**Brain-computer interface.**

**1. Introduction**

Any movement, perception or internal cogitative activities are connected with a certain pattern of activation of neurons which interact with each other by means of electrical impulses.

A Brain-computer interface (BCI) is a new system of communication between man and machine (for example, a computer or an artificial limb), based on the direct transformation of human intentions, which are reflected in the recorded brain signals, into control commands. Over the years, attempts were made to create systems for direct interaction between the brain and external technical devices passing muscular activity which is natural for such communication. For such systems the various signals reflecting activity of a brain can be used: an electroencephalogram (EEG) Magnetoencephalography (MEG) electrocorticogram (EKoG), impulse neuronal activity and intensity of a blood-grove in the brain, etc. However, the greatest number of researches concerns the use of electrical signals. Unwieldy expensive devices are required for MEG registration. The same applies to the use of blood-grove, which is measured by functional magnetic resonance imager. That's why further only the use of electrical signals of the brain will be discussed.

BCI differs with types of registered signals of the brain and with methods their transformation in team of control of the external device. BCI, using brain potentials, which recorded on the surface of the head (EEG), are noninvasive. BCI based on the use of multiple activities of individual neurons are invasive, because this activity is logged by means of the system of microelectrodes implanted in the brain tissue. BCI based of EKoG, often called the semi-invasive, because they use potential on the brain surface as a signal, that’s they are implanted under the skull, but does not penetrate into the brain tissue. Further, BCI will be discussed further in according to this classification.

Long ago, the practical need for BCI appeared. Now tens of thousands patients are need of such interface. First of all - it's completely paralyzed people (the so-called “locked-in syndrome”), for example, some patients with ALS, the total number of which in the U.S. is up to 30 thousand people, and patients with heavy forms of cerebral paralysis, and patients with severe stroke and trauma. It is possible to expect that in process of development this technology can also be used by other patients with less damaged systems of movement, such as kvadroplegiya.

Obviously, the pattern recognition bio-potentials of the brain has to lie at the heart of BCI. If the testee is able to change the nature of his bio-potentials, for example by performing certain mental tasks, the BCI system could translate these changes in the control codes, such as the movement of the mouse cursor on a computer screen or a robotic arm manipulator. Also, these codes can be used to select letters on a "virtual keyboard" or to control the wheelchair.

The first BCI was created in the 60s at the University of California at Berkeley. It was founded on the ability to operate arbitrarily capacity of the EEG alpha rhythm. This BCI could be used to control the device with one binary command (for example, turn on / off or to answer the patient "yes / no"). However, a significant increase of researches and applications of BCI has happened in recent decades. There are scientific, technological, and social backgrounds to do this.

Last laboratory and clinical researches have expanded knowledge about the nature of brain signals used for BCI. Numerous researches have allowed allocating in the brain activity characteristic indicators, which correlate with the execution of movements, as well as the types of mental tasks performed. Thus, the types of indicators of the brain activity, potentially suitable for the construction of BCI, were isolated. Technological precondition is a creation of cheap, powerful computers and mathematical software. It allowed processing multichannel recording brain signals in real time and, accordingly to use results of processing for management of technical devices. Another technological precondition, no less important, is a creation of technological compact systems for multi-electrode registration activity of the brain. The social precondition understanding of requirement for rehabilitation of patients with various motive and neurologic violations was. For patients with impaired ability to control muscles BCI may be the only possible of communication with the outside world.

The researches which resulted in the algorithms for the reconstruction of the movements of signals of the controlled motor function neurons in the motor cortex date back to the 1970s. Research groups, led by Schmidt, Fetzom and Baker in the 1970s found that monkeys can be trained quickly to selectively control the rate of the reaction of individual neurons in the primary motor cortex using a closed positioning operations, a training method of punishment and rewards.

In the 1980s, Apostolos Georgopoulos at Johns Hopkins University found a mathematical dependence between the electrical responses of separate neurons of the cerebral cortex in rhesus monkeys and the direction in which monkeys moved their limbs (based on the cosine function). He is also found that different groups of neurons in different areas of the monkey’s brain jointly controlled motor command.

In the late nineties, the efficiency of BCI was really demonstrated on patients at whom hearing, vision or motor functions were restored with its help. BCI, which provided a one-way transfer of information from the computer to the brain, are used for the recovery of visual or auditory function, and from the brain to a computer -for the recovery of motor function. The recovery of visual function based on the phenomenon of elektrophosphene which consists in the fact that the electrical stimulation of the visual cortex creates feeling the light flash in a certain point of visual space.



**FIG.1.** J.Nauman - a patient to whom matrix of electrode creating electrophosphene was implanted (from www.wikipedia.com).

Television camera is placed in the patient's glasses and various areas of the camera’s screen are projected on the surface of the cortex with a help of the set of implanted stimulating electrodes. If the brightness of an area exceeds the set threshold, the corresponding electrode produces a current pulse that generates a phosphene.

The first operation to restore motor function completely paralyzed patient (the so-called “locked-in syndrome”) was made in 1998 [1] As a result of the operation the patient has learned to move the cursor on a computer screen. In 2005, neurochip BrainGate, developed by Cyberkinetics Neurotechnology, led by Donohue, was implanted to paralyzed patient [2] (FIG. 2).

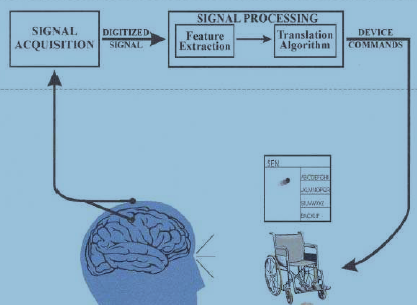


**FIG. 2.** BCI design used in the clinic group Donohue (From [2]).

During the operation, the neurochip containing 96 microelectrodes was implanted to the patient. It was implanted in the area of ​​the motor cortex that controls movement of the right hand. As a result of the operation the patient has learned to move an artificial arm or choose commands on the computer screen, for example, to control lighting and TV, depending on the direction from what the external system interface was connected. Tens of thousands of patients need of such BCI now. First of all – these are completely paralyzed people with locked-in syndrome; the total number only in Russia reaches 10,000 people, patients with severe cerebral palsy, patients with severe stroke and trauma.

 Progress in microelectronics and neurophysiology let’s hope that the BCI will not only help the person in the recovery of lost functions, but also it will greatly expand its capabilities.

General scheme of BCI for controlling external technical devices is shown in FIG. 3. Furthered, we will consider BCI only such of appointment.



**FIG.3.** The general scheme of BCI is designed to control external technical devices

It includes a system for receiving signals of brain activity (signal acquisition), input them into the computer, signal processing, including the allocation of activity indicators that are relevant for management (feature extraction), and transforming brain signals into control commands (translation algorithm), a system for interfacing with an external device and a system that supplies information to the brain about the results of the command (usually it comes with a view).

The data transfer speed (or bandwidth) of this new communication channel is still small. However, continued progress in the area of recording the activity of the brain, signal processing algorithms, a better understanding of the physiological mechanisms of motor control and the involvement of a growing number of scientists in this work provide a steady increase in this rate, the growing number of applications and the dynamic progress of direction in general.

If in 1994 there were only six research groups which are engaged in BCI, then the researchers from 20 laboratories came for the first international congress on the BCI in 1999. At the second congress in 2002 researchers were from 38 research groups, including the U.S., Germany, China, Finland, Switzerland, England, Canada, etc.

Financing of these developments grows also:

• In 1999-2001, the European Union has funded international project to create an adaptive BCI system capable to further training in the course of its use - Adaptive Brain

Interface (ABI);

• In 2002 the National Institute of Health in the United States allocated 3.3 million for the further development of clinical BCI;

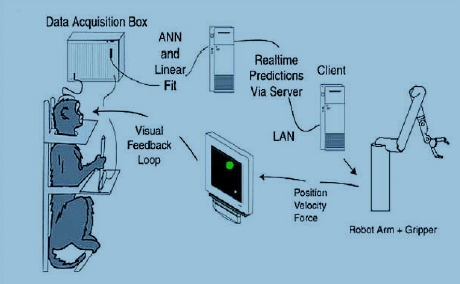
• U.S. Advanced Research Projects Agency (DARPA) has allocated $ 26 million to improve the technology of BCI.

**2. Invasive BCI**

Invasive BCI based on recording the impulse activity of neurons. The prerequisite for their development is experiments which are conducted Fettsem back in the 60s and 70s in animals [28-33]. In these experiments, the monkeys learned to arbitrarily control the activity of individual cortical neurons. Education was made with the help of tool conditioning when the monkey received reinforcements only after it has established a state of brain activity, which the predetermined discharge rate selected by the experimenter neuron. As can manifest any intention to change the activity of certain neurons soon there was an idea [95], it can be recognized by this activity, and used to control the technical devices, in particular prostheses in patients with severe motor impairment.

As another precondition for development of invasive BCI were the experiments in which the registration was carried out multiple electrode impulse activity of neurons of the motor cortex of monkeys and rats during movements [34, 35, 36, 96, etc.]. In these experiments it was shown that the direction of movement of the monkey’s limb coded linear superposition of large population activities (ensemble) neurons.

Thus, the recording of a large population of neurons activity it’s possible to predict the desirable direction of hand movement and using this prediction it’s possible to provide manipulator movement in the same direction. In practice, however, you can register the activity only a small portion of the total ensemble of neurons that control movement (a few hundred of the approximately one hundred thousand). Therefore the calculation of the desired direction of movement by a formula (1), which accounted for only a small part of the ensemble of neurons, will be obviously inaccurate and for precise control of the manipulator we need to modify their activity, which is provided by training for feedback as in Fettsa experiments [28-33] .



**FIG.4.** The scheme of Nicolelis group experiment, where manipulator manages with the activity of neural ensembles, which withdrawn from the motor cortex of monkeys (from [18]).

Connection of management ideas on the activity of a large number of neurons and the modification idea of their activity on the feedback at first led to the development of the BCI, which operated the device with a single degree of freedom [19], and soon to the BCI, which operated the device with several degrees of freedom [111, 105, 94 , 18]. The Scheme of experiment in which the monkey was trained to operate the manipulator is shown in Fig. 4. In this experiment at first, monkey was taught to control cursor movement on the screen with the joystick. Achieving the cursor accompanied by refreshment (giving of fruit juice into the monkey’s mouth). The manipulator was controlled the activity of the primary population of neurons of the motor cortex by the equation (1). Initially, the manipulator was invisible to the monkey.

In this stage of experiment there was an adaptation of transform matrix D to activity of neurons, it is modified so that the maximum compliance between the directions of movement of the cursor on the screen and the manipulator was reached. In the second stage of the experiment the monkey saw the manipulator, but did not see the screen, and refreshment was provided with achievement of the purpose by the manipulator. Thus, biofeedback was included; it allowed seeing at what the movement of the manipulator neuronal activity is transformed. At this stage the monkey studied up to reproduce such condition of activity of the chosen neurons of ensemble which provided the maximum speed and accuracy of movement of the manipulator. Though the monkey continued to move the joystick, but its movements did not influence in manipulator movements. At the last stage, the joystick in general was sampled at a monkey and and management of the manipulator wasn't accompanied by any physical activity of an animal.

Donoghue's group [94] showed that the monkey can learn to operate the manipulator and without an intermediate phase in which the activity of neurons is provoked by need to move the joystick. In their experiments, the monkey learned to operate at once the manipulator on feedback.

In these studies BCI differs by quantity of electrodes in a matrix, by number of the implanted electrode matrixes (one or the several), by brain areas where they were implanted, where they were implanted (frontal or parietal cortex, or both), by type of recorded activity (local potential, the activity of individual neurons or multineural activity) and by the number of neurons used to control. For most invasive BCI microelectrodes were implanted only in one area of ​​the brain (primary motor cortex, [94, 105] or the posterior parietal cortex [117]), they can register either local potential [58, 88, 76, 100] or the activity relative a small number of neurons (less than 30) or multineural activity [94, 105, 106].

In general, application of invasive BCI in clinical practice demands the solution of the following problems:

• Provide a stable and long-term (several years) registration activity of large populations of neurons (hundreds and thousands) from several areas of the brain. For this it is necessary to create a new generation of electrode matrices which will provide registration of activity thousand neurons at small damage of brain tissue and prevention of its scarring.

• Develop technology telemetry data transmission and a contactless food for ensuring full autonomy of the implanted electrode systems who will allow to do without the connecting wires, having excluded thus risk infectious infection through an open trephine opening.

• Develop effictive computing algorithms for transformation of neural activity to team which can precisely operate the device with many degrees of freedom.

• Develop technologies which would allow to incorporate technical devices in internal neural model of the scheme of a body so that they were felt, how own bodies. It means “sensitization” of operated objects, development of ways of transfer of this artificial touch information in a brain, creation of algorithms of adaptation and training for BCI and development of the corresponding techniques of training.

• Develop a new generation of anthropomorphic artificial limbs with a large number of operated degrees of freedom and with the operated articulate rigidity.

**3. The problem of biological compatibility and safety**

One of the main problems connected with the use of multielectrode matrixes - is a gradual overgrowing of electrodes by connecting tissue that leads over time to considerable deterioration of electric contact with a brain, with its full violation subsequently [23, 97, 107, 9, 50].

Another problem — is possibility of infection through an open trephine opening for an exit of an electric cable.

For the solution of the last problem it is necessary to develop a telecommunication communication system from a matrix of electrodes to external receivers for completely isolation of the implanted matrix of microelectrodes from environment.

The modern equipment of implantation of microelectrodes provides possibility of their use during for several months, and in certain cases – during for several years [93]. However, over time, quality of their work decreases because of a covering by connecting tissue and damages of nearby neurons. For delay of a covering of electrodes by connecting tissue it is offered to cover electrodes with the substances stimulating growth of nervous tissue or preventing development of inflammatory process [86, 22, 87, 41, 43, 10], or to do special difficult design of electrodes with an arrangement of contacts in the microcavities, which filled by neurotrophic additives, stimulating growing into them nervous terminations [44–47]. However, there isn’t a satisfactory way of full prevention of the overgrowth of the implanted electrodes by connecting tissue.

Along with a solution of the problem of biological compatibility it is necessary to improve a design of an electrode matrix, in particular, for the purpose of receiving more difficult spatial configuration of electrodes. It would allow increasing number of the neurons registered by one matrix, to several thousand. Available matrix from microelectrodes mounted on a flat basis (Univercity of Uta array) [91], used by Donoghue’s group, has to pass still additional checks before it will be used routinely in clinic, in spite of available example of its experimental clinical application [39]. According to available messages the matrix of University of Utah well contacts to a brain of animals at which it has a flat surface but worse for a man whose the surface of a brain is covered with furrows and crinkles worse. Besides, it doesn't allow registering activity of neurons from deep layers of the brain.

It’s early to judge about success of its application in clinic because messages on results of the operation haven't published yet.

Thus, critical for possibility of invasive BCI application in clinic is not only improvement of their work (registration a larger number of neurons and increase in the duration of their functioning), but also reducing the risk of harm to patients, that is possibility of their wireless implantation together with amplifiers and telemetric transmitters to exclude infectious infection through a connecting cable.

Development of systems of telemetric signal for invasive BCI has been already began [63, 20, 17, 65]. Recently many new ideas of improvement both BCI and ways of their implantation express: from improvement of silicone micromachine technology of their production [66] before their introduction in a brain through blood system [53].

**4. Algorithms for converting brain activity in the team to an external device**

Now still we don’t have full understanding of how information in a brain is coded and processed. The most common is the assumption of coding by the speed of categories of neurons or by temporary and spatial patterns of distribution of categories.

However we don’t need a full understanding of creation of BCI. Moreover, BCI can significantly contribute to this understanding. In the BCI device it’s provided an ability to select in a registered brain activity those parameters which most fully correlate with parameters of a carried-out motor task, and to use them for team generation to external technical devices. As mentioned earlier, the directional tuning of neurons is one of correlation indicators between neural activity and parameters of movement [34, 35]. There are also many data about the correlation of neural activity with kinematic [4, 118, 5] and dynamic parameters of movement [98, 99].

The elementary linear regression models [111, 94, 18, 51, 74] turned out the most effective and almost acceptable algorithms of transformation of neural activity in team of management. In these regression models the team is calculated as the weighed sum of frequencies of separate neurons categories in some previous intervals of time. The number of neurons and intervals of time can be optimized for each BCI concrete appendix [111, 92]. Parameters of linear transformation (the coefficients considering a contribution of each neuron) can continuously adapt during training of examinees [105] that is transformation can be adaptive.

Fundamental result of experiments by means of invasive BCI was the proof of that various parameters of movement are coded by crossed ensembles of neurons, and each neuron gives a contribution to various parameters of movement. Thus, regression models differ only in coefficients which consider a contribution of different neurons and applied to activity of the same neurons. Models can decode various parameters of movement, such, as position of a hand, its speed and acceleration, and also force of compression of fingers [18].

Activities of brain areas which give directly motor command are used for management of external devices. Also areas of the brain which activity precedes formation of motor team, for example, the areas corresponding to definition of the direction to the purpose to a choice of executive body or recognition of parameters of object of a manipulation can be used for management of external devices. Such BCI can operate with information about the sequence of movements [40, 55], about used system of coordinates [73, 7, 8, 38], about purpose [51] movement, etc.

Though such activity can provide only discrete management (while activity of motor areas is continuous) its can reduce considerably reaction time at the expense of an early parcel of team to the manipulator. Also it’s possible to combined use of many areas of a brain for management of external devices [48]. In such interface the teams of high level reporting intentions of the subject can be combined with the teams of low level providing accuracy of movement of the manipulator by means of feedback management.

**5. Training of management skill by external objects**

The success of BCI application is caused by existence of considerable cortical plasticity which allows a brain to adapt to BCI in such a way that the external device operated by it (for example, a hand artificial limb) is perceived as natural executive organ of a human body. Moreover BCI not only catches the electric activity of a brain accompanying natural process of information processing, but also this activity becomes the final product of the brain work. Like muscular activity at natural interaction of the person with the outside world, electric activity of a brain becomes such parcel to external executive body which provides implementation of arbitrary behavioral act. And just as natural movements are learned, constant monitoring of results feedback control is required for development skills in the use of BCI.

Skill of management of external devices by means of BCI is apparently similar to skill of use of working tools. It is known that development of such skill is accompanied by addition of tools in the body scheme [42, 56]. It can be expected, that when we manage of the external device by means of brain signals, then illusion of this device is body continuation, becomes even more. This is supported by data about the activation of human premotor cortex, which is observed in management of a myoelectric artificial limb of the hand [57], and also data about neurons activity of primary motor cortex at imagination of phantom movements of the amputated hand [119]. But the most direct proofs of the handling of external devices as with parts of own body were received in already mentioned experiments with BCI on animals [19, 105, 18, 51], etc. In these experiments movement of the manipulator was carried out in the beginning by the neural activity arising during real movements of a paw, but over time it started being carried out by brain signals already without any movements. Thus the pattern of activity of neurons was modified in comparison with what was observed at natural movements, i.e. an ability was formed which operate a new working point of own body with using the same neurons which are used for management of a working point of natural executive body. It is interesting that at the initial stage of training variability of neural activity sharply increases. There is a search of a new pattern of the activity. Then, when the new pattern is found, variability of activity comes back to former level. For facilitation fuller perception of an artificial limb as part of own body, it is necessary to implement its “ sensitization “, i.e. to provide it with the sensors answering for contacts with external subjects (tactile sensors) and changes of its spatial configuration (proprioceptive sensors), and also to provide receipt of information from these sensors in the brain. In existing currently BCI this information arrives in the brain only by means of vision. There are already some works in which information about change of BCI managed configuration of the manipulator, is reported to monkey’s brain by direct stimulation of sensorimotor cortex [120].

At the conclusion of the literature review about invasive BCI it is necessary to notice that in spite of active advertising and undoubted encouraging first results, it is remained very far before their mass clinical application which is possible, only when there is no other ways of rehabilitation of patients. The main obstacles for such application are short time of their effective functioning and possibility of infection through a trephine opening. However works to overcome of these obstacles are actively conducted. It is hoped that it could be overcome in the next 10–15 years. Also efforts are being made to improve the algorithms of transformation of signals of a brain in team to the external device, and also improvement of artificial limbs, including their “sensitization “. It is hoped that eventually it could be possible to achieve full inclusion of artificial limbs in the scheme of a body and the treatment with them as with natural executive bodies. In the future, it is possible to present and possibility of using remotely operated "additional hands". It could expand an arsenal of motive opportunities of human abilities.

**6. Noninvasive BCI**

Signal for noninvasive BCI usually is multi-channel Electroencephalography (EEG), i.e. the electric potential registered on a surface of the head. The precondition for creation BCI, which based on registration of EEG, are the early works showing that the person and animals is able to learn by means of biological feedback randomly to control electroencephalographic rhythms. In the 60-70th years this ability was shown for an alpha rhythm at the man [71], for a sensorimotor rhythm at cats [116] and the man [102] and hippocampal theta rhythm at dogs [14].

Further we will consider BCI based either on the EEG either BCI which aren't demanding training for generation of operating team. As such indicators we use the visual evoked potentials, slow cortical potentials, the P300 component, the patterns of EEG corresponding to various types of mental activity and sensorimotor rhythms of mu and beta.

**7. Visual evoked potentials (VCP)**

The occipital EEG corresponding to activity of visual cortex is registered in this type of BCI. Such BCI is based on effect of dependence of EEG from the look direction. Allocating from EEG to a component, defining the look direction it is possible to shift the monitor cursor in that point where the testee arbitrarily directs a look.

On Volpou's classification [113] described BCI are "dependent", i.e. they duplicate (depend) on external manifestation of natural motor team. In this case they duplicate manifestation of the team operating the direction of look. However, the direction of a look can be defined more direct way. If VCP amplitude reflected increase in attention at some allocated incentive then in accordance with Volpou's classification it would be IDP "independent" interface because the specific increase in attention has no external muscular manifestations.

**8. Slow cortical potentials**

One of the most low-frequency component of EEG is the slow cortical potential (SCP) changing with characteristic time of 0.5-10 pages. Negative shift of MKP usually is associated with preparation to movement and other functions of cortex demanding increase in cortical activity. And positive shift is associated with its reduction.

**9. P300 component**

The P300 component arises in reply to unexpected (for example, shown with probability 0.2) significant incentive when it appears among insignificant incentives [110, 104, 25]. In the experiment to make significant rare incentive, it is usually offered to the testee to consider number of its presentations. P300 arises approximately on 300 ms after presentation of significant incentive. It has duration about 300-400 ms and positive amplitude 5–15 mkv. The maximum amplitude of P300 is observed under central (Cz) an electrode. The less significant is presented, the more amplitude of P300. As a rule, some averages for its allocation from background activity are required. P300 depends on attention of the testee, but not from physical parameters of incentive.

The undoubted dignity of this BCI is that its use doesn't demand preliminary training. P300 is the natural component arising in a certain experimental situation. At the same time, this component changes in process of repetition of a situation [37, 62, 101, 90]. Until the present time duration of participation of each testee in experiments with BCI on the basis P300 didn't surpass several weeks. At more their long-term use of their P300 amplitude at the specific testee can change, both towards reduction, and towards increase. Therefore in spite of the fact that the testee can start using such BCI practically without preliminary training, ensuring its continuous use requires existence of adaptability of algorithm of allocation of the P300 component.

**10. The patterns of EEG corresponding to various types of mental activity**

Here for management of external devices the existential patterns of EEG corresponding to various types of exchanges of mental activity are used. Generally, as an existential pattern of EEG we use spatial distribution of amplitudes of various rhythms of EEG on the head surface which reorganization, as we know, reflects domination of these or those cognitive processes.

The logic of use of EEG patterns corresponding to various mental conditions consists in the following. In the beginning the testee is offered to execute some types of mental tasks. By means of the adaptive qualifier is defined, what types of mental tasks can be classified with the greatest accuracy. Then under the agreement with the testee each of such mental tasks associates with any team of management of the external technical device. After that the testee mentally executes the corresponding mental task for performance of randomly chosen command. Movement by the right or left hand or the oral account will suited to the presented task.

The most perspective BCI is BCI based on the classification of mental conditions, respective imagination movement of various organs of the body. At people in the waking state the rhythm in the range of 8-12 Hz over primary areas of somatosensory and motor cortex in the absence of sensory input or movement is observed. This rhythm is called as a mu rhythm, and it is supposed that it is made by thalamocortical neural networks [54, 69]. It represents a combination of the rhythms differing with a place of generation, the frequency and touch incentives or the motor acts connected with its generation.

There are some reasons why a mu - and beta rhythms are the most perspective for using in BCI. First, these rhythms associate with brain areas which are most directly connected with a motor exit. Therefore it is represented that they are most adapted and for generation of the motor team serving for management of artificial executive organs. Secondly, dyssynchrony of a mu rhythm doesn't demand real movements, but only their representation [60]. Thus, natural type of mental activity which can be distinguished by the BCI qualifier, representation of movement of any executive body is simply. Thirdly, representations of executive bodies are quite widely distributed on a cortex surface. Therefore representations of different organs movements create a different division distribution activity on surfaces of bark and, respectively, different spatial patterns of EEG that facilitates a problem of the BCI qualifier.

**11. Conclusion**

From the point of view of potential productivity and ability to operate external devices with a large number of freedom degrees the most perspective is the invasive BCI based on transformation in activity of a large number separate neurons to team for the external device. Already now their information productivity can reach 100 bits a minutes, and the number of degrees of freedom can surpass two [52]. However for their practical introduction there are essential difficulties: the electrodes implanted in the brain grow with connecting tissue that reduces time of their effective work, and opened trephine opening through which passes a connecting cable, is a potential source of danger of infection. There is a high ethical threshold of using it because they demand operational intervention in the brain. The technology is very expensive. Besides, their efficiency is currently comparable with that which is provided by the best noninvasive BCI.

Noninvasive BCI are divided into two classes: one demand minimum, others — rather big time for training and mastering by skill of their using. The most perspective of those that require minimal training is BCI, based on classification of patterns of EEG, various types of movements corresponding to imagination. Also, BCI demanding continuous training of testee can have much more high efficiency and, besides, provides possibility of simultaneous continuous control with several degrees of freedom.

Efforts to improve the IMC made ​​in the following areas:

• Improvements of technical means of realization of BCI;

• Improvements of algorithms of brain signals transformation in the team of management of external devices;

• Increasing of the number of sensory channels providing the brain with information about result of command execution on biological feedback;

• Improvements of procedures training in the use of BCI.