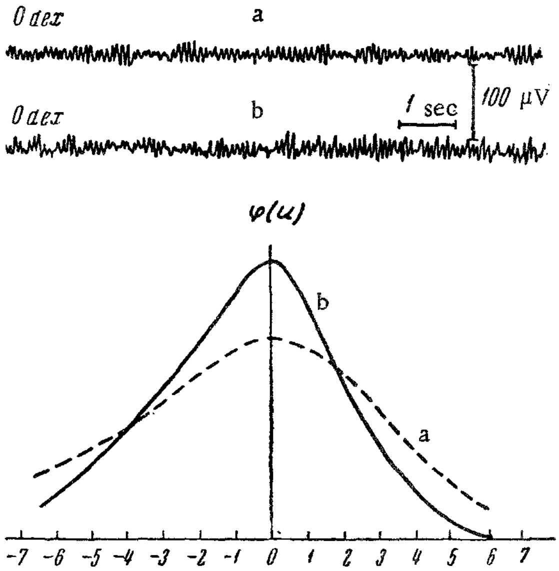

Fig. 3. Segments of the EEG and curves of the distribution functions of the instantaneous values of a healthy person (a) and of a patient with oligophrenia (b). The analysis time (T) is 10 sec. The instantaneous values of the EEG are on the x-axis and the density of the distribution of these values are on the y-axis.

of the discriminators can be varied in 1 V steps in the range from 1 to 100 V. The output of the analyzer is connected to the scaling instrument PST-100. Impulses are sent directly from the gating device to another analogous instrument.

In the PST-100 instrument the readings are taken from neon tubes and from decatrons. The counting capacity is 10^6 impulses. The instrument has an electronic stop watch which stops counting after a set of 10^3, 10^4, 10^5, 10^6 impulses, or upon expiration of a time interval of 10, 100, and 1000 sec. The counting accuracy is ±1%.

The No. 2 PST-100 scaling instrument measures the number of pulses (n) at various levels of analysis (u), and the No. 1 PST-100 instrument measures the total number of impulses (N) during the same time of analysis.

The input of the data into the device is accomplished by means of a standard magnetic tape 6 mm wide. A MG-56 magnetic recorder and an amplitude modulator with a carrier frequency of 800 cps are used to record the EEG. The analyzed segment of the EEG is glued into a ring and is played on the magnetic recorder as many times as the points required to plot the distribution curve. In order to be able to reproduce the same segment of the EEG if the travel of the magnetic tape is uneven, a photodiode device is used which automatically starts and stops the count of the impulses.

The device is simple in design and reliable in operation.

When using the distribution functions the work of the device is based on determining the number of cases (n) where the investigated voltage exceeds the analysis (u) with respect to the total number of inquiry impulses (N) during the analysis time (T). By changing the level of analysis u we can determine the integral probability distribution function:

$$F_T(u) = \frac{n}{N}.$$

In this case the signal from the output of the gating device is sent to the integral discriminator of the AADO-1 instrument and then to the scaling instrument PST-100.

The value of the differential distribution function (probability density) is determined by the formulas:

$$\varphi(u) = \frac{1}{\Delta u} \frac{n}{N},$$

where Δu is the value of the "width of the window" of the differential discriminator.

In the given case the signal from the gating device is sent to the input of the differential discriminator AADO-1 and then to the scaling instrument PST-100.

The accuracy of measuring the distribution function depends upon the number of accumulated impulses. However, an unjustified increase of the analysis time as a consequence of a number of causes (drift of the analyzer channels, unsteady state of the EEG itself, etc.) leads to an increase of the measurement error. Figure 2 shows curves characterizing the dependence of the mean-square error of the measurements on the number of accumulated impulses; curve 2 is used when the process is normal and curve 1 when the distribution law is unknown. We see from Fig. 2 that when $N = 10^6$ the mean square error of the measurements is only 1%.

To calibrate and check the operating stability of the device we measured the distribution function of sinusoidal signals from a 3G-2A generator and random signals from an infra-low-frequency noise generator. The measurements showed a good agreement between the expected and experimental distribution laws. The measurement error was 1-1.5%.

When measuring the distribution functions of instantaneous values of the EEG, we used recordings obtained for a group of healthy persons and those with various neurological and mental diseases. We also investigated the EEG of rabbits.

As an example Fig. 3 shows the curves of the distribution functions of the EEG of a healthy person, aged 22 years, and of a patient with oligophrenia. Appreciable differences of the distribution curves are seen in Fig. 3.

A quantitative comparison of the obtained distribution functions with one another and with some standard distribution, for which a normal distribution can be selected [1], is done by means of the asymmetry and excess coefficients [2]. Calculation of the coefficients is quite laborious, and it is conveniently done on digital electronic computers.

The proposed method of analysis can be successfully used in various areas of experimental and clinical electroencephalography.

LITERATURE CITED

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