AN ATTACHMENT TO THE ELECTROENCEPHALOGRAPH FOR RECORDING A CONSTANT COMPONENT OF THE ELECTRICAL ACTIVITY OF THE BRAIN IN MAN AND ANIMALS

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Electrophysiologists are becoming increasingly interested in investigating the level of the constant potential and of its slow variations in the cerebral cortex and the subcortical structures. Investigations in which the ordinary spectrum of frequencies of the EEG and the level of the constant potential have been recorded simultaneously have raised the theoretical question of the origin of the cortical rhythm, the indices of the functional state of nervous structures, and so on. However, these problems are beset with technical difficulties: it is essential to have constant current amplifiers with an adequate coefficient of amplification and with stable operating characteristics.

In 1946 Liston and co-workers [4] described a model of a constant current amplifier for biological research, based on the discrete recording of a continuous signal. This was achieved by mechanical interruption of the signal at the input of the amplifier with a frequency of 75 per second. Impulses of different amplitude then passed through a step-up transformer into an alternating current amplifier constructed to a nonsymmetrical design. At the output of the amplifier there was an output transformer and another interruptor playing the part of a detector.

In the Soviet Union the principle of discrete recording of a constant potential was used by V. A. Kozhevnikov [1, 2]. He used a polarized relay at the input of a nonsymmetrical amplifier with a negative feedback and a phase-sensitive rectifier at the output.

In contrast to these schemes, Goldring and O'Leary [3] suggested recording the constant component of the EEG by means of an interruptor, introduced at the input of the standard amplifier of the electroencephalograph. In this way the amplitude of the constant signal could be recorded instantly. The frequency of interruption (from 2 to 8 per second) enabled variations in potential from 0 to 3 per second to be recorded. In view of its simplicity, this method achieved popularity in experimental practice. In our opinion, however, it has several important disadvantages. Firstly, because of the presence of grid currents in the input tubes of the amplifier when the device is switched on and off, the useful signal is amplified along with the interference from the grid current of the input tubes. When the curve is analyzed, in order to separate the useful signal from the composite amplified signal it is necessary to resort to a special manipulation – to record the potentials with interchanging the positions of the active and indifferent electrodes. In this way the grid current keeps its original direction, but the useful signal is recorded in the reverse phase. The zero value of the useful signal is thus established on the recording. With high degrees of amplification the interference from the grid current may exceed the level of the useful signal if this is of low amplitude. This system can therefore be used only to record constant potentials of high amplitude (of the order of several millivolts). Secondly, and interruptor of this pattern cannot be used for simultaneous recording from the same electrodes as the ordinary electroenecephalogram, for this requires high amplification of the signal, which is impossible, and also the rate of interruption under these circumstances must be much higher.

It is an advantage of this method, however, that it is based on the use of an alternating current amplifier of symmetrical design, and it enables several parallel systems to be set up for the simultaneous recording of electrical processes in several areas of the brain by the bipolar method.

The scheme which we suggest aims to record the constant and slowly varying components of the electrical activity of the brain by the use of the amplifiers of standard electroenecephalographs and, at the same time, to record the fast activity from the same electrodes. The slow and fast activities are taken through different channels of the amplifier in the form of two parallel curves.

As alternating current amplifier we used the symmetrical input amplifier from the electroencephalograph made by the "Ediswan" firm, but it is possible that any other alternating current amplifier can be used.

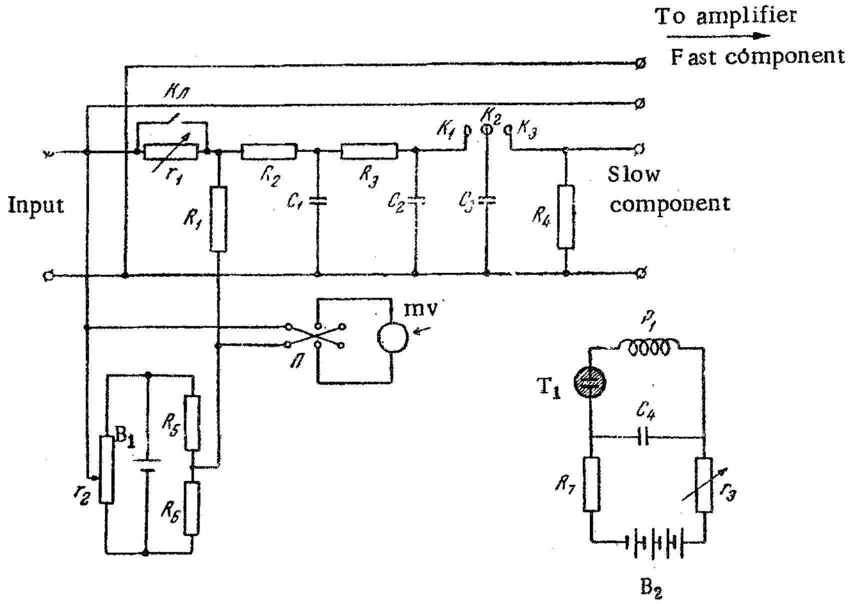

Fig. 1. Theoretical scheme of the apparatus.

The apparatus (Fig. 1) contains a compensation unit for the natural potential of the nonpolarizing electrodes, a filter, a polarized relay, and a generator for feeding the relay. The compensation unit for the natural potential of the electrodes consists of a bridge on the resistors $r_2R_5R_6$, a battery B_1 being included in one diagonal of the bridge and a divider r_1R_1 in the other. The voltage on the resistor r_1 is used to compensate the natural potential of the electrodes. The amplitude and polarity of the voltage taken from the bridge can be changed by the resistor r_2 and measured by the millivoltmeter mv. To increase the accuracy of the registration the value of r_1 should be changed step by step. The filter $R_2R_3C_1C_2$ serves to separate the constant and slow components of the signal. When a constant or slowly varying EMF is applied to the input, the capacitors C_1 and C_2 discharge practically to the value of its amplitude. Closure of the contacts K_1K_2 allows the capacitor C_3 to be charged to the same voltage as C_2. K_2 is then closed to K_3 and C_3 discharges through the resistance of the leaks in the first cascade of the amplifier. The signal is then amplified by the alternating current amplifier and recorded on an ink-recording oscillograph in the form of impulses, the amplitude of which corresponds to the voltage of the constant component of the signal.

As relay feed generator a relaxation generator on a voltage stabilizer SG-3 (T_1) is used. The resistor r_3 is used to change the frequency of the generator. The resistor R_4 serves to minimize the effect of grid currents on the quality of the recording, so that the amplification can be increased to the ordinary limits at which activity of the order of tenths of a microvolt can be recorded. The presence of the filter $R_2R_3C_1C_2$ enables the fast and slow components of the electrical activity to be separated and recorded through parallel channels of the amplifier.

A compensation scheme may be used for application of a calibration signal: marks are placed on the mv scale corresponding to a known value of the calibration signal (100, 500, 1000μV), the input of the whole circuit of the apparatus is shunted by a resistance equal to the resistance of the object (e.g., 50 kΩ), the required voltage of the calibration signal is established in the apparatus by the resistor r_1, and the recording is started. A key (Fig. 1 – Key) may also be provided which, when closed and then opened allows the calibration signal to be registered simultaneously on the channel for the fast component.

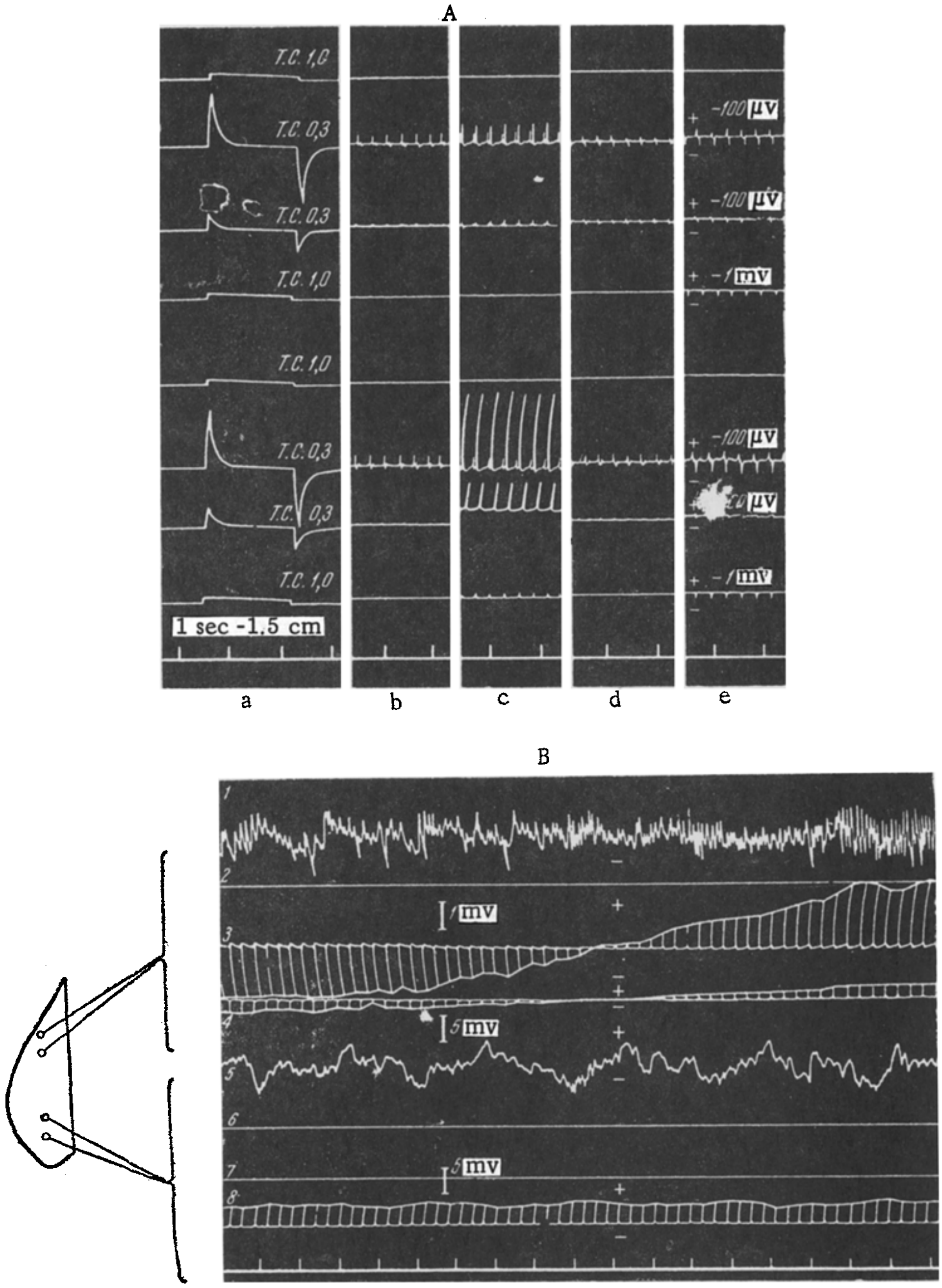

Fig. 2. Recording the EEG and the constant potential by means of a two-channel apparatus. A) Checking of amplifier and apparatus; a) amplification of alternating signal of 100 μV; b) checking of apparatus with a load of 50 k on the input; c) registration of natural potential of the electrodes (nonpolarizing: calomel–mercury–platinum); d) compensation of natural potential of electrodes; e) control of whole scheme (apparatus + amplifier); upward deviation of the pen is due to the grid current of the input tubes; it precedes registration of the useful signal; TC) constant time (1.0 and 0.3 second); B) EEG and variations of the constant potential of a rabbit's cortex in response to local application of $CaCl_2$ close to the first electrode (bipolar recording); 1, 5) recording of the alternating component; 3, 4) recording of the constant component from the first electrode; 8) recording of the constant component from the second electrode; the curve showing the changes in the constant potential is drawn in by hand.

The following are the characteristics of the component parts of the apparatus in use at present:

$R_1 = 100$ kΩ	$r_1 = 10$ kΩ $C_1 = C_2 = C_4 = 1$	$B_1 = 1.5$ v
$R_2 = R_3 = 300$ kΩ	$r_2 = 2.2$ kΩ $C_3 = 0.1$ μF	$B_2 = 200$ v
$R_4 = 36$ kΩ	$r_3 = 1$ MΩ	P_1 – relay RP-7
$R_5 = R_6 = 3$ kΩ		
$R_7 = 500$ kΩ		

When constructed as above, the apparatus possesses the following parameters: optimal sensitivity 100 μV for 5 mm deviation of the pen; recordable frequencies from 0 to 3 oscillations per second; input resistance to alternating current 2.5 MΩ.

This scheme practically excludes the effect of the grid currents of the first cascade of the amplifier on the object to be recorded, and ensures a high input resistance and, consequently, low polarization of the electrodes.

Any number of channels of an electroencephalograph can be supplied with apparatuses of this type, giving simultaneous recording of constant and alternating components of the electrical activity of several areas of the cortex and the subcortical structures of the brain. Since the apparatus is connected to the input terminals of the amplifier, it can easily be disconnected and the amplifier used for its usual purpose. Because of its simplicity, the apparatus can be constructed in any laboratory.

In Fig. 2 we illustrate the checking of the apparatus and examples of the simultaneous recording of the EEG and the variations in the constant potential.

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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.