Karolinska Institutet
Department of Neuroscience
Experimental Dermatology Unit

Stockholm, July 9, 2011

California Public Utilities Commission
Cc Susan Brinchman, Director, Center for Electrosmog Prevention, P.O. Box 655, La Mesa, CA 91944-0655, USA

To: The California Public Utilities Commission,

I understand that you at present are concerned about the fast deployment of smart meters on homes in California, without adequate sharing of information with the public.

I work as an associate professor at the Karolinska Institute; we are world-famous for our Nobel Prize in Physiology or Medicine, which we many times have awarded to your fellow countrymen and –women. I also uphold a professorship at the Royal Institute of Technology; it being closely tied to the Nobel Prizes in Physics and Chemistry. For many years I have been studying health effects of wireless gadgets, such as Smart Meters.

Wireless communication is now being implemented in our daily life in a very fast way. At the same time, it is becoming more and more obvious that the exposure to electromagnetic fields may result in highly unwanted health effects. This has been demonstrated in a very large number of studies and includes cellular DNA-damage (which may lead to an initiation of cancer as well as mutations that carry down generations), disruptions and alterations of cellular functions like increases in intracellular stimulatory pathways and calcium handling, disruption of tissue structures like the blood-brain barrier (which may allow toxins to enter the brain), impact on vessel and immune functions, and loss of fertility. It should be noted that we are not the only species at jeopardy, practically all animals and plants may be at stake.

Because the effects are reproducibly observed and links to pathology can not be excluded, the precautionary principle should be in force in the implementation of this new technology within the society. Therefore, policy makers immediately should strictly control exposure by defining biologically-based maximal exposure guidelines also taking into account long-term, non-thermal effects, and including especially vulnerable groups, such as the elderly, the ill, the genetically and/or immunologically challenged, children and fetuses, and persons with the functional impairment electrohypersensitivity (which in Sweden is a fully recognized functional impairment, and therefore receives an annual governmental disability subsidy).

Prompted by all this, a group of international experts recently published a very important paper, The Seletun Scientific Statement (2011). Among its points are:

1) Low-intensity (non-thermal) bioeffects and adverse health effects are demonstrated at levels significantly below existing exposure standards.

2) ICNIRP/WHO and IEEE/FCC public safety limits are inadequate and obsolete with respect to prolonged, low-intensity exposures.

3) New, biologically-based public exposure standards are urgently needed to protect public health world-wide.

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4) EMR exposures should be reduced now rather than waiting for proof of harm before acting. It is not in the public interest to wait.

5) There is a need for mandatory pre-market assessments of emissions and risks before deployment of new wireless technologies. There should be convincing evidence that products do not cause health harm before marketing.

6) The use of telephone lines (land-lines) or fiber optic cables for SmartGrid type energy conservation infrastructure is recommended. Utilities should choose options that do not create new, community-wide exposures from wireless components of SmartGrid-type projects. Future health risks from prolonged or repetitive wireless exposures of SmartGrid-type systems may be avoided by using fiber-optic cable. Energy conservation is endorsed but not at the risk of exposing millions of families in their homes to a new, involuntary source of wireless radiofrequency radiation, the effect of which on their health not yet known.

Many smart meters are close to beds, kitchens, playrooms, and similar locations. These wireless systems are never off, and the exposure is not voluntary. The smart meters are being forced on citizens everywhere. Based on this, the inauguration of smart meters with grudging and involuntary exposure of millions to billions of human beings to pulsed microwave radiation should immediately be prohibited until ’the red flag’ can be hauled down once and for all.

The recent determination of the World Health Organization (WHO) to include radiofrequent radiation on the 2B list of carcinogens also applies to devices such as smart meters. Already September 4, 2008, the European Parliament voted 522 to 16 to recommend tighter safety standards for cell phones (Europ. Parl. resolution on the mid-term review of the European Environment and Health Action Plan 2004-2010). In light of the growing body of scientific evidence implicating cell phone use with brain tumors, the Parliament said, "The limits on exposure to electromagnetic fields [EMFs] which have been set for the general public are obsolete." The European Parliament "was greatly concerned at the Bioinitiative international report concerning EMFs, which summarises over 1500 studies on that topic and which points in its conclusions to the health risks posed by emissions from mobile-telephony devices such as mobile telephones, UMTS, WiFi, WiMax and Bluetooth, and also DECT landline telephones, and now it is again – and more firmly and seriously - repeated in the form of WHO’s recent cancer classification.

With my very best regards,
Yourssincerely,

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Electro-sensitivity: The cause in the rise of ADD, ADHD?

Posted on May 27, 2013

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April 4, 2013

Have any of the parents of these children diagnosed with ADD or ADHD or school officials or, these psychiatric quacks considered the possibility that these children who are obviously in an agitated state are responding to radio frequencies that permeate the schools, neighborhoods and homes: anywhere and every where?

As the number of SMART meters, cell towers and hidden antennas, rise, so does the number of children diagnosed with so-called attention deficit disorders. These same children appear to be responding to some invisible force that makes it impossible for them to think clearly and stay focused, or to remain still in their seats at school. At home they appear hyper-active and uncontrollable. Many are unable to achieve adequate sleep which adds to the overall distress the child appears to be suffering from.

You can go to www.antennasearch.com and find out just how many cell towers and antennas have been installed and/or hidden in a four mile radius around your home. This information may give you a clue about what might actually be wrong with your child. It may also explain tinnitus, headaches, blurred vision, anxiety attacks, muscle cramping, and a general feeling of dis-ease…experienced by you!

ADD & ADHD

According to Northwestern University:

"ADHD is now a common diagnosis among children and teens," said Craig Garfield, M.D., first author of the study. "The magnitude and speed of this shift in one decade is likely due to an increased awareness of ADHD, which may have caused more physicians to recognize symptoms and diagnose the disorder."

And it is just as likely, if not more so, that what is being diagnosed as ADD or ADHD is actually a physical response to wi-fi, pulsing microwaves from SMART meters and the massive ongoing installation of cell towers and antennas; all of it engulfing every area of our communities. Maybe what these children are really responding to is the continual exposure to microwave radiation.

It is entirely possible that these children are suffering the same adverse side affects of electro-sensitivity that many adults report, especially those living within 100 miles of the GWEN towers stationed across the country. Around the GWEN towers are

clusters of affected individuals, all reporting bizarre and extraordinary things, including physical symptoms that either no one can explain or, no one will explain. Northwestern also reports:

"The number of American children leaving doctors' offices with an attention deficit hyperactivity disorder (ADHD) diagnosis has risen 66 percent in 10 years, according to a new Northwestern Medicine study. Over this same timeframe, specialists, instead of primary care physicians, have begun treating an increasing number of these young patients, the study found."

"According to the study, in 2010, 10.4 million children and teens under age 18 were diagnosed with ADHD at physician outpatient visits, versus 6.2 million in 2000."

That is 10.4 million children who were forcibly medicated with stimulant psychotropic drugs, the effects of which have not been thoroughly investigated and it is unknown what kind of lifetime damage these medications might cause. Maybe what is really needed is to remove these children from these toxic microwave/radio frequency bathed environments, to a safe place where they are protected from the waves. I think it highly probable that in short order many of the symptoms of these so-called mental disturbances would most likely disappear.

Our kids don't stand a chance

We truly are raising an entire generation of damaged children. Between deadly and useless "vaccines" many of which contain human diploid cells (gathered from the lung tissue of aborted babies), our children now have as many as 1 million strands of someone else's dna in their bodies.

"The injections also contain carcinogens, heavy metals, wild viruses, mutated proteins, and the dna in the vaccine can be transfective and recombinant, meaning it can combine with human DNA and mutate."

Alliance for Natural Health reports:

"And we've seen cross-species transfer of DNA happen before. A significant percentage of human DNA is actually viral DNA that became part of us over 40 million years ago. There is concern that virally transmitted DNA may cause mutations and psychiatric disorders such as schizophrenia and mood disorders. GE organisms may exacerbate this phenomenon."

We also feed them genetically modified foods that can contain the DNA of other species and that DNA can transfer over to our DNA, along with pesticides, herbicides and fluoridated water. Aspartame which big dairy producers want added to milk and dairy products for absolutely no reason, is a deadly poison; yet it is in more than 5,000 products already, even though the FDA knows it is extremely harmful.

As if all this was not enough to cause agitation, lets throw a big load of microwave radiation into the mix. Just to make sure they get their share, lets put one or more SMART meters on their homes and on every home in their neighborhood. Then lets put wi-fi in our schools so they can be exposed to it all day long. Then lets add dozens of cell towers and antennas in close proximity to their homes.

Gosh…….I wonder what is wrong with these kids? Electro-sensitivity, too?

DEPARTMENT OF THE ARMY
UNITED STATES ARMY INTELLIGENCE AND SECURITY COMMAND
FREEDOM OF INFORMATION/PRIVACY OFFICE
FORT GEORGE G. MEADE, MARYLAND 20755-5995

REPLY TO
ATTENTION OF:

DEC 13 2006

Freedom of Information/
Privacy Office

Mr. Donald Friedman
Confidential Legal Correspondence
1125 Third Street
Napa, California 94559-3015

Dear Mr. Friedman:

References:

a. Your Freedom of Information Act (FOIA) request dated May 25, 2006, to the Department of the Army, Freedom of Information/Privacy Act Division (DA FOIA/PA DIV), for all documents pertaining to the microwave auditory effect, microwave hearing effect, Frey effect, artificial telepathy, and/or any device/weapon which uses and/or causes such effect; and any covert or undisclosed use of hypnosis. On September 5, 2006, the DA FOIA/PA DIV referred a copy of your request to this office. Your request was received on September 11, 2006.

b. Our letter of September 13, 2006, informing you of the search for records at another element of our command and were unable to comply with the 20-day statutory time limit in processing your request.

As noted in our letter, the search has been completed with another element of this command and the record has been returned to this office for our review and direct response to you.

We have completed a mandatory declassification review in accordance with Executive Order (EO) 12958, as amended. As a result of this review, it has been determined that the Army information no longer warrants security classification protection and is releasable to you. A copy of the record is enclosed for your use.

Fees for processing your request are waived.

If you have any questions concerning this action, please feel free to contact this office at (301) 677-2308. Refer to case #614F-06.

Sincerely,

Susan J. Butterfield
Director
Freedom of Information/Privacy Office
Investigative Records Repository

Enclosure

Bioeffects of Selected Nonlethal Weapons(fn 1)

This addendum to the Nonlethal Technologies--Worldwide (NGIC-1147-101-98) study addresses in summary, some of the most often asked questions of nonlethal weapons technology, the physiological responses observed in clinical settings of the biophysical coupling and susceptibility of personnel to nonlethal effects weapons. These results identify and validate some aspects of maturing nonlethal technologies that may likely be encountered or used as nonlethal effectors in the future including:

- Laser and other light phenomena.
- Radiofrequency directed energy.
- Aural bioeffects.

The study of electromagnetic fields and their influence on biological systems is increasing rapidly. Much of this work is taking place because of health concerns. For example, increased concern has arisen regarding the effects of operator exposure to the electromagnetic fields associated with short-wave diathermy devices, high power microwave ovens, radar systems, magnetic resonance imaging units, etc. In addition, much concern has arisen about extremely low frequency (60 Hz power frequency) electric and magnetic fields that originate from high-voltage transmission lines, industrial equipment, and residential appliances. Both occupational and residential long-term exposure have been the focus of epidemiological studies. The studies have suggested possible adverse effects on human health (e.g., cancer, reproduction, etc.). Laboratory research is still being pursued to identify possible mechanisms of interaction. However, other than thermal heating for microwave frequencies, there is no yet agreed-upon mechanism of action. As a consequence, our knowledge base is developed entirely with phenomenological observations. Because of this fact, it is not possible to predict how nonthermal biological effects may differ from one exposure modality to another. It is especially difficult, because of the small data base for fast pulses, to predict biological effects that might be associated with high-power pulses of extremely short duration.

There is, however, a growing perception that microwave irradiation and exposure to low frequency fields can be involved in a wide range of biological interactions. Some investigators are even beginning to describe similarities between microwave irradiation and drugs regarding their effects on biological systems. For example, some suggest that power density and specific absorption rate of microwave irradiation may be thought of as analogous to the concentration of the injection solution and the dosage of drug administration, respectively. Clearly, the effects of microwaves on brain tissue, chemistry, and functions are complex and selective. Observations of body weight and behavior revealed that rats, exposed under certain conditions to microwaves, eat and drink less, have smaller body weight as a result of nonspecific stress mediated through the central nervous system and have decreased motor activity. It has been found that exposure of the animals to one modality of radiofrequency electromagnetic energy substantially decreases aggressive behavior during exposure. However, the opposite effects of microwaves, in increasing the mobility and aggression of animals, has also been shown for a different exposure modality. Recent published data implicates microwaves as a factor related to a deficit in spatial memory function. A similar type of effect was observed with exposure to a "resonance tuned" extremely low frequency magnetic field. Thus, the data base is replete with phenomenological observations of biological systems "affected" by exposure to electromagnetic energy. (The fact that a biological system responds to an external influence does not automatically nor easily translate to the suggestion of adverse influence on health.) The objective of the present study was to identify information from this developing understanding of electomagnetic effects on animal systems that could be coupled with human biological susceptibilities. Situations where the intersection of these two domains coexist provide possibilities for use in nonlethal applications.

Incapacitating Effect: Microwave Heating

Body heating to mimic a fever is the nature of the RF incapacitation. The objective is to provide heating in a very controlled way so that the body receives nearly uniform heating and no organs are damaged. Core temperatures approximately 41° C are considered to be adequate. At such temperature a considerably changed demeanor will take place with the individual. Most people, under fever conditions, become much less aggressive; some people may become more irritable. The subjective sensations produced by this buildup of heat are far more unpleasant than those accompanying fever. In hyperthermia all the effector processes are strained to the utmost, whereas in fever they are not. It is also possible that microwave hyperthermia (even with only a 1° C increase in brain temperature) may disrupt working memory, thus resulting in disorientation.

Biological Target/Normal Functions/Disease State

The temperature of warm-blooded (homeothermic) animals like the human remains practically unchanged although the surrounding temperature may vary considerably. The normal human body temperature recorded from the mouth is usually given as 37° C, with the rectal temperature one degree higher. Variation between individuals is typically between 35.8° C and 37.8° C orally. Variations also occur in any one individual throughout the day--a difference of 1.0° C or even 2.0° C occurring between the maximum in the late afternoon or early evening, and the minimum between 3 and 5 o'clock in the morning. Strenuous muscular exercise causes a temporary rise in body temperature that is proportional to the severity of the exercise; the level may go as high as 40.0° C.

Extreme heat stress, such that the body's capacity for heat loss is exceeded, causes a pathological increase in the temperature of the body. The subjective sensations produced by this buildup of heat are far more unpleasant than those accompanying fever. In hyperthermia all the effector processes are strained to the utmost, whereas in fevers they are not. The limiting temperature for survival, however, is the same in both cases--a body temperature of 42° C. For brief periods, people have been known to survive temperatures as high as 43 ° C.

In prolonged hyperthermia, with temperatures over 40° C to 41° C, the brain suffers severe damage that usually leads to death. Periods of hyperthermia are accompanied by cerebral edema that damage neurons, and the victim exhibits disorientation, delirium, and convulsions. This syndrome is popularly referred to as sunstroke, or heatstroke, depending on the circumstances. When the hyperthermia is prolonged, brain damage interferes with the central thermoregulatory mechanisms. In particular, sweat secretion ceases, so that the condition is further exacerbated.

Mechanism to Produce the Desired Effects

This concept builds on about 40 years of experience with the heating effects of microwaves. Numerous studies have been performed on animals to identify characteristics of importance to the understanding of energy deposition in animals. As a result of the physics, the relationship between the size of the animal and the wavelength of the radiofrequency energy is most important. In fact, the human exposure guidelines to radiofrequency radiation are designed around knowledge of the differential absorption as a function of frequency and body size. The challenge is to minimize the time to effect while causing no permanent injury to any organ or the total body and to optimize the equipment function. The orientation of the incident energy with respect to the orientation of the animal is also important.

In a study of the effect of RF radiation on body temperature in the Rhesus monkey, a frequency (225 MHz) is purposely chosen that deposits energy deep within the body of the animal. A dose rate of 10 W/kg caused the body temperature to increase to 42° C in a short time (10-15 min). To avoid irreversible adverse effects, the exposure was terminated when a temperature of 42° C was reached. A lower dose rate of 5 W/kg caused the temperature to increase to 41.5° C in less than 2 hours. The reversible nature of this response was demonstrated by the rapid drop in body temperature when RF exposure was terminated before a critical temperature of 42° C was reached. It is estimated for rats that the absorbed threshold convulsive dose lies between 22 and 35 J/g for exposure durations from less than a second to 15 minutes. For 30-minute exposure, the absorbed threshold dose for decrease in endurance is near 20 J/g, the threshold for work stoppage approximately 9 J/g, and the threshold for work perturbation ranges from 5 to 7 J/g. All of the above measures, except convulsions, are types of nonlethal incapacition.

A rough estimate of the power required to heat a human for this technology is on the order of 10 W/kg given about 15 to 30 minutes of target activation. Actual power levels depend on climatic factors, clothing, and other considerations that affect the heat loss from the individual concerned. A method for expressing dose rate in terms of body surface area (i.e., watts per square meter) rather than body mass (i.e., watts per kilogram) would permit a more reliable prediction of thermal effects across species. However, there are large uncertainties in the ability to extrapolate thermoregulatory effects in laboratory animals to those in human beings.

This technology is an adaptation of technology which has been around for many years. It is well known that microwaves can be used to heat objects. Not only is microwave technology used to cook foods, but it is also used as a directed source of heating in many industrial applications. It was even the subject of the "Pound Proposal" a few years ago in which the idea was to provide residential heating to people, not living space. Because of the apparently safe nature of body heating using microwave techniques, a variety of innovative uses of EM energy for human applications are being explored. The nonlethal application would embody a highly sophisticated microwave assembly that can be used to project microwaves in order to provide a controlled heating of persons. This controlled heating will raise the core temperature of the individuals to a predetermined level to mimic a high fever with the intent of gaining a psychological/capability edge on the enemy, while not inflicting deadly force. The concept of heating is straightforward; the challenge is to identify and produce the correct mix of frequencies and power levels needed to do the remote heating while not injuring specific organs in the individuals illuminated by the beam.

A variety of factors contribute to the attractiveness of this nonlethal technology. First, it is based on a well-known effect, heating. Every human is subject to the effects of heating; therefore, it would have a predictability rating of 100%. The time to onset can probably be engineered to between 15 and 30 minutes; however, timing is the subject of additional research to maximize heating while minimizing adverse effects of localized heating. The onset can be slow enough and/or of such frequency to be unrecognized by the person(s) being irradiated. Safety to innocents could be enhanced by the application and additional development of advanced sensor technologies. Incapacitation time could be extended to almost any desired period consistent with safety. (Given suitable R&D, temperature or other vital signs could be monitored remotely, and temperature could be maintained at a minimum effective point).

Time to Onset

The time to onset is a function of the power level being used. Carefully monitored uniform heating could probably take place in between 15 and 30 minutes. Time to onset could be reduced but with increased risk of adverse effects. Minimum time is dependent on the power level of the equipment and the efficiency of the aiming device.

Duration of Effect

Assuming that the heating is done carefully, reversal of elevated body temperature would begin as soon as the source of heat is removed.

Tunability

This concept is tunable in that any rate of heating, up to the maximum capacity of the source, may be obtained. Thus it is suitable for use in a gradual force or "rheostatic" approach. If the situation allows, and the source is sufficiently powerful, there is the possibility to use this technology in a lethal mode as well. Prolonged body temperature above 43° C is almost certain to result in permanent damage to the brain and death.

Distribution of Human Sensitivities to Desired Effects

No reason has been identified to suggest that anyone would be immune to this technology. Individuals with compromised thermoregulatory mechanisms would be susceptible with a lower incident energy density. This would include people with organic damage to the hypothalamus, the part of the brain that integrates the autonomic mechanisms which control heat loss as well as people with compromised somatic features of heat loss (e.g., respiration, water balance, etc.).

The technologies needed for the thermal technology concept are relatively well developed because of the known biophysical mechanism, the universal susceptibility of humans to the mechanism of heating, and because of a well developed technology base for the production of radiofrequency radiation. Because the human body is inhomogeneous, certain organs are, by virtue of their size and geometry, more easily coupled with one radiofrequency wavelength than another. Therefore, to avoid permanent damage to the suspect or to innocent bystanders, it may be necessary to vary the frequency to avoid localized heating and consequent damage to any organ. Additionally, it will be necessary to avoid the conditions thought to be associated with the induction of cataracts. Thus, while the technology of microwave heating in general is mature, adaptation as a nonlethal technology will require sophisticated biophysical calculations to identify the proper regimen of microwave frequencies and intensities; it will also be necessary to optimize existing hardware to meet the biophysical requirements.

Possible Influence on Subject(s)

If the technology functions approximately as envisioned, the targeted individual could be incapacitated within 15 to 30 minutes. Because this technology is focused on a relatively slow onset, it should only be used in situations where speed is not important. The very uncomfortable nature of a high body temperature may be useful in negotiations or possibly for controlling crowds. It would be equally useful on single persons or crowds. Evidence also indicates a disruption of working memory, thus disorientation may occur because of an inability to consolidate memory of the recent (minutes) past.

Technological Status of Generator/Aiming Device

Equipment needed to explore this concept in the laboratory is available today. Design and construction of the RF/microwave generator will depend on the constraints posed by the calculations, potential generation devices, and energy-directing structures. A variety of options exist for both of these equipment needs. The use of advanced frequency and modulation-agile RF generation and amplification circuitry will be required to assess fully the frequency/power/time envelope of RF heating profiles required. Although much equipment is commercially available, it is likely that custom hardware and software will be necessary because available equipment has not been designed with the need for frequency/intensity variability, which will probably be needed for safety purposes. In addition, the design of antennas and other energy-directing structures will almost certainly involve unique configurations. Since this technology utilizes radiofrequency energy, it can be defeated by the use of shielding provided by conductive barriers like metal or metal screen.

Incapacitating Effect: Microwave Hearing

Microwave hearing is a phenomenon, described by human observers, as, the sensations of buzzing, ticking, hissing, or knocking sounds that originate within or immediately behind the head. There is no sound propagating through the air like normal sound. This technology in its crudest form could be used to distract individuals; if refined, it could also be used to communicate with hostages or hostage takers directly by Morse code or other message systems, possibly even by voice communication.

Biological Target/Normal Functions/Disease State

This technology makes use of a phenomenon first described in the literature over 30 years ago. Different types of sounds were heard depending on the particulars of the pulse characteristics. Various experiments were performed on humans and laboratory animals exploring the origin of this phenomenon. At this time, virtually all investigators who have studied the phenomenon now accept thermoelastic expansion of the brain, the pressure wave of which is received and processed by the cochlear microphonic system, to be the mechanism of acoustic perception of short pulses of RF energy. One study (in 1975) using human volunteers, identified the threshold energy of microwave-auditory responses in humans as a function of pulse width for 2450 MHz radiofrequency energy. It is also found that about 40 J/cm^2 incident energy density per pulse was required.

Mechanism to Produce the Desired Effects

After the phenomenon was discovered, several mechanisms were suggested to explain the hearing of pulsed RF fields. Thermoelastic expansion within the brain in response to RF pulses was first studied and demonstrated in inert materials and was proposed as the mechanism of hearing of pulsed RF fields. A pressure wave is generated in most solid and liquid materials by a pulse of RF energy--a pressure wave that is several orders of magnitude larger in amplitude than that resulting from radiation pressure or from electrostrictive forces. The characteristics of the field-induced cochlear microphonic in guinea pigs and cats, the relationship of pulse duration and threshold, physical measurements in water and in tissue-simulating materials, as well as numerous theoretical calculations--all point to thermoelastic expansion as the mechanism of the hearing phenomenon.

Scientists have determined the threshold energy level for human observers exposed to pulsed 2450-MHz fields (0.5-to 32 micron pulse widths). They found that, regardless of the peak of the power density and the pulse width, the per-pulse threshold for a normal subject is near 20 mJ/kg. The average elevation of brain temperature associated with a just-perceptible pulse was estimated to be about $5x10^{-6o}$ C.

Time to Onset

The physical nature of this thermoelastic expansion dictates that the sounds are heard as the individual pulses are absorbed. Thus, the effect is immediate (within milliseconds). Humans have been exposed to RF energy that resulted in the production of sounds.

Duration of Effect

Microwave hearing lasts only as long as the exposure. There is no residual effect after cessation of RF energy.

Tunability

The phenomenon is tunable in that the characteristic sounds and intensities of those sounds depend on the characteristics of the RF energy as delivered. Because the frequency of the sound heard is dependent on the pulse characteristics of the RF energy, it seems possible that this technology could be developed to the point where words could be transmitted to be heard like the spoken word, except that it could only be heard within a person's head. In one experiment, communication of the words from one to ten using "speech modulated" microwave energy was successfully demonstrated. Microphones next to the person experiencing the voice could not pick up the sound. Additional development of this would open up a wide range of possibilities.

Distribution of Human Sensitivities to Desired Effects

Because the phenomenon acts directly on cochlear processes, the thermoelastic pressure waves produce sounds of varying frequency. Many of the tests run to evaluate the phenomenon produced sounds in the 5 kHz range and higher. Because humans are known to experience a wide range of hearing loss due to cochlear damage, it is possible that some people can hear RF induced sounds that others with high frequency hearing loss cannot. Thus, there is a likely range of sensitivity, primarily based on the type of pulse and the condition of the cochlea. Bilateral destruction of the cochlea has been demonstrated to abolish all RF-induced auditory stimuli.

Recovery/Safety

Humans have been subjected to this phenomenon for many years. The energy deposition required to produce this effect is so small that it is not considered hazardous experimentation when investigating responses at the just-perceptible levels.

Possible Influence on Subject(s)

Application of the microwave hearing technology could facilitate a private message transmission. It may be useful to provide a disruptive condition to a person not aware of the technology. Not only might it be disruptive to the sense of hearing, it could be psychologically devastating if one suddenly heard "voices within one's head."

Technological Status of Generator/Aiming Device

This technology requires no extrapolation to estimate its usefulness. Microwave energy can be applied at a distance, and the appropriate technology can be adapted from existing radar units. Aiming devices likewise are available but for special circumstances which require extreme specificity, there may be a need for additional development. Extreme directional specificity would be required to transmit a message to a single hostage surrounded by his captors. Signals can be transmitted long distances (hundreds of meters) using current technology. Longer distances and more sophisticated signal types will require more bulky equipment, but it seems possible to transmit some type of signals at closer ranges using man-portable equipment.

Range

The effective range could be hundreds of meters.

Incapacitating Effect: Disruption of Neural Control

The nature of the incapacitation is a rhythmic-activity synchronization of brain neurons that disrupts normal cortical control of the corticospinal and corticobulbar pathways; this disrupts normal functioning of the spinal motor neurons which control muscle contraction and body movements. Persons suffering from this condition lose voluntary control of their body. This synchronization may be accompanied by a sudden loss of consciousness and intense muscle spasms.

Biological Target/Normal Functions/Disease State

The normal function of the brain is to control all forms of behavior, voluntary control of body, and the homeostatic parameters of the organism. In normal conditions, all the brain structures, neuron populations, networks, and single units function with specific rhythmic activity depending on the incoming sensory information, information from mnemonic structures, and signals from visceral organs. Each single neuron provides specific processing of information it receives and forms a specific pattern of impulse firing as outgoing information. Synchronization of neuron activity is a natural mechanism of the brain function that uses such controlling processes as motivation, attention and memory (experience) in order to organize behavior. For example, motivational processes are considered as activating ascending signals that synchronize the neuron activity of specific brain structures and neuron networks; this activation/synchronization in turn activates specific forms of behavior such as sexual, aggressive, ingestive activities.

In normal functioning the degree of neuronal synchronization is highly controlled. From experiments that record the neuronal activity in different brain areas simultaneously in animals, it is known that correlation of spike activity between neurons (measured by the correlation level of synchronization) changes depending on the stage of behavior, motivation, attention, or activation of the memory processes. However, under some conditions, such as physical stress, heat shock, or strong emotional stress, the level of synchronization may become higher, involving nonspecific large populations of brain neurons and the synchronization may become uncontrollable.

Depending on at which frequency the synchronization rhythm occurs and how many neurons are involved, it may produce different physical effects; muscle weakness, involuntary muscle contractions, loss of consciousness, or intense (tonic) muscle spasms. The higher level of synchronization takes place in persons affected with epilepsy when they experience periodic seizures since they have a pathologic source (e.g., from injury to the brain) of rhythmic synchronization. Because the neurophysiological mechanisms of epileptiform synchronization are better documented, this incapacitating technology is described in terms of epileptogenesis.

The neurophysiological mechanisms active in epileptogenesis involve changes in membrane conductances and neurotransmitter alterations as they affect neuronal interaction. In the process of epileptogenesis, either some neurons are discharging too easily because of alterations in membrane conductances or there is a failure of inhibitory neurotransmission. The actual discharges have been recognized to result from a neuronal depolarization shift with electrical synchrony in cell populations related in part to changes in membrane conductances. The ionic basis and biochemical substrate of this activation have been areas of considerable study but still leave many questions unanswered. What are the basic cellular properties, present in normal cells and tissue, that could contribute to the generation of abnormal activity? What parts of the systems are low threshold and function as trigger elements?

One of the current hypotheses is involved with microcircuitry, particularly local synaptic interactions in neocortical and limbic system structures. In the hippocampus, the role of the trigger element has been long attributed to the CA3 pyramidal cells--a hypothesis based on the fact that spontaneous synchronous burst discharge can be established in CA3 neurons Some studies describe an intrinsically bursting cell type in the neocortex that plays a role similar to that of CA3 cells in the hippocampus and that of deep cells in the pyriform cortex. The intrinsic nature of these cells appears to be an important contributor to the establishment of synchronized bursting in these regions. Another apparent requirement in such a population is for a certain degree of synaptic interaction among neurons, such that discharge of even one cell enlists the activity of its neighbors. Given the presence of these bursting cells and the occurrence of excitatory interactions among them in normal tissue, it may actually be the morphologic substrate for epileptiform discharges.

Another hyptothesis has focused particularly on the role of N-methyl-D-aspartate (NMDA) receptors. Various factors regulate the efficacy of NMDA receptors: their voltage-dependent blockade by magnesium and modulation by glycine and polyamines. For example, in the low magnesium model, spontaneous synchronous burst discharge in hippocampal pyramidal cell populations is sensitive to NMDA antagonists. That finding suggests that it is the opening of NMDA channels, by relieving the magnesium blockade, that facilitates epileptiform activity.

Significant attention in the literature is also being given to gamma-amino butyric acid (GABA) receptors for the potential role in control of excitability. Changes in GABA inhibitory efficacy can lead to important effects on the excitability of the system. GABAergic inhibitory post-synaptic potentials (IPSPs) have been shown to be quite labile in response to repetitive activation of cortical cell populations, as may occur during epileptiform discharge. Scientists have shown that even a small percentage change in GABA inhibition can have profound effects on neocortical epileptogenesis. These changes in GABAergic inhibition may be the key to an explanation of how repetitive discharge patterns give rise to ictal discharge. Further, there appears to be a significant increase in excitatory postsynaptic potential (EPSP) frequency prior to seizure initiation an observation that is consistent with loss of IPSP efficacy prior to ictal onset.

The above hypotheses describe different mechanisms of epileptogenesis, but it is quite possible that all of these mechanisms take place, and they reflect large variety of types of epileptic seizures. The common principle of the mechanisms proposed is the change of membrane properties (i.e., conductance, permeability etc.) of certain neurons which results in depolarization and burst discharging. Some factors (e.g., trauma) can affect these specific neurons and initiate synchrony for neurons that control internal communication and communication with various muscle systems not associated with vital functions (i.e., heart beating, breathing). High strength pulsed electric fields could also be such a factor.

Mechanism to Reproduce the Desired Effects

Application of electromagnetic pulses is also a conceptual nonlethal technology that uses electromagnetic energy to induce neural synchrony and disruption of voluntary muscle control. The effectiveness of this concept has not been demonstrated. However, from past work in evaluating the potential for electromagnetic pulse generators to affect humans, it is estimated that sufficiently strong internal fields can be generated within the brain to trigger neurons. Estimates are that 50 to 100 kV/m free field of very sharp pulses (~ 1 nS) are required to produce a cell membranic potential of approximately 2 V; this would probably be sufficient to trigger neurons or make them more susceptible to firing.

The electromagnetic pulse concept is one in which a very fast (nanosecond timeframe) high voltage (approximately 100 kV/m or greater) electromagnetic pulse is repeated at the alpha brain wave frequency (about 15 Hz). It is known that a similar frequency of pulsing light can trigger sensitive individuals (those with some degree of light-sensitivity epilepsy) into a seizure and it is thought that by using a method that could actually trigger nerve synapses directly with an electrical field, essentially 100% of individuals would be susceptible to seizure induction. The photic-induced seizure phenomenon was borne out demonstrably on December 16, 1997 on Japanese television when hundreds of viewers of a popular cartoon show were treated, inadvertently, to photic seizure induction (figure 31). The photic-induced seizure is indirect in that the eye must receive and transmit the impulses which initially activate a portion of the brain associated with the optic nerve. From that point the excitability spreads to other portions of the brain. With the electromagnetic concept, excitation is directly on the brain, and all regions are excited concurrently. The onset of synchony and disruption of muscular control is anticipated to be nearly instantaneous. Recovery times are expected to be consistent with, or more rapid than, that which is observed in epileptic seizures.

Time to Onset

No experimental evidence is available for this concept. However, light-induced seizures latency onset in photosensitive epileptics varies from 0.1 to about 10 seconds. Because of the fact that the electrical impulses triggered by light must spread to other parts of the brain, photic-induced seizures are expected to have a generally slower onset than neural synchrony induced by high-strength pulsed electric fields.

Duration of Effect

For epileptic individuals, the typical duration of a petit mal event or a psychomotor event is 1 minute or 2, possibly longer, while the duration of a grand mal seizure is 1 to 5 minutes. In a non-epileptic individual who is induced by electromagnetic means, the durations of the different events are expected to be roughly the same as the epileptic individual's events after the external excitation is removed.

Tunability

There are many degrees of epileptic seizure in diseased persons, and it seems reasonable that electromagnetic stimulation of neural synchrony might be tunable with regard to type and degree of bodily influence, depending on the parameters associated with the chosen stimulus. Because there are no actual data to build on, these statements must be considered tentative. It is known that in the study of photic-induced seizures, parameters can be varied so that the individual under study does not actually undergo a grand mal seizure. This knowledge gives confidence that the proposed technology would be tunable.

Distribution of Human Sensitivities to Desired Effects

It is anticipated that 100% of the population would be susceptible. The mechanism is one that could act on many individual neuronal cells concurrently and hence does not depend on spreading regions of electrical activity as in the disease state.

Possible Influence on Subjects(s)

If the technology functions approximately as envisioned, the targeted individual could be incapacitated very quickly. Because there have been no reported studies using the conditions specified, experimental work is required to characterize onset time. Different types of technologies could be employed to influence wide areas or single individuals. Because this technology is considered to be tunable, the influence on subjects could vary from mild disruption of concentration to muscle spasms and loss of consciousness. The subject(s) would have varying degrees of voluntary control depending on the chosen degree of incapacitation.

Technological Status of Generator/Aiming Device

An electric field strength of roughly 100 Kv/m over a time period of 1 nanosecond is approximately the condition thought to be necessary to produce the desired effect when provided to an overall repetition rate of 15 Hz. Such a field may be developed using a radar-like, high-peak-power, pulsed source or an electromagnetic pulse generator operated at 15 Hz. These technologies exist today sufficient to evaluate the disabling concept. Power requirements are not high because the duty factor is so low. Aiming devices are currently available, but a high degree of directionality at long distances will require development. It may be necessary to provide bursts of these nanosecond pulses in order to stimulate the desired effect. As the duty time increases so does the average power requirement for power source. Because there were no open literature reports from which to make inferences, there is some uncertainty about the power levels required.

Range

The effective range could be hundreds of meters.

Defeat Capabilities/Limitations

Shielding can be provided by conductive barriers like metal or metal screen. There are a number of drugs that are capable of inducing convulsive seizures and others, like phenobarbital, diphenyllhydantoin, trimethadione, 2-4 dinitrophenol, and acetazolamide, which are anticonvulsive. Anticonvulsive drugs are known to be helpful in reducing the effect of seizures in epileptic patients, but their ability to reduce the effect of the proposed technology is unknown (possibly no effect) but expected to be less than for photic-induced seizures.

Incapacitating Effect; Acoustic Energy

The nature of the incapacitation consists of severe pressure sensations, nystagmus (a spasmodic, involuntary motion of the eyes), and nausea caused by high intensities of 9140-155 dB). Nystagmus occurs when convection currents are produced (cupula movement) in the lateral ear canal. This cupula movement causes the eyes to move involuntarily; hence, the external world is interpreted as moving. The subject "sees" his surroundings turning round him and at the same time experiences a sensation of turning. Persons exposed to these levels of sound experience nausea.

Biological Target/Normal Functions/Disease State

The two lateral semicircular canals, one located in each inner ear, alert a person to the fact that his upright head is experiencing angular acceleration. Within the ampulla of the canal are several so called hair cells. The cilia of these cells protrude into the lumen of the ampulla where they are encased in a mass of jelly-like material (the cupula) which is attached to the opposite wall of the canal. As the head accelerates, the cilia are bent by an inertial force of the cupula and the viscous liquid in the canal lumen. The bending of the cilia excites hair cells which in turn excite afferent neurons; these then alert the brain that a change of position of the head has occurred. Similar events occur when the head stops moving. The result of a strong hair cell stimulus to the brain is a rapid eye movement, call nystagmus, a feeling of dizziness and disorientation, and a possibility of nausea and vomiting.

Normal hearing is in the range between the frequencies of 20,000 to 16,000 Hz with the optimal sensitivity for most people between the frequencies of 500 to 6000 Hz.

Mechanism to Produce the Desired Effects

Because the end organs for acoustic and vestibular perception are so closely related, intense acoustic stimulation can result in vestibular effects. The hypothesis is that the sound of normal intensity produces oscillations of the endolymph and perilymph, compensated for by oscillations of the round window. High intensity sound produces eddy currents, which are localized rotational fluid displacements. High intensity sound can also produce nonlinear displacement of the stapes, causing a volume displacement, the result of which can be a fluid void in the labyrinth. To fill the void, fluid may be displaced along the endolymphatic duct and/or block capillary pathways, which, in turn, could stimulate vestibular receptors. Stimulation of the vestibular receptors may lead to nausea and vomiting if the sound pressure level is high enough. Conclude that both eddy currents and volume displacement serve to stimulate vestibular receptors in humans, when exposed to high levels of noise.

One study found nystagmum in guinea pigs exposed to high levels of infrasound via stimulation of the vestibular receptors. However, the same lab was unable to produce nystagmus in human subjects at 5- and 10-second exposures to a pure tone at 135 dB, broadband engine noise, or a 100 Hz tone at 120 dB, pulsed three times/s or 2 minutes. The same research was unable to elicit nystagmus at levels up to 155 dB, and also equally unable to produce nystagmus using infrasound levels of 112-150 dB in guinea pigs, monkeys, and humans. However, research with audible components in the sound spectrum with guinea pigs and monkeys produced nystagmus. Other researchers report other vestibular effects in addition to nystagmus at the following thresholds: 125 dB from 200-500 Hz, 140 dB at 1000 Hz, and 155 dB at 200 Hz. Decrements in vestibular function occur consistently for broadband noise levels of 140 dB (with hearing protection).

Human subjects listened to very high levels of low-frequency noise and infrasound in the protected or unprotected modes. Two-minute duration as high as 140 to 155 dB produced a range of effects from mild discomfort to severe pressure sensations, nausea, gagging, and giddiness. Effects also included blurred vision and visual field distortions in some exposure conditions. The nature and degree of all effects was dependent on both sound level and frequency with the most severe effects occurring in the audible frequency range (as opposed to infrasound), at levels above about 145 dB. The investigators found no temporary threshold shift (TTS) among their subjects, and the use of hearing protectors greatly alleviated the adverse effects.

Since the early days of jet-engine testing and maintenance, anecdotal evidence has appeared linking exposure to intense noise, with such complaints as dizziness, vertigo, nausea, and vomiting. As a result of siren noise at 140 dB, subjects consistently reported a feeling of being pushed sideways, usually away from the exposed ear, and one subject reported difficulty standing on one foot.

These effects were not as dramatic as from the jet-engine (broadband) noise at 140 dB. This research concludes that the threshold of labyrinthine dysfunction is about 135 to 140 dB and that these effects occur during, but not after, exposure.

Time to Onset

No times to onset of nausea or nystagmus were identified in the literature but is presumed to be relatively immediate based on effects to the labyrinth system occurring during, but not after, exposure to sound pressure levels of 135 to 140 dB.

Duration of Effect

The incapacitation lasts only as long as the incapacitating sound is present.

Tunability

Based on the data presented above, it is unclear whether the degree of nausea or nystagmus is tunable, but similar symptoms caused by other stimuli are variable in degree.

Distribution of Human Sensitivities to Desired Effects

It is most probable that all individuals will be susceptible to this stimulus with the exception of those with a disease or defect (i.e., deaf mutes) of some part or parts of the vestibular system. Data showed no consistent decrease in vestibulo-ocular reflects with increased age.

Recovery/Safety

Normal subjects are likely to recover immediately and experience no or unmeasurable changes in hearing unless well known frequency-intensity-time factors are exceeded. This is based on studies which found no temporary threshold shift in hearing of subjects tested at low frequency. Occupational safety personnel generally recognize that 115 dB(A) is to be avoided and that 70 dB(A) is assumed safe. Is believed that the noise energy with predominating frequencies above 500 Hz have a greater potential for hearing loss than noise energy at lower frequencies. Occupational standards for noise state that a person may be exposed continuously for 8 hours to 90 dB(A) or 15 minutes to 115 dB(A).

Possible Influence on Subject(s)

Induction of nystagmus and nausea will have variable effects on individuals. Effects may be sufficiently incapacitation to allow offensive advantage; the perception of sickness may make a subject susceptible to persuasion. It would be difficult to target single individuals at the present level of sound directing technology. This technology may be better suited for groups of people.

Technological Status of Generator/Aiming Device

Sound generating technology is well developed but not highly portable. Aiming devices are poorly developed.

Range

Under normal circumstances the sound pressure level decreases 6 dB(A) when the distance from the source is doubled. For example if the sound is 100 dB(A) at 100 ft, at 200 ft the sound would be 94 dB(A). At very high sound levels, certain conditions may lead to nonlinear effects in propagation and greatly increase range accuracy.

Defeat Capabilities/Limitations

Negative effects of audible sound are greatly decreased if hearing protection is worn. High frequency sound is more easily blocked than low frequency sound due to wavelength effects.

Laser-Induced Biological Effects

Their are three basic damage mechanisms associated with exposure to laser radiation: chemical, thermal, and mechanical or acoustic-mechanical.

The laser-induced, chemical alterations in irradiated tissue are referred to as photochemical damage. The likelihood of laser radiation in the blue-light portion of the electromagnetic spectrum (.380 to .550 microns) inducing photochemical reactions progressively decreases with increasing wavelength. Photochemical effects are not observed upon exposure to radiation with wavelengths exceeding .550 to .650 microns because the kinetic energy associated with these photons is insufficient to initiate a photochemical change.

On the other hand, the thermal effect is a primary mechanism for laser-induced injury. The extent of the injuries induced depends upon the wavelength and energy of the incident radiation, duration of exposure, and the nature of the exposed tissue and its absorption characteristics. Generally, this mechanism predominates in the visible and the near-infrared (.760 to 1.4 microns) portions of the electromagnetic spectrum and for almost all CW and pulsed exposures between 0.1 milliseconds and 1 to 5 seconds.

The third injury mechanism associated with exposure to laser radiation is the mechanical or acoustical-mechanical effect. The radiant energy is absorbed into the tissue and, as a result of rapid thermal expansion following a short (1 nanosecond to 0.1 millisecond) laser radiation pulse, a pressure wave is generated that may result in explosive tissue injury.

Generally, all three mechanisms operate concurrently in an irradiated animal. Thermal effects currently predominate for continuous wave (CW) lasers, while mechanical effects are of increased significance for pulsed-mode lasers. With even higher power, one must also consider nonlinear phenomena such as multiphoton absorption and electromagnetic field effects.

The organs most susceptible to external laser radiation are the skin and eyes. The severity of injury is affected by the nature of the target, the energy density delivered to the target, the frequency and power of the laser, atmospheric attenuation of the beam, and the use of filtering or amplifying optics by the target, etc.

The primary effect on the skin is thermal damage (burns). The severity varies from slight erythema or reddening to severe blistering or charring, depending on such factors as total energy deposition, skin pigmentation, and the tissue's ability to dissipate heat.

The eye is particularly susceptible to intense pulse of laser radiation because of its unique sensitivity to light. The focusing effect is similar to that of a magnifying lens, which focuses the energy on a particular spot. Since the cornea and lens of the eye amplify the intensity of the light incident upon the retina, the retina is extremely sensitive to visible and near-infrared light, and damage to the retina may result in temporary or permanent loss of visual acuity. Laser eye injuries vary according to incident power, spot size, beam angle, temporal mode (CW or pulsed), and pulse repetition frequency. Reported effects include corneal lesions, burns, cataracts, and retinal lesions.

Some high-power lasers can cause antipersonnel effects by the deposition of thermal energy. These lasers must operate at a wavelength that is readily absorbed by the skin or the cornea. These generally include the far- and mid-IR regions (10 to 12 microns and 3 to 5 microns) as well as the ultraviolet region (<0.4 microns). However, ultraviolet wavelengths generally do not propagate well in the atmosphere, so the primary threat wavelengths to be considered are between 3 and 12 microns. Although relatively modest amounts of far-IR laser power are required to produce superficial burns on the skin at short ranges, and efforts to design rheostatically lethal laser weapons are on going.

Nonlethal blinding laser weapons generally use collimated beams with very low beam divergence, and the energy contained in the beam diminishes relatively slowly over great distances. Imaging systems such as eyes and EO vision systems have focusing optics that bring the incident plane wave of light to focus at the sensor plane. This results in a high optical gain (greater than 100,000 for eyes), which makes the associated sensor vulnerable to relatively low fluences of laser energy.

The effects of lasers on eyes are threefold:

- Dazzling or induced glare.
- Flashblinding or loss of night adaptation.
- Permanent or semipermanent blinding.

The severity of laser eye injuries varies according to the incident power, spot size, beam angle, pupil diameter (ambient light conditions), temporal mode (CW or pulsed), and PRF of the laser. Reported effects include corneal burns, cataracts (a permanent cloudiness of the lens), and retinal burns and perforations. Low-energy laser weapons are capable of causing the latter.

Exposure to relatively low laser energies can produce temporary changes in the ability to see without producing permanent injury. Exposure to laser light can produce an effect called glare or dazzle, which is similar to the temporary loss of vision experience when viewing the headlights of an oncoming car. The visual effects last only as long as the light is present in the field of view (FOV). At slightly higher energy exposures, the same laser radiation can saturate or flashblind the photoreceptor cells, resulting in after images that fade with time after exposure. Only visible radiation will induce veiling glare or after images; near-IR radiation will not produce these effects even though the radiant energy reaches the photoreceptor cells. Flashblindness and dazzle, while not permanent injuries, can cause discomfort and temporary loss of vision. Some studies have shown that dazzle and flashblindness can seriously impact mission performance, especially in highly visual tasks such as piloting an aircraft or aiming.

Blinding is the permanent or semipermanent loss of visual acuity. The effect can last from several hours onward and generally is evidenced by a dark spot in the field of vision. This spot is called a scotoma. The impact of the scotoma on visual acuity will vary with the size and position of the injury. Human vision is greatly affected when the laser damage is to the central vision area of the retina called the fovea. Nonfoveal laser damage may be less severe or even go unnoticed because it affects only the peripheral vision. The most serious retinal injuries occur when the incident light is so intense that a perforation in the retina is formed, resulting in a hemorrhage into either the subretinal layer or, in the most severe cases, the vitreous humor of the eye. Less severe exposures result in lesions on the retina.

Footnote:

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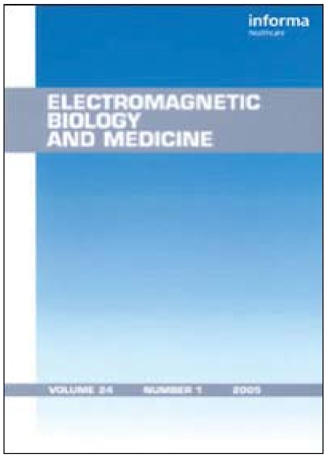

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Radiofrequency and Extremely Low-Frequency Electromagnetic Field Effects on the Blood-Brain Barrier

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Review

Radiofrequency and Extremely Low-Frequency Electromagnetic Field Effects on the Blood-Brain Barrier

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During the last century, mankind has introduced electricity and during the very last decades, the microwaves of the modern communication society have spread a totally new entity—the radiofrequency fields—around the world. How does this affect biology on Earth? The mammalian brain is protected by the blood-brain barrier, which prevents harmful substances from reaching the brain tissue. There is evidence that exposure to electromagnetic fields at non thermal levels disrupts this barrier. In this review, the scientific findings in this field are presented. The result is a complex picture, where some studies show effects on the blood-brain barrier, whereas others do not. Possible mechanisms for the interactions between electromagnetic fields and the living organisms are discussed. Demonstrated effects on the blood-brain barrier, as well as a series of other effects upon biology, have caused societal anxiety. Continued research is needed to come to an understanding of how these possible effects can be neutralized, or at least reduced. Furthermore, it should be kept in mind that proven effects on biology also should have positive potentials, e.g., for medical use.

Keywords Albumin; Blood-brain barrier; Mobile phones; MRI.

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Introduction

During the billions of years that organisms have existed on earth, they have been exposed to, and moulded by, the original physical forces: gravitation, the sun's rhythmically changing radiation, other cosmic irradiation, heat/cold, mechanical forces, and the omnipresent terrestrial static electric and magnetic fields. The existing organisms are created to function in harmony with these forces and have done so for 3.5 billion years.

This was the truth until the last century when mankind introduced the use of electricity, and the very last decades when the microwaves of modern communications spread around the world. The next step is the cordless society based upon microwave penetration in public as well as private surroundings. Today, one third of the world's population are owners of microwave-producing mobile phones, and even more, live in a milieu filled with microwave-emitting equipment such as base stations and other systems for wireless communication.

Is this only for good? Or, might this have effects in biology? Such effects we must anticipate and evaluate as far as possible, and if needed, reduce or avoid.

The questions might seem easily answered; there seems to be little evidence that the human organism is definitively damaged. However, during recent years, several scientific reports have shown significant, but often weak, effects on cells in vitro, experimental animals, and also humans (for reference, see Hyland, 2000).

The first studies on possible risks of microwaves for the living organism were reported in the 1970s, e.g., before the advent of mobile phones, when radar and microwave ovens posed a possible health problem. Frey et al. (1975) found increases in the blood-brain barrier permeability of rats to fluorescein after 30 min of exposure to both pulsed and continous waves at 1.2 GHz. Similar observations were made by Oscar and Hawkins (1977), who demonstrated that at very low energy levels, the fields in a restricted exposure window, caused a significant leakage of ^{14}C-mannitol, inulin, and dextran (with the same molecular weight as albumin) from the capillaries into the surrounding cerebellar brain tissue. These findings, however, were not repeated using ^{14}C-sucrose (Gruenau, 1982). In the following years, much attention was directed to MRI effects upon the blood-brain barrier. It was shown (Shivers et al., 1987; Prato et al., 1990) that combined exposure to RF, pulsed, and static magnetic fields resulted in a pinocytotic transport of albumin across the blood-brain barrier. In more recent years, in vitro models have been increasingly applied to investigate the blood-brain barrier; in one of these, it was shown that EMF at 1.8 GHz increases the permeability to sucrose through the blood-brain barrier (Schirmacher et al., 2000).

Our group has studied the effects of RF electromagnetic fields on the blood-brain barrier and upon tumor growth in the mammalian brain since 1988. Our studies on the effects of CW and pulsed modulated microwaves at 915 MHz have been revealed to cause significantly increased leakage of albumin through the blood-brain barrier of exposed rats as compared to non exposed animals (Persson et al., 1997; Salford et al., 1992, 1993, 1994, 2001, 2003). Recently, we have also examined the effects of long term exposure—55 weeks—upon brain morphology and cognitive functions (Nittby et al., 2008a). The effects of GSM RF upon gene expression have been studied (Nittby et al., 2008b) and 3G exposure studies are under way.

The Blood-Brain Barrier (BBB)

The mammalian brain is protected from exposure to potentially harmful compounds in the blood by the BBB. This is a hydrophobic barrier formed by the vascular endothelial cells of the capillaries in the brain with tight junctions between the endothelial cells, leaving no fenestrae. The tight junctions are composed of tight junction proteins (occludin, claudin, and zonula occludens, where the zonula occludens is the intracellular peripheral membrane protein that anchors claudin and occludin to the actin cytoskeleton; Alberts et al., 2002). An important part is the binding of claudin proteins on opposing membranes, where claudin-5 in particular is crucial in the BBB (Daneman and Barres, 2005). Astrocytes are surrounding the outer surface of the endothelial cells with protrusions, called end feet, and are implicated in the maintenance, functional regulation, and repair of the BBB. The astrocytes form a connection between the endothelium and the neurons and constitute a second barrier to hydrophilic molecules.

Other periendothelial accessory structures of the BBB include pericytes and a bilayer basal membrane which surrounds the endothelial cells and pericytes. The basement membrane (basal lamina) supports the ablumenal surface of the endothelium and may act as a barrier to passage of macromolecules. The pericytes are a type of macrophages, expressing macrophage markers with capacity for phagocytosis but also for antigen presentation. In fact, the pericytes, which cover about 25% of the capillary surface (Frank et al., 1987), seem to be in a position to significantly contribute to central nervous system (CNS) immune mechanisms (Thomas, 1999). The pericytes also have other functional roles: with their capability for contractility they seem to serve as a smooth muscle equivalent, and through regulation of endothelial cells they maintain the stability of blood vessels (Thomas, 1999). Additionally, the astrocytes seem to be highly involved in many diseases, both infectious and autoimmune, and also in other diseases such as Alzheimer's by production of amyloid. Also, by regulating their vascular permeability, the pericytes are supposed to play an important role in inflammatory diseases (Thomas, 1999).

Physiologically, the microvasculature of the central nervous system (CNS) differs from that of peripheral organs. It is characterized not only by its tight junctions, which seal cell-to-cell contacts between adjacent endothelial cells, but also by the low number of pinocytotic vesicles for nutrient transport through the endothelial cytoplasm and its lack of fenestrations, and the five-fold higher number of mitochondria in BBB endothelial cells compared to muscular endothelia in rat (Oldendorf et al., 1977). All this speaks in favor of an energy-dependent transcapillary transport.

These above-described membrane properties of the BBB control the bidirectional exchange of molecules between the general circulation and the central nervous system. By at least four mechanisms, the endothelial cells directly control the flux of solutes into the brain parenchyma. First, the tight junctions and low number of pinocytotic vesicles guarantee that proteins cannot pass freely into the brain parenchyma. Second, solutes which are not highly lipid soluble, or which do not bind to selective transporters with high affinity, are excluded from free exchange. By means of this lipid solubility, carbon dioxide and oxygen, among many others, are able to enter the brain interstitial fluid passively, whereas the passage of, for example sugars and many amino acids, depends on other, active mechanisms. Third, the BBB has a capacity to metabolize certain solutes, such as drugs and nutrients (Ghersi-Egea et al., 1988). Fourth, active transporters maintain the levels of certain solutes at specific values within the brain interstitial fluid, made possible by active transport against the concentration gradients. These enzyme systems are differently distributed between the luminal and the ablumenal membranes of the endothelial cells, thus gaining the BBB polarity properties. For example, Na^+-K^+-ATPase is located on the antilumenal membrane (Betz et al., 1980). It has been proposed that the active transport across the brain capillaries might be the most important mechanism for the regulation of the internal milieu within the brain parenchyma. Also, it has been proposed that this mechanism, requiring energy to function properly, might be the one most sensitive to disease and that interference with this active transport could play an important part in the neurological dysfunction seen in many metabolic disorders (Betz et al., 1980).

In summary, the BBB serves as a regulatory system that stabilizes and optimizes the fluid environment of the brain's intracellular compartment (Oldendorf, 1975; Rapoport, 1976; Salford et al., 2001).

The intact BBB protects the brain from damage, whereas the dysfunctioning BBB allows influx of normally excluded hydrophilic molecules into the brain tissue. This might lead to cerebral oedema, increased intracranial pressure, and in the worst case, irreversible brain damage. The normal selective permeability of the BBB can be altered in several pathological conditions such as epileptic seizures (Mihàly and Bozòky, 1984a,b) or extreme hypertension (Sokrab et al., 1988) and also transient openings of the BBB might lead to permanent tissue damage (Sokrab et al., 1988). Considering the ensuing leakage of substances from the blood circulation into the brain tissue, harmful substances might disrupt the cellular balance in the brain tissue and in the worst case, even carcinogenic substances might pass into the brain tissue. It has also been shown that an increased permeability of the BBB is seen in cases of oxidative stress (Parathath et al., 2006), where BBB dysfunction and neurodegeneration were shown to be mediated through an excitotoxicity mechanism by the serine protease tissue plasminogen activator, with NO and $ONOO^-$ as downstream mediators (Parathath et al., 2006).

Opening of the BBB thus can have detrimental effects and since it has been shown for a few decades that EMFs have the potency to increase the permeability of this barrier, a major debate is going on in society with increasing intensity. In the following, we try to clarify the actual status of the available evidence in the field.

Radiofrequency/Microwave Radiation

Early Studies

In early studies on the effects of low-intensity EMFs on the BBB, various compounds were injected intravenously, followed by EMF exposure and comparisons of the penetration into the brain tissue between sham and exposed animals.

Frey et al. (1975) found increases in the BBB permeability of rats to fluorescein after 30 min of exposure to both pulsed and continuous waves (CWs) at 1.2 GHz with average power densities of 0.2 mW/cm^2. Similar observations were made in a study with 180 animals by Oscar and Hawkins (1977). Exposure of anaesthetized rats for 20 min to 1.3 GHz of pulsed EMFs with average power densities of 0.3 mW/cm^2 resulted in leakage of ^{14}C-mannitol, dextran, and inulin into the cerebellar brain tissue, as well as inulin and dextran leakage from capillaries into hypothalamic and medullar tissue. Also, BBB permeability to mannitol was investigated in un-anaesthetised rats, which were exposed to pulsed radiation or sham exposed for 20 min. The animals were sacrificed at different time intervals after the exposure. BBB permeability was seen in the groups sacrificed 8 min and 4 h after exposure, but to a much lesser extent in those sacrificed after 8 h. Finally, the permeation of mannitol through the BBB was found to be a very definite function of exposure parameters such as power density, pulse width, and the number of pulses per second. However, in later studies, Oscar et al. (1981) emphasised that changes of BBB permeability after microwave exposure partly could be explained by an increase of local cerebral blood flow. In accordance with this, they concluded that their initial findings (Oscar and Hawkins, 1977) might be of less magnitude than originally thought (Table 1).

In an attempt to repeat the findings of Oscar and Hawkins (1977), Preston et al. (1979) found no increase in the uptake of ^{14}C-mannitol in anaesthetised rats after 2450 MHz CW exposure for 30 min at power densities of 0.1 to 30 mW/cm^2. Preston et al. further concluded that the increased BBB permeability, which had been observed by Oscar and Hawkins (1977) in cerebellum and medulla, possibly had been misinterpreted and was not due to the EMF exposure. Rather, changes in blood flow and water influx or egress were supposed to be responsible for the BBB permeability in these caudal parts of the brain. Also, further attempts, made by Merritt et al. (1978), to replicate the findings of Oscar and Hawkins from 1977, resulted in the conclusion that no repetition of the initial findings could be made. Merritt et al. (1978) tried to replicate also the findings of Frey et al. (1975), but reported that no changes were seen. However, Frey commented upon this in an article in 1998, where he pointed out that, in fact, statistical analysis by the editor and reviewer of the data from the study by Merritt et al. provided a confirmation of the findings of Frey et al. (1975) (Frey, 1998).

No alteration of BBB permeation of ^{14}C-sucrose and ^{3}H-inulin was found by Ward et al. (1982) after exposure of anaesthetised rats to CW at 2450 MHz for 30 min at power densities of 0, 10, 20, or 30 mW/cm^2 after correction for thermal effects. Similarly, Ward and Ali (1985) observed no permeation after 1.7 GHz exposure at SAR of 0.1 W/kg, using the same exposure duration and injected tracers as Ward et al. (1982). Absence of EMF induced BBB permeability was also reported by Gruenau et al. (1982), after injection of ^{14}C-sucrose in conscious rats and exposure 30 min pulsed energy (2.8 GHz at 0, 1, 5, 10, or 15 mW/cm^2) or continuous wave (2.8 GHz, 0, 10, or 40 mW/cm^2).

Proof of EMF-induced BBB permeability was put forward by Albert and Kerns (1981), who exposed un-anaesthetised Chinese hamsters to 2,450 MHz CWs for 2 h at SARs of 2.5 W/kg. In one-third of the exposed animals there was an increased permeability of the BBB to horseradish peroxidase (HRP) and the endothelial cells of these irradiated animals had a 2–3-fold higher number of pinocytotic vesicles with HRP than the sham animals. The mechanism of BBB permeability seemed to be reversible, since animals allowed to recover for 1 or 2 h after the EMF exposure had almost no HRP permeation. A total number of 80 animals were included in this study.

Temperature Dependence

In further studies, more attention was directed towards the effects of hyperthermia, resulting from exposure at high SAR-levels, on BBB permeability.

A study correlating changes of BBB permeability with the quantity of absorbed microwave energy (Lin and Lin, 1980), using Evans blue and sodium fluorescein as indicators of BBB permeation, showed that 20 min of 2,450 MHz exposure of anaesthetised Wistar rats caused no alteration of BBB permeability even at SAR-values of 80 W/kg. Notably, the same lack of alteration was observed also at lower SAR-values, down to 0.04 W/kg. In further studies by the same group (Lin and Lin, 1982), no permeation of Evans blue could be observed after exposure to 2,450 MHz

Table 1
BBB permeability after EMF exposure

Reference	EMF Frequency (MHz)	Modulation, pulses per second (pps)	Duration of exposure	SAR (W/kg)	Effect on BBB permeability?	Total number of animals included in the study	Tracer or studied effect	Remark
Findings by the Lund Group								
Salford et al. (1994)	915	CW and pulse-modulated with repetition rates of 8, 16, 50 and 200/s	2 h	0.016–5 W/kg	Yes	246 Fischer 344 rats	Albumin extravasation	
Persson et al. (1997)	915	217, 50 Hz and CW	2–960 min	0.0004–0.95 W/kg average whole-body	Yes	1002 Fischer 344 rats	Albumin extravasation	
Salford et al. (2003)	915	GSM	2 h	0.002–0.2 W/kg	Yes		Albumin extravasation and dark neurons	Effect was seen 50 d after the exposure
Eberhardt et al.	915	GSM	2 h	0.0002–0.2 W/kg	Yes	96 Fischer 344 rats	Albumin extravasation and dark neurons	Albumin extravasation 14 d after exposure, dark

(submitted 2007)								neurons 28 d after exposure
Mobile phone exposure								
Fritze et al. (1997)	900	GSM	4 h	0.3 to 7.5 W/kg	Yes		Albumin	Albumin extravasation only reported for SAR-values of 7.5 W/kg
Töre et al. (2001)	900	GSM	2 h	0.12; 0.5 and 2.0 W/kg	Yes	70 Sprague-Dawley	Albumin leakage, seen with fluorescein-labelled proteins	Albumin extravasation at SAR-values of 0.5 and 2.0 W/kg
Neubauer et al. (1990)	2450	100 pps	30–120 min	Average 2 W/kg	Yes		Rhodamine-ferritin complex	No leakage at 1 W/kg at short-term exposure of 15 min
Tsurita et al. (2000)	1439	TDMA	1 h daily, for 2 or 4 weeks	Average whole-body 0.25 W/kg; peak in the brain of 2 W/kg	No	36 Sprague-Dawley rats	Evans blue, albumin	
Kuribayashi et al. (2005)	1439	TDMA, 50 pps	90 min daily, for 1 to 2 weeks	Average brain power densities of 2 or 6 W/kg; average whole-body 0.29 or 0.87 W/kg	No	40 Fischer 344 rats	Three BBB-related genes; FICT-dextran and albumin extravasation	
Finnie et al. (2001)	898.4	GSM	1 h	Whole-body of 4 W/kg	No	60 mice	Albumin extravasation	
Finnie et al. (2002)	900	GSM	1 h daily, 5 d a		No	207 mice	Albumin extravasation	

(*Continued*)

Table 1 (*Continued*)

			week for 104 weeks	Average whole-body 0.25; 1.0; 2.0 and 4.0 W/kg				
Franke et al. (2005b)	1800	GSM	1 to 5 d	Average 0.3 W/kg	No	—	Sucrose permeation	In vitro model of BBB
Schirmacher et al. (2000)	1800	GSM	4 d	Average 0.3 W/kg	No	—	Sucrose permeation	In vitro model of BBB
Franke et al. (2005a)	1966	UMTS	1 to 3 d	Average 1.8 W/kg	No	—	Sucrose and albumin permeation	In vitro model of BBB
Cosquer et al. (2005)	2450	500 pps	45 min	Average whole-body 2 W/kg	No	Rats	Scopolamine methylbromide extravasation	Indirect investigation of BBB opening by performance in radial arm maze
RF exposure of other kinds								
Frey et al. (1975)	1200	1000 pps and CW	30 min	0.2 mW/cm^2	Yes	Rats	Fluorescein	
Oscar and Hawkins (1977)	1300	50–1000 pps	20 min	0.3 mW/cm^2	Yes	180 Wistar rats	Leakage of mannitol, dextran and inulin	
Preston et al. (1979)	2450	CW	30 min	0.1–30 mW/cm^2	No	Rats	Mannitol	
Merritt et al. (1978)	1200 and 1300	1000 pps and CW	30 min	2–75 mW/cm^2 and 0.1–50 mW/cm^2	No	Sprague Dawley rats	Fluorescein, mannitol, serotonin	Tried to replicate findings by Frey et al. (1975) and Oscar and Hawkins (1977)
	2450	CW	30 min	10–30 mW/cm^2	No	Rats	Sucrose and inulin	

Ward et al. (1982)								
Ward and Ali (1985)	1700	CW and 1000 pps	30 min	0.1 W/kg	No	Rats	Sucrose and inulin	
Albert and Kerns (1981)	2450	CW	2 h	2.5 W/kg	Yes	80 Chinese hamsters	Horseradish peroxidase	Reversible process with no HRP permeation after 1–2 recovery
Gruenau et al. (1982)	2800	CW and 500 pps	30 min	1–40 mW/cm^2	No	31 rats	Sucrose	
Lin and Lin (1980)	2450	500	20 min	0.04–80 W/kg	No	Wistar rats	Evans blue and sodium fluorescein	
Lin and Lin (1982)	2450	25–500	5–20 min	0.04–240 W/kg	No	51 Wistar rats	Evans blue	BBB permeability only at SAR of 240 W/kg, which is a thermal effect
Goldman et al. (1984)	2450	500		240 W/kg	No		Rubidium-86	Hyperthermia induced BBB permeability
Williams et al. (1984a)	2450	CW	30–180 min	4–13 W/kg	No	32 Fischer 344 rats	Fluorescein	BBB permeability only at hyperthermic levels >41°C
Williams et al. (1984b)	2450	CW	30–180 min	4–13 W/kg	No	20 Fischer 344 rats	HRP	
	2450	CW	30–90 min	13 W/kg	No	24 Fischer 344 rats	Sucrose	

(*Continued*)

Table 1 (*Continued*)

Williams et al. (1984c)								
Williams et al. (1984d)	2450	CW	30–180 min	4–13 W/kg	No	66 Fischer 344 rats	Fluorescein, HRP, sucrose	BBB permeability only at brain temperatures >40°C
Quock et al. (1986)	2450	CW	10 min	24 W/kg		Mice	Domperidone	BBB permeability due to temperature increase
Quock et al. (1987)	2450	CW	10 min	24 W/kg		Mice	Domperidone	BBB permeability due to temperature increase
Moriyama et al. (1991)	2450	CW				21 Sprague Dawley rats	HRP	BBB permeability due to temperature increase
Nakagawa et al. (1994)	2450	CW				Japanese monkeys		BBB permeability due to temperature increase
MRI exposure				Magnetic field				
Shivers et al. (1987)			23 min	0.15 T static magnetic field	Yes		HRP	Standard MRI procedure
Preston et al. (1989)			23 min	4.7 T static magnetic field	No	Rats	Sucrose	Standard MRI procedure
Prato et al. (1990)	65		23 min × 2	0.15 T static magnetic field	Yes	43 Sprague		Standard MRI procedure

						Dawley rats	Diethylenetriamine-pentaacetic acid (DTPA)	
Prato et al. (1994)			23 min × 2	1.5 T static magnetic field	Yes	50 rats		Standard MRI procedure
Garber et al. (1989)				0.3–0.5 T static magnetic field	Yes	Rats	Mannitol	Standard MRI procedure
Adzamli et al. (1989)					No			Standard MRI procedure
ELF exposure								
Öztas et al. (2004)	50		8 h daily for 21 d	0.005 T	Yes	34 Wistar rats	Evans-blue	BBB disruption in diabetic rats, but not in normoglycemic rats

RFs for 5–20 min when the SAR-values ranged from 0.04–200 W/kg. Not until a SAR-value of 240 W/kg, with ensuing rise in brain temperature to 43°C, was applied, the BBB permeability increased. These observations of demonstrable increases of BBB permeability associated with intense, microwave-induced hyperthermia were supported by another study by the same group (Goldman et al., 1984).

In a series of EMF exposures at 2,450 MHz CW, Williams et al. (1984a,b,c) concluded that increase of BBB permeability might not be explained by microwave exposure, but rather temperature increases and technically derived artefacts such as increase of the cerebral blood volume and a reduction in renal excretion of the tracer. Significantly elevated levels of sodium fluorescein (Williams et al., 1984a) were found only in the brains of conscious rats made considerably hyperthermic by exposure to ambient heat for 90 min or 2,450 MHz CW microwave energy for 30 or 90 min, but this was at high SAR values, 13 W/kg—far beyond the ICNIRP limit of 2 W/kg (ICNIRP 1998)—and not comparable to the experiments performed by, among others, our group, as described below.

With more research into the area of EMF induced BBB permeability, it became evident that with high-intensity EMF exposure resulting in tissue heating, the BBB permeability is temperature dependent (Williams et al., 1984d). Thus, the importance of differentiating between thermal and non thermal effects on the integrity of the BBB was realized. This is the reason why studies with increases of BBB permeability due to exposure to SAR-values well above recommended exposure levels (Quock et al., 1986; Quock et al., 1987; Moriyama et al., 1991; Nakagawa et al., 1994) need to be considered from another point of view, compared to those focusing on the non thermal effects of EMFs.

Continued Studies—MRI and BBB Permeability

Following the increasing use of magnetic resonance imaging (MRI), the effects of MRI radiation upon BBB permeability were investigated more thoroughly. MRI entails the concurrent exposure of subjects to a high-intensity static field, a radio-frequency field, and time-varying magnetic field. Shivers et al. (1987) observed that exposure to a short (23 min) standard (of those days) clinical MRI procedure at 0.15 Tesla (T) temporarily increased the permeability of the BBB in anaesthetised rats to horseradish peroxidase (HRP). This was revealed by electron microscopy (EM), to be due to an amplified vesicle-mediated transport of HRP across the microvessel endothelium, to the ablumenal basal lamina and extracellular compartment of the brain parenchyma. This vesicle-mediated transport also included transendothelial channels. However, no passage of the tracer through disrupted interendothelial tight junctions was present.

During the next few years, more groups studied the effects of MRI exposure on the BBB permeability by injection of radioactive tracers into rats. One supported (Garber et al., 1989) while others contradicted (Adzamli et al., 1989; Preston et al., 1989) the initial findings made by Shivers et al. (1987). Garber et al. exposed rats to MRI procedures at 1.5, 0.5, and 0.3 T with RFs of 13, 21, and 64 MHz, respectively. Brain mannitol concentration was significantly increased at 0.3 T and 0.5 T but not at 1.5 T. No decrease in plasma mannitol concentration of MRI exposed animals was found and thus the authors concluded that effects of MRI associated energies on mannitol transport do not occur measurably in the body, and might be more specific to brain vasculature.

Preston et al. (1989) found no significant permeation of blood-borne ^{14}C-sucrose into brain parenchyma in anesthetized rats subjected to 23 min of MRI at 4.7 T and RFs at 12.5 kHz. However, the authors pointed out that if the MRI effect was focal and excess tracer counts were found only in restricted sites, there could have been MRI induced extravasation of sucrose that was not detected, due to the preponderance of normal tissue counts. When Preston et al. (1989) compared the lack of BBB leakage in their study to the MRI induced leakage which had been observed by Shivers et al. (1987), they also concluded that certain characteristics of electric and magnetic fields, which were present in the study by Shivers et al. but not in their own work, could have been critical to the observed effects.

In 1990, further studies by the Shivers-Prato group were presented (Prato et al., 1990) and the group could now quantitatively support its initial findings, in a series of 43 Sprague-Dawley rats. The BBB permeability to diethylenetriaminepentaacetic acid (DTPA) increased in rats after two sequential 23 min MRI exposures at 0.15 T. It was suggested that the increased BBB permeability could result from a time-varying magnetic field mediated stimulation of endocytosis. Also, the increased BBB permeability could be explained by exposure-induced increases of intracellular Ca^{2+} in the vascular endothelial cells. Since the Ca^{2+} is an intracellular mediator, increases of BBB permeability could possibly be initiated in this way. A few years later, in a series of 50 rats, the Shivers-Prato group also found that the BBB permeability in rats is altered also by exposure to MRI at 1.5 T for 23 min in 2 subsequent exposure sessions (Prato et al., 1994).

Our group started work on effects of MRI on rat brain in 1988 and found, by the use of Evans Blue, the same increased permeability over BBB for albumin (Salford et al., 1992).

This work was continued by separating the constituents of the MRI field: RF, undulant magnetic field, and static magnetic field. Since RF turned out to be the most efficient component of the MRI, the following studies focused mainly on the RF effects. Striving for investigating the actual real-life situation, endogenous substances, which naturally circulate in the vessels of the animals, were used. In line with this, albumin and also fibrinogen leakage over the BBB were followed after identification with albumin rabbit antibodies and rabbit anti-human fibrinogen.

The work by Blackman et al. (1985, 1989) and discussions with Prof A. R. Liboff, made the ground for studies on the frequency modulation 16 Hz and its harmonies 4, 8, 16, and also 50 Hz, of which the last is the standard voltage of the European power supply. A carrier wave of 915 MHz was used. Also, at an early stage 217 Hz modulation was added as this was the frequency of the then planned GSM system. The result of this work, with exposure to both CWs and pulsed modulated waves, in the most cases lasting for 2 h, showed that there was a significant difference between the amount of albumin extravasation in the exposed animals as compared to the controls. In the exposed group 35–50% of the animals had a disrupted BBB as seen by the amount of albumin leakage, while the corresponding leakage in the sham exposed animals was only 17%. The fact that sham-exposed control animals also show some amount of albumin extravasation, is most likely due to our very sensitive methods for immune histological examination. However, it is hard to explain the fact that although all animals in the 1997 series were inbred Fischer 344 rats, only every second animal at the most showed albumin leakage after EMF exposure. The question, what might protect the remaining 50% of the exposed animals from BBB disruption, is highly intriguing. It should be noted that in our large series, only in one single animal fibrinogen leakage has been observed.

In later studies, a significant ($p < 0.002$) neuronal damage is seen in rat brains 50 d after a 2 h exposure to GSM at SAR values 200, 20, and 2 mW/kg (Salford et al., 2003). This observation is corroborated in another study, where the animals were sacrificed 14 and 28 d, respectively, after an exposure for 2 h to GSM mobile phone electromagnetic fields at SAR values 0 (controls), 120, 12, 1.2, and now also 0.12 mW/kg (Eberhardt et al., submitted). Significant neuronal damage is seen after 28 d and albumin leakage through the BBB after 14 d. These findings may support the hypothesis that albumin leakage into the brain is the cause for the neuronal damage observed after 28 and 50 d.

In the majority of our studies, EMF exposure of the animals has been performed in transverse electromagnetic transmission line chambers (TEM-cells) (Salford et al., 1992, 1993, 1994, 2001, 2003; Van Hese et al., 1992; Martens and van Hese, 1993 and Persson et al., 1997). These TEM-cells are known to generate uniform electromagnetic fields for standard measurements. Each TEM-cell has two compartments, one above and one below the center septum. Thus, two animals can be exposed at a time. The animals are un-anaesthetized during the whole exposure. Since they can move and turn in the TEM-cells as they like, the component of stress-induced immobilization (described by Stagg et al., 2001) is effectively minimized. Through our studies, we have concluded that the amount of albumin leakage is neither affected by the sex of the animals, nor their placement in the upper or lower compartments of the TEM-cells.

Recent Studies on BBB Permeability, Focusing on the Effects of RF EMFs of the Type Emitted by Mobile Phones

With the increasing use of mobile phones, much attention has been directed towards the possible effects on BBB permeability, after exposure to the type of RF EMFs emitted by the different sorts of mobile phones.

Repetitions of our initial findings of albumin leakage have been made (Fritze et al., 1997), with 900 MHz exposure of rats for 4 h at brain power densities ranging from 0.3–7.5 W/kg. Albumin extravasation into the brain tissue was seen, with significant difference between controls and rats exposed reported for 7.5 W/kg, which is a thermal level. However, Fisher exact probability test (two-tailed) performed on the reported results, reveals significant ($p = 0.01$, Fisher exact probability test) difference for the subthermal level group (SAR = 0.3 W/kg plus 1.3 W/kg, compared to sham exposed and cage control animals) where in total 10 out of 20 animals showed one or more extravasations direct after exposure (Salford et al., 2001).

Another group, working in Bordeaux, and led by Prof Pierre Aubineau, has also demonstrated evidence of albumin leakage in rats exposed for 2 h to 900 MHz at non thermal SAR-values, using fluorescein-labeled proteins. The results were presented at two meetings (Töre et al., 2001, 2002). The findings are very similar to those of our group, described above. At the BEMS meeting in 2002 in Quebec City in Canada, the Aubineau-Töre group presented results from exposure GSM-900 EMFs at SAR-values of 0.12, 0.5, and 2.0 W/kg. Seventy Sprague-Dawley rats were included in the study. In addition to normal sham and normal GSM exposed rats, also rats subjected to chronic dura mater neurogenic inflammation, induced by bilateral sympathetic superior cervical ganglionectomy, were included. Arterial blood pressure was measured during the exposure, and Töre et al. (2001, 2002) concluded that the pressure variations (100–130 mm Hg) were well below those limits, which are considered to be compatible with an opening of the BBB of rats. In order to induce opening of the BBB in rats, arterial blood pressure needs to reach values of 170 mmHg, according to Töre et al. (2001, 2002). At SAR of 2 W/kg a marked BBB permeabilization was observed, but also at the lower SAR-value of 0.5 W/kg, permeabilization, although somewhat more discrete, was present around intracranial blood vessels, both those of the meninges and of the brain parenchyma. Comparing the animals, which had been subjected to ganglionectomy, to the other animals, Töre et al. made an interesting observation: as expected, albumin extravasation was more prominent in the sympathectomised sham-exposed rats as compared to normal exposed rats. This was due to the fact that the sympathectomised rats were in a chronic inflammation-prone state with hyper-development of pro-inflammatory structures, such as the parasympathetic and sensory inputs as well as mast cells, and changes in the structure of the blood vessels. Such an inflammation-prone state has a well-known effect on the BBB leakage. However, when comparing sham-exposed sympathectomised rats to GSM-exposed sympathectomised rats, a remarkable increase in albumin leakage was present in the GSM exposed sympathectomised rats compared to the sham rats. In the GSM-exposed sympathectomised rats, both brain areas and the dura mater showed levels of albumin leakage resembling those observed in positive controls after osmotic shock. Indeed, more attention should be paid to this finding, since it implicates that the sensitivity to EMF-induced BBB permeability depends not only on power densities and exposure modulations, but also on the initial state of health of the exposed subject.

In rats, uptake of a systemically administered rhodamine-ferritin complex through the BBB also has been observed, after exposure to pulsed 2.45 GHz EMFs at average power densities of 2 W/kg (Neubauer et al., 1990). The authors observed that the magnitude of BBB permeability depended on power density and duration of exposure. Exposure to a lower power density (1 W/kg) and shorter duration of the exposure (15 min) did not alter the BBB permeability, as compared to higher power densities (SAR 2 W/kg) and longer duration of exposure (30–120 min). The microtubules seemed to play a vital role in the observed BBB permeability, since treatment with colchicine, which inhibits microtubular function, resulted in near-complete blockade of rhodamine-ferritin uptake. The mechanism underlying the observed leakage was presumed to be correlated to pinocytotic-like transport.

In other studies, no effect of EMF exposure has been observed on the BBB integrity. With exposure to 1,439 MHz EMFs, 1 h daily during 2 or 4 weeks (average whole-body energy doses of 0.25 W/kg) no extravazation of serum albumin trough the BBB was observed in a series of 36 animals (Tsurita et al., 2000). However, in this small material only 12 animals in total were EMF exposed (6 rats exposed for 2 weeks and 6 rats exposed for 4 weeks).

Also, lack of interference with the BBB function of rats was found after 1,439 MHz exposure for 90 min/d for 1–2 weeks at average brain power densities of either 2 or 6 W/kg (Kuribayashi et al., 2005). A total number of 40 animals were included in the study.

Also, Finnie et al. (2001) came to the conclusion that no increase in albumin leakage over the BBB resulted from EMF exposure in a series of 60 mice. With whole body exposure of mice to GSM-900 EMFs for 1 h at a SAR of 4 W/kg or sham exposure, no difference in albumin extravazation was observed between the different groups. Also, free-moving cage controls were included in the study, and interestingly, there was no significant difference between these non restrained mice as compared to the sham and EMF-exposed animals. Thus, the authors concluded that there were no stress-related exposure module confinement effects on the BBB permeability.

Finnie et al. (2002) also investigated more long-lasting exposure effects. In a series of totally 207 mice, they exposed the animals for 60 min daily, 5 d a week for 104 weeks at average whole body SARs of 0.25, 1.0, 2.0, and 4.0 W/kg. This lead to a minor disruption of the BBB, as seen by the use of endogenous albumin as a vascular tracer. However, it should be added that the authors performed no statistical analyses to evaluate the albumin leakage through the small vessels in the brain. In an answer under correspondence in the same journal (Finnie and Blumbergs, 2004), the authors presented the original data from the long-term study. From that table one can conclude that non leptomeningeal albumin leaking vessels were seen in few sham-exposed animals, and in one third of the animals in the 0.25 W/kg group and to a lesser extent in the higher SAR groups. However, now significant differences are present.

The integrity of the BBB has also been investigated indirectly. Cosquer et al. (2005) treated rats with the muscarinic antagonist scopolamine methylbromide, which is known to induce memory impairments, followed by EMF exposure at 2.45 GHz for 45 min at average whole-body SARs of 2 W/kg. Opening of the BBB after EMF exposure was hypothesised to affect the performance in a radial arm maze. However, no such alterations were observed and the authors concluded that no BBB opening seemed to have occurred. In agreement with this, no albumin extravasation was noticed.

In a recent study (Ushiyama et al., 2007), the effects on the blood cerebrospinal fluid barrier after RF-EMF exposure were investigated for the first time. With a microperfusion method, cerebrospinal fluid from rat brain was collected in vivo. Fluorescent intensity of FITC-albumin in perfusate was measured. Rats exposed to 1.5 GHz RFs during 30 min at SAR-values of 0.5, 2.0, 9.5 W/kg for adult rats and 0.6, 2.2, 10.4 W/kg for juvenile rats, respectively, were compared to sham-exposed controls. Under these conditions, no increase in FITC-albumin was seen in the cerebrospinal fluid of exposed rats as compared to sham exposed controls. It was concluded that no effect on the function of the blood cerebrospinal fluid barrier was seen.

In Vitro Models

In recent years, there has been an increasing use of in vitro models in the search for BBB effects of EMF exposure.

In vitro models of the BBB have been studied, as by Schirmacher et al. (2000), with co-cultures consisting of rat astrocytes and porcine brain capillary cells. Exposure to GSM-1800 for 4 d with average SAR of 0.3 W/kg increased the permeability of ^{14}C-sucrose significantly compared to unexposed samples in the studied BBB model. These findings were not repeated in experiments performed later by the same group, after modifications of their in vitro BBB model (Franke et al., 2005b). The modified BBB model had a higher general tightness. It was specualted that at a higher original BBB permeability, which was present in the first study (Schirmacher et al., 2000), the cultures were more susceptible to the RF EMFs.

In the search after the mechanism underlying non thermal EMF effects, Leszczynski et al. (2002) observed human endothelial cells, with the interesting finding that GSM-900 exposure for 1 h with SAR-values of 2 W/kg resulted in changes in the phosphorylation status of many proteins. Among the affected pathways, the hsp27/p38MAPK stress response pathway was found, with a transient phosphorylation of hsp27 as a result of the mobile phone exposure. This generated the hypothesis that the mobile-phone induced hsp27-activation might stabilize stress fibers and in this way cause an increase in the BBB permeability. Furthermore, it was also suggested that several brain damaging factors might all contribute to the mobile-phone induced effects observed in the brain and other structures as well.

Following the introduction of the 3G communication system, increasing attention has been drawn also to the effects of these RF fields. Using porcine brain microvascular endothelial cell cultures as an in vitro model of the BBB, no effects on barrier tightness, transport behavior, and integrity of tight junction proteins were observed after exposure to UMTS EMFs at 1.966 GHz for 1–3 d at different field strengths at 3.4–34 V/m, generating a maximum SAR of 1.8 W/kg (Franke et al., 2005a).

Low-Intensity, Extremely Low-Frequency Electromagnetic Field Radiation (ELF)

Only in a few studies have the effects of ELF exposure upon the BBB permeability been investigated. Öztas et al. (2004) found alteration of the BBB permeability in 33% of diabetic rats exposed to 50 Hz EMFs for 8 h at 5 mT. No effect was found in normoglycemic rats, leading to the conclusion that diabetes appears to increase the vulnerability of the BBB to the effects of EMFs.

Discussion

It has been suggested that BBB leakage is the major reason for nerve cell injury, such as that seen in dark neurons in stroke-prone spontaneously hypertensive rats (Fredriksson et al., 1988). Much speaks in favor of this possibility. The parallel findings in the Lund material of neuronal uptake of albumin and dark neurons may support the hypothesis that albumin leakage into the brain is the cause for the neuronal damage observed after 28 and 50 d. It should, however, be pointed out that the connection is not yet proven.

Also, other unwanted and toxic molecules in the blood may leak into the brain tissue in parallel with the albumin, and concentrate in and damage the neurons and glial cells of the brain. In favor of a causal connection between albumin and neuronal damage is a series of experiments performed in rats by another group at Lund University; albumin leaks into the brain and neuronal degeneration is seen in areas with BBB disruption in several circumstances: after intracarotid infusion of hyperosmolar solutions in rats (Salahuddin et al., 1988); in the stroke prone hypertensive rat (Fredriksson et al., 1988); and in acute hypertension by aortic compression in rats (Sokrab et al., 1988). Furthermore, it has been shown in other laboratories that epileptic seizures cause extravasation of plasma into brain parenchyma (Mihàly and Bozòky, 1984a,b), and in the clinical situation the cerebellar Purkinje cells are heavily exposed to plasma constituents and degenerate in epileptic patients (Sokrab et al., 1990). There are indications that an already disrupted BBB is more sensitive to the RF fields than an intact BBB (Töre et al., 2001; Franke et al., 2005b).

It has been stated by other researchers that albumin is the most likely neurotoxin in serum (Eimerl and Schramm, 1991). It has been demonstrated that injection of albumin into the brain parenchyma of rats gives rise to neuronal damage. When 25 micro-liters of rat albumin is infused into rat neostriatum, 10 and 30, but not 3 mg/ml albumin causes neuronal cell death and axonal severe damage (Hassel et al., 1994). It also causes leakage of endogenous albumin in and around the area of neuronal damage. However, it is still unclear whether the albumin leakage demonstrated in our experiments locally reaches such concentrations.

The fact that some research groups observe albumin leakage/transport over the BBB after EMF exposure and others do not has led to a rather intense debate between the researchers but also in society, which is puzzled by the divergent findings. A major concentration of the involved research groups took place at Schloss Reisensburg in Germany in 2003, where the technical approaches in the studies of BBB effects especially were discussed. Two world-renowned researchers in the BBB field, Dr. David Begley of Kings College, London, and Prof. Olaf Poulsen of Copenhagen, Denmark, chaired the FGF/COST 281 Reisensburg, November 2–6 meeting. They made the final statement as a summary of the meeting: "It seems clear that RF fields can have some effects on tissues". The statement was made to a large extent on the basis of the concordant findings of the Bordeaux group, represented by Prof. Aubineau, and the Lund group, represented by Prof. Salford and Prof. Persson.

The biological effects of RF exposure depend on many parameters, such as mean power level and the time variations of the power (Bach Andersen et al., 2002) and whether in vivo or in vitro experiments are performed. In the in vivo situation, different kinds of animals, and also the same kind of animals but of different breeds, might react differently. It might not necessarily be the strongest RF fields that give rise to the most obvious biological effects. This has been observed by us (Persson et al., 1997; Salford et al., 2003). In many cases, the weak and precisely tuned EMFs have the most important biological function; two examples of this are cellular communication and protein folding. It seems quite likely that in different experimental set-ups, and in different living organisms, the signal has to be tuned to different properties in order to cause any effect. This could perhaps in some part explain why, in some cases, there are quite obvious effects of RF exposure, whereas in others, no such effects can be seen.

The search for the mechanisms behind the observed effects continues in several laboratories. As an example, studies in rats on long-term effects of GSM exposure in rats and electron microscopic examination of the brains from short-term GSM exposure can be mentioned (Salford et al., 2007).

Microarray analysis of the expression of all the rats' genes in cortex and hippocampus, after exposure to GSM RFs or sham exposure for 6 h, has shown interesting differences between exposed animals and controls (Nittby et al., 2008b). Genes of interest for membrane transport show highly significant differences. This may be of importance in conjunction with our earlier findings of albumin leakage into neurons around capillaries in exposed animals. It can be noted here that among the significantly altered genes from these evaluations, two variants of the gene RGS4 are upregulated in hippocampal tissue from exposed rats as compared to the sham-exposed rats (unpublished results). RGS is a regulator of G protein signalling, and it has been proposed that RGS4 might regulate BBB permeability in mammals, in a way corresponding to the role of its Loco homolog G protein coupled receptor (GPCR) in developing and maintaining the BBB permeability of Drosophila (Daneman and Barres, 2005).

It has also been suggested in other connections that manifestations of BBB disruption might also be mediated by the formation of free radicals, such as O_2^-, H_2O_2, and hydroxyl radical, which are supposed to oxidize cell membrane lipids by virtue of the high concentration of polyunsaturated fatty acids in these membrane constituents (Davson and Segal, 1996). As an example of this, it was reported by

Chan et al. (1983) that treatment of the brain of rats with a free-radical generating system resulted in lipid-peroxidation, and an increased permeation of Evans blue due to barrier breakdown.

Recently, a detailed molecular mechanism, by means of which mobile phone radiation exerts its effects, has been proposed (Friedman et al., 2007). By using Rat1 and HeLa cells, it was shown that EMF exposure resulted in rapid activation of ERK/MAPKs (mitogen-activated protein kinase). The activation of these ERKs was mediated by reactive oxygen species (ROS), resulting in a signaling cascade ultimately affecting transcription, by the central key role of ERKs in signalling pathways.

In the continued search for the mechanisms behind EMF mediated effects, their interaction with calcium-45 transport in biomembranes has been studied (Persson et al., 1992) and Ca^{2+}-efflux over plasma membranes has been observed in plasma vesicles from spinach exposed to ELF magnetic fields (Bauréus-Koch et al., 2003). With this model, quantum mechanical theoretical models for the interaction between magnetic fields and biological systems are tested. The model proposed by Blanchard and Blackman (1994), in which it is assumed that biologically active ions can be bound to a channel protein and in this way alter the opening state of that channel, could in this way be quantitatively confirmed. Thus, the membrane is one site of interaction between the magnetic fields and the cell, and more specifically, the Ca^{2+}-channels, are one of the targets. More recently, new models for the interaction between magnetic fields and hydrogen nuclei also have been proposed. We are presently investigating these experimentally. Also, application of RF fields will show whether EMF of this kind have the same possibility to affect Ca^{2+}-channels as the low-frequency fields applied in our study from 2003.

EMF-induced Ca^{2+}-efflux over plasma membranes, understandably, can have many different effects on the target cells. Some agents that increase the BBB permeability act through a contractile mechanism that widens the intercellular junctions of the capillary endothelium. An increase of free Ca^{2+} should mediate these changes, thereby resulting in measurable alterations of intracellular Ca^{2+}-levels in brain capillary cells after exposure to BBB-disrupting agents (Davson and Segal, 1996). Another hypothesis is that EMF-induced intracellular Ca^{2+}-alterations might affect Ets genes, which are transcription factors expressed in different tissues (Romano-Spica and Mucci, 2003). In this context, we could add that in our gene expression material from GSM-exposed rats vs., sham-exposed rats, one Ets variant gene is actually significantly up-regulated in hippocampus and one Ets1 gene is significantly up-regulated in cortex of the exposed animals.

In recent years, the GSM phones have been increasingly replaced by the 3G mobile phones, which emit EMFs of different frequencies and pulse modulations. Since these properties have a crucial role in the interaction between EMFs and living organisms, it is important to investigate what exposure to the new 3G fields might result in. Are the effects comparable to those of the GSM phones, or are there new unexpected effects? Or, in the best case, do the 3G fields not affect life at all? We presently study animals exposed to the new 3G fields, in the search of the answers to these questions.

Studies on EMF induced BBB disruption have shown contradictory results from different laboratories. Some groups demonstrate increased BBB permeability with their experimental conditions, whereas others do not. Many factors may contribute to this. One remarkable observation, which we have made in our studies throughout the years, is that exposure with whole-body average power densities below 10 mW/kg gives rise to a more pronounced albumin leakage than higher power densities, all at non thermal levels. In many studies, the SAR exposure has been restricted to the peak power of 2 W/kg and average SAR-values of 0.25 W/kg (Neubauer et al., 1990; Tsurita et al., 2000 among others), since this is the value recommended as the maximum localized SAR-value for head and trunk exposure (ICNIRP 1998). The very low SAR-values, such as 1 mW/kg, which for example exist at a distance of more than one meter away from the mobile phone antenna and at a distance of about 150–200 m from a base station, have been extensively investigated by us and it is our conviction that continued research in this field should include SAR-values at these levels, not only for GSM, but also for systems such as 3G and others to be developed.

Demonstrated effects on the BBB, as well as a series of other effects upon biology (for reference see Hyland, 2000) have given rise to public anxiety. It therefore is up to the public and also the providers of the radiofrequency-emitting technologies to support continued research in order to understand the nature of the effects, thereby neutralizing or at least reducing them. Also, it should be kept in mind that proven effects on biology also means that positive potentials might be revealed. This might be useful in medical applications, for example a controlled opening of the BBB would enable previously excluded pharmaceuticals to reach their targets within the brain tissue.

References

Adzamli, I. K., Jolesz, E. A., Blau, M. (1989). An assessment of BBB integrity under MRI conditions: brain uptake of radiolabelled Gd-DTPA and In-DTPA-IgG. *J. Nucl. Med.* 30:839–840.

Albert, E. N., Kerns, J. M. (1981). Reversible microwave effects on the BBB. *Brain Res.* 230:153–164.

Alberts, B., Johnson, A., et al. (2002). Cell junctions, cell adhesion and the extracellular matrix. In: Gibbs, S., ed. *Molecular Biology of the Cell*. New York, Garland Publishing. ch. 19.

Bach Andersen, J., Mogensen, P., Pedersen, G. F. (2002). Possible exposures from future mobile communication systems. In: *Review of Radio Science 1999–2002*. New York: Wiley-Interscience, pp. 935–941.

Bauréus-Koch, C. L. M., Sommarin, M., et al. (2003). Interaction between weak low frequency magnetic fields and cell membranes. *Bioelectromagnetics* 24:395–402.

Blackman, C. F., Benane, S. G., et al. (1985). A role of the magnetic field in the radiation induced efflux of calcium ions from brain tissue in vitro. *Bioelectromagnetics* 6:327–337.

Blackman, C. F., Kinney, L., et al. (1989). Multiple power-density windows and their possible origin. *Bioelectromagnetics* 10:115–128.

Blanchard, J. P., Blackman, C. F. (1994). Clarification and application of an ion parametric resonance model for magnetic field interactions with biological systems. *Bioelectromagnetics* 15:217–238.

Chan, P. H., Fishman, R. A., et al. (1983). Induction of brain edema following intracerebral injection of arachidonic acid. *Ann. Neurol.* 13:625–632.

Cosquer, B., Vasconcelos, A. P., et al. (2005). BBB and electromagnetic fields: effects of scopolamine methylbromide on working memory after whole-body exposure to 2.45 GHz microwaves in rats. *Behav. Brain Res.* 161:229–237.

Daneman, R., Barres, B. (2005). The BBB—lessons from moody flies. *Cell* 123:9–12.

Davson, H., Segal, M. B. (1996). Breakdown of the barriers and cerebral edema. In: Davson, H., ed. *Physiology if the CSF and the BBBs*. Boca Raton, FL, CRC Press, Inc. pp. 538–539.

Eberhardt, J., Persson, B. R. R., et al. Blood-Brain Barrier permeability and nerve cell damage in the rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones. Submitted manuscript.

Eimerl, S., Schramm, M. (1991). Acute glutamate toxicity and its potentiation by serum albumin are determined by the Ca^{2+} concentration. *Neurosci. Lett.* 130:125–127.

Finnie, J. W., Blumbergs, P. C., et al. (2001). Effect of global system for mobile communication (GSM)-like radiofrequency fields on vascular permeability in mouse brain. *Pathology* 33:338–340.

Finnie, J. W., Blumbergs, P. C., et al. (2002). Effect of long-term mobile communication microwave exposure on vascular permeability in mouse brain. *Pathology* 34:244–347.

Finnie, J. W., Blumbergs, P. C. (2004). Mobile telephones and brain vascular leakage. *Pathology* 36:96–97.

Frank, R. N., Dutta, S., Mancini, M. A. (1987). Pericyte coverage is greater in the retinal than in the cerebral capillaries of the rat. *Invest. Ophthalmol. Vis. Sci.* 28:1086–1091.

Franke, H., Feld, S. R., et al. (2005a). Effects of universal mobile telecommunications system (UMTS) electromagnetic fields on the BBB in vitro. *Radiat. Res.* 164:258–269.

Franke, H., Ringelstein, E. B., Stögbauer, F. (2005b). Electromagnetic fields (GSM1800) do not alter BBB permeability to sucrose in models in vitro with high barrier tightness. *Bioelectromagnetics* 26:529–535.

Fredriksson, K., Kalimo, H., et al. (1988). Nerve cell injury in the brain of stroke-prone spontaneously hypertensive rats. *Acta Neuropathol. (Berl)* 76:227–237.

Frey, A. H. (1998). Headaches from cellular phones: are they real and what are the implications?. *Environ. Health Perspect.* 106:101–103.

Frey, A. H., Feld, S. R., Frey, B. (1975). Neural function and behaviour: defining the relationship. *Ann. NY Acad. Sci.* 247:433–439.

Friedman, J., Kraus, S., et al. (2007). Mechanism of a short-term ERK activation by electromagnetic fields at mobile phone frequency. *Biochem. J.* 405:559–568.

Fritze, K., Sommer, C. (1997). Effect of global system for mobile communication (GSM) microwave exposure on BBB permeability in rat. *Acta Neuropathol.* 94:465–470.

Garber, H. J., Oldendorf, W. H., et al. (1989). MRI gradient fields increase brain mannitol space. *Magn. Reson. Imaging,* 7:605–610.

Ghersi-Egea, J. F., Minn, A., Siest, G. (1988). A new aspect of the protective functions of the BBB: activities of four drug-metabolizing enzymes in isolated rat brain microvessels. *Life Sci.* 42:2515–2523.

Goldman, H., Lin, J. C., et al. (1984). Cerebrovascular permeability to 86Rb in the rat after exposure to pulsed microwaves. *Bioelectromagnetics* 5:323–330.

Gruenau, S. P., Oscar, K. J., et al. (1982). Absence of microwave effect on blood-brain-barrier permeability to [C-14]-labeled sucrose in the conscious rat. *Exp. Neurol.* 75:299–307.

Hassel, B., Iversen, E. G., Fonnum, F. (1994). Neurotoxicity of albumin in vivo. *Neurosci. Lett.* 167:29–32.

Hyland, G. (2000). Physics and biology of mobile telephony. *Lancet* 356:1833–1836.

ICNIRP (1998). Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz). *Health Phys.* 74:494–522.

Kuribayashi, M., Wang, J., et al. (2005). Lack of effects of 1439 MHz electromagnetic near field exposure on the BBB in immature and young rats. *Bioelectromagnetics* 26:578–588.

Leszczynski, D., Joenväärä, S., et al. (2002). Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanisms for cancer- and BBB-related effects. *Differentiation* 70:120–129.

Lin, J. C., Lin, M. F. (1980). Studies on microwave and BBB interaction. *Bioelectromagnetics* 1:313–323.

Lin, J. C., Lin, M. F. (1982). Microwave hyperthermia-induced BBB alterations. *Radiat. Res.* 89:77–87.

Martens, L., van Hese, J. (1993). Electromagnetic field calculations used for exposure experiments on small animals in TEM-cells. *Bioelectrochem. Bioenerget*. 30:73–81.

Merritt, J. H., Chamness, A. F., Allen, S. J. (1978). Studies on BBB permeability. *Radial Environ. Biophys*. 15:367–377.

Mihàly, A., Bozòky, B. (1984a). Immunohistochemical localization of serum proteins in the hippocampus of human subjects with partial and generalized epilepsy and epileptiform convulsions. *Acta Neuropathol*. 127:251–267.

Mihàly, A., Bozòky, B. (1984b). Immunohistochemical localization of extravasated serum albumin in the hippocampus of human subjects with partial and generalized and epileptiform convulsions. *Acta Neuropathol*. 65:471–477.

Moriyama, E., Salcman, M., Broadwell, R. D. (1991). BBB alteration after microwave-induced hyperthermia is purely a thermal effect: I. Temperature and power measurements. *Surg. Neurol*. 35:177–182.

Nakagawa, M., Matsumoto, K., et al. (1994). Acute effects of interstitial hyperthermia on normal monkey brain–magnetic resonance imaging appearance and effects on BBB. *Neurol. Med. Chir. (Tokyo)* 34:668–675.

Neubauer, C., Phelan, A. M., et al. (1990). Microwave irradiation of rats at 2.45 GHz activates pinocytotic-like uptake of tracer by capillary endothelial cells of cerebral cortex. *Bioelectromagnetics* 11:261–268.

Nittby, H., Grafström, G., et al. (2008a). Cognitive impairment in rats after long-term exposure to GSM-900 mobile phone radiation. *Bioelectromagnetics* 29:219–232.

Nittby, H., Widegren, B., et al. (2008b). Exposure to Radiation from Global System for Mobile Communications at 1800 MHz Significantly Changes Gene Expression in Rat Hippocampus and Cortex. Environmentalist published online.

Oldendorf, W. H. (1975). Permeability of the BBB. In: Tower, D., ed. *The Nervous System*. New York, Raven Press. pp. 229–289.

Oldendorf, W. H., Cornford, M. E., Brown, W. J. (1977). The large apparent work capability of the BBB: a study of the mitochondrial content of capillary endothelial cells in brain and other tissues of the rat. *Ann. Neurol*. 1:409–417.

Oscar, K. J., Gruenau, S. P., et al. (1981). Local cerebral blood flow after microwave exposure. *Brain Res*. 204:220–225.

Oscar, K. J., Hawkins, T. D. (1977). Microwave alteration of the BBB system of rats. *Brain Res*. 126:281–293.

Öztas, B., Kalkan, T., Tuncel, H. (2004). Influence of 50 Hz frequency sinusoidal magnetic field on the BBB permeability of diabetic rats. *Bioelectromagnetics* 25:400–402.

Parathath, S. R., Parathath, S., Tsirka, S. E. (2006). Nitric oxide mediates neurodegeneration and breakdown of the BBB in tPA-dependent excitotoxic injury in mice. *J. Cell. Sci*. 119:239–249.

Persson, B. R. R., Salford, L. G., et al. (1992). EMF interaction with calcium-45 transport in biomembranes. *Nanobiology* 3:483–490.

Persson, B. R. R., Salford, L. G., Brun, A. (1997). BBB permeability in rats exposed to electromagnetic fields used in wireless communication. *Wireless Networks* 3:455–461.

Prato, F. S., Frappier, R. H., et al. (1990). Magnetic resonance imaging increases the BBB permeability to 153-gadolinium diethylenetriaminepentaacetic acid in rats. *Brain Res*. 523:301–304.

Prato, F. S., Wills, J. M., et al. (1994). BBB permeability in rats is altered by exposure to magnetic fields associated with magnetic resonance imaging at 1.5 T. *Microsc. Res. Technol*. 27:528–534.

Preston, E., Buffler, K., Haas, N. (1989). Does magnetic resonance imaging compromise integrity of the BBB? *Neurosci. Lett*. 101:46–50.

Preston, E., Vavasour, R. J., Assenheim, H. M. (1979). Permeability of the BBB to mannitol in the rat following 2450 MHz microwave irradiation. *Brain Res*. 174:109–117.

Quock, R. M., Fujimoto, J. M., et al. (1986). Microwave facilitation of methylatropine antagonism of central cholinomimetic drug effects. *Radiat. Res.* 105:328–340.

Quock, R. M., Kouchich, F. J., et al. (1987). Microwave facilitation of domperidone antagonism of apomophine-induced stereotypic climbing in mice. *Bioelectromagnetics* 8:45–55.

Rapoport, S. I. (1976). *BBB in Physiology and Medicine*. New York, Raven Press.

Romano-Spica, V., Mucci, N. (2003). Biological effects of EMF exposure on Ets genes. *Radiat. Biol. Radioecol.* 43:528–530.

Salahuddin, T. S., Kalimo, H., et al. (1988). Observations on exsudation of fibronectin, fibrinogen and albumin in the brain after carotid infusion of hyperosmolar solutions. An immunohistochemical study in the rat indicating longlasting changes in the brain microenvironment and multifocal nerve cell injuries. *Acta Neuropathol. (Berl)* 76:1–10.

Salford, L. G., Brun, A., et al. (1992). Electromagnetic field-induced permeability of the BBB shown by immunohistochemical methods. In: Nordén, B., Ramel, C., eds. *Interaction Mechanism of Low-Level Electromagnetic Fields in Living Systems*. Oxford, Oxford University Press. pp. 251–258.

Salford, L. G., Brun, A., et al. (1993). Permeability of the blood-brain-barrier induced by 915 MHz electromagnetic-radiation, continuous wave and modulated at 8, 16, 50 and 200 Hz. *Bioelectrochem. Bioenerg.* 30:293–301.

Salford, L. G., Brun, A., et al. (1994). Permeability of the blood-brain-barrier induced by 915 MHz electromagnetic-radiation, continuous wave and modulated at 8, 16, 50 and 200 Hz. *Microsc Res. Tech.* 27:535–542.

Salford, L. G., Brun, A., Persson, B. R. R. (1997). Brain tumour development in rats exposed to electromagnetic fields used in wireless cellular communication. *Wireless Networks* 3:463–469.

Salford, L. G., Brun, A. E., et al. (2003). Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. *Environ. Health Perspect.* 111:881–883.

Salford, L. G., Nittby, H., et al. (2007). Non-thermal effects of EMF upon the mammalian brain: the Lund experience. *Environmentalist* 27:493–500.

Salford, L. G., Persson, B., et al. (2001). Téléphonie Mobile et Barrière Sang-Cerveau. In: Pietteur, M., ed. *Téléphonie Mobile—Effects Potentiels sur la Santé des ondes Electromagnétiques de haute Fréquence*. Emburg (Belgium), pp. 141–152.

Schirmacher, A., Winters, S., et al. (2000). Electromagnetic fields (1.8 GHz) increase the permeability to sucrose of the BBB in vitro. *Bioelectromagnetics* 21:338–345.

Shivers, R. R., Kavaliers, M., et al. (1987). Magnetic resonance imaging temporarily alters BBB permeability in the rat. *Neurosci. Lett.* 76:25–31.

Sokrab, T. E. O., Johansson, B. B. (1988). A transient hypertensive opening of the BBB can lead to brain damage. *Acta Neuropathol.* 75:557–565.

Stagg, R. B., Havel, L. H., III, et al. (2001). Effect of immobilization and concurrent exposure to a pulse-modulated microwave field on core body temperature, plasma ACTH and corticosteroid, and brain ornithine decarboxylase, Fos and Jun mRNA. *Radiat. Res.* 155:584–592.

Thomas, W. E. (1999). Brain macrophages: on the role of pericytes and perivascular cells. *Brain Res. Brain Res. Rev.* 31:42–57.

Tsurita, G., Nagawa, H., et al. (2000). Biological and morphological effects on the brain after exposure of rats to a 1439 MHz TDMA field. *Bioelectromagnetics* 21:364–371.

Töre, F., Dulou, P. E., et al. (2001). Two-hour exposure to 2-W/kg, 900-MHZ GSM microwaves induces plasma protein extravasation in rat brain and dura matter. In: *Proc. 5th Int. Congr. EBEA*. Finland, Helsinki. pp. 43–45.

Töre, F., Dulou, P. E., et al. (2002). Effect of 2 hour GSM-900 microwave exposures at 2.0, 0.5 and 0.12 W/kg on plasma protein extravasation in rat brain and dura mater. *Proc. 24th Annu. Meeting of the BEMS*, pp. 61–62.

Ushiyama, A., Masuda, H., et al. (2007). Biological effect on blood cerebrospinal fluid barrier due to radio frequency electromagnetic fileds exposure of the rat brain in vivo. *Environmentalist* 27:489–492.

Van Hese, J., Martens, L., et al. (1992). Simulation of the effect of inhomogenities in TEM transmission cells using the FDTD-method. *IEEE Trans. Electromagn. Comp.* 34:292–298.

Ward, T. R., Ali, J. S. (1985). BBB permeation in the rat during exposure to low-power 1.7-GHz microwave radiation. *Bioelectromagnetics* 6:131–143.

Ward, T. R., Elder, J. A., et al. (1982). Measurement of BBB permeation in rats during exposure to 2450-MHz microwaves. *Bioelectromagnetics* 3:371–383.

Williams, W. M., del Cerro, M., del Michaelson, S. M. (1984b). Effects of 2450 MHz microwave energy on the BBB to hydrophilic molecules. B. Effects on the permeability to HRP. *Brain Res. Rev.* 7:171–181.

Williams, W. M., Hoss, W., et al. (1984a). Effects of 2450 MHz microwave energy on the BBB to hydrophilic molecules. A. Effect on the permeability to sodium fluorescein. *Brain Res. Rev.* 7:165–170.

Williams, W. M., Lu, S. T., et al. (1984d). Effect of 2450 MHz microwave energy on the BBB to hydrophilic molecules. D. Brain temperature and BBB permeability to hydrophilic tracers. *Brain Res.* 319:191–212.

Williams, W. M., Platner, J., del Michaelson, S. M. (1984c). Effects of 2450 MHz microwave energy on the BBB to hydrophilic molecules. C. Effects on the permeability to [14C]sucrose. *Brain Res. Rev.* 7:183–190.

The Mammalian Brain in the Electromagnetic Fields Designed by Man-with Special Reference to Blood-Brain Barrier Function, Neuronal Damage and Possible Physical Mechanisms

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Life on earth was formed during billions of years, exposed to, and shaped by the original physical forces such as gravitation, cosmic irradiation, atmospheric electric fields and the terrestrial magnetism. The Schumann resonances at 7.4 Hz are an example of oscillations possibly important for life.[1)]

The existing organisms are created to function in harmony with these forces. However, in the late 19th century mankind introduced the use of electricity, in the early 20th century long-wave radio and in the 1940-ies short-wave radio. High frequency RF was introduced in the 50-ies as FM and television and during the very last decades, microwaves of the modern communication society spread around the world. Today, however, one third of the world's population is owner of the microwave-producing mobile phones and an even larger number is exposed to the cordless RF emitting systems. To what extent are all living organisms affected by these, almost everywhere present radio frequency fields? And what will be the effects of many years of continuing exposure?

Since 1988 our group has studied the effects upon the mammalian blood-brain barrier (BBB) in rats by non-thermal radio frequency electromagnetic fields (RF-EMF). These have been shown to cause significantly increased leakage of the rats' own blood albumin through the BBB of exposed rats, at energy levels of 1W/kg and below, as compared to non-exposed animals in a total series of about two thousand animals.[2)−6)] One remarkable observation is the fact that the lowest energy levels, with whole-body average power densities below 10mW/kg, give rise to the most pronounced albumin leakage. If mobile communication, even at extremely low energy levels, causes the users' own albumin to leak out through the BBB, also other unwanted and toxic molecules in the blood, may leak into the brain tissue and concentrate in and damage the neurons and glial cells of the brain.

In later studies we have shown that a 2-h exposure to GSM 915 MHz, at non-thermal SAR-values of 0.2, 2 and 200 mW/kg, gives rise to significant neuronal damage, seen not only 50 days after the exposure[7)] but also after 28 days but not after 14 days. Albumin extravasations and uptake into neurons was enhanced after 14 days, but not after 28.[8)]

In our continued research, also the non-thermal effects on tissue structure and memory function of long-term exposure for 13 months are studied.[9)] We have also performed micro-array analysis of brains from rats exposed to short term GSM both at 1,800 MHz and at 900MHz and have found significant effects upon gene expression of membrane associated genes as compared to control animals.[10),11)]

Most of our findings support that living organisms are affected by the non-thermal radio frequency fields. Some other studies agree while others find no effects.

The mechanisms by which the EMFs may alter BBB permeability are not well understood. At low field strengths, the effects on body temperature are negligible and thus heating effects are not involved. A change in the physicochemical characteristics of membranes has been suggested as a cause.[12)]

We have performed experiments to verify a quantum mechanical model for interaction with protein-bound ions. Our results show that controlled frequency and amplitude of ELF EM fields upon spinach plasma vesicles can steer transport over the membrane.[13)] This may be a first proof of a resonance phenomenon where appropriate levels of frequency and amplitude in the right combination have the potency to communicate with the biology of membranes and transport systems. Our study has prompted us to elaborate on magnetic resonance models; the Ion Cyclotron Resonance (ICR) model and the Ion Parametric Resonance (IPR) Model in an attempt to explain the occurrence of resonance frequencies. This is extensively described here under the heading: Mechanisms behind the effects of electromagnetical fields upon biology.

We also bring forward the concept of solitons being active in membranes and DNA/RNA-transcription as a possible mean to understand and prove the biological effects of EMF.

The Nishinomiya-Yukawa International and Interdisciplinary Symposium 2007 raised the question: What is Life? An obvious and simple answer could be: It is DNA!

The DNA strand can be looked upon as an antenna resonating in the microwave band 6GHz with its harmonics and subharmonics.[14)−18)] If this holds true, the dramatic situation might exist, that all living organisms have a receptor for the newly constructed and world-wide man-made microwaves, leading to a direct effect upon the function of DNA - in concordance with our experimental findings!

Our generation invented the microwave emitters. We now have an imperative obligation to further investigate the links between EMF and biology in order to prevent possible detrimental effects of the microwaves.

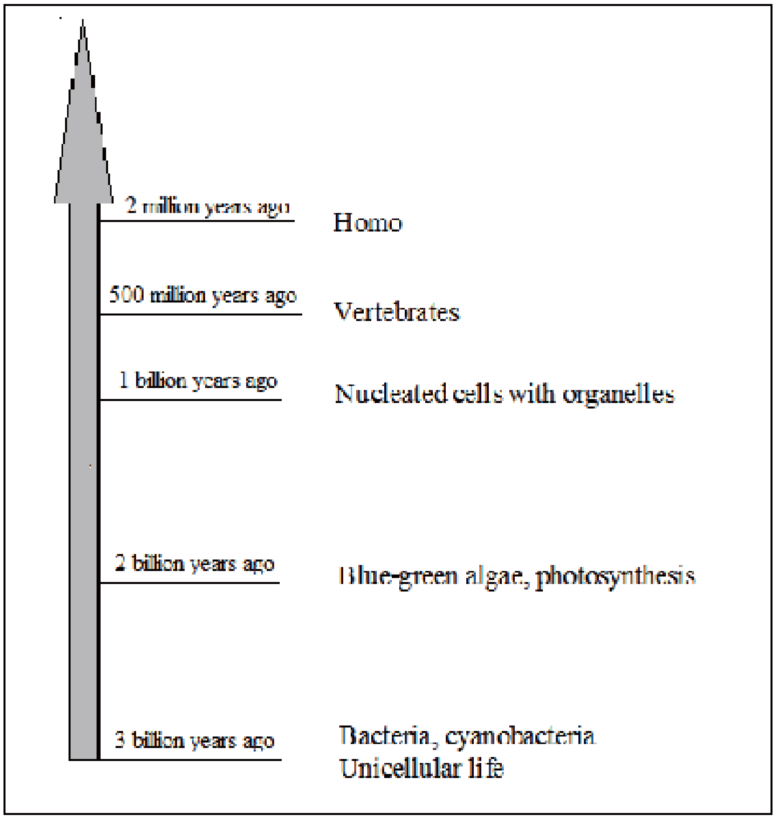


Fig. 1. Time-line for the origin of life (for a more detailed time tree, see Williams 2007).

§1. Introduction

Our Universe was born in the "Big Bang" approximately 15 billion years ago, our sun and most of the stars were formed 10 billion years later.

Four and a half billion years ago our Earth was formed and already 1.5 billion years after this, the earliest unicellular life/bacteria/cyanobacteria started life on Earth.

Two and a half billion years ago the first photosynthesis by blue-green algae took place and 1 billion years ago the first nucleated cells with organelles emerged. This was followed 500 million years ago by the creation of the first vertebrates and they finally lead to the development of mammals and then, 2 million years ago, the emergence of our own species, Homo.

Since its origin, life on Earth has been exposed to, and shaped by, the original physical forces such as gravitation, cosmic irradiation, atmospheric electric fields and the terrestrial magnetism.

Life has also developed in a multitude of cyclic events occurring with different intervals: Earth's own rotation (1 day), Earth's revolution around the sun (1 year),

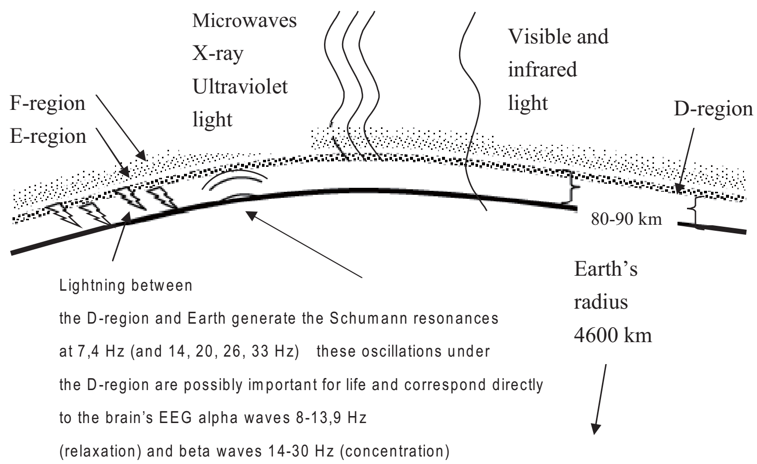


Fig. 2. Ionosphere and Schumann resonances.

the sun's rotation around its own axis (27 days), the synodic period of the moon (29.5 days) and further, the magnetic storms generated by the solar flare generating solar winds with plasma flows which appear 10 times in a month and vary with an eleven year periodicity. These magnetic storms produce alterations of the Earth's geomagnetic field (GMF) lasting from hours to days all around the Earth. The GMF forms an extremely important shield around the Earth, the magnetosphere with its magnetosheath, preventing the solar wind to reach Earth's surface at a harmful level. The protective effect of the magnetosheath can be seen as the solar wind approaches the magnetosphere, where it drops abruptly. A shock wave, known as a bow shock, develops, reminding of the waves in front of a ship travelling through the water, and thus the solar wind deflects around the magnetosphere.

Earth is surrounded by its thin atmosphere reaching only about 180 km above its surface. In parallel with this exists the 3-layered ionosphere (Fig. 2), with its innermost D-region surrounding Earth 80-90 km above its surface. Between 100 and 150 km is the E-region and between 150 and 180 km the F-region. The existence of the ionosphere is an absolute prerequisite for the development and persistence of life.

The enhanced X-rays from solar flares, extreme ultraviolet and all other forms of ultraviolet light are prevented from reaching Earth by the ionosphere whilst visible light and infrared rays pass it.

Ionized particles (mainly protons and electrons) and the enhanced X-rays from solar flares are prevented from reaching Earth by the ionosphere. Short wave ultraviolet radiation is absorbed by the ozone-layer in the stratosphere, whilst longer wave UV-radiation, visible light and infrared rays pass it.

The level of naturally occurring microwaves at the Earth's surface is extremely low. High frequency microwaves are stopped by the ionosphere, especially its D-region. This function is of importance for the conclusions drawn in this presentation.

Natural extremely low frequency electromagnetic fields are formed by electrical discharges in the atmosphere due to the resonance cavity formed by the surface of the Earth and the charged ionosphere resonances occur. These resonance frequencies are named after W. O. Schumann who already 1952 predicted their existence, and were recorded in 1960 by Balser and Wagner.[30)]

The Schumann resonances at 7.8, 14, 20, 26, 33, 39, and 45 Hz[21)−23)] are examples of natural oscillating electromagnetic fields of importance. It is possible that these resonances with their frequency predominantly at 7.8 Hz but also at 14-45 Hz, have played — and play — a role in the tuning of the spontaneous frequencies of the mammalian brain, where the frequency during relaxation is around 8 to 14 Hz, and during concentration 14-30 Hz.

Natural extremely low frequency ELF magnetic fields are also generated by the currents in the electrical discharges between clouds and the surface of the Earth.[24)] The daily variation of these ELF magnetic fields is strongly correlated to variations in the atmospheric magnetic field.[25)]

The always present geomagnetic field (GMF) of the Earth is a prerequisite for life. It not only shields us from the solar wind, but also has direct functions for life such as orientation of pigeons,[26)] plant branching, orientation of root branches and shielding of the geomagnetic field causes biological alterations such as decrease of the vital functions in bacteria and effects upon meristem (cf. stemcells in animals) of seedling roots of pea, flax and lentil and electron microscopy reveals changes in the mitochondrial structure.[27)]

Evidence has also been brought forward that we have endogenous internal rhythms in blood pressure and heart rate, which are close to, however not identical to, the period length of the rhythms in the solar wind. So, it has been proposed, that these were installed genetically by natural selection at some time in the distant geological past.[28)] It has also been shown that magnetic storms cause additional biological dysfunctions. Thus, bacterial bioluminescent intensity varies according to the amplitude and duration of the MSs. Further, medical studies correlate MSs with anxiety and irritability and lower attention and accuracy, with an increment of the probability of road accidents[29)] and aviation accidents.[30)] Also, acute attacks of cardiovascular diseases, such as myocardial infarction and stroke, become more frequent.[31)]

We have to conclude that the existing organisms are created to function in harmony with the abovementioned fields and forces which existed when life was born 3 billion years ago. And so was the situation until the generation of our grandparents. They invented the wonders of our modern life. Thus, in the late 19th century mankind introduced the use of electricity. Until then the ELFs, extremely low frequency electromagnetic fields, were represented on Earth principally only by the Schumann resonances. But now Tesla constructed the induction motor, Morse introduced the long-range telegraph, Bell the telephone, Edison developed the commercial electrical networks and electricity spread around the globe. Marconi introduced the wireless receiver 1896 and in the early 20th century long-wave radio and in the 1940-ies short-wave radio appeared.

Compared to the estimated natural background level of natural ELF magnetic fields below 1 pT/Hz (10^{-12} T/Hz) for which the previous generations of human beings had been exposed, the average exposure in the modern world is about 100 000 times higher!

§2. Microwaves

In 1964 Penzias and Wilson discovered the cosmic microwave background (CMB) which fills the whole universe and which originates from the Big Bang. Also ongoing cosmic processes in for example intergalactic gas clouds with temperatures of about 30°K contribute to some cosmic microwaves. But microwaves are heavily attenuated by the ionosphere and the atmosphere. *Thus the natural electromagnetic background radiation in radiofrequency and the microwave band is extremely low at the Earth's surface.*

The integrated spectral distribution of the microwave background in space results in a power density of about 0.4 μW m^{-2}. A great deal of this radiation is thus reflected by the Earth's magneto- and ionosphere or is absorbed by water and other molecules in the atmosphere. A rough estimate of the power density of CMB at the Earth's surface varies from 10^{-21} to 10^{-14} Wm^{-2} equivalent to 10^{-15}–10^{-8c} μWm^{-2}. This level of radiation is extremely low and extremely sensitive measuring equipment is required for its recording.

Thus microwaves had so far been extremely low on Earth's surface, but in the 1950-ies high frequency RF was introduced as FM and television and during the very last decades, *microwaves of the modern communication society spread around the world for the first time and now exceed the natural levels by many orders of magnitude* (Table I).

Today one third of the world's population owns the microwave-producing mobile phones and an even larger number is exposed to the cordless RF emitting systems ("passive mobile phoning"[5]). To what extent are all living organisms affected by these new, almost everywhere present radio frequency fields? And what will be the effects of many years of continuing exposure?

Table I. Incident energy from a spectrum of sources of electromagnetic energy. These are not actually measured values. They are guideline values set by authorities. (For microwave ovens U.S. Food and Drug Administration since 1971). The actual standard 5 mW/cm^2= 50 W/m^2 at 5 cm from oven surface, 0.5 mW/m^2 at 50 cm at 2.45 GHz corresponds to 10 W/m^2 = 2W/kg, and 50 W/m^2 = 10 W/kg.

Source	Energy flux density (W/m2)
Natural Background	$< 10^{-14}$
Microwave oven, RF leakage standard	
5 cm for surface	50
50 cm from surface	0.5
Cell telephone (2 GHz) public guideline	10
Cell telephone (850 MHz) public guideline	4.3
RF levels near cellular base antenna (calculated)*)	0.05

*)Typical E-field levels in proximity to cellular telephone base stations (< 200 m).[32)]

These questions are extremely important to answer. Our generation and our children are the first to be exposed during a lifetime to the microwaves, which are exponentially increasing underneath the ionosphere which was intended to prevent their access to Earth, at least partially.

Scientists have studied the effects of ELF and MW since the 60-ies, and an abundance of reports have emerged, especially during recent years, many of them demonstrating significant effects upon biology and health, while others have failed to show effects. In this communication we will summarize the results of some of our work in the field since 1988 and also comment to a lesser extent upon the work of other research groups. During recent years, several scientific reports in respected journals have shown significant, but often weak, effects upon cells *in vitro*, experimental animals and also humans (for reference see 33)-35)).

Recent epidemiological studies indicate that long term exposure might increase the risk for some tumour forms (for review see 36)). In a Swedish case-control study it was reported that the use of analogue and digital cellular telephones and cordless phones was correlated to an increased risk for malignant brain tumours. Regarding the use of digital cellular telephones, an odds ratio of 1.9 was observed and with a $>$ 10-year latency period this odds ratio was increased to 3.6.[37)]

It has also been shown that mobile phone emission modulates (with increase in some cases, and decrease in others) inter hemispheric functional coupling of EEG alpha rhythms.[38)]

The mechanisms through which the electromagnetic fields exert their effect upon cells and organisms are not well understood. This may be part of the reason why the results of different laboratories diverge and it should be pointed out that it is as important to reveal the mechanisms as it is to demonstrate their effects upon biology. In this publication we also dwell at some length at the theoretical models trying to explain the biological effects of EMF in relation to our own experiments on EMF steering of calcium passage over spinach plasma vesicle membranes.

§3. The Blood Brain Barrier (BBB) of the mammalian brain

Since 1988 our group has studied the effects of RF electromagnetic fields upon the blood-brain barrier (BBB) and we have collected an extensive experimental experience in this field. RF electromagnetic fields have been revealed to cause significantly increased leakage of albumin through the BBB of exposed rats as compared to non-exposed animals — in a total series of about two thousand animals. We have exposed rats to various magnetic and electromagnetic fields, as well 915 MHz continuous wave (CW) as pulse-modulated at various repetition rates (50-200 pulses per s), and we have confirmed these findings in our laboratory in follow-up studies with real GSM-900 and GSM-1800 exposures.[2),3),5)−7),39)]

The mammalian brain is protected from exposure to potentially harmful compounds in the blood by the blood-brain barrier (Fig. 3). Being formed by the vascular endothelial cells of the capillaries in the brain, this hydrophobic barrier maintains and regulates the very sensitively tuned environment within the mammalian brain.

The blood-brain barrier is a highly complex system, in which several kinds of

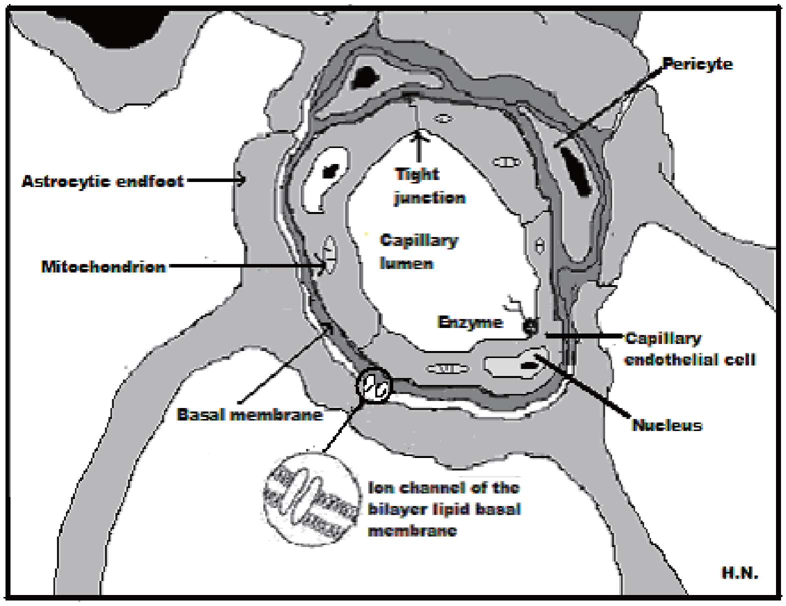


Fig. 3. The blood-brain barrier.

cells exert a wide range of functions. Some of the main characteristics are described below.

- The cell-to-cell contacts between the capillary endothelial cells are sealed with tight junctions, forming a permeability barrier, which is much more selective as compared to the fenestrated sealing of other capillaries.

- The outer surface of the endothelial cells is surrounded by protrusions (end feet) from astrocytes. Thereby, the endothelial cells and the neurons are connected and also, a second hydrophilic barrier is formed. Also, the astrocytes are implicated in the maintenance, functional regulation and repair of the blood-brain barrier.

- A bilayer basal membrane supports the ablumenal surface of the endothelial cells. This membrane might also further restrict the passage of macromolecules into the brain parenchyma.

- Pericytes are other periendothelial accessory structures of the blood-brain barrier. These have capacity for phagocytosis as well as antigen presentation and in fact, they seem to contribute significantly to the immune mechanisms of the central nervous system.[40)]

In addition to these structural properties of the blood-brain barrier, there are also several physiological characteristics of major importance, e.g. the high number of mitochondria within the endothelial cells (five-fold higher as compared to muscular endothelial cells of rats)[41)] and also, the low number of pinocytotic vesicles for nutrient transport through the endothelial cytoplasm. These are properties, which speak in favour for an energy-dependent transcapillary transport system. Of importance in the context of the blood-brain barrier permeability restriction, is also the enzymatic barrier of the cerebral endothelium, which metabolizes drugs and nutrients and thereby prevent their passage into the brain parenchyma.[42)]

Taken together, all these characteristics of the blood-brain barrier guarantee that only those molecules, which are either hydrophobic (such as oxygen, nitric oxygen and steroid hormones), or bind to specific receptors (such as certain amino acids and sugars), can pass freely from the blood circulation out into the brain parenchyma. Additionally, there is also a weight-selectivity, where particles of a larger molecular weight are more effectively excluded from passage over the blood-brain barrier. Also, active transport out from the brain parenchyma and metabolization of certain drugs, made possible by an intact blood-brain barrier, stabilises and optimises the environment surrounding the neurons of the mammalian brain.

In a number of pathological conditions, such as epileptic seizures, sepsis and severe hypertension, the integrity of the blood-brain barrier is disturbed. The sensitively tuned balance within the brain parenchyma is thereby disrupted. This might lead to cerebral oedema, increased intracranial pressure and in the worst case, irreversible brain damage. Also, potentially carcinogenic molecules can gain free access to otherwise protected areas of the mammalian brain. Of importance to remember, is also, that transient openings might be harmful enough to result in permanent tissue damage.[43)]

In conclusion, an intact and fully functioning blood-brain barrier is essential for the proper function of the mammalian brain.

Rectangular pulsed RF were generated by switching the MW generator (900 MHz) on and off with a rectangular pulse train of various repetition frequencies (4-217 Hz). We started our studies on albumin passage over the BBB a repetition frequency of 16 Hz and then with its harmonies of 4, 8 and also 50 Hz, which was felt relevant, as it is the standard voltage of the European power supply, with a carrier wave of 915 MHz. At an early stage also 217 Hz modulation was added as this was the frequency of the then planned GSM system. In all experiments endogenous substances such as albumin and fibrinogen, which occur naturally in the blood circulation, were used for the detection of BBB leakage, which is identified by anti-rat albumin rabbit antibodies and rabbit anti-human fibrinogen.

This work was published in 1994[3)] and 1997[6)] and comprised sham or 915 MHz exposure for in most cases 2 hours (both CWs and pulsed modulated waves). These results, based on 246 rats 1994 and more than 1,000 rats 1997 (the majority EMF exposed and about 1/3 sham-exposed) concluded that there was a significant difference between the albumin extravasation from brain capillaries into the brain tissue between the differently exposed groups and the controls. It is important to point out that though all animals in the 1997 series (and basically all of our experiments) are inbred Fischer 344 rats, only at the most 50% of the identically exposed animals display albumin extravasation (in CW animals and somewhat less in the other exposed animals). Even the sham exposed animals had some albumin leakage though only in seventeen per cent as a mean of all controls and at a lesser extent. The detection of leakage in unexposed animals presumably is due to our very sensitive immune histological methods.

The most remarkable observation was that exposure with whole-body average power densities below 10mW/kg gave rise to a more pronounced albumin leakage than higher power densities, all at non-thermal levels. If the reversed situation were at hand, we feel that the risk of cellular telephones, base-stations and other RF emitting sources could be managed by reduction of their emitted energy. The SAR value of around 1 mW/kg exists at a distance of more than one meter away from the mobile phone antenna and at a distance of 150-200 metres from a base station. This has led us to coin the concept passive mobile phoning for all non-users who are exposed.[5)]

The maximally allowed SAR-value for occupational exposure is 10 W/kg, and 2 W/kg is the maximally allowed SAR-value for public exposure. At a frequency of 900 MHz, these values are reached at power densities of 22.5 W/m^2 for maximally allowed occupational exposure, and 4.5 W/m^2 for maximally allowed public exposure. That is, 1 W/kg corresponds to 2.25 W/m^2 at a frequency of 900 MHz.

In many studies of pharmacological effects in connection with RF exposure, response is only seen at a certain dose range, and not at higher or at lower dosages. This is named "the inverted U-function". A similar RF response characteristic has been observed by us, seen as a more pronounced albumin leakage at lower than at higher power densities. According to Adey, this kind of dose response might constitute the basis for window effects observed in connection to RF exposure.[44)]

In the majority of our studies, EMF exposure of the animals has been performed in transverse electromagnetic transmission line chambers (TEM-cells)(for reference see 2),3),5)-7),39),45),46).) These TEM-cells are known to generate uniform electromagnetic fields for standard measurements. In each TEM-cell, two animals can be placed, one in an upper compartment and one in a lower compartment. The experimental model allows the animals, which are un-anaesthetized during the whole exposure, to move and turn around in the exposure chamber, thus minimising the

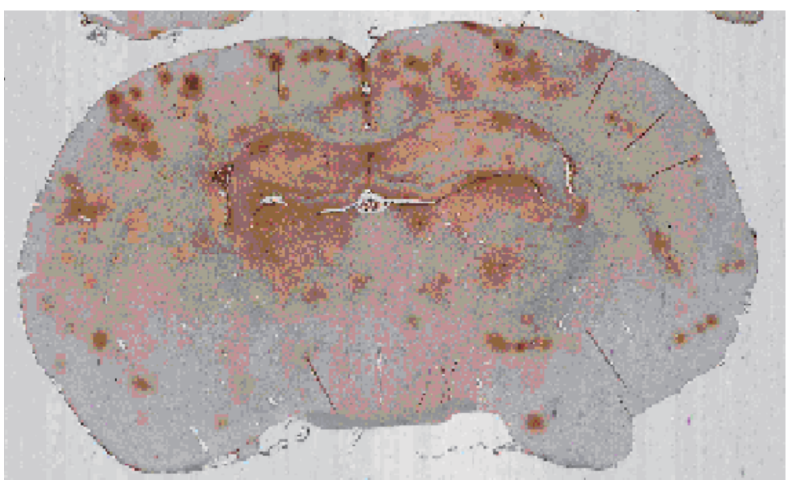


Fig. 4. Pathological leakage around brain capillaries demonstrated by immuno assaying against blood albumin. Fischer 344 male rat (# 3987, weighing 292 g) exposed to 1899 MHz CW microwaves in an anechoic chamber for 2 hours at SAR $\approx$ 2mW/kg. Ten minutes after this exposure, the animal was anaesthetised and sacrificed.

effects of immobilization induced stress, described by Stagg et al.[47]

It is important to point out that the position of the animals in upper or lower compartments does not affect the magnitude of observed albumin leakage. Also, we have concluded, with our total series of more than two thousand exposed animals, that there is no difference in the sensitivity to EMF exposure between male and female animals as far as albumin leakage is concerned.

Our initial findings of albumin leakage have been repeated by others,[48] with 900 MHz exposure of rats for 4 hours at brain power densities ranging from 0.3 to 7.5 W/kg. Another group, working in Bordeaux, and led by Prof Pierre Aubineau, has also demonstrated evidence of albumin leakage in rats exposed for 2 hours to GSM-900 MHz at non-thermal SAR-values of 0.12, 0.5 and 2.0 W/kg, using fluorescein-labelled proteins. The results were presented at two meetings[49] and are very similar to ours, described above.

Support for our findings that low intensity GSM 900 MHz electromagnetic fields influence the BBB is also found in the *in vitro* proteomic studies on a human endothelial cell line by the group of Leszcynski.[50],[51]

§4. Neuronal damage

Our consistent findings of albumin passage over the BBB and spread in the surrounding brain tissue with albumin uptake in the cytoplasm of neurons and glial cells brought up the question whether this might lead to neuronal damage.

In a series of experimental situations, neuronal degeneration has been observed in areas with BBB disruption and it has been suggested that BBB leakage is the major reason for nerve cell injury such as that seen in dark neurons.[52]

It has also been observed after intracarotid infusion of hyperosmolar solutions in rats;[53] in the stroke-prone hypertensive rat;[52] and after acute hypertension by aortic compression in rats.[55] Further, epileptic seizures cause extravasation of plasma into brain parenchyma.[54] The cerebellar Purkinje cells are heavily exposed to plasma constituents and degenerate in epileptic patients.[55] This effect may, however, as

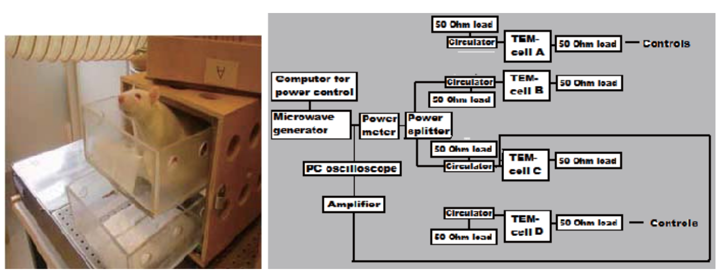


Fig. 5. Left: A rat in the upper exposure tray of a TEM-cell for 915 MHz microwaves. Right: Block diagram of the 4 TEM-cell arrangement used in the experiments in Lund. A microwave power generator is used for feeding the TEM-cells. A power splitter divides the power form the RF generator into equal parts that are fed to each TEM-cell. The output from the cells is terminated in a 50 Ohm dummy load.

well be attributed to hypoxia. It has been postulated that albumin is the most likely neurotoxin in serum.[56)]

In order to seek for neuronal damage in our experimental model, we exposed Fischer 344 rats for 2 hours with non-thermal GSM at SAR values 120, 12 and 1.2 mW/kg.[7)] We made the remarkable observation that a significant ($p<0.002$) neuronal damage is seen in rat brains 50 days after such an exposure.

It is notable, that we see areas in hippocampus and cortex of exposed animals where the cytoplasm of neurons are filled with autologous albumin while neighbouring neurons display the shrunken and dark state of a "dark neuron" which is a very sick or dying neuron. It may be so that the leakage of albumin out in the neuropil starts a deleterious process whereby more albumin leaks through the endothelium and finally becomes too heavy a burden for the affected neurons. Hassel et al.[57)] have demonstrated that injection of albumin into the brain parenchyma of rats gives rise to neuronal damage. When 25 micro litres of rat albumin is infused into rat neostriatum, 10 and 30, but not 3 mg/ml albumin causes neuronal cell death and severe axonal damage. It also causes leakage of endogenous albumin in and around the area of neuronal damage.

Findings similar to ours in the animals sacrificed late after exposure have been reported in Wistar rats.[58)] Twenty-two female rats were exposed to a 900 MHz electromagnetic GSM near-field signal for one hour a day for seven days. The peak specific absorption rate (SAR) of the brain was 2 W/kg. This resulted in scattered and grouped dark neurons in the cortex, hippocampus and basal ganglia, mixed in among normal neurons with distributions of scores significantly different between the control and the GSM exposure group ($p< 0.01$).

In continued work we have proven our own finding from 2003 — in a study of 96 non-anaesthetized rats which were exposed or sham exposed for a duration of 2 hours at specific absorption rates (SAR) of 120, 12, 1.2 and now also 0.12mW/kg. The extravasation of albumin, uptake into neurons and occurrence of damaged neurons were assessed 14 or 28 days later. Albumin extravasation and uptake into neurons was significantly enhanced after 14 days, but not after 28. The occurrence of dark neurons, on the other hand, was significantly enhanced only after 28 days. After 28 days, neuronal albumin uptake was significantly correlated to occurrence of damaged neurons.[8)]

In ongoing and recently completed experimental work, we have studied lifelong exposure to GSM 900 as well as the effects of short term exposure to GSM 900 and 1800 in living rats. Lifelong exposure to microwaves seems to be the future of the young generation. Therefore, we have studied male and female Fischer 344 rats, exposed for 2 hours to GSM 900, and sham exposed in our TEM-cells once a week for 13 months. After this they were studied for cognitive functions and compared to cage controls. Significant effects of exposure upon episodic memory function have been demonstrated and published.[9)] In short, the cognitive functions were evaluated in the episodic-like memory test. The GSM-exposed rats had significantly impaired memory for objects and their temporal order of presentation ($p=0.02$). The detection of a place in which an object was presented, that is the spatial memory function, was not affected by the GSM exposure. In rats, hippocampus is involved in aspects comparable to human declarative memory, and is seems possible that the reduced memory functions that we observed are correlated to hippocampal alterations induced by the mobile phone exposure. Also, temporal order memory, depending on cortical areas such as the perirhinal cortex in the medial temporal lobe, the prefrontal cortex and the interaction between these areas, might explain the reduced temporal order memory of the GSM exposed rats. Finally, after the memory tests had been performed, all animals were sacrificed and the brains are now under examination for albumin leakage, neuronal and glial damage and other signs of pathology.

The possibility that microwaves may affect our DNA has received increased attention since recent epidemiological studies indicate that long term exposure (10 years mobile phone use) increases the risk for developing tumours in the exposed brain hemisphere, both the benign vestibular schwannoma arising from the balance nerve and the highly malignant glioblastoma multiforme.[36),37),59)] Regarding the development of vestibular schwannoma, the relative risk seen ten years after the start of mobile phone use, was 1.9 (with confidence interval 0.9-4.1).[59)] When only tumours occurring at the same side of the head as the mobile phone had been normally used, the relative risk increased to 3.9 (with confidence interval 1.6-9.5). In a pooled analysis of case-controlled studies on malignant brain tumours, cumulative life use of $>$ 2, 000 hours of mobile phoning revealed an odds ratio of 3.7 (confidence interval of 1.7-7.7).[60)]

Studies of gene expression patterns in the living animal may elucidate also other aspects such as effects on genes involved in membrane transport and other basal functions of the living cell *in situ*.

In collaboration with Belyaev and his group we have exposed rats for 6 hours to GSM-900 RFs at SARs of 0.4mW/kg and investigated the genetic expression from cerebellar tissue. Alterations of genes encoding proteins for BBB functions were observed.[10)]

We have now studied whether 6 hours of exposure to the radiation from a GSM mobile phone at 30mW/kg has an effect upon the gene expression pattern in rat brain cortex and hippocampus — areas where we have observed albumin leakage from capillaries into neurons and neuronal damage. Microarray analysis of 31 099 rat genes, including splice variants, was performed in cortex and hippocampus of 8 Fischer 344 rats, 4 animals exposed to GSM for mobile communications electromagnetic fields for 6 hours in an anechoic chamber and 4 controls kept for the same length of time in the same anechoic chamber without exposure. Gene ontology analysis of the differentially expressed genes of the exposed animals versus the control group revealed interesting differences between exposed animals and controls. Genes of interest for membrane transport show highly significant differences.[11)] This may be of importance in conjunction with our earlier findings of albumin leakage into neurons around capillaries in exposed animals and has also lead us to look into the mechanisms behind these effects — see below under **DNA Transcription process, Solitons and Microwaves.**

§5. Mechanisms behind the effects of electromagnetic fields upon biology

5.1. *Interaction of ELF with calcium metabolism*

Beyond what is described above, we have also performed experiments where an increase of the Ca^{2+}-efflux over plasma membranes has been observed in plasma vesicles from spinach exposed to ELF.[13)]

We could show that suitable combinations of static and time varying magnetic fields directly interact with the Ca^{2+}-channel protein in the cell membrane, and we could quantitatively confirm the model proposed by Blanchard.[61)]

Calcium has many important roles in all living organisms. Apart from its structural role in, for example, bone matrix, plant cell walls, and in stabilizing membranes, it plays an essential role in cellular homeostasis, most notably as an intracellular messenger.[62)] The free Ca^{2+} concentration in the cytosol is strictly kept at 0.1-0.2 μM, which is much lower than that found in the intracellular Ca^{2+}-stores or the extra-cellular space. The cytosolic free Ca^{2+} ion concentration has influence upon growth and development of the organism and its daily functions as well as death in apoptosis.[62)]

It has been suggested that the mechanism underlying alterations of Ca^{2+}-fluxes involves inducible changes of both static and time varying magnetic fields.[63] The studies of the effects on Ca^{2+}-influx over cell membranes are of importance in the perspective of human health, considering the crucial role of Ca^{2+}-flux played in cellular communications.

The mechanism, by which magnetic fields might interact with biological systems, has been called magnetoreception. Different models try to provide the theoretical framework explaining how this is made possible, and these models are also important for future model-guided investigations of the magnetoreception.

In order to explore the mechanism for possible biological effects of the enhanced ELF radiation environment, we investigated how the transport of Ca^{2+} ions over the membrane of spinach plasma vesicles varies with frequency and amplitude of ELF magnetic field exposure. Bauréus-Koch et al.[13)] studied the calcium flux through calcium channels in highly purified plasma membranes of spinach (Spinacia oleracea L.).[13)]

A bio-resonance phenomenon was found where appropriate combinations of frequency and amplitude have the potency to affect bio-membranes and their Ca^{2+} -ion transport systems at various degrees and directions. With a static magnetic field $B_{DC} = 37.0 \pm 0.5$ μT we found resonances of $B_{AC} = 25.9 \pm 0.3$ μT (peak), at the frequencies of 7, 21, 24, and 31 Hz. The Ca2+ -ion efflux ratio at those exposure conditions appears to deviate significantly compared to that of sham exposures.[13)]

Three Gaussian peaks with the same width of 2.5±0.4 Hz could be fitted through the data points with peaks at the frequencies 20.9±0.3, 25.4±0.4, and 30.2±0.5 Hz with a χ^2 value of 6.0. These frequencies correspond well to the resonance frequencies 20.7 Hz (Mn_{ion}, $n = 1$) 25.2 Hz ($^{45}Ca_{ion}$, $n = 1$), and 31.1 Hz (Mn_{ion}, $n = 1$), respectively.[13)]

With our Ca^{2+}-efflux studies over plasma membranes as a basis, our research was further extended into the field of magnetic resonance models; mainly the Ion Parametric Resonance (IPR) Model as proposed by Lednev;[64),65)] in an attempt to explain the occurrence of resonance frequencies. In short, Lednev's model considers the polarization of the oscillation of an ion bound to a protein in a combination of static and time-varying magnetic fields.

In our studies of spinach vesicles, the calcium flux was modified at frequencies that corresponded to resonance frequencies for non-hydrated ions of $^{40}Ca^{2+}$, Mn^{2+} and Mn^{3+}. The resonance frequencies were linearly related to the strength of the static magnetic field applied. The resonance frequency of 24 Hz could be attributed to $^{45}Ca^{2+}$ ($n = 1$) or $^{24}Mg^{++}$ ($n = 2$). Lednev[64)] predicts an amplitude dependence that follows the Bessel functions.

In our experiments, we concluded that the resonance could be attributed to $^{45}Ca^{2+}$. However, as in the experiments performed by Blackman,[66)] a factor of two had to be included in the argument of the Bessel function.

In 1996, Lednev[65)] modified his model, in order to avoid some of the problems identified in the original theory.[67)] In this modified version the amplitude window is described by the square of the Bessel functions. A fit to our data[13)] demonstrates that the factor of two is not required as previously to fit the experimental data to the theory.

Taken together, our experimental results of the interaction of ELF magnetic fields with Calcium bound to proteins in the cell membrane fit extremely well with quantum mechanical interaction models.[61),63),68)] Thus, we have shown that ELF magnetic fields interact with Calcium and Manganese ions in plasma membranes at specific frequencies in accordance to a quantum mechanical interaction model.[13)]

The search for the mechanisms behind the effect of electromagnetic interactions with biological systems has continued. Another way to address the issue, as compared to our model with the purified membrane system, with theoretical, physical models as a basis, is the biological examination of signalling pathways possibly affected by magnetic fields. As has been shown by Sun et al.,[68)] a possible mechanism for the bioeffects produced by ELF-EMF exposure could be protein tyrosine phosphorylation. 50 Hz power-frequency magnetic fields could activate the stress-activated protein kinase (SAPK),[70)] however, not through the phosphorylation of the upstream kinase of SAPK (SEK1/MKK4).[71)] Noise MF with certain intensity could inhibit the biological effect induced by 50 Hz MF, as seen by the reduced activation of SAPK when noise and 50 Hz exposures were applied simultaneously.[72)] With continued research of this kind, a mosaic of EMF target proteins might crystallize.

§6. Transmembral transportation — Solitons and microwaves

A major portion of this paper dwells on the passage of albumin from the brain capillaries out into the surrounding brain and the cytoplasm of neurons and astrocytes, and the remarkable observation that it is the lowest energy levels that give rise to the most pronounced albumin leakage.

The mechanisms by which the EMFs may alter BBB permeability are not well understood. At low field strengths, the effects on body temperature are negligible and thus heating effects are not involved. It has been suggested that physicochemical characteristics of membranes are changed.[12] One of the great pioneers in the field, Ross Adey discussed the mechanisms behind a possible direct, non-thermal effect of RF radiation upon the central nervous system. He studied amplitude-modulated radiofrequency fields and suggested in 1988 that co-operative processes in the cell membrane might be reactive to the low energy of an electromagnetic field. This oscillating field might result in changes of the membrane potential.[74]

The question might find an answer within a theory which we hereby bring forward

– **the possible soliton function in membranes.**

The word soliton emanates from John Scott Russell's observation of the solitary wave

In 1834, while conducting experiments to determine the most efficient design for canal boats, this young Scottish engineer made a remarkable scientific discovery, which he described in his "Report on Waves" after his first sighting of a soliton or solitary wave, by Russell called a "Wave of Translation" on the Union Canal near Edinburgh.[73]

The migration of soliton energy in molecular systems was first considered by Davydov and Kisluka[75] by the use of a quantum coherent wave theory. Solitons were considered important for energy transfer and storage in biological structures, as described by Davydov[76] and then by Fröhlich,[77] as coherent dipolar propagating waves. These applications of quantum field theory to biological systems inspired many theoretical physicists to study biological systems with a special interest focused upon tubulin. This filamentous protein is a fundamental building block of the cytoskeleton matter.[78],[79] Microtubules are important components of the cytoskeleton, responsible for cellular organization and information processing.[80] Microtubules of the neurons in the brain might be active components of brain functioning and information processing. Endogenous electromagnetic waves are considered to be moving in the cavity of the microtubules, transporting and carrying information. The relevant mechanism of electromagnetic wave interaction has been suggested to be spontaneous breakdown of symmetry in the biological, well ordered structures. Such interaction occurs with the dipole moments of the molecules in the brain microtubules.[79]

Abdalla et al.[81] studied the problem of information propagation in the brain microtubules, considering propagation of electromagnetic waves in a fluid of permanent electric dipoles. The problem reduces to sine-Gordon wave equation in one space and one time dimension. The energy balance of the voltage along with the neuronal projection and the microtubule z-axis, results in generation of solitons and propagation of kinks or anti-kinks along the microtubule proto-filaments. The tubulin tails are coupled to the dipoles of nearby water molecules at the microtubule surface and the change of their conformational status at the place of the soliton twist. The standing breather swinging at certain tubulin tail (or breather formed by 2-3 coupled swinging tubulin tails) could catalyze microtubule attachment proteins (MAP) and promote or inhibit the action of kinesin-proteins involved in the microtubule dynamics.[82]

Another interesting result of the work of Abdalla et al.[81] is the fact that the frequency parameters, which showed up in the model, are compatible with the size of microtubules of brain structures and with the transition period observed for the so called conformational changes of the tubulin dimer protein (namely 1-100 GHz).

The applications of exogenous, electromagnetic waves in this frequency interval, that coincide with that we use for wireless communication, interact with the endogenous electromagnetic wave that might result in biological actions. This may be the mechanism behind our observation of memory impairment in rats exposed to 0.9 GHz microwaves as described above.

Solitons as actors in biology thus have been discussed since the 1970-ies. The effects in biological membranes have recently been brought to the fore by two researchers at the Niels Bohr Institute in Copenhagen, T. Heimburg and AD Jackson in their publication: "On soliton propagation in biomembranes and nerves".[83] They write:"The lipids of biological membranes and intact biomembranes display chain melting transitions close to temperatures of physiological interest. During this transition the heat capacity, volume and area compressibilities, and relaxation times all reach maxima. Compressibilities are thus nonlinear functions of temperature and pressure in the vicinity of the melting transition, and we show that this feature leads to the possibility of soliton propagation in such membranes. In particular, if the membrane state is above the melting transition, solitons will involve changes in lipid state". The authors discuss solitons in the context of several properties of nerve membranes under the influence of the action potential, including mechanical dislocations and temperature changes.

In a recent paper, the same authors support their hypothesis by pointing out that the Hodgkin-Huxley model for nerve signal transduction never explained the function of anesthesia. The soliton model on the other hand might give an answer. They conclude that anesthetics lower the temperature at which lipids become solid, making it difficult for the soliton waves to form. This should prevent nerves from sending pain signals.

It is known that the action of general anaesthetics is proportional to their partition coefficient in lipid membranes (Meyer-Overton rule). This solubility is, however, directly related to the depression of the temperature of the melting transition found close to body temperature in biomembranes. Heimburg and Jackson proposed a thermodynamic extension of the Meyer-Overton rule, which is based on free energy changes in the system and thus automatically

incorporates the effects of melting point depression. This model accounts for the pressure reversal of anaesthesia in a quantitative manner. Further, it explains why inflammation and the addition of divalent cat-ions reduce the effectiveness of anesthetics.[84] (Charles Overton was professor of pharmacology at Lund University 1907-1930.)

The statement by Heimburg and Jackson is extremely interesting in reference to an extensive and thorough work on pain perception and electromagnetic fields performed by a research group in London Ontario since the early 1980-ies. (Their work stimulated our group to visit London Ontario and to join in the field in 1988.) In a recent review by the group, "Pain perception and electromagnetic fields", it is concluded that the effects on pain, nociception (pain sensitivity) and opiate-mediated analgesia (pain inhibition) constitute one of the most reproducible and reliable effects of EMFs with observed decrease in pain threshold (Del Seppia et al. 2007). In early studies on the nociception of rodents, the animals were placed on a metal surface at a standard temperature (50°C for mice) and the time taken to respond to the heat stimulus with a stereotypic averse withdrawal was recorded. The exposure to a heterogenous time-varying magnetic field resulted in an enhanced basal nocturnal sensitivity and reduced levels of morphine induced analgesia in mice. Also in connection with geomagnetic storms, mice were similarly less responsive to the analgesic effect of morphine. Further studies, with the land snail Cepaea nemoralis, showed that continuous EMF exposure induced hyperalgesia in a duration-dependent manner (at exposure times ranging from 2 hours to 120 hours). It is also pointed out that the increased pain perception by EMF may be a reason for the increasing prevalence of pain problems in the modern society. (For further discussion of these results, see 84).)

With the solid evidence collected from more than 50 publications, most of them based on studies on the land snail, Cepaea nemoralis but also mice and rats, it is tempting to give the solitons a chance in the search for, and definition of, the physiological mechanisms involved.

Exposure to pulsed magnetic fields (MF) has been shown to have a therapeutic benefit by increasing pain thresholds not only in animals, but also in humans. In a recent study it was concluded that MF exposure does not affect basic human perception, but can increase pain thresholds in a manner indicative of an analgesic response.[85)]

We suggest that soliton models will be considered in studies on the relation between pain, anaesthesia and electromagnetic field exposure. Further those models could be applied to study the effect of EMF field on membrane permeability for various molecules such as calcium and albumin.

It is striking that the soliton theory also may be instrumental in the explanation of how the DNA transcription process is possibly influenced by the Microwaves:

§7. DNA Transcription process, solitons and microwaves

The Nishinomiya-Yukawa International & Interdisciplinary Symposium 2007 raised the question: What is Life? An obvious and simple answer could be: It is DNA!

The DNA strand can be looked upon as an antenna resonating in the microwave band 6GHz with its harmonics and subharmonics.[14)–18)] If this holds true, the dramatic situation might exist, that all living organisms have a receptor for the newly constructed and world-wide man-made microwaves, leading to a direct effect upon the function of DNA — in concordance with our experimental findings!

Screening of gene expression by microarray technology provides new powerful means for the search for molecular pathways and to elucidate possible molecular markers of response of brain cells to MWs. However, to our knowledge, only two studies have been published on the effects of GSM microwaves upon the gene expression in the CNS after exposure of the whole organism.[10),11)] This material was first presented at the 4th International Workshop, 16-20 October 2006, Crete Greece.[87)]

Those studies are described above and have shown that 6 hours of exposure to GSM 900 MW (at the very low SAR value of 0.4 mW/kg) and 1800 MW (at SAR value 30 mW/kg), to brain cells *in vivo* gives rise to highly significant alterations of gene expressions in cerebellar, cortical and hippocampal cells.

These findings are supported by a series of recent publications where the influence of RF of the type emitted in GSM has been studied in vitro in different cell cultures, proving effects upon gene expression in cultured human cells[88)−90)] and rat neurons[91)] through non-thermal mechanisms.

In the search for a possible mechanism behind these effects of the man-made microwaves upon living organisms, we have explored the effects of microwaves on the DNA/RNA transcription process. In the following we bring forward the possibility of a soliton mechanism in the interaction between microwaves and the DNA/RNA transcription process.

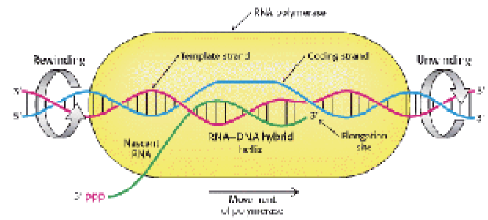
§8. The DNA transcription process

The first step in genome expression is DNA transcription from the original DNA template contained in the cell, is to make a copy — the RNA messenger — which will then be used as a 'master copy' in determining protein sequences in accordance with the genetic information. The evolutionary advantage of such a messenger is obvious: in this way, the original DNA is opened — and thus less protected — for as small a time as possible.[92)]

In the DNA transcription process, a specialized enzyme (RNA-Polymerase or RNAP) binds to a specific site of the DNA double helix and unwinds it in a local region of 15-20 bases, thus creating a "transcription bubble"; the RNAP and the bubble travel then along the DNA, copying its sequence and producing a RNA-Messenger to be later used to express genes or replicate the local sequence. This process requires a very finely tuned coordination of the motion of RNAP — and production of the RNA-Messenger — with the dynamics of the DNA double chain. In the active phase of the process, the RNAP proceeds along the DNA chain at a speed of several tens or hundreds of base pairs per second. Since each base pair is linked by two or three hydrogen bonds, the energy involved in such a process, even considering only the one to open (and close) the DNA chain, is of the order of at least hundred, if not thousand, H bonds per second. This corresponds to about to a power 300 fW (1 fW = 1 femto-W = 10^{-15} W).

§9. Solitons hiding in DNA and their role in RNA transcription

In a pioneering paper which appeared in 1980, Englander, Kallenbach, Heeger, Krumhansl and Litwin suggested that nonlinear excitations in the DNA double chain could be instrumental in this process and allow the motion of the transcription bubble to occur at near-zero energy cost. In particular, as the fundamental motion undergone by DNA nucleotides in this process is a roto/torsional one, they suggested



Transcription Bubble. A schematic representation of a transcription bubble in the elongation of an RNA transcript. Duplex DNA is unwound at the forward end of RNA polymerase and rewound at its rear end. The RNA-DNA hybrid rotates during elongation.

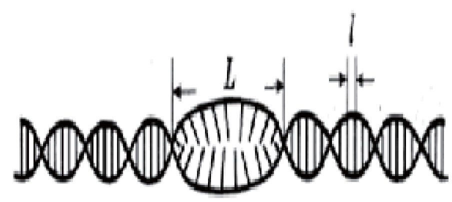


FIG. 1. Diagram of a mobile defect within DNA. The base-pair spacing l is 3.4 Å for the normal B helix, shown to the left and right of an open state. The open state involves loss of one half turn of helix, spread over a length L of 10 base pairs, and corresponds to a $-\pi$ soliton. The defect travels to the right or left by opening base pairs in the direction of motion and reclosing behind. The bases within the soliton are shown as tilted to suggest their altered winding with retention of stacking but loss of base-pair hydrogen bonds.

(Englander et al., 1980)

Fig. 6. Solitons in transcription.

modelling the DNA molecule as a double chain of coupled pendulums; the relevant nonlinear excitations would then be (topological) solitons pretty much like those, well known in the sine-Gordon equation[93)] (Fig. 6).

Englander et al.[93)] concluded that precedent for a frequency w, of MHz in double helices implies extended open segments with $(L/l) = 10$, compatible with the mobile defect model hypothesized (Fig. 7). Experimental indications for processes as fast as GHz exist, but imply very large open structures with $(L/1) = 1000$. Characteristic attempt frequencies of MHz, on the other hand, seem to be more reasonable in terms of hydrodynamic, melting, and NMR data. The overall activation energy for forming solitons was estimated to 6 kcal/mol which corresponds to $(L/l) = 100$.[93)] The binding energy of individual hydrogen bonds is in the same order of magnitude.

Nonlinear-waves in DNA was suggested by Polozov and Yakushevich[94)] to be involved in the regulation of transcription.[94)] Prohofsky[95)] proposed that the hydrogen-bond-stretch (HBS) bands of the double helix appear to be nonlinear enough to support solitary-wave energy concentration. Coupling this fact to predictions of a self-consistent theory of helix melting gives rise to speculations of a mechanism for base pair melting in RNA transcription which is consistent with the known energy needs of that process.[95)]

Guided by the idea of the order parameter of Landau, Zhou and Zhang[96)] analysed the structure and various nonlinear motions in DNA. They argued for the use of four significant variables, i.e., the conformational, rotational, longitudinal and transverse motions. Several sets of nonlinear discrete equations with more reasonable Hamiltonian were established, and their solution of small amplitude (phonons) and large amplitude (soliton or solitary waves) have been given. They speculated in the possible significant implications in duplication, transcription and drug intercalation in DNA.[96)]

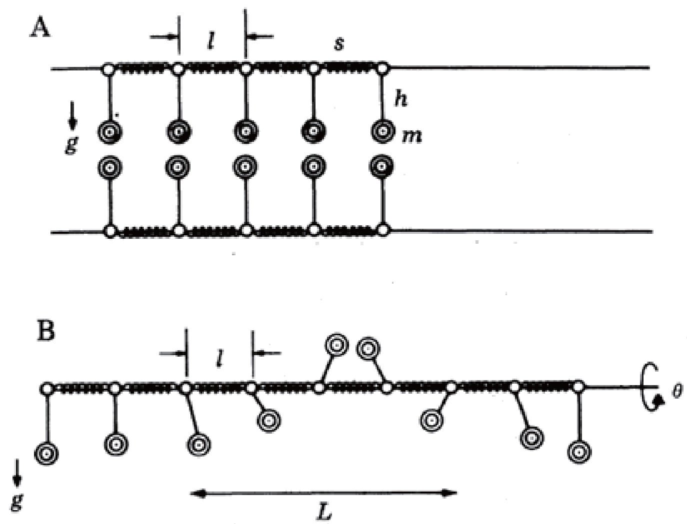


Fig. 7. A mechanical analogue of the DNA double chain, as presented by Englander et al.[92] Linear chains of the bases (here modelled as pendulums, each with a mass m and length h, with a space in between corresponding to l≈ 3.4Å) are connected by sugar-phosphate backbones (modelled as springs). One strand of the DNA double helix is able to undergo torsional oscillations (angle θ) about the sugar-phosphate backbone in the presence of the restoring gravitational force $= m * g$.
A) The DNA double helix in its ground state.
B) Soliton excitation mode, with large-amplitude excursion of one of the pendulum. The excitation is spread to the group of pendulums within the range of L.

Gaeta[97] suggested that nonlinear excitations could play a role in the process of DNA transcription, i.e. that the transcription bubble could correspond to a solitary wave travelling along the chain, which the RNAP could then 'surf' in order to access the base sequence with no energy to provide for opening the double helix. He discussed the general idea of providing a simple model for a specific DNA process, and argued that despite the tremendous complexity of the DNA model, this approach is not bound to fail. Recalling the main features of the model proposed by Yakushevich, he mentioned some encouraging achievements and several limitations.[97]

These limitations, however, more than being inherent to the model, are limitations of the studies conducted so far. It is clear that the model is too simple to be valid as it is. What is needed is to go 'one step further' in the Yakushevich classification of DNA models, but only a more thorough analysis can focus on the detailed refinements which are needed.[98] In particular, Gaeta[97] pointed out several directions in which he suggested that it is necessary to generalize the model and to investigate its behaviour, such as considering real nucleic acid base sequences and microwave thermal effects.

9.1. *Dissociation phase transition in DNA*

Bishop, Dauxois, and Peyrard proved the existence of a 'dissociation' phase transition in DNA, considered as a one dimensional system.[99)–103)] Indeed it models DNA as a one-dimensional chain, and by singling out *one* degree of freedom per base — corresponding to 'radial' displacements along the axis joining the two bases of a pair — that is, the degree of freedom thought to be the most relevant for the process under study.

Their theory for DNA melting compares successfully to experimental data on the detailed (spatiotemporal) dynamics of DNA melting. It can predict not only average quantities, as should anyway be the case with a statistical mechanics approach, but a spatiotemporal pattern.[104)]

9.2. *DNA and microwave absorption*

A nontrivial theory for dsDNA phonons and its associated nonlinear modes is provided by the Peyrard-Bishop model[104)] whose Hamiltonian is given by:

$$H_{PB} = \sum_{i=0}^{N} (\frac{P_i^2}{2m} + \frac{k}{2}(x_{i+1} - x_i)^2 + V_{H(x_i)}),$$
$$V_{H(y)} = U_0(\exp(-y/\lambda) - 1)^2,$$

where $p_i = mv_i$ is the momentum of the ith base pair,

x_i is the relative coordinate of displacement at each base pair,

v_i its velocity,

k is the harmonic coupling along each of the chains, and

V_H refers to the Morse potential representing hydrogen bonds between each base pair.

Fits to experimental data reveal that the well-depth is about normal room temperature (O(10-2 eV)). In a more realistic Peyrard-Bishop-Dauxois model the spring constant k is allowed to vary along the double chain to reflect the requisite stacking energy dependence.[105)]

In the presence of an electric field oscillating in time but spatially homogeneous on the length scale of the dsDNA, we make the following replacement, which follows from standard classical electrodynamics:

$$p_i \to p_i - q_i A\left(t\right)/c,$$
$$A\left(t\right) = -\frac{E_O c}{\omega_0} \sin\left(\omega_0 t\right),$$

where

q_i is the charge at the ith bond,

A is a component of the vector potential that exhibits solely a time-dependence,

c is the speed of light,

E_0 is the amplitude of the incident EM radiation, and

ω_0 is its frequency.

The charge could be electronic, or it could be a counter-ion adsorbed from the aqueous, ionic solvent. We are primarily interested in small perturbations, with a view to estimating at what level they become sinister.

Chivantis describes a dsDNA system, with the following Hamiltonian density, which is the continuum version of the Peyrard-Bishop-Dauxois model.[14),105)]

$$H_{dsDNA} = \frac{1}{2}\left[(1-\Lambda(t))\left(\partial_t\phi(x,t)\right)^2 + c_D^2(\phi(x,t)\left(\partial_x\phi(x,t)\right)^2\right] + V_H(\phi(x,t))$$
$$c_D^2(\phi(x,t)) = c_0^2(1+\rho\exp(-2\alpha\phi(x,t)))$$

where

$\Lambda(t) = \alpha^2\sin(\omega_0 t)^2$

$\alpha = \sqrt{\frac{2\beta Q^2\sigma^2}{m\omega_0^2}} < 1$

$cD(\phi)$ refers to the extension proposed by Dauxois.[100)]

It causes a stiffening of the backbone as the hydrogen bonds fluctuate. This stiffening reflects the stacking energy dependence of dsDNA. This extension was found to be crucial in understanding the thermal denaturation of dsDNA

It is important to note that the solvent serves to siphon off energy from the disturbance in a very sensitive way. Small changes in the coupling to the solvent bath of phonons affect dramatically the breather modes excited by the EM fields. Experiments where the coupling between the solvent and a DNA molecule is varied will be extremely useful in directing the future development of the understanding of EM effects on the dynamics of DNA.[14)]

The free energy needed to melt a GC base pair is generally accepted to be 3.5 kcal/mole and that for an AT base pair 1 kcal/mole. If inflow of this amount of energy occurred, the net energy requirements of transcription would easily be met. The reason to consider this form of energy transfer to the transcription complex is that we believe it would involve the nonlinear hydrogen-bond stretch (HBS) modes. The regime in which the bands of the torsional acoustic (TA) and hydrogen-bondstretch (HBS) modes of DNA interpenetrate each other has been considered by Golo.[16)] He proposes a simple model accommodating the helix structure of DNA and, within its framework, to find a three-wave interaction between the TA and HBS modes. This phenomenon is useful for studying the action of microwave radiation on a DNA molecule. Thus, using Zhang's mechanism of the interaction between the system of electric dipoles of a DNA molecule and microwave radiation, he showed that the latter could bring about torsional vibrations that maintain HBS vibrations.

Microwave radiation would maintain the HBS modes and there is no need for long exposures of the sample to radiation. Golo[16)] estimated for the pure experimental system, the critical power density, 100 mW/cm^2, which is by orders of magnitude larger than that officially prescribed, i.e., at 900 MHz 2W/kg corresponds to 4500 mW/m^2 or 0.45 mW/cm^2, and at $>$ 2 GHz 10 W/kg corresponds to 10000 mW/m^2 or 1 mW/cm^2.[16)] The question is, however, if the theoretically derived limit of 100 mW/cm^2 is valid for in vivo exposure conditions. Thus there is still much more research to be done before we might answer that question.

§10. Conclusion

The first living organisms arose on Earth when it had existed for 1.5 billion years. During the following 3 billion years, life on Earth was formed by, and existed in harmony, with the original physical forces such as gravitation, cosmic irradiation, atmospheric electric fields and the terrestrial magnetism and the cyclic celestial events. This was the world where evolution resulted in Homo sapiens, "the wise man". It took him 200 000 years to reach the level of knowledge where he could dramatically alter the physical forces on Earth. During the last century the levels of ELFs and MWs have been hugely increased in our habitat under the ionosphere.

Even if many studies have seen no effects of the EMFs upon biology, an abundance of scientific reports in respected journals have shown significant, though often weak, effects upon cells *in vitro*, in experimental animals and also in humans.

If the man made EMFs, such as those utilized in mobile communication, even at extremely low SAR values, causes the users' own albumin to leak out through the BBB, which is meant to protect the brain, also other unwanted and toxic molecules in the blood, may leak into the brain tissue. There they concentrate in, and damage, the neurones and glial cells of the brain according to our studies. It cannot be excluded that this, (especially after many years intense use) may promote the development of autoimmune and neuro-degenerative diseases!

It is our generation who invented the microwave emitters. We now have an imperative obligation to further investigate the links between EMF and biology in order to prevent the possible detrimental effects of the microwaves. The concept of solitons as active in membranes and RNA-transcription may be one key to open new paths in the search — a search which must be an imperative not only for researchers but also for states and organisations world-wide.

References

1) N. Cherry, Natural Hazards **26** (2002), 279.
2) L. G. Salford, A. Brun, J. Eberhardt, L. Malmgren and B. Persson, in *Interaction Mechanism of Low-Level Electromagnetic Fields in Living Systems*, ed. B. Nordén and C. Ramel (Oxford University Press, Oxford, 1992), p. 251.
3) L. G. Salford, A. Brun, K. Sturesson, J. Eberhardt and B. Persson, Microscopy Research and Technique **27** (1994), 535.
4) L. G. Salford, B. Persson and A. Brun, in *Non-Thermal effects of RF Electromagnetic Fields*, ed. J. H. Bernhardt, R. Matthes and M. H. Repacholi (International Commission on Non-Ionizing Radiation Protection, Munich, 1997), p. 131.
5) L. G. Salford,B. Persson, L. Malmgren and A. Brun, in *Téléphonie Mobile - Effets Potentiels sur la Santé des Ondes Électromagnétiques de Haute Fréquence*, ed. M. Pietteur (Embourg, Belgium, 2001), p. 141.
6) B. Persson, L. Salford and A. Brun, Wireless Networks **3**, 455.
M. Peyrard and A. R. Bishop, Phys. Rev. Lett. **62** (1997), 2755.
7) L. G. Salford, A. E. Brun, J. L. Eberhardt, L. Malmgren and B. R. R. Persson, Environmental Health Perspectives **111** (2003), 881.
8) J. Eberhardt, B. R. R. Persson, L. Malmgren, A. Brun and L. G. Salford, "Blood-brain barrier permeability and nerve cell damage in the rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones", (submitted manuscript).
9) H. Nittby, G. Grafström, D. P. Tian, L. Malmgren, A. Brun, B. R. R. Persson, L. G. Salford and J. Eberhardt, Bioelectromagnetics (2008a), published on line Dec. 2007.
10) I. Y. Belyaev, C. B. Koch, O. Terenius, K. Roxstrom-Lindquist, L. O. Malmgren, W. H.

Sommer, L. G. Salford and B. R. Persson, Bioelectromagnetics **27** (2006), 295.
11) H. Nittby, M. Krogh, G. Grafström, H. Berlin, G. Rehn, J. Eberhardt, L. Malmgren, B. R. R. Persson, B. Widegren and L. G. Salford, "Exposure to global system for mobile communications at 1800 MHz significantly changes gene expression in rat hippocampus and cortex", (submitted manuscript).
12) R. Shivers, M. Kavaliers, G. Teskey, F. Prato and R. Pelletier, Neuroscience Lett. **76** (1987), 25.
13) C. L. M. Bauréus-Koch, M. Sommarin, B. R. R. Persson, L. G. Salford and J. L. Eberhardt, Bioelectromagnetics **24** (2003), 395.
14) S. M. Chitanvis, J. Polymer Science Part B-Polymer Physics **44** (2006), 2740.
15) G. S. Edwards, C. C. Davis, J. D. Saffer and M. Swicord, Phys. Rev. Lett. **53** (1984), 1284.
16) V. L. Golo, J. Exp.Theor. Phys. **101** (2005), 372.
17) E. W. Prohofsky, Bioelectromagnetics **25** (2004), 441.
18) C. T. Zhang, Phys. Rev. A **35** (1987), 886; Phys. Rev. A **40** (1989), 2148.
19) R. J. P. Williams, J. R. Soc. Interface **4** (2007), 1049.
20) M. Balser and C. Wagner, Nature **188** (1960), 638.
21) W. O. Schumann, Z. Naturforsch. **7a** (1952), 149.
22) P. V. Bliokh, A. P. Nicholaenko and Yu. Fillipov, in *IEE Electromagnetic Waves Series 8* (P. Peregrinus Ltd., Stevenage, 1980).
23) D. D. Sentman, Radio Science **22** (1987), 595.
24) D. D. Sentman, in *Handbook of Atmospheric Electrodynamics*, vol. I, ed. H. Volland (CRC Press, Boca Raton, 1995).
25) R. E. Holzer and D. E. Deal, Nature **177** (1956), 536.
26) T. E. Dennis, M. J. Rayner and M. M. Walker, Proc. Biol. Sci. **274** (2007), 1153.
27) P. Galland and A. Pazur, J. Plant Res. **118** (2005), 371.
28) F. Halberg, G. Cornélissen, P. Regal, K. Otsuka, Z. Wang, G. S. Katinas, J. Siegelova, P. Homolka, P. Prikryl, S. M. Chibisov, D. C. Holley, H. W. Wendt, C. Bingham, S. L. Palm, R. P. Sonkowsky, R. B. Sothern, E. Pales, M. Mikulecky, R. Tarquini, F. Perfetto, R. Salti, C. Maggioni, R. Jozsa, A. A. Konradov, E. V. Kharlitskaya, M. Revillam, C. Wan, M. Herold, E. V. Syutkina, A. V. Masalov, P. Faraone, R. B. Singh, R. K. Singh, A. Kumar, R. Singhs, S. Sundaram, T. Sarabandi, G. Pantaleoni, Y. Watanabe, Y. Kumagai, D. Gubin, K. Uezono, A. Olah, K. Borer, E. A. Kanabrockia, S. Bathina, E. Haus, D. Hillman, O. Schwartzkopff, E. E. Bakken and M. Zeman, Biomed Pharmacother. **58** (2004), Suppl 1, S150.
29) P. Volpe, Photochem. Photobiol. Sci. **2** (2003), 637.
30) F. I. Komarov, V. N. Oraevski ĭ, Iu. P. Sizov, L. B. Tsirul'nik, Kh. D. Kanonidi, I. B. Ushakov, P. M. Shalimov, M. V. Kimlyk and D. V. Glukhov, Heliogeophysical Factors and Aviation Accidents **43** (1998), 742.
31) G. Villoresi, T. K. Breus, L. I. Dorman, N. Iuchi and S. I. Rapoport, Biofizika **40** (1995), 983, (Article in Russian).
32) R. Coray, P. Krähenbühl, M. Reiderer, D. Stoll and G. Neubauer, *Immissionen in Salzburg. Bundesamt für Metrologie und Akkreditierung* (Lindenweg 50, CH-3003 Bern-Wabern, 2002).
33) G. Hyland, Lancet **356** (2000), 1833.
34) L. G. Salford, H. Nittby, A. Brun, G. Grafström, J. L. Eberhardt, L. Malmgren and B. R. R. Persson, The Environmentalist **27** (2007), 493.
35) H. Nittby, G. Grafström, J. L. Eberhardt, L. Malmgren, A. Brun, B. R. R. Persson and L. G. Salford, Electromagnetic Biology and Medicine (2008b). Article accepted for publication.
36) M. Kundi K. Mild, L. Hardell and M. O. Mattsson, J. Toxicol. Environ. Health B: Crit. Rev. **7** (2004), 351.
37) L. Hardell, M. Carlberg and K. H. Mild, Environmental Research **100** (2006a), 232.
38) F. Vecchio, C. Babiloni, F. Ferreri, G. Curcio, R. Fini, C. Del Percio and P. M. Rossini, Eur. J. Neuroscience **25** (2007), 1908.
39) L. G. Salford, A. Brun, J. L. Eberhardt and B. R. R. Persson, Bioelectrochem Bioenerg **30** (1993), 293.
40) W. E. Thomas, Brain Res. Rev. **31** (1999), 42.

41) W. H. Oldendorf, M. E. Cornford and W. J. Brown, Ann. Neurol. **1** (1977), 409.
42) J. F. Ghersi-Egea, A. Minn and G. Siest, Life Sciences **42** (1988), 2515.
43) T. E. O. Sokrab, B. B. Johansson, H. Kalimo and Y. Olsson, Acta Neuropathology **75** (1988), 557.
44) W. R. Adey, in *Interaction Mechanism of Low-Level Electromagnetic Fields in Living Systems*, ed. B. Nordén and C. Ramel (Oxford University Press, Oxford, 1992), p. 47.
45) J. Van Hese, L. Martens, D. De Zutter, C. De Wagter, L. Malmgren, B. R. R. Persson and L. G. Salford, IEEE Transactions on Electromagnetic Compatibility **34** (1991), 292.
46) L. Martens, J. Van Hese, D. De Sutter, C. De Wagter, L. O. G. Malmgren, B. R. R. Persson and L. G. Salford, Bioelectrochem Bioenerg **30** (1993), 73.
47) R. B. Stagg, L. H. Havel3rd, K. Pastorian, C. Cain, W. R. Adey and C. V. Byus, Radiat. Res. **155** (2001), 584.
48) K. Fritze, C. Sommer, B. Schmitz, G. Mies, K. -A. Hossmann, M. Kiessling and C. Wiessner, Acta Neuropathologica **94** (1997), 465.
49) F. Töre, P. E. Dulou, E. Haro, B. Veyret and P. Aubineau, *Proc. the 5th International congress of the EBEA, Helsinki, Finland* (2001), p. 43; *Proc. the 24th annual meeting of the BEMS* (2002), p. 61.
50) D. Leszczynski, S. Joenväärä, J. Reivinen and R. Kuokka, Differentiation **70** (2002), 120.
51) R. Nylund and D. Leszcynski, Proteomics **4** (2004), 1359.
52) K. Fredriksson, H. Kalimo, C. Nordborg, B. B. Johansson and Y. Olsson, Acta Neuropathologica (Berl) **76** (1988), 227.
53) T. S. Salahuddin, H. Kalimo, B. B. Johansson and Y. Olsson, Acta Neuropathologica (Berl) **76** (1988), 1.
54) A. Mihày and B. Bozo'ky, Acta Neuropathology **127** (1984a), 251; Acta Neuropathology **65** (1984b), 471.
55) T. E. Sokrab, H. Kalimo and B. B. Johansson, Epilepsia **31** (1990), 1.
56) S. Eimerl and M. Schramm, Neuroscience Lett. **130** (1991), 125.
57) B. Hassel, E. G. Iversen and F. Fonnum, Neuroscience Lett. **167** (1994), 29.
58) A. Ilhan, A. Gurel, F. Armuten, S. Kamisifi, M. Iraz, O. Akyol and S. Ozen, Clinica Chimica Acta **340** (2004), 153.
59) S. Lőnn, A. Ahlbom, P. Hall and M. Feychting, Epidemiology **15** (2004), 653.
60) L. Hardell, M. Carlberg and K. H. Mild, Int. Arch. Occup. Environ. Health **79** (2006b), 630.
61) J. P. Blanchard and C. F. Blackman, Bioelectromagnetics **15** (1994), 217.
62) G. E. Kass and S. Orrenius, Environ. Health Perspect **107** (1999) (Suppl. 1), 25.
63) C. Fanelli, S. Coppola, R. Barone, C. Colussi, G. Gualandi, P. Volpe and L. Ghibelli, FASEB J. **1** (1999), 95.
64) V. V. Lednev, Bioelectromagnetics **12** (1991), 71.
65) V. V. Lednev, Biophysics **41** (1996), 224.
66) C. F. Blackman, J. P. Blanchard, S. G. Benane and D. E. House, Bioelectromagnetics **15** (1994), 239.
67) R. K. Adair, Bioelectromagnetics **13** (1992), 231.
68) V. V. Lednev, *Electricity and Magnetism in Biology and Medicine* (1993), p. 550.
69) W. J. Sun, Y. N. Yu, H. Chiang, Y. D. Fu and D. Q. Lu, Electro- and Magnetobiology **20** (2001a), 207.
70) W. J. Sun, H. Chiang, Y. D. Fu, Y. N. Yu, H. Y. Xie and D. Q. Lu, Electro- and magnetobiology **20** (2001b), 415.
71) W. J. Sun, Y. N. Yu, H. Chiang, Y. D. Fu, H. Y. Xie and D. Q. Lu, Electro- and Magnetobiology **21** (2002a), 97.
72) W. J. Sun, H. Chiang, Y. Fu, D. Lu and Z. Xu, Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi **20** (2002b), 246, (Article in Chinese).
73) W. R. Adey, Prog. Clin. Biol. Res. **257** (1988), 81.
74) J. S. Russell, *Report on Waves, 14th meeting of the British Association for the Advancement of Science* (BAAS, 1844).
75) A. S. Davydov and N. I. Kislukha, Phys. Status Solidi B **59** (1973), 465; Phys. Status Solidi B **75** (1976), 735.
76) A. S. Davydov, Studia Biophysica **62** (1977), 1.
77) H. Fröhlich, Int. J. Quantum Chem. **23** (1983), 1589.

78) S. R. Hameroff and R. C. Watt, J. Theor. Biology **98** (1982), 549.
79) E. Del Guidice, S. Doglia, M. Milani and G. Vitiello, Nucl. Phys. B **275** (1986), 185.
80) L. A. Amos and A. Klug, J. Cell Science **14** (1974), 523.
81) E. Abdalla, B. Maroufi, B. C. Melgar and M. B. Sedra, Physica A **301** (2001), 169.
82) L. A. Amos and D. Schlieper, *Microtubules and maps. Fibrous Proteins: Muscle and Molecular Motors* (Elsevier Academic Press Inc., San Diego, 2005).
83) T. Heimburg and A. D. Jackson, Proc. Natl. Acad. Sci. USA **102** (2005), 9750.
84) T. Heimburg and A. D. Jackson, Biophysical J. **92** (2007), 3159.
85) C. Del Seppiaa, S. Ghionea, P. Luschib, K. P. Ossenkopp, E. Choleris and M. Kavaliers, Neuroscience and Biobehavioral Reviews **31** (2007), 619.
86) N. M. Shupak, F. S. Prato and A. W. Thomas, Neuroscience Lett. **363** (2004), 157.
87) L. G. Salford, M. Krogh, G. Grafstöm, H. Nittby, G. Rehn, H. Berlin, J. L. Eberhardt, L. Malmgren, R. B. R. Persson and B. Widegren, *Abstract for the 4th International Workshop: "Biological Effects of Electromagnetic Fields", 16–20 Oct. 2006, Crete, Greece.*
88) S. Lee, D. Johnson, K. Dunban, H. Dong, X. Ge, Y. C. Kim, C. Wing, ,N. Jayathilaka, N. Emmanuela, C. Q. Zhou, H. L. Gerber, C. C. Tseng and S. M. Wang, FEBS Lett. **579** (2005), 4829.
89) S. Pacini, M. Ruggiero, I. Sardi, S. Aterini, F. Gulisano and M. Fulisano, Oncol. Res. **13** (2002), 19.
90) D. Remondini, R. Nylund, J. Reivinen, F. Poulletier de Gannes, B. Veyret, I. Lagroye, E. Haro, M. A. Trillo, M. Capri, C. Franceschi, K. Schlatterer, R. Gminski, R. Fitzner, R. Tauber, J. Schuderer, N. Kuster, D. Leszczynski, F. Bersani and C. Maercker, Proteomics **6** (2006), 4745.
91) R. Zhao, S. Z. Zhang, G. D. Yao, D. Q. Lu, J. Huai and Z. P. Xu, Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi **24** (2006), 222, (Article in Chinese).
92) W. Saenger, *Principles of nucleid acid structure* (Springer, Berlin, 1988).
93) S. W. Englander, N. R. Kallenbach, A. J. Heeger, J. A. Krumhansl and S. Litwin, Proc. Natl. Acad. Sci. USA **77** (1980), 7222.
94) R. V. Polozov and L. V. Yakushevich, J. Theor. Biology **130** (1988), 423.
95) E. W. Prohofsky, Phys. Rev. A **38** (1988), 1538.
96) G. F. Zhou and C. T. Zhang, Physica Scripta **43** (1991), 347.
97) G. Gaeta, J. Biol. Phys. **24** (1999), 81.
98) L. V. Yakushevich, Quarterly Reviews of Biophysics **26** (1993), 201; Physica D **79** (1994), 77.
99) T. Dauxois and M. Peyrad, Phys. Rev. Lett. **70** (1993), 3935.
100) T. Dauxois, M. Peyrad and A. R. Bishop, Phys. Rev. E **47** (1993a), 684.
101) T. Dauxois, M. Peyrad and P. A. Bishop, Phys. Rev. E **47** (1993b), R44.
102) T. Dauxois, M. Peyrad and C. R. Willis, Physica D **57** (1992), 267.
103) M. Peyrard, T. Dauxois, H. Hoyet and C. R. Willis, Physica D **68** (1993), 104.
104) M. Peyrard and A. P. Bishop, Phys. Rev. Lett. **62** (1989), 2755.
105) N. Theodorakopoulos, T. Dauxois and M. Peyrard, Phys. Rev. Lett. **85** (2000), 6.

http://stopsmartmeters.org.uk/live-blood-analysis-observable-effects-of-rfmw-radiation-from-smart-meter/

Live Blood Analysis – Observable Effects of RF/MW Radiation from 'Smart' Meter

The following clip is an excerpt from upcoming documentary, Take Back Your Power – a critical investigation of the Smart Metering phenomenon and Smart Grid. It shows observable effects of the RF/MW radiation from a Smart Meter on human blood cells using dark-field microscopy.

Please watch and and take action to share this information as widely as possible.

More than 5,000 studies now show RF/MW radiation to be harmful to human biology, animals and plants. Acute and chronic exposure to RF (radio-frequency) and MW (microwave) radiation can, even at very low power-densities, lead to not only the negative health effects shown in this video, but calcium ion damage in cells, endothelial cell dysfunction, nitric oxide depletion, oxidative stress, melatonin disruption, blood-brain-barrier leakage, DNA damage, sperm damage and more.

Glucose metabolism changes within the brain are observable after just minutes of cell phone use.

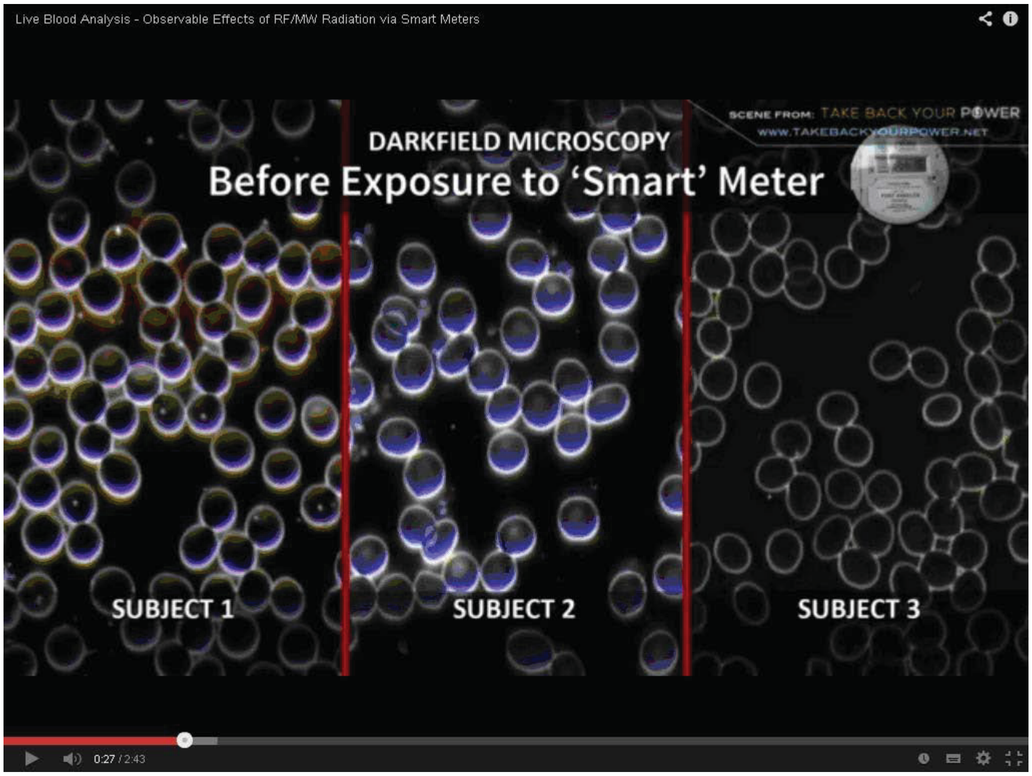
The mechanisms for damage from non-thermal, non-ionising radiation exposure are now becoming clear.

Unfortunately, so-called "safety" thresholds maintained in the UK are woefully out of date and obsolete, permitting a deluge of highly-profitable, RF-emitting technologies to be introduced into our lives. Whilst attempts by campaigners in every country are being made to stem and reverse the tide of these environmental toxins, you can take positive action to protect yourself and your family by limiting your own exposure to RF and MW-emitting devices, such as Smart Meters, cell phones, WiFi routers and devices, wireless baby monitors, wireless alarm systems, wireless games consoles, etc.

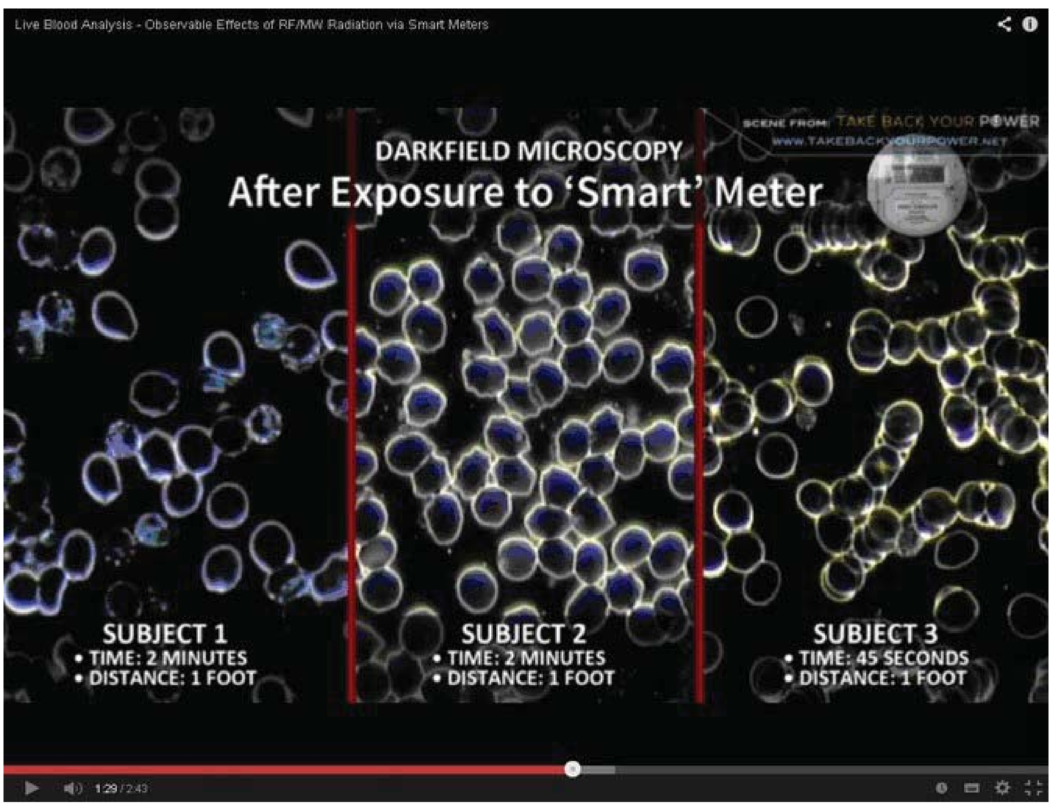
For more information on Smart Meters, visit www.StopSmartMeters.org.uk. To watch the Take Back Your Power documentary, from 5 September 2013, visit www.StopSmartMeters.org.uk/film

You have the lawful right to refuse a Smart Meter. www.DontSmartMeter.me

Please alert your neighbours, friends and families to this important information.



Live Blood Analysis - Observable Effects of RF/MW Radiation via Smart Meters
SCENE FROM: TAKE BACK YOUR POWER
WWW.TAKEBACKYOURPOWER.NET
DARKFIELD MICROSCOPY
Before Exposure to 'Smart' Meter
SUBJECT 1
SUBJECT 2
SUBJECT 3
0:27 / 2:43



Live Blood Analysis - Observable Effects of RF/MW Radiation via Smart Meters
SCENE FROM: TAKE BACK YOUR POWER
WWW.TAKEBACKYOURPOWER.NET
DARKFIELD MICROSCOPY
After Exposure to 'Smart' Meter
SUBJECT 1
• TIME: 2 MINUTES
• DISTANCE: 1 FOOT
SUBJECT 2
• TIME: 2 MINUTES
• DISTANCE: 1 FOOT
SUBJECT 3
• TIME: 45 SECONDS
• DISTANCE: 1 FOOT
1:29 / 2:43

http://stopsmartmeters.org.uk/www-scribd-comdoc79928679the-who-iarc-listing-of-rfr-as-a-possible-human-carcinogen/

Email from Dr Robert Baan, the principal author of the 2011 IARC Monograph on the carcinogenicity of radiofrequency radiation, in which he interprets the 2B classification of RFR as applicable to all form of RFR exposures, including Smart Meters and Wi-Fi:

Subject: EMF Class 2B Classification

Dear Dr Hudson,

Thank you for your message, which was forwarded to me, and to which I would like to respond as follows. The IARC Working Group classified "Radiofrequency Electromagnetic Fields" (RF-EMF) as possibly carcinogenic to humans (Group 2B). The information that formed the main basis for this evaluation was found in epidemiological studies on cell-phone use, where a slightly increased risk for glioma (amalignant form of brain cancer) and acoustic neuroma (a non-cancerous type) was reported among heavy users. There were some indications of increased cancer among radar-maintenance workers(occupational exposure), but no reliable data from studies among, e.g., people living close to base-station antennas, radio/TV towers, etc (environmental exposure). Although the key information came from mobile telephone use, the Working Group considered that the three types of exposure entail basically the same type of radiation, and decided to make an overall evaluation on RF-EMF, covering the whole radiofrequency region of the electromagnetic spectrum.In support of this, information from studies with experimental animals showed that effects on cancer incidence and cancer latency were seen with exposures to different frequencies within the RF region. So the classification 2B, possibly carcinogenic, holds for all types of radiation within the radio frequency part of the electromagnetic spectrum, including the radiation emitted by base-station antennas, radio/TV towers, radar, Wi-Fi, smart meters, etc. An important point is the radiation level. The exposure from cellular phones (personal exposure) is substantially higher and much more focused (usually on the brain) than exposures from radio/tv towers, antennas, or Wi-Fi. I hope this is useful. Thank you for your interest in our work.

Sincerely yours,
Robert A Baan PhD The IARC Monographs IARC, Lyon, FRANCE

SAGE
Associates
ENVIRONMENTAL CONSULTANTS

Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters

Sage Associates
Santa Barbara, CA
USA

January 1, 2011

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SUMMARY OF FINDINGS

This Report has been prepared to document radiofrequency radiation (RF) levels associated with wireless smart meters in various scenarios depicting common ways in which they are installed and operated.

The Report includes computer modeling of the range of possible smart meter RF levels that are occurring in the typical installation and operation of a single smart meter, and also multiple meters in California. It includes analysis of both two-antenna smart meters (the typical installation) and of three-antenna meters (the collector meters that relay RF signals from another 500 to 5000 homes in the area).

RF levels from the various scenarios depicting normal installation and operation, and possible FCC violations have been determined based on both time-averaged and peak power limits (Tables 1 - 14).

Potential violations of current FCC public safety standards for smart meters and/or collector meters in the manner installed and operated in California are predicted in this Report, based on computer modeling (Tables 10 – 17).

Tables 1 – 17 show power density data and possible conditions of violation of the FCC public safety limits, and Tables 18 – 33 show comparisons to health studies reporting adverse health impacts.

FCC compliance violations are likely to occur under normal conditions of installation and operation of smart meters and collector meters in California. Violations of FCC safety limits for uncontrolled public access are identified at distances within 6" of the meter. Exposure to the face is possible at this distance, in violation of the time-weighted average safety limits (Tables 10-11). FCC violations are predicted to occur at 60% reflection (OET Equation 10 and 100% reflection (OET Equation 6) factors*, both used in FCC OET 65 formulas for such calculations for time-weighted average limits. Peak power limits are not violated at the 6" distance (looking at the meter) but can be at 3" from the meter, if it is touched.

This report has also assessed the potential for FCC violations based on two examples of RF exposures in a typical residence. RF levels have been calculated at distances of 11" (to represent a nursery or bedroom with a crib or bed against a wall opposite one or more meters); and at 28" (to represent a kitchen work space with one or more meters installed on the kitchen wall).

FCC compliance violations are identified at 11" in a nursery or bedroom setting using Equation 10* of the FCC OET 65 regulations (Tables 12-13). These violations are predicted to occur where there are multiple smart meters, or one collector meter, or one collector meter mounted together with several smart meters.

FCC compliance violations are not predicted at 28” in the kitchen work space for 60% or for 100% reflection calculations. Violations of FCC public safety limits are predicted for higher reflection factors of 1000% and 2000%, which are not a part of FCC OET 65 formulas, but are included here to allow for situations where site-specific conditions (highly reflective environments, for example, galley-type kitchens with many highly reflective stainless steel or other metallic surfaces) may be warranted.*

*FCC OET 65 Equation 10 assumes 60% reflection and Equation 6 assumes 100% reflection. RF levels are also calculated in this report to account for some situations where interior environments have highly reflective surfaces as might be found in a small kitchen with stainless steel or other metal counters, appliances and furnishings. This report includes the FCC’s reflection factors of 60% and 100%, and also reflection factors of1000% and 2000% that are more in line with those reported in Hondou, 2001; Hondou, 2006 and Vermeeren et al, 2010. The use of a 1000% reflection factor is still conservative in comparison to Hondou, 2006. A 1000% reflection factor is 12% (or 121 times as high) a factor for power density compared to Hondou et al, 2006 prediction of 1000 times higher power densities due to reflection. A 2000% reflection factor is only 22% (or 441 times) that of Hondou’s finding that power density can be as high as 2000 times higher.

In addition to exceeding FCC public safety limits under some conditions of installation and operation, smart meters can produce excessively elevated RF exposures, depending on where they are installed. With respect to absolute RF exposure levels predicted for occupied space within dwellings, or outside areas like patios, gardens and walk-ways, RF levels are predicted to be substantially elevated within a few feet to within a few tens of feet from the meter(s).

For example, one smart meter at 11” from occupied space produces somewhere between 1.4 and 140 microwatts per centimeter squared (uW/cm2) depending on the duty cycle modeled (Table 12). Since FCC

OET 65 specifies that continuous exposure be assumed where the public cannot be excluded (such as is applicable to one's home), this calculation produces an RF level of 140 uW/cm2 at 11" using the FCCs lowest reflection factor of 60%. Using the FCC's reflection factor of 100%, the figures rise to 2.2 uW/cm2 – 218 uW/cm2, where the continuous exposure calculation is 218 uW/cm2 (Table 12). These are very significantly elevated RF exposures in comparison to typical individual exposures in daily life. Multiple smart meters in the nursery/bedroom example at 11" are predicted to generate RF levels from about 5 to 481 uW/cm2 at the lowest (60%) reflection factor; and 7.5 to 751 uW/cm2 using the FCCs 100% reflection factor (Table 13). Such levels are far above typical public exposures.

RF levels at 28" in the kitchen work space are also predicted to be significantly elevated with one or more smart meters (or a collector meter alone or in combination with multiple smart meters). At 28" distance, RF levels are predicted in the kitchen example to be as high as 21 uW/cm2 from a single meter and as high as 54.5 uW/cm2 with multiple smart meters using the lower of the FCCs reflection factor of 60% (Table 14). Using the FCCs higher reflection factor of 100%, the RF levels are predicted to be as high as 33.8 uW/cm2 for a single meter and as high as 85.8 uW/cm2 for multiple smart meters (Table 14). For a single collector meter, the range is 60.9 to 95.2 uW/cm2 (at 60% and 100% reflection factors, respectively) (from Table 15).

Table 16 illustrates predicted violations of peak power limit (4000 uW/cm2) at 3" from the surface of a meter. FCC violations of peak power limit are predicted to occur for a single collector meter at both 60% and 100%

reflection factors. This situation might occur if someone touches a smart meter or stands directly in front.

Consumers may also have already increased their exposures to radiofrequency radiation in the home through the voluntary use of wireless devices (cell and cordless phones), PDAs like BlackBerry and iPhones, wireless routers for wireless internet access, wireless home security systems, wireless baby surveillance (baby monitors), and other emerging wireless applications.

Neither the FCC, the CPUC, the utility nor the consumer know what portion of the allowable public safety limit is already being used up or pre-empted by RF from other sources already present in the particular location a smart meter may be installed and operated.

Consumers, for whatever personal reason, choice or necessity who have already eliminated all possible wireless exposures from their property and lives, may now face excessively high RF exposures in their homes from smart meters on a 24-hour basis. This may force limitations on use of their otherwise occupied space, depending on how the meter is located, building materials in the structure, and how it is furnished.

People who are afforded special protection under the federal Americans with Disabilities Act are not sufficiently acknowledged nor protected. People who have medical and/or metal implants or other conditions rendering them vulnerable to health risks at lower levels than FCC RF limits may be particularly at risk (Tables 30-31). This is also likely to hold true for other subgroups, like children and people who are ill or taking medications, or are elderly, for they have different reactions to pulsed RF. Childrens' tissues absorb RF differently and can absorb more RF than adults (Christ et al, 2010; Wiart et al, 2008). The elderly and those on some medications respond more acutely to some RF exposures.

Safety standards for peak exposure limits to radiofrequency have not been developed to take into account the particular sensitivity of the eyes, testes and other ball shaped organs. There are no peak power limits defined for the eyes and testes, and it is not unreasonable to imagine situations where either of these organs comes into close contact with smart meters and/or collector meters, particularly where they are installed in multiples (on walls of multi-family dwellings that are accessible as common areas).

In summary, no positive assertion of safety can be made by the FCC, nor relied upon by the CPUC, with respect to pulsed RF when exposures are chronic and occur in the general population. Indiscriminate exposure to environmentally ubiquitous pulsed RF from the rollout of millions of new RF sources (smart meters) will mean far greater general population exposures, and potential health consequences. Uncertainties about the existing RF environment (how much RF exposure already exists), what kind of interior reflective environments exist (reflection factor), how interior space is utilized near walls), and other characteristics of residents (age, medical condition, medical implants, relative health, reliance on critical care equipment that may be subject to electronic interference, etc) and unrestrained access to areas of property where meter is located all argue for caution.

INTRODUCTION

How Smart Meters Work

This report is limited to a very simple overview of how smart meters work, and the other parts of the communication system that are required for them to transmit information on energy usage within a home or other building. The reader can find more detailed information on smart meter and smart grid technology from numerous sources available on the Internet.

Often called 'advanced metering infrastructure or AMI', smart meters are a part of an overall system that includes a) a mesh network or series of wireless antennas at the neighborhood level to collect and transmit wireless information from all the smart meters in that area back to a utility.

The mesh network (sometimes called a distributed antenna system) requires wireless antennas to be located throughout neighborhoods in close proximity to where smart meters will be placed. Often, a municipality will receive a hundred or more individual applications for new cellular antenna service, which is specifically to serve smart meter technology needs. The communication network needed to serve smart meters is typically separate from existing cellular and data transmission antennas (cell tower antennas). The mesh network (or DAS) antennas are often utility-pole mounted. This part of the system can spread hundreds of new wireless antennas throughout neighborhoods.

Smart meters are a new type electrical meter that will measure your energy usage, like the old ones do now. But, it will send the information back to the utility by wireless signal (radiofrequency/microwave radiation signal) instead of having a utility meter reader come to the property and manually do the monthly electric service reading. So, smart meters are replacements for the older ‘spinning dial’ or analog electric meters. Smart meters are not optional, and utilities are installing them even where occupants do not want them.

In order for smart meters to monitor and control energy usage via this wireless communication system, the consumer must be willing to install power transmitters inside the home. This is the third part of the system and involves placing power transmitters (radiofrequency/microwave radiation emitting devices) within the home on each appliance. A power transmitter is required to measure the energy use of individual appliances (e.g., washing machines, clothes dryers, dishwashers, etc) and it will send information via wireless radiofrequency signal back to the smart meter. Each power transmitter handles a separate appliance. A typical kitchen and laundry may have a dozen power transmitters in total. If power transmitters are not installed by the homeowner, or otherwise mandated on consumers via federal legislation requiring all new appliances to have power transmitters built into them, then there may be little or no energy reporting nor energy savings.

Smart meters could also be installed that would operate by wired, rather than wireless means. Shielded cable, such as is available for cable modem (wired internet connection) could connect smart meters to utilities. However, it is not easy to see the solution to transmit signals from power transmitters (energy use for each appliance) back to the utility.

Collector meters are a special type of smart meter that can serve to collect the radiofrequency/microwave radiation signals from many surrounding buildings and send them back to the utility. Collector meters are intended to collect and re-transmit radiofrequency information for somewhere between 500-5000 homes or buildings. They have three operating antennas compared to two antennas in regular smart meters. Their radiofrequency microwave emissions are higher and they send wireless signal much more frequently. Collector meters can be place on a home or other building like smart meters, and there is presently no way to know which a homeowner or property owner might receive.

Mandate

The California Public Utilities Commission has authorized California's investor-owned utilities (including Pacific Gas & Electric, Southern California Edison Company and San Diego Gas & Electric) to install more than 10 million new wireless* smart meters in California, replacing existing electric meters as part of the federal SmartGrid program.

The goal is to provide a new residential energy management tool. It is intended to reduce energy consumption by providing computerized information to customers about what their energy usage is and how they might reduce it by running appliances during 'off-time' or 'lower load' conditions. Presumably this will save utilities from having to build new facilities for peak load demand. Utilities will install a new smart meter on every building to which electrical service is provided now. In Southern California, that is about 5 million smart meters in three years for a cost of around $1.6 billion dollars. In northern California, Pacific Gas & Electric is slated to install millions of meters at a cost of more than $2.2 billion dollars. If consumers decide to join the program (so that appliances can report energy usage to the utility), they can be informed about using energy during off-use or low-use periods, but only if consumers also agree to install additional wireless power transmitters on appliances inside the home. Each power transmitter is an additional source of pulsed RF that produces high exposures at close range in occupied space within the home.

> *"Proponents of smart meters say that when these meters are teamed up with an in-home display that shows current energy usage, as well as a communicating thermostat and software that harvest and analyze that information, consumers can see how much consumption drives cost -- and will consume less as a result. Utilities are spending billions of dollars outfitting homes and businesses with the devices, which wirelessly send information about electricity use to utility billing departments and could help consumers control energy use."*
>
> Wall Street Journal, April 29, 2009.

The smart meter program is also a tool for load-shedding during heavy electrical use periods by turning utility meters off remotely, and for reducing the need for utility employees to read meter data in the field.

Purpose of this Report

This Report has been prepared to document radiofrequency radiation (RF) levels associated with wireless smart meters in various scenarios depicting common ways in which they are installed and operated.

The Report includes computer modeling of the range of possible smart meter RF levels that are occurring in the typical installation and operation of a single smart meter, and also multiple meters in California. It includes analysis of both two-antenna smart meters (the typical installation) and of three-antenna meters (the collector meters that relay RF signals from another 500 to 5000 homes in the area).

RF levels from the various scenarios depicting normal installation and operation, and possible FCC violations have been determined based on both time-averaged and peak power limits (Tables 1 - 14).

Potential violations of current FCC public safety standards for smart meters and/or collector meters in the manner installed and operated in California are illustrated in this Report, based on computer modeling (Tables 10 – 17).

Tables which present data, possible conditions of violation of the FCC public safety limits, and comparisons to health studies reporting adverse health impacts are summarized (Tables 18 – 33).

The next section describes methodology in detail, but generally this Report provides computer modeling results for RF power density levels for these scenarios, analysis of whether and under what conditions FCC public safety limit violations may occur, and comparison of RF levels produced under these scenarios to studies reporting adverse health impacts with chronic exposure to low-intensity radiofrequency radiation at or below levels produced by smart meters and collector meters in the manner installed and operated in California.

1) Single 'typical' meter - tables showing RF power density at increasing distances in 0.25' (3") intervals outward for single meter (two-antenna meter). Effects of variable duty cycles (from 1% to 90%) and various reflection factors (60%, 100%, 1000% and 2000%) have been calculated.
2) Multiple 'typical' meters - tables showing RF power density at increasing distances as above.
3) Collector meter - tables showing RF power density related to a specialized collector meter which has three internal antennas (one for every 500 or 5000 homes) as above.
4) Collector meter - a single collector meter installed with multiple 'typical' two-antenna meters as above.
5) Tables are given to illustrate the distance to possible FCC violations for time-weighted average and peak power limits (in inches).
6) Tables are given to document RF power density levels at various key distances (11" to a crib in a bedroom; 28" to a kitchen work area; and 6" for a person attempting to read the digital readout of a smart meter, or inadvertently working around a meter.
7) Tables are given to compare RF power density levels with studies reporting adverse health symptoms and effects (and those levels of RF associated with such health effects).
8) Tables are given to compare smart meter and collector meter RF to BioInitiative Report recommended limit (in feet).

Framing Questions

In view of the rapid deployment of smart meters around the country, and the relative lack of public information on their radiofrequency (RF) emission profiles and public exposures, there is a crucial need to provide independent technical information.

There is very little solid information on which decision-makers and the public can make informed decisions about whether they are an acceptable new RF exposure, in combination with pre-existing RF exposures.

On-going Assessment of Radiofrequency Radiation Health Risks

The US NIEHS National Toxicology Program nominated radiofrequency radiation for study as a carcinogen in 1999. Existing safety limits for pulsed RF were termed "not protective of public health" by the Radiofrequency Interagency Working Group (a federal interagency working group including the FDA, FCC, OSHA, the EPA and others). Recently, the NTP issued a statement indicating it will complete its review by 2014 (National Toxicology Program, 2009). The NTP radiofrequency radiation study results have been delayed for more than a decade since 1999 and very little laboratory or epidemiological work has been completed. Thus, he explosion of wireless technologies is producing radiofrequency radiation exposures over massive populations before questions are answered by federal studies about the carcinogenicity or toxicity of low-intensity RF such as are produced by smart meters and other SmartGrid applications of wireless. The World Health Organization and the International Agency for Research on Cancer have not completed their studies of RF (the IARC WHO RF Health Monograph is not expected until at least 2011). In the United States, the National Toxicology Program listed RF as a potential carcinogen for study, and has not released any study results or findings a decade later.

There are no current, relevant public safety standards for pulsed RF involving chronic exposure of the public, nor of sensitive populations, nor of people with metal and medical implants that can be affected both by localized heating and by electromagnetic interference (EMI) for medical wireless implanted devices.

Considering that millions of smart meters are slated to be installed on virtually every electrified building in America, the scope of the question is large and highly personal. Every family home in the country, and every school classroom – every building with an electric meter – is to have a new wireless meter – and thus subject to unpredictable levels of RF every day.

1) Have smart meters been tested and shown to comply with FCC public safety limits (limits for uncontrolled public access)?

2) Are these FCC public safety limits sufficiently protective of public health and safety? This question is posed in light of the last thirty years of international scientific investigation and public health assessments documenting the existence of bioeffects and adverse health effects at RF levels far below current FCC standards. The FCC's standards have not been updated since 1992, and did not anticipate nor protect against chronic exposures (as opposed to acute exposures) from low-intensity or non-thermal RF exposures, particularly pulsed RF exposures.

3) What demonstration is there that wireless smart meters will comply with existing FCC limits, as opposed to under strictly controlled

conditions within government testing laboratories?

4) Has the FCC been able to certify that compliance is achievable under real-life use conditions including, but not limited to:

- In the case where there are both gas and electric meters on the home located closely together.

- In the case where there is a "bank" of electric and gas meters, on a multi-family residential building such as on a condominium or apartment building wall. There are instances of up to 20 or more meters located in close proximity to occupied living space in the home,in the classroom or other occupied public space.

- In the case where there is a collector meter on a home that serves the home plus another 500 to 5000 other residential units in the area, vastly increasing the frequency of RF bursts.

- In the case where there is one smart meter on the home but it acts as a relay for other local neighborhood meters. What about 'piggybacking' of other neighbors' meters through yours? How can piggybacking be reasonably estimated and added onto the above estimates?

- What about the RF emissions from the power transmitters? Power transmitters installed on appliances (perhaps 10-15 of them per home) and each one is a radiofrequency radiation transmitter.

- How can the FCC certify a system that has an unknown number of such transmitters per home, with no information on where they are placed?
  - Where people with medical/metal implants are present? (Americans with Disabilities Act protects rights)

5) What assessment has been done to determine what pre-existing conditions of RF exposure are already present. On what basis can compliance for the family inside the residence be assured, when there is no verification of what other RF sources exist on private property? How is the problem of cumulative RF exposure properly assessed (wireless routers, wireless laptops, cell phones, PDAs, DECT or other active-base cordless phone systems, home security systems, baby monitors, contribution of AM, FM, television, nearby cell towers, etc).

6) What is the cumulative RF emissions worst-case profile? Is this estimate in compliance?

7) What study has been done for people with metal implants* who require protection under Americans with Disabilities Act? What is known about how metal implants can intensity RF, heat tissue and result in adverse effects below RF levels allowed for the general public. What is known about electromagnetic interference (EMI) from spurious RF sources in the environment (RFID scanners, cell

towers, security gates, wireless security systems, wireless communication devices and routers, wireless smart meters, etc)

*Note: There are more than 20 million people in the US who need special protection against such exposures that may endanger them. High peak power bursts of RF may disable electronics in some critical care and medical implants. We already have reports of wireless devices disabling deep brain stimulators in Parkinson's patients and there is published literature on malfunctions with critical care equipment.

PUBLIC SAFETY LIMITS FOR RADIOFREQUENCY RADIATION

The FCC adopted limits for Maximum Permissible Exposure (MPE) are generally based on recommended exposure guidelines published by the National Council on Radiation Protection and Measurements (NCRP) in "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," (NCRP, 1986).

In the United States, the Federal Communications Commission (FCC) enforces limits for both occupational exposures (in the workplace) and for public exposures. The allowable limits are variable, according to the frequency transmitted. Only public safety limits for uncontrolled public access are assessed in this report.

Maximum permissible exposures (MPE) to radiofrequency electromagnetic fields are usually expressed in terms of the plane wave equivalent power density expressed in units of milliwatts per square centimeter (mW/cm2) or alternatively, absorption of RF energy is a function of frequency (as well as body size and other factors). The limits vary with frequency. Standards are more restrictive for frequencies at and below 300 MHz. Higher intensity RF exposures are allowed for frequencies between 300 MHz and 6000 MHz than for those below 300 MHz.

In the frequency range from 100 MHz to 1500 MHz, exposure limits for field strength and power density are also generally based on the MPE limits found in Section 4.1 of "*IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*," ANSI/IEEE C95.1-1992 (IEEE, 1992, and approved for use as an American National Standard by the American National Standards Institute (ANSI).

US Federal Communications Commission (FCC) Exposure Standards

Table 1, Appendix A FCC LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm2)	Averaging Time $[E]^2$ $[H]^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	$(900/f_2)$*	6
30-300	61.4	0.163	1.0	6
300-1500			f/300	6
1500-100,000			5	6

B) FCC Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm2)	Averaging Time $[E]^2$ $[H]^2$ or S (minutes)

0.3-3.0	614	1.63	(100)*	30
3.0-30	824/f	2.19/f	(180/f^2)*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

f = frequency in MHz *Plane-wave equivalent power density

NOTE 1: ***Occupational/controlled*** limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

NOTE 2: ***General population/uncontrolled*** exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure. Source: FCC Bulletin OET 65 Guidelines, page 67 OET, 1997.

In this report, the public safety limit for a smart meter is a combination of the individual antenna frequency limits and how much power output they create. A smart meter contains two antennas. One transmits at 915 MHz and the other at 2405 MHz. They can transmit at the same time, and so their effective radiated power is summed in the calculations of RF power density. Their combined limit is 655 uW/cm2. This limit is calculated by formulas from Table 1, Part B and is proportionate to the power output and specific safety limit (in MHz) of each antenna.

For the collector meter, with it's three internal antennas, the combined public safety limit for time-averaged exposure is 571 MHz (a more restrictive level since it includes an additional 824 MHz antenna that has a lower limit than either the 915 MHz or the 2405 MHz antennas). In a collector meter, only two of the three antennas can transmit simultaneously (the 915 MHz LAN and the GSM 850 MHz (from the FCC Certification Exhibit titled RF Exposure Report for FCC ID: SK9AMI-2A). The proportionate power output of each antenna plus the safety limit for each antenna frequency combines to give a safety limit for the collector meter of 571 uW/cm2. Where one collector meter is combined with multiple smart meters, the combined limit is weighted upward by the additional smart meters' contribution, and is 624 uW/cm2.

Continuous Exposure

FCC Bulletin OET 65 guidelines require the assumption of continuous exposure in calculations. Duty cycles offered by the utilities are a fraction of continuous use, and significantly diminish predictions of RF exposure.

At present, there is no evidence to prove that smart meters are functionally unable to operate at higher duty cycles that some utilities have estimated (estimates vary from 1% to 12.5% duty cycle, and as high as 30%). Confirming this is the Electric Power Research Institute (EPRI) in its "Perspective on Radio-Frequency Exposure Associated with Residential Automatic Meter Reading Technology (EPRI, 2010) According to EPRI:

> *"The technology not only provides a highly efficient method for obtaining usage data from customers, but it also can provide up-to-the-minute information on consumption patterns since the meter reading devices can be programmed to provide data as often as needed."* Emphasis added

The FCC Bulletin OET 65 guidelines specify that continuous exposure (defined by the FCC OET 65 as 100% duty cycle) is required in calculations where it is not possible to control exposures to the general public.

> *"It is important to note that for general population/uncontrolled exposures it is often not possible to control exposures to the extent that averaging times can be applied. In those situations, it is often necessary to assume continuous exposure."* (emphasis added)
>
> FCC Bulletin OET 65, p, 10

> ***"Duty factor***. *The ratio of pulse duration to the pulse period of a periodic pulse train. Also, may be a measure of the temporal transmission characteristic of an intermittently transmitting RF source such as a paging antenna by dividing average transmission duration by the average period for transmissions. A duty factor of 1.0*

corresponds to continuous operation."
(emphasis added)

FCC Bulletin OET 65, p, 2

This provision then specifies duty cycles to be increased to 100%.

The FCC Guidelines (OET 65) further address cautions that should be observed for uncontrolled public access to areas that may cause exposure to high levels of RF.

Re-radiation

The foregoing also applies to high RF levels created in whole or in part by re-eradiation. A convenient rule to apply to all situations involving RF radiation is the following:

(1) Do not create high RF levels where people are or could reasonably be expected to be present, and (2) [p]revent people from entering areas in which high RF levels are necessarily present.

(2) Fencing and warning signs may be sufficient in many cases to protect the general public. Unusual circumstances, the presence of multiple sources of radiation, and operational needs will require more elaborate measures.

(3) Intermittent reductions in power, increased antenna heights, modified antenna radiation patterns, site changes, or some combination of these may be necessary, depending on the particular situation.

FCC OET 65, Appendix B, p. 79

Fencing, distancing, protective RF shielded clothing and signage warning occupants not to use portions of their homes or properties are not feasible nor desirable in public places the general public will spend time (schools, libraries, cafes, medical offices and clinics, etc) These mitigation strategies may be workable for RF workers, but are unsuited and intolerable for the public.

Reflections

A major, uncontrolled variable in predicting RF exposures is the degree to which a particular location (kitchen, bedroom, etc) will reflect RF energy created by installation of one or more smart meters, or a collector meter and multiple smart meters. The reflectivity of a surface is a measure of the amount of reflected radiation. It can be defined as the ratio of the intensities of the reflected and incident radiation. The reflectivity depends on the angle of incidence, the polarization of the radiation, and the electromagnetic properties of the materials forming the boundary surface. These properties usually change with the wavelength of the radiation. The reflectivity of polished metal surfaces is usually quite high (such as stainless steel and polished metal surfaces typical in kitchens, for example).

Reflections can significantly increase localized RF levels. High uncertainty exists about how extensive a problem this may create in routine installations of smart meters, where the utility and installers have no idea what kind of reflectivity is present within the interior of buildings.

Reflections in Equation 6 and 10 of the FCC OET Bulletin 65 include rather minimal reflection factors of 100% and 60%, respectively. This report includes higher reflection factors in line with published studies by Hondou et al, 2006, Hondou, 2002 and Vermeeren et al, 2010. Reflection factors are modeled at 1000% and 2000% as well as at 60% and 100%, based on published scientific evidence for highly reflective environments. Hondou (2002) establishes that power density can be higher than conventional formulas predict using standard 60% and 100% reflection factors.

> *"We show that this level can reach the reference level (ICNIRP Guideline) in daily life. This is caused by the fundamental properties of electromagnetic field, namely, reflection and additivity. The level of exposure is found to be much higher than estimated by conventional framework of analysis that assumes that the level rapidly decreases with the inverse square distance between the source and the affected person."*
>
> *"Since the increase of electromagnetic field by reflective boundaries and the additivity of sources has not been recognized yet, further detailed studies on various situations and the development of appropriate regulations are required."*

Hondou et al (2006) establishes that power densities 1000 times to 2000 times higher than the power density predictions from computer modeling (that does not account properly for reflections) can be found in daily living situations. Power density may not fall off with distance as predicted by formulas using limited reflection factors. The RF hot spots created by reflection can significantly increase RF exposures to the public, even above current public safety limits.

> *"We confirm the significance of microwave reflection reported in our previous Letter by experimental and numerical studies. Furthermore, we show that 'hot spots' often emerge in reflective areas, where the local exposure level is much higher than average."*

"Our results indicate the risk of 'passive exposure' to microwaves."

"The experimental values of intensity are consistently higher than predicted values. Intensity does not even decrease with distance from the source."

"We further confirm the existence of microwave 'hotspots', in which he microwaves are 'localized'. The intensity measured at one hot spot 4.6 m from the transmitter is the same as that at 0.1 m from the transmitter in the case with out reflection (free boundary condition). Namely, the intensity at the hot spot is increased by ***approximately 2000 times*** *by reflection."* Emphasis added

"To confirm our experimental findings of the greater-than-predicted intensity due to reflection, as well as the hot spots, we performed two numerical simulations...". " intensity does not monotonically decrease from the transmitter, which is in clear contrast to the case without reflection."

"The intensity at the hot spot (X, Y, Z) = 1.46, -0.78, 105) around 1.8 m from the transmitter in the reflective boundary condition is ***approximately 1000 times higher*** *than that at the same position in the free boundary condition. The result of the simulation is thus consistent with our experiments, although the values differ owing to the different conditions imposed by computational limits."*

Emphasis added

"(t)he result of the experiment is also reproduced: a greater than predicted intensity due to reflection, as well as the existence of hot spots."

"In comparison with the control simulation using the free boundary condition, we find that the power density at the hot spot is increased ***by approximately a thousand times*** *by reflection."*

Emphasis added

Further, the author comments that:

"*we may be passively exposed beyond the levels reported for electro-*

medical interference and health risks."

"Because the peak exposure level is crucial in considering electro-medical interference, interference (in) airplanes, and biological effects on human beings, we also need to consider the possible peak exposure level, or 'hot spots', for the worst-case estimation."

Reflections and re-radiation from common building material (tile, concrete, stainless steel, glass, ceramics) and highly reflective appliances and furnishings are common in kitchens, for example. Using only low reflectivity FCC equations 6 and 10 may not be informative. Published studies underscore how use of even the highest reflection coefficient in FCC OET Bulletin 65 Equations 6 and 10 likely underestimate the potential for reflection and hot spots in some situations in real-life situations.

This report includes the FCC's reflection factors of 60% and 100%, and also reflection factors of 1000% and 2000% that are more in line with those reported in Hondou, 2001; Hondou, 2006 and Vermeeren et al, 2010. The use of a 1000% reflection factor in this report is still conservative in comparison to Hondou, 2006. A 1000% reflection factor is 12% of Hondou's larger power density prediction (or 121 times, rather than 1000 times)/ The 2000% reflection factor is 22% of Hondou's figure (or 441 times in comparison to 2000 times higher power density in Hondou, 2006).

Peak Power Limits

In addition to time-averaged public safety limits that require RF exposures to be time-averaged over a 30 minute time period, the FCC also addresses peak power exposures. The FCC refers back to the ANSI/IEEE C95.1-1992 standard to define what peak power limits are.

The ANSI/IEEE C95.1-1999 standard defines peak power density as "*the maximum instantaneous power density occurring when power is transmitted*." (p. 4) Thus, there is a second method to test FCC compliance that is not being assessed in any FCC Grants of Authorization.

> "*Note that although the FCC did not explicitly adopt limits for peak power density, guidance on these types of exposures can be found in Section 4.4 of the ANSI/IEEE C95.1-1992 standard.*"
>
> *Page 10, OET 65*

The ANSI/IEEE limit for peak power to which the FCC refers is:

> *"For exposures in uncontrolled environments, the peak value of the mean squared field strengths should not exceed 20 times the square of the allowed spatially averaged values (Table 2) at frequencies below 300 MHz, or the equivalent power density of 4 mW/cm2 for f between 300 MHz and 6 GHz".*

The peak power exposure limit is 4000 uW/cm2 for all smart meter frequencies (all transmitting antennas) for any instantaneous RF exposure of 4 milliwatts/cm2 (4 mW/cm2) or higher which equals 4000 microwatts/cm2 (uW/cm2).

This peak power limit applies to all smart meter frequencies for both the smart meter (two-antenna configuration) and the collector meter (three-antenna configuration). All these antennas are within the 300 MHz to 6 GHz frequency range where the 4000 uW/cm2 peak power limit applies

(Table 3, ANSI/IEEE C95.1-1999, page 15).

Smart meters emit frequencies within the 800 MHz to 2400 MHz range.

Exclusions

This peak power limit applies to all parts of the body with the important exception of the eyes and testes.

The ANSI/IEEE C95.1-1999 standard specifically excludes exposure of the eyes and testes from the peak power limit of 4000 uW/cm2*. However, nowhere in the ANSI/IEEE nor the FCC OET 65 documents is there a lower, more protective peak power limit given for the eyes and testes (see also Appendix C).

> *"The following relaxation of power density limits is allowed for exposure of all parts of the body except the eyes and testes." (p.15)*
>
> *"Since most exposures are not to uniform fields, a method has been derived, based on the demonstrated peak to whole-body averaged SAR ratio of 20, for equating nonuniform field exposure and partial body exposure to an equivalent uniform field exposure. This is used in this standard to allow relaxation of power density limits for partial body exposure, except in the case of the eyes and the testes." (p.20)*
>
> *"In the case of the eyes and testes, direct relaxation of power density limits is not permitted."(p. 30)*

*Note: This leaves unanswered what instantaneous peak power is permissible from smart meters. The level must be below 4000 uW/cm2. This report shows clearly that smart meters can create instantaneous peak power exposures where the face (eyes) and body (testes) are going to be in close proximity to smart meter RF pulses. RF levels at and above 4000 uW/cm2 are likely to occur if a person puts their face close to the smart meter to read data in real time. The digital readout of the smart meter requires close inspection, particularly where there is glare or bright sunlight, or low lighting conditions. Further, some smart meters are installed inside buildings within inches of occupied space, virtually guaranteeing exposures that may violate peak power limits. Violations of peak power limits are likely in these circumstances where there is proximity within about 6" and highly reflective surfaces or metallic objects. The eyes and testes are not adequately protected by the 4000 uW/cm2 peak power limit, and in the cases described above, may be more vulnerable to damage (Appendix C for further discussion).

METHODOLOGY

Radiofrequency fields associated with SMART Meters were calculated following the methodology described here. Prediction methods specified in Federal Communications Commission, Office of Engineering and Technology Bulletin 65 Edition 97-01, August 1997 were used in the calculations.[1]

Section 2 of FCC OET 65 provides methods to determine whether a given facility would be in compliance with guidelines for human exposure to RF radiation. We used equation (3)

$$S = \frac{P \times G \times \partial}{4 \times \pi \times R^2} = \frac{EIRP \times \partial}{4 \times \pi \times R^2} = \frac{1.64 \times ERP \times \partial}{4 \times \pi \times R^2}$$

where:

S = power density (in $\mu W/cm^2$)
P = power input to the antenna (in W)
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
∂ = duty cycle of the transmitter (percentage of time that the transmitter actually transmits over time)
R = distance to the center of radiation of the antenna

EIRP = PG
ERP = 1.64 EIRP

where:

EIRP = is equivalent (or effective) isotropically radiated power referenced to an isotropic radiator
ERP = is equivalent (or effective) radiated power referenced to a half-wave dipole radiator

Analysis input assumptions

1. SMART Meters [SK9AMI-4] have two RF transmitters (antennas) and are the type of smart meters typically installed on most buildings. They contain two antennas that transmit RF signals (916 MHz LAN and 2405 MHz Zigbee). The antennas CAN transmit simultaneously, and thus the maximum RF exposure is determined by the summation of power densities (from the FCC Certification Exhibit titled RF Exposure Report for FCC ID: SK9AMI-4).

   Model SK9AMI-4 transmits on 915 MHz is designated as LAN Antenna Gain for each model.

   a. Transmitter Power Output (TPO) used is as shown on the grant issued by the Telecommunications Certification Body (TCB).
   b. Antenna gain in dBi (decibels compared to an isotropic radiator) used comes from the ACS Certification Exhibit.

2. Collector Meters [SK9AMI-2A] have three RF transmitters (antennas)

and are installed where the utility needs them to relay RF signals from surrounding smart meters in a neighborhood. Collector meters contain a third antenna (GSM 850 MHz, 915 MHz LAN and 2405 MHz Zigbee). Collector meters can be placed on any building where a collector meter is needed to relay signals from the surrounding area. Estimates of the number of collector meters varies between one per 500 to one per 5000 smart meters. Collector meters will thus ‘piggyback’ the RF signals of hundreds or thousands of smart meters through the one collector meter. In a collector meter, only two of the three antennas can transmit simultaneously (the 915 MHz LAN and the GSM 850 MHz (from the FCC Certification Exhibit titled RF Exposure Report for FCC ID: SK9AMI-2A).

3. The Cell Relay transmitting at 2480 MHz is <u>not</u> on most meters and <u>not</u> considered in this analysis.

    a. Transmitter Power Output (TPO) used is as shown on the grant issued by the Telecommunications Certification Body (TCB).

    b. Antenna gain in dBi (decibels compared to an isotropic radiator) used comes from the ACS Certification Exhibit.

ERP (Effective Radiated Power) used in the computer modeling here is calculated using the TPO and antenna gain established for each model

Red figures used to Calculate ERP		**ACS and TCB Certification data sheet**							
		SK9AMI-2A				**SK9AMI-4**			
		ACS			TCB	**ACS**			TCB
Radio	Frequency	dBm	Watts	dBi	Watts	dBm	Watts	dBi	Watts
GSM	850	31.8	1.5136	-1.0					
LAN	915	21.92	0.1556	3.0		24.27	0.2673	**2.2**	**0.267**
LAN	916								0.257
GSM	1900	28.7	0.7413	1.0					
Register	2405	18.71	0.0743	**1.0**	**0.074**	19.17	0.0826	4.4	
Cell Relay	2480	-14.00	0.00004	4.00					

Assumptions: TPO per TCB , Antenna Gain per ACS Certification

ERP Calculation: **Bold** figures are used for single meter ERP in modeling							
Type	TPO	dBi	dB	Mult	ERP	Freq	
1900 GSM	0.741	1.0	-1.15	0.77	0.5689	1900	
850 GSM	1.514	-1.0	-3.15	0.48	0.7328	850	Model
RFLAN	0.267	2.2	0.05	1.01	**0.2704**	915	SK9AMI-4
ZIG BEE	0.074	1.0	-1.15	0.77	**0.0570**	2405	SK9AMI-2A

Reflection Factor

This equation is modified with the inclusion of a ground reflection factor as recommended by the FCC. The ground reflection factor accounts for possible ground reflections that could enhance the resultant power density. A 60% (0.6) enhancement would result in a 1.6 (1 + 0.6) increase of the field strength or a $2.56 = (1.6)^2$ increase in the power density. Similar increases for larger enhancements of the field strength are calculated by the square of the original field plus the enhancement percentage. [2.3.4]

Reflection Factors:

$60\% = (1 + 0.6)^2 = 2.56$ times
$100\% = (1 + 1)^2 = 4$ times
$1000\% = (1 + 10)^2 = 121$ times
$2000\% = (1 + 20)^2 = 441$ times

Duty Cycle

How frequently SMART Meters can and will emit RF signals from each of the antennas within the meters is uncertain, and subject to wide variations in estimation. For this reason, and because FCC OET 65 mandates a 100% duty cycle (continuous exposure where the public cannot be excluded) the report gives RF predictions for all cases from 1% to 100% duty cycle at 10% intervals. The reader can see the variation in RF emissions predicted at various distances from the meter (or bank of meters) using this report at all duty cycles. Thus, for purposes of this report, duty cycles have been estimated from infrequent to continuous. Duty cycles for SMART Meters were calculated at:

Duty cycle ∂:

1% 50%

5%	60%
10%	70%
20%	80%
30%	90%
40%	100%

Continuous Exposure

FCC Bulletin OET 65 and the ANSI/IEEE C95.1-1992, 1999 requires that continuous exposure be calculated for situations where there is uncontrolled public access. Continuous exposure in this case means reading the tables at 100% duty cycle.

> *"Another feature of the exposure guidelines is that exposures, in terms of power density, E2 or H2, may be averaged over certain periods of time with the average not to exceed the limit for continuous exposure.*[11]
>
> *"As shown in Table 1 of Appendix A, the averaging time for occupational/controlled exposures is 6 minutes, while the averaging time for general population/uncontrolled exposures is 30 minutes. It is important to note that for general population/uncontrolled exposures it is often not possible to control exposures to the extent that averaging times can be applied. In those situations, it is often necessary to assume continuous exposure*." (FCC OET 65, Page 15)

Calculation Distances in Tables (3-inch increments)

Calculations were performed in 3-inch (.25 foot) increments from the antenna center of radiation. Calculations have been taken out to a distance of 96 feet from the antenna center for radiation for each of the conditions above. The antenna used for the various links in a SMART Meter is assumed to be at the center of the SMART Meter from front to back – approximately

3 inches from the outer surface of the meter.

Calculations have also been made for a typical nursery and kitchen. In the nursery it has been assumed that the baby in his or her crib that is located next to the wall where the electric SMART Meters are mounted. The closest part of the baby's body can be as close as 11 inches* from the meter antenna. In the kitchen it has been assumed that a person is standing at the counter along the wall where the electric SMART Meters are mounted. In that case the closest part of the adult's body can be located as close to the meter antenna as 28 inches.

The exposure limits are variable according to the frequency (in megahertz). Table 1, Appendix A show exposure limits for occupational (Part A) and uncontrolled public (Part B) access to radiofrequency radiation such as is emitted from AM, FM, television and wireless sources.

* Flush-mounted main electric panels that house smart meters are commonly installed; placing smart meters 5" 6" closer to occupied space than box-mounted main electric panels that sit outward on exterior building walls. Assumptions on spacing are made for flush-mounted panels.

Conditions Influencing Radiofrequency Radiation Level Safety

The location of the meter in relation to occupied space, or outside areas of private property such as driveways, walk-ways, gardens, patios, outdoor play areas for children, pet shelters and runs, and many typical configurations can place people in very close proximity to smart meter wireless emissions. In many instances, smart meters may be within inches or a few feet of occupied space or space that is used by occupants for daily activities.

Factors that influence how high RF exposures may be include, but are not limited to where the meter is installed in relation to occupied space, how often the meters are emitting RF pulses (duty cycle), and what reflective surfaces may be present that can greatly intensify RF levels or create 'RF hot spots' within rooms, and so on. In addition, there may be multiple wireless meters installed on some multi-family residential buildings, so that a single unit could have 20 or more electric meters in close proximity to each other, and to occupants inside that unit. Finally, some meters will have higher RF emissions, because – as collector units – their purpose is to collect and resend the RF signals from many other meters to the utility. A collector meter is estimated to be required for every 500 to 5000 buildings. Each collector meter contains three, rather than two transmitting antennas. This means higher RF levels will occur on and inside buildings with a collector meter, and significantly more frequent RF transmissions can be expected. At present, there is no way to predict whose property will be used for installation of collector meters.

People who are visually reading the wireless meters 'by sight' or are visually inspecting and/or reading the digital information on the faceplate may have their eyes and faces only inches from the antennas.

Current standards for peak power limit do not have limits to protect the eyes and testes from instantaneous peak power from smart meter exposures, yet relevant documents identify how much more vulnerable these organs are, and the need for such safety limits to protect the eyes and testes.

No Baseline RF Assessment

Smart meter and collector meter installation are taking place in an information vacuum. FCC compliance testing takes place in an environment free of other sources of RF, quite unlike typical urban and some rural environments. There is no assessment of baseline RF conditions already present (from AM, FM, television and wireless communication facilities (cell towers), emergency and dispatch wireless, ham radio and other involuntary RF sources. Countless properties already have elevated RF exposures from sources outside their own control.

Consumers may also have already increased their exposures to radiofrequency radiation in the home through the voluntary use of wireless devices (cell and cordless phones), PDAs like BlackBerry and iPhones, wireless routers for wireless internet access, wireless home security systems, wireless baby surveillance (baby monitors), and other emerging wireless applications.

Neither the FCC, the CPUC, the utility nor the consumer know what portion of the allowable public safety limit is already being used up or pre-empted by RF from other sources already present in the particular location a smart meter may be installed and operated.

Consumers, for whatever personal reason, choice or necessity who have already eliminated all possible wireless exposures from their property and lives, may now face excessively high RF exposures in their homes from smart meters. This may force limitations on use of their otherwise occupied space, depending on how the meter is located, building materials in the structure, and how it is furnished.

RESULTS, FINDINGS AND CONCLUSIONS

The installation of wireless 'smart meters' in California can produce significantly high levels of radiofrequency radiation (RF) depending on many factors (location of meter(s) in relation to occupied or usable space, duty cycle or frequency of RF transmissions, reflection and re-radiation of RF, multiple meters at one location, collector meters, etc).

Power transmitters that will relay information from appliances inside buildings with wireless smart meters produce high, localized RF pulses. Any appliance that contains a power transmitter (for example, dishwashers, washers, dryers, ranges and ovens, convection ovens, microwave ovens, flash water heaters, refrigerators, etc) will create another 'layer of RF signals' that may cumulatively increase RF exposures from the smart meter(s).

It should be emphasized that no single assertion of compliance can adequately cover the vast number of site-specific conditions in which smart meters are installed. These site-specific conditions determine public exposures and thus whether they meet FCC compliance criteria.

Tables in this report show either distance to an FCC safety limit (in inches) or they show the predicted (calculated) RF level at various distances in microwatts per centimeter squared (uW/cm2).

Both depictions are useful to document and understand RF levels produced by smart meters (or multiple smart meters) and by collector meters (or collections of one collector and multiple smart meters).

Large differences in the results of computer modeling occur in this report by bracketing the uncertainties (running a sufficient number of computer scenarios) to account for variability introduced by possible duty cycles and possible reflection factors.

FCC equations from FCC OET 65 provide for calculations that incorporate 60% or 100% reflection factors. Studies cited in this report document higher possible reflections (in highly reflective environments) and support the inclusion of higher reflection factors of 1000% and 2000% based on Vermeeren et al, 2010, Hondou et al, 2006 and Hondou, 2002. Tables in the report provide the range of results predicted by computer modeling for duty cycles from 1% to 100%, and reflection factors of 60%, 100%, 1000%, and 2000% for comparison purposes. FCC violations of time-weighted average calculations and peak power limit calculations come directly from FCC OET 65 and from ANSI/IEEE c95.1-1992, 1999. Duty cycle (or how frequently the meters will produce RF transmissions leading to elevated RF exposures) is uncertain, so the full range of possible duty cycles are included, based on best available information at this date.

- Tables 1-2 show radiofrequency radiation (RF) levels at 6" (to represent a possible face exposure). These are data tables.
- Tables 3-4 show RF levels at 11" (to represent a possible nursery/bedroom exposure). These are data tables.
- Tables 5-6 show RF levels at 28" to represent a possible kitchen work space exposure. These are data tables.
- Tables 7-9 show the distance to the FCC violation level for time-weighted average limits and for peak power limits (in inches). These are data tables.
- Tables 10-15 show where FCC violations may occur at the face, in the nursery or in the kitchen scenarios. These are colored tables highlighting where FCC violations may occur under all scenarios.
- Tables 16-29 show comparisons of smart meter RF levels with studies that report adverse health impacts from low-intensity, chronic exposure to similar RF exposures. These are colored tables highlighting where smart meter RF levels exceed levels associated with adverse health impacts in published scientific studies.
- Tables 30-31 show RF levels in comparison to Medtronics advisory limit for MRI exposures to radiofrequency radiation at 0.1 W/Kg or about 250 uW/cm2. These are colored tables highlighting where smart meter RF levels may exceed those recommended for RF exposure.
- Tables 32-33 show RF levels from smart meters in comparison to the BioInitiative Report recommendation of 0.1 uW/cm2 for chronic exposure to pulsed radiofrequency radiation.

Findings

RF levels from the various scenarios depicting normal installation and operation, and possible FCC violations have been determined based on both time-averaged and peak power limits (Tables 1 - 14).

Potential violations of current FCC public safety standards for smart meters and/or collector meters in the manner installed and operated in California are illustrated in this Report, based on computer modeling (Tables 10 – 17).

Tables that present data, possible conditions of violation of the FCC public safety limits, and comparisons to health studies reporting adverse health impacts are summarized (Tables 18 – 33).

Where do predicted FCC violations occur for the 655 uW/cm2 time-averaged public safety limit at the face at 6" distance from the meter?

Table 10 shows that for <u>one smart meter</u>, no violations are predicted to occur at 60% or 100% reflection factor at any duty cycle, but violations are predicted to occur with nearly all scenarios using either 1000% or 2000% reflection factors.

Table 10 also shows that for <u>multiple smart meters</u>, FCC violations are predicted to occur at 60% reflection factor @ 50% to 100% duty cycles; and also at 100% reflection factor @ 30% to 100% duty cycle. All scenarios using either 1000% or 2000% reflection factors indicate FCC violations can occur (or conservatively at 12% to 22% of those in Hondou et al, 2006).

Table 11 shows that for <u>one collector meter</u>, one violation occurs at 60% @ 100% duty cycle; and at 100% reflection factor for duty cycles between 60% and 100%. Violations are predicted to occur at all scenarios using either 1000% or 2000% reflection factors.

Table 11 also shows that for <u>one collector meter plus multiple smart meters</u>, FCC violations can occur at 60%reflection factor @ 40% to 100% duty cycles; and also at 100% reflection factor @ 30% to 100% duty cycle. All scenarios using either 1000% or 2000% reflection factors indicate FCC violations can occur.

Where do predicted FCC violations occur for the 655 uW/cm2 time-averaged public safety limit in the nursery crib at 11" distance?

Table 12 shows that for <u>one smart meter</u>, no violations are predicted to occur at 60% or 100% reflection factor at any duty cycle, but violations would be predicted with nearly all scenarios using either 1000% or 2000% reflection factors.

Table 12 also shows that for <u>multiple smart meters</u>, no FCC violations are predicted to occur at 60% reflection factor at any duty cycle; and also at 100% reflection factor @ 90% and 100% duty cycle. All scenarios using either 1000% or 2000% reflection factors indicate FCC violations can occur.

Table 13 shows that for <u>one collector meter</u>, one violation occurs at 100% reflection @100% duty cycle. No violations at 60% reflection are predicted. Violations are predicted to occur at all scenarios using 1000% reflection except @ 1% duty cycle. All 2000% reflection scenarios indicate FCC violations can occur.

Table 13 shows that for <u>one collector meter plus multiple smart meters</u>, FCC violations are not predicted to occur at 60% reflection factor. At 100% reflection factor, violations are predicted at 60% to100% duty cycles. FCC violations are predicted for all1000% and 2000% reflection factors with the exception of 1000% reflection at 1% duty cycle.

Where do predicted FCC violations occur for the 655 uW/cm2 time-averaged public safety limit in the kitchen work space at 28" distance?

Table 14 shows that for <u>one smart meter</u>, no violations are predicted to occur at 60% or 100% reflection factor at any duty cycle. Violations would be predicted with scenarios of 1000% reflection @ 70% to 100% duty cycles and at 2000% reflection factor @ 20% to 100% duty cycles.

Table 14 also shows that for <u>multiple smart meters</u>, no FCC violations are predicted to occur at 60% or at the 100% reflection factors at any duty cycle. Violations are predicted at 1000% reflection factor @ 70% to 100% duty cycles and at 2000% reflection factor @20% to 100% duty cycles.

Table 15 shows that for <u>one collector meter</u>, one violation occurs at 100% reflection @100% duty cycle. No violations at 60% reflection are predicted. Violations are predicted to occur at all scenarios using 1000% reflection except @ 1% duty cycle. All 2000% reflection scenarios indicate FCC violations can occur.

Table 15 shows that for <u>one collector meter plus multiple smart meters</u>, FCC violations are not predicted to occur at 60% or at 100% reflection factors at any duty cycle. At 1000% reflection factor, violations are predicted at 30% to 100% duty cycles.   FCC violations are also predicted at 2000% reflection factor @10 to 100% duty cycles.

Where can peak power limits be violated? The peak power limit of 4000 uW/cm2 instantaneous public safety limit at 3" distance? This limit may be exceeded wherever smart meters and collector meters (face plate or any portion within 3" of the internal antennas can be accessed directly by the public.

Table 16 shows that for <u>one smart meter</u>, no violations are predicted to occur at 60% or 100% reflection factor at any duty cycle. Peak power limit violations would be predicted with scenarios of 1000% reflection @ 10% to 100% duty cycles and at 2000% reflection factor @ 10% to 100% duty cycles.

Table 16 also shows that for <u>multiple smart meters</u>, peak power limit violations are predicted to occur at 60% reflection @ 60% to 100% duty cycle and for 100% reflection @ 40% to 100% duty cycles. Violations are predicted at 1000% reflection factor @ 10% to 100% duty cycles and at 2000% reflection factor @1% to 100% duty cycles.

Table 17 shows that for <u>one collector meter</u>, peak power limit violations are predicted to occur at 60% reflection @80% to 100% duty cycles and at 100% reflection @ 50% to 100% duty cycles.   Violations of peak power limit are predicted to occur at all scenarios using 1000% reflection except @ 1%; and for 2000% reflection violations of peak power limit are predicted at all duty cycles.

Table 17 shows that for one collector meter plus multiple smart meters, peak power limit violations are predicted to occur at 60% @ 40% to 100% and 100% reflection @ 30% to 100% duty cycles. At 1000% and 2000% reflection factors, peak power limit violations are predicted at all duty cycles.

Where are RF levels associated with inhibition of DNA repair in human stem cells at 92.5 uW/cm2 exceeded the in the nursery crib at 11" distance?

Table 18 shows that for one smart meter, RF exposures associated with inhibition of DNA repair in human stem cells are predicted to occur at 60% reflection factor@ 70% to 100% duty cycles, and at 100% reflection factor @ 50% to 100% duty cycles. All scenarios using either 1000% or 2000% reflection factors exceed these RF exposures except 1000% at 1% duty cycle.

Table 18 also shows that for multiple smart meters, RF exposures associated with inhibition of DNA repair in human stem cells are predicted to occur at 60% reflection factor@ 20% to 100% duty cycles, and at 100% reflection factor @ 20% to 100% duty cycles. All scenarios using either 1000% or 2000% reflection factors exceed these RF exposure levels except 1000% at 1% duty cycle.

Table 19 shows that for one collector meter, RF exposures associated with inhibition of DNA repair in human stem cells are predicted to occur at 60% reflection factor@ 30% to 100% duty cycles, and at 100% reflection factor @ 20% to 100% duty cycles. All scenarios using either 1000% or 2000% reflection factors exceed these RF exposure levels.

Table 19 shows that for one collector meter plus multiple smart meters, RF exposures associated with inhibition of DNA repair in human stem cells are predicted to occur at 60% reflection factor@ 20% to 100% duty cycles, and at 100% reflection factor @ 10% to 100% duty cycles. All scenarios using either 1000% or 2000% reflection factors exceed these RF exposure levels.

Where are RF levels associated with pathological leakage of the blood-brain barrier at 0.4 – 8 uW/cm2 exceeded the in the nursery crib at 11" distance?

Table 20 shows that for <u>one smart meter</u>, RF exposures associated with pathological leakage of the blood-brain barrier at 8 uW/cm2 are predicted to occur at 60% reflection factor@ 10% to 100% duty cycles, and at 100% reflection factor @ 5% to 100% duty cycles. RF levels at 0.4 uW/cm2 (the lower end of the range) are exceeded at all duty cycles and at all reflection factors in the nursery in the crib.

Table 20 also shows that for <u>multiple smart meters</u>, RF exposures associated with pathological leakage of the blood-brain barrier at 8 uW/cm2 are predicted to occur at 60% reflection factor@ 5% to 100% duty cycles, and at 100% reflection factor @ 5% to 100% duty cycles. RF levels at 0.4 uW/cm2 (the lower end of the range) are exceeded at all duty cycles and at all reflection factors in the nursery in the crib.

Table 21 shows that for <u>one collector meter</u>, RF exposures associated with pathological leakage of the blood-brain barrier at 8 uW/cm2 are predicted to occur at 60% reflection factor@ 5% to 100% duty cycles, and at 100% reflection factor @ 5% to 100% duty cycles. RF levels at 0.4 uW/cm2 (the lower end of the range) are exceeded at all duty cycles and at all reflection factors in the nursery in the crib.

Table 21 shows that for <u>one collector meter plus multiple smart meters, </u>.RF exposures associated with pathological leakage of the blood-brain barrier at 8 uW/cm2 are predicted to occur at 60% reflection factor@ 5% to 100% duty cycles, and at 100% reflection factor @ 1% to 100% duty cycles. RF levels at 0.4 uW/cm2 (the lower end of the range) are exceeded at all duty cycles and at all reflection factors in the nursery in the crib.

Where are RF levels associated with adverse neurological symptoms, cardiac problems and increased cancer risk exceeded in the nursery crib at 11" distance?

Table 22 shows that for <u>one smart meter</u>, RF exposures associated with adverse neurological symptoms above 0.1 uW/cm2 are exceeded at all duty cycles and at all reflection factors in the nursery in the crib.

Table 22 shows that for <u>multiple smart meters</u>, RF exposures associated with adverse neurological symptoms above 0.1 uW/cm2 are exceeded at all duty cycles and at all reflection factors in the nursery in the crib.

Table 23 shows that for one collector meter, RF exposures associated with adverse neurological symptoms above 0.1 uW/cm2 are exceeded at all duty cycles and at all reflection factors in the nursery in the crib.

Table 23 shows that for one collector meter plus multiple smart meterss, RF exposures associated with adverse neurological symptoms above 0.1 uW/cm2 are exceeded at all duty cycles and at all reflection factors in the nursery in the crib.

Where are RF levels associated with inhibition of DNA repair in human stem cells at 92.5 uW/cm2 exceeded the in the kitchen work space at 28" distance?

Table 24 shows that for one smart meter, RF levels do not exceed those associated with inhibition of DNA repair at 60% or 100% reflection factor at any duty cycle. RF levels are exceeded at 1000% @ 10% to 100% duty cycles; and at 2000% reflection factor @ 5% to 100% duty cycles.

Table 24 also shows that for multiple smart meters, RF levels do not exceed those associated with inhibition of DNA repair at 60% or 100% reflection factor at any duty cycle. RF levels are exceeded at 1000% @ 5% to 100% duty cycles; and at 2000% reflection factor @ 1% to 100% duty cycles.

Table 25 shows that for one collector meter, RF levels do not exceed those associated with inhibition of DNA repair at 60% at any duty cycle; at 100% reflection factor they are exceeded at 70% to 100% duty cycles.. RF levels are exceeded at 1000% @ 5% to 100% duty cycles; and at 2000% reflection factor @ 1% to 100% duty cycles.

Table 25 shows that for one collector meter plus multiple smart meters, RF levels exceed those associated with inhibition of DNA repair at 60% reflection@100% duty cycle; at 100% reflection factor they are exceeded at 70% to 100% duty cycles.. RF levels are exceeded at 1000% @ 5% to 100% duty cycles; and at 2000% reflection factor @ 1% to 100% duty cycles.

Where are RF levels associated with pathological leakage of the blood-brain barrier and neuron death at 0.4 – 8 uW/cm2 risk in the kitchen work space at 28" distance?

Table 26 shows that for one smart meter, RF exposures associated with pathological leakage of the blood-brain barrier at 8 uW/cm2 are predicted to occur at 60% reflection factor@ 40% to 100% duty cycles, and at 100% reflection factor @ 30% to 100% duty cycles, and at all 1000% and 2000% reflections. RF levels at 0.4 uW/cm2 (the lower end of the range) are exceeded at all duty cycles and at all reflection factors in the kitchen work space except at 1% duty cycle for 60% and 100% reflections.

Table 26 also shows that for multiple smart meters, RF exposures associated with pathological leakage of the blood-brain barrier at 8 uW/cm2 are predicted to occur at 60% reflection factor@ 30% to 100% duty cycles, and at 100% reflection factor @ 20% to 100% duty cycles, and at all 1000% and 2000% reflections. RF levels at 0.4 uW/cm2 (the lower end of the range) are exceeded at all duty cycles and at all reflection factors in the kitchen.

Table 27 shows that for one collector meter, RF exposures associated with pathological leakage of the blood-brain barrier at 8 uW/cm2 are predicted to occur at 60% reflection factor@ 20% to 100% duty cycles, and at 100% reflection factor @ 10% to 100% duty cycles. RF levels at 0.4 uW/cm2 (the lower end of the range) are exceeded at all duty cycles and at all reflection factors in the kitchen work space.

Table 27 shows that for one collector meter plus multiple smart meters, .RF exposures associated with pathological leakage of the blood-brain barrier at 8 uW/cm2 are predicted to occur at 60% reflection factor@ 20% to 100% duty cycles, and at 100% reflection factor @ 20% to 100% duty cycles. RF levels at 0.4 uW/cm2 (the lower end of the range) are exceeded at all duty cycles and at all reflection factors in the kitchen work space.

Where are RF levels associated with adverse neurological symptoms, cardiac problems and increased cancer risk in the kitchen work space at 28" distance?

Table 28 shows that for one smart meter, RF exposures associated with adverse neurological symptoms above 0.1 uW/cm2 are exceeded at all duty cycles and at all reflection factors in the kitchen work space.

Table 28 shows that for multiple smart meters, RF exposures associated with adverse neurological symptoms above 0.1 uW/cm2 are exceeded at all duty cycles and at all reflection factors in the kitchen work space.

Table 29 shows that for one collector meter, RF exposures associated with adverse neurological symptoms above 0.1 uW/cm2 are exceeded at all duty cycles and at all reflection factors in the kitchen work space.

Table 29 shows that for one collector meter plus multiple smart meterss, RF exposures associated with adverse neurological symptoms above 0.1 uW/cm2 are exceeded at all duty cycles and at all reflection factors in the kitchen work space.

Where do RF levels exceed the Medtronics Safety Advisory?

Table 30: At no duty cycles for either 60% or 100% reflection factors; between 10% and 100% duty factors for 1000% and between 5% and 100% duty factors for 2000% reflection (for one smart meter).

Table 30: At 60% reflection @ 60% to 100% duty cycle; and at 100% reflection @ 40% to 100% duty cycle; at 1000% reflection @ 5% to 100% duty cycle and for all duty cycles at 2000% reflection (for multiple smart meters).

Table 31: At 60% reflection @ 70% to 100% duty cycle; at 100% reflection at 50% to 100% duty cycles; at 1000% reflection @ 5% to 100% and at all duty cycles for 2000% reflection (for one collector meter).

Table 31: At 60% reflection @ 40% to 100% duty cycle; at 100% reflection at 30% to 100% duty cycles; and at all duty cycles for both 1000% reflection and for 2000% reflection (for one collector meter plus three smart meters).

Where are RF levels associated with smart meters in all their configurations (one meter, multiple smart meters, one collector meter, one collector plus multiple smart meters) above those recommended in the BioInitiative Report

(2007)?

Tables 32 and 33 depict the distance from the center of radiation for the smart meter(s) and collector meter scenarios in feet. The distances (in feet) at which RF levels exceed the BioInitiative Report recommended limit of 0.1 uW/cm2 is as small as 3.4' (one smart meter at 60% reflection and 1% duty cycle). At 60% reflection and 100% duty cycle, the distance to the BioInitiative recommended limit increases to 34 feet for one smart meter.

When multiples of smart meters are considered, the shortest distance to where the BioInitiative Report recommended limit is exceeded is 9.7 feet (for 60% reflection @ 1% duty cycle). It increases to 97' @100% duty cycle for multiple smart meters.

For a single collector meter, the shortest distance to a BioInitiative Report exceedence is 5.9 feet (60% reflection @ 1% duty cycle). At 60% reflection and 100% duty cycle, it increases to 59 feet.

For a collector and multiple smart meters, the shortest distance is 10.9 feet at 60% reflection @ 1% duty cycle, and increases to108 feet at 100% duty cycle.

Conclusions

FCC compliance violations are likely to occur under widespread conditions of installation and operation of smart meters and collector meters in California. Violations of FCC safety limits for uncontrolled public access are identified at distances within 6" of the meter. Exposure to the face is possible at this distance, in violation of the time-weighted average safety limits (Tables 10-11). FCC violations are predicted to occur at 60% reflection and 100% reflection factors*, both used in FCC OET 65 formulas for such calculations for time-weighted average limits. Peak power limits are not violated at the 6" distance (looking at the meter) but can be at 3" from the meter, if it is touched.

This report has also assessed the potential for FCC violations based on two examples of RF exposures in a typical residence. RF levels have been calculated at distances of 11" (to represent a nursery or bedroom with a crib or bed against a wall opposite one or more meters); and at 28" (to represent a kitchen work space with one or more meters installed on the kitchen wall).

FCC compliance violations are identified at 11" in a nursery or bedroom setting using Equation 10* of the FCC OET 65 regulations (Tables 12-13). These violations are predicted to occur where there are multiple smart meters, or one collector meter, or one collector meter mounted together with several smart meters.

FCC compliance violations are not predicted at 28" in the kitchen work space for 60% or for 100% reflection calculations. Violations of FCC public safety limits are predicted for higher reflection factors of 1000% and 2000%, which are not a part of FCC OET 65 formulas, but are included here to allow for situations where site-specific conditions (highly reflective environments, for example, galley-type kitchens with many highly reflective stainless steel or other metallic surfaces) may be warranted (see Methodology Section).

In addition to exceeding FCC public safety limits under some conditions of installation and operation, smart meters can produce excessively elevated RF exposures, depending on where they are installed. With respect to absolute RF exposure levels predicted for occupied space within dwellings, or outside areas like patios, gardens and walk-ways, RF levels are predicted to be substantially elevated within a few feet to within a few tens of feet from the meter(s).

For example, one smart meter at 11" from occupied space produces somewhere between 1.4 and 140 microwatts per centimeter squared (uW/cm2) depending on the duty cycle modeled (Table 12). Since FCC OET 65 specifies that continuous exposure be assumed where the public cannot be excluded (such as is applicable to one's home), this calculation produces an RF level of 140 uW/cm2 at 11" using the FCCs lowest reflection factor of 60%. Using the FCC's reflection factor of 100%, the figures rise to 2.2 uW/cm2 – 218 uW/cm2, where the continuous exposure calculation is 218 uW/cm2 (Table 12). These are very significantly elevated RF exposures in comparison to typical individual exposures in daily life. Multiple smart meters in the nursery/bedroom example at 11" are predicted to generate RF levels from about 5 to 481 uW/cm2 at the lowest (60%) reflection factor; and 7.5 to 751 uW/cm2 using the FCCs 100% reflection factor (Table 13). Such levels are far above typical public exposures.

RF levels at 28" in the kitchen work space are also predicted to be significantly elevated with one or more smart meters (or a collector meter alone or in combination with multiple smart meters). At 28" distance, RF levels are predicted in the kitchen example to be as high as 21 uW/cm2 from a single meter and as high as 54.5 uW/cm2 with multiple smart meters using the lower of the FCCs reflection factor of 60% (Table 14).

Using the FCCs higher reflection factor of 100%, the RF levels are predicted to be as high as 33.8 uW/cm2 for a single meter and as high as 85.8 uW/cm2 for multiple smart meters (Table 14). For a single collector meter, the range is 60.9 to 95.2 uW/cm2 (at 60% and 100% reflection factors, respectively) (from Table 15).

Table 16 illustrates predicted violations of peak power limit (4000 uW/cm2) at 3" from the surface of a meter. FCC violations of peak power limit are predicted to occur for a single collector meter at both 60% and 100% reflection factors. This situation might occur if someone touches a smart meter or stands directly in front.

Uncertainty About Actual RF Levels

Consumers may also have already increased their exposures to radiofrequency radiation in the home through the voluntary use of wireless devices (cell and cordless phones), PDAs like BlackBerry and iPhones, wireless routers for wireless internet access, wireless home security systems, wireless baby surveillance (baby monitors), and other emerging wireless applications.

Neither the FCC, the CPUC, the utility nor the consumer know what portion of the allowable public safety limit is already being used up or pre-empted by RF from other sources already present in the particular location a smart meter may be installed and operated.

Consumers, for whatever personal reason, choice or necessity who have already eliminated all possible wireless exposures from their property and lives, may now face excessively high RF exposures in their homes from smart meters. This may force limitations on use of their otherwise occupied space, depending on how the meter is located, building materials in the structure, and how it is furnished.

People who are afforded special protection under the federal Americans with Disabilities Act are not sufficiently acknowledged nor protected. People who have medical and/or metal implants or other conditions rendering them vulnerable to health risks at lower levels than FCC RF limits may be particularly at risk (Tables 30-31). This is also likely to hold true for other subgroups, like children and people who are ill or taking medications, or are elderly, for they have different reactions to pulsed RF. Childrens' tissues absorb RF differently and can absorb more RF than adults (Christ et al, 2010; Wiart et al, 2008). The elderly and those on some medications respond more acutely to some RF exposures.

Eyes and Testes - Safety standards for peak exposure limits to radiofrequency have not been developed to take into account the particular sensitivity of the eyes, testes and other ball shaped organs. There are no peak power limits defined for the eyes and testes, and it is not unreasonable to imagine situations where either of these organs comes into close contact with smart meters and/or collector meters, particularly where they are installed in multiples (on walls of multi-family dwellings that are accessible as common areas).

What can be determined from the relevant standards (FCC and ANSI/IEEE and certain IEEE committee documents is that the eye and testes are potentially much more vulnerable to damage, but that there is no scientific basis on which to develop a new, more protective safety limit. What is certain is that the peak power limit of 4000 uW/cm2 exceeds what is safe (Appendix C).

In summary, no positive assertion of safety can be made by the FCC, nor relied upon by the CPUC, with respect to pulsed RF when exposures are chronic and occur in the general population. Indiscriminate exposure to environmentally ubiquitous pulsed RF from the rollout of millions of new RF sources (smart meters) will mean far greater general population exposures, and potential health consequences. Uncertainties about the existing RF environment (how much RF exposure already exists), what kind of interior reflective environments exist (reflection factor), how interior space is utilized near walls), and other characteristics of residents (age, medical condition, medical implants, relative health, reliance on critical care equipment that may be subject to electronic interference, etc) and unrestrained access to areas of property where meter is located all argue for caution.

Electronic Interference

Consumers may experience electronic interference (electromagnetic interference or EMI) from smart meter wireless signals. The FCC also is charged with investigating consumer complaints about electronic interference.

> *"The FCC requires that unlicensed low-power RF devices must not create interference and users of such equipment must resolve any interference problems or cease operation. According to the FCC*

> *(47CFR Part 15): "The operator of a radio frequency device shall be required to cease operating the device upon notification by a Commission representative that the device is causing harmful interference. Operation shall not resume until the condition causing the harmful interference has been corrected."*
>
> (EPRI, 2010)

Medical and other critical care equipment in the home environment may not work, or work properly due to electronic interference from smart meters.

Security systems, surveillance monitors and wireless intercoms may be rendered inoperable or unreliable. Some cordless telephones do not work reliably, or have substantial interference from smart meter RF emissions.

Electronic equipment and electrical appliances may be damaged or have to be replaced with other, newer equipment in order not to be subject to electromagnetic interference from smart meter RF bursts.

Americans With Disabilities Act

People who have medical implants, particularly metal implants, may be more sensitive to spurious RF exposures for two reasons. Electromagnetic interference (EMI) with critical care medical equipment and medical implants is a potentially serious threat. Patients with deep-brain stimulators (Parkinson's disease patients) have reported adverse health effects due to RF from various environmental sources like security gates and RFID scanners. Patients with deep brain stimulators have reported the devices to be reprogramming or electrodes shut-down as a result of encounters with wireless RFID scanners. One manufacturer, Medtronics, has issued a warning for DBS implant patients to limit RF exposure to less than 0.1 W/Kg SAR (or sixteen times lower than for the general public) for MRI exposures.

The IEEE SC4 committee (2001) considered changes to existing ANSI/IEEE standards adopted in 1992 (C95.1-1992). They discussed vulnerable organs (eyes, testes) and metallic implants that can intensify localized RF exposures within the body and its tissues.

> *"Question 20: Are there specific tissues or points within the body that have particularly high susceptibilities to local heating due to thermal properties in the immediate vicinity of the tissue?"*

Committee minutes include the following discussion on metallic implants.

> "*Metallic implants are an interesting example of this question. There can be very localized high field concentrations around the tips of long metal structures, in the gaps of wire loops. Of course, these metal devices don't create energy, but can only redistribute it, so the effect is limited to some extent. Also the high thermal conductivity and specific heat capacity make them good thermal sinks for any localized heat sources generated around them."*

Since deep brain stimulators in Parkinson's patients involve metal implants that are essentially long metal structures with tips that interface with brain tissue and nerves within the brain and body, exposing such patients with implants to high levels of pulsed RF that can produce localized, high RF within the body is certainly inadvisable. It is clear the IEEE SC4 committee recognized the potential risk by to calling such implanted metallic devices good ‘thermal sinks’ for localized heating dissipation.

The FCC’s Grants of Authorization and other certification procedures do not ensure adequate safety to safeguard people under Department of Justice protection under the Americans with Disabilities Act.

References

ANSI/IEEE standards adopted in 1992 (C95.1-1992) and 1999 revisions June 2001 SC-4 Committee Minutes

Christ A Gosselin MC Christopoulou M Kühn S Kuster N. Age dependent tissue-specific exposure of cell phone users. Physics in Medicine and Biology, Volume 55, Issue 7, pp. 1767–1783, 7 April 2010, online March 5

EPRI, 2010. A Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading Technology, Electric Power Research Institute, Palo Alto, CA.

Federal Communications Commission, 1997. FCC Bulletin OET 65 97-01 Guidelines Evaluating Compliance with FCC Guidelines for Human

Exposure to Radiofrequency Electromagnetic Fields.

Hondou T Ueda T Sakat Y Tanigwa N Suzuki T Kobayashi T Ikeda K. Passive Exposure to Mobile Phones: Enhancement of Intensity by Reflection, Journal of the Physical Society of Japan Vol. 75, No. 8, August, 2006, 084801 (2006) The Physical Society of Japan

Hondou T, Rising Level of Public Exposure to Mobile Phones:Accumulation through Additivity and Reflectivity. Journal of the Physical Society of Japan, Vol. 71, No. 2, February, 2002, pp. 432–435 (2002) The Physical Society of Japan.

The Institute of Electrical and Electronic Engineers, Inc. 1999. IEEE Standards Coordinating Committee 28, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields 3 kHz to 300 GHz. December, 1998.

Khurana VG Hardell L Everaert J Bortkiewicz A Carlberg M Ahonen M, 2010. Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations. Int Journal of Occupational Environmental Health 2010;16:263–267

Kundi M Hutter HP Mobile phone base stations—Effects on wellbeing and health. Pathophysiology 16 (2009) 123–135

Markova E Malmgren LOG Belyaev IY. Microwaves from mobile phones inhibit 53PB1 focus formation in human stem cells stronger than in differentiated cells: Possible mechanistic link to cancer risk. Environmental Health Perspectives On-line 22 October 2009 doi:10.1289/ehp.0900781

National Council on Radiation Protection and Measurements (NCRP) in "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, Sections 17.4.1, 17.4.1.1, 17.4.2 and 17.4.3. Copyright NCRP, 1986, Bethesda, Maryland 20814

National Toxicology Program Fact Sheet, (2009). *Cell Phone Radiofrequency Radiation Studies*, (September 2009).

Vermeeren G Gosselin MC Gosselin Kuhn S Kellerman V Hadmen A Gati A Joseph W Wiart J Meyer F Kuster N Martens L. The influence of the reflective environment on the absorption of a human male exposed to representative base station antennas from 300 MHz to 5 GHz, Phys. Med. Biol. 55 (2010) 5541–5555 doi:10.1088/0031-9155/55/18/018

Wiart, J., Hadjem, A., Wong, M.F., & Bloch, I. (2008). Analysis of RF exposure in the head tissues of children and adults. *Physical Medicine & Biology*, 53, 3681-3695.

Appendix A Tables A1- A 48

RADIOFREQUENCY RADIATION VERSUS DISTANCE

One Smart Meter

Table A1	60% Reflection	(1%-100% duty cycles in each table)
Table A2	100% Reflection	(1%-100% duty cycles in each table)
Table A3	1000% Reflection*	(1%-100% duty cycles in each table)
Table A4	2000% Reflection*	(1%-100% duty cycles in each table)

Multiple Smart Meters (Four)**

Table A5	60% Reflection	(1%-100% duty cycles in each table)
Table A6	100% Reflection	(1%-100% duty cycles in each table)
Table A7	1000% Reflection	(1%-100% duty cycles in each table)
Table A8	2000% Reflection	(1%-100% duty cycles in each table)

One Collector Meter

Table AA9	60% Reflection	(1%-100% duty cycles in each table)
Table A10	100% Reflection	(1%-100% duty cycles in each table)
Table A11	1000% Reflection	(1%-100% duty cycles in each table)
Table A12	2000% Reflection	(1%-100% duty cycles in each table)

One Collector Meter + 3 SM**

Table A13	60% Reflection	(1%-100% duty cycles in each table)
Table A14	100% Reflection	(1%-100% duty cycles in each table)
Table A15	1000% Reflection	(1%-100% duty cycles in each table)
Table A16	2000% Reflection	(1%-100% duty cycles in each table)

TABLES OF CRITICAL DISTANCES IN NURSERY (CRIB AT 11") AND KITCHEN SINK (AT 28") FROM SMART METER (A17-A48)

Table A17 Nursery Set –
Table A18 One Smart Meter – Critical Distance 11" to baby in crib
Table A19 60%, 100%, 1000%, 2000% duty cycle
Table A20 1% thru 90% duty cycle

Table A21 Nursery Set –
Table A22 Eight Smart Meters – Critical Distance 11" to baby in crib
Table A23 60%, 100%, 1000%, 2000% reflection
Table A24 1% thru 100% duty cycle

Table A25 Nursery Set –
Table A26 One Collector– Critical Distance 11" to baby in crib
Table A27 60%, 100%, 1000%, 2000% reflection
Table A28 1% thru 100% duty cycle

Table A29 Nursery Set –
Table A30 One Collector Meter + 7 SM– Critical Distance 11" to baby crib
Table A31 60%, 100%, 1000%, 2000% reflection
Table A32 1% thru 100% duty cycle

Table A33 Kitchen Set –
Table A34 One Smart Meter – Critical Distance 28" to kitchen sink person
Table A35 60%, 100%, 1000%, 2000% reflection
Table A36 1% thru 100% duty cycle

Table A37 Kitchen Set -
Table A38 Eight Smart Meters – Critical Distance 28" to kitchen sink person
Table A39 60%, 100%, 1000%, 2000% reflection
Table A40 1% thru 100% duty cycle

Table A41 Kitchen Set –

Table A42	One Collector – Critical Distance 28” to kitchen sink person
Table A43	60%, 100%, 1000%, 2000% reflection
Table A44	1% thru 100% duty cycle
Table A45	Kitchen Set –
Table A46	One Collector + 7 SM – Critical Distance 28” to kitchen
Table A47	60%, 100%, 1000%, 2000% reflection
Table A48	1% thru 100% duty cycle

Appendix B Tables 1 – 33 of Report

Data Tables, FCC Violation Tables, Health Comparisions

Table 1 Radiofrequency Level at Each Duty Cycle and Reflection Factor at 6” in uW/cm2 (One Meter, Four Meters)

Table 2 Radiofrequency Level at Each Duty Cycle and Reflection Factor at 6” in uW/cm2 (One Collector, 1C + 3 SM)

Table 3 RF Level of Each Duty Cycle and Reflection Factor at 11” in uW/cm2 in the Nursery (One meter, Four meters)

Table 4 RF Level of Each Duty Cycle and Reflection Factor at 11” in uW/cm2 in the Nursery (One Collector, 1C + 3 SM)

Table 5 RF Level of Each Duty Cycle and Reflection Factor at 28” in uW/cm2 in the Kitchen (One Meter, Four Meters)

Table 6 RF Level of Each Duty Cycle and Reflection Factor at 28” in uW/cm2 in the Kitchen (One Collector, 1C + 3 SM)

Table 7 Distance at which FCC Safety Limit is exceeded for 655 uW/cm2 time-weighted average limit (One Meter, Four Meters)

Table 8 Distance at which FCC Safety Limit is exceeded for 571/624 uW/cm2

TWA limit (One Collector, 1C+ 3 Smart Meters)

Table 9 Distance at which FCC Safety Limit is exceeded for peak power limit of 4000 uW/cm2 – (1 SM, 4 SM; 1Collector, 1C + 3 SM)

Table 10 FCC Violations of the 655 uW/cm2 FCC limit at the face at 6” (One Meter, Four Meters)

Table 11 FCC Violations of the 571/624 uW/cm2 FCC limit at 6” at the face (One Collector, 1C + 3 SM)

Table 12 FCC Violations of the 655 uW/cm2 FCC limit at 11” in the Nursery (One Meter, Four Meters)

Table 13 FCC Violations of the 571/624 uW/cm2 FCC limit at 11” in the Nursery (One Collector, 1C + 3 SM)

Table 14 FCC Violations of the 655 uW/cm2 FCC limit at 28” in the Kitchen (One Meter, Four Meters)

Table 15 FCC Violations of the 571/624 uW/cm2 FCC limit at 28” in the Kitchen (One Collector, 1C + 3 SM)

Table 16 Potential FCC Violations of Peak Power Limit of 4000 uW/cm2 at 3” (One SM, 4 SM)

Table 17 Potential FCC Violations of Peak Power Limit of 4000 uW/cm2 at 3” (One Collector, 1C + 3 SM)

Table 18 Nursery Radiofrequency Radiation Level Associated with Inhibition of DNA Repair in Human Stem Cells (92.5 uW/cm^2 with 24 and 72-hour exposure – Markova et al, 2009) (One SM, 4 SM)

Table 19 Nursery Radiofrequency Radiation Level Associated with Inhibition of DNA Repair in Human Stem Cells (92.5 uW/cm^2 with 24 and 72-hour exposure – Markova et al, 2009) (One Collector, 1 C + 3 SM)

Table 20 Nursery Radiofrequency Radiation Level Associated with Pathological Leakage of the Blood-brain Barrier (0.4 to 8 uW/cm^2 with chronic exposure - Persson et al, 1997) (One SM, 4 SM)

Table 21 Nursery Radiofrequency Radiation Level Associated with Pathological Leakage of the Blood-brain Barrier (0.4 to 8 uW/cm^2 with chronic exposure - Persson et al, 1997) (One Collector, 1 C + 3 SM)

Table 22 Nursery Radiofrequency Radiation Level Associated with Adverse Health

Symptoms from Cell Tower Studies (8 studies in total reporting sleep disruption, headache, fatigue, memory loss, concentration difficulties, irritability, increased cancer risk) (0.01 uW/cm^2 with chronic exposure - Kundi, 2009; Khurana et al, 2010) (One SM, 4 SM)

Table 23 Nursery Radiofrequency Radiation Level Associated with Adverse Health Symptoms from Cell Tower Studies (8 studies in total reporting sleep disruption, headache, fatigue, memory loss, concentration difficulties, irritability, increased cancer risk) (0.01 uW/cm^2 with chronic exposure - Kundi, 2009; Khurana et al, 2010) (One Collector, 1 C + 3 SM)

Table 24 Kitchen Radiofrequency Radiation Level Associated with Inhibition of DNA Repair in Human Stem Cells (92.5 uW/cm^2 with 24 and 72-hour exposure – Markova et al, 2009) (One SM, 4 SM)

Table 25 Kitchen Radiofrequency Radiation Level Associated with Inhibition of DNA Repair in Human Stem Cells 92.5 uW/cm^2 with 24 and 72-hour exposure – Markova et al, 2009) (One Collector, 1 C + 3 SM)

Table 26 Kitchen Radiofrequency Radiation Level Associated with Pathological Leakage of the Blood-brain Barrier (0.4 to 8 uW/cm^2 with chronic exposure - Persson et al, 1997) (One SM, 4 SM)

Table 27 Kitchen Radiofrequency Radiation Level Associated with Pathological Leakage of the Blood-brain Barrier (0.4 to 8 uW/cm^2 with chronic exposure - Persson et al, 1997) (One Collector, 1 C + 3 SM)

Table 28 Kitchen Radiofrequency Radiation Level Associated with Adverse Health Symptoms from Cell Tower Studies (8 studies in total reporting sleep disruption, headache, fatigue, memory loss, concentration difficulties, irritability, increased cancer risk) (0.01 uW/cm^2 with chronic exposure - Kundi, 2009; Khurana et al, 2010) (One SM, 4 SM)

Table 29 Kitchen Radiofrequency Radiation Level Associated with Adverse Health Symptoms from Cell Tower Studies (8 studies in total reporting sleep disruption, headache, fatigue, memory loss, concentration difficulties, irritability, increased cancer risk) (0.01 uW/cm^2 with chronic exposure - Kundi, 2009; Khurana et al, 2010) (One Collector, 1 C + 3 SM)

Table 30 Radiofrequency Radiation Level Exceeds Medtronics Metal Implant Advisory for MRI SAR Exposure of 0.1 W/Kg at Frequencies also Used in Smart Meters at 11” (One SM, 4 SM)

Table 31 Radiofrequency Radiation Level Exceeds Medtronics Metal Implant Advisory for MRI SAR Exposure of 0.1 W/Kg at Frequencies also Used

	in Smart Meters at 11”	(One Collector, 1 C + 3 SM)
Table 32	Predicted RF levels exceed BioInitiative Report recommended limit of 0.1 uW/cm2	(One SM, 4 SM)
Table 33	Predicted RF levels exceed BioInitiative Report recommended limit of 0.1 uW/cm2	(1 Collector 1C + 3 SM)

Appendix C

Other Sources of Information on sensitivity of the eyes and testes

In the most recent proposed revisions of RF safety standards, the IEEE SC4 committee (2001) deliberated at length over the problem of peak power limits and non-uniform RF exposure with respect to the eye and testes. The quotes below come from committee drafts submitted in response to questions from the committee moderator.

ANSI/IEEE standards adopted in 1992 (C95.1-1992) and 1999 revisions
June 2001 SC-4 Committee Minutes

These committee discussions are informative on the issue of particular organ sensitivity to RF, and unanswered questions and differences of opinion on the subject among members. They discussed vulnerable organs (eyes, testes) and metallic implants that can intensify localized RF exposures within the body and its tissues (see also discussion on metallic implants).

Question 20: Are there specific tissues or points within the body that have particularly high susceptibilities to local heating due to thermal properties in the immediate vicinity of the tissue?

Committee minutes include the following discussion on the particular sensitivities of 'ball shaped' organs including the eyes and testes.

"*Eye balls are commonly regarded as the critical organ*"

"In the range of a few GHz (gigahertz)*, reasonances may occur in ball shaped eyes and testes. They are also electrically and thermally partly insulated from other tissues. Additionally these organs or some of their parts (lens) are thermally a little bit more vulnerable than other tissues."*

"(m)odeling has noted that rapid changes in dialectrics such as cerebral spinal fluid in the ventricles of the brain and surrounding brain tissue lead to high calculated SARs. Secondly, exposure of the eye to microwave radiation can lead to increased temperature that is sufficient to damage tissues. The temperature rise will, of course, depend on the intensity of the irradiation, how well the energy is coupled into tissues, and how well the deposited energy is removed by normal mechanisms such as conduction and blood flow. Microwaves at the lower frequencies will be deposited deeper in the eye, while at higher frequencies they will be absorbed near the front surface of the eye. The eye does not efficiently remove heat deposited internally by microwave exposure. The main avenue of heat removal is

conduction and blood flow through the retina and choroid. The lens has been thought to be the most vulnerable tissue since it has no blood flow. Other than conduction through the sclera and convection from the surface of the cornea, heat removal is poor compared to other body tissues. Because the lens is avasular it has been thought to be particularly sensitive to thermal effects of microwave exposure. These facts have led many investigators to postulate that the poor heat dissipation from within the eye of humans and other animals may lead to heat buildup and subsequent thermal damage."

"Eyes do not have good blood circulation and testes have lower than body temperature."

"These organs are not well-perfused, hence have been singled out for the exclusion."

"Are the above numbers valid for all parts of the body in all exposure conditions over the time averaging period of the exposure? They (the basic limits) were derived in the manner you describe in body reasonance conditions i.e. coherent exposure over the whole body length of a human. Could the limit values of SAR be increased for partial body exposure? Yes, but we do not have the data to make this decision. In the near field of a source, clearly the limit value will depend on frequency (depth of penetration), organ blood supply and tolerance of that organism to sustain a certain rate of temperature increase during the time averaging period and the environmental conditions. If you have to deal with possible pathologies of organs then matters become even more complicated, because you are dealing not only with heat physiology, but also with general pathology, whose books are much thicker than those on physiology.