# Electromagnetic Aspect of Mind Control: A Scientific Analysis

Vlad N. Binhi

*General Physics Institute of the Russian Academy of Sciences*

## Contents

Abstract

General notes on electromagnetic mind control

- What is mind control?
- Mind reading
- Electromagnetic weapons
- Electromagnetic neurotechnologies
- Criteria for literature selection

A historical look at the research into electromagnetic mind control

Electromagnetic brain control

- Magnetic resonance imaging
- Magnetoencephalography
- Transcranial magnetic stimulation
- Standard magnetic stimulation
- Microwave hearing effect
- Brain-machine interfacing

Experimental grounds for biological effects of superweak fields

- Biological effects of low-frequency MFs
- Biological effects of microwaves
- Neurological effects of EMFs

Theoretical grounds for biological effects of superweak fields

- Magnetic nanoparticles in organisms
- Molecular targets for magnetic fields
- Metastable states underlie biological sensitivity to weak EMFs

Discussion

Conclusion

Bibliography

About the author

## Abstract

Many publications, primarily in newspapers and popular magazines, discuss so called "Electromagnetic Mind Control" and "Electromagnetic Weapons". This controversial theme originates from two well known facts: (i) electromagnetic (EM)[1] fields and radiations can affect the human organism and (ii) the impact of EM fields occurs invisibly and so it may be organized in a way that people do not know about it. Particularly intriguing is the idea that relatively weak EM radiations can affect human brain causing some specific mental processes, conscious or subconscious, which means the principal possibility to control the human mind. The fundamental scientific basis underlying this particular type of mind control is biological effects of weak EM fields. Since I have been engaging in such studies for decades, I was invited by Cheryl Welsh, J.D., director of the Mind Justice Org., to opine on this matter.

In this article, are considered general questions associated with the concept of EMF control of the human organism and particularly of the human mind. The definition of EM mind control is specified first. A brief historical overview is further presented showing main milestones of the development of this concept in the USA and in Russia. Then, we analyze known methods that allow extracting information about brain processes. Other methods are reviewed as well, which in contrast allow delivery of information into the human brain, by exposing it to EM fields and radiations. Any EM mind control, whatever it would be, should be based on general principles of EMF interaction with living objects. Therefore, also considered are scientific grounds for possible EM mind control. They include (i) a variety of biological effects of superweak MFs and EM radiations, and neurological effects among them; (ii) some theoretical grounds that give examples of molecular and subcellular mechanisms validating the effects of superweak EMFs, and (iii) technical limitations of the targeted exposure of humans to EM fields and radiations. Also, a comment is given to the microwave hearing effect with regard to its potential for EM mind control. Finally, conclusive remarks are focused on what is possible and what is not possible in the EM mind control area. In particular, based on the review of literature made, we deduce which kind of mind reading is scientifically grounded and in what sense we may speak about mind control.

[1] Abbreviations: ac – alternating current, cw – continuous wave, dc – direct current, EM – electromagnetic, EMF – electromagnetic field, MF – magnetic field, MRI – magnetic resonance imaging, QED – quantum electrodynamics, RF – radiofrequency, TMS – transcranial magnetic stimulation.

# General notes on electromagnetic mind control

The Universal Declaration of Human Rights adopted by the United Nations in 1948 lists basic human rights that should be guaranteed to all people. One of the most important principles declared is *freedom of thought* closely bound to *freedom of conscience*. It is the freedom of an individual to hold opinion, viewpoint, or thought without interference, i.e. regardless of anyone else's view (GAUN, 1948). Two important consequences result from theses principles.

First, it clearly means that everybody has right to have a possibility to keep his or her thoughts concealed. Would any person or group of persons or an institution find a possibility of screening another person's mind, it would be direct violation of the basic law. It is the main reason why some human right organizations consider any interference in consciousness as an inadmissible and illegal act.

Second, in addition to the abovementioned social component, the freedom-of-thought principle also has likely unobvious implication related to the scientific view of the world. It may be seen, that the principle considers thought as a fundamental category adopted by humankind as being free of social responsibility. For example, hatred is non-punishable unless it was expressed as an action resulted in harm. This means, in particular, that no one could be prosecuted or sued for his or her thoughts. Thus, people recognize, by their practical activity, by their legislation, that *thought* by itself cannot produce action or matter. Important is that science relies on the same postulate. The scientific method separates an object of a study from a cognizing individual, or subject of the study, and takes the object existing regardless of the subject's mental activity. This also finds everyday confirmations in general scientific observations. We emphasize that the social aspect of the postulate is even more substantial than its scientific counterpart, since it originates from the collective historical human experience. The social law surpasses science since not only it includes the latter but as it also encompasses the entire human practical knowledge.

Reviewing literature on such complex theme as "mind control," it is necessary to be consistent with a certain position regarding the question of whether a thought can create matter. In what follows, we adhere to natural scientific positivism, according to which, in particular, matter exists independently of the thoughts on it, science deals with phenomena, i.e. replicated events, and new knowledge appears as a generalization of empirical data. We will specially discuss the case where observations of mind control are beyond the scope of science.

## What is mind control?

In what follows, the term "mind control" is a key term. It is important to come to an agreement about its meaning in advance. The definition of mind control and the extent of its possible influence on individuals are debated. The term is of isolated use in scientific literature. Usually, mind control is defined as a general term for a number of controversial theories and/or techniques designed to subvert an individual's control of their own thinking, behavior, emotions, or decisions, or to manipulate the consciousness of a person.

The feasibility of such control and the methods by which it might be attained are also debated. Social psychology sees mind control as a systematic use of well known communication principles. Under this definition, people, who persuade or thrust their opinion on others, implement mind control, in a varying degree. As is seen, social psychology does not take into account that individual's control of their consciousness might be suppressed not only by the communicative processes themselves (conversation, reading, TV, mass media, hypnosis, etc.), but also by non-communicative outer causes. Among such are different chemicals, which reduce self control biochemically (psychotropic drugs, smells), and physical factors like visual perception of light and hearing of sound patterns, temperature influences, and EM field exposures. Of course, these can be used in a variety of combinations.

In the problem of mind control, we should distinguish two aspects that are very different from the physical viewpoint. First, it is a way by which one could secretly obtain or read-out information from an individual; it is a "mind reading". The second aspect is a way of delivering and embedding information to an individual's mind.

Among all types of mind control technologies, the most intriguing one is the technology that uses EM fields and radiations as a delivery vehicle for mind control signals. The point is that the EM radiation can be easily organized so as to unexpectedly or even secretly expose large groups of people using relatively distant EM sources. Optionally, under certain conditions, EM radiation can be focused on a local target. Electromagnetic mind control may be understood in a wider sense, as a technology designed to scan the consciousness and to read mind by means of EM radiations. EM mind control implies the following essential and unique features. It is a remote control technology, potentially large area of exposition, and capacity for quick adjustments and targeting. However, most important feature of EM mind control is the possibility of a secret EM influence. The individuals are not aware about it, they believe their doing is under complete control of their mind and cannot guess that some of their thoughts are implanted from external sources. Sometimes, ultrasonic sounds are considered as a carrier of hidden information for subliminal perception as well as EMFs. However, EMFs have much higher penetrating power.

In accordance with the aim of this article, below we consider only electromagnetic mind control and mind reading.

## Mind reading

We should clarify a few most general relations between such notions as word, phrase, thought, and sense.

One can understand the sense of the following phrase, reading it quickly: "Aoccdrnig to a rscheearer at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe." It is a well known example showing also that one and the same sense may be transferred by many ways. Even when the words are scrambled in a phrase, the latter is still able to transfer the sense of it, to some extent. It means that a sense is an independent entity that may be expressed by different means. Even nonverbal art facilities can transfer senses. What kind of thoughts are behind phrases and senses? It is not yet known.

The human mind is able to operate with senses without encasing them into verbal constructions, words or phrases. Even covert speech does not always accompany the flow of senses. Apparently, humans do think mostly keeping inner silence, and only when they need to actually transfer the results to others, they "switch on" a special mental translator, which interprets individual senses in common for all words and phrases. This does not, of course, rule out inner monologs, when a human speaks covertly. Even in these cases, the monologs are just reflections of the play of senses. In my opinion, mind reading, if to imagine it real, would consist in receiving the flow of senses. To read your mind means to know what you think, and you think by senses. But how it is possible?

How do we perceive senses, or thoughts, which are not ours? One way is to read previously written text or contemplate an image; the other way is to hear what was pronounced. It is practically impossible to understand a sense using other organs of sense. Some kind of senses or thoughts, to say information, may be perceived by sensitives during paranormal contacts. However it would be an experience inexplicable in scientific terms. It follows that thoughts cannot be read at least until they are spoken, openly or covertly, or expressed in any other way.

Usually, thoughts are considered to be propagating excitations of neurons in the brain cortex and their interaction. One could hypothesize that with knowing which neurons are "fired" at a given moment in time, it would be possible to understand what the human thinks. As was said above, such a technology would have to convert the distribution of fired neurons into the text with a sense, i.e., first, to explain the pattern of fired neurons in terms of senses and, second, to interpret the obtained sense using words and phrases. That is, this technology, and a computer program in its core, have to replace the brain in its most enigmatic and subtle function, consciousness. It seems impossible, at least at first glance.

## Electromagnetic weapons

Anything using EM fields or radiation to damage or destroy including damage of normal psychic or social processes can be referred to as an electromagnetic weapon.

Among such weapons are known laser and microwave weapons as a part of the Strategic Defense Initiative (1983). Reviews on EM weapons may be found in many sources, for example (Liebig and others, 1988). Another known type of powerful EM radiators, which might be used as weapons (Falmer, 1995), is related to the project HAARP, or High Frequency Active Auroral Research Program (1993). It is the project aimed to control ionospheric processes that might alter the performance of communication and surveillance systems (Gordon, 1997). Located in the remote country of Alaska, HAARP antennas, 180 pieces in all, are organized in a so called phase array antenna, which can focus EM power, a few megawatts in the given case, in a relatively small volume of the terrestrial ionosphere and temporarily modify its physical properties. Possible influences on the biosphere are widely debated.

A relatively recent concept of non-lethal weapons is aimed at minimizing civilian casualties (Giri, 2004, Kiss, 2005). These are weapons not intended to kill or to cause great bodily injury to a living target.

Electromagnetic non-lethal weapons use EM radiations to cause pain, fear, or similar reactions in personnel, to influence the perceptions and attitudes of individuals and groups, which finally could destroy military operations. Such technologies are now considered to be useful also in civilian operations to suppress illegal marches and strikes. Apparently, most commonly known are microwave guns, which produce pain from sudden heating of the skin of humans it is directed on. Current knowledge of biological effects from short microwave pulses is very limited; underlying biophysical mechanisms are not identified. However, available results of military funded studies, e.g. (Pakhomov et al., 2003), on the effect on neuronal functions in rat brain slices are consistent with the concept of heating of the tissue and provide no indication of any specific effects.

EM heating is the only type of EM biological effects, so called EM thermal effects, that are recognized by most of the scientific community. There are also less known non-thermal EM biological effects. In these effects, EM fields and radiations do not appreciably heat tissues; however they carry information which is assimilated at a biophysical/biochemical level and leads to a biological endpoint. It is these effects that constitute a potential scientific ground for mind control. Therefore, also discussed in literature is a possible use of EM microwaves or RF facilities at low powers that cannot produce perceivable reactions like a pain or fear, but nonetheless directly affect the cognitive aspects of an individual. Externally applied EM fields are thought to be capable of implanting information in an individual's brain.

Because an EM exposure can be carried out secretly, such facilities are often associated with a special type of electromagnetic weapons by which secret groups or institutions might control minds of people. Some conspiracy theories are known to be based on the existence of such EM facilities. There is a general term for these in Russia: "psychotronic weapons". In the most extreme cases, according to conspiracy theorists, even simple innocuous laboratory EM generators became psychotronic generators that could bring people in a changed state of mind, driven by a malefactor. However, sometimes, it is actually hard to distinguish truth from falsehood or error.

One more aspect of EM mind control is worth mentioning. The fact is that EM mind control as a method of mind reading, let alone mind intrusion, may not be accessible to all levels of people. If in use by everyone, mind reading would quickly destabilize the society. Knowing precisely what an individual is thinking would allow complete power over their personality. This means that EM mind control is a sort of "absolute weapon" that will ever be represented either by the unique ability of some esoterics or by extremely secret engineering achievements and technological breakthroughs. In addition to this problem, relating to the society's viability, a variety of ethical implications to the issue of mind control have been considered in (Moreno, 2006). We can see that science, as a method for knowledge-mining, together with moral and ethics are intricately intertwined with each other thus securing global society's stability and development.

## Electromagnetic neurotechnologies

Can modern scientific and technical achievements help read and manipulate mind? We will look at electromagnetic neurotechnologies below. It appears that electromagnetic mind manipulation, unlike mind reading, is a matter of fact.

Electromagnetic neurotechnologies are the technologies focused on the central nervous system, in particular the brain, which use EMFs as a necessary intermediate between the brain and technical sensors. There are several types of such neurotechnologies: magnetoencephalography, magnetic resonance imaging (MRI), transcranial and standard magnetic stimulation of the human brain.

In magnetic encephalography, the electric activity of brain is recorded by an array of small magnetic sensors arranged close to the head of a human (Presissl, 2005). A computer gathers information from the sensors and converts it into 3-dimensional distribution of the brain activity. The number of sensors reaches now as many as a few hundred, which gives an idea of how many parts within the brain may be resolved with regard to their activity. The 3D distribution of the brain activity is a pattern that changes in time. Millisecond time slices are available to researchers.

MRI utilizes another principle to scan brain for its structure or distribution of the chemical or elemental composition. Here, in a small zone of the brain tissue, external EM fields excite atoms so that they begin irradiate their own EM radiation. This radiation is captured by special detectors. The zone of excitation sequentially goes throughout the brain. Then a computer reconstructs 3D distribution of a given chemical element in the brain.

Biophysical structures, like vessels, bones, soft tissues, etc. have their own chemical compositions, which also change according to their physiological state. Therefore, the elemental distributions well show what the brain is and how it works. Spatial and time resolutions of this method are about a millimeter and a millisecond, varying depending on specialization. For example functional MRI (fMRI), focusing on quick processes of brain excitations, has the best time resolution at the expense of worse spatial resolution.

The clearest results in neurological effects from exposure to EM fields were obtained using so called transcranial magnetic stimulation (TMS) which uses short pulses of magnetic energy to stimulate nerve cells in the brain (Cowey, 2005). The method is effective in treatment of epileptic seizures, depression, and probably Parkinson's disease. As well effective were results of the exposure of patients to magnetic pulses, in a way similar to TMS but with MFs by many orders of magnitude weaker (Anninos et al., 2006). In all these cases, utmost non-uniform MFs have been used to stimulate brain tissues.

Plain electromagnetic stimulation, unlike TMS, uses mainly uniform and much weaker magnetic or electric fields. This method is primarily used for fundamental scientific research aimed at determination of the mechanisms underlying electromagnetic reception. The method is used for its simplicity and ease to monitor all parameters of the EM exposure. The method is so widely used that there is no reason to reference a special literature; the books (Bersani, 1999, Binhi, 2002), which present the designs and results of many original studies and provide a unified viewpoint on the nonthermal EM bioeffects would be a reasonable choice for introduction to bioelectromagnetics.

## Criteria for literature selection

Criteria used in selecting scientific and non-scientific literature to review were as follows.[2]

All available non-scientific documents on the subject of EM mind control were divided into the following groups: (i) dramatic news stories, (ii) articles from military journals, and (iii) declassified security documents allegedly showing that governmental structures wield EM weapons of mind control. Of course, newspaper material was not analyzed, just referenced in a limited number of cases. As to the military articles and documents, since there is no way to be conclusive with regard to such material, we avoided commenting on it wherever it was possible.

Before a military research program in a given direction appears, some prerequisites, or preliminary scientific knowledge, should exist in order to generate a military concept. For example, before the first nuclear weapon was created in 1944, there has been a long period of open scientific research since the discovery of natural radioactivity in 1896 and of atomic nuclear structure in 1911. A more apparent example is the development of the microwave gun that works as crowd control, using a thermal shock. That RF and microwave EM fields can heat biological tissues has been known for many decades. But only now, when different high-tech technologies have been developed, which allow producing nanosecond microwave pulses at hundreds of megawatt power level, the creation of a microwave weapon has become a reality.

Military research may contain secret knowledge. At the same time, military research deals mainly with technical realizations of known scientific concepts. An example of "Brainwavescience" [www.brainwavescience.com] and many other projects, e.g. (Hoag, 2003), supported by DARPA (the Defense Advanced Research Projects Agency) show how military institutions invest in brain/neurological explorations. Therefore, it is a technology or know-how rather than a scientific concept that usually holds secret knowledge.

In that way, there are many reasons to expect that publicly available scientific literature would contain explicit evidence that EM fields and radiations are capable of controlling the human mind, in principle. However, direct scientific studies on EM mind control have not been found in public journals.

Could they be classified? Forman (Forman, 1987) notes that in 1950s, i.e. during the period of intense studies of nuclear weapons, the cumulative number of papers published in U.S. physics journals was about 50000. He then surmises that it was probably only some small percentage of the number of security classified reports in physics and its military technical applications prepared in that decade.

The present review only covers the development of unclassified and related technologies described in publicly available literature.

---

[2] The term "scientific literature" stands for the works published by peer-reviewed scientific journals and written by professionals under the strict requirement to provide full information necessary to replicate the results of the work.

In principle, studies on EM mind control could be based on existing knowledge of (i) brain interaction with EMFs and (ii) non-thermal biological effects of weak EMFs. Therefore, the methods utilizing EMFs in brain research and also literature on biological/neurological effects of weak and superweak EM fields and radiations were selected and reviewed. In order to gain an objective view on the progress in these directions, original scientific works have been examined with a special focus on EM powers, frequencies, time parameters, neurological parameters measured, and possible applicability to mind control.

# A historical look at the research into electromagnetic mind control

A brief historical overview is given below of the research into EM mind control in the USA, former USSR, and Russia. It should be noted, this review is based mainly on newspaper articles and books that do not go through the peer reviewing process usual for scientific literature. Also, the newspaper articles of our interest provide information that hardly may be examined. Therefore the information below is for orientation in a general way. In a few cases, however, open documents have been found, which confirm the statements made in the review.

History of EM weapons in the USA is known from many open literature sources, for example (Phillips et al., 2006).[3] A number of facts about the history of EM weapons in USA showing plurality of opinions are presented in (Welsh, 2003). Most often are discussed the following military programs within which the use of EM radiations as the factor of damage or control over people behavior is supposed or documented.

In the 1950s, a mind control research project named MKULTRA and grown from the previous projects BLUEBIRD and ARTICHOKE (1951–1953) was launched by CIA. The activity within MKULTRA was concerned with the research and development of chemical, biological, and radiological materials capable of employment in secret operations to control human behavior. There is only a little evidence that the project involved the use of EMF to alter brain functioning (Marks, 1979, MKULTRA, 2007). The project continued until the late 1960s at a gradual reduction of financial support. In 1970s, after the revelation that the CIA had conducted partly illegal experiments on U.S. citizens, the project has received negative ethical value. Based on the declassified document (MKULTRA Subproject 119, 1960), one could state that CIA had some interest in studying activation of human behavior by remote means. However, there is no evidence that any substantial progress has been reached in controlling an individual through EM mind control techniques within the projects.

The "Moscow signal" discovered in 1960 caused a great concern of the West military structures. The plot was that the power of the "signal" was by orders of magnitude lower than the safe level adopted by the EM safety standard in the USA for that frequency range. Nonetheless, possible health effects from exposure to weak EM microwaves have been taken seriously. In 1965 the Pentagon launched the Project PANDORA, a secret scientific investigation of behavioral and biological effects of microwaves similar to those used for exposure of the U.S. Embassy in Moscow. The project involved CIA, DARPA, the Army and the Navy. The results were not conclusive, little was learned, interest waned, and PANDORA ended in 1970. There is an opinion concerning PANDORA that the military departments of the USA and USSR were diligently playing the disinformation game, at least at the end of this project, and this game could not continue longer (Riebling, 2004). However, it should be emphasized that the inconclusive results were related to EM mind control rather than to the non-thermal biological effects from EMFs. The latter have just been developing since then, and we now have vast evidence for such effects, despite the lack of financing due to the discussed opposition by the manufacturers of mobile communication systems and electric appliances.

In 1975, WRAIR (Walter Reed Army Institute of Research) and DARPA initiated research into possible use of the so called microwave auditory effect for wireless voice transfer (Justesen, 1975). Microwave auditory effect is the hearing of short pulses of EM microwaves irradiating the head of a human. The effect is based on non-uniform thermal expansion of living tissues in the skull, which generates sound pulses, under pulsed microwaves. Since then, the effect has been thoroughly studied (Lin, 2004b) and shown to be effective only at rather high microwave powers, which significantly reduces its possible application as a clandestine EM mind control technique. Nonetheless, the Air Force Research Laboratory supported the works on microwave hearing that lasted from 1994 to at least 2002. The work within the SBIR Contract F41624-95-C-9007 was conducted under the title "Communicating Via the

[3] The author of the present article (VB) does not necessarily share the opinions given in this report.

Microwave Auditory Effect" and the results of that work are still classified, which is known from the US Air Force response to FOIA request dated 1999.

Set out in 2005 by several US institutions and supported by DARPA, the project BICA (Biologically Inspired Cognitive Architectures) aimed to combine knowledge of neuroscientists, psychologists, and computer scientists in order to map and engineer the human mind, is now closed (Coughlin, 2007). Also closed was a related project, Architectures for Cognitive Information Processing, which sought to develop special computer hardware. A possible reason for this is not enough progress in this research.

It should be noted that according to latest open information, military departments and agencies and security establishments are rather far from any practical realization of EM mind control. Future novelties discussed in this area are limited by those where military personal could receive commands and monitor equipment via electrodes implanted in their brains (Hoag, 2003); hundreds of electrodes can be implanted. However, EM mind control is also debated (Sazaki et al., 2004).

Among 10 newest weapon technologies (Hecht, 2006), only three are based on beamed EM radiation: high-energy lasers, high-power microwave bombs, and Active Denial System (microwave guns). All the three are high-power technologies, and only the latter one, also called non-lethal crowd-control weapon, is to affect people.

Microwave beams, about 0.1 THz EMF, may typically be irradiated by a 1–2-meter antenna powered by a generator mounted on a vehicle, in crowd control situations. Such a radiation is absorbed by human skin within a few seconds and does result in intense pain. Serious injury is possible if people delay escaping the radiation. Tests have shown that microwave guns, when used in built-up areas, can produce hotspots due to reflections off the surface of buildings, the ground or water. Then peak power may be several times higher than that of the main beam. Obviously, such EM weapon, causing just the avoidance response, has nothing to do with EM mind control that implies secret incognizable influence. However, as is easily seen, technically, nothing prevents from using the microwave beams at low powers to insensibly affect human brain, of course to the extent that is permitted by physical laws.

Data on EM weapons in the former USSR and Russia are less available than those in the USA. Information on this may be found in newspapers and in the Internet. The number of journal articles is limited. Unlike scientific data, information of this sort could hardly be tested on its correctness. It would require a separate study. Here, some facts and short comments, based in particular on the book (Kandyba, 1995) and the personal experience of the author (VB), are presented.

In 1853, A. Butlerov, a prominent Russian chemist of the time, put forward a hypothesis that "neural currents" of an organism are identical to the electrical currents in conductors and assumed that brains of different humans may communicate via propagating signals of electrical nature. This hypothesis has been developed in works by Yu. Okhorovich in 1877 and by V. Bekhterev in 1910-1920s. Bekhterev has established, for the first time in the world, the Institute on Research into Brain and Psychic Activity. In 1913, Prof. V. Pravdich-Neminskii records the first EEG, and in 1920, acad. P.P. Lazarev considers an electromagnetic nature of mental influences. In 1923, B. Kazhinskii, a researcher in an academic institution, proposed a device reproducing the EM oscillations similar to natural brain waves, i.e. an "artificial thought", and raises the question about distant control on humans, hence, EM weapons (Kazhinskii, 1963).

Since 1932, L. Vassiliev and S. Turlygin continue the studies on mental hypnosis, its physical nature, and the role of EM radiations in it. S. Turlygin assumed that brain waves were EM waves of 1.8–2.1 mm in wavelength, however noted that brain radiation differed from EM radiations in some aspects. In 1959, there appear the book "Mysterious phenomena of the human mind" by L. Vassiliev and the newspaper "Radiotransmission of thoughts" in Komsomolskaya Pravda of 15 Nov. Technologies for long-distant mental information transfer were studied in 1960s at The Moscow Scientific and Technical Society for Radioengineering, Electronics and Communication (I. Kogan, V. Kaznacheev) and at The Institute of Automation and Electroenergetics, Siberian Division of the USSR Academy of Sciences, Novosibirsk (V. Perov).

Not commenting the scientific merit of those studies, which were the product of their time, it is important to emphasize their historical value and to pay a tribute to the pioneers of EM neurotechnology.

Many research projects into medical applications of RF EMFs and their biological effects were carried out in the USSR in the 1930s in the All-Union Institute of Experimental Medicine and in the State Institute for Physical Therapy.

In 1950-60s, the work to standardize EMFs was under way in research institutes of occupational hygiene and diseases (Moscow, St. Petersburg, Kharkov, Gorky), and also in institutes of general and communal hygiene (Kiev, Moscow). The methodological principle of hygienic standardization, which was used in the USSR, included the following studies: (a) short-term studies on laboratory animals exposed to high- and low-intensity EMFs, (b) long-term experiments with low intensities, (c) hygienic and clinical-physiological investigations of the public health under respective occupational conditions both on volunteers and with the population in the areas near EMF sources.

In the USSR, the first standard, the Provisional Sanitary Rules of Work with Centimeter Wave Generators (no.273–58), was approved and enforced by the Ministry of Public Health of the USSR in 1958. This standard incorporated the standardized levels of EM fields in the frequency range of 300 MHz – 30 GHz, and of 100 kHz – 300 MHz for occupational exposures.

Comprehensive experiments were staged to justify the permissible EMFs for the general public at the Institute of Occupational Hygiene and Diseases of the Academy of Medical Sciences of the USSR (now the Occupational Medicine Institute) in Moscow; at the All-Union Research Institute of Labor Protection of the All-Union Central Council of Trade Unions (Leningrad), at the All-Union Institute of Standardization in Machine Building (Moscow).

These general works on EM safety levels have brought out clearly and indisputably that weak EM radiations affect humans and that one of the most vulnerable physiological systems is a nervous system.

In the USA, the first national standard of electromagnetic safety in the radio frequency range was issued in 1966 by the US National Institute of Standards (USAS C95.1–66). The EM safety levels adopted by the USSR and the USA standards differed in a thousand times. The West standard permitted exposure of humans to much more powerful EM radiations. This indicated the lack of knowledge concerning the theoretical fundamentals of the phenomenon and the difference in scientific approaches to it. This misbalance continues existing even now. And historically, Russia remains one of the central places for studying the non-thermal biological effects of EMFs. For example, the Institute of Theoretical and Experimental Biophysics and the Institute of Cell Biophysics of the Russian Academy of Sciences, Puschino Scientific Center, have the research direction "Mechanisms of EMF effects on biological systems" as one of the basic directions, and the majority of their publications in this direction relate to the non-thermal effects.

A powerful impetus to research into biological effects of EM radiations was given by the school of N.D. Devyatkov in the former USSR that developed EM generators of microwave radiation in the 1960s. These works were reproduced abroad. From the very beginning, it became clear that microwaves had marked biological effects (Devyatkov, 1973). Of special interest was the fact that the microwave power was frequently too low to cause an appreciable heating of tissues. At the same time, a quantum of radiation energy was two orders of magnitude smaller than the characteristic energy of chemical transformations kT. Moreover, microwave effects were observable only at selected frequencies which suggested their non-thermal nature. Also, they depended on low-frequency modulations. Researchers have received an instrument of studying biological effects of the shorter EM waves that had a potential of affecting human mind.

As was discussed in literature, in 1960, the U.S. embassy in Moscow was being bombarded by low-level EM radiation. This fact has entailed marked worldwide growth of military research into microwave weapons.

In 1970, a state commission of scientific experts on mental hypnosis was appointed at the direction of a secretary of Central Committee of the CPSU. In 1970s, leading research centers studying brain radiations are located in Moscow, Leningrad, Kiev, Novosibirsk, Minsk, Rostov, Alma-Ata, Gorki, Perm, and Sverdlovsk. In Kiev, technical solutions are developing at the factory "Arsenal" (V. Kandyba) and fundamental questions at the scientific production association "Otklik" (S. Sit'ko); the latter was established by a governmental regulation of Council of Ministers of USSR. Many experiments were conducted with participation of N. Kulagina, who displayed the ability to mentally affect physical measurement instrumentation. These effects have been repeatedly documented in studies of many noted scientists in different institutes. Electromagnetic nature of those effects has been discussing.

Since approximately 1973, the works in this direction have become classified. In 1973, the first installation was constructed and tested, which induced sleep in humans exposed to a microwave EM radiation (radiosleep). The work was conducted by the Institute of Radioelectronics of the Academy of Sciences of the USSR and some effective results were reported after experiments made together with a military department.

It is hardly possible to check if the above information is correct. Nonetheless, some conclusions are possible for example from analyzing the facts about microwave-induced sleep. Scientific literature includes only limited number of such studies, despite their potential significance. Direct EMF-induced sleep has been observed in

(Subbotina et al., 2004) under RF EMF exposure[4] and in (Ban'kov, 1972, Wang et al., 1997) under ELF EM fields. A lot of studies have been conducted in which only indirect influences of EMFs on sleep have been found, see for example (Akerstedt et al., 1999, Borbely et al., 1999, Altpeter et al., 2006). At that, a variety of sleep disturbances under EMF exposures are discussed much more often (Mann and Roschke, 2004, Huber et al., 2003). It is interesting that nothing prevented researchers from changing frequencies, powers, modulations of the microwaves they used to find those inducing sleep. However this has not been done, evidently. This, of course, would be done, if the effect existed. The only microwaves inaccessible to civil researchers were high-power microwaves. Most likely, such EMFs have been examined in the above mentioned semi-military research of radiosleep in1973. Such microwaves heat a body not only on its surface but also over a significant depth of the organism. This confounds the organism's physiological responses and might cause a sleep. Another scenario involves microwave auditory effect, since the information on that research mentioned the microwave-induced acoustic oscillations in the brain; this is possible also only at high powers. Any way, high-power microwaves are of thermal influence and have a little to do with the subject of this review.

There was approximately 10-year interval during which Kiev coordinating research center "Otklik" has been financially secured. Judging from available open literature, the main achievement of this center could be presented by the patent (Sit'ko, 1996). The invention relates to a method of medical treating a series of functional disturbances by exposure of biologically active points to a very weak microwave radiation. There were multiple observations of non-thermal biological effects from microwaves including such effects from noise microwave radiations. No other outstanding results are known.

In 1982, the State Institute of Problems of Physics and Technology was established by the Ministry of Instrument Engineering. Judging from the contents of the books published by the Institute, it was engaged in studies of biological effects of EM fields and radiations, see for example (Lupichev, 1989). That time, the author of this review (VB) was affiliated with a theoretical department of the Institute and was searching physical mechanisms that could explain biological EMF reception. A few collections of works of the Institute, which were published during 1989–2001, show that there was no significant theoretical or experimental insight in the nature of those effects. Now the Institute is significantly reduced and is no longer a center for research in bioelectromagnetics.

In 1982, there was established a laboratory for research into the human and organisms radiations. In a few years of intensive research, the results had been published reporting no other radiations except those known to modern physics (Gulyaev and Godik, 1983, Gulyaev et al., 1984, Godik and Gulyaev, 1991).

In 1989, the USSR State Committee on Science and Technology (SCST) issued the Regulation No.724 "on appointment of the Center of Non-Conventional Technologies of the SCST USSR." A year later, this structure was reformatted into the Inter-branch Scientific and Technical Center for Venture Non-Conventional Technologies (ISTC VENT) with a status of a non-state enterprise. In 1996, the International Institute for Theoretical and Applied Physics (IITAP) was established under the aegis of the Russian Academy of Natural Sciences, a civil society organization, united many noted scientists (not to confuse with the official Russian Academy of Sciences). The number of workers varied between 3 and 30 depending on the available financial support. The main goal of all these three institutions, which were headed by the late Dr. A.E. Akimov, was to investigate into the so-called torsion fields and related technologies. I was signed up by the SCST in 1990 and had been working there and then in the daughter institutions until 2000, i.e. for about 10 years.

These institutions, particularly ISTC VENT, are often noted in the Internet, newspapers, books, and popular journals as a leading institution where the so called psychotronic generators have been developed and a large amount of research has been deployed into psychotronics (Tsygankov and Lopatin, 1999). At that, far too much attention has been drawn to the fact itself that such studies took place and nothing was said about the results of these studies. However, the results were rather disappointing than satisfying, at least to the author of the present review, who was one of the top researchers at these institutions.

No special physics has been found behind the generators proposed personally by Akimov. The generators of a few different constructions have been replicated in some dozens of copies. They were distributed by A.E. Akimov mainly among researchers in non-academic institutions to research into possible effects of torsion fields, or more precisely, into possible effects caused by the generators of a given design. Many such studies reported that the generators induced measurable effects in physical, chemical, or biological systems (Zarubin, 2007). However, to the best of my knowledge, no one academic institution has found any effects from exposure to the supposed fields of these generators. And no replication academic studies have been organized. As well, there is no reliable information

[4] The author of the present article (VB) has managed to find the only publication on this subject.

about any industrial production of such generators or about research and development into mind control effects of torsion fields.

Generators, similar to the torsion field generators by their declared abilities, are known from the works of many other inventors, both in the former Soviet block countries and the Russian Federation. For example, report (Maire and LaMothe, 1975) provides information about such psychotronic generators, however the description is far from scientific one.

The failure to observe distinct effects of the torsion field generators does not necessarily mean non-existence of the effects that are at variance with the up-to-date science. Torsion fields do exist as a mathematical object that might find a reference in real physical world later (Shipov, 1998). At present, torsion fields are considered to be a physical basis for the paranormal.

Possible weapon technologies based on different paranormal phenomena have been discussing for many decades (Alexander, 1980). This article comments the results of a few unclassified studies (actually, it just lists these studies) in a sense that the "phenomena" described—telepathy, precognition, telekinesis, out-of-body experience, etc.—are real effects, probably of electromagnetic origin, that could be used for military needs.

Referencing the old declassified report (Maire and LaMothe, 1975), Alexander writes: "The reality of paranormal events has been accepted by Soviet researchers, and theories have been developed to explain and study those events. The Soviets have further developed techniques to control and actively employ their knowledge of parapsychology … The amount of information scientifically verified by the Soviets is voluminous". These categorical statements do not actually reflect the state-of-art. It is, of course, strange that the author could not see a variety of different opinions among former Soviet scientists regarding paranormal studies and their results. The overwhelming majority of researchers would dispute the existence of such effects. This situation has not changed since then and now the Russian Academy of Sciences stands aside from paranormal studies as well as before (Ginzburg, 1999). The reason for this is that the paranormal is out of science by methodological grounds.

# Electromagnetic brain control

We will now survey modern neurotechnologies, in which EM fields play a crucial role.

Any technology focused on the central nervous system, in particular the brain, is referred to as neurotechnology. Neurotechnology approaches are often classified into a few general categories: invasive versus noninvasive or passive imaging versus active manipulation. Also, they may be viewed as real-time technique, directly displaying neural processes, or that averaging incoming signals to show it later. Averaging over time or space allows collecting useful information to exceed a noise level. With regard to EM mind control, naturally, we will only consider the noninvasive methods with a little attention to the time character, bearing in mind the terms "brain reading" or "brain mapping" for passive imaging and "brain stimulation" for active manipulation.

## Magnetic resonance imaging

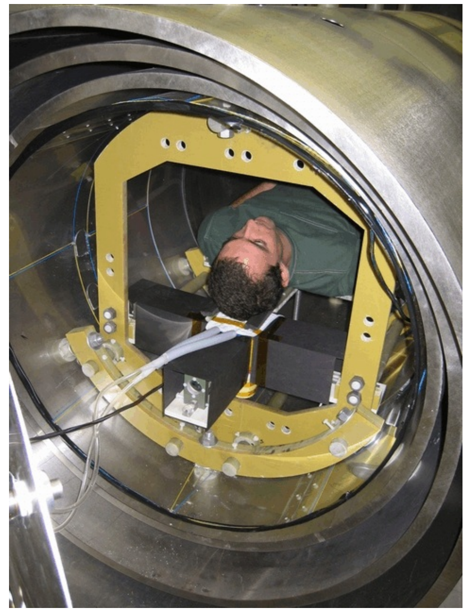
Magnetic resonance imaging is an extensively used technique (dozens of thousands MRI units worldwide) designed primarily for medical practice and research (Westbrook et al., 2005). It produces high quality images of the inside of the human body. There are a variety of modern MRI devices, produced by different manufacturers. MRI is based on the physics of nuclear magnetic resonance (NMR).

The basic principles of NMR are those of a spin motion. Substance consists of atoms. Any atom has an electronic shell and a nucleus. Some nuclei having at least one unpaired constituent subparticle (proton or neutron) have a magnetic moment, like a compass needle. In a dc MF, nuclear magnetic moments behave like spinning tops in the gravity field, i.e. they precess. The frequency of precession, proportional to the dc MF strength, is called NMR frequency. When an additional ac MF of that frequency excites the magnetic moments they begin to emit a RF EM radiation. The MFs of other frequencies cannot cause the moments to emit. Therefore, this effect is a resonance, hence NMR.

A simplest method, MRI scanners utilize, is as follows. The dc MF slightly changes over the scanned object. Consequently, at the NMR frequency of the ac MF, the resonance conditions are fulfilled just in a small area of the object, usually a narrow slice of it. Weak RF radiation emitted by the nuclei of this slice is picked up by a special coil antenna and passed to a computer. Then the dc MF changes so that the resonance conditions are fulfilled within the next neighboring slice. After scanning the object in three directions, a computer program reconstructs a 3D distribution (MRI images) of the radiation emitted by the nuclei. The more the density of atoms and molecules carrying this sort of nuclei, the more the radiation intensity is. Real modern devices are based on more complex protocols with repetitive trains of ac MF pulses.

Not all magnetic nuclei are suitable for MRI. It can only be performed on naturally abundant nuclei. Most widely used are nuclei $^{1}H$ which are present in water molecules $H_2O$ and in most of other biologically significant molecules. The distributions of this element over tissues bring much information. Also used in MRI studies are $^{13}C$, $^{14}N$, $^{19}F$, $^{23}Na$, $^{31}P$, $^{129}Xe$, and others.

To detect fast changes in an organ, like those in brain areas during their functioning at cognition, quick scans are needed. However, it is clear that the quicker the scan the worse the resolution. The only way is to increase the dc MF magnitude, since the radiation intensity of nuclei rapidly, as the fourth power, grows with the MF strength. Therefore, strong magnetic fields, usually of a few Tesla in magnitude,[5] are used in functional MRI studies. Time resolution in such devices is in the order of seconds and spatial resolution is about 1 mm and less. For these reasons, fMRI has become very popular in brain research: signals from local brain areas may be collected within milliseconds, which is enough to study their specific functions.



A new advanced laser magnetometer will probably be a complementary tool for brain studies.

Two most powerful fMRI machines working at 9.4 T are at the University of Illinois (Chicago) and at the University of Minnesota. The weight of their magnets is hundreds tons. Probably, wide use of such machines will be limited by their high cost and possible health problems for patients. Though there are no immediate side effects from MRI scanning (Schenck, 2005), opinions on its long-term health consequences are diverse (McCann et al., 1998, Ikehata et al., 1999, Takashima et al., 2004, Miyakoshi, 2006).

It is reported, these new MRI machine can track brain neurons. It is a metaphor. Since the number of neurons in a human brain is about $10^{11}$, to track a single neuron would require impossible resolution. Evidently, it is brain areas bound with neurons rather than the neurons themselves that could be tracked.

At the same time, brain mapping can provide much information. Even if only $n$=12 parts of the brain are being monitored with regard to their activity, and only two possible states of each, activated or not activated, are taken into account, there is as many as $\exp(2n/3)/\pi$, i.e. about a thousand possible brain states that could be distinguished. Since the resolution of brain mapping technique is somewhat higher and it grows constantly, the perspective of brain mapping is great. If it were not ethical reasons, it could find numerous practical applications besides medicine.

However, there are severe physical constraints for MRI applications. For example, a brain-mapping devices set in airports could screen passengers' brain patterns to detect those typical to terrorists (Pasternak, 2000). But we should remember that modern MRI devices use strong static magnetic fields on the order of Tesla and mainly take minutes to scan a human head in fixed position. The stronger the magnetic field and the longer the time of signal accumulation, the better the resolution. Even at that, it needs to remove all metal things and to dispose the head in close proximity to the apparatus. All this makes it hopeless to scan brain without a person being informed and specially prepared. But if individual knew about the fact of screening, who knows what kind of thoughts they would prepare for brain reading machine?

The physical constraints indicated (strong MF, order-of-minute scanning time, immobilized object) are of principle character; these could not be overcome in the course of technical improvements. However, one new magnetometry method is developing, with no need in a strong MF (Savukov et al., 2006). Partially supported by DARPA, the method is promising for MRI-like scanning (Savukov et al., 2005). It also could make scans distantly, as it uses laser beams for gathering information. But this technique now is in its infancy.

---

[5] Such fields are called strong fields because they are million times greater than the level of the natural geomagnetic field, about 50 μT.

Even with this advanced high-tech solutions, it would not be possible to read thoughts in the direct meaning. What is possible now is only to distinguish between pre-given thoughts or senses. With regard to EM mind control, we are interested in the senses of thoughts rather than in their locations in neurons or any other time-space ordering. Apparently, senses are distributed between many neurons, and will remain inaccessible for screening by the scientific methods for a long time.

We do not consider positron emission tomography (PET), a medical technique, which also produces 3D images of functional processes in the human body, since their use is based on introducing radioactive chemicals into the body.

## Magnetoencephalography

Magnetoencephalography, or MEG, has its starting point in the so called SQUID (superconducting quantum interference device) technique. SQUID enables one to measure MFs as small as of the order of $10^{-15}$ T, while electrically active nerve tissue in the brain produce MFs some three orders higher. Biomagnetic measurements using SQUID technique seem now so perfect that it has become possible even to distinguish between cancer and benign hyperplasia by their magnetic emissions (Anninos et al., 2003b).

Usually, the magnetic activity of brain is recorded by an array of SQUIDs arranged in many points, or channels, within the special helmet on the head (Hamalainen et al., 1993). This makes it possible to reconstruct 3D distribution of electric currents of brain activity. The signals from SQUIDs are recorded by a computerized data acquisition system and processed by the so-called source localization techniques, software algorithms to disentangle contributions of various active brain areas in the signals. Then the data are displayed, and may be interpreted by trained personal for many reasons. Compared to EEG, MEG has higher resolution and sensitivity. There are various MEG devices. The most advanced system, produced by Elekta Neuromag, has 510 SQUIDs and up to 306 MEG channels at 5 kHz sampling rate. At present, MEG is regarded as the most efficient and sophisticated method for tracking brain activity in real-time.

When focusing on highest resolution, complications of interpreting MEG data are encountered that relate to the necessity of knowing the anatomical peculiarities of an individual's head (Knosche et al., 2005). This requires combination of MEG with other mapping methods, like MRI or NMR (Volegov et al., 2004). In general, the source localization technique is a model-based and ambiguous procedure, which sets a natural limit on the accuracy of the computed spatial distribution of the brain activity (Lutkenhoner, 2003). However, this does not prevent MEG analysis of brain activity associated with hand movements (Takahashi et al., 2004), human syntax processing (Kubota et al., 2003, Halgren et al., 2002), audio pitch processing (Krumbholz et al., 2003, Lutkenhoner et al., 2006), exposure to visual and auditory stimuli (Sokolov et al., 2004), and others (Knosche et al., 2005).

Apparently, MEG technique is presently close to the ability of discerning between *selected* mental activities caused by stimuli of different nature. It is very interesting that MEG patterns allow detecting neural responses associated with linguistic modifications of phrase structure. At the same time, no indications have been found in scientific literature that one could determine, by MEG, different thoughts or intentions of an individual, which were not selected in advance. Hence, in this manner, no mind reading in its direct sense is possible yet. It should be noted also that spatial resolution and sensitivity of MEG crucially depends on the close proximity of the SQUID sensors to the human head. Simple physical constraints dictate no MEG would be possible at a distance greater than about 0.5–1 m.

The report (Pinneo and Hall, 1975) is sometime cited to support the possibility of mind reading by EEG analysis. It was shown that EEG responses for covert speech mimic those of overt speech for the same subject, electrode and spoken word. Since thoughts accompanied by covert speech are known to induce muscle activity somewhat similar to that of the overt speech, principal possibility exists of detecting such thoughts by analyzing EEG patterns. The authors had no journal publications following the report; so we might guess that they have failed to realize their idea at that time. However now, with rapid development of accurate physical measurements, the idea is reviving. NASA scientists have learned to detect silent reading using nerve signals in the throat that control covert speech. In preliminary experiments, small sensors placed on the neck could convert nerve signals and transmit information to a computer, which translated the signals into words, with a special program (Bluck, 2004). On the other hand, some simple parameters of the covert speech and human vision are now detectable by fMRI, as is studied in (Huang et al., 2007, Kamitani and Tong, 2006). One might assume that a combination of these two techniques could bring something similar to mind reading. To put it more precisely, it would be "mind eavesdropping" rather than mind reading.

## Transcranial magnetic stimulation

Transcranial magnetic stimulation, or TMS, as follows from its name, is a stimulation of the brain by external magnetic fields from outside the cranium. It is very simple and inexpensive method that allows exciting the brain regions locally. The method has been developing since 1980s (Hess et al., 1986), and there are no obvious reasons why it had not been known before. During TMS, an electromagnet, or inductor, is positioned close to the skull and a magnetic pulse is generated when the inductor is energized by a pulsed electric current. The MF gets into the brain through the skull freely, without being distorted. Pulses of the MF induce eddy electric currents in the brain tissue close to the inductor. The position of the inductor determines areas where the maximum of the current density takes place. In these areas, the electric currents can cause the neurons to fire or become active since nerve impulses are excited by polarization and membrane electrical currents. In this way, it is possible to excite or suppress the activity of different brain regions and activate certain mind functions.

Studies in General Physics Institute RAS. Standard magnetic stimulation by weak MFs and electric fields alters cognitive functions.

A big advantage of TMS in comparison with other methods of brain activation is in that there is no need in surgery or any other invasion into the head, even no electrodes are needed. TMS is also a tool for mapping out brain activity as it can study associations between the stimulation of different brain areas and the reactions which follow. This helps understand the function of different parts of the brain.

At present, the TMS has clear implications for treatment of individuals suffering from many brain disorders like epilepsy, depression, attention deficit, and migraine (Fregni et al., 2005, Clarke et al., 2006). Also, it has likely implications for development as a scientific method in neurology (Cowey, 2005, Kobayashi and Pascual-Leone, 2003, Siebner and Rothwell, 2003, Verdon et al., 2004).

Usually, special figure-8 shaped loop inductors are used to have better focusing on a given brain area. The MF under the inductors is a highly non-uniform single or repetitive MF pulses of about 0.1 ms duration and of a few Tesla in magnitude so that induced electric field pulses in the brain, of the order of 100 V/m, can trigger action potentials of underlying cortical neurons. There is paradoxical evidence that MF pulses with magnitude as small as of the order of pT also affect human brain functions (Anninos et al., 2006). TMS is limited to mostly surface brain stimulation, since the MF quickly decays with distance from the inductor. The long-term effects on neural functions are still unclear.

Evidently, this technique implies positioning of a magnetic inductor directly on the head. Therefore, it is impossible to remotely control mind in this manner.

## Standard magnetic stimulation

In order to distinguish a general type of magnetic stimulation that significantly differs from those relatively complex magnetic stimulations that were described above, a term “standard magnetic stimulation” is used below.

With the standard magnetic stimulation, a brain is exposed to a uniform MF, the source of which, usually a Helmholtz pair of coils, is greater in size than the head. With this type of stimulation, all parts of the brain are exposed to the same MF so that no mapping information is possible.

Standard stimulation is used mainly in scientific purposes focused on the general effects of EMFs on biological systems. In this case, the fundamental mechanisms underlying biomagnetic reception are of primary interest. Since the fundamental mechanisms are associated with the properties of yet unknown targets for the MF in a biological tissue, and such targets are assumed to be of molecular or subcellular size, the position of these targets in the brain or in other tissues is immaterial. Then, the use of uniform MFs, which are easily controllable, is justified. In that way, standard magnetic stimulation enables a researcher to eliminate a possible independent factor of biological influence, the magnitude of the heterogeneity of EMFs that could affect organisms in its own way.

As well, standard stimulation can simulate well the natural electromagnetic conditions featured by the sources of EM fields and radiations that are relatively far from humans.

At the same time, providing rich information about molecular and chemical processes under EM exposure in general, standard magnetic stimulation gives nothing like a space distribution of those processes. The information appears to be space-averaged.

The laboratory systems of the standard magnetic exposure are usually from half-a-meter to a meter in size. Sometimes, larger systems are used, where a whole-body EM exposure is preferred.

It should be noted that standard magnetic stimulation is an only type of brain magnetic stimulation that can be organized as a remote noncontiguous influence. The exposure system is not necessarily like the Helmholtz system of coils: it may be designed as a lengthy wired construct.

## Microwave hearing effect

The microwave auditory phenomenon, or the microwave hearing effect, first observed in 1940s (Elder and Chou, 2003), is the hearing of short pulses of EM microwaves incident on the head of a human or an animal (Frey, 1961, Guy et al., 1975, Lin, 1978). For example, single 10-μs pulses of 2.45 GHz microwave energy may be heard as clicks at rather high peak powers corresponding to energy flux densities above 4 $W/cm^2$ or at SAR of greater than 1.6 kW/kg (Lin, 2004a). A series of pulses can be heard as an audible tone at a frequency corresponding to that of the pulse repetition rate. The more the power, the louder the clicks are. It is clear, therefore, that, depending on the modulation signal, modulated microwaves were found to produce sounds, which seemed to emanate from within the head (Justesen, 1975). This latter work indicates that with the pulse-rate modulation it was possible to transmit even some words; however it has never been verified in scientific literature.

In (Justesen, 1975), the level 10 $mW/cm^2$ of a mean microwave power density is cited as a threshold for this effect, and the work (Guy et al., 1975) gives 100 times less value for hearing of separate clicks and "chirps". It essentially depends on the microwave or RF pulse parameters.

One would think the auditory effect might be used in communications. However a high power, which is necessary to cause it, makes it hazardous to one's health. Even if a signal with audio quality as low as within the band 500 Hz modulates the repetition rate of microwave pulses with the above parameters, the average microwave energy flux density is about 20 $mW/cm^2$. It is high enough to cause heating of the head structures and it exceeds known human safety standards (ICNIRP, 1998). Exposure to such microwaves may be dangerous to human health: it is known to be accompanied by dizziness, headaches, and other long-term effects (Belyaev, 2005). There is a note in the Internet that research by NASA in the 1970s showed microwave hearing occurs even at low power density, however neither the power level nor the source of information has been provided.

An important result of numerous theoretical and experimental studies of the microwave auditory effect (Lin, 1990) consists in the following. The effect does not arise from an interaction of microwaves directly with the auditory nerves or neurons of the CNS. Being absorbed by soft tissues in the head, the microwave pulses initiate thermoelastic waves of acoustic pressure that travel to the inner ear where they excite cochlear receptors, like usual sound waves do. According to the review (Elder and Chou, 2003) effective frequencies for the effect range from 2.4 MHz to 10 GHz, and the fundamental frequency of the induced sounds is independent of the EMF frequency and dependent upon head dimensions and individual particularities. For these reasons it is hardly possible to transfer words or phrases to the brain in this way. Obviously, physical reasons prevent generation of sounds with wide spectrum, which severely impedes brain identification of words, or voice recognition.

Some people, however, suppose that this effect is used for mind control. The author of (McMurtrey, 2005) discussed methods for and experiments on recording sounds in proximity to the head of individuals, potentially subjected to microwave harassment. The literature is claimed to be scientific, however, no similar publications by this author have been found in known scientific journals. We add that the results of a few such home-made experiments are inconclusive due to methodological failure.

A number of patents are usually referenced by those who insist microwave hearing may be used for EM mind control. Another modality for implanting information into human mind was connected with a widespread but rather naive idea that mind activity may be well characterized by the brain electrical activity observed, for example, by EEG in the form of so called brain waves. Accordingly, as was assumed, electric stimulation of the brain by modulated signals similar to brain waves could transfer information into the mind. We have now to investigate some patents, which are often cited, focusing on the extent of their consistency, either with physics or with the subject of our study.

There is a huge amount of ill-founded speculations around the mind control theme. It is often that irrelevant information is presented to readers as a conclusive evidence for this or that thesis. For example, www.exoticwarfareproof.org lists a few patents "for Electromagnetics and Biomanipulation" that allegedly prove the existence of mind control technology.

It should be noted that the fact of the existence of a patent does not necessarily prove that the physical processes described in the patent might actually take place. In fact, a significant part of patents worldwide have never been confirmed by corresponding devices, and mental constructs suggested could not be embodied because the processes they are based on had no relation to real physical world. It does happen often, since patenting takes into account only practical aspects of a supposed invention and not its scientific grounds.

It is rather difficult to comment on some patents, because there is no matter to comment on: only general idea is presented without any workup. To this group of patents we relate USP3393279 "Nervous System Excitation Device".

The next group of patents may be featured as that having no relation to EM mind control, since the necessary manipulations include a contact interaction with human head or body. For example, a patented method uses electrodes fixed on the skull or implantable electrodes and cannot be used secretly. Patents of this group are gathering in Table 1. Descriptions of these documents are available. Table 1 contains the numbers of the patents, their titles, and our brief comments.

Table 1

| Pat US# | Title | Comment |
|---|---|---|
| 3629521 | Hearing systems | Contact influence |
| 3646940 | Implantable electronic stimulator electrode and method | Uses implantable electrodes and cannot be used secretly |
| 3727616 | Electronic system for the stimulation of biological systems | The same |
| 3835833 | Method for obtaining neurophysiologic effects | Electrodes are positioned on the body |
| 3837331 | System and method for controlling the nervous system of a living organism | Electrodes are positioned on the head |
| 3967616 | Multichannel system for and a multifactor method of controlling the nervous system of a living organism | Set of electrodes affixed to the skull |
| 4335710 | Device for the induction of specific brain wave patterns | The same |
| 4834701 | Apparatus for inducing frequency reduction in brain wave | Usage of sound signals to affect brain |
| 4883067 | Method and apparatus for translating the EEG into music to induce and control various psychological and physiological states and to control a musical instrument | Electroencephalogram (EEG) is obtained via electrodes located on the scalp. Then a signal processor converts the EEG into music, which is acoustically fed back to the brain. |
| 5036858 | Method and apparatus for changing brain wave frequency | The method uses electrodes positioned on the head to take a signal, which then is processed by a computer, converted to an acoustic signal and returned through headphones |
| 5123899 | Method and system for altering consciousness | Sounds are used to affect human consciousness |
| 5213562 | Method of inducing mental, emotional and physical states of consciousness, including specific mental activity, in human beings | It is a method of inducing various states of consciousness in human beings through generation of stereo audio signals having specific wave shapes |
| 5330414 | Brain wave inducing apparatus | A random signal generator is used to form, after a series of conversions, a light signal, emitted into the subject's eyes, in order to induce the desired brain wave from the subject |
| 5356368 | Method of and apparatus for inducing desired states of consciousness | A method of inducing various states of consciousness in human beings by audio signals converted from previously recorded EEG patterns |
| 5507291 | Method and an associated apparatus for remotely determining information as to person's emotional state | In this proposal, physiological or physical parameters of blood pressure, pulse rate, pupil size, respiration rate, and perspiration level (not the brain state) are measured remotely by use of the beamed/reflected EMFs. |
| 6011991 | Communication system and method including brain wave analysis and/or use of brain activity | This system is based on gathering EEG or MEG patterns |

It is interesting to comment on a few other patents with more details.

USP3951134 "Apparatus and method for remotely monitoring and altering brain waves". A method for remotely monitoring "brain waves" is suggested. High frequency, on the order of 100 MHz, transmitters radiate EM energy that is directed to the brain of a test subject. The radiated signals of different frequencies penetrate the skull of the subject and mix in the brain to yield an interference wave. In this way, the power of the wave may be focused on a desired area of the brain. Then, two signals, transmitted simultaneously, combine in the brain to form a resultant wave of frequency equal to the difference in frequencies of the incident signals, which enables one to separate it effectively. This interference wave is assumed to be modulated by radiations from the brain's natural electrical activity. Then, the modulated interference wave is re-transmitted by the brain and received by an antenna at a remote station. After it is demodulated and processed, it provides a profile of the subject's "brain waves". However, this idea suffers several serious physical flaws. (i) The wavelength of a 100-MHz wave is about 1 m, in the order of magnitude, which is far not enough to focus on a certain place in the brain. (ii) to produce the reflected signal at the difference frequency, brain tissue has to have nonlinear impedance, which is possible only at EM powers far exceeding thermal threshold. (iii) Natural electrical activity of the brain, if measured in the same units as the incident waves, is many orders lower than the natural noise of these incident waves; attempt to extract the brain signal from the reflected wave is hopeless. The author has no works indexed by the PubMed database, which indicates failure of this project. In this regard, it would be interesting to note the work (Petrosyan et al., 1995) where it was found out that liquid media and biological objects irradiated by microwaves begin emitting EM waves in the decimeter range above the thermal level. The response of the object to an RF radiation was measured by a microwave radiometer at 0.4 or 1 GHz in a frequency band of 50 MHz. They measured luminescence excitation spectra by scanning excitation frequency in a range 4–120 GHz. The spectra exhibited sharp peaks with fine structure at 51, 65, and 103 GHz that might carry information on the properties of irradiated biological objects. However, it is still very far from practical implementation with regard to brain scanning, not to mention mind reading. Hence, it is not suitable practically.

USP4858612 "A method and apparatus for simulation of hearing in mammals by introduction of a plurality of microwaves". It is also not suitable practically. It is a supposed hearing device for those having damaged auditory nerve or the auditory cortex. It is assumed that microwaves forming standing waves within a skull may be arranged so as to focus their power on the auditory cortex. The author suggests that the auditory cortex normally produces its own microwave radiation, allegedly "brain waves". External microwaves, modulated by a sound signal, simulate these brain waves and provide "hearing" of the sound. — In laboratory conditions, thoroughly picking up frequency and the geometry of microwave radiators with respect to a fixed head, it would be possible to find a configuration when absorption of the EM waves had a maximum within the auditory cortex. However, the Q-factor of such a skull resonator is so low that the gain would be minimal as compared to the case of no resonator, i.e. no standing waves. As to the suggestion that the auditory cortex can produce microwave radiation, it is, of course, a science fiction.

USP6506148 "Nervous system manipulation by electromagnetic fields from monitors". Not suitable practically. According to the patent, many video display terminals, when displaying pulsed images with frequencies near 0.5 or 2.4 Hz, emit pulsed EM fields sufficient to cause a sensory reaction of the skin; it is therefore possible to manipulate the nervous system of a subject by pulsing images displayed on a nearby monitor. The method is based on the statement that "Physiological effects have been observed in a human subject in response to stimulation of the skin with weak electromagnetic fields that are pulsed with certain frequencies". No convincing evidence for this has been given by the author. Despite a biological effect from exposure to a weak EM field of those frequencies could be real, its informational charge is poorly compared with that of the images displayed, so one could hardly speak of EMC. If the effect existed, it would be much easier to generate such a weak EM field without any VDTs.

USP4858612 "Hearing device". It is hypothesized that the mammalian brain generates and uses EM microwaves as an integral part of the functioning of the central and peripheral nervous systems. Based on this, it is assumed further that simulating the microwave radiation, which is allegedly produced by the auditory cortex, and introducing these simulated brain waves into the region of the auditory cortex could provide for intelligible sounds recognition. It should be stressed completely speculative character of this suggestion, which is based on an only anecdotal evidence (Bise, 1978).

USP3951134 "Apparatus and method for remotely monitoring and altering brain waves". In this proposal, EMFs are beamed to the brain of a subject in which they are modulated by the subject's brain waves and re-transmitted by the brain to a receiver. If this method were real, it would provide the information similar to EEG or MEG, at best. However, it is absolutely hopeless for technical reasons. The author has not addressed the physics of the processes of RF absorption, reflection and interference, nor the level of the brain generated EMFs. Any signal-to-noise analysis would immediately disclose physical inconsistency of this proposal.

USP5935054 "Magnetic excitation of sensory resonances". The nervous system of a subject is suggested to be influenced by a weak externally applied magnetic field with a frequency near 0.5 Hz that can excite the known physiological effect causing a somnolence. Within the framework of thermal-like mechanisms, a 0.5-Hz MF could cause a physiological reaction just at rather high amplitudes, when the MF induce eddy currents comparable with natural biocurrents in their density. This is milliTesla level that significantly exceeds known safety standards and may be applied only as a medical treatment under the strict professional control. At the same time, we know that non-thermal mechanisms of bioeffects from MFs are not prohibited by physics, and these mechanisms may explain biological effects of slowly varying MFs on the order of 100–200 nT. However, they are relatively seldom observed and even in this case this effect would have no relation to mind control, at least the effect the patent claims.

There are also patents that have clear and reasonable implication concerning the subject of mind control.

USP4877027 "Hearing system" (1989). It is supposed that high frequency EM radiation is projected to the head of a human being and the EM radiation is modulated to create signals that can be discerned regardless of the hearing ability of the person. Sound is suggested to be induced in the head of a person due to the microwave hearing effect. The microwave radiation is in the range 0.1–10 GHz, below about 3 $mW/cm^2$ in mean power density, and presents a series of bursts. The rate of bursts is modulated by the audio input to create the sensation of hearing in the person whose head is irradiated.

USP6587729 "Apparatus for audibly communicating speech using the radio frequency hearing effect" (2003), in which a special modulating signal is claimed. The modulating signal is the result of a frequency cut-off and a nonlinear distortion of the initial audio signal. This is to make the demodulation due to RF hearing effect intelligible.

One could see that a number of the above patents, cited by specialized mind control sites, are mostly irrelevant or not suitable for realizing EM mind control. The technical feasibility of a few relevant patents/methods remains undecided. As was said above, there are physical constraints significantly impeding voice recognition through the RF auditory effect. However, the patents preceding and following the USP4877027 are common in that they claim a specific type of the microwave modulation that would secure not only the hearing effect but voice recognition through hearing effect as well. Unfortunately, there are still no published scientific articles validating this way of communication. The authors are not in PubMed. The only indication is that corresponding military research are classified. However this would not be a crucial argument for the existence of such mind control technology.

## Brain-machine interfacing

Implanted electronics can give a significant impetus to the development of EM mind control, since special microdevices can be embedded directly into the brain. After the first works on electric brain stimulation by implanted electrodes (Delgado, 1952), many studies have shown that behavior of experimental animals can be changed in a controllable way. Using incentive signals applied to different brain areas through electrodes, the researchers can train animals to perform certain tasks. The level of complexity of reactions increases with the number of electrodes, which can be of about several hundred and more. The possibilities related to direct communication between the brain and an outer controlling system is discussed as "brain-machine interface" (Hoag, 2003).

With this type of EM mind control, there is no necessity of positioning sensors and inductors close to the brain, since the current level of micro- and nanoelectronics allows wireless neural data acquisition chips as small as of about 2 mm for a few hundred neural channels (Olsson and Wise, 2005). The same microelectrode arrays can be used both for reading brain signals from many neurons and for stimulating these by outer commands (Nam et al., 2006, Hofmann et al., 2006).

Rapid growth of nanotechnologies in very different areas makes it possible to produce both bioelectrodes, having enhanced biocompatible features, and microarrays of hundreds of electrodes with sizes in the micrometer range. Nanotechnology is crucial here to minimize also weight and power consumption of the array integrated electronic circuits.

Evidently, EM mind control via implantable nanoelectronics is not the EM mind control in its direct sense. Since it requires a brain surgery, it is impossible to think about implantable transceivers in human brain, besides some obvious cases of medical illnesses. At present, microelectrode arrays, designed to be implanted into the cerebral cortex and in peripheral nerves, provide means for improving injured visual and auditory systems.

However, in the future, the growth of the quantity of implantable nanosensors and of the power of computers and information processing may provide a new *quality* resulting in technological effects that we cannot imagine now.

# Experimental grounds for biological effects of superweak fields

Are there physical grounds to assume that EM mind control is possible? As was said above, any EM mind control should be based on general principles of EMF interaction with living objects.

Mankind just relatively recently began to use EM communication technologies in so dense a way. Therefore, we do not know and we cannot know now the long-term consequences of such a Janus-like progress. We have not had enough time to empirically observe the possible chronic EM effects. This partly depreciates the significance of any negative EM epidemiological studies. Laboratory studies regarding non-thermal biological effects arising from exposure to weak EM fields are difficult to replicate. However, this does not necessarily mean the absence or insignificance of those effects. Many social, ethical, and health problems arisen around non-thermal EM biological effects are discussed in (Slesin, 2007).

The power and frequency of electromagnetic waves are similar to the brightness and color of the optical radiation that human eyes discern. The eye sees the world colored, not gray. There is a great deal of scientific evidence for the "colored" perception of the electromagnetic waves by the human body. This means non-thermal effects are real. Why don't we observe those effects always and everywhere in laboratories? Because it would be very problematic to detect a 1% biological effect of EMFs in any scientific study, given the great variance in biological and epidemiological studies. Yet, such an effect, being real, entails huge social consequences in people who die. EM fields may be less evident but not less insidious than smoking. From the other side, there is no recognized physical theory of those effects. The U.S. EM safety standards and those proposed by WHO are 100 times more lenient, depending on frequency range, than the Russian standard. The latter is based on the observed biological effects under chronic EM exposures. There are many similar gaps in EM safety standards in other countries, too. It indicates the lack of theoretical knowledge in this area. At the same time, there is a great body of evidence in laboratory experiments.

A body of experimental evidence is gradually taking shape that testifies to biological activity of superweak MFs, lesser than 1 μT. The mean intensity of an ac MF in those observations is much lower than the possible level of a local dc field. Such experiments form a separate group since mechanisms for biological effectiveness of superweak fields seem to be different from those for the action of fields at the geomagnetic level and higher. The physical nature of biological effects from EM microwaves below thermal level, about 0.1 $mW/cm^2$, is also unknown at this time. Particularly paradoxical are effects of superweak EMFs with power density less than 1 $\mu W/cm^2$.

## Biological effects of low-frequency MFs

Earlier experimental evidence for the biological detection of superweak variable magnetic signals, up to 1 nT, is given in (Presman, 1970).

Changes in peroxidase activity in leukocytes of peripheral blood in rabbits upon a 3-h exposure to superweak MFs of 8 Hz were observed in (Vladimirskii et al., 1971). In those experiments MF strengths were 0.02, 0.2, 1, and 2 nT. At all of those field values they observed changes in cytochemical activity of neutrophiles as compared with controls. The changes varied from about 9±2 % at 0.02 nT to 72±23 % at 2 nT. The authors believe that this could bear witness to living systems being directly affected by geomagnetic storms.

Delgado et al. studied changes in morphological parameters of chicken embryo growth upon a 48-h exposure to pulsed MFs (Delgado et al., 1982). The body of evidence is insufficient to construct amplitude or frequency spectra; however a statistically significant effectiveness of regimes 0.12 μT 100 Hz and 1000 Hz has been shown.

Chick embryos were exposed in (Juutilainen et al., 1987) to sinusoidal 50 Hz MF during their first 2 days of development. The percentage of abnormal embryos was statistically significant, about 30% at 1.2 and 1.7 μT MFs, approximately twice as that in the sham-exposed control groups.

In the study (Liburdy et al., 1993) authors investigated whether a 60 Hz MF can act on cancer cells. The results showed that ac MFs can enhance breast cancer cell proliferation by blocking melatonin's natural oncostatic action. The effect had a threshold between 200 and 1200 nT. These data were confirmed in (Ishido et al., 2001) and challenged in (Dees et al., 1996).

(Rea et al., 1991) reported that 16 humans they had studied showed a sufficient sensitivity to an EMF to sense the switching on of a weak MF. Volunteers were exposed to an inhomogeneous MF, which varied from 2.9 μT in the region of their feet to 0.35 μT near their knees, and to 70 μT near their heads.

The influence of a 0.05–5 Hz, 100-nT sine-wave field on the pulsed activity of neurons in a mouse cerebellum section was observed in (Agadzhanian and Vlasova, 1992). The assays were conducted in a chamber shielded from external magnetic interferences.

(Kato et al., 1994) determined the action of a circularly polarized 50-Hz, 1-μT MF on the level of nocturnal melatonin density in mouse blood. Controls were animals placed in a similar exposure chamber with a residual field of less than 20 nT. By the end of a 6-week exposure in both chambers melatonin density was in controls 81.3±4.0 pg/ml, and in exposed groups 64.7±4.2 pg/ml. This difference disappeared when measurements were made a week after the exposure. Obviously, division into control and case groups here is fairly conditional, since exposure in fields of such a low intensity is in itself not indifferent to animals. In any case, however, the studies have demonstrated the effectiveness of fields at a level of 1 μT.

Works (Novikov, 1996) and (Fesenko et al., 1997) are devoted to investigations into the molecular polycondensation reaction of some amino acids in solutions exposed to a variable MF of about 20 nT parallel to a local dc MF of about the geomagnetic field. The MF had a frequency of several hertz, which corresponded to characteristic cyclotron frequencies of amino acid molecules. The very fact of MF being effective at such a low level was shown quite convincingly. There are evidences on the confirmation of those interesting assays in independent laboratories (Pazur, 2004, Comisso et al., 2006).

(Blank and Soo, 1996) determined the sensitivity limit for the activity of Na,K-ATPase enzyme in a medium with microsomes in relation to power-frequency MFs. The sensitivity level was 200–300 nT.

It was found in (West et al., 1996) that when a JB6 cell culture of mouse epidermis was exposed for several days to a 60-Hz, 1-μT MF against the background of a static laboratory MF, the number of cells grew by a factor of 1.2–2.4 as compared with controls.

(Akerstedt et al., 1999) studied the effect of nocturnal exposure to a 50-Hz, 1-μT MF on various physiological characteristics of human sleep (with 18 volunteers). They found that such an MF drastically curtailed the so-called slow sleep phase.

It was found in (Harland and Liburdy, 1997, Harland et al., 1999) that a 60-Hz, 0.28–1.7 μT MF suppressed the inhibitory action of melatonin and tamoxifen. Melatonin at a physiological concentration $10^{-9}$ M and tamoxifen at a pharmacological concentration $10^{-7}$ M were used to inhibit the growth of MCF-7 cancer cells in humans. The evidence was of importance since it pointed to a potential hazard of even very weak fields, and so the research was reproduced in another laboratory by other workers, see (Blackman et al., 2001). In all the cases, the results appeared to be the same, with inhibitory effects declining in a statistically significant manner by tens of percent.

The effect of exposure to combined ac MF 100 nT and dc MF 65 μT at 3–10 Hz on the production of tumor necrosis factor in macrophages of mice with experimental tumors was studied in (Novoselova et al., 2001). It was found that exposure of mice to the MF enhanced the adaptive response of the organism to the onset of tumor growth: the production of tumor necrosis factor in macrophages of exposed mice was higher than that in unexposed mice.

The results (St-Pierre and Persinger, 2003) suggested that complex MFs with temporal parameters corresponding to that of normal biochemical processes, can permanently alter the development of the rat brain. The brains of adult rats, exposed prenatally to MFs between 30 nT and 180 nT, exhibited significant anomalous organizations of cells within the hippocampal formation.

Female Lewis rats were exposed in (Persinger, 2000) to weak, 7-Hz MFs with a computer-generated waveform, whose amplitude varied from 15 to 60 nT every 6 to 12 sec. The MF was presented for 6 min every hour overnight. The rats exposed to the MF, vs sham controls, displayed statistically significant 55% suppression of the symptoms of experimental allergic encephalomyelitis. The effect was frequency dependent (Cook and Persinger, 2000).

Seized rats were continuously exposed to a frequency-modulated MF of 7 to 500 nT in (McKay and Persinger, 2006). After 14 days of exposure, the rats exhibited markedly slower response durations than rats in controls.

The influence of infinitesimal external magnetic fields on epileptic patients was shown in (Anninos et al., 1991, Anninos et al., 2003a) and in other works of this group using measurements in 64 MEG channels. Magnetic stimulation at the field intensity 1 to 7.5 pT and frequency within the alpha-rhythm band 8-13 Hz was applied to the head for 2 to 6 minutes. The emitted brain magnetic activity was recorded before and after the stimulation. The application of superweak MF resulted in rapid attenuation of the MEG activity of epileptic patients.

The author of (Jacobson, 1994) used variable MFs as small as 5 to 25 pT to treat epilepsy and Parkinson disease cases. A sinusoidal field of 2–7 Hz was applied to the brain so that to affect the epiphysis. MF stimulation was correlated with melatonin production.

Brief, at a duration of units to dozens of minutes, extracerebral applications of picotesla range ELF MFs have been shown to produce rapid improvement in symptoms in Parkinson's disease, an increase in the amplitude of visual evoked potential (Sandyk, 1996) and improvement of smell during administration of a few pT 7-Hz MFs (Sandyk, 1999).

We emphasize the fact that pT MFs caused biological effects, which looks like a paradox from the physical viewpoint. A similarity of appearance between the MF coils used in (Anninos et al., 2003a) and those used in TMS permitted the authors to identify their method as a kind of transcranial magnetic stimulation.

Also striking results in the domain of biological effects of superweak MFs go from observation of human sensitivity to the geomagnetic storms. Geomagnetic storms vary from hundreds nT to rarely about 1 μT; their frequency spectra are below 0.01 Hz in the order of value. A number of evidences are great (Dubrov, 1978).

Another, though also indirect, evidence that very small quasistatic MFs are capable of significantly affecting organisms is the established fact of the so called magnetic navigation. Many migratory birds and other animals annually travel thousands of miles and accurately find the locations of their seasonal habitats. The reason for this is not completely understood in spite of the established involvement of terrestrial magnetism (Kirschvink et al., 2001). In case of birds, known explanations involve either incorporation of naturally grown nanoscaled crystals of magnetic mineral, magnetite $Fe_3O_4$, in bird's brain or scull (Walker et al., 2002, Wiltschko and Wiltschko, 2005), or magnetosensitive chemical reactions in bird's eyes (Ritz et al., 2004, Johnsen and Lohmann, 2005). In both cases, to navigate a bird needs to percept infinitesimal changes of the geomagnetic field vector components, which are closely bound to the Earth surface in a large scale. Perceptible changes should be about 100 nT and even orders less (Binhi, 2006). In this regard, we should stress that magnetic nanoparticles have been also found in human brain (Kirschvink et al., 1992, Dobson, 2002) and other organs.

## Biological effects of microwaves

As well, accumulated are observations of biological effects from exposure to very weak RF EMFs with powers much below 0.1 mW/cm$^2$, i.e., at power densities that practically cause no heating.

Non-thermal biological effects of microwaves at low power density on the order of 0.1 mW/cm$^2$ have been first observed in USSR (Devyatkov, 1973). The studies of neurological effects, including the effects on central nervous system, brain, and behavior, from very weak EMFs have been made by W.R. Adey and his colleagues (Adey, 1975). For example in (McRee et al., 1979), it was reported that 147-MHz low-frequency modulated EMF at about 0.5 mW/cm$^2$ caused significant biological response. The effect was nonlinear, i.e. it did not occur at the EMFs of greater powers, 2 and 5 mW/cm$^2$. What is important, modulating signal alone, as an electric field as weak as 10 V/m, but not 100 V/m, was also effective.

Often cited work (Bise, 1978) reports that cw mode EMFs $10^{-6}$ nW/cm$^2$ at several frequencies within the range 130 to 960 MHz caused marked changes in the EEG patterns and in behavior characteristics. The antenna was a 1 m wire rod monopole placed 1 m from the head. This was a pilot study that tested 10 human subjects only and which contained methodologically imperfect ideas like the existence of interference patterns from standing waves within the skull. Many people were excited about the apparent possibility of mind control, and many patents have appeared soon suggesting a variety of technical implementations for this idea, unfortunately without due scientific background. To the best of my knowledge, the results (Bise, 1978) have never been replicated anywhere else.[6] However, the fact itself that extremely weak RF EMFs are capable of affecting biology has found a few confirmations.

In some works, biological effects of EM microwaves of very small intensity were observed. The possible effects of RF radiation, TV and FM-radio broadcasting frequency range, at power densities between approximately

[6] All known publications of W.L. Van Bise on this subject, except the indicated one, include technical reports, abstracts of conferences, and patents, the latest one is EP0223354.

0.2 μW/cm$^2$ and 1 μW/cm$^2$ on prenatal development in mice has been investigated in (Magras and Xenos, 1997). Newborns were collected, measured, and examined macro- and microscopically. Some association between RF radiation and infertility and developmental parameters was discussed.

In (Pyrpasopoulou et al., 2004), GSM-like pulsed RF microwaves, with a pulse length of 20 ms and a pulse repetition rate of 50 Hz, at a frequency of 9.4 GHz were applied for the exposure of pregnant rats during a few days. The power flux was 5 μW/cm$^2$. The results suggested that the EM radiation interfered with gene expression during early gestation and led to aberrations in a protein expression.

It is shown in (Gapeyev et al., 1996), that low-intensity electromagnetic radiation of extremely high frequency 41.8–42.05 GHz in near field zone modifies the activity of mouse peritoneal neutrophils on a resonance-like manner. 10% effect at 41.95 GHz was observed at 1 μW/cm$^2$ and 5% at 70 nW/cm$^2$.

In (Novoselova et al., 2004), it was observed the effect of repeated treatment with weak microwaves 8.15–18 GHz, 1 μW/cm$^2$, 1.5 h daily on production of tumor necrosis factor in macrophages and T lymphocytes of healthy and tumor-bearing mice. Prolonged treatment of mice to MW decreased tumor growth rate and increased overall animal longevity.

It was demonstrated in (Agafonova et al., 1998) that exposure of living insects labeled with radioactive phosphorus $^{32}$P to 42.2-GHz microwave radiation with energy flux density 0.5 μW/cm$^2$ changed the rate of $^{32}$P accumulation in the insects' antennas. The maximum effect was about 200%, and it took only about 2-min exposure.

An influence of a pulse-modulated 915-MHz RF EMF of power density 10 μW/cm$^2$ and modulation frequencies 2 to 20 Hz on the deamination activity of the enzyme monoamine oxidase in rat brain has been shown in (Dolgacheva et al., 2000). 10-min exposure of the rats resulted in maximally 160% effect observed in the brain preparations.

Production of cataracts in the bovine eye lens was observed in (Aarholt et al., 1988) under exposure to 55 MHz, 10 nW/cm$^2$ EM radiation.

Irradiation experiments (Grundler and Kaiser, 1992) with growing yeast cells during two generations resulted in the following. The cell growth rate depended on frequency in the studied range 41.689–41.707 GHz and either increased or decreases by 10–20% in a resonance-like manner. The shape of the resonance curve depended on the radiation intensities; the lowest effective power flux was 5 pW/cm$^2$.

The effect of 51.755 GHz EM microwaves on the conformational state of genom in E.coli cells persisted at the attenuation of the microwave power flux to $10^{-6}$ pW/cm$^2$ (Belyaev et al., 1996).

Yeast culture *S. cerevisiae* was exposed to 7.1-mm microwaves within a wide range of powers in (Kuznetsov et al., 1997). There was a response that consisted in the emergence in a synchronous cell culture of a proliferation process, such that the temporal dependence of the density looked like a step function. Such a response appeared some time *t* after the beginning of the exposure, and that time depended on the microwave power. The dependence was close to a linear one (from power logarithm) within $t$=5 min at 1 mW/cm$^2$ and $t$=240 min at $10^{-6}$ pW/cm$^2$.

There are also many other works devoted to non-thermal biological effects of EM fields and radiations, reviewed in (Belyaev, 2005), which adjoin the discussed observations of biological efficacy of superweak fields and radiations. In these works, a variety of biological effects were observed under the exposure to laboratory RFs within the intensity range 1 to 100 μW/cm$^2$ or to mobile phone radiations at low energy flux densities that could not heat biological tissues.

In (Koldaev, 1987) the results of almost 20-year studies in the field of acute microwave effects on different living objects and tissues are reported. In these researches, mostly microwaves of near thermal energy flux density have been used. Despite such radiations may cause heating of biological tissues, the author concluded that besides thermal effects there is also a non-thermal one that could not be explained by heating.

The physical nature of biological effects of weak variable MFs (about the geomagnetic one) remains unclear. We should hold the same conclusion about non-thermal biological effects of RF EMFs. In this regard, experimental data on biological reception of MFs many orders of magnitude weaker than the geomagnetic field look, of course, quite challenging. Biological effects of pT MFs and of pW/cm$^2$ RF EMFs present a paradox that is still awaiting its solution. The body of that evidence is not large so far, but knowledge is being gleaned.

## Neurological effects of EMFs

Neurological effects of ELF MFs and RF EMFs have been studied for decades. There are many reviews on this subject, both relatively old (Lai, 1992, Lai, 1994) and recent (Cook et al., 2002, Sienkiewicz et al., 2005). Many reviews devoted to neurological effects of RF EMFs may be found in special issues of Bioelectromagnetics journal, Volume 24, Issue S6 and Volume 26, Issue S7.

The brain and nervous systems are considered particularly vulnerable to EMFs because their functioning is based on transfer of nerve impulses, which involve electrical processes within and in between nerve cell membranes. Many laboratory animal and human studies have been conducted to investigate the possible effects of weak EMFs on nervous system including cognitive, neurobehavioral and neuroendocrine functions.

Neurobehavioural studies, reviewed in (Sienkiewicz et al., 2005), include the effects of the direct stimulation of nerves and nerve tissues, and the effects on CNS functions. A recent review of the research into EMF effects on brain tissues, starting from pioneering works by W.R. Adey, is given in (Blackman, 2006). The effects are shown to feature amplitude and frequency selectivity, hence it is non-thermal effects.

Neurological effects of the EMFs have been repeatedly reviewed by many institutions: National Research Councils, National Institute of Environmental Health Sciences (U.S.), International Agency for Research on Cancer, International Commission on Non-Ionizing Radiation Protection, WHO and others. In general, there are many different field-induced responses. Some of them are well established; others are small in magnitude and inconclusive. Most studies investigating cognitive function and brain activity under acute exposure to EMFs were conducted to determine possible physiological or behavioral impairment, or health effects. In general, the available evidence is not sufficient to draw a clear conclusion. However, the existence of a variety of neurological effects from EMFs is indubitable.

In view of many reviews, which describe EM neurological effects in details, we will just indicate those of the effects that are caused by relatively weak MFs: (Rea et al., 1991, Agadzhanian and Vlasova, 1992, Akerstedt et al., 1999, McKay and Persinger, 2006, Anninos et al., 2003a, Jacobson, 1994, Sandyk, 1999, Keeton et al., 1974, Ruhenstroth-Bauer et al., 1993, Schienle et al., 2001, Belisheva et al., 1995, Tambiev et al., 1995, Dornfeldt, 1996, Starbuck et al., 2002, Ashkaliev et al., 1995, Gordon and Berk, 2003, Kay, 2004, Booth et al., 2005, Chibrikin et al., 1995) and EM radiations (Bise, 1978). General information about these works is given above. It is interesting that most neurological effects of weak fields have been observed in the low-frequency range.

# Theoretical grounds for biological effects of superweak fields

The nature of biological effects of weak electromagnetic fields remains unclear, despite numerous experimental data. The difficulty in explaining these effects is usually related to the fact that an energy quantum of the low-frequency EMF is essentially less than the characteristic energy of chemical conversions, of the order of dozens of kT, where k is the Boltzmann constant, T is absolute temperature. It is generally recognized that this fact reveals a paradox and even allegedly proves the impossibility of magnetobiological effects. This problem is known in the literature as the kT problem.

For the first time, the kT problem seems to be formulated in 1960s, in the broad sense, with respect to the biological effects of EM microwaves. At that time, microwaves were discovered to cause different biological effects at rather small energy flux densities of the order of 0.1 mW/cm2, well below the thermal limit (Devyatkov, 1973). Though the energy quantum of such EM fields was 1–3 orders lower than kT, some physical mechanisms have been developed that take into account collective excitations in biological structures (Frohlich, 1968, Pokorny and Wu, 1998).

Particularly effective were modulated microwaves, with a modulating signal in the low frequency range (Bawin et al., 1973). Later, it was found that the modulating signal itself, as a weak magnetic field signal, can affect the state of an organism appreciably (Liboff et al., 1984). Since then, a number of evidences have been accumulated showing that weak static and low frequency MFs cause variety of biological effects (Volpe, 2003). The kT paradox is especially dramatic in such cases, as the energy quantum of the magnetic field was 11 to 12 orders of magnitude less than kT.

We will consider the kT problem with regard to the EMFs of low frequency. Unlike RF or microwave fields, here there are no technical difficulties related to the non-uniform absorption or reflection, and consideration of the interaction between low-frequency EMFs and biological targets becomes particularly clear. We will specify that the low-frequency, units to hundreds of hertz, MFs in question are below the level of the geomagnetic field and do not cause any essential inductive heating.

A lot of hypothetical mechanisms have been suggested to explain biological effects of weak extremely-low-frequency MFs. A brief review of the mechanisms may be found in (Binhi and Savin, 2003) and the detailed examination in (Binhi, 2002). Most researchers often discuss the following hypothetical physical targets for MF action in magnetobiological phenomena: (i) iron-bearing magnetic nanoparticles growing in biological tissues, (ii) spin-correlated radical pairs, in some biochemical reactions, interacting with magnetic field by their spin magnetic moments, (iii) long-lived rotational states of some molecules inside protein structures, which interact with MF by their orbital magnetic moments.

The basic problem is that the interaction energy of biologically active molecules and the MF at the level of the geomagnetic field $H_{geo}$ is very small. It is by many orders of magnitude smaller than the energy of thermal fluctuations $kT \approx 4\times10^{-14}$ erg at physiological temperatures: $\mu H <<< kT$, where $\mu$ is the molecular magnetic moment. Obviously, magnetic effects cannot exist here! It is the essence of the most heated arguments raised by the opponents of the idea that weak MFs, on the order of the geomagnetic field and lesser, can affect organisms (Binhi, 2007). At the same time, there are an ever-growing number of experimental evidences that demonstrate biological effects of weak and superweak MFs and require attentive and careful theoretical study.

Apparently, to explain observed biological effects of weak magnetic fields one needs to equalize the inequality $\mu H <<< kT$: either the magnetic moment $\mu$ of a suggested target in an organism should be sufficiently large, or the effective temperature T of the target should be sufficiently small. The former possibility is used in mechanisms based on magnetic nanoparticles (Kirschvink and Gould, 1981) found in tissues of many organisms including the human brain tissues (Kirschvink et al., 1992, Mikhaylova et al., 2005). Magnetic energy of such particles may exceed kT by many times and cause a biological response. In a recent work (Binhi and Chernavskii, 2005), as small MFs as of 200 nT were shown to significantly change nonlinear stochastic dynamics of the particles.

On the other hand, the above inequality relies on the implicit assumption that a target is in thermal equilibrium with the surrounding medium. Evidently, one could overcome the kT problem also having found possible targets whose effective temperature differs from that of the medium, so that the inequality would no longer be valid. Hence, no fundamental limitations would be placed on the possibility of observing biological effects of weak MFs that interact with such targets.

Reactions involving free radical pairs give a clear example of the case where the inequality fails. Magnetic processes based on spin dynamics of the radicals develop so quickly that the thermodynamic equilibrium has no time to be established. This means spins move coherently and no temperature of spins exists within these small time intervals. Another example where the inequality fails is the molecular gyroscope model (Binhi and Savin, 2002). In this model, a small biologically active molecule bound within a protein cavity is well isolated from the surrounding thermal perturbations. Interacting with the MF, it can coherently rotate for a long time. This makes the notion of temperature inapplicable to this type of molecular targets as well.

If to look at the kT problem closer, it clearly contains three implicit assumptions: (i) primary magnetoreception occurs at the atomic or molecular level, (ii) the interaction of an ac MF and a molecular target is a single-quantum process, (iii) the interaction of the field and the target occurs under thermal equilibrium conditions. However, an analysis made in (Binhi and Rubin, 2007) shows that the postulates are not completely correct: besides molecular targets, relatively large particles with almost macroscopic magnetic moment may be found in organisms. As regards molecular targets, their interaction with low-frequency magnetic field is of multiple-quantum character and may develop in the absence of thermal equilibrium.

## Magnetic nanoparticles in organisms

In many organisms, magnetic nanoscale particles consisting of magnetite crystals were found. Magnetic moment $\mu$ of these particles exceeds the elementary one by 7–9 orders. The energy of their turn in the weak magnetic field H is significantly greater than the energy of thermal fluctuations kT.

Of particular interest are magnetite particles found in brain tissues of many animals and humans. They proved to have a biogenic origin, i.e. they form as a direct result of the crystallization in a brain matter. Particles of biogenic magnetite are often called "magnetosomes." The content of magnetosomes in a human brain is about $10^6$–$10^8$ crystals per gram (Kirschvink et al., 1992) and about 50 ng/g on average (Dobson, 2002).

As was shown in (Binhi and Chernavskii, 2005), a natural limitation on the MF magnitude capable to affect biochemical system through magnetosomes is about 1–2 μT, however the biologically detectable level of the MF may be even tenfold less, about 200 nT, if magnetosomes rotate in double-well energy potential.

The MF produced by magnetosomes is rather intensive and is of the order of 0.1 T in the vicinity of the magnetosome surface. This is thousands times greater than the level of biologically natural MF, the geomagnetic field. So, magnetosome rotations can distinctly affect the rate of free-radical reactions in biological cells containing such particles. As proved today, such effects as precise orientation of many biological species during their seasonal migrations are based on the MF interaction with magnetosomes (Walker et al., 2002) and their nonlinear stochastic dynamics may be a mechanism underlying the phenomenon of biological reception of MF variations as small as the geomagnetic variations (Binhi, 2006).

## Molecular targets for magnetic fields

As often suggested, the MF interaction with a molecular target is a single-quantum process. The question is closely related to the method of the EM field description, i.e. classical or quantum mechanical one. As is known from quantum electrodynamics, or QED, low-frequency EMFs may be described as a classical field, i.e. in terms of the amplitude rather than the number of quanta of that field. However, QED allows most general description and describes EMF states close to the classical states by means of the so-called coherent states, which minimize the quantum uncertainty. The coherent states are multiple-quantum field excitations. Therefore, the interaction with the classical field is a multiple-quantum process. It is clear now that the absorption of a single quantum of a low-frequency field is just a speculative process. Thus, such a process can't be the real basis to assert the possibility or impossibility of the biological effects of weak low-frequency MFs.

As is shown in (Binhi, 2002), physical principles practically do not limit the sensitivity of possible targets to EMFs. The fundamental sensitivity limit is defined by the lifetime of the quantum states of a molecular target. The sensitivity of real systems, including biophysical targets, also depends on the probability to absorb EMF quanta. It is significantly lower than the fundamental limit. However, the probability for EMF quanta to be absorbed is determined by a specific target structure only.

Thus, interaction of an ELF MF with a quantum target is a multiple quantum process; the conventional formulation of the kT problem and its consequences are not valid for such processes. The primary principles of physics impose virtually no limitations on the sensitivity limit. The microscopic structure of a MF bioreceptor and the lifetime of its states control the level of the sensitivity in any special case. It is important that the lifetime may be sufficiently great if the state of elements in the system is far from thermal equilibrium. An example of such molecular target, a gyroscopic molecular rotator, has been discussed in (Binhi and Savin, 2002).

Generally speaking, the use of such notions as number of quanta of EMF, as well as energy states of a quantum system, implies that the field and the quantum system are sufficiently isolated from each other. This means their interaction energy is significantly less than the energies of quantum jumps between the states of the field and quantum system correspondingly. For example, in the case of the interaction of optical radiation of a laboratory HeNe-laser with an atom, we have $eEr/\hbar\Omega \sim 10^{-7}$, $\hbar\Omega \sim \Delta\epsilon$. Here $eEr$ is the interaction energy of an electron of charge $e$ of an atom of the size $r$ with an electrical field $E$, $\Omega$ is the circular frequency of the radiation, and $\Delta\epsilon$ is the energy difference between atom's quantum states. That is why the approach based on the field quanta and atom energy level notions appears to be effective. In other words, the states of the whole system "field-atom" are reduced to the combination of the states of the atom and field separately.

In another case, when an atom interacts with weak low-frequency MF, all three energies are of the same order of magnitude. The interaction energy (the energy $\mu H$ of the magnetic moment of an orbital motion $\mu = e\hbar/2mc$ in a magnetic field $H$) practically coincides both with the Zeeman splitting $\hbar\Omega c$ ($\Omega c = eH_{geo}/mc$ is the cyclotron frequency) and with the quantum of the ac MF $\hbar\Omega$. In this case, the interaction energy is not a small parameter. It means that the presentation of the state of the whole system "field-atom" in the form of a combination of the states of atom and field taken separately is not fully true. QED may provide more reliable description.

There is also another reason to think that QED description is necessary to explain weak MF effects on biosystems. Usually, a field-atom interaction is reduced to the scenario, in which EM radiation causes quantum jumps between atom's energy levels that changes the population of these levels.

With regard to the possible mechanism of the primary magnetoreception, this scenario is not quite perspective since the changes in populations of the states, which are very close in their energy (by the order of a field quantum), could hardly affect a chemical reaction. Even in some hypothetical ideal conditions, if the energy of the field quanta was pumped to increase the energy of a quantum oscillator, this would take too long time, about a year, to accumulate the energy of the order of kT.

It is more realistic to suggest a scenario, where the populations of the target states remain constant, but an interference pattern of their space distribution changes. In this scenario, a quantum system or an "atom" with an orbital magnetic moment is placed, for simplicity, in a uniaxial MF. The latter is varied just in magnitude. In such MF, following quantum mechanical description, the atomic energy does not change at all. But what is changed here, in a resonance-like manner, is the space distribution of the density of the atomic quantum state. As a result, different orientations appear where the probabilities to find the atom are significantly distinct from each other. This redistribution of the probability density may influence the rate of a chemical process (Binhi, 2002, Binhi and Savin, 2002).

However, in this scenario, as was shown above, the energy of an atom does not change. Therefore, it is not possible to estimate the sensitivity of the system, following the quantum mechanical and semiclassical approaches. In this case, a quantum description should be used also for ac MF, i.e. for the low-frequency EMF. Obviously, within this description it is not possible to consider EMF quanta separately, since changes in their number do not correspond to any change in the energy of an atom, which remains constant. In this description just the whole field-atom system has the stationary states, but not the atom and the field taken separately. At these stationary states, dynamical states of the atom and field may be distinguished, having no definite energies. The stationary states of the system differ by populations of the quantum states of the field oscillators, or, that is the same, by the amplitudes of the field oscillations, on the one hand, and by corresponding amplitudes of the oscillation of the interference pattern or the phases of atom states, on the other hand. Note that here the term “field amplitude” appears, since in the ELF range multiple-quantum states are adequate, thus allowing to consider amplitudes.

It should be stressed again that it is not correct to consider the number of quanta absorbed by an atom in the MF that changes only its magnitude. The states with different numbers of quanta are stationary states of the EMF; however there are no atomic stationary states that could match them: the states of an atom with different phases are not stationary states, i.e. they all have the same energy.

It follows, that an atom and weak MF present an integrated system that cannot be divided into isolated field and atom without demolishing the holistic entity of the system. At first sight, this statement might seem to be in contradiction with everyday scientific evidence. There are many methods to measure atomic states, and usually nothing happens when MF is slightly changing, of course unless special magnetometry methods are used. However, such methods are destroying methods. In order to measure the state of an atom, such a method has to bring another observable system into interaction with the atom, but the energy of this measuring interaction is greater than that of the original field-atom interaction. In other words, these methods first isolate an atom from a weak field and only then measure its properties. As a result, what is measured has nothing to do with the properties of the original field-atom system.

How to measure the state of a molecular target without destroying its quantum states common for both the target and the field? Probably, some particular biophysical structures with long living molecular rotational states, similar to molecular gyroscopes, perform quantum non-demolition measurements that fix just the transfers between those common states. Then variations in MF superimposed on a constant MF might cause the system field-atom to transfer between its stationary states, which would change the results of the measurements of the target state.

## Metastable states underlie biological sensitivity to weak EMFs

The conventional formulation of the kT problem brings about the skepticism in regard to the plausibility of the observed biological effects of weak EM fields and, as it is, does not provoke any efforts to overcome the paradox. Therefore, we believe it is useful to concentrate on two aspects of the paradox: (i) what is the mechanism of the weak MF signal conversion into a (bio)chemical signal and (ii) why such mechanism could be efficient on the background of thermal disturbances of the medium?

It is worthwhile to bear in mind two points. First, the notion of kT itself comes from statistical physics. This notion is justified for the systems, which are near thermal equilibrium. Indeed, in such systems, neither a single quantum nor many quanta corresponding to a weak low-frequency MF can practically change the mean energy of dynamical degrees of freedom. However, in the systems just weekly bound to the thermostat, the process of thermalization is relatively slow so that such systems may remain for a long time far from the equilibrium. Then a MF can bring about a great relative change in energy of some dynamical variables, the energy of which may be low due to some reason. In other words, the notion of the temperature itself, in its traditional thermodynamic meaning, is not applicable to some degrees of freedom, if the thermalization time of these degrees of freedom is greater than the characteristic lifetime of the system. It follows there is no sense to compare changes in their energy with kT at the absorption of EMF quanta.

An example of the non-equilibrium processes are changes in protein structures proceeding at slower rate as compared to their functioning. That is, some of their relevant degrees of freedom have no time to thermalize. This may happen also in other biophysical nanostructures. We suggest that weak MFs may change the state of such nonthermalized degrees of freedom and thereby affect the functioning of proteins.

Second, the interaction energy of a weak MF with a molecular target is rather low. It takes at least one year for the energy of an ideal molecular or ion oscillator to change by the amount of kT even under magnetic resonance conditions. It follows, that MF may play a role of a controlling signal rather than a power factor. Therefore, specific mechanisms are possible, where MF controls the probabilities of the processes to proceed in one or another direction rather than triggers the processes themselves.

In this regard, non-equilibrium or metastable state of a target and probabilistic character of the weak MF signal conversion into a biochemical response are necessary properties for the molecular mechanism of magnetoreception.

Reactions involving free radical pairs give a clear example of an MF target in a metastable state. An idealized magnetosensitive chemical reaction may be depicted as AB ↔ A* B* ↔ A* + B*, where the intermediate A* B* is a spin-correlated radical pair in a virtual cage formed by the molecules of the surrounding viscous medium. The rate of recombination A* B* → AB and so the rate of free radical formation may change depending on the MF value. Magnetic processes based on spin dynamics of the radicals develop so quickly that the thermodynamic equilibrium has no time to be established. This means spins move coherently and no temperature of spins exists within these small time intervals, usually 1–10 ns. The MF dephases coherent spin motion and changes the probability of the pair recombination. Yet, this radical pair mechanism does not provide a firm explanation for biological effects of EMFs. It is limited by values of relative changes about 0.1% in MFs similar to the geomagnetic field, though there is a hypothesis that this could be much greater (Ritz et al., 2004).

One more example of a non-equilibrium molecular target is the molecular gyroscope mechanism (Binhi and Savin, 2002). Yet another example of a metastable molecular target is water medium. The suggestion that water medium may be a mediator in the MF signal transduction at the biological level was made by many scientists. There are theoretical and experimental works to support this idea, for example (Preparata, 1995, Belov et al., 1996). In this case, the target is located not inside the protein molecule, but surrounds it and interacts with its surface. The state of water influences the protein conformation changes and, consequently, its activity. Elementary targets in water matrix are most likely the magnetic moments of protons, which are in long-living metastable states, forming the hydrogen bonds in water (Binhi and Rubin, 2007). Concerted simultaneous MF effect on the magnetic moments, and thus on the proton spin states, may affect hydrogen bond rearrangements owing to the Pauli Exclusion Principle for spins. In that way, MF may influence conformational mobility of proteins.

Many ingenious mechanisms have been suggested to explain magnetobiological effects of weak EMFs; they are reviewed and analyzed in (Binhi, 2002). Only a few of them discussed the kT problem in part. Possible mechanisms of EMF biological effects, which directly address the kT paradox and demonstrate its misleading character, include (i) stochastic nonlinear dynamics of magnetosomes in biological tissues, (ii) interference of the angular modes of long-living molecular states, (iii) radical pair mechanism, and (iv) proton-exchange mechanism related to the metastable states of the proton subsystem in liquid water. The main principles that underlie these mechanisms are probabilistic character of magnetic effects and non-equilibrium state of weak MF molecular targets. This unequivocally shows that biological effects of weak low-frequency magnetic fields are not at variance with physical laws and they may be explained in terms of classical and quantum physics.

As is seen, the effect of weak EMFs on the elementary acts of bio/chemical reactions gradually finds an explanation. It is a good basis for searching what this primary effect leads to at the next levels of the biological hierarchy, for example, at the level of nerve pulse propagation.

It is worth to comment on the other argument used by the partisans of the thermal EMF effects on biology. They argue that the biological effects of weak EMFs are poorly reproducible and so have no scientific or social significance. Indeed, some 10–20% of the recent publications report failed attempts to observe such effects. Given a lengthy and uncontrollable process of transformation of an EMF signal into a biological response, there is nothing extraordinary in the absence of the effect in a specific experiment. Many researchers emphasize that the effect may develop when an EMF affects a biological system in a proper physiological state. Also, the time factor is of importance, because the system is capable of responding to EMF within a relatively narrow time window. In the majority of experiments, their success depended on a rare happy coincidence of suitable EM and physiological conditions. There are individuals, a few percent in the human population, probably as well as in other biological species, that are less or more sensitive to EMFs (Hillert et al., 1999, Markova et al., 2005, Schrottner et al., 2007). Collectively, these and other limitations account for the difficulty to reproduce the results of low-field experiments in bioelectromagnetics. Many of them await confirmation by independent laboratories.

It follows that the biological effects of EM fields and radiations, where they are non-thermal effects, are of probabilistic character. Epidemiological studies show, on the whole, rather low association between various disease incidences and the level of occupational or residential exposures to EMFs (Ahlbom et al., 2001). Should we rely on these results and agree that EMF effects on humans are socially insignificant? Note that epidemiological studies are averaged by definition, but an EM effect on an individual may be significant. How we react when human rights are broken even with respect to one person? Precisely the same attitude should be adopted towards hypersensitive persons, because their social rights can be violated by the use of EMFs.

# Discussion

There is a great difference between brain control and mind control or between brain mapping and mind reading. Brain magnetic manipulation also does not necessarily give rise to mind manipulation. Does EM mind control exist? What could be a proof for this? Obviously, it is technologies or methods that are able to control over mind of a person. At that, both the technologies and theoretical knowledge behind these technologies should satisfy the criterion of science, otherwise, as was said above, we are not on firm ground. What does it mean? First, it is physical feasibility for EM mind control principles; they should not be at variance with well known general laws of physics, chemistry, etc. Second, enough, socially significant volume of evidence should exist that such technologies have been using by this or that group or institution. In what follows, we will discuss whether these criteria are fulfilled.

The information appears from time to time about people who believe the government is beaming voices into their minds and Pentagon has pursued a weapon that can do just that (Weinberger, 2007). Indeed, it should be taken as a well established fact that some people hear voices in their heads without any apparent cause. They are usually called "voice-to-skull" persons, or V2K, and "targeted individuals", or TIs. Usually, the individuals hearing such voices ascribe this to high-tech devices intentionally designed to control people. However, good sense suggests that there are a few possible causes. The voices are the consequence of either (i) a mental illness or a paranormal experience or (ii) a high-tech science. In all the cases, voices are real and deserve respectful consideration. However, these cases distinctly differ in their social significance. While mental illness mainly isolates the person in itself, scientific facilities are potentially aimed at the society at large and so are potentially dangerous. In this latter case, the "voice" evidences are one of the main reasons to think that a hidden electronic or similar technique exists as mind control engineering. Other essential reason to think in this way is continuing military attempts to take hold of the control of human mind.

By no means can the dramatic reports of V2K persons and TIs be indications of EM mind controlling, since there is no way to understand whether their reports themselves reflect physical reality or medical pathology (mental illness). Neither similarities between TIs' individual experiences, nor the failures of drugs to fix their problems can serve as a proof of real deliberate electronic surveillance or harassment. And as well, the facts that some institutions have been engaging in studies around EM mind control actually prove nothing definite. Attempts to search for new effects, to overcome limits set by modern technical knowledge have always existed and will be going on. However the results of such studies are far from always positive.

This study is not addressing probable causes of mental illness of TIs and other like persons. It would be an area of medicine or psychology (Weinberger, 2007). Despite some experts assume voice-hearing people suffer auditory hallucinations or schizophrenia, and others consider some of the reports about "mind control experiences" as likely reflecting delusional beliefs (Bell et al., 2006), there are reasons to examine possible technical sources of that voices. The review made above provides specific scientific evidence of what is possible and what is not possible from a technical viewpoint.

We can see that there are both pros and cons regarding EM mind control. Let us be specific. Con arguments are as follows.

Social insignificance:

On the request "electromagnetic mind control," Google returns about two thousand links. Is it many or few, is it socially significant number? For comparison, that of a more general term "psychotronic weapons" that include high-power technique gives almost 13 thousand links and "mind control" scores up to 1320 thousand.

It is interesting that the scientific program of the 3rd International interdisciplinary congress "Neuroscience for Medicine and Psychology", which includes 16 sections and about 150 original works, does not contain reports that could be associated with EM mind control. The program of the 4th European Symposium on Non-Lethal Weapons to be held in Germany, May 2007, does not mention the word "mind" or "brain".

There are no evident reasons for a government to use so expensive facility, assuming it exists, to control minds of rather usual inhabitants.

Failure to prove:

Of course, evidences reported by TIs cannot be taken as proofs for existence of EMC. As is stated in (Weinberger, 2007) "it's reasonable to assume that if the defense establishment could develop mind-control or long-distance ray weapons, it almost certainly would." There are reasons to share this conclusion. Nuclear weapons are a matter of fact. Therefore we know outrageous facts of its war application; we can track many nuclear tests, crashes, etc. The same is true with regard to chemical and biological weapons, but not to EM weapons.

The main weakness of almost all publications on EM mind control is in a clear bias, which is the prejudication that secret EM mind control technology exists. This immediately makes the material unsuitable for analysis, since facts are being organized so as to draw pre-given conclusions.

Technical lack:

Technically, in order to perform microwave targeting at a given person, who is free to move anywhere, two arrangements have to be done. First, the position of the person should be detected. In principle, a global positioning and tracking system might be used for locating and targeting EM radiation beam at the person. GPS systems are very exact and can locate target at an accuracy of about 1 meter, which would be well enough to target EM radiation by a phase array microwave antenna. However, such a targeting might be effective only in conditions of open country. The conditions of building area would make microwave targeting ineffective due to multiple reflections, absorptions, and scattering at any substances. Hence, targeting by EM radiation at a person moving over streets, shops, transport vehicles, etc. would be impossible.

Analyzing known brain magnetic stimulation technique, we could not see indications that even transcranial magnetic stimulation—almost contact and rather strong influence—was able to induce voices or specific ideas in tested humans. Second, microwave auditory effect is also hardly possible because of high power required to induce hearing and because of expected low speech discrimination and phrase intelligibility.

Where low-frequency MFs and non-thermal effects are supposedly used to affect an individual, there are difficulties as follows. (i) Targeting is impossible since a low-frequency MF source necessarily covers large areas. (ii) Known non-thermal effects are of probabilistic character, it is difficult to get a non-thermal effect even in laboratory conditions, since its appearance depends on too many physiological parameters, which always vary, and physical parameters, such as static MF, static electric field, polarization, etc. They also unpredictably vary in non-laboratory conditions. (iii) There are no known scientific studies where low-frequency MFs were able to transfer sensible information or to induce a sort of thoughts, even in laboratory conditions.

Remote EM mind reading is not possible:

The number of neurons in a human brain is about $10^{10}$, each one being connected with approximately $10^3$ other neurons, there are also neurons connected to $10^4$–$10^5$ other neurons. These communication connections between neurons do form a giant neuronet. The number of the axon/dendrite connections, which perform thinking and carry thoughts is then about $10^{13}$, on the order of value. Now, we can roughly estimate the number of different thoughts that might be produced by the net, suggesting, very speculatively, that a thought may be represented, on average, by a thousand excited connections. This quantity is enormously[7] large: about $10^{10428}$. It is the hundredth power of the Googol, the large number, $10^{100}$, that exceeds the number of all particles in the known Universe. This example well illustrates really boundless opportunities of our minds to generate thoughts. Generally speaking, to know thoughts one should know the state of a significant part of neuron connections. Despite only small part of neurons may take part in thinking, the number of connections is still enormous enough to make hopeless the attempts of reading a single thought.

Short range technique, like that used for brain mapping with fMRI and magnetoencephalography, allows one to watch for activity in particular parts of the brain and correlate it with what someone is telling. It is of course, very far from actual mind reading, since space/time resolution is not enough to monitor the state of each neuron and the states of its connections. However, the resolution is enough to discern types of thoughts, which are known to correlate with pattern-like space distributions of excited parts of the brain. As for today, the technique provides

---

[7] The number of combinations of size k from a set with n elements can be approximated by the formula $(en/k)^k/(2\pi k)^{1/2}$, for n>>k.

patterns consisting of about hundreds elements. This enables one to distinguish certain thoughts among several pre-given thoughts that should reflect rather different types of thinking.

Beside the stationary facilities, under discussion now are “cognitive feedback helmets” that would allow remote monitoring of a human mental state.

As is seen, these modern technologies require a lot of sensors to locate on the surface of a human head. The possibilities of the MRI technologies are also space-constrained, as was discussed above. No technology, able of remotely gathering data on the brain activity, could be conceived of being real for purely physical reasons.

Below, as well, pro arguments are listed.

EM mind control, if it existed, would have a great potential of violating human rights when used without due supervision. This means that it is socially significant, even in its present state of a hypothetical possibility.

Natural scientific ground for EM mind control is nonthermal biological effects of weak EMFs. There is a widespread opinion that such nonthermal effects of weak MFs are not possible as they are allegedly in conflict with physics. The same is even more insisted on with regard to biological effects of superweak EM radiations. However, it is not true at least until a good physical theory is developed and full scientific knowledge is obtained for the EM biological effects. In opposite, some theoretical reasons exist which show that such effects are not at variance with physics (Binhi, 2007, Binhi and Rubin, 2007).

As was seen above, targeting humans with directed EM fields or radiations for some long time necessary to cause a reaction is hardly possible. It is just possible to expose to EMFs large populated areas. Probably not all people are sensitive to weak EMFs (Leitgeb and Schrottner, 2003), though it is not an ultimate fact yet (Rubin et al., 2006). Then, only a small part of humans covered by EM fields or radiations would react; this would look like the effects of targeted radiation.

From published experiments, we know technical parameters of those EM fields and radiations that may cause biological reactions in human organisms. Taking these parameters, one could estimate, whether it is technically real to expose large groups of people by EMFs in a clandestine way. From the above review, there is evidence, though limited, that nonthermal biological effects may be induced by microwaves at a power flux $10^{-4}$ to $10^{-18}$ W/cm$^2$. Taking the log mean value $p = 10^{-11}$ W/cm$^2$ and the power of a microwave source $P = 1$ W only, we can calculate that this source would cover areas at distances up to $r = (P/4\pi p)^{1/2} \approx 1$ km.

Low-frequency MFs as low as $10^{-6}$ to $10^{-12}$ T were shown above to be able to cause biological responses. Again, taking the log mean value $B = 10^{-9}$ T, i.e. 1 nT, the size of a magnetic dipole about 1 m, and the feeding current $10^3$ A (a thousand-turn wire coil fed by 1 A electrical current) one could calculate that this source can produce 1-nT MF at a distance about 60 m. In the other embodiment, a distributed one-turn closed wire contour of about 1 km in size and energized by 1-A current would generate the same 1-nT MF. An artificial magnetic storm of about 100 nT, imitating a natural geomagnetic storm, could be produced by 5 A current passing through a 60-m contour.

What is apparent is that a brain may be remotely exposed to EMFs only as a single whole. Only relatively large parts of the brain could be in different EM conditions under the exposure to an EM radiation, when there is a certain orientation of the head regarding the source of the radiation. However, obviously, this makes no connection to localized brain stimulation like in TMS. So, what we could expect in the future is a modification of a human brain by a special EM radiations or fields, which could work like specific drugs making a human mind vulnerable to an intelligent speech or commands. No specific thought induction by remote EM exposure would be possible.

The above EMF sources, both the microwave and the compact low-frequency ones, would be easy to install in a usual apartment, even if they were 10-fold more powerful. At that, an important question is raised why the EM signals as small as $10^{-11}$ W/cm$^2$ or 1 nT generated by those particular sources should cause specific biological effects on the much stronger natural background produced by a lot of home or municipal electric appliances and technique, like mobile communications, lighting units, power lines, transportation, etc. We have to conjecture that it is human mind that should somehow hear or see only the “useful” signal and be immune to the noise EM background. It is a sticky problem awaiting solution. Well-known geomagnetic storms that often occur in the days of acute health condition in some people make this problem quite urgent.

Sometimes, localized delivery of EMFs to individuals or groups of people is considered to be realized through the available electric wiring or by means of mobile phones (Grigoriev et al., 2006). The work (Havas, 2006), devoted to the so called "dirty power," confirms that home electric wiring might be used as a way to incorporate malicious signals into home life. Usage of mobile phones to affect human minds when mobiles are on line is assumed to be through cell-phone-viruses, on the analogy of the computer viruses. In that way, phone wearables might be caused to change the generated code so as to reach a maximum link to brain tissues. However, in view of the technical and principal physical difficulties considered above, these latter conjectures seem to be too speculative.

Under the principles discussed, with all the pros and cons, most likely there is no even one good example of what we could consider a technology for remote EM mind control, at present. However this does not mean such examples could not appear tomorrow. Science quickly becomes more and more powerful, the results move to levels never imagined. Scientific methodology is also developing so as to envisage possible contribution of the consciousness of a researcher making a study into the results of the study. Such a contribution raises another important question about the role of consciousness in the above discussed voice-hearing evidence.

# Conclusion

To the best knowledge available, among EM facilities, only SQUID magnetometry, MRI devices, and TMS inductors can *noncontactly* map the brain electrical activity. Even in this case, the absence of electrodes is rather conditional: sensors should be placed in the very proximity to the head in order to get information at a suitable signal-to-noise ratio.

There is no scientific information about the hypothetical possibility of EM scanning brain activity *remotely*, even in open laboratory conditions, when the head of a human can be fixed with regard to a scanning facility. As well, there is no evidence that TMS or standard stimulation could induce any intelligible information flows in the mind of a treated individual.

The author of the present review does not think EM mind reading is possible as a phenomenon. For that, there are no natural scientific prerequisites. There are neither well established facts of EM mind reading, nor experimental and theoretical grounds that could secure the existence of this sort of mind control. Difficulties are related to simple physical constraints. The resolution of brain-mapping devices drastically decreases with the distance to the brain surface.

As to the possible influence of EM fields and radiations on human mind, specific technical aspects of EM targeting and the probabilistic character of the nonthermal EM interaction with biological systems set certain limitations making mind control somewhat problematic as well. However, there are no physical reasons to assert that EM mind control is not possible. Under the influence of a remote source of EMF, the brain is exposed to the EMF as a whole. Therefore, one could expect that the EM impact would be similar to that of chemicals, which do not carry information but can induce particular states of mind. Human mind in such a state could be sensitive to verbal suggestions transmitted by usual communication tools. Then, it could be in fact a weapon. As well, there is no complete clarity as yet regarding the potential use of the microwave auditory effect, though with the physical constraints discussed above. Weak EM fields can be delivered to individuals or to the groups of people secretly. For example, large-scale wire coil, on the order of about a building or even a city, can produce MFs similar to the geomagnetic storms. There are no principal obstacles that might block the development of such weapons.

At the same time, much non-scientific information about EM mind control mainly presents a meld of fact and fiction. The associations of sensitive individuals exist, which claim attention and insist that they are subjected to electronic surveillance and harassment by means of EM radiations. Two factors prevent from recognizing TIs' personal testimonies as substantial data: (i) their subjective character and (ii) uncontrolled conditions of their gathering. It is precisely that that everyday knowledge differs from scientific one. And if the first limitation could be avoided by a suitable statistical approach, as it takes place for example in medicine, the second one is an insuperable hindrance. However, such a state of affairs is not hopeless. Scientific experiments might be conducted with the participation of TIs. The experiments would not be expensive; they require only the good will of the potential victims and a minimal set of radio equipment. Of course, he that won't be counseled can't be helped (B. Franklin). However, a part of TIs might be wishing to scientifically clarify their cases, taking part in experiments specially designed to find a cause, or at least to rule out some causes they see probable, primarily, the EM hypothesis. What could be done then?

We might think about passive and active methods to test TIs. Passive shielding from the electric and magnetic fields are most simple. On the other hand, ELF MFs or RF radiations can be modulated by signal carrying audio information. Under exposure to such EMFs, TIs would either hear or not hear modulating audio signal, which might be easily determined. TIs are probably the best choice to research into mind control as they are aware of what kind of mental signaling they should cognize.

There is some strange odd connection between altered states of consciousness and MFs. On the one hand, when during meditation, consciousness is capable of producing extra MF (Seto et al., 1992, Hisamitsu et al., 1996) of about 100 nT in the order of value. These MFs could not be explained as generated by natural body electric currents, which produce no more than 1 nT. On the other hand, people with epilepsy, which might be considered as in altered state of consciousness, demonstrate highest sensitivity to MFs (Anninos et al., 2003a) on the order of 10 pT.

Finally, does EM mind control exist, or does it constitute regularity? There is no criterion other than common human practice. The social criterion for a suppositional regularity is an actual regularity, i.e. that it belongs to the area of science, states that it should be replicated in different places/laboratories, in different times, and by different people, or scientific teams. However, there are no generally accepted ideas about quantitative measure of that replicability. Recognition of a phenomenon as such is a long social process that provides for wide discussion by the scientific community.

EM mind control is a real one just for extremely limited number of people. For the time being, it is far from correspondence to the criteria of scientific knowledge. At the same time, there are no fundamental restrictions to realization of remote EM control over the human brain with the goal to bring the mind into obedience of the will or another vulnerable state. Uncontrolled use of such a technology would pose a certain threat for the society. For this reason, it would be important to continue research into nonthermal biological effects of weak EMFs from the viewpoint of their possible antisocial use.

Whether there is a classified project of the EM mind control cannot be determined from open literature. However, the social significance, experimental facts, and theoretical evidence support that EM mind control should be investigated further as a possible future weapon, even though there is not enough scientific proof of its existence at this time. Recent book (Moreno, 2006), articles in Nature (Hoag, 2003, Rizzuto et al., 2003, Nat.Editorial, 2003, Rudolph, 2003) and in other journals (Gusterson, 2007, Fins, 2007) raise the ethical and social issues of possible "mind wars." They urge scientists to become involved in public discussion of both benefits from civilian use of mind control and the dangers of its military applications. This paper might start an international conversation between physicists, neuroscientists, ethicists, and security specialists regarding the EM type of mind control.

# Bibliography


AARHOLT, E., JABERANSARI, M., JAFARY-ASL, A. H., MARSH, P. N. & SMITH, C. W. (1988) NMR conditions and biological systems. IN MARINO, A. (Ed.) *Modern Bioelectricity.* New York, Marcel Dekker.

ADEY, W. R. (1975) Introduction: Effects of electromagnetic radiation on the nervous system. *Annals of the New York Academy of Sciences,* vol. 247**,** 15-20.

AGADZHANIAN, N. A. & VLASOVA, I. G. (1992) Effect of an infralow frequency magnetic field on nerve cell rhythm and their resistance to hypoxia. *Biofizika,* 37**,** 681-689.

AGAFONOVA, N. K., KRASSOVA, N. E. & FESENKO, E. E. (1998) Rapid changes in phosphoinositides metabolism of the antenna of insects exposed to low intensity millimeter microwaves (article in Russian). *Biofizika,* 43**,** 353-357.

AHLBOM, A., CARDIS, E., GREEN, A., LINET, M., SAVITZ, D. & SWERDLOW, A. (2001) Review of the epidemiologic literature on EMF and health. *Environmental Health Perspectives,* 109**,** 911-933.

AKERSTEDT, T., ARNETZ, B., FICCA, G., PAULSSON, L. E. & KALLNER, A. (1999) A 50-Hz electromagnetic field impairs sleep. *Journal of Sleep Research,* 8**,** 77-81.

ALEXANDER, J. B. (1980) The new mental battlefield: "Beam me up, Spock". *Military Review,* LX**,** 47-54.

ALTPETER, E. S., ROOSLI, M., BATTAGLIA, M., PFLUGER, D., MINDER, C. E. & ABELIN, T. (2006) Effect of short-wave (6-22 MHz) magnetic fields on sleep quality and melatonin cycle in humans: The Schwarzenburg shut-down study. *Bioelectromagnetics,* 27**,** 142-150.

ANNINOS, P., KOTINI, A., ADAMOPOULOS, A. & TSAGAS, N. (2003a) Magnetic stimulation can modulate seizures in epileptic patients. *Brain Topogr,* 16**,** 57-64.

ANNINOS, P., KOTINI, A., TAMIOLAKIS, D. & TSAGAS, N. (2006) Transcranial magnetic stimulation. A case report and review of the literature. *Acta Neurol Belg,* 106**,** 26-30.

ANNINOS, P., PAPADOPOULOS, I., KOTINI, A. & ADAMOPOULOS, A. (2003b) Differential diagnosis of prostate lesions with the use of biomagnetic measurements and non-linear analysis. *Urological Research,* 31**,** 32-36.

ANNINOS, P. A., TSAGAS, N., SANDYK, R. & DERPAPAS, K. (1991) Magnetic stimulation in the treatment of partial seizures. *International Journal of Neuroscience,* 60**,** 141-171.

ASHKALIEV, Y. F., DROBZHEV, V. I., SOMSIKOV, V. M., TURKEEVA, B. A. & YAKOVETS, T. K. (1995) Effect of heliogeophysical factors on ecological conditions. *Biofizika,* 40**,** 1031-1037.

BAN'KOV, V. I. (1972) Induction of experimental sleep in cats by the action of low-frequency modulated electromagnetic fields. *Biull Eksp Biol Med,* 73**,** 14-6.

BAWIN, S. M., GAVALAS-MEDICI, R. J. & ADEY, W. R. (1973) Effects of modulated very high frequency fields on specific brain rhythms in cats. *Brain Res,* 58**,** 365-84.

BELISHEVA, N. K., POPOV, A. N., PETUKHOVA, N. V., PAVLOVA, L. P., OSIPOV, K. S., TKACHENKO, S. E. & VARANOVA, T. I. (1995) Qualitative and quantitative assessment of exposure to geomagnetic field variations on the functional status of the human brain. *Biofizika,* 40**,** 1005-1012.

BELL, V., MAIDEN, C., MUNOZ-SOLOMANDO, A. & REDDY, V. (2006) 'Mind control' experiences on the internet: implications for the psychiatric diagnosis of delusions. *Psychopathology,* 39**,** 87-91.

BELOV, A. A., KONYUKHOV, V. K., LOGVINENKO, V. P. & TIKHONOV, V. I. (1996) Determination of permittivity of spin-modified water. *Bull. Lebedev Phys. Inst., Allerton Press, New York***,** 38-42.

BELYAEV, I. (2005) Nonthermal biological effects of microwaves: Current knowledge, further perspective, and urgent needs. *Electromagnetic Biology and Medicine,* 24**,** 375-403.

BELYAEV, I. Y., SHCHEGLOV, V. S., ALIPOV, Y. D. & POLUNIN, V. A. (1996) Resonance effect of millimeter waves in the power range from 10^(-19) to 3x10^(-3) W/cm2 on Escherichia coli cells at different concentrations. *Bioelectromagnetics,* 17**,** 312-321.

BERSANI, F. (Ed.) (1999) *Electricity and Magnetism in Biology and Medicine,* London, Kluwer/Plenum.

BINHI, V. N. (2002) *Magnetobiology: Underlying Physical Problems,* San Diego, Academic Press.

BINHI, V. N. (2006) Stochastic dynamics of magnetosomes and a mechanism of biological orientation in the geomagnetic field. *Bioelectromagnetics,* 27**,** 58-63.

BINHI, V. N. (2007) A few remarks on 'Combined action of DC and AC magnetic fields on ion motion in a macromolecule'. *Bioelectromagnetics,* 28**,** 409-412.

BINHI, V. N. & CHERNAVSKII, D. S. (2005) Stochastic dynamics of magnetosomes in cytoskeleton. *Europhysics Letters,* 70**,** 850-856.

BINHI, V. N. & RUBIN, A. B. (2007) Magnetobiology: The kT paradox and possible solutions. *Electromagn Biol Med,* 26**,** 45-62.

BINHI, V. N. & SAVIN, A. V. (2002) Molecular gyroscopes and biological effects of weak extremely low-frequency magnetic fields. *Physical Review E,* 65**,** 051912.

BINHI, V. N. & SAVIN, A. V. (2003) Effects of weak magnetic fields on biological systems: Physical aspects. *Physics-Uspekhi,* 46**,** 259-291.

BISE, W. (1978) Low power radio-frequency and microwave effects on human electroencephalogram and behavior. *Physiol Chem Phys,* 10**,** 387-98.

BLACKMAN, C. F. (2006) Can EMF exposure during development leave an imprint later in life? *Electromagn Biol Med,* 25**,** 217-25.

BLACKMAN, C. F., BENANE, S. G. & HOUSE, D. E. (2001) The influence of 1.2 microT, 60 Hz magnetic fields on melatonin- and tamoxifen-induced inhibition of MCF-7 cell growth. *Bioelectromagnetics,* 22**,** 122-128.

BLANK, M. & SOO, L. (1996) The threshold for Na,K-ATPase stimulation by electromagnetic fields. *Bioelectrochemistry and Bioenergetics,* 40**,** 63-65.

BLUCK, J. (2004) NASA develops system to computerize silent, 'subvocal' speech. http://www.nasa.gov/centers/ames/news/releases/2004/04_18AR.html.

BOOTH, J. N., KOREN, S. A. & PERSINGER, M. A. (2005) Increased feelings of the sensed presence and increased geomagnetic activity at the time of the experience during exposures to transcerebral weak complex magnetic fields. *International Journal of Neuroscience,* 115**,** 1053-1079.

BORBELY, A. A., HUBER, R., GRAF, T., FUCHS, B., GALLMANN, E. & ACHERMANN, P. (1999) Pulsed high-frequency electromagnetic field affects human sleep and sleep electroencephalogram. *Neuroscience Letters,* 275**,** 207-210.

CHIBRIKIN, V. M., SAMOVICHEV, E. G., KASHINSKAIA, I. V. & UDAL'TSOVA, N. V. (1995) Dynamics of social processes and geomagnetic activity. 1. Periodic components of variations in the number of recorded crimes in Moscow. *Biofizika,* 40**,** 1050-1053.

CLARKE, B. M., UPTON, A. R., KAMATH, M. V., AL-HARBI, T. & CASTELLANOS, C. M. (2006) Transcranial magnetic stimulation for migraine: clinical effects. *J Headache Pain,* 7**,** 341-6.

COMISSO, N., DEL GIUDICE, E., DE NINNO, A., FLEISCHMANN, M., GIULIANI, L., MENGOLI, G., MERLO, F. & TALPO, G. (2006) Dynamics of the ion cyclotron resonance effect on amino acids adsorbed at the interfaces. *Bioelectromagnetics,* 27**,** 16-25.

COOK, C. M., THOMAS, A. W. & PRATO, F. S. (2002) Human Electrophysiological and Cognitive Effects of Exposure to ELF Magnetic and ELF Modulated RF and Microwave Fields: A Review of Recent Studies. *Bioelectromagnetics,* 23**,** 144-157.

COOK, L. L. & PERSINGER, M. A. (2000) Suppression of experimental allergic encephalomyelitis is specific to the frequency and intensity of nocturnally applied, intermittent magnetic fields in rats. *Neuroscience Letters,* 292**,** 171-174.

COUGHLIN, K. (2007) A quiet death for bold project to map the mind. The Star Ledger, March 15.

COWEY, A. (2005) The Ferrier Lecture 2004: What can transcranial magnetic stimulation tell us about how the brain works? *Philosophical Transactions of the Royal Society of London Series B Biological Sciences,* 360**,** 1185-1205.

DEES, C., GARRETT, S., HENLEY, D. & TRAVIS, C. (1996) Effects of 60-Hz fields, estradiol and xenoestrogens on human breast cancer cells. *Radiation Research,* 146**,** 444-452.

DELGADO, J. M. (1952) Permanent implantation of multilead electrodes in the brain. *Yale J Biol Med,* 24**,** 351-358.

DELGADO, J. M. R., LEAL, J., MONTEAGUDO, J. L. & GARCIA GRACIA, M. (1982) Embryological changes induced by weak, extremely low frequency electromagnetic fields. *Journal of Anatomy,* 134**,** 533-551.

DEVYATKOV, N. D. (1973) Effect of a SHF (mm-band) radiation on biological objects. *Uspekhi Fizicheskikh Nauk,* 110**,** 453-454.

DOBSON, J. (2002) Investigation of age-related variations in biogenic magnetite levels in the human hippocampus. *Experimental Brain Research,* 144**,** 122-126.

DOLGACHEVA, L. P., SEMENOVA, T. P., ABZHALELOV, B. B. & AKOEV, I. G. (2000) The effect of electromagnetic radiation on monoamine oxidase A activity in the rat brain (article in Russian). *Radiation Biology. Radioecology (Radiatsionnaya Biologiya. Radioekologiya),* 40**,** 429-432.

DORNFELDT, K. (1996) Pigeon homing in the meteorological and solar-geomagnetic environment: What pigeon race data say. *Ethology,* 102**,** 413-435.

DUBROV, A. P. (1978) *The Geomagnetic Field and Life,* New York, PLenum.

ELDER, J. A. & CHOU, C. K. (2003) Auditory Response to Pulsed Radiofrequency Energy. *Bioelectromagnetics,* 24.

FALMER, M. (1995) Heating up the airwaves - The US HAARP research programme and its potential for military applications. *Jane's Defence Weekly,* 23**,** 21-22.

FESENKO, E. E., NOVIKOV, V. V. & SHVETSOV, I., P. (1997) Molecular mechanisms of biological action of low magnetic fields. III. Regulation of intermolecular interaction in water phase of DNA, DNAse 1 and a DNAase 1 inhibitor under combined action of low constant and alternating magnetic fields adjusted to cyclotron resonance of polar amino acid ions. *Biofizika,* 42**,** 742-5.

FINS, J. J. (2007) Mind wars: Brain research and national defense. *J. Am. Med. Assoc.,* 297**,** 1382-1383.

FORMAN, P. (1987) Behind quantum electronics: National security as basis for physical research in the United States, 1940-1960. *Historical Studies in the Physical and Biological Sciences,* 18**,** 149-229.

FREGNI, F., SCHACHTER, S. C. & PASCUAL-LEONE, A. (2005) Transcranial magnetic stimulation treatment for epilepsy: can it also improve depression and vice versa? *Epilepsy Behav,* 7**,** 182-9.

FREY, A. H. (1961) Auditory system response to radio frequency energy. Technical note. *Aeromed Acta,* 32**,** 1140-2.

FROHLICH, H. (1968) Long-range coherence and energy storage in biological systems. *Int. J. Quantum Chem.,* 2**,** 641-649.

GAPEYEV, A. B., SAFRONOVA, V. G., CHEMERIS, N. K. & FESENKO, Y. Y. (1996) The modification of mouse peritoneal neutrophil activity at effect of millimeter waves in near field and far field zones of radiator. *Biofizika,* 41**,** 205-219.

GAUN (1948) General Assembly of the United Nations. Declaration of Human Rights. Art. 18-19. www.un.org/Overview/rights.html.

GINZBURG, V. L. (1999) On "What is happening to us?" by E.P. Kruglyakov *Physics - Uspekhi,* 42**,** 295-296.

GIRI, D. V. (2004) *High-Power Electromagnetic Radiators: Nonlethal Weapons and Other Applications,* Cambridge, MA, Harvard University Press.

GODIK, E. E. & GULYAEV, Y. V. (1991) Functional Imaging of the Human Body. *IEEE Engineering Medicine and Biology,* 10**,** 21-29.

GORDON, C. & BERK, M. (2003) The effect of geomagnetic storms on suicide. *South African Psychiatry Review,* 6**,** 24-27.

GORDON, W. E. (1997) HAARP facility in Alaska. *Science,* 275**,** 1861.

GRIGORIEV, O. A., GRIGORIEV, Y. G., STEPANOV, V. S. & CHEKMAREV, O. M. (2006) Bioelectromagnetic terrorism: Analysis of possible threat (Article in Russian). IN GRIGORIEV, O. A. (Ed.) *Annual of the Russian National Committee on Non-Ionizing Radiation Protection.* Moscow, ALLANA.

GRUNDLER, W. & KAISER, F. (1992) Experimental evidence for coherent excitations correlated with cell growth. *Nanobiology,* 1**,** 163-176.

GULYAEV, Y. V. & GODIK, E. E. (1983) The Physical Fields of Biological Objects (Article in Russian). *Vestnik AN USSR* 8.

GULYAEV, Y. V., GODIK, E. E., PETROV, A. V. & TARATORIN, A. M. (1984) Possibilities of the remote functional diagnosis of biological objects by their infrared radiation (Article in Russian). *Dokl Akad Nauk SSSR,* 277**,** 1486-1491.

GUSTERSON, H. (2007) The militarization of neuroscience. www.thebulletin.org/columns/hugh-gusterson/20070410.html

GUY, A. W., CHOU, C. K., LIN, J. C. & CHRISTENSEN, D. (1975) Microwave-induced acoustic effects in mammalian auditory systems and physical materials. *Ann N Y Acad Sci,* 247**,** 194-218.

HALGREN, E., DHOND, R. P., CHRISTENSEN, N., VAN PETTEN, C., MARINKOVIC, K., LEWINE, J. D. & DALE, A. M. (2002) N400-like magnetoencephalography responses modulated by semantic context, word frequency, and lexical class in sentences. *NeuroImage,* 17**,** 1101-1116.

HAMALAINEN, M., HARI, R., ILMONIEMI, R. J., KNUUTILA, J. & LOUNASMAA, O. V. (1993) Magnetoencephalography - theory, instrumentation, and applications to noninvasive studies of the working human brain. *Reviews of Modern Physics,* 65**,** 413-497.

HARLAND, J., ENGSTROM, S. & LIBURDY, R. (1999) Evidence for a slow time-scale of interaction for magnetic fields inhibiting tamoxifen's antiproliferative action in human breast cancer cells. *Cell Biochemistry and Biophysics,* 31**,** 295-306.

HARLAND, J. D. & LIBURDY, R. P. (1997) Environmental Magnetic Fields Inhibit the Antiproliferative Action of Tamoxifen and Melatonin in a Human Breast Cancer Cell Line. *Bioelectromagnetics,* 18**,** 555-562.

HAVAS, M. (2006) Electromagnetic hypersensitivity: biological effects of dirty electricity with emphasis on diabetes and multiple sclerosis. *Electromagn Biol Med,* 25**,** 259-68.

HECHT, J. (2006) Top 10: Weapons of the future. *NewScientistTech. Special Reports, Weapons Technology,* 4 September.

HESS, C. W., MILLS, K. R. & MURRAY, N. M. (1986) Magnetic stimulation of the human brain: facilitation of motor responses by voluntary contraction of ipsilateral and contralateral muscles with additional observations on an amputee. *Neurosci Lett,* 71**,** 235-40.

HILLERT, L., HEDMAN, B. K., SODERMAN, E. & ARNETZ, B. B. (1999) Hypersensitivity to electricity: working definition and additional characterization of the syndrome. *J Psychosom Res,* 47**,** 429-38.

HISAMITSU, T., SETO, A., NAKAZATO, S., YAMAMOTO, T. & AUNG, S. K. H. (1996) Emission of extremely strong magnetic fields from the head and whole body during oriental breathing exercises. *Acupuncture and Electro-Therapeutics Research,* 21**,** 219-227.

HOAG, H. (2003) Remote control. *Nature,* 423**,** 796-798.

HOFMANN, U. G., FOLKERS, A., MOSCH, F., MALINA, T., MENNE, K. M., BIELLA, G., FAGERSTEDT, P., DE SCHUTTER, E., JENSEN, W., YOSHIDA, K., HOEHL, D., THOMAS, U., KINDLUNDH, M. G., NORLIN, P. & DE CURTIS, M. (2006) A novel high channel-count system for acute multisite neuronal recordings. *IEEE Trans Biomed Eng,* 53**,** 1672-7.

HUANG, J., FRANCIS, A. P. & CARR, T. H. (2007) Studying overt word reading and speech production with event-related fMRI: A method for detecting, assessing, and correcting articulation-induced signal changes and for measuring onset time and duration of articulation. *Brain Lang*.

HUBER, R., SCHUDERER, J., GRAF, T., JUTZ, K., BORBELY, A. A., KUSTER, N. & ACHERMANN, P. (2003) Radio Frequency Electromagnetic Field Exposure in Humans: Estimation of SAR Distribution in the Brain, Effects on Sleep and Heart Rate. *Bioelectromagnetics,* 24**,** 262-276.

ICNIRP (1998) Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). International Commission on Non-Ionizing Radiation Protection. *Health Phys,* 74**,** 494-522.

IKEHATA, M., KOANA, T., SUZUKI, Y., SHIMIZU, H. & NAKAGAWA, M. (1999) Mutagenicity and co-mutagenicity of static magnetic fields detected by bacterial mutation assay. *Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis,* 427**,** 147-156.

ISHIDO, M., NITTA, H. & KABUTO, M. (2001) Magnetic fields (MF) of 50 Hz at 1.2 microT as well as 100 microT cause uncoupling of inhibitory pathways of adenylyl cyclase mediated by melatonin 1a receptor in MF-sensitive MCF-7 cells. *Carcinogenesis,* 22**,** 1043-1048.

JACOBSON, J. I. (1994) Pineal-hypothalamic tract mediation of picotesla magnetic fields in the treatment of neurological disorders. *Panminerva medica,* 36**,** 201-205.

JOHNSEN, S. & LOHMANN, K. J. (2005) The physics and neurobiology of magnetoreception. *Nature Reviews Neuroscience,* 6**,** 703-712.

JUSTESEN, D. R. (1975) Microwaves and behavior. *American Psychologist,* 30**,** 391-401.

JUUTILAINEN, J., LAARA, E. & SAALI, K. (1987) Relationship between field strength and abnormal development in chick embryos exposed to 50 Hz magnetic fields. *International Journal of Radiation Biology,* 52**,** 787-793.

KAMITANI, Y. & TONG, F. (2006) Decoding seen and attended motion directions from activity in the human visual cortex. *Curr Biol,* 16**,** 1096-102.

KANDYBA, D. V. (1995) *Mental hypnosis technique,* Rostov-na-Donu, Feniks.

KATO, M., HONMA, K., SHIGEMITSU, T. & SHIGA, Y. (1994) Recovery of nocturnal melatonin concentration takes place within one week following cessation of 50 Hz circularly polarized magnetic field exposure for six weeks. *Bioelectromagnetics,* 15**,** 489-492.

KAY, R. W. (2004) Schizophrenia and season of birth: Relationship to geomagnetic storms. *Schizophrenia Research,* 66**,** 7-20.

KAZHINSKII, B. B. (1963) *Biological Radio Communication,* Kiev, Academy of Sciences, Ukrainian SSR. (Book in Russian).

KEETON, W. T., LARKIN, T. S. & WINDSOR, D. M. (1974) Normal fluctuations in the earth's magnetic field influence pigeon orientation. *J.COMP.PHYSIOL.SER.A,* 95**,** 95-103.

KIRSCHVINK, J. L. & GOULD, J. L. (1981) Biogenic magnetite as a basis for magnetic field detection in animals. *BioSystems,* 13**,** 181-201.

KIRSCHVINK, J. L., KOBAYASHI-KIRSCHVINK, A. & WOODFORD, B. J. (1992) Magnetite biomineralization in the human brain. *Proceedings of the National Academy of Sciences of the United States of America,* 89**,** 7683-7687.

KIRSCHVINK, J. L., WALKER, M. M. & DIEBEL, C. E. (2001) Magnetite-based magnetoreception. *Current Opinion in Neurobiology,* 11**,** 462-467.

KISS, T. (2005) Non-lethal weapons (Internet resources, books, documents, periodicals). http://www.au.af.mil/au/aul/bibs/soft/nonlethal.htm

KNOSCHE, T. R., MAESS, B., NAKAMURA, A. & FRIEDERICI, A. D. (2005) Human communication investigated with magnetoencephalography: Speech, music, and gestures. *International Review of Neurobiology,* 68**,** 79-120.

KOBAYASHI, M. & PASCUAL-LEONE, A. (2003) Transcranial magnetic stimulation in neurology. *Lancet Neurology,* 2**,** 145-156.

KOLDAEV, V. M. (1987) Pharmacological correction of the acute effects of microwave irradiation in an experiment (Article in Russian). *Nauchnye Dokl Vyss Shkoly Biol Nauki,* No.1**,** 20-26.

KRUMBHOLZ, K., PATTERSON, R. D., SEITHER-PREISLER, A., LAMMERTMANN, C. & LUTKENHONER, B. (2003) Neuromagnetic evidence for a pitch processing center in Heschl's gyrus. *Cereb Cortex,* 13**,** 765-72.

KUBOTA, M., FERRARI, P. & ROBERTS, T. P. L. (2003) Magnetoencephalography detection of early syntactic processing in humans: Comparison between L1 speakers and L2 learners of English. *Neuroscience Letters,* 353**,** 107-110.

KUZNETSOV, A. P., GOLANT, M. B. & BOZHANOVA, T. P. (1997) Exposure of a cell culture to an RF field with intensity below that of background noise. *Millimeter Waves in Biology and Medicine.* Moscow, Inst. of Radio-engineering and Electronics.

LAI, H. (1992) Research on the neurological effects of nonionizing radiation at the University of Washington. *Bioelectromagnetics,* 13**,** 513-526.

LAI, H. (1994) Neurological Effects of Radiofrequency Electromagnetic Radiation. IN LIN, J. C. (Ed.) *Advances in Electromagnetic Fields in Living Systems.* NY, Plenum.

LEITGEB, N. & SCHROTTNER, J. (2003) Electrosensibility and Electromagnetic Hypersensitivity. *Bioelectromagnetics,* 24**,** 387-394.

LIBOFF, A. R., WILLIAMS JR, T., STRONG, D. M. & WISTAR JR, R. (1984) Time-varying magnetic fields: Effect on DNA synthesis. *Science,* 223**,** 818-820.

LIBURDY, R. P., SLOMA, T. R., SOKOLIC, R. & YASWEN, P. (1993) ELF magnetic fields, breast cancer, and melatonin: 60 Hz fields block melatonin's oncostatic action on ER+ breast cancer cell proliferation. *Journal of Pineal Research,* 14**,** 89-97.

LIEBIG, M. & OTHERS (1988) *Electromagnetic-Effect Weapons: The Technology and the Strategic Implications. EIR Special Report,* Washington, DC, Executive Intelligence Review.

LIN, J. C. (1978) *Microwave Auditory Effects and Applications,* Springfield, IL, Charles C. Thomas.

LIN, J. C. (1990) Auditory perception of pulsed microwave radiation. IN GANDHI, O. P. (Ed.) *Biological effects and medical applications of electromagnetic fields.* NY, Prentice-Hall.

LIN, J. C. (2004a) Studies on Microwaves in Medicine and Biology: From Snails to Humans. *Bioelectromagnetics,* 25**,** 146-159.

LIN, J. C. (2004b) Studies on microwaves in medicine and biology: from snails to humans. *Bioelectromagnetics,* 25**,** 146-59.

LUPICHEV, L. N. (Ed.) (1989) *Research on Dynamic Properties of Distributed Media,* Moscow, State Inst. Phys. Tech. Problems.

LUTKENHONER, B. (2003) Magnetoencephalography and its Achilles' heel. *Journal of Physiology Paris,* 97**,** 641-658.

LUTKENHONER, B., SEITHER-PREISLER, A. & SEITHER, S. (2006) Piano tones evoke stronger magnetic fields than pure tones or noise, both in musicians and non-musicians. *Neuroimage,* 30**,** 927-37.

MAGRAS, I. N. & XENOS, T. D. (1997) RF Radiation-Induced Changes in the Prenatal Development of Mice. *Bioelectromagnetics,* 18**,** 455-461.

MAIRE, L. F. & LAMOTHE, J. D. (1975) Soviet and Czechoslovakian Parapsychological Research. Washington, Defense Intelligence Agency, DST-18105-387-75.

MANN, K. & ROSCHKE, J. (2004) Sleep under exposure to high-frequency electromagnetic fields. *Sleep Medicine Reviews,* 8**,** 95-107.

MARKOVA, E., HILLERT, L., MALMGREN, L., PERSSON, B. R. & BELYAEV, I. Y. (2005) Microwaves from GSM mobile telephones affect 53BP1 and gamma-H2AX foci in human lymphocytes from hypersensitive and healthy persons. *Environ Health Perspect,* 113**,** 1172-7.

MARKS, J. (1979) *The Search for the "Manchurian Candidate",* NY, W.W. Norton and Company.

MCCANN, J., DIETRICH, F. & RAFFERTY, C. (1998) The genotoxic potential of electric and magnetic fields: An update. *Mutation Research - Reviews in Mutation Research,* 411**,** 45-86.

MCKAY, B. E. & PERSINGER, M. A. (2006) Weak, physiologically patterned magnetic fields do not affect maze performance in normal rats, but disrupt seized rats normalized with ketamine: Possible support for a neuromatrix concept? *Epilepsy and Behavior,* 8**,** 137-144.

MCMURTREY, J. J. (2005) Recording Microwave Hearing Effects: Literature Review and Case Report of an Affiant to Recording Remote Harassment. http://www.slavery.org.uk/science.htm

MCREE, D. I., ELDER, J. A., GAGE, M. I., REITER, L. W., ROSENSTEIN, L. S., SHORE, M. L., GALLOWAY, W. D., ADEY, W. R. & GUY, A. W. (1979) Effects of noinionizing radiation on the central nervous system, behavior, and blood: a progress report. *Environ Health Perspect,* 30**,** 123-31.

MIKHAYLOVA, A., DAVIDSON, M., TOASTMANN, H., CHANNELL, J. E. T., GUYODO, Y., BATICH, C. & DOBSON, J. (2005) Detection, identification and mapping of iron anomalies in brain tissue using X-ray absorption spectroscopy. *Journal of the Royal Society, Interface / the Royal Society,* 2**,** 33-37.

MIYAKOSHI, J. (2006) The review of cellular effects of a static magnetic field. *Science and Technology of Advanced Materials,* 7**,** 305-307.

MKULTRA (2007) Declassified MKULTRA documents. http://www.intellnet.org/mkultra/ ; http://www.nemasys.com/rahome/library/programming/mkultra.shtml ; http://www.michael-robinett.com/declass/c000.htm.

MORENO, J. D. (2006) *Mind Wars,* NY, Dana Press.

NAM, Y., WHEELER, B. C. & HEUSCHKEL, M. O. (2006) Neural recording and stimulation of dissociated hippocampal cultures using microfabricated three-dimensional tip electrode array. *J Neurosci Methods,* 155**,** 296-9.

NAT.EDITORIAL (2003) Silence of the neuroengineers. *Nature,* 423**,** 787.

NOVIKOV, V. V. (1996) Cooperative effect of resonance enhancement of ion current in water solutions of amino acids under weak electromagnetic exposures. *Biofizika,* 41**,** 973-978.

NOVOSELOVA, E. G., OGAY, V. B., SOROKINA, O. V., GLUSHKOVA, O. V., SINOTOVA, O. A. & FESENKO, E. E. (2004) The production of tumor necrosis factor in cells of tumor-bearing mice after total-body microwave irradiation and antioxidant diet. *Electromagnetic Biology and Medicine,* 23**,** 167-180.

NOVOSELOVA, E. G., OGAY, V. B., SOROKINA, O. V., NOVIKOV, V. V. & FESENKO, E. E. (2001) Effects of centimeter waves and combined magnetic field on tumor necrosis factor production in cells of mice with experimental cancer. *Biofizika,* 46**,** 131-135.

OLSSON, R. H. & WISE, K. D. (2005) A three-dimensional neural recording microsystem with implantable data compression circuitry. *Solid-State Circuits, IEEE Journal of,* 40**,** 2796-2804.

PAKHOMOV, A. G., DOYLE, J., STUCK, B. E. & MURPHY, M. R. (2003) Effects of High Power Microwave Pulses on Synaptic Transmission and Long Term Potentiation in Hippocampus. *Bioelectromagnetics,* 24**,** 174-181.

PASTERNAK, D. (2000) Reading your mind - and injecting smart thoughts. *U.S. News & World Report.*

PAZUR, A. (2004) Characterisation of weak magnetic field effects in an aqueous glutamic acid solution by nonlinear dielectric spectroscopy and voltammetry. *Biomagn Res Technol,* 2**,** 8.

PERSINGER, M. A. (2000) Suppression of experimental allergic encephalomyelitis in rats exposed nocturnally to magnetic fields. *International Journal of Neuroscience,* 100**,** 107-116.

PETROSYAN, V. I., GULYAEV, Y. V., ZHITENEVA, E. A., ELKIN, V. A. & SINITSYN, N. I. (1995) Interaction of physical and biological objects with Ka-band electromagnetic radiation. *Radiotekhnika i Elektronika,* 40**,** 127-134.

PHILLIPS, P., BROWN, L. & THORNTON, B. (2006) US Electromagnetic Weapons and Human Rights. Sonoma State University, CA. http://www.projectcensored.org/newsflash/ElectromegnaticWeapons.pdf.

PINNEO, L. R. & HALL, D. J. (1975) Feasibility study for design of a biocybernetic communication system. Menlo Park, Stanford Research Inst.

POKORNY, J. & WU, T.-M. (1998) *Biophysical Aspects of Coherence and Biological Order,* Prague, Academia, Springer-Verlag.

PREPARATA, G. (1995) *QED Coherence in Matter,* NY, World Scientific.

PRESISSL, H. (2005) *Magnetoencephalography,* San Diego, Ca., Academic Press.

PRESMAN, A. S. (1970) *Electromagnetic Fields and Life,* New York, Plenum.

PYRPASOPOULOU, A., KOTOULA, V., CHEVA, A., HYTIROGLOU, P., NIKOLAKAKI, E., MAGRAS, I. N., XENOS, T. D., TSIBOUKIS, T. D. & KARKAVELAS, G. (2004) Bone Morphogenetic Protein Expression in Newborn Rat Kidneys after Prenatal Exposure to Radiofrequency Radiation. *Bioelectromagnetics,* 25**,** 216-227.

REA, W. R., PAN, Y., FENYVES, E. J., SUJISAWA, I., SAMADI, N. & ROSS, G. H. (1991) Electromagnetic field sensitivity. *J. Bioelectricity,* 10**,** 241-256.

RIEBLING, M. (2004) The Pandora Project. www.markriebling.com/archives/00000304.html

RITZ, T., THALAU, P., PHILLIPS, J. B., WILTSCHKO, R. & WILTSCHKO, W. (2004) Resonance effects indicate a radical-pair mechanism for avian magnetic compass. *Nature,* 429**,** 177-180.

RIZZUTO, D. S., BREZNEN, B. & GREGER, B. (2003) Military-funded research is not unethical. *Nature,* 424**,** 369.

RUBIN, G. J., DAS MUNSHI, J. & WESSELY, S. (2006) A systematic review of treatments for electromagnetic hypersensitivity. *Psychotherapy and Psychosomatics,* 75**,** 12-18.

RUDOLPH, A. (2003) Military: brain machine could benefit millions. *Nature,* 424**,** 369.

RUHENSTROTH-BAUER, G., GUNTHER, W., HANTSCHK, I., KLAGES, U., KUGLER, J. & PETERS, J. (1993) Influence of the Earth's magnetic field on resting and activated EEG mapping in normal subjects. *International Journal of Neuroscience,* 73**,** 195-201.

SANDYK, R. (1996) Effect of weak electromagnetic fields on the amplitude of the pattern reversal VEP response in Parkinson's disease. *International Journal of Neuroscience,* 84**,** 165-175.

SANDYK, R. (1999) Treatment with AC pulsed electromagnetic fields improves olfactory function in Parkinson's disease. *International Journal of Neuroscience,* 97**,** 225-233.

SAVUKOV, I. M., LEE, S. K. & ROMALIS, M. V. (2006) Optical detection of liquid-state NMR. *Nature,* 442**,** 1021-4.

SAVUKOV, I. M., SELTZER, S. J., ROMALIS, M. V. & SAUER, K. L. (2005) Tunable atomic magnetometer for detection of radio-frequency magnetic fields. *Phys Rev Lett,* 95**,** 063004.

SAZAKI, G., MORENO, A. & NAKAJIMA, K. (2004) Novel coupling effects of the magnetic and electric fields on protein crystallization. *Journal of Crystal Growth,* 262**,** 499-502.

SCHENCK, J. F. (2005) Physical interactions of static magnetic fields with living tissues. *Progress in Biophysics and Molecular Biology,* 87**,** 185-204.

SCHIENLE, A., STARK, R. & VAITL, D. (2001) Sferics provoke changes in EEG power. *International Journal of Neuroscience,* 107**,** 87-102.

SCHROTTNER, J., LEITGEB, N. & HILLERT, L. (2007) Investigation of electric current perception thresholds of different EHS groups. *Bioelectromagnetics,* 28**,** 208-13.

SETO, A., KUSAKA, C., NAKAZATO, S., WEI RONG, H., SATO, T., HISAMITSU, T. & TAKESHIGE, C. (1992) Detection of extraordinary large bio-magnetic field strength from human hand during external QI emission. *Acupuncture and Electro-Therapeutics Research,* 17**,** 75-94.

SHIPOV, G. I. (1998) *A theory of physical vacuum: A new paradigm,* Moscow, GART.

SIEBNER, H. R. & ROTHWELL, J. (2003) Transcranial magnetic stimulation: New insights into representational cortical plasticity. *Experimental Brain Research,* 148**,** 1-16.

SIENKIEWICZ, Z., JONES, N. & BOTTOMLEY, A. (2005) Neurobehavioural effects of electromagnetic fields. *Bioelectromagnetics,* 26**,** S116-S126.

SIT'KO, S. P. (1996) Microwave resonance therapy. US Pat. 5507791.

SLESIN, L. (2007) Microwave News. A report on Non-Ionizing Radiation. www.microwavenews.com

SOKOLOV, A., PAVLOVA, M., LUTZENBERGER, W. & BIRBAUMER, N. (2004) Reciprocal modulation of neuromagnetic induced gamma activity by attention in the human visual and auditory cortex. *NeuroImage,* 22**,** 521-529.

ST-PIERRE, L. S. & PERSINGER, M. A. (2003) Conspicuous histomorphological anomalies in the hippocampal formation of rats exposed prenatally to a complex sequenced magnetic field within the nanotesla range. *Perceptual and Motor Skills,* 97**,** 1307-1314.

STARBUCK, S., CORNELISSEN, G. & HALBERG, F. (2002) Is motivation influenced by geomagnetic activity? *Biomedicine and Pharmacotherapy,* 56.

SUBBOTINA, T. I., KHADARTSEV, A. A., YASHIN, M. A. & YASHIN, A. A. (2004) Effect of delta-rhythm-modulated extremely high frequency electromagnetic radiation on rats. *Bull Exp Biol Med,* 137**,** 423-4.

TAKAHASHI, M., WATANABE, Y., HARAGUCHI, T., KAWAI, T., YAMANE, G. Y., ABE, S., SAKIYAMA, K., HIRAIDE, Y., LEE, W. H., IDE, Y. & ISHIKAWA, T. (2004) Neuromagnetic analysis of the late phase of the readiness field for precise hand movements using magnetoencephalography. *The Bulletin of Tokyo Dental College,* 45**,** 9-17.

TAKASHIMA, Y., MIYAKOSHI, J., IKEHATA, M., IWASAKA, M., UENO, S. & KOANA, T. (2004) Genotoxic effects of strong static magnetic fields in DNA-repair defective mutants of Drosophila melanogaster. *Journal of Radiation Research,* 45**,** 393-397.

TAMBIEV, A. E., MEDVEDEV, S. D. & EGOROVA, E. V. (1995) The effect of geomagnetic disturbances on the functions of attention and memory. *Aerospace and Environmental Medicine,* 29**,** 43-45.

TSYGANKOV, V. D. & LOPATIN, V. N. (1999) *Psychotronic War and the Security of Russia (Book in Russian),* Moscow, SINTEG http://www.mindjustice.org/rustrans.htm

VERDON, C. M., SABA, G. & JANUEL, D. (2004) Transcranial magnetic stimulation in cognition and neuropsychology. *Encephale,* 30**,** 363-368.

VLADIMIRSKII, B. M., VOLYNSKII, A. M., VINOGRADOV, S. A., BRODOVSKAYA, Z. I., TEMURIYANTS, N. A., ACHKASOVA, Y. N., ROSENBERG, V. D. & CHELKOVA, Z. D. (1971) Experimental studies of the effect of ELF EM fields on haematherms and microorganisms. *Effect of Solar Activity on the Terrestrial Atmosphere and Biosphere.* Moscow, Nauka.

VOLEGOV, P., MATLACHOV, A. N., ESPY, M. A., GEORGE, J. S. & KRAUS JR, R. H. (2004) Simultaneous magnetoencephalography and SQUID detected nuclear MR in microtesla magnetic fields. *Magnetic Resonance in Medicine,* 52**,** 467-470.

VOLPE, P. (2003) Interactions of zero-frequency and oscillating magnetic fields with biostructures and biosystems. *Photochemical and Photobiological Sciences,* 2**,** 637-648.

WALKER, M. M., DENNIS, T. E. & KIRSCHVINK, J. L. (2002) The magnetic sense and its use in long-distance navigation by animals. *Current Opinion in Neurobiology,* 12**,** 735-744.

WANG, M., FENG, Y. & GUO, Q. (1997) Experimental study on induction animal sleep by low-frequency pulsed magnetic field. *Chinese Journal of Biomedical Engineering,* 16**,** 23-27.

WEINBERGER, S. (2007) Mind Games. *Washington Post Magazine,* January 14**,** W22.

WELSH, C. (2003) Survey of Evidence Regarding Mind Control Experiments. Davis, Mind Justice Org. www.mindjustice.org/2003_survey.htm . See also www.mindjustice.org/emr13.htm , www.apfn.net/messageboard/07-04-05/discussion.cgi.48.html.

WEST, R. W., HINSON, W. G. & SWICORD, M. L. (1996) Anchorage-independent growth with JB6 cells exposed to 60 Hz magnetic fields at several flux densities. *Bioelectrochemistry and Bioenergetics,* 39**,** 175-179.

WESTBROOK, C., CAROLYN KAUT ROTH, C. K. & TALBOT, J. (2005) *MRI in Practice,* Oxford, Blackwell.

WILTSCHKO, W. & WILTSCHKO, R. (2005) Magnetic orientation and magnetoreception in birds and other animals. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology,* 191**,** 675-693.

ZARUBIN, A. P. (2007) Torsion fields and spin-torsion interactions. (Bibliography in Russian). Novosibirsk, http://www.prometeus.nsc.ru/partner/zarubin/torfield.ssi

## About the author

Vlad N. Binhi, a physicist at the General Physics Institute, Russian Academy of Sciences, is well known for his work on bioelectromagnetics and magnetobiology. His area of expertise includes electromagnetobiology, magnetic processes in molecular systems, and magnetic measurements. Binhi has intensively researched this area for over 25 years. He is a regular speaker at conferences, symposia, and other meetings on the interactions of electromagnetic fields with living systems. Binhi has published over 50 works in peer-reviewed journals. His main publications are in leading journals such as Physical Review, Europhysics Letters, Bioelectromagnetics, Biochimica et Biophysica Acta, Bioelectrochemistry, Electromagnetic Biology and Medicine, Physics-Uspekhi, Biophysics, etc. His monograph "Magnetobiology," with a foreword by Nobel Laureate A.M. Prokhorov, remains unique in that it is entirely devoted to the physics of magnetobiology. Binhi graduated from the Moscow Institute of Physics and Technology as a specialist in electronic processes in 1977. He then received his Ph.D. from the P.N. Lebedev Physics Institute of the USSR Academy of Sciences in 1982, and his D.Sc. degree in physics/mathematics from Moscow State University in 2005 for his work in theoretical magnetobiology. Since 1983, Binhi has been involved in the study of the physical processes of biological magnetoreception. Prof. Binhi now heads a biophysics laboratory that develops experimental methods for the primary physical mechanisms of magnetoreception.