Mobile Communications and Public Health
Contents

Preface: To the Reader ................................................................. vii
Editor .......................................................................................... ix
Contributors .............................................................................. xi
5G Appeal ...................................................................................... xiii

Chapter 1 Mobile Communications and Public Health .................. 1
Marko S. Markov

Chapter 2 Cell Phone Radiation: Evidence From ELF and RF Studies Supporting More Inclusive Risk Identification and Assessment...... 25
Carl Blackman

Chapter 3 Public Exposure to Radio Frequency Electromagnetic Fields........ 47
Peter Gajšek

Chapter 4 Health Effects of Chronic Exposure to Radiation From Mobile Communication .......................................................... 65
Igor Belyaev

Chapter 5 Can Electromagnetic Field Exposure Caused by Mobile Communication Systems in a Public Environment Be Counted as Dominant? ................................................................. 101
Jolanta Karpowicz, Dina Šimunić, and Krzysztof Gryz

Chapter 6 Low-Level Thermal Signals: An Understudied Aspect of Radio Frequency Field Exposures with Potential Implications on Public Health ........................................................................ 129
Lucas A. Portelli

Chapter 7 How Cancer Can Be Caused by Microwave Frequency Electromagnetic Field (EMF) Exposures: EMF Activation of Voltage-Gated Calcium Channels (VGCCs) Can Cause Cancer Including Tumor Promotion, Tissue Invasion, and Metastasis via 15 Mechanisms ........................................................................ 165
Martin L. Pall

Henry Lai

Chapter 9  Radiobiological Arguments for Assessing the Electromagnetic Hazard to Public Health for the Beginning of the Twenty-First Century: The Opinion of the Russian Scientist.............................. 223

Yury G. Grigoriev

Chapter 10  A Longitudinal Study of Psychophysiological Indicators in Pupils Users of Mobile Communications in Russia (2006–2017): Children Are in the Group of Risk................................. 237

Yury G. Grigoriev and Natalia I. Khorseva

Index......................................................................................................................................................... 253
Preface: To the Reader

At the end of the second decade of the twenty-first century, we evidence a dramatic increase of all means of mobile communications, which includes space signals, smartphones, and smart meters. Recent data indicate that the number of mobile devices surpasses 7.5 billion users. The integration between the mobile devices and smart home environments and the emerging advances in mobile phone technology including recent 4G and 5G modalities open the discussions on the potential hazard for the biosphere and mankind.

Unfortunately, the scientific, medical, and public health communities, after more than a quarter of century of discussions, still do not have a common opinion on the issue of if, and to what extent, the EMF from mobile communications represent a hazard for public health. The entire world population is exposed to various RF EMF signals. The problem here is that the population has no knowledge of the exposure or of the parameters of the received EMF. It would be correct to say that the international system for control and regulation had failed.

Obviously, it is impossible to evaluate the daily, monthly, and yearly rate of use, or the total value of the absorbed energy. This is even more important because mobile devices and cell phones may be seen in the hands of children as young as 1–3 years in age. It is already recognized that children have a unique vulnerability to external adverse factors of the environment.

As wireless broadband technology has evolved from generation to generation, the manufacturers were able to upgrade and adapt to necessary changes in the products. Today, the situation is different—the problem is not to upgrade—any new generation is basically new technology, and 5G is an especially deep step in the millimeter range of the electromagnetic spectrum. In addition to the new frequency range, the distribution of the signal requires a large number of antenna elements which need to be integrated into advanced device packaging. It is clear now that the standards for 5G are not yet available. Therefore, it is another jump in developing technology which will lead the entire biosphere and civilization to be exposed to new levels of electromagnetic pollution that are not defined and for which there are no standards and methods of control.

This was the reason that I started this project—to emphasize the necessity of terminology clarification, the specific absorption rate (SAR) use, and the thermal versus nonthermal effects.

Due to the courtesy of Drs. Rainer Nyberg and Lennart Hardell, I am able to open this book with the petition to the European Union that nearly 200 scientists from three continents signed asking that the 5G generation of mobile communications not be allowed before the standards for protection of the human population are developed and introduced.

This book would not be possible without the contribution of scientists from Europe and North America. Igor Belyaev and Carl Blackman helped in clarification of biological issues, Peter Gajšek, Jolanta Karpowicz, Dina Šimunić and Krzysztof Gryz wrote about the engineering problems. Biomedical engineer Lucas A. Portelli reported the recent advances in studying low-level thermal signals, while Henry Lai
offered the readers a summary of recent literature on the neurobiological effects of radio frequency radiation. Martin Pall proposed a possible mechanism explaining how cancer can be caused by microwave frequency EMF exposures. Yury Grigoriev and Natalia Khortzeva reported Russian experience in setting standards and the investigations of the RF EMF effects on children in Russian schools.

Dear reader, please do not forget that we are at the bottom of the ocean of electromagnetic waves. The mobile communication industry is creating newer and newer tools in order to eventually increase the speed of communications. Smartphones and smart meters significantly change the electromagnetic environment not only for occupational conditions, but in every home. Billions of people are even not informed about the fact that their homes and their organisms are subjected to the “new and advanced” technological development. This cohort includes babies and elderly people, schoolboys and professionals.

It is our duty, we biologists, physicists, engineers, and medical professionals need to help today and future generations in the creation of standards for healthy life. It is time to ring the bell. Please help.
Editor

Marko S. Markov earned his BS, MS, and PhD from Sofia University, Bulgaria. He has been professor and chairman of the Department of Biophysics and Radiobiology of Sofia University for 22 years. He has been an invited professor and lecturer in a number of European and American academic and industry research centers.

Dr. Markov is well recognized as one of the world’s premier experts in clinical applications of electromagnetic fields. He has given 288 invited and platform presentations at more than 70 international meetings. His list of publications includes 196 papers and 18 books.

Dr. Markov has more than 45 years’ experience in basic science research and more than 40 years’ experience in the clinical application of electromagnetic fields for treatment of bone and soft tissues pathologies and injuries.

His commercial affiliation started in Bulgaria with a series of contractual appointments and continued in the USA in his capacity as vice president of three companies involved in manufacturing and distribution of devices for magnetic field therapy. The spectrum of the signals ranges from static magnetic fields to 27.12 MHz. The clinical targets are in the area of bone and soft tissue problems, pain control, and innovation of the low frequency range for inhibition of angiogenesis and tumor growth. Recently, he introduced an analytical method for designing signals and devices for bioelectromagnetics research.


Dr. Markov has edited seven special issues of two journals, The Environmentalist and Electromagnetic Biology and Medicine consisting of selected papers of biannual International Workshops on Biological Effects of Electromagnetic Fields.

Dr. Markov is cofounder of the International Society of Bioelectricity, the European Bioelectromagnetic Association (EBEA), and the International Society of Bioelectromagnetism. He has been a member of the Board of Directors of Bioelectromagnetics Society and an organizer of several NATO research meetings.
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5G Appeal

The following text is a reproduction of the Appeal for Moratorium of 5G technology sent to the European Union and Council of Europe from more than 190 scientists and doctors worldwide.

To: The Council of the European Union

Scientists Call For Moratorium on 5G

Over 190 scientists and doctors have signed a 5G-Appeal (see Attachment) to the European Union and Council of Europe seeking a moratorium on the deployment of 5G (Fifth Generation of Telecommunication) using super-high 10–100 GigaHz frequencies, so new that they are not scientifically proven safe. However, the signatories determined that the microwave radiation emitted by lower frequency wireless technology is “harmful to humans and the environment.” Deployment of 5G will substantially increase the total exposure to wireless radiation. We refer to the EU Council recommendation (1999/519/EC) of 12 July 1999: (4) “It is imperative to protect members of the general public within the Community against established adverse health effects that may result as a consequence of exposure to electromagnetic fields.”

The current safety guidelines only recognize heating effects. The independent scientists are in agreement that science has shown that wireless radiation “affects living organisms at levels well below most international and national guidelines.” These effects are seen at non-thermal radiation levels and cannot be explained by heating. Thus, the current guidelines based on tissue heating do not protect against health hazards.

The scientists who signed the Appeal demand the EU and Council of Europe – instead of massively increasing total exposure – now apply the Parliamentary Assembly of the Council of Europe PACE Resolution 1815 and “take all reasonable measures necessary to reduce exposure to electromagnetic fields” and to halt the 5G expansion until an expert group of truly independent scientists can assure that 5G and the increased sum of radiation levels caused by 5G wireless technology added to 2G, 3G, 4G, Wi-Fi1) etc. will be safe.

October 24, 2017

Respectfully submitted

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1 EU decided 29/05/2017: “Free public Wi-Fi hotspots...across the EU” will be installed for €120 million before 2020
Scientists and doctors warn of potential serious health effects of 5G

September 13, 2017

We the undersigned, more than 180 scientists and doctors from 36 countries, recommend a moratorium on the roll-out of the fifth generation, 5G, for telecommunication until potential hazards for human health and the environment have been fully investigated by scientists independent from industry. 5G will substantially increase exposure to radiofrequency electromagnetic fields (RF-EMF) on top of the 2G, 3G, 4G, Wi-Fi, etc. for telecommunications already in place. RF-EMF has been proven to be harmful for humans and the environment.

(Note: Underlined links below are references.)

5G leads to massive increase of mandatory exposure to wireless radiation

5G technology is effective only over short distance. It is poorly transmitted through solid material. Many new antennas will be required and full-scale implementation will result in antennas every 10 to 12 houses in urban areas, thus massively increasing mandatory exposure.

With “the ever more extensive use of wireless technologies,” nobody can avoid to be exposed. Because on top of the increased number of 5G-transmitters (even within housing, shops and in hospitals) according to estimates, “10 to 20 billion connections” (to refrigerators, washing machines, surveillance cameras, self-driving cars and buses, etc.) will be parts of the Internet of Things. All these together can cause a substantial increase in the total, long term RF-EMF exposure to all EU citizens.

Harmful effects of RF-EMF exposure are already proven

Over 230 scientists from more than 40 countries have expressed their “serious concerns” regarding the ubiquitous and increasing exposure to EMF generated by electric and wireless devices already before the additional 5G roll-out. They refer to the fact that “numerous recent scientific publications have shown that EMF affects living organisms at levels well below most international and national guidelines”. Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans. Damage goes well beyond the human race, as there is growing evidence of harmful effects to both plants and animals.

After the scientists’ appeal was written in 2015 additional research has convincingly confirmed serious health risks from RF-EMF fields from wireless technology. The world’s largest study (25 million US dollar) National Toxicology Program (NTP), shows statistically significant increase in the incidence of brain and heart cancer in animals exposed to EMF below the ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines followed by most countries. These results support results in human epidemiological studies on RF radiation and brain tumour risk. A large number of peer-reviewed scientific reports demonstrate harm to human health from EMFs.

The International Agency for Research on Cancer (IARC), the cancer agency of the World Health Organization (WHO), in 2011 concluded that EMFs of frequencies 30 KHz – 300 GHz are possibly carcinogenic to humans (Group 2B). However, new studies like the NTP study mentioned above and several epidemiological investigations including the latest studies on mobile phone use and brain cancer risks confirm that RF-EMF radiation is carcinogenic to humans.
The EUROPA EM-EMF Guideline 2016 states that “there is strong evidence that long-term exposure to certain EMFs is a risk factor for diseases such as certain cancers, Alzheimer's disease, and male infertility...Common EHS (electromagnetic hypersensitivity) symptoms include headaches, concentration difficulties, sleep problems, depression, lack of energy, fatigue, and flu-like symptoms.”

An increasing part of the European population is affected by ill health symptoms that have for many years been linked to exposure to EMF and wireless radiation in the scientific literature. The International Scientific Declaration on EHS & multiple chemical sensitivity (MCS), Brussels 2015, declares that: “In view of our present scientific knowledge, we thereby stress all national and international bodies and institutions...to recognize EHS and MCS as true medical conditions which acting as sentinel diseases may create a major public health concern in years to come worldwide i.e. in all the countries implementing unrestricted use of electromagnetic field-based wireless technologies and marketed chemical substances. Action is a cost to society and is not an option anymore...we unanimously acknowledge this serious hazard to public health...that major primary prevention measures are adopted and prioritized, to face this worldwide pan-epidemic in perspective.”

Precautions

The Precautionary Principle (UNESCO) was adopted by EU 2005: “When human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm.”

Resolution 1815 (Council of Europe, 2011): “Take all reasonable measures to reduce exposure to electromagnetic fields, especially to radio frequencies from mobile phones, and particularly the exposure to children and young people who seem to be most at risk from head tumours...Assembly strongly recommends that the ALARA (as low as reasonably achievable) principle is applied, covering both the so-called thermal effects and the athermic [non-thermal] or biological effects of electromagnetic emissions or radiation” and to “improve risk-assessment standards and quality”.

The Nuremberg code (1949) applies to all experiments on humans, thus including the roll-out of 5G with new, higher RF-EMF exposure. All such experiments: “should be based on previous knowledge (e.g., an expectation derived from animal experiments) that justifies the experiment. No experiment should be conducted, where there is an a priori reason to believe that death or disabling injury will occur; except, perhaps, in those experiments where the experimental physicians also serve as subjects.” (Nuremberg code pts 3-5). Already published scientific studies show that there is “a priori reason to believe” in real health hazards.

The European Environment Agency (EEA) is warning for “Radiation risk from everyday devices” in spite of the radiation being below the WHO/ICNIRP standards. EEA also concludes: “There are many examples of the failure to use the precautionary principle in the past, which have resulted in serious and often irreversible damage to health and environments...harmful exposures can be widespread before there is both ‘convincing’ evidence of harm from long-term exposures, and biological understanding [mechanism] of how that harm is caused.”

“Safety guidelines” protect industry — not health

The current ICNIRP “safety guidelines” are obsolete. All proofs of harm mentioned above arise although the radiation is below the ICNIRP “safety guidelines”. Therefore new safety standards are necessary. The reason for the misleading guidelines is that “conflict of interest of ICNIRP members due to their relationships with telecommunications or electric companies undermine the impartiality that should govern the
regulation of Public Exposure Standards for non-ionizing radiation...To evaluate cancer risks it is necessary to include scientists with competence in medicine, especially oncology.”

The current ICNIRP/WHO guidelines for EMF are based on the obsolete hypothesis that “The critical effect of RF-EMF exposure relevant to human health and safety is heating of exposed tissue.” However, scientists have proven that many different kinds of illnesses and harms are caused without heating (“non-thermal effect”) at radiation levels well below ICNIRP guidelines.

We urge EU:

1) To take all reasonable measures to halt the 5G RF-EMF expansion until independent scientists can assure that 5G and the total radiation levels caused by RF-EMF (5G together with 2G, 3G, 4G, and WiFi) will not be harmful for EU-citizens, especially infants, children and pregnant women, as well as the environment.

2) To recommend that all EU countries, especially their radiation safety agencies, follow Resolution 1815 and inform citizens, including, teachers and physicians, about health risks from RF-EMF radiation, how and why to avoid wireless communication, particularly in/near e.g., daycare centers, schools, homes, workplaces, hospitals and elderly care.

3) To appoint immediately, without industry influence, an EU task force of independent, truly impartial EMF-and-health scientists with no conflicts of interest¹ to re-evaluate the health risks and:
   a) To decide about new, safe “maximum total exposure standards” for all wireless communication within EU.
   b) To study the total and cumulative exposure affecting EU-citizens.
   c) To create rules that will be prescribed/enforced within the EU about how to avoid exposure exceeding new EU “maximum total exposure standards” concerning all kinds of EMFs in order to protect citizens, especially infants, children and pregnant women.

4) To prevent the wireless/telecom industry through its lobbying organizations from persuading EU-officials to make decisions about further propagation of RF radiation including 5G in Europe.

5) To favor and implement wired digital telecommunication instead of wireless.

We expect an answer from you no later than October 31, 2017 to the two first mentioned signatories about what measures you will take to protect the EU-inhabitants against RF-EMF and especially 5G radiation. This appeal and your response will be publicly available.

Respectfully submitted,

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¹ Avoid similar mistakes as when the Commission [2008/723/EC] appointed industry supportive members for SCENIHR, who submitted to EU a misleading SCENIHR report on health risks, giving telecom industry a clean bill to irradiate EU-citizens. The report is now quoted by radiation safety agencies in EU.
1 Mobile Communications and Public Health

Marko S. Markov

CONTENTS

1.1 Introduction ................................................................. 1
1.2 Evolution of the Smartphone ........................................ 2
1.3 Definitions: Biological Effects, Health Effects, Health Hazard ........ 4
  1.3.1 SAR ........................................................................... 6
1.4 EMF Interactions with Living Systems ................................ 7
  1.4.1 Thermal Effects .......................................................... 9
  1.4.2 Nonthermal Effect ...................................................... 10
1.5 Mobile Communications and Public Health ......................... 12
  1.5.1 “Hot Spots” .............................................................. 13
  1.5.2 Protect Children ....................................................... 15
References ............................................................................. 19

1.1 INTRODUCTION

Recent research on the distribution of mobile devices indicated that at present their number surpasses 7.5 billion users especially with increasing distribution of smartphones and electronically driven utility meters. Tighter integration between the mobile devices and smart home environments will ultimately provide the infrastructure with a wide range of applications, further personalizing consumer and citizen interaction with the world around them. The emerging advances in mobile phone technology, including recent 4G and 5G modalities, open the discussions on the potential hazard for the biosphere and mankind.

Unfortunately, the scientific, medical, and public health communities at present (after more than a quarter of a century of discussions) do not have a common opinion on the issue if, and to what extent, the EMF from mobile communications represent a hazard for public health, including identification of the conditions and parameters at which the exposure of the population to these microwaves became chronic. The clarification had been basically searched for the signal emitted by base stations and practically no attention was paid to the mobile devices themselves. The base stations operate 24/7 and expose the entire biosphere (including the human population) to various electromagnetic signals. The problem here is that the population is exposed to this radiation with no knowledge of the exposure or of the parameters of the received EMF. It would probably be correct to say that the international system for control and regulation has failed. In order to get a license, the manufacturers need to
follow some artificially created guidelines which are basically far away from the care for the health of users of mobile devices, for the entire population, and even for the biosphere. Every discussion starts with “thermal effects” and the possibility to create overheating of the critical organs in human organisms, mainly the brain.

The influence of radio frequency electromagnetic fields (RF EMF) on the brain when mobile phones are in use could vary with periodicity, carrier frequency, and modulation. Thus, it is difficult, if not impossible, to evaluate the daily, monthly, and yearly rate of use, including the total value of the absorbed energy. Therefore, even the epidemiological studies performed with a large cohort of participants could not provide reliable information. The other problem is connected to the gender and age of the user, the life style use, and the business use of mobile phones. Therefore, mobile phones should be relegated to the sources of EMF that cannot be properly characterized, despite the already proven potential hazard of this emission.

Several specific problems have arisen in respect to the health of a small, but very important fraction of the human population: children. (IARC, 2002; WHO, 2003; Markov, 2012; Markov and Grigoriev, 2013; Grigoriev and Khorseva, 2014; Grigoriev and Grigoriev, 2013). This is even more important because mobile devices and cell phones may be seen in the hands of children as young as 1–3 years in age. It is already recognized that children have a unique vulnerability to external adverse factors of the environment (WHO, 2003). There is no way to assess and predict the potential damage to children’s brains exposed to RF radiation. The industry is offering now new toys and various electronic games based upon Internet access and these toys are now in the hands of 1-year old children. A recent report of the National Toxicology Program (NTP) provides more information about the possibility of cancer promotion as result of exposure to the microwave EMF of cellular communications.

1.2 EVOLUTION OF THE SMARTPHONE

The use of mobile communications started in the late 1980s with bulky devices that quickly became popular; the public demand and industry interest led to transfer of the bulky telephone to small devices and later to smartphones. Today, smartphones are difficult to simply call “phones.” They are portable, powerful computers which are “on” immediately after the battery is installed. When the user switches the phone “off,” it basically means nothing. The unit is “on” 24/7 receiving and emitting information, data, etc. In less than 10 years, simple mobile phones became smartphones with increasing capacity, frequency range, number of users, and so on. They have changed the way of communications between individuals in their everyday and business uses. They became the universal controller of household and business facilities. A new term was created, IoT (Internet of Things), bringing the business people, retirees, and even small children into this miracle world of wireless communication.

It is clear now that the future of mobile communications belongs to the smartphones. If in 2015 there were 3.5 billion subscribers, the prediction for 2022 shows 6.8 billion users. It is expected that the data used by a single smartphone will rise by 8 times up to 1 GB/month (Gillenwater, 2017). To handle this increase of the mobile data network, providers offer 2G, 3G, 4G, and the coming 5G generations which elevate the carrier frequency bands. Not going into technicalities, I should
point out that the peak to average power ratio will exceed 4.5 dB and will be introduced as a new power standard (Power class 2) that doubles the output power to 26 dBm to overcome the greater losses at high frequency bands. Thermal performance becomes critical at this higher power and the dissipation of the additional heat becomes very important (Gillenwater, 2017). So far, the industry does not speak about the extent to which this technical issue will potentially elevate biological importance and hazards.

As wireless broadband technology has evolved from generation to generation, the manufacturers were able to upgrade and adapt to necessary changes in the products. Today, the situation is different—the problem is not to upgrade—any new generation is basically new technology, especially 5G which is a step deeper in the millimeter range of the electromagnetic spectrum. In addition to the new frequency range, the distribution of the signal requires a large number of antenna elements which need to be integrated into advanced device packaging. It is clear now that the standards for 5G are not yet available. Therefore—it is another jump in developing technology which will lead the entire biosphere and civilization to be exposed to new levels of electromagnetic pollution which are not defined, which have no standard, and have no methods of control. As with the entire development of wireless communication, the industry is pushing to first develop mobile devices and networks and then to further develop the standards (Oltman, 2017).

We have been on this avenue for about a quarter of a century. Did we not learn something? For me, it is not clear as why the 5G generation is called the Internet of Things. Looks intriguing, doesn’t it? Consequently, smart operators and providers are learning all they can about 5G now to understand how they will need to evolve their backhaul strategy to create more effective and financially viable business models.

The industry is pushing for development of controversial legislation to expedite the distribution of this new technology. This new legislation is related to the fact that local governments and private citizens can not oppose the dense installations of antennas (at every 20 houses in urban areas). As result, the potential health risk for the population is ignored. Since the distribution of millimeter waves is blocked by buildings and even walls, it may be that at any school or office building, several transmitters will need to be placed on each floor of the building.

The FCC (Federal Communication Commission in USA) in 1996 introduced a limit for thermal effects from EMF of 1.5–100 GHz to be 1 mW/cm² for 30 min of use. This limit was set 20 years ago and is related only to thermal effects. The engineering community of today continues claiming that nonthermal effects of EMF do not exist. This statement is absolutely incorrect and negates hundreds of publications reporting the nonthermal effects of EMF. I would emphasize here that most of the reports of the effects of millimeter waves have reported on short term exposure, while there is practically no information about long term exposure. Even short exposure to millimeter waves was reported to cause significant nonthermal effects (Betskii and Lebedeva, 2004).

The writings of more than 160 scientists with experience in the evaluation of the hazards of wireless communications (published in this book) demonstrate that scientific assessment of the development of this new way of communication has been learned from past experience. (See “5G Appeal” Introduction in front section of this book.)
1.3 DEFINITIONS: BIOLOGICAL EFFECTS, HEALTH EFFECTS, HEALTH HAZARD

These three terms need special attention from any point of view: physics, engineering, biology, and medicine. Something here is wrong. Although a number of institutions assume the privilege of setting guidelines and standards, we do not have proper definitions of these categories. Moreover, by misusing the words, the scientific community has created havoc in discriminating what is a biological effect, what is a health effect, and what is a hazardous effect. Unfortunately, this was further transferred to the language and terminology of the policy, standard, and regulation bodies.

The industry publications as well as the papers from the engineering community have time and time again promoted the notion that the only harm might be the thermal effect. The “experts” claimed that there is no hazard from mobile phone radiation since the intensity levels are low and there is no thermal effect reported. Moreover, Nikita and Kiourri (2011) defined three types of physical effects: thermal, athermal, and nonthermal. The introduction of the term “athermal” is nonsense. By definition, athermal means the absence of temperature, which is impossible for any living system. The authors continue in this wrong direction with the statement of an athermal effect because even though the energy is capable of heating the tissue, the temperature does not increase because of tissue thermoregulation mechanisms. (In parallel, there are number of publications referring to “hot spots.”)

On the other hand, the WHO policy is that “not every biological effect is a health effect.” This is not a correct definition. Obviously, by saying “health effect,” WHO is considering the adverse effects in the sense of diseases, pathologies, and injuries. If the action of EMF is to be evaluated, the correct WHO statement should be “Not every biological effect initiated by EMF is a health hazard.” There is at least one reason for such a statement: the worldwide development of bioelectromagnetic medicine clearly indicates that properly chosen EMF/magnetic field (MF)/electric field (EF) and electric current may be beneficial in the treatment of various diseases and injuries, even when all other known medical treatments dramatically failed (Rosch and Markov, 2004; Barnes and Greenebaum, 2007; Markov, 2015).

There is an abundance of publications pointing out that some biological effects of EMF are reversible, while others are transient. “Transient” indicates biological effects which quickly disappear once the application is terminated. Reversible effects require a longer time to disappear.

So, the term “hazard” should be kept for irreversible effects caused by short or prolonged exposure to EMF. In the 1990s, the hazard was associated with the EMF of power and distribution lines. Lately, the power lines have been forgotten and discussions within the scientific community, policy makers, medical establishment, news media, and general public are mostly oriented toward cellular communications, mainly cell phones and base stations.

There are several international (International commission of non-ionization radiation protection [ICNIRP], International committee of electromagnetic safety [ICES]) and American (Institute of Electrical and Electronic Engineering [IEEE], American National Standard Institution [ANSI]) committees which more or less attempt to
Mobile Communications and Public Health

direct the world standards. However, even the simple fact of the existence of several committees indicates the existence of a problem. There should be only one recognized and largely accepted standard institution which should develop various national and international standards. Following this idea, in the late 1990s, WHO initiated a project involving different laboratories, standard organizations, and countries called “EMF Project of Harmonization of Standards.” Basically, nobody opposes such an action, but everybody wants his standard to be in use. This, however, is the smallest problem.

The big problem is: Which standard should be used; that based on SAR which is the USA approach, or the ones based on the biological response as many scientists from Eastern Europe and the former Soviet Union requested? This is a problem with several faces: East versus West; Biophysics versus Engineering; Thermal versus NonThermal. What is curious is that all three basically reflect the last possibility. Why is this so?

Eastern standards are based upon biophysics (biological response) which assumes nonthermal mechanism(s). In contrast to the ICNIRP, the Russian safety standards for example, which are based on nonthermal effects, do not use SAR values but instead limit the duration of exposure and power flux density (PD, W/cm²) (SanPiN, 1996). Western standards are based on engineering/computation and assume thermal mechanisms only.

As pointed out earlier, heat based mechanisms exclude the possibility for the occurrence of nonthermal effects. In a document adopted by the International Committee of Electromagnetic Safety (ICES) cited by Cho and D’Andrea (2003), “Nonthermal RF biological effects have not been established and none of the reported nonthermal effects are proven adverse to health. Thermal effect is the only established adverse effect.” Interestingly enough, the same document started with, “The RF safety standards should be based on science.” There is no doubt that the standards should be based on science, but what science is this that neglects hundreds and hundreds of published results on the nonthermal effects of RF EMF?

It is interesting to know that the value of 100 W/m² (10 mW/cm²) was proposed by the late Herman Schwan in his letter to the US Navy in 1953 as a safe limit for human exposure to microwave energy based on calculations (Foster, 2005).

Let me remind the reader, too, of the early statement of Becker (1990) that “Based solely on calculations, the magic Ture of 10 milliWatts per square centimeter was adopted by the air force as the standard for safe exposure. Subsequently the thermal effects concept has dominated policy decisions to the complete exclusion of nonthermal effects. While the 10 mW/cm² standard was limited to microwave frequencies, the thermal concept was extended to all other parts of the electromagnetic spectrum. This view led to the policy of denying any nonthermal effects from any electromagnetic usage, whether military or civilian.” The majority of the international and national guidelines for the exposure limits of health protection are still based on the recommendations by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) taking into account only the thermal effects resulting in tissue heating (ICNIRP, 1998). On the other hand, many studies in humans and animals have reported the biological and physiological effects of microwave radiation at levels of exposure below the thermal limits. The effects include cellular stress, increase in free radicals, changes in DNA, functional changes in the reproductive system, alterations in the brain bioelectrical activity, and learning and memory deficits in humans and animals (Valentini et al., 2007;
Mobile Communications and Public Health

Blank and Goodman, 2009; De Iuliis et al., 2009; Jutttilainen et al., 2011; Leszczynski et al., 2012; Lerchl et al., 2015). As Belyaev (2018) pointed out in this book “At chronic conditions, exposure to mobile phones may reproduce a number of real signals even during the same exposure session and thus provide a better possibility to assess detrimental effects from mobile telephony than experiments with fixed frequencies/frequency bands/modulations, which evaluate only a minor part of real signals.” In addition, mobile phones emit not only MW but also extremely low frequency magnetic (ELF) EMF, which have also been shown to produce detrimental health effects and to interfere with MW effects (IARC, 2002; Belyaev, 2010). Szmigielski (2013) reviewed studies on the impacts of weak RF/MW fields, including cell phone radiation on various immune functions, both in vitro and in vivo. The bulk of available evidence clearly indicated that various shifts in the number and/or activity of immunocompetent cells are possible, although the results were inconsistent. In particular, a number of lymphocyte functions have been found to be either enhanced or weakened based on exposure to similar MW intensities although the other important variables of the experiments were different. The author concluded that, in general, short-term exposure to weak MW radiation may temporarily stimulate certain humoral or cellular immune functions, while chronic irradiation inhibits the same functions.

The ICNIRP guidelines for high frequency EMF (covering 100 kHz–300 GHz) was established in 1988—just at the time of the start of the development of mobile communications. Since this time, research on the GHz frequency region has started. The question arises—what are the scientific bases for such standards? Moreover, in 2014, ICNIRP announced that a revision of the guidelines would be made then on December 7, 2017, the deadline was reset to the middle of 2018. Four years are needed for the revision of guidelines? It is not surprising that in the same note, ICNIRP declares that “…the 1998 guidelines remain protective…” and “…still provide protection against all known health effects of high frequency radiation…”. What will happen with 4G and 5G technologies that the industry aggressively distributes if the ICNIRP comes up with a revision and they are pronounced as hazardous? Will the standardization bodies follow the industry rules?

It is strange that on November 27, 2017, the EMF portal announced that “due to the lack of financial resources the site had to suspend import of any new radio-frequency and mobile phone-related articles as of now. The portal will continue to import other EMF papers.” To me, there is something suspicious here.

The problem here is that for ICNIRP, the only possible effects of high frequency EMF are thermal. Also, ICNIRP does not see any thermal effects possible. Period. Therefore, any non-ionizing radiation will possibly be applied over the human population.

Because they are well-funded and respond to the interests of influential political, military, and business circles, the supporters of the thermal mechanisms of action prevail so far. For how long will this continue?

1.3.1 SAR

We should emphasize the lack of clear understanding and use of the terminology, especially the specific absorption rate (SAR). It is obvious that the SAR is a useful
Mobile Communications and Public Health

 criterion and the only criterion which attempts to estimate the energy absorbed by the body. However, the name clearly indicates absorption and I personally wonder why for so many decades we, the entire bioelectromagnetics community, has used the SAR to clarify the energy delivered by the generating system, no matter how far the source is from the target, nor what the specific structure of this target is.

Up until today, SAR has more often been used to describe the energy delivered by the source of the electromagnetic field (EMF). One can only wonder how a device may be characterized by SAR. Let me repeat, the SAR identifies the amount of energy that is absorbed in a gram of tissue. The use of the SAR should be a measure of the absorbed energy, and this will result in a serious debate among researchers, since that would mean the safety standards would need to be restated in terms of internal energy absorption in addition to power density at the surface.

For more than half a century, a very serious group of policy makers and even scientists have been playing around with the term SAR. Let me repeat, SAR given in terms of Watts per Kilogram (W/Kg) or milliWatts per gram (mW/g) is assumed to provide a measure of absorbed energy in a given tissue. Once again, absorption, not delivery.

The aim of SAR is to assess the probability of temperature increase as result of the exposure of a biological body to EMF. This parameter is introduced in some “artificial” way. The problem is that it assumes homogeneous tissue, which biological bodies certainly are not. Basically, even from the point of equilibrium thermodynamics, such an approach is not appropriate. It is well known that the penetration of EMF is a function of the body size and dielectric properties as well as the parameters of the “arriving” field, not to mention energy dispersion and thermoregulation. Thus, by performing external measurement of EMF, it is hard to accept the estimation and spatial distribution of SAR (Bienkowski and Trzaska, 2015).

1.4 EMF INTERACTIONS WITH LIVING SYSTEMS

It would be plausible to start this section with the statement that “Life is a set of electromagnetic events performed in an aqueous medium.” This did not happen yesterday. It is a product of a long evolution of the physical conditions on our planet and adaptation of the electromagnetic nature of life to these conditions. Take as an example bird and fish navigation along a geomagnetic field and the “suffering” of microorganisms when deprived of the usual ambient magnetic and electric fields.

It is clear now that the whole biology and physiology of living creature(s) are based upon three types of transfer:

- Energy
- Matter
- Information

While the first two processes might be described in terms of classical (equilibrium) thermodynamics, the information transfer obviously needs another approach and this may be found in nonequilibrium thermodynamics. As the late Ross Adey (2004) wrote in his last paper, “Current equilibrium thermodynamics models fail to explain...
an impressive spectrum of observed bioeffects at non-thermal exposure levels. Much of this signaling within and between cells may be mediated by free radicals of the oxygen and nitrogen species.” Cell signaling, signal transduction cascades, and conformational changes are events and processes that may be explained only by nonequilibrium thermodynamics.

For unicellular organisms, the cellular membrane is both detector and effector of physical and chemical signals. As a sensor, it detects altered conditions in the environment and further provides pathways for signal transduction. As an effector, the membrane may also transmit a variety of electrical, magnetic, and chemical signals to the neighboring cells with an invitation to “whisper together” as suggested by Ross Adey (2004). One condition is necessary here, that cells are tuned to the same signal. In general, this leads to resonance or a window hypothesis. What does this hypothesis actually mean? Exactly that a given tissue, organ or organism needs to be tuned to a given EMF signal. When the applied EMF has the parameters (amplitude or frequency, for example), the biological object will respond. If these parameters are beyond the resonance parameters, the target may not respond at all or the response will be not optimal/maximal.

It was shown that selected exogenous, weak, low frequency electric or magnetic fields can modulate certain important biochemical and physiological processes (Todorov, 1982; Deltavs, 1987; Carpenter and Ayrapetyan, 1994; McLean et al., 2003; Rosch and Markov, 2004, Barnes and Greenebaum, 2007; Markov, 2015). An estimate of detectable EMF exposure can, therefore, only be made if the amplitude and spatial dosimetry of the induced EMF at the target site are evaluated for each exposure system and condition (Markov, 2015). The electrostatic interactions involving different proteins are assumed to result primarily from polarization and reorientation of dipolar groups as well as changes in the concentrations of charged species in the vicinity of charges and dipoles. These effects could be well characterized for interactions in isotropic, homogeneous media. However, biological structures represent complex inhomogeneous systems for which the ionic and dielectric properties are difficult to predict. In these cases, factors such as the shape and composition of the surface and presence/absence of charged or dipolar groups appear to be especially important. The problem of the sensitivity of living cells and tissues to exogenous EMF is principally related to the ratio of the signal amplitude to that of thermal noise at the target site (Markov, 2006). It is clear now that in order for electric and/or electromagnetic field bioeffects to be possible, the applied signal should not only satisfy the dielectric properties of the target, but also induce sufficient voltage to be detectable above thermal noise (Markov and Pilla, 1995). Such an approach relies on conformational changes and transfer of information (Markov, 2004).

It appears useful to point out some features of the information transfer:

• Static EMF, time varying EMF, and pulsed EMF affect biological systems via information transfer.
• This information transfer can trigger various biochemical processes, ion binding, and signal transduction.
• The EMF information may be detected in an ion binding pathway via Larmor precession in the presence of thermal noise.
Mobile Communications and Public Health

- For oscillating or pulsed signals, MF information is encoded in the frequency/amplitude spectrum of the signal.
- Signal decoding occurs via the impedance of electrochemical processes at a cell surface subject to signal/noise ratio requirements.

1.4.1 **Thermal Effects**

There is a classical thermodynamics dogma, “You get energy, you will have heating.” Even if one accepts this statement, several questions remain to be answered:

- How does EMF heating occur within complex biological structures?
- Do we have a flow of heat?
- What happens at the interface between tissues with different dielectric properties?

These questions, which interpret the physics of interactions, should be complemented with at least two biological questions:

- What are the biological implications of heat generation?
- What is the cascade of events and the alterations in the signal transduction and in the enzyme reaction rate?

I would ask what heat is expected in elementary biochemical processes, such as the transport of ions through membranes or blood flow? Yes, energy is needed, but heating (or more precisely overheating) had never been observed. Why do we need to accept that the chemical factors can modulate biological activity, but forbid this for physical factors?

When the effects of magnetic fields are discussed, the issue of an induced electric field immediately appears on the scene. Although basically correct, this improperly shifts the emphasis from the primary to a secondary factor. The acting factor is the incident magnetic field and the biological effects should be analyzed from that point of view. One should not forget that when EMF is applied to a biological body, the electric component is shielded by the surface of the body creating surface electric current, while the magnetic component is capable of penetrating inside the body volume and will be distributed within the target without a change in the intensity (Otano-Lata et al., 1996).

Another problem is that engineers often (if not always) apply models that do not consider the fact that biological systems are heavily nonlinear systems and in such cases, nonlinear thermodynamics must be applied.

Material and ionic fluxes are territories that magnetobiology avoids. Energy interactions are always the focus of the research. However, transfer of information is constantly neglected in bioelectromagnetics, even though communication technologies are based upon modulation. Nobody is capable of estimating the SAR alteration inside the human brain that results from EMF modulation. This is not and cannot be a thermal effect. Here, one should introduce nonequilibrium thermodynamics in order to search for mechanisms of action, instead of classical, heat based thermodynamics.
The occurrence of hot spots in which the temperature increase is significantly higher than in a neighboring cell cannot be explain by equilibrium thermodynamics. It is strange that the thermal approach accepts some features from classical thermodynamics, but neglects others. For example, the classical “kT” criterion is always used to deny the possibility of occurrence of biological responses to static and low frequency MF.

It is hard to understand why the papers on thermal mechanisms of high frequency EMF do not consider a set of parameters which more than 29 years ago had been pointed as important EMF characteristics (Markov, 1994; Valberg, 1995), such as vector, gradient, component, modulation, etc., but instead only emphasize the SAR values.

In addition, in order to understand the biological consequence of RF exposure, one must know whether the effect is cumulative, whether compensatory responses result, and if or when homeostasis will break down.

1.4.2 Nonthermal Effect

There is a whole series of biologically important modifications that appear under weak static or alternating EMF action that could be explained only from the view point of nonthermal mechanisms. The spectrum includes changes at various levels: alterations in membrane structure and function and changes in a number of subcellular structures such as proteins and nucleic acids, protein phosphorylation, cell proliferation, free radical formation, ATP synthesis, etc. (Basset, 1994; Adey, 2004). Another important evidence in favor of the nonthermal character of EMF interaction could be found in the systemic effects (Markov et al., 2004; Barnes and Greenebaum, 2007; Markov, 2015). The wide range of reported beneficial effects of using electric current or EMF/EF/MF therapy worldwide shows that more than 3 million patients received relief from their medical problems. From bone unification (Detlavs, 1987; Basset, 1994), pain relief (Holcomb et al., 2003; Markov, 2004; Rosch and Markov, 2004; Barnes and Greenebaum, 2007; Pilla, 2007) and wound healing (Vodovnik and Karba, 1992; Markov and Pilla, 1995; Pilla, 2007, 2015; Mayrovitz, 2015) to relatively new applications for victims of multiple sclerosis (Lapin, 2004), Parkinson’s, and Alzheimer’s diseases (Richter and Lozano, 2004), bioelectromagnetic medicine has an important place in twenty-first century medicine (Rosch and Markov, 2004; Markov, 2015).

Continuing with the review of nonthermal biological effects, I would point to the fact that the EMF effects are better seen within the systems out of equilibrium. The observation showed a kind of “pendulum effect”—the larger the deviation from equilibrium, the stronger the response is. Such regularity may be seen in changes in the cell cycle, signal transduction, free radical formation, and performance, as well as in therapeutic modalities.

It should be remembered that during evolution, living organisms developed specific mechanisms for perception of natural electric and magnetic fields. These mechanisms require specific combinations of physical parameters of the applied field to be detected by biological systems. In other words, the “windows” are means by which discrete MF/EMF are detected by biological systems. Depending on the level
of structural organization, these mechanisms of detection and response may be seen at different levels, for example, at membrane, cellular or tissue levels. Sometimes the “windows” function via signal transduction cascade, brain activity or the central nervous system (Markov, 2004). Neither of the above effects and mechanisms requires thermal contributions, but the biological response is evident. The sensitivity of the biological systems to weak MF has been described elsewhere, mainly in respect to the dependence of bioeffects on the amplitude or frequency of applied fields. It may be interesting to know that all early publications made a link between “windows” and information transfer (Adey, 1981, 1989; Markov, 1979, 1984, 1994).

Such “windows of opportunities” are very successfully used in magnetic and electromagnetic field therapies. This is sometimes based upon systematic research, but more often, selected magnetic/electromagnetic fields used for therapy are based upon the intuition of the inventor of the device and the medical staff. Why “selected?” Because these selected values of the physical characteristics of the MF/EMF correspond to the “windows of opportunities.” Living systems are ready to detect, absorb, and utilize signals with specific characteristics and remain “silent” or unresponsive for the rest of the amplitude and/or frequency spectrum.

Resonance mechanisms, frequency, and intensity windows, as well as reports of modulated fields producing stronger or different effects than continuous wave fields, and the presence of effects that occur at very low intensities could be indications of nonthermal effects and cannot be explained by SAR or thermal effects.

An interesting approach to the mechanism of low-level microwave radiation was proposed by Hinrikus and his team (Hinrikus et al., 2008, 2011, 2015, 2017a,b). This model considers the microwave radiation as a physical stressor. Therefore, the physical approach is applied as a primary factor in this analysis. The basic physical model can be extended for further interpretation of biological effects. The content of water in various living tissue is high, about 80% (Foster and Schwan, 1995). Therefore, the water model has been frequently used for describing the properties of tissues. Without a doubt, low-level microwave radiation can rotate dipolar molecules and causes dipolar polarization of water and other dielectric materials. This is the fundamental starting point of the model. Foster and Schwan (1995) provide exhaustive information about the frequency-dependent dielectric properties of water. The calculations by the Debye model show that the relaxation time of free water at 20°C is picoseconds. A corresponding peak in $\varepsilon''$ occurs around 16 GHz. Experimental data confirm that $\varepsilon''$ keeps its value of around 80 up to GHz, decreases to around 40 at 10 GHz, and the rotation-related part of permittivity becomes negligible at frequencies close to 100 GHz. The upper response frequency is set by intermolecular forces that produce a rotational time constant of a few picoseconds. At greater frequencies, the orientational polarization becomes negligible and the dielectric constant has the frequency independent value of 1.8 determined only by the molecular polarization (Hasted, 1973). The values of relative permittivity measured at different frequencies showed a decrease with frequency for the major types of tissues: muscle, liver, lung, kidney, brain white and gray matter, blood, etc. (Foster and Schwan, 1995; Gabriel et al., 1996a,b). The measured relative permittivity of tissues is about 80–50 at frequencies of about 100 MHz–3 GHz and reaches values of 18–23 at the frequency of 35 GHz.
Recently, the results of the US National Toxicology Program Carcinogenesis Studies of Cell Phone Radio Frequency Radiation confirmed an increased cancer risk in rats and mice. In the cases of confirmed low-level microwave radiation effects, a mechanism other than tissue heating should be involved. There is justified demand for the clarification of the nonthermal mechanisms of low-level microwave radiation effects.

1.5 MOBILE COMMUNICATIONS AND PUBLIC HEALTH

I want to make clear that the potential hazard of mobile communication is related more to the nonthermal effects of this physical factor (RF EMF), which was unknown to mankind until half a century ago. The cellular telephone delivers a power density of RF radiation that is 2 billion times greater than occurs naturally in the environment. The absorbed energy potentially could cause dangerous and damaging biological effects within the human brain. Biological effects initiated by non-ionizing radiation could be achieved via conformational changes of important biological molecules (proteins, nucleic acids) and structures (as biological membranes) directly or via signal transduction pathways.

The small cellular telephones effectively deposit large amounts of energy into small areas of the user’s head and brain. The major guidelines and standards established by the engineering community provide an approach and terminology which are not accepted by the physics and biological communities, but nevertheless remain the guiding rules (mainly for the industry). One can only wonder how it is possible to speak about the potential “health effects” of RF EMF instead of a “health hazard.” The misuse of the term “health effect” completely neglects the fact that physical/chemical factors could have either positive (beneficial) or negative (hazardous) effects (Markov, 2012). We are suspicious that this is done on purpose in order to not alarm the general public about the hazards of the use of microwave radiation in close proximity to the human brain.

It has been pointed out elsewhere (Markov, 2006) that when the engineering committees stated “Nonthermal RF biological effects have not been established,” they were basically guiding science and society in the wrong direction. To deny the possibility of nonthermal effects is not reasonable, but more important is that they mixed “effect” and “hazard.” If nonthermal effects do not exist, why do societies such as Bioelectromagnetics society (BEMS) and European bioelectromagnetic association (EBEA) exist? What is discussed at any yearly meeting of BEMS? Why has the journal Bioelectromagnetics existed for 38 years? Why, since 1984, has another journal, Electromagnetic Biology and Medicine, published hundreds and hundreds of papers?

One of the first papers on the absorption of electromagnetic energy was published by Schwan and Piersol (1978), in which absorption was connected to the tissue composition. It is important to note once again that the composition of living tissues is very complex and varies from organ to organ and from person to person. From a biophysics point of view, the energy absorption also depends on the depth of penetration for the specific frequency range (for 825–845 MHz the penetration depth into brain tissue is from 2 to 3.8 cm) (Polk and Postow, 1986; Kane, 1995).

Forty-five years ago, Michaelson (1972) wrote, “It should be understood that a cumulative effect is the accumulation of damages resulting from repeated exposures
each of which is individually capable of producing some small degree of damage.” In other words, the repeated irritation of a particular biological area, such as a small region of the brain, can lead to irreparable damage.

The EMF effects on human tissues and the human brain specifically are strongly related to the tissue dielectric properties. However, these dielectric properties are basically not well known for the human brain, and especially for children’s brains. To better understand the problem of the hazard of RF EMF for the human brain, it will be useful to consider the structure of the human head. It is known that the human head is a complex structure of many different tissue types. Each of the tissues—skin, bone, cerebrospinal fluid, fat, brain, dura, etc., absorbs and reflects RF energy in its own way. In addition, the human head is far from having a uniform shape, volume or structure. Therefore, the RF EMF interacts with the human head in a nonuniform way depending on the specific location of the brain areas/volumes. Sage (2012) presented a remarkable review of the similarity of low dose effects of ionizing and non-ionizing radiation on the initiation of genotoxic effects, which are nonthermal.

Interestingly enough, the Parliamentary Assembly, Council of Europe, in its Resolution 1815 from 2011 recommends to “reconsider the scientific basis for the present electromagnetic fields exposure standards set by the ICNIRP, which have serious limitations and apply ‘as low as reasonably achievable’ (ALARA) principles, covering both the thermal effects and the nonthermal or biological effects of electromagnetic emissions or radiation” (Parliamentary Assembly, 2011).

1.5.1 “Hot Spots”

It is clear that “hot spot” is a term that scientists have introduced to describe exactly what is happening at specific locations within the brain or other tissues. Which regions of the brain will be subjected to “hot spot” absorption depend on a number of factors related to head size, shape, curvature, subcutaneous fat layer thickness, and internal skull structures as well as the parameters of the applied signal (especially frequency, pulsing, and modulation).

Some of the interior “hot spots” in the brain are related to the radius of curvature of the human head. First, one should recognize that human head is far from the ideal spherical shape that is used in the modeling. It is easy to assume that the radius of the curvature is different for a baby, a little child, a teenager or an adult individual. The energy absorption within the brain tissue was found to be about 20 times greater than in the skull and subcutaneous fat. RF EMF energy can be concentrated into very high-intensity spots just as sunlight may be concentrated with a magnifying glass. The same effect occurs within living tissue at RF radiation “hot spot” locations. Please keep in mind that most, if not all of the biological effects, are nonlinear. Importantly, during short exposures from a few seconds to a few minutes, very little heat accumulation could take place. This is important in view of “hot spot” absorptions. If a “hot spot” was formed, a rapid energy absorption would have a maximum destructive effect because, as shown by Lin (1977), very little of the absorbed heat will have an opportunity to dissipate. “Because, microwave absorption occurs in a very short time, there will be little chance for heat conduction to take place.”
At these “hot spots,” however, the heating is rapid and the cooling is slow. The inability of biological tissue to get rid of excess heat quickly and efficiently may be the mechanism leading to destructive exposure. If “hot spots” occur at microscopic regions within the brain, where there are no thermal or sensory receptors, there is no reason to expect that the body will attempt to compensate for the overheating. The human brain simply does not have the capacity to prevent the damage. Human brain tissue is the most sensitive to any change in the physical parameters of the environment. There is evidence that with an increase in temperature of only 0.5°C in specific locations, various adverse effects might occur, the most important of which are (1) increase in membrane permeability; (2) modification of normal cell metabolism through changes in the enzyme activity; and (3) tissue destruction and death.

Consider now the same structural features on the heads of children and smaller adults. The curved area behind and above the ears is more arched and the total width of the head is correspondingly reduced. Since “hot spot” absorption is a function of head curvature, children and some adults are more susceptible to this type of “hot spot” formation. Long before the introduction of cellular telephones, scientists obtained data indicating that children absorb approximately 50% more radiation within their heads than adults (Durney et al., 1979). Lin in 1976 placed the increased absorption effect into a better perspective when he reported that “hot spot” energy absorption can be as much as ten times higher at certain areas within the brain. From experiments performed using models of the human head, he reported energy absorptions in the center of the head that were even higher than absorption levels near the surface. This is a prime example of “hot spot” energy deposition.

The presence of nonuniform energy absorption that indicated the new type of “hot spot” was initially characterized by Schwan in 1972 (Schwan, 1972a,b). He suggested that when the diameter is smaller, the energy absorbing “hot spots” become more pronounced. The research found that for heads significantly smaller than that of a mature man, the “hot spot” effects increase and so does the amount of energy that is absorbed into the interior of the brain. Clearly, this indicates an increased risk of “hot spot” absorption within the brains of women and children, with small children being at maximum risk for “hot spot” absorption within their brains. It had also been reported by Schwan (1972a,b) that maximum “hot spot” energy absorption occurs in the frequency region around the cellular telephone frequencies. There were no cellular telephones on the market at that time.

Johnson and Guy (1972) report that “for human brain exposed to 918 MHz power, the absorption at a depth 2.3 times the depth of penetration (depth of penetration = 3.2 cm) is twice the absorption at the surface. This corresponds to a factor greater than 200 times that expected.” This means that at a depth within the human brain of about 7 cm, “hot spots” have energy absorption 200 times greater than would be the case if no “hot spot” existed.

During the past several decades, the absorption of RF energy in various body tissues has been investigated by homogeneous and/or heterogeneous models. Looking at these models, we were impressed that the most serious review of the models was done in 1978 by Durney et al. (1978). Interestingly enough, nearly 40 years later, this manual is the most comprehensive document on modeling RF absorption.
1.5.2 **Protect Children**

For the first time during the whole period of civilization, massive electromagnetic radiation reaches the most critical system of the body—the brain and nervous system structures of the inner ear of the child and adolescent. Children and adolescents are exposed to conditions analogical with professionals and are at risk of being in the zone of constantly determining the impact of a harmful type of radiation, which makes the potential risk to the health of children very high (Grigoriev, 2012; Grigoriev and Khortzeva, 2018). At the 2001 WHO meeting on harmonization of standards, I made a statement that allowing little children to use the cell phones is a crime against humanity (Markov, 2001). I think that it is still a valid statement.

Despite the large number of reports on the effects of RF EMF on human organisms, the publications on the potential hazard for the organisms of children are a relatively small fraction in the world literature. In most cases, the publications are based on epidemiological data collected by some surveys and quite frequently without having direct contact with children or their parents. Therefore, this approach passes the issues to statistics, not to science. One needs to operate with huge numbers in order to evaluate the presence or absence of an effect. But these numbers basically do not go to the biology, to the process of occurrence of one or another modification of the living tissue. Following this approach they state, “there is no conclusive and consistent evidence that nonionizing radiation emitted by cell phone is associated with cancer risk” (Boice and Tarone, 2011).

In the international meetings organized mainly by the WHO (Seol, 2001; Istanbul, 2004; Sanct Petersburg, 2005; London, 2008; Brussel, 2013), there were special sessions related to the hazards of RF EMF for children. However, the approach of engineering and standard creation authorities to the evaluation of RF hazards for children using cellular phones does not account for the specifics of the developing brain.

We would like to point to the study of Wiart et al. (2008) that utilized MRI data obtained in different French hospitals for the creation of six child head models at different ages (5, 6, 8, 9, 12, 15 years). In publication 66 of the ICNIRP (1998, 2009), an adult human model was scaled for reference to that of a 10-year old child. The most widely accepted database of human tissue (Gabriel et al., 1996a,b) lacks data for children. Not only is there a lack of information for children's brains, but for children's tissues in general.

There are several models scaling adult models down to children heads, which appears to be wrong. This approach does not account for geometrical differences, and what is more important, the anatomical and physiological differences between an adult brain and a developing brain of a child. Nikita and Kiourri (2011) published barograms that express 37% difference in local SAR for adult and child brains. If the data really present SAR for the brain of adults and children—in accordance with the engineering approach, these values should be similar. If not—as the case is—it means that the scaling exercises should be forgotten and forbidden.

The same authors stated that “in the case of canonical models, the child model is perfectly proportional to an adult model.” This is possible only in theoretical (more likely mathematical) modeling when no one take into account the specifics of
geometry, composition, and development of children’s heads and brains. It is even written that Koulouridis and Nikita (2004) obtained a children’s model through uniform deformation of spherical adult head models. I should remind the authors that an adult head is spherical, nor is the brain composition of adults and children homogeneous.

Several publications on cell phone dosimetry in children (ICNIRP, 2009; Christ et al., 2010a,b) reported a higher SAR for children’s brains which is correctly attributed to the geometrical difference in the heads of children and adults. Scientists working in the dosimetry areas proposed different explanations for the fact that different laboratories concluded that SAR in children’s brains is higher, smaller or equal to the SAR in adult brains.

More than 40 years ago, Joines and Spiegel (1974) analyzed human head models composed of six layers: skin, subcutaneous fat, skull, dura, cerebrospinal fluid, and brain tissue. The total thickness of the five layers that surround the brain is assumed to be 1.10 cm. However, we must keep in mind that the layers could vary significantly from one human head to another. What is more important, the proportion of these five layers changes during a child’s aging. As the models become more complex and increasingly representative of an actual human head, the findings continue to indicate that the energy absorption is much higher than previously thought.

The range of sizes includes almost all human heads. It is clear that what was first observed as a danger to those with smaller cranial structures, most notably including children, has been extended by additional studies to include nearly all humans. Of course, the most dramatic “hot spot” peaks are within the smaller heads.

It would be plausible to point out the Russian experience in studying the hazards of the RF EMF for children and the legislation in this direction. In 2001, the Russian National Committee for protection from non-ionizing radiation recommended that children under the age of 18 as well as pregnant women not use mobile phones. These recommendations had further been incorporated into the Hygienic Norms for EMF of mobile communications (SanPiN 2.1.8/2.2.4.1190-03, valid from 2003). In 2004, Grigoriev suggested that a precautionary principle must be applied for evaluation of hazards for children. Beginning in 2006, a number of studies of RF EMF effects on children have been conducted in Russia. These longitudinal studies of effects of microwave radiation were oriented mainly toward the evaluation of the cognitive functions of different aged children by using a complex of psychophysiological tests. It has been detected that an increase in the time of the reaction to light or sound signals, disturbances in the phonematic association, decrease of the work ability, faster occurrence of fatigue, and increase of time for completion of the task has been associated with a simultaneous decrease of accuracy (Grigoriev and Khorseva, 2014; Grigoriev and Khorseva, 2018).

Since the industry and unfortunately, the scientific community, do not have appropriate care for the health of children, the responsibility is on parents. Look what has happened: Children in kindergarten or primary school are considering a mobile phone as a nice toy and play with it for hours and hours. At that age, their body and more importantly their brain is not yet developed. Who may be so brave as to claim that the use of a mobile phone at that age is not dangerous? Who may predict what would happen with these “users” 20–30–50 years later?
As WHO postulated, we should know that children are more sensitive to all factors of the environment than adults: “Children differ from adults. Children are uniquely vulnerable when they grow and develop, they have ‘windows of susceptibility’: periods when their organs and systems may be particularly sensitive to the effect of certain environmental threats” (WHO, Backgrounder, 2003). Therefore, it should not be doubted that the developing brain is exposed to increasing irradiation during the formation of higher nervous activity. Society, in general, and scientists, in particular, should not forget this.

One thing that I think about when I listen to or read the epidemiologists papers on children's exposure to RF radiation is that they do not take into account the fact that the cancer does not occur overnight and that there is a slow accumulation of damages that after a certain time may turn in a dangerous direction.

“These studies have not provided any sign that RF EMF emitted by cellular phones increases the chance for carcinogenesis” (Nikita and Kiourri, 2011). I certainly do not think that this statement is correct. At the risk of being confronted by epidemiologists, I should say that they do not do science, they do statistics. Look at any study performed by epidemiologists—it operates with huge numbers in order to evaluate the presence or absence of an effect. But these numbers basically do not go to biology, to the process of occurrence of one or another modifications of the living tissue. Then the epidemiological team claims “there isn’t consistent evidence for occurrence of the modification.” They also state “there is no conclusive and consistent evidence that nonionizing radiation emitted by cell phone is associated with cancer risk” (Boice and Tarone, 2011). It is remarkable that this paper was published after IARC defined RF as “possible cancerogenic for humans.” In another paper, (Markov, 2012), the fact that the long-delayed publication of the INTERPHONE data resulted in a strange situation is discussed: two groups of participants in the project published papers that basically contradict each other. In addition, some epidemiologists wrote that the rates of tumor incidence in Swedish children decrease (over 50%) in the presence of increasing and substantial usage of cell phones (Aydin et al., 2011). This is another confirmation that the conclusion of epidemiological studies should not be trusted, especially since in most cases, the investigators are funded by the industry. The epidemiological community was separated in publications of the results of the INTERPHONE project. But they became surprised by the IARC classification of the RF microwave as possibly carcinogenic. The quick publication of Swerdlow et al. (2011) attempted to negate the classification and continue guiding the general public and scientific community.

The thermal approach to the absorbance of RF energy assumes that the energy is converted to heat, and the resulting heat, when sufficient, “cooks” the brain cells. Since nobody reported such a “cooking” effect it does not exist—this is the general conclusion of the epidemiology and industry supported papers.

However, a number of studies had pointed out that electromagnetic energy in the 900 MHz region may be more harmful because of its greater penetrating capability compared to 2,450 MHz, therefore, more energy in the 900 MHz frequency range is deposited deep within biological tissue. In 1976, Lin concluded that 918 MHz energy constitutes a greater health hazard to the human brain than does 2,450 MHz energy for a similar incident power density.
It is not difficult to envision that even one cubic centimeter of brain tissue (corresponding to 1 g) includes billions of molecules and interconnecting bonds. Each of these molecules or bonds may be susceptible to extremely high energy absorption under certain conditions even while other molecules, only a short distance away, might receive lower energy levels.

Let me remind the reader that studies of diathermy applications consistently show that electromagnetic energy at frequencies near and below 900 MHz is best suited for deep penetration into brain tissue. The depth of penetration is noticeably greater at this frequency range, which includes the cellular phone frequencies as compared with higher frequencies. What is also important is the proven fact that deep tissue heating is obtained without detecting significant heating in the surface tissues. By their nature, the frequencies that provide the best therapeutic heating would also be frequencies that could be the most hazardous to man in an uncontrolled situation. High absorption in inner tissue such as the brain occurs while fat and bone absorption is many times less (Johnson and Guy, 1972).

Aside from the thermal issues, I should point out that the nonlinear properties of biological tissues could provide conditions for conformational changes in various important biological molecules via nonthermal effects (Markov, 2006). These changes could modify the entire signal transduction cascade.

I could agree that the first step in modeling the thermal effects should be the creation and building of tissue models. However, it sounds strange that this first step is addressed in papers published in 2011 (Nikita and Kiourri, 2011). Various models have been created in the decades before now, and surprisingly, they are neglected by the engineering community. More amazing is that these head models consist of only three layers: skin, fat, and muscle.

In addition, the dielectric properties of brain tissues are still not known with the degree of precision that would allow the accurate prediction of the absorbance of RF energy. If this is correct, how one can estimate the SAR? Despite the claims of IEEE and ICNIRP members, the experimental dosimetry is very insufficient for creating safety conditions for the users of mobile communications.

In 1994, I was planning to build a tissue phantom for evaluating the temperature effects caused by A 27.12 MHz pulsed electromagnetic field, approved by the food and drug administration (FDA) for therapeutic use. Richard Olsen, who was known to me as an expert in dosimetry of EMF, informed me that even placing a cadaver bone inside a liquid/gel model would not be accurate enough in respect to real tissues. Why in 2017 are we discussing the models without taking into account the complexity of the biological tissues, especially the human brain? From the physics and thermodynamics viewpoint, biological tissues represent nonlinear systems (see White et al., 2011). The occurrence of a “hot spot” in response to RF radiation to a great extent corresponds to this nonlinearity.

Let me point to one very important fact: the manufacturers of diathermy devices should indicate the maximum safe distances and directions that must be maintained by therapists. Of course, if there must be defined some safe distance to be maintained from devices emitting 5.0 mW/cm², then certainly we might expect some safe distance to be kept from devices emitting higher levels of RF radiation—portable cellular telephones. This should be especially true when suggesting the spacing between the portable device and a human head, and respectively, to the human brain.
Since the human brain has little, if any, sensory capability, damage or trauma occurring internally will not be felt until the effects, such as heating, are so severe that they work their way outward. If tissue damage occurs within a localized region of the brain, it may be completely unnoticed. The threshold for irreversible skin damage is about 45°C which is also the temperature at which pain is felt. So, by the time a person exposed to RF radiation feels pain at the skin, that skin is irreversibly damaged as is the deeper tissue beneath the skin. Similarly, internal heating of brain tissue would not be sensed as a burning sensation. Likely, there would be no sensation at all. Interest in the ability to “sense” the presence of high levels of RF radiation motivated researchers to determine threshold levels for detecting heat sensations due to radiation exposure (Justesen, 1982).

Considering the lack of sensory detectors in the brain, we can expect that no warning of brain tissue destruction would be provided to a cellular telephone user until the damage was so extensive that the scalp, which absorbs very little energy, sensed heating. There is value in the research as they observed and documented an energy absorption “hot spot” associated with high electric fields at the tip of their antenna (Balzano et al., 1978a, b). One of the problems that needs to be stressed is that the brain did not absorb the energy uniformly.

In conclusion, today the entire biosphere and mankind are subjected to signals from space and terrestrial sources, unknown by numbers and by their physical characteristics. We are at the bottom of the ocean of electromagnetic waves. What is worse—this global “experiment” is conducted without protocol, monitoring, and the possibility to produce any protections. The mobile communication industry is creating newer and newer tools in order to eventually increase the speed of communications. Smartphones and smart meters significantly change the electromagnetic environment not only for occupational conditions, but in every home. Billions of people are not informed about the fact that their homes and they themselves are subjected to the “new and advanced” technological developments. This cohort includes babies and elderly people, schoolboys and professionals.

What is even worse, the new 5G mobile technology is being introduced even before the development of industrial standards. No health hazard estimation is planned, no guidance for protection and standards are developed. It is time to ring the bell.

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ECERI. Newsletter. No. 6, June 2017, access mode http://www.saferemr.com/2017/06/


