Methods of analysis of encephalograph signals using neural networks

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ABSTRACT

In this paper, a system for read-out sensing and analyzing human brain signals using an encephalograph is considered.Characteristics of human brain signals are considered. Based on this system it is proposed to create a neurointerface in which the received signals will be analyzed by neural networks.

Keywords. Encephalograph, neurointerface, neural networks, human brain signals.

1. INTRODUCTION

The possibility of recording brain electrical activity from intact skull bones was first shown in animal experiments at the physiology laboratory of Kiev (St Vladimir) University by Vladimir Vladimirovich Pravdich–Neminsky(1913).The first electroencephalogram of a person in the 1920s was recorded by the German psychiatrist Hans Berger, who is rightly considered the founder of electroencephalography.

The history of electroencephalography is related to the improvement of methods of EEG registration and the development of methods of its analysis.The development of microelectronic technology has led to the fact that modern electroencephalographs are hardware and software complexes that allow to register EEG signal qualitatively and process it with powerful mathematical methods.Mathematical-statistical methods of analysis allow to give an accurate numerical estimation of EEG parameters, to establish patterns of EEG signal consistency in space and time.

As of this date, electroencephalography is one of the most common and available methods of diagnosing changes in the brain. This study of the nervous system allows to estimate the electrical activity of the brain. During the procedure, brain damage sites, convulsive readiness, electrical activity are detected. Special preparation for the study is not necessary, it has no contraindications and does not cause unpleasant feelings.

On the basis of the further development of medicine, technologies and methods of data analysis, a Neurocomputer Interface (also called a direct neural interface, a brain interface, a «brain-computer» interface [1]) was created.It is a system created to exchange information between the brain and electronic equipment (such as a computer).In unidirectional interfaces, external equipment can either receive signals from the brain or send signals to it.Bidirectional interfaces allow the brain to share information in both directions with external equipment. Based on the neurocomputer interface, the biological feedback method is often used.

The neurocomputer interface system includes:

1. Electrodes for biopotential withdrawal.The minimum number is 2, more often records are made with 21, 64 and even 128 channels.With a large number of electrodes, electrode helmets are used to quickly establish and increase the positioning accuracy of the electrodes over specific brain fields, as well as reproducibility of their location from experiment to experiment.
2. A biopotential amplifier connected to a computer either directly (e.g. via a USB port) or via an interface card using an operational amplifier.
3. Personal computer for signals recording and their processing.Many systems use feedback elements, either the same computer or an optional PC, which shows incentives and produces recognition results, such as the text that was typed.
4. Software for registration and processing of EEG, recognition of patterns, presentation of incentivesand output of recognition results.

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Due to technological development in the direction of increasing the compactness of devices, all these elements can be combined in the form of a small compact device and used as an input device or module for PCs, mobile phones, augmented and virtual reality devices, etc.

2. LATCHING APPROACH OF HUMAN BRAIN SIGNALS

Registration and analysis of EEG in modern science and clinic is carried out using computer electroencephalographic complexes, consisting of several functional blocks:

- Signal recording unit,
- Filter and amplifier unit,
- Analog-to-digital converter (ADC),
- computer program for signal storage, visualization and mathematical analysis.

The electroencephalography uses metal electrodes with a silver chloride coating. To ensure electrical contact of the electrode with the skin, either an electrically conductive gel (cup) or a gauze impregnated with physiological saline is used.

The arrangement of electrodes on the surface of the head is called mounting (Fig. 1).In clinical and scientific electroencephalography, the standard is the «10-20%» scheme, which was introduced in the 1950s by Canadian neurophysiologist Henry Jasper.

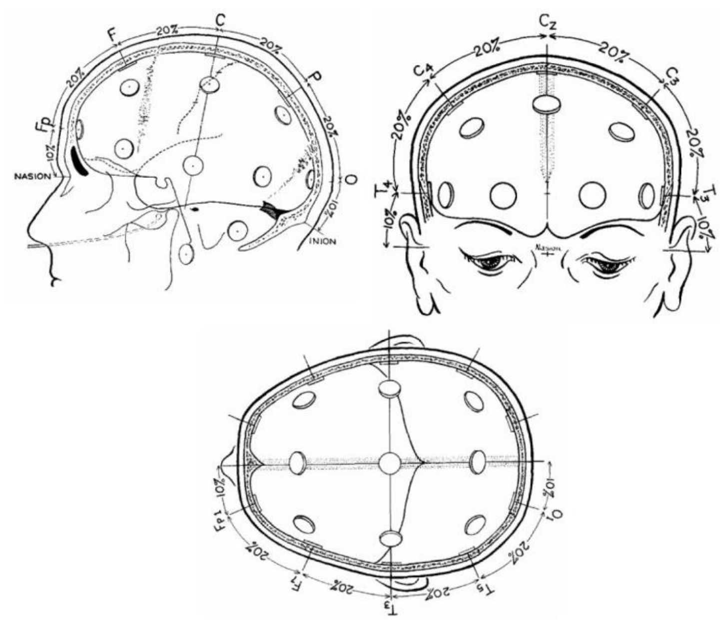


Fig. 1 - Scheme of electrode arrangement in accordance with the system 10-20%.

To determine the locations of electrode overlay through the vertex, two conditional meridians are drawn - the first from the nasion to the Inion, the second between the external auditory passages (diagrams below). Through these points a conditional meridian is laid, which is divided into segments of 10 and 20% of the total length. The transverse meridians are deposited along an axis that passes between the external auditory passages through the vertex. The electrodes are placed at the intersection of the conditional lines. The electrodes that are placed on the left side of the head have odd indices; on the right - even; the electrodes placed on the vertices have the z index. The smaller the electrode index, the closer it is to the major meridians. Designations of electrodes: F (Frontalis); T (Temporalis); C (Centralis); P (Parientalis); O (Occipitalis); A (Auricularis). The number of electrodes applied depends on the specific purpose of the study. If necessary, the 10-20% scheme can be expanded by holding additional meridians between the principal ones [7,8,20].

Standardization of the electrode application scheme allows researchers and doctors to compare results obtained at different times in different laboratories.

In order to register EEG, it is necessary to have two electrodes between which the difference in electrical processes will be measured. The pair of electrodes between which the potential difference is recorded is called retraction [9,10,21].

Total postsynaptic currents are measured during EEG. The action potential (AP, short-term potential change) in the presynaptic axon membrane causes the neurotransmitter to release into the synaptic cleft [2].A neuromediator, or neurotransmitter, is a chemical that transmits nerve impulses through synapses between neurons.After passing through the synaptic cleft, the neurotransmitter binds to the receptors of the postsynaptic membrane.This causes ionic currents in the postsynaptic membrane. This causes ionic currents in the postsynaptic membrane. It is these extracellular currents that form the potential of the EEG.EEG is insensitive to AP axons.

Although postsynaptic potentials are responsible for the formation of the EEG signal, surface EEG is unable to record the activity of a single dendrite or neuron. Rather, the surface EEG is the sum of the synchronous activity of hundreds of neurons having the same orientation in space, located radially to the scalp.Currents directed tangent to the scalp are not recorded. Thus, during the EEG, the activity of radially located apical dendrites is recorded. As the field voltage decreases in proportion to the distance to its source in the fourth degree, the activity of neurons in the deep layers of the brain is much more difficult to record than currents in the immediate vicinity of the skin [11,12,13].

Currents registered for EEG are characterized by different frequencies, spatial distribution, and interconnections with different brain states(e.g. sleep or wakefulness). Such potential fluctuations represent the synchronized activity of an entire network of neurons.Only some of the neural networks responsible for registered oscillations (for example, the thalamocortical resonance underlying «sleep spindles», thatare accelerated alpha rates during sleep), have been identified, while many others (for example, a system forming the occipital main rate) have not yet been established [3].

In order to obtain a conventional surface EEG, recording is made using electrodes placed on the scalp using an electroproid gel or ointment.Usually, before placing the electrodes, as far as possible, the dead skin cells are removed, which increase the resistance [4, 14, 26]. The technique can be improved using carbon nanotubes that penetrate the upper layers of the skin and contribute to improved electrical contact.This sensor system is called ENOBIO; however, the technique presented in general practice (neither in scientific studies nor in the clinic) has not yet been used.Of course, many systems use electrodes, each with a separate wire. Some systems use special caps or helmet-like mesh structures in which electrodes are enclosed; most often this approach justifies itself when a kit with a large number of tightly arranged electrodes is used [15,16,22].

For most applications in the clinic and for research purposes (except for sets with a large number of electrodes), the location and name of the electrodes is determined by the International «10-20%» system. The use of this system ensures that electrode names between different laboratories are strictly consistent. The clinic most commonly uses a set of 19 outlet (plus ground and reference electrode).Generally, fewer electrodes are used to register EEG of infants. Additional electrodes can be used to obtain EEG of a particular region of the brain with higher spatial resolution.A set with a large number of electrodes (usually in the form of a cap or helmet mesh) can contain up to 256 electrodes located on the head at more or less the same distance from each other.

Each electrode is connected to one input of the differential amplifier (i.e., one amplifier is a pair of electrodes) in a standard system, the reference electrode is connected to the other input of each differential amplifier.Such an amplifier increases the potential between the measuring electrode and the reference electrode (typically 1,000-100,000 times, or the voltage gain is 60-100 dB). In the case of analog EEG, the signal then passes through the filter. At the output, the signal is recorded. For clinical surface EEG, the frequency of analog-to-digital conversion occurs at 256-512 Hz; Conversion frequency up to 10 kHz is used for scientific purposes.

In order to obtain a compact portable structure, which needs to be lubricated with gel, it is necessary to perform preliminary amplification of the signal with the help of a differential amplifier made directly on the sensor (Fig. 2) [4,17,23]. It will also filter out noises and increase the quality of the sensesignal.

In modern electroencephalography, a monopolar EEG record is more common, as much as it allows easy transition to bipolar recording by mathematically listing of recorded signals.

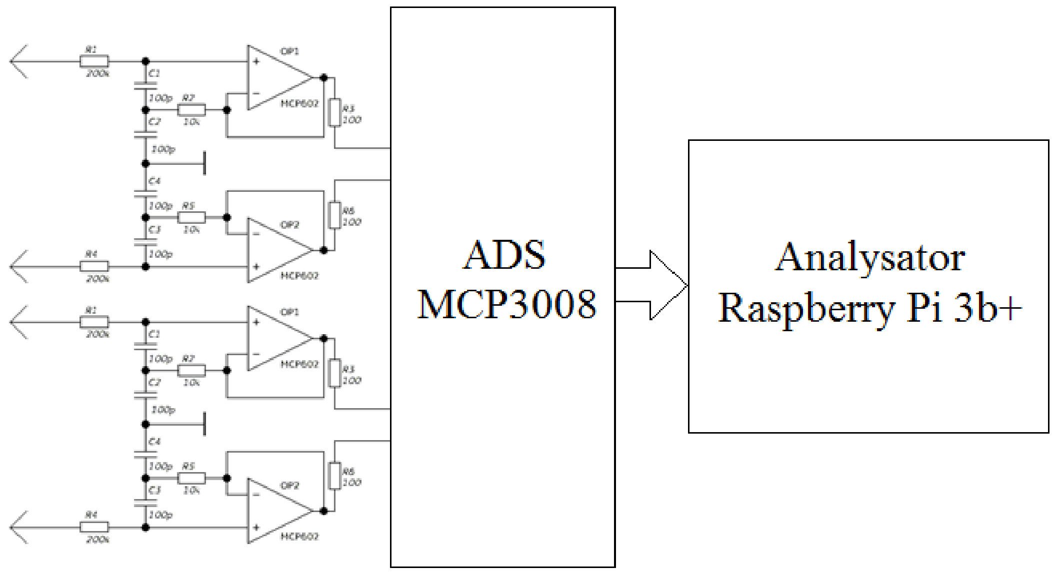


Fig. 2 - Functional diagram of dry electrodes connection [5,6]

As a result, the signal is sent to the analog-to-digital converter of the controller, after which the received data is processed and analyzed using a compact personal computer Raspberry Pi 3b+.

3. CHARACTERISTICS OF HUMAN BRAIN SIGNALS

The electrical signal, which is output from the scalp of the person, has a sufficiently low amplitude (10-4 - 10-6 V), and therefore must be amplified for registration.AC amplifiers are used for this purpose. Modern EEG complexes are implemented on the basis of personal computers and allow to simultaneously record the signal and display it on the monitor in on-line mode.In order for the electroencephalographic signal to be processed by a computer, it must be converted from analog to digital.For this purpose its amplitude is measured periodically and the result is transmitted to the computer (signal digitization). The recorded EEG signal can be stored in a computer and processed by numerous mathematical methods [18,19,20].

There are two categories of taps: monopolar and bipolar.In a monopolar tap, one of each pair of electrodes is placed above a certain area of the brain, the other at a certain distance from the brain. The first of these electrodes is called active or working electrode, and the second is called passive or reference electrode.A combined auricularreference is most commonly used. In bipolar retraction, both electrodes are located above the brain, and therefore the potential difference of these two areas will be recorded in such retraction.

The purpose of electroencephalogram recording is to record the potentials generated by brain cells. However, under certain conditions, the detected signal may have components which nature is unrelated to neuronal activity.Such components are called artifact. Artifacts can be of physical and physiological nature.The former are caused by external electric fields, but the latter are generated by biological tissues that differ from the brain.

Brain rates are diagnosed with electrical fluctuations of the brain - the central part of the nervous system of animals, usually located in the main (front) part of the body, consisting of a compact cluster of nerve cells and their processes.

EEG consists of oscillations of different frequency and amplitude [2,24,27]. From the expressiveness of fluctuations of a particular frequency in different physiological states, several major physiological frequency ranges were identified at the beginning of the history of the EEG method. These are shown in Table 1.

Table 1 - Basic physiological frequency ranges

Range	Frequency	Physiological properties
Δ	up to4Hz	Fluctuations of amplitude 20-30 μV can occur in the EEG of a healthy sane person; presence of higher amplitude fluctuations (40-300mkV) in EEG of the healthy sane person is a pathological characteristic (brain tumors) δ-oscillations become pronounced in certain phases of natural sleep, narcotic sleep or in coma condition
Θ	4-7 Hz	Fluctuations of amplitude up to 40 mcV can occur in EEG of a healthy imputed person, growth of their lobe is a sign of emotional activation and other types of brain activity, presence of θ-fluctuations in large quantities is connected with pathological states or changed states of consciousness (sleep, meditation, etc.).
A	8-13 Hz	Sinusoidal oscillations with amplitude up to 100 mcV, the amplitude of which grows in the frontal-occipital direction, is the most pronounced in the EEG of a healthy imputed person with closed eyes, in the form of a pronounced rate is recorded in 80-90% of people, suppressed during eye opening, transition to activity, analysis of information
β	13-40 Hz	Oscillations of amplitude 5-30 mcV, the presence of which in EEG is related to the active functional state of the brain, the growth of the brain activation level is mainly accompanied by a decrease in the proportion of α-oscillations and an increase in the proportion of β-fluctuations; Presence of a pronounced β-rate with amplitude above 40 μV is a pathological sign
Γ	from30-40 Hz	Fluctuations up to 10 mcV amplitude, is considered a sign to 70-500 cognitive processes and consciousness; Presence of Hz oscillations (over this range amplitude above 15 mcV is pathological different sign of authors

For a healthy sane person normal is the presence of α-rate, the presence in EEG of fluctuations in the form of rate of other ranges is a sign of pathological states or changed states of consciousness.

Alpha rate (α rate) has oscillation frequency that varies from 8 to 13 Hz. Amplitude 5-100 mcV, the highest amplitude appears in closed eyes and in a darkened room. It is recorded mainly in occipital and parietal regions (visual parts of the brain).

It is registered in 85-95% of healthy adults. Alpha rate is associated with a relaxed state of waking, resting. Alpha waves occur when we close our eyes and start relaxing.

Alpha rate depression (lack of alpha waves) occurs when a person opens eyes or thinks about a task that requires certain visual representations. As the functional activity of the brain increases, the amplitude of the alpha rate decreases until complete disappearance. Can also be a sign of anxiety, anger, fear, cause depression; disorders associated to varying degrees with changes in activity activate brain systems and, as a result, with an increased level of activation of the vegetative and central nervous system.

Beta rate (β-rate) has oscillation frequency that varies from 14 to 40 Hz. The oscillation amplitude is usually up to 20 μV. Normally it is very weak and in most cases has an amplitude of 3-7 μV. It is registered in the area of the front and center gyrus. It extends to the posterior central and frontal gyrus.

Beta waves are the fastest. Beta rate is normally associated with higher cognitive processes and focus of attention, in the normal alert state when we keep our eyes open for events that are happening or are focused on solving any current problems.

Beta rate is associated with somatic, sensory and motor cortical mechanisms and gives attenuation response to motor activation or tactile simulation. When performing or even a mental representation of the movement, the beta rate disappears in the zone of appropriate activity. Increasing beta rate is an acute response to stress.

Gamma rate (γ rate) has an oscillation frequency above 30 Hz, sometimes reaching 100 Hz, the amplitude usually does not exceed 15 μV. It is recorded in the precentral, frontal, temporal and parietal areas of the cerebral cortex.

It is usually well observed when solving tasks that require maximum focus.

Delta rate (δ rate) has oscillationfrequency that varies from 1 to 4 Hz. The amplitude is in the range of 20-200 μv (high amplitude waves).

Delta rate (slow waves) is associated with restorative processes, especially during sleep, and low levels of activation. In many neurological and other disorders, delta waves are markedly amplified. Excessive amplification of delta waves virtually guarantees the presence of disorders of attention and other cognitive functions. It occurs in natural and narcotic sleep, and is observed in the same way as when registering from areas of the cortex, border with the area affected by the tumor.

Theta rate (θ rate) has the frequency of oscillation from 4 to 8 Hz. The amplitude ranges from 20 to 100 μV. It is registered in the frontal zones and hippocampus.

Theta waves appear when calm, relaxed wakefulness becomes drowsiness. Fluctuations in the brain become slower and rateic. This condition is also called "twilight" because the person is between sleep and wakefulness. Normally, theta waves are associated with a change in state of consciousness. Often, this state is accompanied by the sight of unexpected, snobbish images, accompanied by vivid memories. Most people fall asleep as soon as a significant number of theta waves appear in the brain.

Theta rate is associated with search behavior, increases with emotional tension, often observed with psychotic disorders, states of confusion, concussions.

High levels of theta rate may indicate a state of drowsiness and fatigue, which may be a manifestation of asthenic syndrome, chronic stress.

Kappa rate (rate) has the frequency of oscillation that lies in the range of 8 to 13 Hz. The amplitude is located in the range of 5-40 μV. The registration of this rate occurs in the temporal region of the brain.

It is similar in frequency to alpha rate. It is observed in suppression of alpha rate in other areas in the process of mental activity.

Mu-rate (μ-rate) hasrate fluctuations from 8 to 13 Hz. The amplitude does not usually exceed 50 μV. It is registered in the roland area, i.e. according to the beta-beat distribution.

It has parameters similar to alpha rate, but differs in the shape of waves, which have rounded vertices and therefore resemble arches. It is observed in 10-15% of individuals.

It is associated with tactile and proprioceptive stimuli and movement imagination. It is activated during mental exertion and mental stress.

The frequency of oscillation of the tau rate (τ rate) lies in the range of 8 to 13 Hz, the frequency of oscillation of the lambda rate (λ rate) and sleep spindlescoincides and is in the range of 12 to 14 Hz. Tau and lambda rates are recorded in the temporal cortex. Sleepy spindles are recorded throughout the cerebral cortex, but are most pronounced in the central branches.

Tau rate responds to the blockade of sound stimuli. In turn, sleepy spindles are kind of flashes of activity.

When a person is excited by alpha waves, they are replaced by low-voltage irregular rapid oscillations. Increase of beta activity while decreasing alpha activity may indicate an increase in psycho-emotional stress, the appearance of anxiety states (with closed eyes). Reduce of alpha rate, increase of theta rate indicates depression (with closed eyes).

Strengthening of the beta component and simultaneous weakening of the theta consists in various epileptic syndromes, in the syndrome of attention deficit hyperactivity, post-stroke disorders (spasticity, paresis, plegia), post-traumatic syndromes, etc.

Theta and delta oscillations can occur in a sleeping person in small quantities and at an amplitude not exceeding the alpha rate amplitude. Pathological are the contents of δ and θ, which exceed 40 μV amplitude and occupy more than 15% of the registration time.

Signal filtering is used to estimate the "number" of oscillations of a beat. For the first time, analog filters were applied to the EEG signal, that is, devices that, with the input having a mixture of vibrations of different frequencies (EEG) at the output, gave only components of certain frequency ranges. Computer-aided signal processing uses digital filters, that is, computational algorithms whose operation is similar to that described by analog filters.

Because the electroencephalogram is a consequence of changes in the potentials of postsynaptic neuron membranes, it is possible to evaluate changes in the nature of brain function under certain influences. Standard tests are used to assess the normal functioning of the brainin clinical examinations. The main functional tests are:

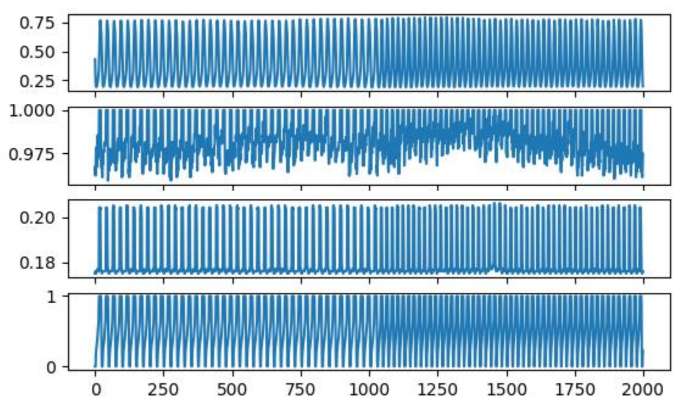
The activation reaction (AR) consists in the depression (decrease in amplitude) of the main resting rate (α-rate) when opening the eyes or when activating the sensory stimulus examined (light burst, sound). The effect of inhibition of α-rate in this sample is more pronounced in the subjects with well-expressed at rest α-rate (synchronized EEG type). In a clinical trial, this test can be used to detect abnormalities in brain activation systems.

Rateic stimulation by light flashes (photostimulation, RFS). During this test, stimulation of the rateic light flashes of different frequencies is performed. In this case, the EEG signal increases the proportion of oscillations with a frequency that coincides with the frequency of stimulation; it is the rate assimilation response. The effect of rate assimilation is more pronounced in subjects with poorly expressed α-rate at rest (desynchronized EEG type) and may differ for different frequencies. People with epilepsy or who have a predisposition to this disease (convulsive readiness), RFS can lead to a deterioration of health or provoke an attack, so the specified test with such people can only be carried out under the supervision of a doctor. Rateic phonimulation by mechanisms similar to RFS, but is less pronounced due to the less powerful input to the neocortex by the auditory analyzer compared to visual [25].

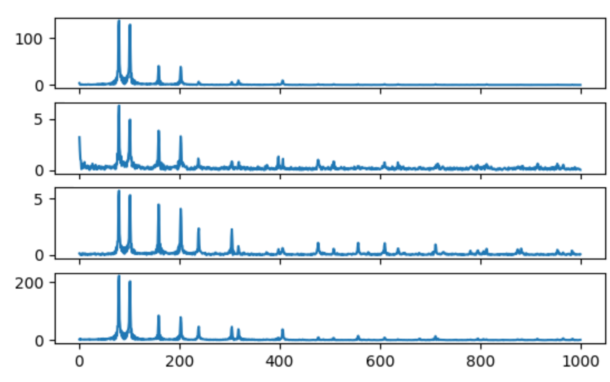
For person with hyperventilation the task to breathe deeply in the mode of about 20 min-1 for three minutesis given. Increased lung ventilation leads to more intense removal of carbon dioxide from the blood, which in turn leads to a slight increase in blood pH. An increase in the alkalinity of the blood (and intercellular fluid) leads to an increase in neuronal excitability. This test is used to detect pathological activity when it is not observed in EEG rest (for example, latent epilepsy), due to increased excitability of the nervous tissue as a whole, and therefore the focus of the pathology. Sleep deprivation is to limit sleep time and is used to increase the likelihood of pathological activity in the EEG (primarily epileptiform).

4. THE SPECTRAL ALGORITHM OF ENCEPHALOGRAPH SIGNAL ANALYSIS

One of the advantages of computer electroencephalography over the methods of "manual" analysis of the EEG signal is the possibility of using numerous methods of mathematical analysis, which give much more information about the organization of electrical activity of the brain. Most EEG numerical analysis is based on spectral analysis using Fourier transform (more precisely, one of its varieties – Fast Fourier Transform). The resulting dependence is called a spectral function, or simply a spectrum of a signal. Depending on the characteristic of the signal being analyzed, the spectra of amplitudes, phases, power, coherence, etc. are distinguished. The most often analyzed is the power spectrum of the signal, which is mathematically equivalent to the square of the amplitude of the discrete frequency components of the total signal and has a dimension of μV^2. This spectrum is shown in Fig. 3



a)



b)

Fig. 3 – Results of the survey: a) Fragment of EEG occipital abduction; b) Calculated power spectrum.

In most studies, the interest is not the value of the spectral power of certain discrete frequencies of the Fourier series, but the total spectral power of oscillations in a certain frequency range. Frequency range limits may be the same as traditional (δ, θ, α, β, γ), or be arbitrary depending on the purpose of the particular study. The spectral power of a given frequency range is defined as the area under the spectral power curve bounded by the lines of minimum and maximum frequencies of the specified range.

The calculation of the EEG power spectrum allows us to estimate such an EEG organization parameter as the level of local synchronization. In the general case, synchronization refers to the increase in the signal of the harmonic oscillations of a certain frequency. In the case of a healthy conscious human, synchronization is manifested in an increase of the amplitude and time of the α-rate registration. In contrast, desynchronization isthe inverse process it associated with an increase in the fraction of fast oscillations (β, γ bands) and a decrease in the proportion of the major resting rate.

Another indicator is the level of distant synchronization that reflects the degree of consistency over time of two different signals, that is, the signals of two spatially separated points (monopolar leads). According to the classical notions, the high level of synchronicity of electrical processes occurring in spatially separated areas of the brain is regarded as a condition of establishing between these regions of functional communication, that is, effective transfer from one brain structure to another excitation or inhibition. There are several mathematical methods for setting the distance between two leads. The simplest is to calculate the linear correlation coefficient of two leads. Cross-spectral and coherent EEG analysis can provide more accurate information regarding the organization of the two leads of electrical activity. With these indicators, it is possible to detect a high degree of synchrony between the two leads, even at low power. The graph of the coherence spectrum is usually characterized by high synchrony at one frequency and low at others, and the specific "pattern" of this dependence is quite variable over time.

Such variability of synchrony at different frequencies is thought to reflect the cycles of rapid on/off synchronization structures whose role is to create the preconditions for the functional interaction of different neural groups. A physiological significance is derived from the coherence spectrum index – the average coherence levels, which are calculated as the arithmetic mean of the spectral function over a given range. This indicator is more stable over time and its changes are related to changes in the functional state of the brain. Clinical studies have shown that significant (greater than 10%) deviation from mean coherence values is associated with the presence of brain pathologies.

To facilitate rapid analysis of EEG parameters, use the mapping method, that is a graphical representation of the scalp distribution of EEG indicators of interest to researchers. The values of these parameters are visualized by a color gradient.

The electrical activity recorded from the human scalp reflects mainly the activity of nerve elements that are directly in the area of the overlay electrode. Signals with subcortical origin can reach the scalp electrodes due to the ability of brain tissues to conduct electrical pulses, but their intensity is significantly reduced (inversely proportional to the cube of the distance between the activity source and the recording electrode), and they become analysis the most common methods, in particular those based on the calculation of the spectral power of the EEG. The researcher is interested in the ability to analyze the signals of individual parts of the brain, i.e. the signals of independent components. In order to do this, it is necessary to solve the so-called inverse EEG problem. One way to solve it is to use the Independent Component Analysis (ICA) signal decomposition method developed in the 1990s. This method is one of the most promising modern methods of so-called "blind" division of activity, which has different origin.

As a result of the operation of the ICA algorithm, we will receive at the output the signals of independent components or sources of EEG (the number of which is limited by the number of recording electrodes) and the transformation matrix, that is, the coefficients with which the signals of the components included in the signals of each of the taps. Further, the component signals may be subjected to any of the above-described methods of mathematical analysis. By performing another transformation, multiplying the component signals by the matrix coefficients we will get the EEG output.

The application of the ICA method gives better results in signal separation, have significantly different characteristics. Such signals may be artifact or pathological activity compared to normal (background) EEG. In the case where the artifact signal is due to the activity of a single physical or physiological source, it is very likely to be isolated into a separate component. Examples of such artifacts may be oculographic, miographic (in one lead), the appearance of an electrocardiographic signal, or low frequency activity caused by fluctuations of transient resistance ("swimming" of the signal). In such a case, we will be able to perform rejectionof this artifact without cutting out or excluding certain time fragments of the signal from the analysis. For this purpose, the coefficients of the artifact component in the decomposition matrix are corrected, namely, they are made equal to zero. By multiplying the signals of the components by the coefficients of the matrix being corrected, we will obtain an EEG without an "excluded" component whose analysis results will not be distorted by artifact activity.

5. CONCLUSION

An analytical review of methods and tools for analyzing human brain signals using an encephalograph was performed, component parameters were calculated and recommendations were made for the necessary components. The existing methods of receiving signals and characteristic frequencies of the human brain are analyzed, the possible characteristic artifacts of the input signal and methods of combating them are identified.

Thus, the developed brain potential meter can be used as an input or input module for PCs, mobile phones, augmented and virtual reality devices, etc.

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