780. Biomedical signal identification and analysis

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Abstract. In the article there have been presented methods of measuring and analysis biological signals, which may be used as signals control mechanical system. Among others, ther have been decribed the usage of EEG (electroencephalographic signal).

Like in the case of other signals, the analysis of bio-medical signals most often resolves itself to the frequency analysis of their content with the help of Fourier transformation, and their processing the most often has a form of frequency filtering; in other words, removing from a signal its components with defined frequencies, for example, interferences.

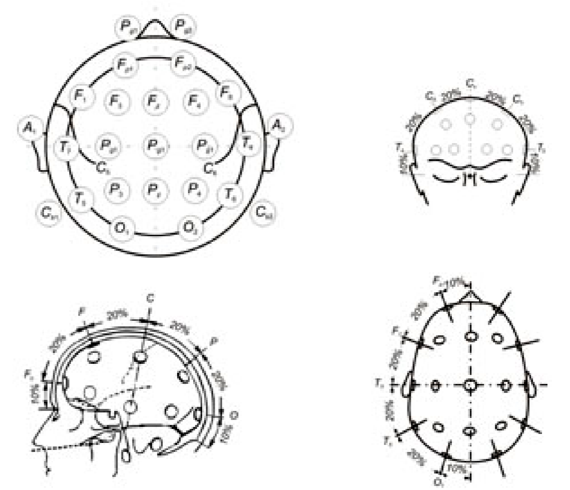
The researches have two parts. In the first part date was generated in Lab View program, and next the analysis was done (it was an example of EEG signal). In the next part the EEG signal was measured using 32 channels apertures and next real signal was analyzed using Lab View.

Keywords: biomedical signals, EEG signal, evoked potentials.

Introduction

The formation of electric potential distribution on the surface of the head has its origins in the chemical and electrical processes taking place in the brain. This electrical brain activity is recorded with a help of electrodes placed on the scalp or on the surface of the cerebral cortex. In case of recording signals from the surface of the scalp, we deal with electroencephalography (EEG). When measuring the electrical activity of the cerebral cortex is carried out directly from its surface, the method is then called electroencephalography (ECoG). The most often, the measurements of the electrical activity of the brain is conducted on a head surface, as it is a non-invasive method. Unfortunately, the amplitude of potentials gathered in this way is much lower than in case of electroencephalography. The amplitude of EEG signal varies from 0 μV to 100 μV; that is why the recorders used for recording an electroencephalographic signal must display high sensitivity. The electrical activity of the brain shows high changeability, which stems from the influence of stimuli reaching it. It results in changes of the electric potential on the surface of the head. Moreover, the electrical activity of the brain changes in space, depending on the activity of the center responsible for the function. That is why, the EEG signal measurement is conducted with a help of proper number of electrodes placed on the surface of the head.

The placing of electrodes on a head of a person examined should mirror the anatomical structure of the brain structures in the best way. The most often, the electrodes during trials are placed on the surface of the head in accordance with the 10-20 setup, proposed for the use of electroencephalography in 1958 by the International Federation of Clinical Neurophysiology (IFCN). Such a setup allows for a proportional placing of electrodes against characteristic points of the scalp regardless of the size of the head, which allows for comparing electroencephalographs of different patients. In this arrangement, the relative distances between the electrodes remain constant for all subjects and are equal to 10 or 20 % of the distance along which they are positioned (Fig. 1). The used marking of the electrodes correspond to the places of their attachment on the head.



Z - midline electrodes,

F_p - prefrontal electrodes,

F - frontal electrodes,

C - central poles,

T - temporal electrodes,

P - parietal electrodes,

O - occipital electrodes,

A - electrodes placed on ears,

C_b - cerebellar electrodes [3].

Fig. 1. The location of electrodes:
a) general diagram and naming, b) front view, c) side view, d) top view

Evoked potentials - definitions and basic concepts

Electrical phenomena occurring in the brain as a consequence of stimulus-induced potentials are called evoked potentials (EP). They are generally associated with the stimulation of sensory and sensual receptors, however they can also include a neural activity timely associated with a planning of motor functions, cognitive processes and an activity induced by a stimulation of motor cortex. As a result of a proper stimulation with help of electric impulses, acoustic or visual stimuli, in the nervous system there occur changes in the electric voltage, which are later recorded by surface electrodes located on the skin of the head [5]. Figure 2 presents the diagram of a conducted test on evoked potentials.

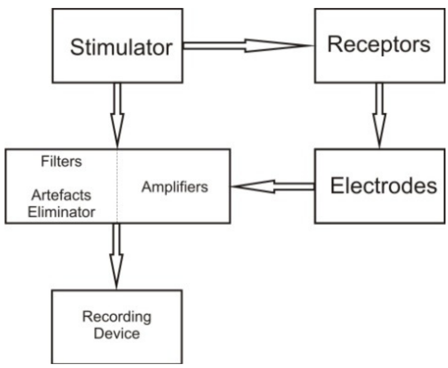


Fig. 2. Idea diagram of evoked potentials test

At the beginning of recording EEG signals, the registry of evoked potentials was difficult due to their very low amplitude. A traditional registry of responses for a given stimulus was impossible because a spontaneous brain activity generates on the electrodes outlets a potential with the amplitude of about 60 μV and more, whereas the EP has the amplitude no bigger than 20 μV. That is why, for the registration of signal responses, it is necessary to use proper amplifiers. Moreover, due to the occurrence of background noise with the level similar to the amplitude of the response, in order to select it, it is necessary to use a device that would average single responses. The time invariant of EEG recording and a zero value of the spontaneous activity amplitude are assumed. The rule of synchronized detection is about registering a certain period of time, which is synchronized with the evoking stimulus. This activity is repeated several or tens of times. After summing up the samples at the same moments of time from the moment when the stimulus worked, an average EP value is received. It should be remembered that the received course is only an average value and is not identical to any real EP realization, which, with subsequent samples may differ from each other regarding both the amplitude, shape and the delay in reference to the excitation [5]. The course obtained by the averaging method can be observed in the form of a curve on a logarithmic scale (Fig. 3). Its description involves the marking of waves, that is the oscillations of the potential evoked around the zero line, which are the characteristic for the registration in a defined setup of electrodes. Each of the waves brings such information as its amplitude, shape, as well as the period of latency, which is the time elapsed since the activation of the stimulus. The peaks are most frequently marked with the letter P for positive values, and with the letter N for negative values as well as with a number representing an average latency in milliseconds. It often happens that there is a succeeding wave occurring instead of latency. For example, in auditory evoked potentials, the P300 wave is often referred to as P3 wave. In case of auditory evoked potentials, the Roman number marking of succeeding waves has become popular [6].

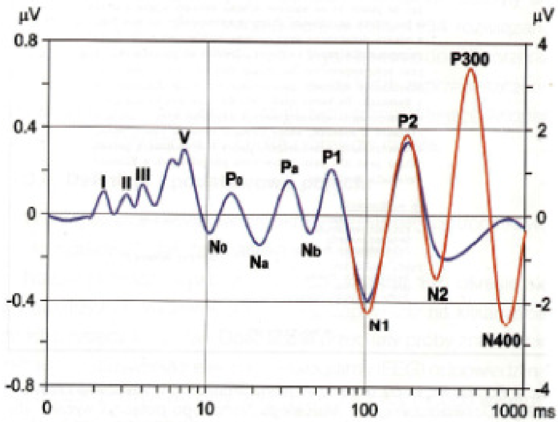


Fig. 3. Diagram of an auditory evoked potential in the logarithmic scale. The endogenous components are marked with red color [6]

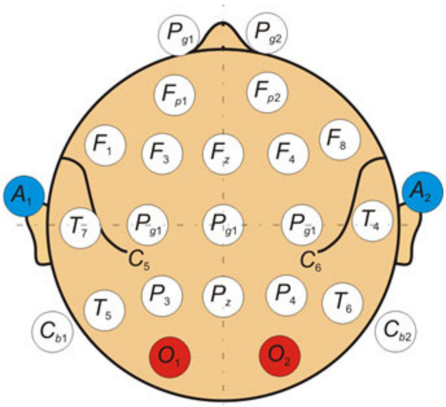
The time of response to a stimulus (exogenous and endogenous potentials) and a kind of stimulus were assumed as a criterion for classification of evoked potentials. The evoked potentials are divided into exogenous ones, which depend on the physical parameters of a stimulus, and endogenous ones, which reflect the cognitive processes in the brain.

The exogenous potentials are the ones which are evoked as a direct reaction to a stimulus and which are created without the interference of cognitive processes. They depend mainly on the physical parameters of a stimulus and are characterized with shorter values of latency than endogenous ones (usually smaller than 100 ms) and with a maximum amplitude in these areas of the brain which are responsible for receiving given stimuli. The exogenous potentials include Somatosensory Evoked Potentials (SEP), Brainstem Auditory Evoked Potentials (BAEP) and Visual Evoked Potentials, (VEP).

The endogenous potentials do not depend directly on the kind of the stimulus, but to a large extent – on the psychological factors; for example they are modulated by the importance of the language and the information content of the stimulus. The latency period of endogenous potentials (over 100 ms) is much longer than in case of exogenous ones, and the location of the registration place of the highest amplitude of the endogenous potential wave is less correlated with the properties of the stimulus [5].

Registration of signals used for the analysis

The signals used for the analysis have been registered using the TruScan 32 EEG system, which is used for registering, analyzing and filing of EEG. The registered waveforms were responses to a series of flashes of varying frequency. The registration was conducted by placing electrodes in the occipital area, corresponding to the leads O_1 and O_2, in accordance to the 10 – 20 system. The signal was registered against the grounding electrodes placed on the earlobes in the points A_1 and A_2 (Fig. 4).



- red color - the electrodes gathering the signal from the occipital area;
- blue color - the grounding electrodes.

Fig. 4. The arrangement of electrodes during the signal registration

The stimulation was conducted with the help of a photo- stimulator. A series of stimuli were provided at different intervals from 1 to 40 Hz. The signal was sampled at a frequency of 128 samples per second. The stationary visual potentials obtained in this way (Fig. 5), were recorded and divided into sections corresponding to the stimulation at different frequencies.

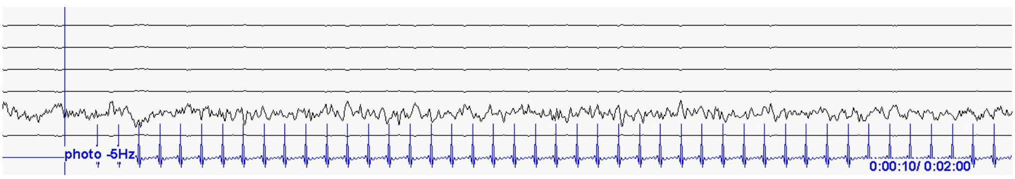


Fig. 5. A sample record, received as a result of SSVEP registration, together with a marked beginning of the stimulation by a series of flashes at the frequency of 5 Hz

Proposed application

The program is designed to analyze the EEG recorded during a visual stimulation and to compare the value of the power spectrum in the area of frequency at which the stimuli were provided, to the power of the signal spectrum recorded without any stimulation. The analysis is conducted simultaneously for two signals. One of them is the EEG recorded from the occipital area, without any stimulation. It is a simple recording of brain potential changes. The second signal is EEG recording, which was registered during a visual simulation of a tested person; i.e. the evoked potentials. The light stimuli were applied at various frequencies of 20 Hz, 30 Hz and 40 Hz. In order to correctly compare both signals, they must have an identical course time, i.e.

they must have an identical number of samples. That is why the duration time of the signals analyzed was adjusted to the duration time of the evoked potential.

Averaging of analyzed signals

Both signals have been averaged. As it was mentioned before, the ratio of the amplitude of the useful signal (the evoked potential) to the noise, which in this case is the amplitude of the basic brain activity, is very small. That is why it is necessary to use the averaging method, which would "reinforce" the useful signal. Averaging is about calculating the average amplitude of the signals of the same duration, correlated with the time of applying the stimulus. The registered evoked potentials have a very short course. Assuming that exogenous potentials, which constitute the visual evoked potentials are a direct reaction to the stimulus, it can be stated that the response to the stimulation will always be the same. That is why in order to average the evoked potential, it should be divided into several even time periods, and then its mean value should be calculated. For this purpose, a time window of a set value was used, which, when moving on the EEG recording, divides it into even time intervals. The used method and its effects are presented on Figure 6.

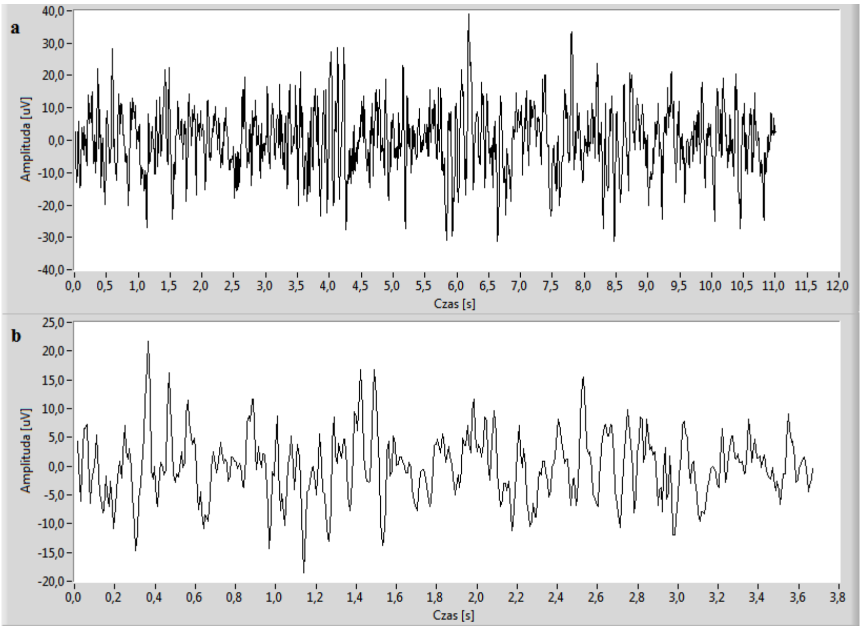


Fig. 6. Graphs showing: a) EEG recording and b) an averaged EEG recording

The frequency analysis of the tested signals

The analysis of the signal bases on calculating its power spectrum. The users of LabVIEW were provided with numerous functions, which are used for conducting the frequency analysis of a signal.

A proper configuration of parameters is very useful during the analysis of signals with a continuous course in time. During the realization of the application, there were used short segments of averaged EEG recording, thus the averaging of the spectrum from several courses was impossible.

This function was mainly used due to the possibility of applying on the signal of a window, which does not allow for "flooding" of the signal power spectrum. Moreover, the application has been designed to use it for analyzing signals gathered directly from the EEG register, for which the averaging of spectra of further segments would give better results. The quantity given back by the function is the averaged power spectrum (Fig. 7).

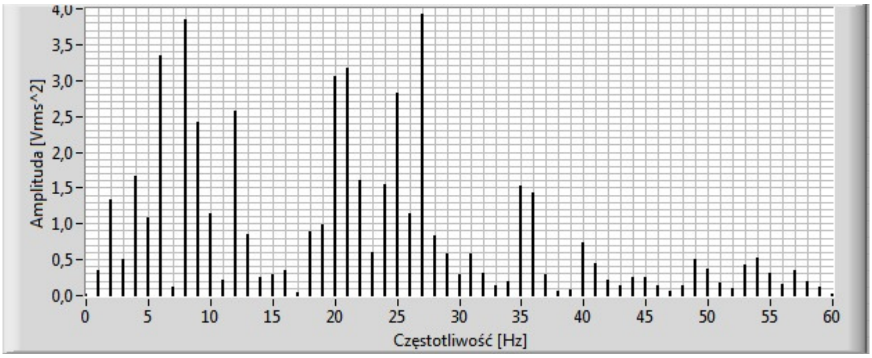


Fig. 7. A sample graph of the averaged signal spectrum power, calculated by the FFT Power Spectrum VI function

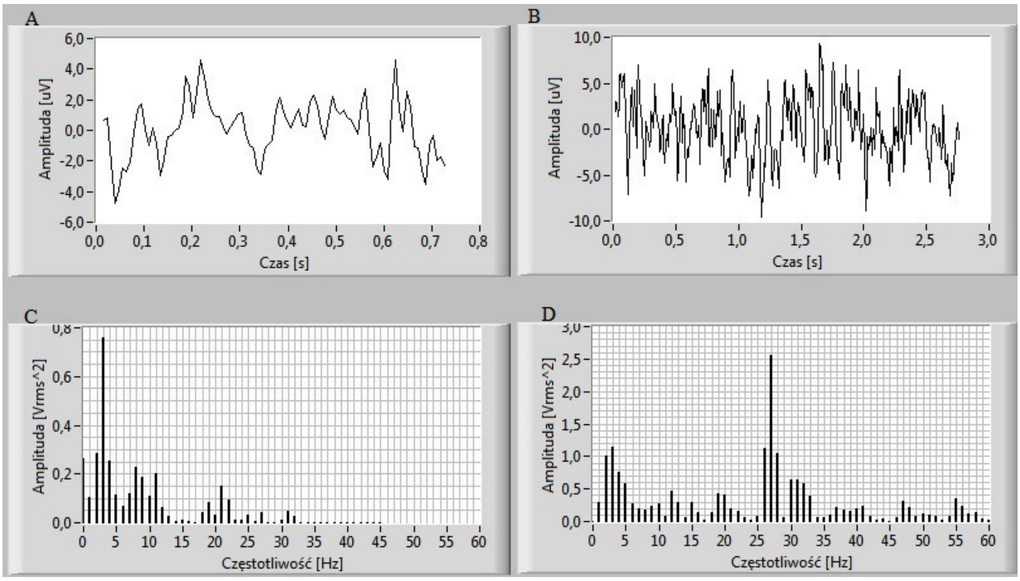


Fig. 8. The influence of the number of averaging segments on the signal: A) The signal averaged when divided into 15 segments; B) The signal averaged when divided into 4 segments; C) A signal power spectrum; D) B signal power spectrum

Conclusions

When comparing the EEG signals gathered during the stimulation by a series of stimuli with the signals stemming from a basic brain function, one can notice differences between them. An effective tool for their assessment is a frequency analysis, which allows for obtaining a spectrum of signal power. The target of this transformation is to make the signal frequency components visible. Through a proper comparison of power spectra of the evoked potential and the signal from the basic brain function, one can assess the frequency of providing a stimulus during the stimulation. This method can be used in the construction of BCI systems, based on the analysis of stationary evoked potentials.

The solutions used in this work enable an easy analysis of the evoked potentials and a transparent presentation of the results. The main objective of creating the application was the possibility to find its applications in systems that enable brain- computer communication for disabled people. Although the program operates on short signal recordings, yet its proper modification would allow for an analysis of EEG signal registered in real time. Connecting the application with a measuring device and selecting its proper parameters would give a chance for a direct communication between a human and a computer system. Moreover, the analysis of evoked potentials in real time would allow for a better signal averaging, i.e. reinforcement of the amplitude of useful signal to the noise amplitude, through increasing the number of samples averaging the signal, which would further improve the effectiveness of the program operation.

Programs processing evoked potentials can have a very wide use, especially in domains dealing with steering of all kinds of devices. Systems steered by brain waves are especially useful for disabled people or people completely paralyzed. Moreover, the possibility of communication with devices would allow for remote steering. The perspectives offered by the use of processing EEG signal are very wide, that is why the works on their analysis in recent times have brought many achievements and the research on the development of this domain has had a dynamic progress.

Acknowledgements

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