METHODS

A METHOD FOR SIMULTANEOUS AUTOMATIC ANALYSIS OF MANY ELECTROGRAMS

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V. M. Anan'ev

(Presented by Active Member AMN SSSR P. D. Gorizontov)
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For the successful introduction of multipoint recording of biological potentials a quantitative analysis of the material obtained is necessary [4]. Hand preparation of the data for feeding into modern computers [5, 6] cannot be justified in those cases when millions of numbers must be analyzed. The multichannel devices we have developed for recording various types of electrical activity in man and animals [1, 2] cannot be fully used whithout an automatic quantitative analysis of the data.

Even the materials obtained by commonly used electrophysiological devices (electroencephalographs, electrocardiographs, etc.) are presently, as a rule, processed manually. Despite the numerous attempts to introduce into electrophysiological practice instrumented methods of amplitude analysis of data [8, 9], these methods have still not become widespread. The existing amplitude analyzers can analyze only one electrogram [11]. The modern multidimensional analyzers [10] are very complicated and rather inaccessible to most researchers.

Because there was no simple method for the simultaneous automatic analysis of many electrograms we attempted to solve this problem by our own efforts. Several problems immediately face us: by what method could we accomplish the simultaneous analysis of several electrograms, what form of recording to use for recording the data of the analysis, and how to ensure a high speed input of the recorded data of the analysis into the memory of modern computers.

When searching for the solution it was necessary to take into account the basic requirement – the accessibility of the method.

The essence of our method is that, for the simultaneous analysis of several electrograms the signals are fed to a multi-input analyzer in which continuous signals are transformed into intermittent signals and then the latter are transferred from several channels to a common channel. For these purposes electronic computation of the signals has been used [1-3]. In the common channel the signals are analyzed by magnitude. The data of the analysis are written on one track of the magnetic tape, reproduced by means of a tag selector, and fed into the magnetic memory of the computers, by means of which the final analysis of the experimental material is performed by suitable programs.

We use magnetic recording of the data since this type of recording makes it possible to ensure, comparatively, simply high speed when recording the experimental material and when feeding the information into the computer. However, it is known that under the conditions of most physiological laboratories the direct proportional magnetic recording of signals within a wide range of amplitudes inevitably involves considerable difficulties. These difficulties can be avoided by using ordinary magnetic recorders. We do not record the signals themselves (as was noted above, such recording without distortions is difficult) but preliminarily, before recording, we run their amplitude analysis in electrical circuits. On the magnetic tape we record the results of this analysis in the form of a serial code of standard impulses. Such recording of standard impulses is not difficult on any magnetic recorder whose tape travel speed is sufficient for separating impulses. We recommend the MAG-59 magnetic recorder whose tape travel speed can be brought up to 760 mm per second by quadrupling the diameter of the drive shaft. With this modification the magnetic recorder reliably records and separates the square positive standard impulses of the code having a duration t_n equal to 20 μsec (with an interval t_n between them of about 30 μsec). Code recording is not disrupted with repeated work. The MÉZ-28A magnetic recorder is used without modification.

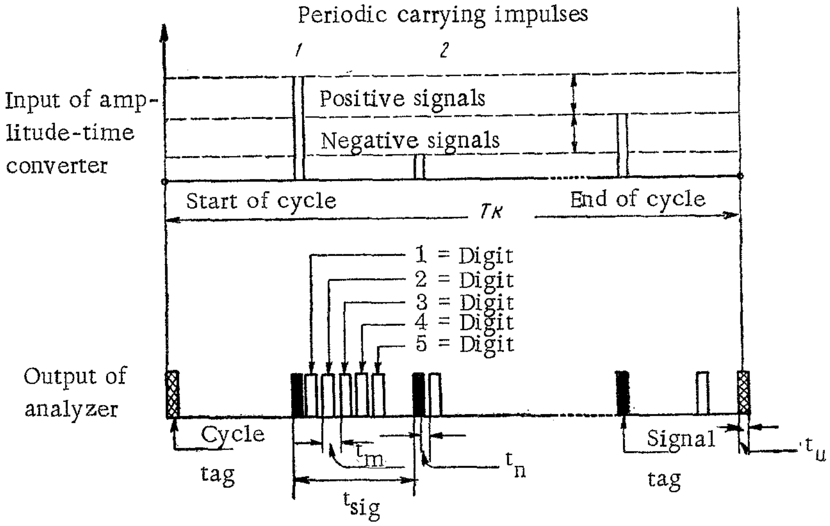

Fig. 1. Transformation of signals in certain components of the analysis system. 1,2,...) Peroidic carrying signals modulated in magnitude by suitable input signals; T_k) duration of one commutation cycle; t_{sig}) interval between adjacent carrying impulses; t_n) duration of one standard impulse (tag); t_n) shortest duration of interval between adjacent tags; t_m) interval between adjacent tags. Meaning of the dashed lines, top to bottom: maximal signal (31st level); zero value of signal (15th level); minimal signal (first level).

The code we used differs somewhat from the usual binary code consisting only of digit tags. We introduced into the code additional standard impulses (signal tags) which mark the correlation of a number (expressed by the digit tags) to a certain input signal; other additional impulses (cycle tags) mark the start of each cycle of commutation. The mutal arrangement of the digit tags, signal tags, and cycle tags within the commutation cycle is shown in Fig. 1, where, for an example, the codes of the maximal, minimal, and zero values of the signal are given.

At a commutation frequency F_k amounting to 100 cycles per second, each cycle of commutation T_k is equal to 0.01 sec ($T_k = 1/F_k$). All of the n carrying impulses modulated in magnitude by the input signals (for n different input signals), i.e., n different electrograms, pass sequentially in the common analysis channel during one commutation cycle. The time between adjacent carrying impulses depends on the number of input signals and amounts to $t_{sig} = T_k/n$. We use this time in the multi-input analyzer to form the code of the magnitude of a given signal (given level of the signal). Actually, $t_{sig} = T_k/n + 1$ since some time is needed for forming the cycle tag. We see from Fig. 1 that at the start of each cycle of commutation there is a cycle tag. At various time intervals (t_{sig}) there are signal tags (in our case for 20 electrograms $t_{sig} \approx 500$ µsec). Next to the signal tag are digit tags expressing, in a binary code, the magnitude of a given signal (level of signal).

At present five digits are sufficient. They enable us to code 31 different signal levels. The minimal magnitude of signals, the first level, is level No. 1. The maximal magnitude of the signals is level No. 31. The range of values between them is divided into equal intermediate sections. The intervals between the digit tags (t_m) in our analyzer are determined by the capabilities of the MAG-59 magnetic recorder and amount to about 50 µsec. Thus, under these conditions the entire complex of the signal (t_{sig}) cannot be less than 300 µsec. This circumstance limits the maximal number of analyzed electrograms. Since $n = T_k/t_{sig}$, to increase the number of simultaneously analyzed electrograms we must increase the time of the commutation signal or, what is the same, reduce the commutation frequency. However, a low commutation frequency does not permit running an analysis of rapid oscillations.

The term "multichannel analyzer" has taken root in practice in amplitude analysis (in nuclear physics and other branches of science and technology). The authors of the term at their time had in mind a large number of levels of analyses of some quantity. But meanwhile in other branches of science (electrophysiology, etc.) the term "multichannel" more correctly, from our point of view, emphasizes the presence of many channels of information (multichannel electroencephalographs, electrocardiographs, etc.).

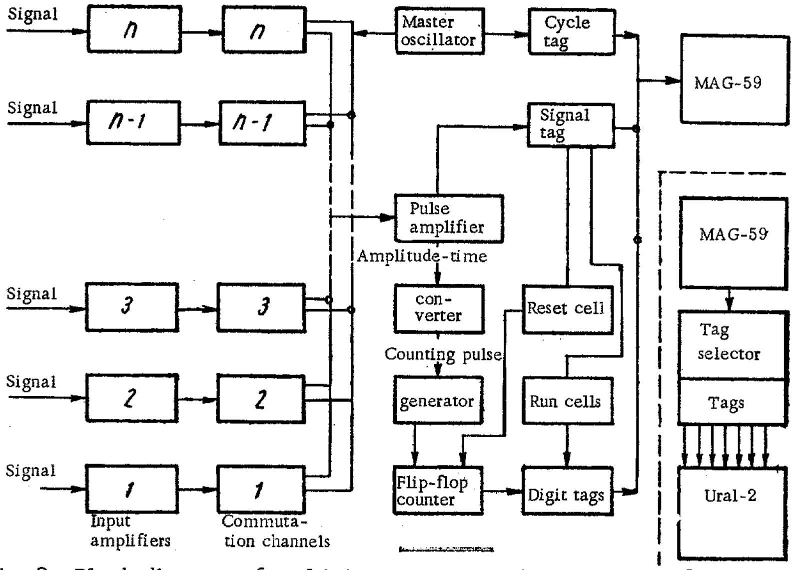

Fig. 2. Block diagram of multi-input commutation analyzer of electrogram ordinates.

When we found the need for simultaneous analysis at many levels of the magnitude of many electrograms (many processes occurring over different channels), we had to call the analyzer multi-input and not multichannel, as would have been desirable, in order to avoid terminological confusion.

For a more detailed familiarization with the proposed method we will describe the multi-input commutation analyzer of electrogram ordinates at 30 level which we have developed and fabricated. The block diagram of this multi-input analyzer is shown in Fig. 2.

During a biological experiment the continuous input signals (in the 1-50 cps frequency range) are amplified, if necessary, by input amplifiers and fed to the commutation channels. If the analyzer is operating with multichannel electroencephalographs there is no need for input amplifiers. The commutation system changes the continuous signals into intermittent ones and collects them for various channels into one common amplification channel. From the output of the common pulse amplifier the periodic carrier impulses of positive polarity (with a maximal strength up to 100 V) in turn, in a strict sequence, go to the input of the amplitude-time converter. In this unit the different strengths of the arriving carrier impulses are converted to a proportional capacitor discharge duration. A square pulse of the same duration is formed from the sawtooth discharge of the capacitor. This impulse is fed to the blanked oscillator (counting pulse generator) and opens it for the time of its action. Thus, if the generator is tuned to a frequency of 1 Mc, then during an action time of 1 μsec it will produce 1 oscillation; during several microseconds, several oscillations. Thus, the different strengths of the carrier impulses at the input of the amplitude-time converter is expressed at the output of the generator by a different number of oscillations. The circuit is adjusted so that the maximal number of oscillations is equal to the number of levels of analysis: the first level of the strength of the carrier impulse (i.e., the minimal signal) will produce 1 oscillation, whereas the maximal signal will produce 31 oscillations. It is necessary to remember, however, that actually in our signal commutation system the zero value of their strength is expressed by the No. 15 level; the maximal positive signal is the No. 31 level and the maximal negative signal is the No. 1 level.

The oscillations go to the flip-flop counter and are counted (the usual 5-digit flip-flop counter is needed for the 31 levels). Before the start of counting each level (expressed by the number of impulses of the generator – the number of counting impulses) all flip-flop circuits of the counter are automatically brought to the starting state (from the reset cell). Each counting impulse arriving from the generator changes the state of the trigger of the first digit. The trigger of the second digit responds to each second arriving impulse, the trigger of the third digit to each fourth, the trigger of the fourth digit to each 8th, and the trigger of the fifth digit to each sixteenth counting impulse. After the arrival of the last counting impulse (for a given signal level) the triggers no longer change their state and await read-out of the number obtained (from the digit triggers which are in a display state). The digit triggers are connected with their own digit tag units through the run cells which provide read-out only after the end of counting. During read-out the appropriate digit tag unit is activated only when the digit trigger connected with it is in a display state. In this case the digit tag unit reads out, on the general load of the analyzer, the output digit tag for recording on magnetic tape.

In addition to the digit tags the input signal tag is read out on the general output load of the analyzer. The formation of this tag is accomplished in a separate unit upon each arrival of any carrier impulse.

The circuit of the unit transmits all arriving carrier impulses and from them forms standard impulses, signal tags, on the general output load of the analyzer. The signal tags mark on the magnetic tape the start of the number characterizing the magnitude of a given signal (signal level). In the computers, in which the data is subsequently analyzed, the signal tags separate various numbers and serve for recording the digit tags of the numbers corresponding to them in the magnetic memory of the computer.

To mark the start of each commutation cycle in the analyzer there is a cycle tag unit connected with the master oscillator of the input commutation system. This unit forms on the general output load of the analyzer a standard impulse, a cycle tag. It separates cycles from one another and serves for recording one zero in the magnetic memory of the computer.

Thus, at the output of the analyzer is formed the code shown in Fig. 1. At the output of the analyzer the code consists of standard square-wave positive impulses with a duration of 20 μsec and strength of 5-10 V.

During an experiment the output of the analyzer is connected with the input of the magnetic recorder. All tags in strict sequence are recorded on one magnetic track. The material can be recorded at any time of the experiment. Visual observation of the course of the experiment is done on the screen on an oscilloscope.

Multitrack recording of material, as other authors have done [7], would facilitate the stated problems, but multi-track magnetic recorders are rather inaccessible to the ordinary researcher and therefore we do not use them.

The experimental material recorded on one track of a magnetic tape should be fed into the memory of an electronic computer for their quantitative analysis. For this purpose the code on the magnetic tape is reproduced in the computer room by means of a magnetic recorder similar to that on which the recording was made. It is necessary to emphasize in particular that to reproduce the short impulses of the code (when the MAG-59 magnetic recorder is used) a magnetic recording head is used since the factory-made reproducing head is not suitable for our purposes. From the output of the magnetic recorder the impulses are fed to the tag selector which sorts the various tags by channels. In the input unit of the tag selector positive impulses of standard shape are obtained from the irregular impulses arriving from the magnetic recorder and the standard impulses accurately reproduce the recorded code and are fed to all other units of the tag selector. In these units, by means of triggers and gates all unlike tags are delivered strictly by their channels (tag of the first digit-first channel, tag of the second digit-second channel, tag of the third digit-third channel, tag of the fifth digit-fifth channel, signal tag-signal channel, cycle tag-seventh channel).

The tags from these channels are fed to a special input device which was developed for the Ural-2 machine by V. A. Nazarov.*

When using the proposed method it is best to have a magnetic recorder, a tag selector, and an input device as a component of the computer.

The time for recording the data of the analysis in the memory of the machine is equal to the useful time of recording the experiment itself. The signal tags and cycle tags are not put in the memory of the machine but they are used as control pulses and are needed for observing strict sequence when plugging in all digit markers into the memory. As a result of the analysis of the electrograms, discrete quantities of the ordinates of the electrograms with consideration of their sign are put into the machine. The number of these ordinates per unit time for each individual electrogram is determined by the commutation frequency. The information entered into the machine memory is analyzed according to suitable programs. The same material can be analyzed by several different programs.

* The device is described in this issue of the journal on page 95).

Testing of the multi-input analyzer showed that it was completely suitable for analyzing material obtained in biological experiments. The proposed method of simultaneous automatic analysis of many electrograms can be used not only in biology and medicine but when analyzing any electrograms.

The work was performed in constant contact with V. A. Nazarov who developed for the multi-input analyzer the input device of the Ural-2 machine and thus promoted the introduction of the new method, for which the author expresses his sincere thanks.

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SUMMARY

A new method is suggested for simultaneous automatic analysis of many electrograms.

The method provides for transformation of continuous input signals into intermittents, their transference into the common tract, analysis of signals with regard to strength, coding of signal strength and recording of analysis data on a single-track magnetic tape.

The experimental findings are processed on a "Ural-2" electronic computing machine which "memorizes" analysis data fed into it by means of a marking selector and a special input device.

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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.