ELECTROMAGNETIC MIND CONTROL, FACT OR FICTION

A SCIENTIFIC VIEW

V. N. BINHI

NOVA

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Electromagnetic Mind Control: Fact or Fiction? A Scientific View

V. N. Binhi

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FOREWORD

The subject of electromagnetic mind control is truly fascinating but also very complex. Prof. Vlad Binhi must be congratulated for tackling this question. Moreover, he has been careful to use *A Scientific View* in the subtitle. In so doing he makes a key distinction at the outset, bringing this subject out of the shadows and placing it squarely in a scientific context.

For more than 50 years, this area has been the playground for assorted charlatans, nuts, conspiratorialists, and people who simply do not believe the laws of physics. As in most discussions surrounding the potential influence, whether harmful or beneficial, of electromagnetism on humans, the loud presence of pseudoscientific fringe elements has made it very difficult for serious workers to be heard. It is therefore very useful to find in Prof. Binhi's book a large source of references on this subject that is free of the usual unfiltered claims one normally has to deal with when it come to matters of mind control. Especially important in this regard are the relevant scientific reports from Eastern Europe, up to now not readily available in the West.

There are two questions that those interested in this subject always ask: first, is mind control possible? and, second, is such stuff being practiced by the government?

The answer to the first question depends on what is meant by mind control. There are many shades to defining how a mind can be manipulated. Simply because imbibing too much alcohol can cause a person to lose his inhibitions, if you help someone get drunk, then in effect you are manipulating that person's mind. A certain degree of mind control occurs under hypnosis, albeit in a limited way, closer to somnambulism. Mind control of yet another sort can occur in successful advertising campaigns, whether one is selling a new car or a politician. Can electromagnetic fields affect one's decisions in ways similar to what is observed in drunkenness, advertising campaigns or hypnosis? The answer is, very likely, yes. But if one stretches the meaning and takes an extreme position asking whether electromagnetism could allow one individual to "take over" someone else's brain, this is another matter. Many people have homed in on this extreme view of electromagnetic neural effects, preferring to imagine what happens in a Grade B horror movie, rather than the less dramatic, but potentially important scientific possibilities.

Not that this "take-over" scenario lacks a technological basis. It depends on the use of the acoustic response that sometimes occurs when the head is exposed to microwave signals, otherwise called microwave hearing. This microwave-induced acoustic response is a very real thing. I once had the good fortune to be flying to New Zealand in First Class in the first row, and noticed that for one particular position of my head, there was a distinct thumping sound, repeated every few seconds. When I asked the steward about this sound, he was very familiar with it, confirming what I already suspected, that it was due to the circulating radar beam in the nose of the 747.

Of course, in principle one can modulate a high frequency signal with low frequency patterns that correspond to speech, and even electronically create certain statements. If we were to assume that this was technically feasible, I doubt very much that mind "take-over" would ever occur. It is more likely that subjects would simply become greatly distracted, driven out of their minds, or even become suicidal. There are much easier methods to achieve these ends.

In the same vein occasionally one hears talk about electromagnetically induced zombie-like effects, allegedly practiced by this or that government on unsuspecting citizens. Presumably, the word zombie is connected to what was popularized in films like *Night of the Living Dead*, or *The Island of Doctor Moreau*, where already deceased victims walk around at night, always after sunset, expressionless, with hands outstretched, mumbling incoherently, while searching out those who are still alive, with murderous intentions.

These popular versions of what is meant by electromagnetic mind make it is necessary for the underlying definitions to be clearly stated. I prefer to divide the possibilities into three categories: *mild* effects similar to inducing sleep or losing one's inhibitions, way-out *extreme* effects, where one's mind is "taken over" by another human being or even a smart machine, and finally all the in-between, and probably more interesting, behavioral possibilities.

It is well to recognize that devices in the first, or mild, category are already on the market, advertised as electromagnetic means for fighting insomnia.[1]

In the middle category, one should be aware that electromagnetically induced changes in key traits such as aggressiveness, memory and learning, have all been observed in rats. There is good reason to think that these effects on important behavioral functions can also be made to occur in humans. Thus we think it highly feasible that we can induce loss of memory in people, make individuals more fearful or perhaps more willing to take chances, or simply compromise one's ability to make simple decisions. There can be no question that electromagnetic effects like these represent extraordinary opportunities for the military, to say nothing of corporate advertising or even political advancement.

In the third, most extreme category I know of no experimental evidence to support the claims that one can electromagnetically "take over" someone else's mind, or otherwise make human zombies. The main reason driving this possibility is the microwave hearing effect, coupled with speculations, first that this effect can be technically transformed into a device that transmits thoughtful commands, and second that individuals who were unluckily at the receiving end of this device, would necessarily be willing to follow orders. It is one thing to interfere with one's actions, quite another to manipulate them.

Looking more closely at the evidence for electromagnetically-induced *behavioral* effects, many of the most relevant experiments were hidden from view by the Cold War. One contribution to this literature is found in the Project Pandora Report,[2] dealing with the alleged microwave "attack" by the Soviet Union on the US Embassy in the 1950s. This report, prepared for the office of the US State Department, came to no clear conclusion. Thus, although the Russian government probably did direct microwave beams at the Embassy on Tchaikovsky Street, to this day the purpose remains unclear as do the consequences.

In the US the most important research contributions to this area were made by two physician/scientists, W. Ross Adey and Robert O. Becker. Both felt that electromagnetic mind control was inevitable. Adey concentrated on studying calcium effects in animal brain (cats, chicks) exposed to high frequency electromagnetic fields. Becker, working with Dr. Andrew Marino, concentrated on low frequency effects in humans.

The seminal experiment[3] by Adey and Bawin showed that radiofrequency electromagnetic fields modulated at selective frequencies can have profound effects on calcium transport in brain tissue. One cannot minimize the lasting importance of this work, which in time came to be known as the calcium efflux experiment. It opened the door to many other findings, by scientists including Blackman,[4] myself,[5] and Zhadin,[6] conclusively showing that there are truly remarkable interactions between electromagnetic fields and the brain. When it was first reported in the mid seventies there was great criticism of the experimental results, mainly because the old paradigm held that it was physically impossible to affect the brain with the extremely low electromagnetic intensities that were used.

It is commonly recognized that the laws of physics can be used to set lower limits on the field intensities that can interact with tissue in a meaningful way, that is provide electrical signals that are not swamped by naturally occurring electrical noise within the tissues. At higher intensities there are well recognized thermal effects (e.g., microwave heating). As such, it was difficult for many to believe that nonthermal fields were capable of affecting brain function, and even harder to believe that such effects were only possible at certain frequencies.

One of the by-products of the Ca efflux studies was a series of nonthermal experiments on rats starting in the mid-eighties showing that low frequency magnetic fields, specified according to a set of empirical rules termed ion cyclotron resonance (ICR), will have profound effects on rat behavior. The first of these,[7] by Dr. John Thomas and myself at the Naval Medical Research Institute in Bethesda, Maryland, found that in all cases tested, rats temporarily lose their short-term memory after just one hour of exposure to ICR fields.

Since then, successive experiments[8–10] have shown that rats exposed to these magnetic field combinations can be made to learn either more quickly than controls or less, depending on the field combination that is used. These magnetic fields are also capable of producing greater aggressiveness or greater passivity, again as compared to controls. In effect, the way has been pointed towards selective frequency control of behavior.

Further a connection has been hypothesized to explain these effects, connecting these magnetic field combinations to a key enzyme in the brain, the NMDA glutamate receptor. Glutamate has long been implicated by neurophysiologists in memory and learning.

Given this strong likelihood that the concept is quite feasible, it is reasonable to assume that government would pursue this matter, if for no other reason than to be prepared in the event an unfriendly nation or group were to develop such technology for other than peaceful purposes. To illustrate this point, I recall once being approached by individuals from one of the US security agencies to render an opinion on the abilities of the "seer" Edgar Cayce. At first I was shocked by this request, but came to realize that responsible authorities felt it necessary to explore any possibility, no matter how remote from reality, in providing an edge for national security, even if this was something that I regarded as one step away from a side show at a circus.

I certainly think that governments have been actively involved for some time in trying to bring this possibility into reality. The underlying research is likely focused on two very different frequency ranges, first, at extremely low frequencies, from just one or two to several hundred hertz, and second, in the gigahertz region and beyond. It is also highly probable that signals encompassing both frequencies would be of great interest. Even more important, there is every reason to think that additional, as yet untried electromagnetic modalities, other than the resonance techniques mentioned above, will also affect our behavior.

In personal conversations with Dr. Becker, even some 25 years ago, he always maintained that both the US and Russian governments were very much involved in such research. But he also felt that there was a deliberate attempt by authorities to cover up these clandestine activities by means of deliberate disinformation tactics. These included weird and bizarre stories that were leaked to the public for one purpose: to muddy the waters, to make the whole question of mind control seem absolutely unbelievable.

For this reason alone we should be deeply indebted to Prof. Binhi. His work represents the first scholarly attempt to examine the reality of electromagnetic mind control in stark, scientific terms. In so doing he begins to unmuddy the waters.

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Vladimir N. Binhi

Chapter 1

INTRODUCTION

Rapid advances in cognitive neuroscience and its related technologies significantly facilitated the detection of psychological states of mind. Modern functional neuroimaging makes it possible to visualize and measure different brain functions, enabling one to detect the association of activity in a particular portion of the brain with the specific features of cognitive processes and behavior. The progress in cognitive studies has generated huge scientific, military, and governmental interest in the development and future applications of the neurotechnologies (NRC, 2008). Cognitive neuroscience has also created considerable public interest, which is accompanied by a large amount of pseudoscientific information and journalistic exaggeration. People are often concerned about possible use of electromagnetic (EM)[1] fields to read their minds and associate this possibility with the advances in neuroscience and microelectronics.

There are many publications, primarily in newspapers and popular magazines, discussing "electromagnetic weapons" and so-called "electromagnetic mind control." This controversial theme originates from two well-known facts: (i) EM fields and radiations can affect human beings and (ii) the impact of electromagnetic fields occurs invisibly and so it may be used covertly on unwitting people without their consent. Particularly intriguing is the idea that relatively weak EM fields can affect the human brain causing specific mental processes, conscious or subconscious, which raises the prospect of control of the human mind.

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

In this book, we first consider general questions associated with the concept of EMF control of the human organism and particularly of the human mind. EM mind control is defined. A brief historical overview will be presented showing the significant milestones of the development of this concept in the USA and in Russia. Then known methods that allow extracting information about brain processes are analyzed. Other methods are reviewed as well, which in contrast allow delivery of information into the human brain, by exposure to EM fields and radiations.

Any EM mind control 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 weak MFs and EM radiations, and neurological effects among them; (ii) some theoretical grounds that provide examples of molecular and subcellular mechanisms validating the effects of weak EMFs, and (iii) technical limitations of the targeted exposure of humans to EM fields and radiations. A comment is given to the microwave hearing effect with regard to its potential for EM mind control.

Then, there are observations, experiments, facts, where the human mind is not only an object but also the subject of a study. Here, the observations may not be explained within the scientific context. Therefore, the limitations of the scientific method are discussed. It is the interaction of human mind with the surrounding reality that is most vulnerable from the viewpoint of its scientific description. Finally, conclusive remarks focus 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.

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 conscience” and closely bound to it *freedom of thought*. It is the freedom of an individual to hold an opinion, viewpoint, or thought without interference, i.e., regardless of anyone else’s view (GAUN, 1948). Two important consequences result from these principles.

First, it clearly means that everybody has the right to keep his or her thoughts concealed. Would some person or group of persons or an institution find a method of reading another person’s mind, it would be a direct violation of the basic law. Some human rights 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 an implication, although not obvious, related to the scientific view of the world. With a closer look, it becomes clear that the principle embodies thought as a fundamental category adopted by humankind free of direct social responsibility. For example, hatred is non-punishable unless it was expressed as an action resulting in harm. This means, for example, that no one could be prosecuted for his or her thoughts. Thus, people recognize, by their practical activity and by their legislation, that *thought* by itself cannot produce action or matter. It is significant that science relies on the same postulate. A principle of the scientific method is to separate the object from the subject of study and to take the object as that existing regardless of the subject's mental activity. This principle is in excellent agreement with both general scientific observations and everyday experience. The social aspect of the postulate is even more significant than its scientific counterpart because it originates from the historical human experience. The social law transcends science since it not only includes the latter, but also encompasses the entire human practical informal knowledge.

Review of the literature on such a complex subject as "mind control" requires clarifying the position with regard to the materialist and idealist standpoints. 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. The particular case where observations of mind control are beyond the scope of science will be specifically discussed.

MIND CONTROL

It is important to come to an agreement about the meaning of the key term "mind control." The notion of mind control and the extent of its possible influence on individuals have not been conclusively determined. The term is rarely used 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 in dispute. Social psychology sees mind control as a systematic use of well known communication principles. Under this definition, people who persuade or impose their opinion on others, implement mind control to some extent. Evidently, social psychology does not take into account that an 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 external causes. This would include 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, two aspects are very different from a physical viewpoint. First, mind reading *per se* is a method by which one could secretly obtain or read-out information, the thoughts that an individual is thinking. The second aspect is a method of delivering and embedding information to an individual's mind.

Among all types of mind control technologies, the most intriguing is the technology that uses EM fields and radiations as a delivery vehicle for mind control signals. The dilemma is that EM radiation can be easily organized so as to unexpectedly or even secretly expose large groups of people using relatively distant EM sources. Or, 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 with the ability to cover a potentially large area of exposure and with a capacity for quick adjustments and targeting. However, the most important feature of EM mind control is the possibility of a covert EM exposure. The exposed individuals would be unaware of the EM influence and would believe that their actions are under their own control. They would be unaware that some of their thoughts could originate 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 study, only electromagnetic mind control and mind reading is considered.

MIND READING

A few of the general relationships between such concepts as words, phrases, thoughts, and senses should be clarified before proceeding with the subject of mind reading.

One can understand the sense of the following phrase: "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." This is a well-known example showing that the general meaning of a sentence may be communicated in many ways. In other words, there are many ways to say the same thing. Even when the words are scrambled in a phrase, the sense of the latter is still understandable to some extent. This demonstrates that a sense is an independent entity that may be expressed by different means. In addition, creative abilities can also communicate senses, for example, the meaning of artwork.

Clearly, a sense exists separately from the form of its expression. What kind of thoughts are behind phrases and senses? It is not yet known.

The human mind is able to think without expressing senses, or meanings, in the form of verbal constructions, words or phrases. Even covert speech does not always accompany the flow of senses. Apparently, humans can think silently without covert words, i.e., they think with an "inner silence," and only when they need to actually transfer their thoughts to others, humans can "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 speech, when a human speaks covertly. Even in these cases, the speech reflects the interactions between many different senses. It is reasonable to assume that if mind reading existed, it would consist of receiving the flow of senses. To read a person's mind means to know what that person thinks, and a person thinks 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; another way is to hear what was spoken. It is practically impossible to understand a sense using other organs of sense such as the sense of taste or smell. Some people believe that some kind of sense or thought, that is to say information, may be perceived by a person who is sensitive to paranormal experiences. 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 knowing which neurons are "fired" at a given moment in time would make it possible to understand what the human thinks. As 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, particularly a comprehensive computer program, would have to replace the brain in its most enigmatic and subtle function, consciousness.

It seems impossible even within the physicalist framework. At the level of computational and memory power of the modern computers, one could assume that 10^{12} is a likely current limit for a fast memory array. The network of 10^{10} human brain neurons involves about 10^{14} conjunctions, or synapses, that are necessary to create a thought. A 100-fold difference cannot be overcome here by a mere expansion without a qualitative change. Moreover, a major problem would be to produce the "initial conditions" necessary for such a system to be able to function as a brain. If this were somehow achieved, electromagnetic mind reading would also be met by severe physical and technical limitations, which are considered below.

EM 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, which were 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). This is a project aimed to control ionospheric processes, which might alter the performance of communication and surveillance systems (Gordon, 1997). Located in the remote area of Alaska, HAARP antennas, 180 components in all, are organized in a so-called phase array antenna (Figure 1). It 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. This power is about a thousand times smaller than that of a mid-size hydroelectric plant. The 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 intended to immobilize rather than 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 disrupt military operations. Such technologies are now considered to be useful in civilian operations to suppress violent, unruly or illegal riots and protests. The most commonly known are microwave guns, which produce pain from the microwave emissions that cause sudden heating of the skin of humans. 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 nonthermal 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 the 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 be operated by a criminally motivated individual and change a person's state of mind or behavior. However, sometimes, it is actually hard to distinguish the truth from conspiracy theory.

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 a capability accessible to all levels of society. Assume for a moment that an efficient mind reading technology really exists. If everyone had access to such technology, it would quickly destabilize a society. Knowing precisely what an individual is thinking would allow the possibility of significant power over their personality. This means that EM mind control is a sort of "ultimate weapon" that will probably always be associated either with the unique ability of some esoterics or with 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 discovering and using new knowledge, together with moral and ethics are intricately intertwined with each other thus securing a global society's stability and development.

Figure 1. HAARP antennas geometrically ordered to beam the EM power to a given place in the ionosphere (www.haarp.alaska.edu).

NEUROTECHNOLOGIES

Can modern science and technology achieve the ability to read and manipulate the mind? We will look at electromagnetic neurotechnologies below. Electromagnetic mind manipulation, unlike mind reading, appears to be 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 or other utilities. There are several types of such neurotechnologies: magnetoencephalography, magnetic resonance imaging (MRI), and transcranial and standard magnetic stimulation of the human brain.

In magnetic encephalography, the electrical activity of the 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 3D (three-dimensional) distribution of the brain activity. At this time, the number of sensors can be as many as a few hundred, which gives an illustration of the hardware resolution, i.e., 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 the brain. MRI provides information about tissue structure based on the distributions of the chemical or elemental composition. Here, in a small zone of the brain tissue, external EM fields excite atoms so that they begin to irradiate their own EM radiation. This radiation is captured by special detectors. The zone of excitation sequentially travels 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 provide a great deal of information about the structure of the brain and its functions. 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 the fast processes of brain excitations, offers the best time resolution at the expense of spatial resolution.

Interesting results in neurological effects from exposure to EM fields were obtained with the so-called transcranial magnetic stimulation (TMS), a technique that applies short pulses of magnetic energy to stimulate nerve cells in the brain (Cowey, 2005). It is used primarily for localizing various brain functions, because the magnetic field in TMS can be focused in a small area of the brain. Utmost non-uniform MFs are used to achieve a better focusing ability. Currently, TMS is not as widespread as MRI, seemingly because the space resolution here is lower. However, TMS can provide greater energy to brain areas to block their natural activity. The method is promising for use in research, diagnosis, and possibly in treatment of epileptic seizures, depression, and other neurological and psychiatric disorders.

Standard 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 biological effects would be a reasonable choice for introduction to bioelectromagnetics.

SELECTING LITERATURE

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) articles from military journals, (ii) declassified security documents showing that governmental agencies were funding investigations into EM weapons and mind control, and (iii) newspaper articles. Of course, the newspaper material was not analyzed and was only 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, comments were avoided whenever possible.

Apparently, before a military research program in a given direction could develop, some prerequisites, or preliminary scientific knowledge, should exist in order to generate the military concept, on which the research program can be based. For example, before the first nuclear weapon was created in 1944, there was a long period of open scientific research beginning with 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, has the creation of a microwave weapon become a reality.

Military research may contain secret knowledge, or know-how. At the same time, military research deals mainly with technical realizations of known scientific concepts. An example of this is "Brainwavescience" (www.brainwavescience.com). Many other projects supported by DARPA (the Defense Advanced Research Projects Agency) demonstrate how military institutions invest in brain/neurological explorations (e.g., Hoag, 2003). These types of projects are aimed at the technologically new practical applications of

[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.

already-published scientific findings. Obviously, it is the technology or know-how rather than the scientific concept that usually contains sensitive information that an institution will classify. Therefore, 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 50,000. 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.

In principle, studies on EM mind control could be based on existing knowledge of (i) brain interaction with EMFs and (ii) nonthermal biological effects of weak EMFs. Therefore, the methods utilizing EMFs in brain research and also literature on biological/neurological effects of weak 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.

Chapter 2

Historical Overview

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 that this review is based mainly on newspaper articles and books that do not go through the peer reviewing process usual for scientific literature. 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 some cases, however, open documents have been found, which confirm the statements made in the review.

USA

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's 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 the 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

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

functioning (Marks, 1979; MKULTRA, 2007). The project continued until the late 1960s at a gradual reduction of financial support. In the 1970s, after the revelation that the CIA had conducted partly illegal experiments on U.S. citizens, the project received negative ethical value. Based on the declassified document (MKULTRA Subproject 119, 1960), one could state that the 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 problem 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 the 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 nonthermal 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, 2004) 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 Microwave Auditory Effect" and the results of that work are still classified, which is known from the US Air Force response to a 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 was cancelled (Coughlin, 2007). Also cancelled 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 the latest open information, military departments and agencies as well as 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 personnel 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 the 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 three are high-power technologies, and only the latter one, also-called a non-lethal crowd-control weapon, is to affect people.

Microwave beams, about 0.1 THz EMF, may typically be irradiated by a one- to two-meter antenna powered by a generator mounted on a vehicle, in crowd control situations. Human skin absorbs such a radiation within a few seconds, which results 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 a clandestine influence. However, as is easily seen, technically nothing prevents use of the microwave beams at low powers to insensibly affect the human brain to the extent permitted by physical laws.

RUSSIA

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 on the

Internet. The number of journal articles is limited. Unlike scientific data, information of this sort could hardly be tested for 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. Yu. Okhorovich and V. Bekhterev developed this hypothesis in 1877 and 1910-1920s, correspondingly. Bekhterev has established, for the first time in the world, the Institute on Research into Brain and Psychic Activity. In 1913, Prof. V. Pravdich-Neminsky records the first EEG in a dog (Pravdich-Neminsky, 1913).[4]

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, have L. Vassiliev and S. Turlygin continued 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, he noted that brain radiation differed from EM radiations in some aspects. In 1959, there appeared the book *Mysterious Phenomena of the Human Mind* by L. Vassiliev and the newspaper article "Radiotransmission of Thoughts" in Komsomolskaya Pravda dated November 15. Technologies for long-distant mental information transfer were studied in the 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). In 1962, an effect of "cutaneous vision" had been registered: R. Kuleshova, suffering from epilepsy, demonstrated her ability to read printed texts by touch balls and to perceive the images enveloped into optically opaque materials (Bongard and Smirnov, 1965a; Bongard and Smirnov, 1965b; Romanovskii, 2004). One of the hypotheses tested was that EM radiations underlay this striking effect.

[4] In the U.K., an early work on an electrical activity in animal brain was reported by: CATON, R. (1875) The electric currents of the brain. *British Medical Journal,* 2, 278. The first EEG in human was recorded in Germany: BERGER, H. (1929) Über das Elektroenkephalogramm des Menschen. *Archiv für Psychiatrie und Nervenkrankheiten,* 87, 527-570.

In this regard, it is interesting to note that some organisms have regular arrays of photoreceptors on their surface that can serve as an additional optical warning system (Aizenberg et al., 2001). Some humans are able to discern the spectral composition of light incident on their skin. The possibility of the human brain to process "optical" signals from skin was studied in (Bekhtereva et al., 2002). However, this ability could not be enough to confirm the possibility of cutaneous vision, because a lens is also needed to convert the image to be read into one on the skin for further perception.

Not commenting on the scientific merit of those early 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 the 1950s and 1960s, the work to standardize EMFs was under way in research institutes of occupational hygiene and diseases (Moscow, St. Petersburg, Kharkov, Gorky), and 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; and (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. The 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.

Figure 2. Experimental stand to study the EMF biological effects in the Occupational Medicine Institute of the Russian Academy of Medical Sciences.

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, Figure 2) in Moscow; at the All-Union Research Institute of Labor Protection of the All-Union Central Council of Trade Unions (Leningrad), and 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 United States, the first national standard of electromagnetic safety in the radio frequency range was issued in 1966 by the U.S. National Institute of Standards (USAS C95.1–66). The EM safety levels adopted by the USSR and the USA standards differed by about a thousand. The western 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. Historically, Russia remains one of the central places for studying the nonthermal 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 (www.psn.ru/english), study mechanisms of EMF effects on biological systems as one of the basic areas of research, and the majority of their publications in this area relate to the nonthermal effects.

A powerful impetus for research into biological effects of EM radiations was given by the school of N.D. Devyatkov in the former USSR that developed EM microwave generators (the millimeter range) in the 1960s. These works were reproduced abroad. From the very beginning, it became clear that the 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. Moreover, microwave effects were observable only at selected frequencies, which suggested their nonthermal nature. The effects also depended on low-frequency modulations. Thus, researchers obtained a tool with the help of which it became possible to study biological effects of the shorter EM waves that had a potential of affecting the human mind.

As was discussed in literature, in the 1960s the U.S. embassy in Moscow was being bombarded by low-level microwave EM radiation, with estimated exposures 5–18 $\mu W/cm^2$, see for example (Wade, 1979; Goldsmith, 1997) and the reference to the "Lilienfeld Report" therein. It is interesting that the power density of the radiation was a thousand times smaller than the maximum safe exposure level adopted by U.S. safety standards in 1966 (Steneck et al., 1980). Even so, the "Moscow signal" 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 the Secretary of Central Committee of the CPSU. In the 1970s, leading research centers studying brain radiations were located in Moscow, Leningrad, Kiev, Novosibirsk, Minsk, Rostov, Alma-Ata, Gorki, Perm, and Sverdlovsk. In Kiev, technical solutions were 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 the USSR. Many experiments were conducted with participation of N. Kulagina, who displayed the ability to mentally affect physical measurement instrumentation. Many noted scientists in different institutes have repeatedly documented these effects in their studies. Electromagnetic nature of those effects was discussed.

Since approximately 1973, the works in this direction have been 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.

Some conclusions are possible from analyzing the facts about microwave-induced sleep. Scientific literature includes only a limited number of such studies, despite their potential significance. Direct EMF-induced sleep has been observed under RF EMF exposure (Subbotina et al., 2004)[5] and under ELF EM fields (Ban'kov, 1972; Wang et al., 1997). Many 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 the same time, a variety of sleep disturbances under EMF exposures are discussed much more often (Mann and Roschke, 2004; Huber et al., 2003; Hung et al., 2007). It is interesting that nothing prevented researchers from changing frequencies, powers, or 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 in 1973. 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 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. At any rate, high-power microwaves are of thermal influence and have a little to do with the subject of this book.

There was an approximately 10-year interval during which Kiev coordinating research center "Otklik" had 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 nonthermal 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). At that time, the author of this book 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

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

during 1989–2001, show that there was no significant insight in the nature of those effects, neither theoretical nor experimental. Now the Institute is significantly reduced and is no longer a center for research in bioelectromagnetics.[6]

In 1982, there was established a laboratory for research into the human and organisms radiations. After a few years of intensive research, the results were 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." This institution was aimed to coordinate research into the so-called "torsion field", its theory and practical implications. The existence of such a field followed the idea that all objects that have mass produce a gravitational field, and those having electric charge produce an electromagnetic field. Many elementary particles also have a spin, something like a rotation. Consequently, rotation of matter should allegedly generate a specific field of its own, the torsion field. A great amount of money, approximately hundreds of millions of rubles,[7] was planned to be spent on this program. However, the program has never been started because of the strong opposition of academic establishment and vulnerable position of the Soviet government before the dissolution of the State Union. Later in 1991, the Center was formally disbanded. Actually, it 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.

This structure has been receiving minor support from the Military until the dissolution of the USSR and some time after that (Alexandrov and Ginzburg, 1999). 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 that united many noted scientists (not to be confused with the official Russian Academy of Sciences). The number of workers in the Center and the Institute varied between 3 and 30 depending on the available financial support. The main goal of all these institutions, which were headed by the late Dr. A.E. Akimov, was to investigate into the torsion fields and related technologies. The author (VB) 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.

[6] Disbanded in 2008.
[7] Late in 1989, that would be about tens of millions dollars.

These institutions, particularly ISTC VENT, are often noted on the Internet, in newspapers, books, and popular journals as a leading institution where (i) the so-called psychotronic generators have been developed and (ii) a large amount of research has been deployed into psychotronics (Tsygankov and Lopatin, 1999). In those notes, 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 more disappointing than satisfying, at least to the author of the present book, who was one of the top researchers at these institutions.

No special physics has been placed behind the generators proposed personally by Akimov. Their interior arrangements were inspired just by intuition. The generators of a few different constructions have been replicated in some dozens of copies; an example of a torsion field generator is shown in Figure 3. 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 our knowledge, none of the academic institutions have 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 about any industrial production of such generators or about research and development into mind control effects of torsion fields.

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

Apparently, torsion fields as an object of experimental study should be completely out of normal science due to the lack of their scientific observations. Torsion generators were not a deception of Akimov: he actually believed in what he did. But it was a bright example of pseudoscience. A firm belief instead of doubt, which is a pivotal methodological principle, kills science, making fiction instead of making knowledge.

In general, torsion fields are known as a mathematical object since Cartan's time. They are related with a geometric property of space–time. The gravitational fields describe the space–time curvature. Similarly, the torsion fields describe another geometric property, the space–time torsion. In standard gravitational field theories, the effects of torsion fields were calculated to be extremely small as compared to the gravity: torsion fields should not be observed. However, some novel theories, in particular (Shipov, 1998), predict the opposite; admittedly, the torsion field here is not exactly the same as usual torsion.

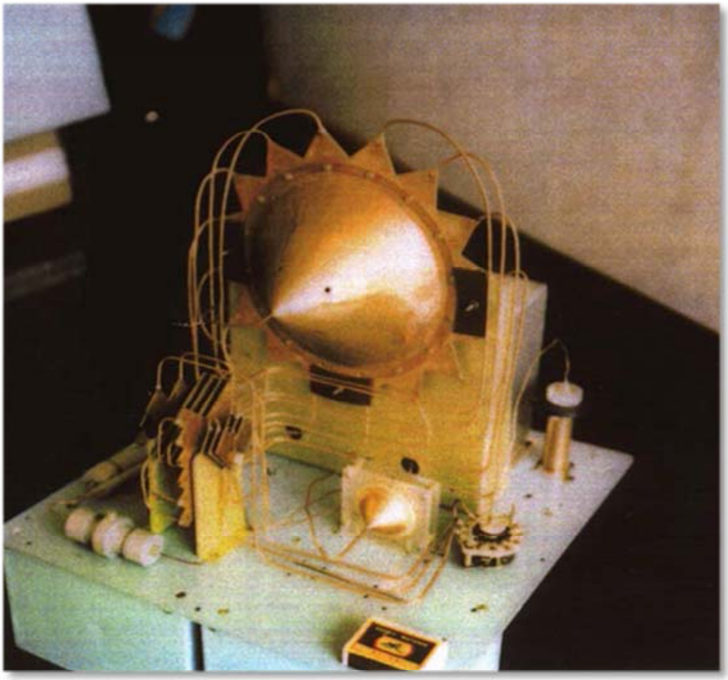

Figure 3. A “psychotronic” generator. The box of matches in the foreground is a scale element.

It is interesting that in this theory, the well-known fundamental fields and their equations emerge as some limiting cases of more general equations, in accordance with the requirement of scientific method. So the theory deserves attention. At the same time, this theory is not without difficulties (Rubakov, 2000). In any case, until the ontological status of the torsion field is clear, one should consider it an unscientific area of study, precisely an area having no connection to the material world.

In Shipov (1998), torsion fields are considered to be a “physical basis” for the paranormal. Because both torsion fields and paranormal are out of science, nothing prevents acceptance of the statement. Science deals with objective reality, i.e., with the world that exists independently and before any cognizing subject. Out of the scientific worldview, where things depend on consciousness, all is possible, at least at first glance, what contradicts scientific observations.

However, common sense says science is not the only source of true knowledge. There are many other forms of comprehension and cognition beyond science: art, intuition, mysticism, etc. At least as a heuristic conjecture we should admit that science is not omnipotent and hence miracles[8] can happen. Of course, in any case, because of their irregular character, there is no possibility of their practical use. What is interesting is that some people insist that would be possible.

Hypothetical weapon technologies based on different paranormal phenomena have been discussed for many decades (Alexander, 1980). This latter article comments on 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 in the past (Ginzburg, 1999). As is discussed below, the reason for this is that the paranormal is out of science by methodological grounds.

[8] By definition, miracle is a divine interference into natural laws and human affairs.

Chapter 3

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. Neurotechnologies may be viewed either as a real-time technique, directly displaying neural processes, or as a technique, averaging and storing incoming signals for future use. Averaging over time or space implies 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. Therefore, the following methods and technologies will be addressed: magnetic resonance imaging, magnetoencephalography, transcranial magnetic stimulation, standard magnetic stimulation, microwave auditory effect, and brain-machine interface. The latter neurotechnology may be thought of as a noninvasive method in the future.

We will 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.

FUNCTIONAL MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging is an extensively used technique (many thousands of 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 (see Figure 4). MRI is based on the physics of nuclear magnetic resonance (NMR).

Figure 4. Typical MRI scanner. The bed lifts a human, and then the slider moves the body through the magnet.

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 basic description of the physics that 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 nonplanar 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 (Figure 5). The more the density of atoms and molecules carrying the emitting sort of nuclei, the more the radiation intensity is. Actually, modern devices are based on more complex protocols with repetitive trains of radiofrequency MF pulses.

The resonance frequency of a magnetic nucleus is sensitive to the presence of other magnetic nuclei in its vicinity, because the latter generates additional MFs around them. A special type of MRI called "magnetic resonance spectroscopy" is based on this effect and is capable of noncontactly detecting biochemical molecules that contain many specifically arranged nuclei.

Not all magnetic nuclei are suitable for MRI. It can only be performed on naturally abundant nuclei. Most widely used are hydrogen nuclei ^{1}H which are present in water molecules H_2O and in most other biologically significant molecules. Also used in MRI studies are ^{13}C, ^{14}N, ^{19}F, ^{23}Na, ^{31}P, ^{129}Xe, and others. The distributions of these elements over tissues bring much information. However, their content in the human body is not high. For example, the number of sodium atoms is less than that of hydrogen atoms by a factor of about 1500. The wide practical use of ^{1}H MRI is explained by the large concentration of ^{1}H nuclei in living tissues, which secures a high signal-to-noise ratio of the output signal and consequently a good resolution.

A better resolution is possible with use of special contrasting agents introduced into the human tissues. The MRI signal quality depends on the so-called spin-lattice, or longitudinal, or T_1, relaxation time: the shorter the time, the higher the rate of the repetitions of RF MF pulses may be chosen. This allows accumulating the useful signal on the background of thermal noise; hence the quality of the signal becomes better. Contrasting agents shorten the relaxation time. Usually, contrasting agents are molecules that carry the paramagnetic gadolinium ion. It has relatively large magnetic moment 7.6 μ_B that produces a rather high nonuniform MF around it, about 10 mT at a distance of 1 nm (10 Å). Thermal perturbations randomly change the field direction. In such a field, the precession of nuclear spins quickly loses its regular character, which means the shortening of spin relaxation time and increasing of the output signal quality.

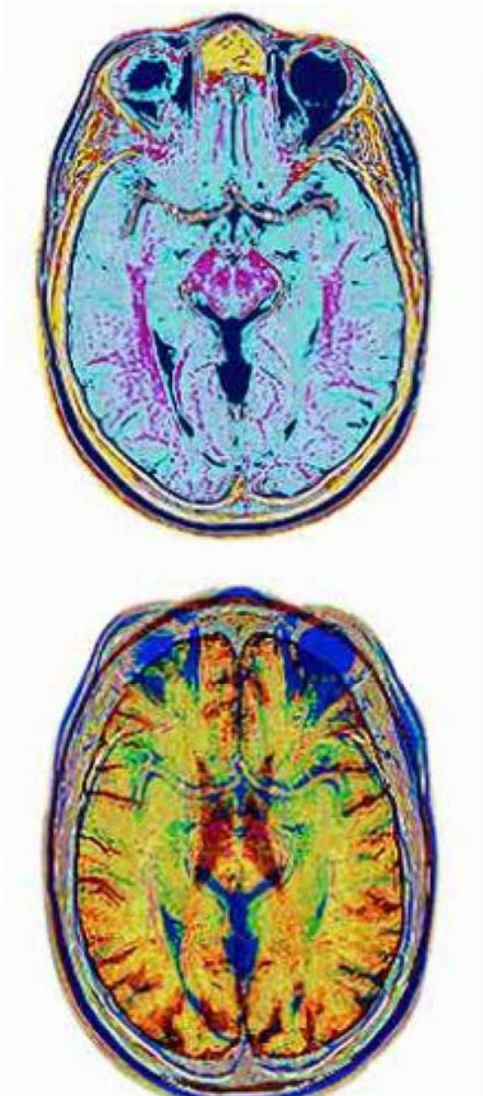

Figure 5. Examples of the images of brain slices. Computer reconstruction from MRI scans.

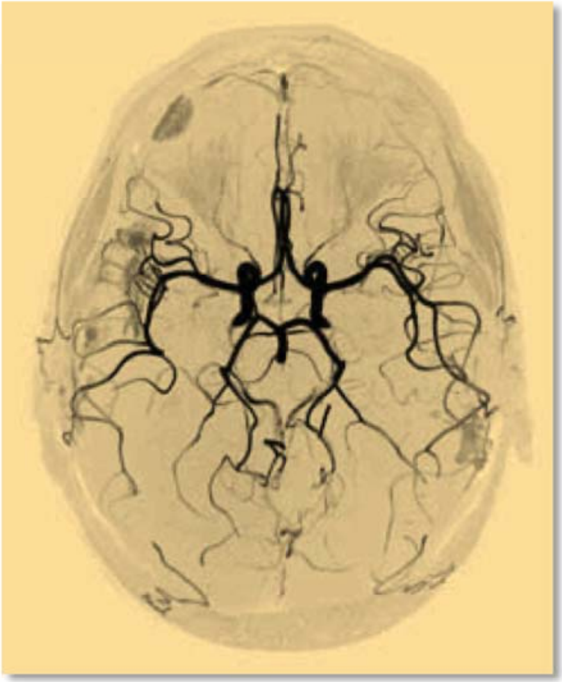

Figure 6. An example of the image of brain blood vessels at spatial resolution of $0.2{\times}0.2{\times}0.5$ mm^3 (Philips 3-T MRI scanner).

Modern MRI scanners allow images of about a few megapixels and spatial resolution of about 0.1 mm at a slow scanning with contrasting (Figure 6).

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 faster the scan the worse the resolution. The only way to improve the resolution 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,[9] are used in functional MRI studies. Time resolution in such devices is in the order of seconds and less and spatial resolution is about 1 mm and less. For these reasons, fMRI has become very popular in brain research: signals from local brain regions may be collected within milliseconds, which is enough to study their specific functions.

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

Two of the 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 of 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 that these new MRI machines can track brain neurons. But this is a metaphor. Since the number of neurons in a human brain is about 10^{11}, to track a single neuron in such a multitude of neurons would require resolution on about 0.01 mm that is now impossible. 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 increases constantly, the perspective of brain mapping is great. If it were not for ethical reasons, it could find numerous practical applications besides medicine.

However, there are severe physical constraints for MRI applications other than scientific or medical screenings. For example, 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 of the order of Tesla and mainly take minutes to scan a human head in a 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 a brain without a person being informed and specially prepared. But if individuals knew about the fact of screening, who knows what kind of thoughts they would prepare for a 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.

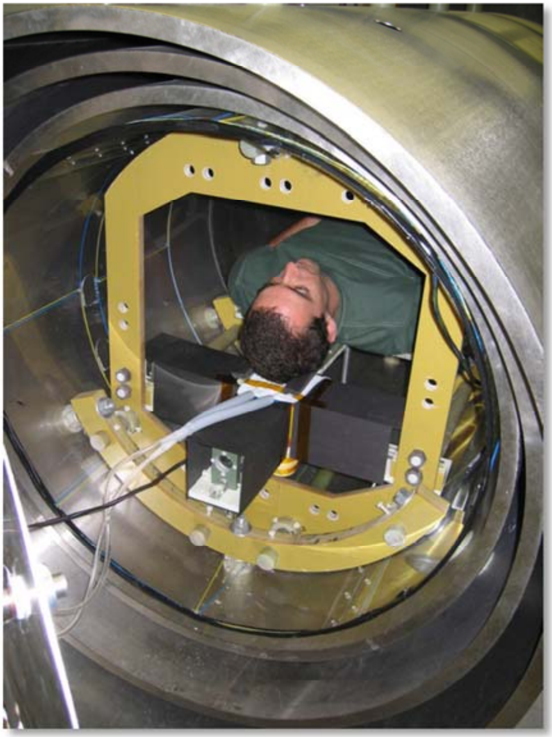

Figure 7. An advanced laser magnetometer will probably be a complementary tool for brain studies.

However, one new magnetometry method is developing, with no need for a strong MF (Savukov et al., 2006). Partially supported by DARPA, the method is promising for MRI-like scanning (Savukov et al., 2005) (Figure 7). It also could make scans distantly, as it uses laser beams for gathering information. But this technique now is in its infancy.

Another new imaging approach can do MRI not using a strong MF: the geomagnetic field is sufficient. It uses superconducting sensors to measure the spatial distribution of the pre-polarized and so emitting nuclear spins (Zotev et al., 2008). The space resolution of this imaging system is about 3 mm; however, it takes hours to scan a brain.

Even with these advanced high-tech solutions, it would not be possible to read thoughts in the direct sense. 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 sense of thoughts rather than in their locations in neurons or any other space-time ordering. Apparently, senses are distributed between many neurons, and will remain inaccessible for screening by the scientific methods for a long time.

In this regard, interesting insights into the possibility to determine what others see or think, by means of fMRI, were recently published in the leading scientific journals, Nature and Science. In (Kay et al., 2008), the authors first recorded fMRI scans of two persons while they were looking at different photographs showing animals, buildings, food, etc. There were a total of 1750 photographs and corresponding dynamical images. A special computer program called “brain model” was calibrated using those photographs and images. Then, the persons looked at another 120 photographs while being scanned by fMRI. After that, researchers were able to determine, with accuracy of about seven to nine hits per ten tries, which one of these new photographs each person had been looking at, based on just their fMRI scans treated by that computer model. They suggest that it is, in principle, possible to reconstruct the visual content of personal dreams and imagery from measurements of brain activity alone.

Figure 8. A newest magnetic encephalograph manufactured by Elekta Neuromag.

In the other work (Mitchell et al., 2008), researchers made an fMRI study, not unlike in concept, but with words (nouns) rather than with photographs. It has been demonstrated that they could correctly determine the noun, from the list of 60 nouns, that a subject was thinking, three out of four times. There are limitations: verbs cannot yet be identified, nor can the context of the thoughts be determined. However, the work has shown that there is a commonality in how different people's brains represent the same objects, which is promising for further exploratory studies.

Apparently, some simple thoughts, linked with perception, that can be mapped out in the brain space, could be deciphering in principle. But complex thoughts linked with cognition of the meaning of statements would be impossible to get hold of without such a powerful "computer" as the human brain.

Though reading thoughts may still be science fiction, there is a joke that MRI stands not for "Magnetic Resonance Imaging," but rather for "Mind Reading Interface."

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. It is billions of times less than the natural geomagnetic field, about 5×10^{-5} T, and thousands of times less than the level of geomagnetic fluctuations. Electrically active nerves in the brain produce MFs some three orders higher than the SQUID limit, which makes measurements of their magnetic fields possible.

Usually, the magnetic activity of a 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. It is software algorithms to disentangle contributions of various active brain areas in the signals. Then the data are displayed, and may be interpreted by trained personnel. Compared to EEG, MEG has higher resolution and sensitivity. The most advanced system has 510 SQUIDs and up to 306 MEG channels at 5 kHz sampling rate (Figure 8). At present, MEG is regarded as the most efficient and sophisticated method for tracking brain activity in real-time.

When focusing on the 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 the combination of MEG with other mapping methods, like MRI or NMR (Volegov et al., 2004). In general, the source localization technique is model-based and is an ambiguous procedure. This 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, the MEG technique is presently close to the ability of discerning between *preselected* 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 of the above referenced work had no journal publications following the report; so we might guess that they had 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, because it was images of the covert speech and not those of their original thoughts that would be detected by fMRI.

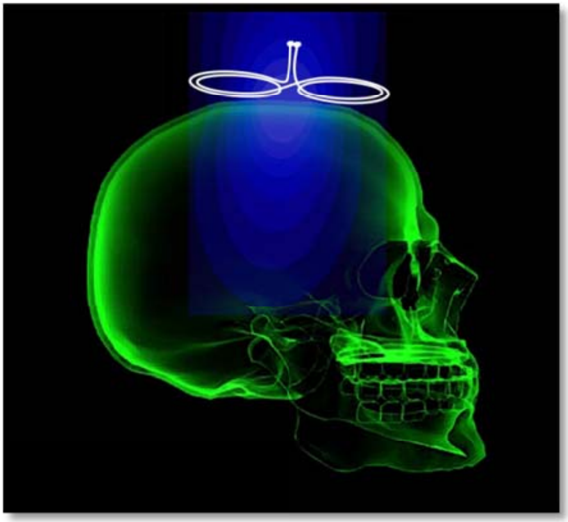

Figure 9. The electromagnet generates pulses of magnetic field, which induce eddy electric currents spatially localized in a small region of the brain.

TRANSCRANIAL MAGNETIC STIMULATION

Transcranial magnetic stimulation, or TMS, as described by its name, is a stimulation of the brain tissues by external magnetic fields from outside the cranium. It is a simple and inexpensive method that allows selective influence on the brain regions

During the TMS procedure, an MF inductor is placed beside the cranium, practically on the head surface. The inductor is connected to the source of electric current pulses and consequently generates the pulses of MF. MF passes through the skin and cranium into the brain without distortions, because all these tissues are diamagnetic. Then, MF pulses induce closed electric currents (eddy currents)

During TMS, an electromagnet, or inductor, is positioned close to the skull (Figure 9). The inductor is energized by a pulsed electric current, which generates a magnetic pulse. The MF gets into the brain through the skull freely, without being distorted. Pulses of the MF induce closed electric currents (eddy currents) in the brain tissue under the inductor. The position of the inductor determines areas where the maximum of the current density takes place. In these areas, the induced electric field depolarizes neuron membranes and thus changes the passage of neural signals. In other words, here the electric current can "fire" or block neurons. In this way, it is possible to excite or, in opposite, suppress the activity of different brain regions and activate or block certain mind functions.

For example, one can cause a human to "see" light flashes without light actually entering the eyes (phosphenes) with magnetic stimulation of the visual cortex in the occipital lobe. Electric pulses induced in the motor cortex are accompanied by corresponding involuntary muscle contractions. The stimulation of the prefrontal cortex responsible for thinking causes unconscious changes in memory and mood, in the level of attention and anxiety, and in other cognitive functions.

An advantage of TMS in comparison with other methods of brain activation is in that this method does not involve implanted electrodes. No surface electrical contacts with the surface of the head are needed to interfere with human brain functions, as well. At the same time, spatial resolution of this method is not high as compared to MRI. However, in some cases, researchers could achieve the resolution about 1 mm, reducing the pulse intensity to a value a little above the motor threshold.

Usually, special figure-8-shaped loop inductors, of a few centimeters in size, are used. As compared to ordinary ring-shaped inductors, 8-shaped inductors generate more nonuniform MF and so have better focusing on a given brain area. The MF under the inductors is a highly non-uniform single or repetitive MF pulse of about 0.1–0.2 ms duration and of a few teslas in magnitude. The induced electric field pulses in the brain are of the order of 100 V/m, which is enough to trigger action potentials of underlying cortical neurons.

There is anecdotal evidence that MF pulses with magnitude as small as of the order of pT also affect human brain functions (Anninos et al., 2006), but these results cannot be explained in scientific terms.

In some cases, large ring-shaped inductors or even the Helmholtz exposure systems are used for stimulation of the deep brain areas to lower depression levels in some patients. However, this type of stimulation, in fact, makes no relation to TMS, because it lacks the basic characteristic feature of TMS, locality of the action.

By (i) stimulating different cortex areas and (ii) recording caused reactions, one can map the functional brain activity and study the functions of these areas depending on experimental conditions. Unlike fMRI and MEG, TMS can only provide two-dimensional scalp maps of the associative links to be analyzed, because the electric currents induced by an MF pulse reach a maximum just near the cranium. The best magnetic focusing is achieved for the brain regions close to the inductor, i.e., for the cerebral cortex. It is a wrinkled 2–4 mm layer on the brain surface under the cranium that plays a key role in many brain functions. Among them are attention, perception, thinking, and consciousness. TMS-modulation of cortical processes is used to evaluate memory, language, vision, sensory-motor functions, etc. (Devlin and Watkins, 2007; Kluger and Triggs, 2007).

Mapping of the brain with use of TMS is of highest time resolution. It enables one to study the speed of nerve pulse propagation in various body systems at neuropathology. Simultaneous or time-shifted stimulation of different cortex areas makes it possible to study local neurochemical abnormalities.

Different brain regions are known to be interdependent: suppression of the brain activity in one region can cause activation of another region. This allows regulating some brain functions changing the activity in those areas that are accessible to TMS. At present, TMS is examined as a method of treatment of psychic abnormalities due to an organic lesion, i.e., various neuropsychiatric disorders (Wassermann et al., 2008). The potential use of TMS is also discussed for treatment of individuals suffering from brain functional disorders like epilepsy, depression, attention deficit, and migraine (Fregni et al., 2005; Clarke et al., 2006).

There are two types of TMS: one using single pulses and one using repetitive pulse trains. At that, the rate of pulse repetition is in the range of about 1–10 Hz, the pulse train duration is 1–10 s, and the session duration is 5 to 30 minutes. In case of long-lasting sessions, appreciable aftereffects appear which depends on the stimulation parameters: the localization of action, the intensity and repetition rate of pulses, and the session duration. This important fact is used to develop effective protocols for the treatment of the above mentioned diseases. In addition, modulating the excitability of cortical areas, TMS permits study of the mechanisms of those diseases that usually cause the similar changes.

It is known that TMS by repetitive pulses results in the sensation of discomfort or slight pain and is capable of initiating seizures. Therefore, the questions of safety at TMS, including possible remote consequences, are in the scope of attention of both scientists and state institutions. Use of TMS devices in definite conditions and with definite purposes is regulated by corresponding bodies, for example, by FDA in the U.S., and remains under the control of institutional commissions on the ethics in science.

The possibility of noninvasive excitation and suppression of cerebral cortex areas is a new method in neuroscience research (Cowey, 2005; Kobayashi and

Pascual-Leone, 2003; Verdon et al., 2004). The method has been developing since the 1980s (Barker et al., 1985; Ueno et al., 1988), and there are no obvious reasons why it had not been used before. The potential of scientific, diagnostic, and therapeutic applications of TMS is particularly wide and continues growing at the expense of combined usage with other methods of functional diagnostics.

TMS is a technique that 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 these effects, 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, like that shown in Figure 10, when a whole-body EM exposure in a non-magnetic environment is preferred.

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

MICROWAVE AUDITORY 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, 2004b). 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 on 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.

Figure 10. Studies in General Physics Institute RAS. Standard magnetic stimulation by weak MFs and electric fields alters cognitive functions (Binhi and Sarimov, 2008).

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, as 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.

BRAIN WAVE MONITORING

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 the human mind was connected with a widespread but rather naive idea that mind activity may be exhaustively 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. Some patents, which are often cited, should be investigated now with a focus on the extent of their consistency, either with physics or with the subject of this 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 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.

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 biological stimulation	The same
3835833	Method for obtaining neurophysiologic effects	Electrodes are positioned on the body
3837331	System and method for controlling the nervous system of an organism	Electrodes are positioned on the head
3967616	Multichannel system for and a multifactor method of controlling the nervous system	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 on the head to take a signal, which then is processed by a computer, converted to an acoustic signal and returned by 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	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, 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 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 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 the 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 having no relation to EM mind control, since the necessary manipulations include a contact interaction with the 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 at http://patft.uspto.gov/. Table 1 contains the numbers of the patents, their titles, and brief comments.

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, of 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; and (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 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 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 that completely speculative character of this suggestion is based only on 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 a milliTesla level that significantly exceeds known safety standards and may be applied only as a medical treatment under strict professional control. At the same time, we know that nonthermal mechanisms of biological effects from MFs are not prohibited by physics, and these mechanisms may explain biological effects of slowly varying MFs of the order of 100–200 nT. However, such effects are seldom observed and even in this case would have no relation to mind control, at least not 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 is classified. However, this would not be a crucial argument for the existence of such mind control technology.

BRAIN-MACHINE INTERFACE

Implanted electronics can give a significant impetus to the development of EM mind control, because 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. Now it can be of approximately several hundred or more. The possibilities related to direct communication between the brain and an outer controlling system are discussed as "brain–machine interface" (Hoag, 2003; Lebedev and Nicolelis, 2006). They are also referred to as "brain-computer interface," because a computer is usually needed to process the electrical signals between the brain and "machine."

With this type of EM mind control, there is no necessity of positioning sensors and inductors close to the brain. The current level of micro- and nanoelectronics allows wireless neural data acquisition chips as small as 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).

A difficulty is that invasive neurochips are prone to initiate the process of scar-tissue formation around them, because the organism reacts to a foreign object in the brain. This causes the signal trunsduction between the chip and neurons to become weaker with time or stop completely. However, rapid growth of nanotechnologies in different areas makes it possible to produce bioelectrodes, having enhanced biocompatible features. Microarrays of hundreds of electrodes with sizes in the micrometer range is a fact now as well. Nanotechnology is crucial here to minimize weight and power consumption of the array integrated electronic circuits.

At present, microelectrode arrays, designed to be implanted into the cerebral cortex and in peripheral nerves, provide means for improving injured visual, auditory, and motor systems.

It has been shown that the spatial organization of sensorimotor areas in the brain cortex can be changed in response to training. The term "brain plasticity" is used for this brain ability of neuronal reorganization. Brain plasticity provides the condition, in which a person with the implanted neurochip can be trained to control information coming from the outer world. For example, a neurochip implanted into the visual cortex of a human brain and a digital camera connected to the chip formed a system of artificial vision (Dobelle, 2000). Researchers consider the possibility of "bioskin," a material with embedded receptors that will provide tactile sense.

Neurochips can also convert a personal will, or mental effort, into electrical signals controlling biomechanical prostheses. In such cases, the term "neuroprosthetics" is used. Neuroprosthetics is aimed at restoring sight, hearing, movement, and some cognitive functions.

For example, monkeys could learn to directly, without moving their limbs, control the movements of an artificial arm by using a brain–machine interface driven by approximately one hundred cortical neurons (Lebedev et al., 2008). A paralytic could use neural control through a microelectrode array implanted in the primary motor cortex to perform simple actions with a prosthetic hand (Hochberg et al., 2006).

From the viewpoint of mind control, most interesting would be noninvasive brain–machine interfaces. Known for today are those that use EEG, MEG, and fMRI as methods to acquire primary information from the neurons. In the latter case, it was even possible to arrange a game similar to ping-pong that two trained persons could play in real time using just the power of their minds (Peplow, 2004). Though these possibilities are interesting by themselves, they all require practically contact interaction with a subject and, therefore, could not be used for remote monitoring of a human mind.

Evidently, EM mind control via implantable nanoelectronics is not the EM mind control in its direct sense. Since it requires brain surgery, it is impossible to think about implantable transceivers in a human brain, except for some obvious cases of medical illnesses and abnormalities.

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

Chapter 4

EXPERIMENTAL GROUNDS FOR EM MIND CONTROL

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 relatively recently began to use EM communication technologies in so dense a way. Therefore, the long-term consequences of such a Janus-like progress are not yet known. Researchers 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 nonthermal 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.

For example, many epidemiological studies examined a possible cancer risk from the background EM fields of power frequency. Some of them revealed a correlation between the rate of childhood leukemia incidence and exposure to power-frequency MF of a few hundred nT (Ahlbom et al., 2001). This made the International Agency for Research on Cancer classify magnetic fields as a possible carcinogen to humans. The nature of the processes underlying this association remains unclear. Many social, ethical, and health problems arisen around nonthermal EM biological effects are discussed in (Slesin, 2007). Bioelectromagnetics and magnetobiology are fields of great social significance. Recent list of books devoted to bioelectromagnetics include approximately 40 publications (Berg, 2004), and the body of papers amounts to a few tens of thousands.

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 that points to the “color perception” of the electromagnetic waves by the human body. This means that EM fields of close but different frequencies can cause different effects in organisms. The nature of such effects, called “nonthermal effects”, is absolutely different than in the opposite case of thermal effects. Thermal effects originate from heating of tissues by the absorbed EM radiation. Nonthermal effects can occur at exposure levels that exclude any appreciable heating; experimental and theoretical grounds for the nonthermal effects are considered below.

There is a controversy among scientists on the possible role of the nonthermal EM effects in human life because they are difficult to replicate in independent laboratory studies.

Why don’t we observe those effects always and everywhere in laboratories? Many reasons have been discussed in literature. Primarily, it is non-reproducibility of the physical conditions of the EM exposure and physiological conditions of the organisms tested. It is also a relatively small magnitude of the nonthermal effects in general. Observation of a stable 10% nonthermal EM effect in a laboratory study is mostly considered to be a rare case of luck; greater effects are also known. Probably, 1% is what would be reasonable to expect here. But it would actually be very problematic to detect a 1% effect in any biological study, given the great variance inherent to biological and epidemiological studies. Yet, such EM effects, being real, can entail great social consequences. EM fields may be less evident but not less insidious than smoking.

The EM safety standards proposed by WHO and different national institutions may vary more than 100-fold, depending on the frequency range. The strict standards adopted in Russia are based on the observed biological effects under chronic EM exposures, while the most EM safety standards in the world are based on calculated thermal effects. It indicates the lack of theoretical knowledge in this area. Indeed, there is no recognized physical theory of the EM nonthermal effects. At the same time, there is a great body of evidence in laboratory experiments.

In biology and biophysics of non-ionizing radiations, low-frequency magnetic fields of the order of the geomagnetic field, about 50 μT, and microwave radiations below 0.1–1 mW/cm^2 are usually called weak EMFs because they do not cause biologically significant heating of biological tissues. There are many works in scientific literature reviewing biological effects of such EMFs (e.g., Binhi, 2002; Volpe, 2003; Belyaev, 2005). However, they are not considered here. Instead, what will be addressed are the effects caused by the EMFs of even much lower intensities.

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 level of a local dc field. Such experiments form a separate group because 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 $\mu W/cm^2$.

ELF 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 these experiments MF strengths were 0.02, 0.2, 1, and 2 nT. At all of these 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. This data was 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 six-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.

The work of 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 is evidence on the confirmation of those interesting assays in independent laboratories (Pazur, 2004; Comisso et al., 2006; Alberto et al., 2008).

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, against 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.

Effect of whole-body MF exposure on the glucose and cortisol hormone levels in Guinea pigs was studied in (Zare et al., 2005). Thirty six Guinea pigs were exposed to sinusoidal 5-Hz 13 nT and 50-Hz 207 nT MF, 2 and 4 h/day during 5 days. MF exposure under 207 nT caused 30–50% decrease in the level of the hormones at $p<0.05$.

GEOMAGNETIC FLUCTUATIONS

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 body of observational evidence was great even before the 1980s (Dubrov, 1978). Here we discuss briefly more recent findings.

Magnetic storms are the disturbances of the Earth's magnetosphere caused by solar flares, i.e., enormous eruptions of plasma from the Sun's visible surface. The mechanism of magnetic storm formation involves many cosmic and terrestrial phenomena.

The Earth generates its own magnetic field—the geomagnetic field—that declines from the magnetic poles to the magnetic equator from about 70 to 40 μT, the geomagnetic field vector in the north hemisphere pointing down. It is widely accepted that it is a result of hydrodynamic flow within the Earth's liquid core.

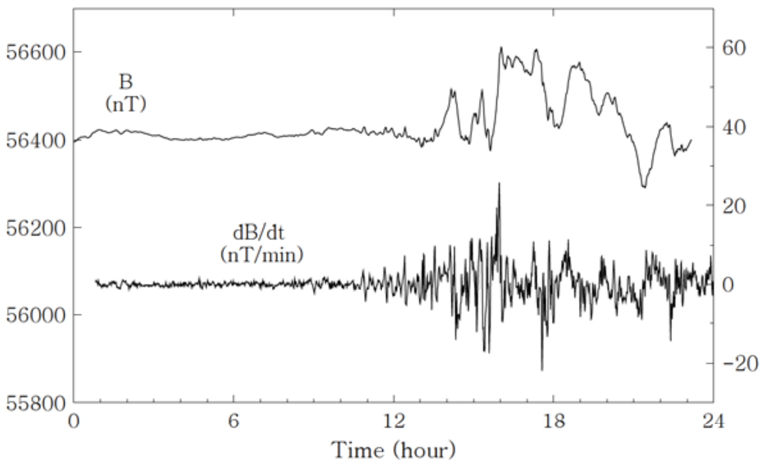

Figure 11. Variations of the geomagnetic field magnitude on June 14, 2008 that show a minor magnetic storm between about 2 p.m. and 10 p.m. Qaanaaq observatory, Greenland. Intermagnet data.

The geomagnetic field forms the magnetosphere, a complex system of electromagnetic fields and charged particles including the solar wind, which is mostly a flux of protons and electrons. The magnetosphere is compressed by the solar wind on the diurnal side and extended on the nocturnal side. Therefore, the geomagnetic field experiences diurnal variations, normally about a few tens of nanoteslas. At the same time, the solar wind is subject to random fluctuations due to the solar flares and so the magnetosphere reacts to the flares by abrupt and relatively strong variations, of the order of hundreds of nanoteslas, called magnetic storms (Figure 11).

Some medical researchers and practicing physicians warn that magnetic storms may be dangerous for those afflicted with cardiovascular illnesses and for healthy people too. Regular geomagnetic activity forecast is being published by many Russian newspapers and in broadcasting as well. Surprisingly, the nature of the correlation between magnetic storms and biological observables is not clear.

Magnetic storms are single random events; they have unique time-course changes of their parameters. Therefore, they cannot be exactly reproduced. However, what is well reproduced is a correlative association between the magnetic parameters of the storms and different biological measurable quantities.

Associations have been observed with human biorhythms (Chernukh et al., 1982), morphine analgesia in mice (Ossenkopp et al., 1983), DNA-related biochemistry (Vogl et al., 1991; Hoffmann et al., 1991), EEG mapping (Ruhenstroth-Bauer, et. al., 1993) and EEG spectra (Schienle et al., 2001), capillary blood flow (Gurfinkel et al., 1995), functional status of the human brain (Belisheva et al., 1995), memory and attention in humans (Tambiev et al., 1995), morphofunctional status of cell cultures (Belisheva and Popov, 1995), pigeon homing (Dornfeldt, 1996), melatonin production (Rapoport et al., 1997), arterial blood pressure in humans (Ghione et al., 1998) and hemodynamic index in rabbits (Gmitrov and Ohkubo, 1999), baroreflex sensitivity (Gmitrov, 1999), heart rate variability (Otsuka et al., 2000; Oinuma et al., 2002; Delyukov et al., 2001), cardiovascular parameters (Stoupel, 2002; Dimitrova et al., 2004b; Dimitrova et al., 2004a; Gmitrov and Ohkubo, 2002; Gurfinkel et al., 1998), motivation (Starbuck, et. al., 2002), suicide rate (Ashkaliev et al., 1995; Gordon and Berk, 2003), rate of development of schizophrenia (Kay, 2004), blood cell counts (Dasso et al., 2004), psychic activity (Booth et al., 2005), metabolism in rat tissue (Podkovkin and Gribkova, 2005), myocardial infarctions and sudden death (Villoresi et al., 1995, Rapoport et al., 2006), etc.

A thorough discussion of the quality of the methods used and the coherence of the structure behind these studies seems to be right. However, this would not be relevant, for the book has other purposes. Therefore, merely listing these studies, we should emphasize an exceptional diversity of the biological processes that correlate with geomagnetic disturbances. This suggests that the geomagnetic field is invisibly involved into the life of the biosphere.

Particularly dramatic is the correlative link between geomagnetic storms and social phenomena like money emissions (Chibrikin et al., 1995a), criminal activity (Chibrikin et al., 1995b), and the probability of air crashes (Sizov et al., 1997). These point out the hypothetical possibility of a large-scale MF control on social processes by virtue of slight but specially organized magnetic disturbances.

Recent reviews analyze many other observations. The functional status of the human organism under the geomagnetic variations is discussed in (Oraevskii et al., 1998), perceptual and motor skills in (Houtkooper et al., 1999), the associations with heart rate variability, myocardial infarction, and cardiovascular regulation in (Cornelissen et al., 2002; Gmitrov and Gmitrova, 2004), the interferential influence on personal experience under transcerebral exposure to another magnetic field in (Booth et al., 2005), behavior and suicide cases in (Berk et al., 2006), and ecological and other general factors in (Breus et al., 2002; Chernykh et al., 2005, Palmer et al., 2006).

It should be emphasized: what is actually observed in the days of magnetic storms is that some measurable characteristics are changed. It may be psychophysiological characteristics of a human organism or behavioral characteristics in groups of people. The correlative link between these observable characteristics and geomagnetic storms does not necessarily mean that slow variations in MF during geomagnetic disturbances can *directly* affect organisms. There could be other factors, like radon concentration, infralow-frequency sounds, static electric fields, etc., reviewed in (Binhi, 2002), and the microwave radiation of the ionosphere (Avakyan, 2005), which also change in the days of magnetic storms. Such changes could also in turn cause biological reactions. At present, the direct magnetic effect remains a hypothesis; however, many laboratory investigations do support it (Agadzhanian and Vlasova, 1992; Kashulin and Pershakov, 1995; Ruhenstroth-Bauer et al., 1994; Tiasto et al., 1995; Dupont et al., 2004; Del Seppia et al., 2006; Persinger et al., 2005) and also does a correlation analysis (Mikulecky and Michalkova, 2003). Some contradictory data is known as well (Schnabel et al., 2003).

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 the case of birds, known explanations involve either incorporation of naturally grown nanoscale crystals of magnetic mineral, magnetite Fe_3O_4, in a bird's brain or scull (Walker et al., 2002; Wiltschko and Wiltschko, 2005), or magnetosensitive chemical reactions in a 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 also been found in the human brain (Kirschvink et al., 1992; Dobson, 2002) and other organs. A possible mechanism by which magnetic nanoparticles can mediate biological effects of weak magnetic fields as low as a few hundred nanoteslas, will be exposed in a special section below.

Pooled data combining all the types of biological effects of superweak MFs presented above are shown in Figure 12. The figure plots data of (i) the effects observed in laboratory conditions, (ii) the effects of magnetic navigation by migrants, and (iii) the effects of correlation between geomagnetic disturbances and biospheric processes. Marked places of this frequency–magnitude diagram show the parameters of MFs that caused statistically significant biological effects. Effective MFs are well below the level of a permanent constituent of the geomagnetic field. Position of the threshold of thermal effects indicates that all the magnetobiological effects shown are not thermal effects. Plurality of these observations says that biological effects of superweak MFs could be a fact.

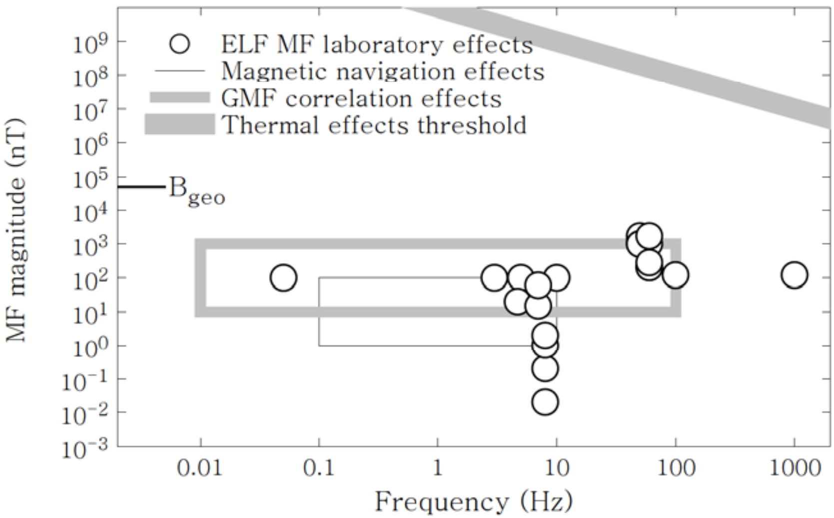

Figure 12. Frequency-magnitude diagram of the observable biological effects of superweak MFs. The frequency range for magnetic navigation is conditional.

MICROWAVE EMFS

Scientific evidence is accumulated for biological effects from exposure to very weak RF EMFs. Their powers may be much below 0.1 mW/cm², i.e., the energy flux density that practically cause no heating.

Nonthermal biological effects of the microwaves of MM range at low power density of the order of 0.1 mW/cm^2 were first observed in the USSR (Devyatkov, 1973). The studies of neurological effects, including the effects on the 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 is that 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. The study 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 suggesting a variety of technical implementations for this idea, unfortunately without due scientific background. The results (Bise, 1978) have never been replicated anywhere else.[10] 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 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.

Based on the available epidemiological studies, the so-called "Moscow study" and community studies in the vicinity of large FM and TV broadcasting facilities, a conclusion was made in (Goldsmith, 1997) that there seems to be some evidence that exposures as low as 2 μW/cm^2 may have long-term health effects. To be unbiased, we should note that according to (Wade, 1979), those epidemiological studies were inconclusive.

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

[10] 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.

9.4 GHz were applied for the exposure of pregnant rats during a few days. The power flux was 5 μW/cm². 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/cm² and 5% at 70 nW/cm².

In (Novoselova et al., 2004), it was observed the effect of repeated treatment with weak microwaves 8.15–18 GHz, 1 μW/cm², 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/cm² changed the rate of ^{32}P accumulation in the insects' antennas. The maximum effect was about 200%, and it took only about 2-min of exposure.

An influence of a pulse-modulated 915-MHz RF EMF of power density 10 μW/cm² 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/cm² 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 decreased by 10–20% in a resonance-like manner. The shape of the resonance curve depended on the radiation intensities: the width of the resonances grew with the intensities. This indicated a molecular origin of the effect observed. The lowest effective power flux was 5 pW/cm².

The resonance 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/cm² at a few MHz bandwidth (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.

The power density of the thermal EM radiation by a living tissue over a MHz bandwidth at physiological temperature is about 10^{-12} W/cm^2, i.e., a picowatt per squared centimeter. In this regard, observations of biological effects at power densities of the order of 10^{-6} pW/cm^2 should be associated with a paradox.

There are also many other works devoted to nonthermal biological effects of EM fields and radiations, reviewed in (Hyland, 2000; 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 were reported. In these studies, mostly microwaves of near thermal energy flux density have been used. Despite the fact that such radiations may cause heating of biological tissues, the author concluded that besides thermal effects there is also a nonthermal 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 nonthermal 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, where they are confirmed by independent laboratories, 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 the journal *Bioelectromagnetics*, 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 the 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 nonthermal 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; 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., 1995b). 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.

Chapter 5

CAN SUPERWEAK EM FIELDS AFFECT ORGANISMS?

The nature of biological effects of weak electromagnetic fields remains unclear, despite numerous experimental data. The difficulty in explaining these effects is usually associated with the fact that an energy quantum of the low-frequency EMF is essentially less than the characteristic energy of a chemical conversion, about dozens of kT, where k is the Boltzmann constant and T is the 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 have been formulated in the 1960s, in the broad sense, with respect to the biological effects of EM microwaves. At that time, millimeter waves were discovered to cause different biological effects at rather small energy flux densities of the order of 0.1 mW/cm^2, 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 body of evidence has been accumulated showing that weak static and low frequency MFs cause a variety of biological effects (Volpe, 2003). The kT paradox is especially dramatic in such cases of low-frequency fields, as their energy quantum 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. Then consideration of the interaction between low-frequency EMFs and biological targets becomes particularly clear. We will specify that the MFs in question, in the low-frequency range from units to hundreds of hertz, are below the level of the geomagnetic field and do not cause any essential inductive heating. They still can cause biological effects; the effects are often called "magnetobiological effects."

Historically the first nonthermal concept of biological effects from exposure to weak EMFs appeared in (Liboff, 1985). This concept was focused on the similarity of biologically effective frequencies of magnetic exposures and the cyclotron frequencies of biologically relevant ions. Many hypothetical mechanisms of biological effects of weak extremely-low-frequency MFs have been suggested since then. A brief review of the mechanisms may be found in (Berg, 1999; 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, and (iii) long-lived rotational states of some ions and 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 in the MFs 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: $\mu H \ll kT$, where μ 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, of 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 observations 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 $\mu H \ll kT$: either the magnetic moment μ 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 the 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.

To look at the kT problem more closely, 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, and (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 these postulates are not completely correct: (i) besides molecular targets, relatively large particles with almost macroscopic magnetic moment may be found in organisms. As regards molecular targets, (ii) their interaction with a low-frequency magnetic field is of multiple-quantum character and (iii) may develop in the absence of thermal equilibrium.

SUBMICRON LEVEL OF MAGNETORECEPTION

In many organisms, magnetic nanoscale particles consisting of magnetite crystals were found. Magnetic moment μ 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 (Figure 13). They proved to have a biogenic origin, i.e., they form as a direct result of the crystallization in 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).

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

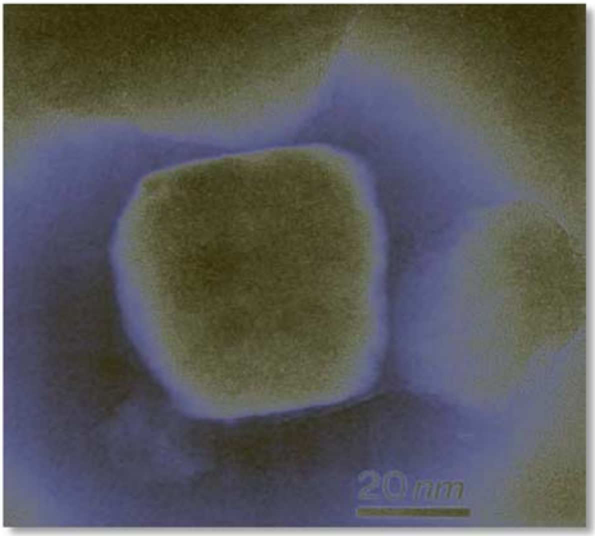

Figure 13. Magnetic nanoparticle, about 40 nm in size, extracted from human brain. Adapted from photography in (Kirschvink et al., 1992).

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, of the order of a hundred nanoteslas (Binhi, 2006).

The magnetic nanoparticles have either natural biogenic origin from intracellular ferritin or appear in cells due to exogenous contamination by widely spread iron oxide nanoparticles. 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 of times greater than the level of biologically natural MF, the geomagnetic field. The magnetic field of magnetosomes gradually decreases to the geomagnetic field level at the distance of about 0.5 micron.

Near a magnetosome, the MF gradient can reach as much as 10^7 that of a usual MRI magnet and be close to that of the electron spin magnetic moment, at a characteristic distance of about 1 nm. A unique situation is that, unlike a single spin, a magnetosome nonuniform MF covers much greater space. It is interesting that the MF nonuniformity around nanoparticles makes the basis for an additional mechanism, by which magnetosensitive reactions, known in spin chemistry, can react to MF. Therefore, magnetosome rotations can distinctly affect the rate of these free-radical reactions in biological cells containing such particles. If a cell contains a magnetic particle, even as small as a few nanometers across, a significant part of the cell is covered by the MF of that particle, so that the average rate of free radical formation may increase by a few percent (Binhi, 2008).

The severity of neurodegenerative diseases, such as Alzheimer and Parkinson, has been found to correlate with the amount of magnetite in the human brain, e.g., Bartzokis et al. (1997). A well-known link between excessive iron content in the brain and neurodegenerative diseases is explained in the literature by both direct influence of toxic ferrous ions, by catalyzing free radical formation, and by indirect influence through biogenic magnetite Fe_3O_4 (Hautot et al., 2007).

Magnetic nanoparticles in brain tissues can provide the sensitivity of animals and humans to weak MFs. However, the research into this area is still in its infancy.

MAGNETIC FIELD INTERACTION WITH MOLECULAR TARGET

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., a 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 a 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 cannot 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), general physics 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 molecular 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 great if the state of the target is far from thermal equilibrium. This means higher sensitivity. An example of such molecular target, a gyroscopic molecular rotator, has been discussed by 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 or between those of the quantum system, correspondingly. For example, in the case of the interaction of optical radiation of a laboratory HeNe-laser with an atom, we have $eEr/\hbar\Omega \sim 10^{-7}$, $\hbar\Omega \sim \Delta\varepsilon$. Here eEr is the interaction energy of an electron of charge e of an atom of the size r with an electrical field E, Ω is the circular frequency of the radiation, and $\Delta\varepsilon$ 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[11] 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 a more reliable description.

There is also another reason to think that a 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 an 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 a 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 a 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 an alternating (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

[11] It is the energy $\mu_B H$ of the magnetic moment $\mu_B = e\hbar/2mc$ of an orbital motion in a magnetic field H; m and c are the electron mass and the speed of light; CGS units.

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 an 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 state that is 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.

NON-EQUILIBRIUM STATES AND BIOLOGICAL SENSITIVITY TO EMFS

The conventional formulation of the kT problem brings about skepticism with 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 weakly bound to the thermal environment, or the thermostat, the process of thermalization is relatively slow so that such systems may remain for a long time far from the equilibrium. Then an 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 is a functioning of some proteins: 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; A* and B* are free radicals. It is known that 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 minor intervals, usually 1–10 ns. Normally, spins are bound with magnetic moments and so are capable of interacting with MF. 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; Ponomarev et al., 2004).

One more example of a non-equilibrium molecular target is the molecular gyroscope mechanism (Binhi and Savin, 2002). This theory allows one to calculate frequency spectra and other dependences of the reaction probability on any parameters of the EM exposure. In particular, the theory predicts a specific MF dependence for those MBEs that feature resonance like frequency spectra in combined parallel ac/dc MFs. A biological effect should then vary approximately as the squared Bessel function of the argument — the ratio H_{ac}/H_{dc} of the ac and dc MF components. Indeed, theoretical calculations and experimentally observable dependences show a good agreement (Figure 14).

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 can influence 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, affects hydrogen bond rearrangements owing to the

Pauli Exclusion Principle for spins. In that way, MF may influence conformational mobility of proteins.

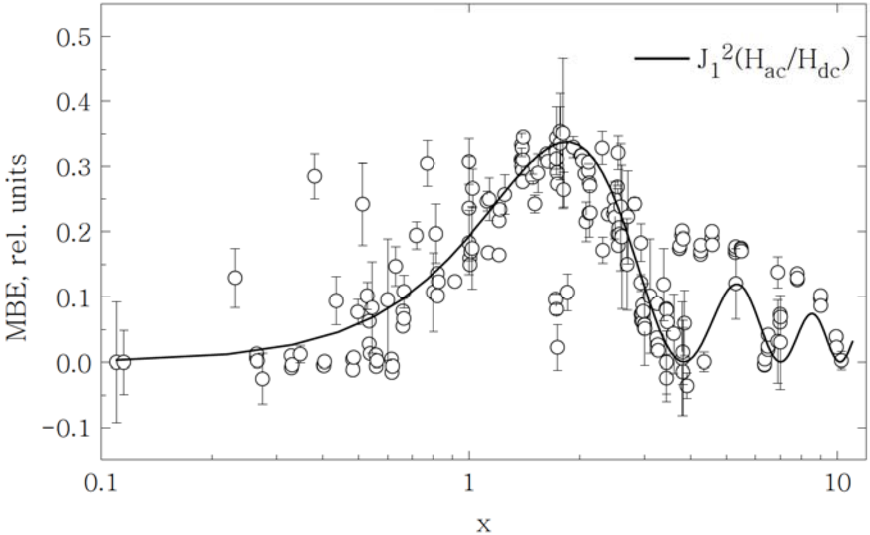

Figure 14. Theoretical amplitude spectrum (solid curve) calculated for ion-protein complexes; MBEs (points) in parallel ac/dc MFs as functions of $x \sim H_{ac}/H_{dc}$. Adapted from the data analyzed in (Binhi, 2002).

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 commenting 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 that the effect is absent in a specific experiment. Many researchers emphasize that the effect may develop only when an EMF affects a biological system in a proper physiological state. The time factor is of importance also, 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. In addition, 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). In a laboratory study (Binhi and Sarimov, 2008), only a few of 40 tested people have shown remarkable 12–17% cognitive reactions to a zero magnetic field, while the mean level of all the people was statistically significant 1.5%. At that, different groups of the persons showed opposite magnetic effects.

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 nonthermal 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 do 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.

Chapter 6

DISCUSSION

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

EM TARGETING

Information appears from time to time about people who believe the government is beaming "voices" into their minds and the Pentagon has pursued a weapon that can do that (Weinberger, 2007). Indeed, it should be taken as a well established fact that some people hear another's speech in their heads without any apparent cause. They are called in literature "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 effect might be the consequence of either (i) a high-tech science or (ii) a mental illness or (iii) a kind of personal experience. In all the cases, the verbal signals are real to these persons and deserve respectful consideration.

The two cases distinctly differ in their social significance. While mental illness mainly isolates the person in itself, scientific facilities are potentially aimed at society at large and so are potentially dangerous. In the latter case, the "voice" evidence is one of the main reasons to think that a hidden electronic or similar technique exists as mind control engineering. The other essential reason to think in this way is continuing military attempts to take hold of the control of the 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 the reports themselves reflect physical reality or medical pathology, a mental illness or an occasional personal experience. Neither similarities between TIs' experiences, nor the failures of drugs to fix their problems, can serve as a proof of real deliberate electronic surveillance or harassment as well as 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 continue to exist. 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. Despite the fact that 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 those verbal signals. The material presented in the previous sections of this book provided specific scientific evidence of what is possible and what is not possible from a technical viewpoint.

What pros and cons exist regarding EM mind control?

CON ARGUMENTS

Social Insignificance

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

It is interesting that the scientific program of the Third international interdisciplinary congress "Neuroscience for Medicine and Psychology", which included 16 sections and approximately 150 original works, did not contain reports that could be associated with EM mind control. The program of the Fourth European Symposium on Non-Lethal Weapons, Germany, May 2007, does not mention the word "mind" or "brain."

As we can see above, the highest level brain-controlling technique that could, in principle, be used as a necessary constituent of even imperfect mind reading technology is very expensive. There are no evident reasons for a government to use such an expensive facility, assuming it exists, to control minds of rather usual inhabitants that TIs are.

Failure to Prove

Of course, evidence reported by TIs cannot be taken as a proof of 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 mind control weapons.

The main weakness of almost all publications on EM mind control is in a clear bias, which is the prejudication that either secret EM mind control technology already exists, or such technology is not possible in principle. In both cases, it immediately makes the material unsuitable for analysis, since facts are being organized so as to draw pre-given conclusions. Until now, there are no scientific works examining and studying physical aspects of the problem, besides its possible medical aspects.

Technical Lack

Technically, in order to perform microwave targeting at a given person who is free to move anywhere, two arrangements must 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 an EM radiation beam at the person. GPS systems are very exact and can locate a 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 an 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 verbal signals or specific ideas in tested humans. Second, microwave auditory effect is also hardly possible because of the high power required to induce hearing and because of expected low speech discrimination and low phrase intelligibility.

Where low-frequency MFs and nonthermal effects are supposedly used to affect an individual, the following difficulties must be addressed. (i) Targeting is impossible since a low-frequency MF source necessarily covers large areas. (ii) Known nonthermal effects are of probabilistic character; it is difficult to get a nonthermal 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 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 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, called synapses, do form a giant neuronet. Figure 15 illustrates such a net. The number of the connections, which perform thinking and carry thoughts is then about 10^{14}, in order of magnitude. 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[12] large: about 10^{11430}. It is more than the hundredth power of the Googol, the large number, 10^{100}, that exceeds the

[12] 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.

number of all particles in the known Universe. This example well illustrates 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 the fact that only a small part of neurons may take part in thinking, the number of their 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 magnetic encephalography, allows one to watch for activity in a particular part of the brain and correlate it with what someone is telling or thinking. 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 patterns consisting of hundreds of elements. This enables one to distinguish certain thoughts among several pre-given thoughts that intentionally reflect rather different types of thinking.

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

However, as is seen, these modern technologies require many sensors to be located 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.

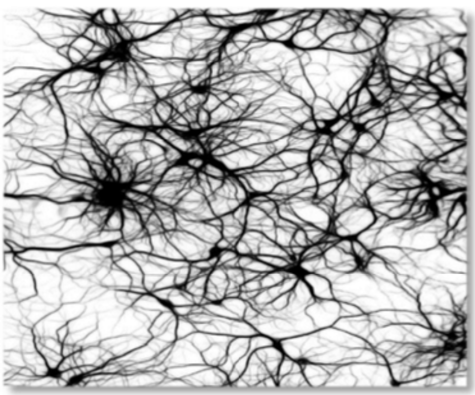

Figure 15. A tiny part of a net formed by interacting neurons in the brain. The black nodes portray neurons.

PRO ARGUMENTS

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: as we saw, there are both direct experimental evidence and theoretical grounds for believing these effects are real. A prejudice should be avoided at least until full scientific knowledge is obtained for the EM biological effects.

As was seen above, targeting humans with directed EM fields or radiations for a long time, which would be necessary to cause a reaction, is hardly possible. Only large populated areas are possible for EMF exposure. 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 looks like the effects of targeted radiation.

From published experiments, we know the technical parameters of those EM fields and radiations that may cause biological reactions in human organisms. Using these parameters, one could estimate whether it is technically real to expose large groups of people by EMFs in a clandestine way. From the observations cited above, 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, with omnidirectional radiation.

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 another 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 then be produced by 5-A current passing through a 60-m contour.

What is apparent is that a brain might 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 a certain orientation of the head regarding the source of the radiation is kept fixed. However, 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 expose a whole brain and 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.

It is interesting that drug-based methods of mind control are also somewhat problematic. The drugs that have an effect on the brain can be divided into known categories: sedative-hypnotics, tranquilizers, stimulants, narcotics, and hallucinogenics. However, among these there were no drugs known in the 1960s that would have any usefulness in the control of the mind (Berger, 1967).

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 the 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 a solution. Well-known geomagnetic storms that often occur in the days of acute health conditions 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.

It is worth remembering here that some people have magnetic iron oxide nanoparticles in their brain that have grown naturally or penetrated from the outside as an occasional contamination. A hypothetical possibility could then be easily suggested that a number of magnetic particles occupy the brain center for anxiety and fear, as a purely individual particularity. Such persons could actually react to EM fields and radiation by feeling anxious, for the particles mediate the energy transfer from an EM field to brain neurons. Sooner or later, they would associate this anxious state of mind with its real reason—the sources of EM fields and radiations—generating the only conceivable explanation, a deliberate action that is targeted on them personally.

Under the principles discussed, with all the pros and cons, most likely there is presently not even one good example of what we could consider a technology for remote EM mind control. However, this does not mean such examples could not appear tomorrow. Science quickly becomes more and more powerful and the results move to levels never imagined. Scientific methodology is also developing so as to envision possible contribution of the consciousness of a researcher who performs 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.

Chapter 7

BEYOND SCIENCE

From the above information, it becomes more or less clear that there are serious physical constraints for EM mind control as a kind of objective remote control. Remote EM mind reading is not possible in general. Remote EM implanting information into the human mind is limited by two possibilities. The first one is the microwave auditory effect. The second possibility is chemical-like modulation of the physiological state of the human brain by means of a plain EM stimulation. The second possibility implies further influence on mind by any usual communicative means. None of these two ways is for subliminal transfer of intelligible information. At that, both ways are hypothetical and are related to future technical achievements rather than to up-to-date technology.

However, facts are inexorable: some people really hear another's speech without an acoustic source. This might be understood in terms other than EM transmission of information. Traditionally, such unusual means for information transmission or extrasensory perception are associated with psi- or paranormal phenomena, or with "fields of consciousness" of unknown nature, that might allegedly be produced by the human mind. The main difficulty here is that science does not know such fields.

A basic postulate of modern science is that there are only four kinds of fundamental interactions: the gravitational, EM, weak and strong short-range nuclear ones. This postulate is in perfect agreement with a number of experiments in physics. But we are also aware that just very recently, a hundred years ago, physics knew only two kinds of interactions; and who knows how many new ones will be discovered in the next hundred years.

However, it is not a very compelling argument. Scientists of past centuries had in front of their eyes many obvious and spectacular phenomena, which were awaiting a scientific explanation. The attraction and repulsion exhibited by amber, the mysterious interaction between some stones and bits of iron, "falling apples," lightning, sun radiation, alchemical conversions, the life, etc.: all the phenomena did comprise natural electricity, gravity, specific atomic behavior, and radioactivity. At that, they were available for observation by everyone, in principle. Quite another story is the paranormal. Such observations are extremely rare and occasional; most people have never experienced paranormal events.

Parascience is defined in the *Oxford English Dictionary* as "the study of phenomena assumed to be beyond the scope of scientific inquiry or for which no scientific explanation exists."

This situation finds its expression in the following opinions of the majority of the scientific community on the one hand, and of those involved in the paranormal, on the other hand. One opinion: paranormal effects do not exist because they are not possible in terms of modern science. The other opinion: the paranormal is a fact of life and science will adopt it later as it is developing.

It is interesting to support a complementary view: The paranormal is a reality, but science is severely limited in its ability to know what to do with it. This viewpoint reconciles the above incompatible opinions and gives some space to continued research. The basic idea, which underlies this viewpoint, is that introducing consciousness in an experiment does not allow interpreting the results of the experiment. Consciousness may either be the constituent of the object of a study, or belong to a subject of the study, the knowing subject. Where consciousness is intended to be the object and the subject of study simultaneously, one goes beyond the scientific method. Therefore, paranormal experience will ever be out of science, — however, probably, not absolutely. In what follows it is discussed, where the paranormal could be combined with a legitimate scientific inquiry.

LIMITATIONS OF THE SCIENTIFIC METHOD

At present, science has come closer to the limits of its epistemological/methodological possibilities. In increasing frequency, scientific journals have begun publishing studies devoted to a particular role of the consciousness of the knowing subject in a process of getting new knowledge. In these studies, it is stated that the role of consciousness cannot be reduced to a purely cognitive activity, i.e., to contemplating, comprehending, etc. The idea that consciousness could play a specific role in physics, precisely in quantum measurements, has been discussed since the time of its birth (Schrodinger, 1959). Consciousness is assumed to be able to actively change the physical characteristics of a studied object itself, or at least the results of their measurements. As is accepted, this area of research is associated with so-called parascience that studies the paranormal. A by far not complete list of such interesting studies could include the following works: (Targ and Puthoff, 1974; Puthoff and Targ, 1981; Jahn and Dunne, 1986; Stapp, 1994; Stapp, 2001; Bekhtereva et al., 2002; Targ and Puthoff, 2005; Menskii, 2005; Dunne and Jahn, 2005). We intentionally omit a huge volume of publications in the specialized parapsychological journals, wishing to stay within the framework of physics, because the paranormal is mostly a physics problem.

Even being limited by only the ontological aspect in discussing the paranormal, a risk is high to be accused of the lack of judiciousness. There is a serious medical research that considers paranormal beliefs to be a sign of an abnormality (Wiseman and Watt, 2006).

In the above references, the authors, who are recognized authorities in their fields, shy away from the term "paranormal," preferring inconspicuous "consciousness effects." This is caused, in addition, by the circumstance that most often parascience is referred to as pseudoscience, of which the following examples are notoriously known: astrology, alchemy, occultism, etc. Pseudoscience only mimics science, ignoring the scientific method and, therefore, it is unable to provide new knowledge.

One should distinguish between parascience in a wide sense, as a social activity opposed to science, and parascience in a narrow sense, as almost usual scientific activity that deviates only little from what is prescribed by strict science, dealing with the involvement of consciousness, usually weak or insignificant involvement, in the results of laboratory experiments.

It is intuitively clear that mind control is "genetically" close to paranormal effects such as remote viewing or extrasensory perception, in general, because of the crucial role of consciousness in all these phenomena. Why not assume that reported events of the remote mind reading were actually paranormal effects?

To understand it better where we could stay on firm ground, the basic principles of the scientific method are outlined below.

Science is a social human activity aimed at mining new *knowledge*. Knowledge is one of the most general philosophical categories, for which the precise definition is not possible. There are many formal definitions in terms of different philosophy teachings, which elucidate this or that aspect of this notion. Here, it is convenient to define knowledge in the spirit of natural scientific positivism. Knowledge is what expands the boundaries of our being in time and space. What does "to know" mean? Always, when we say we know something, we implicitly have in mind the following. First, what we are speaking about, an object, is an element of the group of similar objects. Second, this object as well as the group, existed for some time before, and will exist for some time forward. And third, the behavior of any such object is governed by a *regularity* that, as well, was, is, and will be for some time in the future. It is this relative stability of the regularity, in particular, its independence from mental contemplation or the acts of cognition, that is the basis of knowledge. Knowledge is a right idea about the regularity. Knowledge, formulated in accepted scientific terms and arranged within the present theoretical structure of science, is a *theory*. Thus, knowledge gives a true insight on past and future, expanding the boundaries of our being.

What does knowledge have to do with? We will look into the variety of events constituting the reality. One should first define what is an *event*. An event is a motion that takes place at a given moment in time and at a given point in space. That is, an event is the idealization where duration of a motion is neglected and where the motion is considered to be a fact that has occurred at some point in space-time.

The real world consists of the events. It consists principally of the nonrecurring events. There are also those that, in a way, recur, or replicate. Such events form a physical *phenomena* available for measurements. The multitude of phenomena is much narrower than the world of events. It is phenomena and not the events that science, aimed at getting new knowledge, has to do with. In this way, the scientific method relies on the assumption that the object exists by itself and that regularity exists, which drives the object's appearance as a chain of recurring events. In other words, it is assumed that regularities exist in themselves without regard to the fact that someone studies them. Thus, science asserts that an object may be studied and the regularity, or the law, may be established.

However, the scientific method cannot be used for studying the paranormal, that is, in the cases where consciousness is included into experiment. This might be easily shown in the following way. As has been already said, the scientific method is based on isolating the object of study from the knowing subject. It is adopted that the object exists by itself regardless of the consciousness of the subject. But obviously, the very existence of the object means the existence of consciousness itself, because they constitute a dialectical pair. Consciousness may also be an object of study. In both cases, it presents an independent entity, or independent self-reality.

Then, to define consciousness as something existing objectively, one needs to use entities, or things, which are independent of consciousness; otherwise the definition would be impossible. It is this order that is adopted by science. However, if to assume consciousness is able to change entities, the very possibility of defining consciousness as such, as an object, will be lost. But then, the other entities are also indefinable as objects. The world appears here as a single whole, as a holistic substance where all depends on all; and even more, there is no these all, the multitude of things, since each one is indefinable. It is the other world view, which is close to the Eastern mysticism (Capra, 2000). Here, perceiving the world, one cannot analyze, i.e., divide the reality into objects. One might just contemplate and try to understand the world intuitively, by irrational perception.

It follows, that the notion of consciousness is of double meaning: It may present both subject and object of study. It should be emphasized that it is this subjective cognitive aspect of consciousness that is meant when they speak about the paranormal. It is seen from the circumstance that cognitive activity is a manifestation of will, but it is the dependence of matter on will that is the essence of the paranormal. In that way, it is not possible to study the paranormal; it is not a scientific object. It may only be taken as is.

There is much to be done, of course, regarding the arrangement of the paranormal in philosophical theory, because now it is in the best consistency only with the least popular and least acceptable teaching—subjective idealism.

In the above reasoning, we managed to do without using general philosophical notions of idea and matter, though it is almost obvious that idea as the product of consciousness should be a relevant term to explain the relation between the paranormal and scientific reality. In this regard, a remark is appropriate that the material and ideal forms of being are both constituents of reality. It is well known that some ideal constructs of the human mind are very real in that general and common meaning that they do not depend on individual thinking. Individual mind can be thought only as a passive interface between these two forms of reality; although dialectical materialism assumes the ideal is a product of the evolution of the collective human mind (objective idealism says ideal entities are of divine origin). The paranormal may be thought as a way of the direct idea-to-matter connection induced by an individual will. Then the paranormal is not objective and goes beyond science. This statement, or truth, can be shown in many other ways and expressed in different terms. However, there is a substantial nuance. It addresses the criteria used to determine that a set of observations has enough quality and one may speak about new scientific knowledge.

Reproducibility

One of the most essential criteria is the criterion of reproducibility. The results of a scientific experimental study should be reproduced regardless of who makes the experiment, where, when and by which instruments the experiment is made. This means the results would be of objective character. But there are no generally accepted prescriptions as to *how many times* the experiment should be successfully reproduced. Here, all depends on the specificity of the given scientific area and on hands-on experience. In this way, sufficient reproducibility is determined by the human practice in general. It is interesting that the paranormal, in some cases, demonstrates quite a good level of reproducibility and, based on this, might be considered scientific. Only the fundamental and extraordinary character of the conclusions that could be drawn from such experiments makes the majority of scientific community to display skepticism and to demand higher and higher levels of reproducibility. Could statistics sink the paranormal (Bosch et al., 2006)?

It seems that paranormal observations acquire or lose scientificity depending on their reproducibility. With all that, it is understandable that just a limited number of paranormal observations show enough reproducibility, and most of them feature a unique irreproducible character.

Practically however, there is no distinct boundary between science and the paranormal. Where consciousness affects matter only in an insignificant measure, in some sense, the effects are rather well reproducible and may be a subject of a quite usual scientific research, described, for example, in (Jahn, 1986; Radin and Nelson, 1989; Radin et al., 2006). At that, the more strong the effects and the less number of people who could demonstrate them, the farther from science these effects are. For example, only a few individuals can demonstrate extraordinary paranormal abilities of their minds (Geller, 1975), if any.

Such clear paranormal effects are even considered as the basis for new ways of warfare (Puthoff, 1996). Though the CIA closed the remote viewing program in 1995, with a conclusion that the results were disappointing (Moreno, 2006), studies are going on (Steinberg, 2005).

There are mind technologies based on collective meditation technique worked out by different psychotechnology schools, for example Maharishi University (TMP, 2007). This latter technique, called transcendental meditation, or TM, seems to cause real individual effects, judging on statistical data (Walton et al., 2004). The TM technique was proposed by Maharishi Mahesh Yogi, an expert on the ancient Indian tradition. It is a simple psychophysiological 20-min twice-a-day procedure taught by trained instructors. During the meditation, a reduction in mental and physical activity occurs as a result of experience of a state different from usual waking, dreaming, or sleep states. People practicing it have beneficial health effects.

What is surprising is that TM, when it is practiced by a large group of people, or by a smaller group but simultaneously (TM-Siddhi technique), causes an effect that might be thought of as paranormal. It is a social effect caused by a collective meditation. Statistically significant improvement of the quality of life was measured in cities, countries, and even in geopolitical regions, where more than 1% of the population were practicing TM, see (TMP, 2007) and references therein to social research studies. Even less meditating people were required with the TM-Siddhi technique, about square root of that 1%, to affect the social processes appreciably. Measured indexes were associated with the following social indicators: traffic accidents; crime rate; terrorism and international conflicts; social stress; unemployment and economic indices, alcohol, nicotine, and drug abuse, etc. The way in which statistics has been used in these studies was argued in (Schrodt, 1990); it is therefore difficult to conclude on the scientific quality of those studies. However, it is worth mentioning the volume of research performed concerning the effect: over 600 studies at more than 200 research institutions in 35 countries during the past 40 years. Possibly, the Maharishi effect is a part of reality, but certainly, it is neither a part of a physical, nor a part of the ideal world, for it necessarily involves their direct connection.

In any way, social effects of TM imply that many people meditate more or less synchronously, and so TM technique could not be used for improper purposes and be considered a mind control technique.

Proponents of the paranormal mostly do not raise the question of the physical nature of it. It is clear why. There is no possibility to explain these phenomena, because they are beyond science. It means, for example, that the question about the physics of the carrier of the paranormal information transmission is meaningless. The same is valid with regard to the energy transfer: no energy transfer occurs and the energy conservation law breaks in the paranormal. The paranormal appears out of physics. It is the reason why paranormal observations are principally irreproducible: there is no objective reality behind them.

Some researchers, however, think the paranormal could find an explanation within an advanced physical theory. There is a long history of attempts to interpret paranormal observations within the context of the physical theories (Beichler, 2001). Mainly, researchers look into quantum mechanics, more accurately, into quantum metaphysics, to find a place for human consciousness and explain the effects of mind on matter (Schrodinger, 1959; Penrose, 1994; Stapp, 2001; Josephson, 2003; Menskii, 2005).

This position is based on a belief that consciousness transcends the material world. On the other hand, quantum mechanics is not reduced to just physics. At a closer view, it poses very profound questions about the relationship between the observable reality and an observer. It turns out that some properties of matter *do not exist* before an observer observes them. It is this aspect of quantum mechanics called quantum metaphysics that is so attractive for explaining the consciousness-related phenomena (Bohm, 2002).

It is interesting to point out another theory that develops the general relativity theory and pretends to high scientific status. In this theory, the well-known equations of the fundamental fields—gravitational, EM, and quantum fields—appear as some limiting cases (Shipov, 1998), i.e., the theory satisfies the basic requirement of scientific methodology. One of the most senior experts in general relativity theory, M. Carmeli, professor in theoretical physics at Ben Gurion University, writes: *I find the work of Dr. Shipov quite original and creative. His ideas about "Universal Relativity" and "Physics Vacuum" are greatly interesting, and are excellently developed by him to a theory, which seems as a continuation of Einstein's work* (Carmeli, 2005). Other experts dismiss the theory because its development was not accompanied by publications in specialized journal periodicals, which would be a normal process in the scientific community (Rubakov, 2000).

A specific object of this theory is the fields of space torsion, which is associated with the known geometric properties of space-time. Being "primary," torsion fields supposedly have very unusual properties, which might be a basis for the paranormal. As for today, torsion fields remain a hypothesis due to the lack of experimental evidence.

In finalizing this section, one could suppose that many strange events that the involved individuals incline to identify as an electronic harassment are actually only bright manifestations of the paranormal. It would be rather difficult to study such observations in a scientific manner. As was assumed above, scientific method is applicable to the paranormal only at small values of the effects, which in turn requires large statistics. This would be hardly possible for that sort of observations.

It is only a matter of time that the facts of verbal signals induced in some people's heads will either become an area of science or will not. This, however, does not mean that these facts do not deserve attention. They are real facts that are worth being taken into attentive consideration.

Chapter 8

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 obtain information at an acceptable signal-to-noise ratio.

There is no scientific information about the hypothetical possibility of EM scanning brain activity *remotely*, even in 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 book thinks EM mind reading is not possible as a phenomenon. There are no natural scientific prerequisites for that to be possible. 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 the 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. The 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 where EM fields and radiations really cause significant chemical-like effects. But, though nonthermal

EM biological effects have been observed in laboratories, their social significance remains questionable.

As well, there is no complete clarity yet regarding the potential use of the microwave auditory effect, provided 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, of about the size of 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.

Overall, possible scientific grounds for EM mind control look rather unconvincing.

At the same time, much non-scientific information about EM mind control mainly is 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 us from recognizing TIs' personal testimonies as substantial data: (i) their subjective character and (ii) uncontrolled conditions of their gathering. It is precisely why everyday knowledge differs from the 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 clarify their cases scientifically, 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?

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

There is some strange 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 the highest sensitivity to MFs (Anninos et al., 2003) of the order of 10 pT. This connection is only speculative though, because all those experimental findings look impossible in terms of physics and need rigorous validation by independent researchers.

It is interesting to suppose the essential role of the paranormal in the considered hearing experience. In this case, some people in an altered state of their consciousness could get information through the extrasensory perception. As was discussed above, in some irregular and therefore non-scientific cases, consciousness significantly contributes to the results of observations. We have to state that in such cases the object of a study and the knowing subject do present in a way a holistic entity unable to be analyzed.

Finally, does EM mind control exist, or does it constitute a scientific regularity? There is no criterion other than common human practice. The social criterion for a hypothetical regularity to be an actual one, 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 norms about the quantitative measure of that replicability. Recognition of a supposed phenomenon as an objectively existing phenomenon is a long social process that provides for wide discussion by the scientific community.

EM mind control is a real phenomenon just for a very limited number of people, though they constitute a social organism: "there is a big subculture that believes that their brains are being manipulated by insidious forces" (Moreno, 2006). For the time being, it is far from correspondence to the criteria of scientific knowledge. At the same time, there are no fundamental constraints 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 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 threat, even though there is not enough scientific proof of its existence at this time. In a 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) the ethical and social issues of possible "mind wars" are raised. They urge scientists to become involved in public discussion of both the benefits of civilian use of mind control and the dangers of its imprudent applications.

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ELECTROMAGNETIC MIND CONTROL, FACT OR FICTION

A SCIENTIFIC VIEW

Vladimir Binhi, a physicist at the General Physics Institute, Russian Academy of Sciences, is well known for his work on bioelectromagnetics and magnetobiology. His areas of expertise include electromagnetobiology, magnetic processes in molecular systems, and magnetic measurements. Dr. Binhi has intensively researched this area for more than 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 more than 50 works in peer-reviewed journals. His main publications have appeared in leading journals, including *Physical Review, Europhysics Letters, Bioelectromagnetics, Biochimica et Biophysica Acta, Bioelectrochemistry, International Journal of Radiation Biology, Electromagnetic Biology and Medicine, Physics-Uspekhi, and Biophysics*. 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. Dr. 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 and D.Sc. degree in physics/mathematics from Moscow State University for his work in theoretical magnetobiology. Since the 1980s, Dr. Binhi has been involved in the study of the physical processes of biological magnetoreception. Dr. Binhi now heads a biophysics laboratory that develops experimental methods for the primary physical mechanisms of magnetoreception.

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