Outdated FCC "Safety" Standards

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(https://www.addtoany.com/share#url=https%3A%2F%2Fehtrust.org%2Fpolicy%2Ffcc-safety-standards%2F&title=Outdated%20FCC%20%E2%80%9CSafety%E2%80%9D%20Standards)

When these guidelines were developed, a cell phone was the size of a brick and there was no Wi-Fi at the coffee shop. Times have changed. The laws have not.

Fact: There Are No Safety Standards Currently there are no national or international "standards" for safe levels of the radiation emitted by wireless or microwave devices.

As stated by the FCC, there are no federally developed safety standards. After years of a robust research effort by US agencies, the US EPA was tasked to develop proper safety standards and was developing two tiered guidelines on both thermal and biological effects. Then in 1996 it was defunded. Instead of proper safety limits, the US government adopted "guidelines" developed by industry based on decades old research. Guidelines have a much lower certainty than a "standard" as proper long term safety testing was not done to ensure the public was protected from all possible harm. In fact, no "safe" level has been scientifically determined for children or pregnant women. Therefore, the claim that a device "meets government standards" or that radiation levels are "FCC compliant" gives a false impression of safety.

If you are interested in the history of US government reports on wireless, click here. (https://ehtrust.org/policy/us-government-reports-on-cell-phones-radiofrequency-electromagnetic-fields/)

The FCC guidelines rest on five fallacies (false assumptions) and therefore renders FCC guidelines obsolete. Compliance with "federal safety standards" does not assure your nor your family's safety. In fact, our federal safety limits are in essence meaningless when it comes to our health.

The Five Fallacies Of The Electromagnetic Radiation Exposure Limits

Developed by ANSI, IEEE and by ICNIRP in association with industry and military organizations, the existing exposure limits are based on these five false assumptions:

Fallacy 1: The only adverse biological effect from exposure to electromagnetic radiation (EMR) is heating.

Fact: Heating is not the issue. Hundreds if not thousands of studies show adverse health effects from headaches and sperm damage to many types of cancer including brain cancer. In all of studies with no temperature change. These were the kinds of studies that led the World Health Organization (WHO) to declare radio frequency radiation a Group 2B (possible) Human Carcinogen.

Fallacy 2: Only immediate (acute) adverse biological effects are important to consider; long-term (chronic) effects are not a concern.

Fact: The FCC's exposure limits did not consider the health effects to people if they are exposed to hours and hours of this radiation over several years. Cancers can have long latency periods, and several significant research studies show links between long-term exposure and brain tumors. Such research led to the IARC Group 2B (possible) Human Carcinogen classification, and this information on long term effects was not considered when FCC's exposure limits were developed decades ago.

Fallacy 3: Measuring radiation power levels by averaging over time allows us to understand the impact to our health. Peak radiation exposures are not necessary to measure to understand the potential impact from an exposure.

Fact: Peak millisecond radiation bursts impact our bodies at the cellular level. FCC's exposure limits average the radiation exposures for 30 minutes, rather than consider the intense pulses that people are exposed to. Many scientists are concerned that it is the erratic nature of the wireless signal that can cause the harmful biological effects. If you report averages then those are numbers determined by calculation instead of reporting the actual peak levels. How much lower are the averages than the peaks? Averages can report numbers that appear to be far lower than peak levels. Background: In the U.S., the FCC regulations (mostly for IEEE C95.1-1991) averaged exposure to the public over a 30 minute time period, and for workers a 6 minute time period. ICNIRP defines the averaged exposure to the public and to workers over a 6 minute time period. To illustrate: I punch you, and that breaks your nose. I say the power of my punch can be averaged over the last year (that's 365 days) and therefore you should not be hurt as I really did not punch you hard over the entire year—considering only the average power. Does this make sense? Should we use average or peak when we talk about measuring the impact on our bodies?

Fallacy 4: Assessments of the the unique vulnerability of children and the fetus is not necessary—only the radiation absorption into a large man is important.

Fact: FCC compliance testing utilizes a model of a 220 pound male head. Research repeatedly indicates that the radiation penetrates deeper into children's smaller bodies and brains. The current FCC exposure limits did not consider the higher energy absorption in fetuses, children and women.

Fallacy 5: All body tissue uniformly absorbs radio frequency radiation. The ability of radiofrequency radiation to be absorbed differently into different body tissues and to have different biological effects due to the unique makeup of different body tissues and organs is not important to consider in understanding risks to public health.

Fact: The FCC's exposure limits do not consider how this radiation is differentially absorbed by various body tissues. For example, female breast tissue is highly absorbent tissue, therefore the radiation will result in a much higher dose. Eyes and testes are also particularly vulnerable to electromagnetic radiation. Children's bodies have been shown to have a higher water content making their tissues more absorptive of the radiation. However scientific documentation of the different electrical properties of different tissues in humans of various ages does not exist in the decades old FCC exposure limit guidelines. FCC compliance testing for wireless devices utilizes a system whereby David Gultekin, working with Bell Labs electrical engineer Lothar Moeller, reported this month that normal working cell phones can create tiny hotspots within living brain tissue.

Some other examples of how FCC exposure limits have not kept up with the times:

1. FCC exposure limits are based on the assumption that wireless signals at a human body from a distance are from only one transmitter antenna.
    - In the 21st century, we are not exposed to one Wi-Fi transmitter antenna. One typical school classroom might have dozens of radiation streams from dozens of transmitting antennas: 30 laptops, 30 cell phones, a wireless printer, a wireless security system, an overhead internet access point and a cell tower located in line of sight outside the window.
2. FCC "standard operating positions" do not reflect the way we use our devices today.
    - FCC regulations specify what are called consumer "standard operating positions", such as that laptops are distanced at least 20 cm (8 inches) from the user. Placing a laptop on the lap is then in violation of this "standard operating position". Devices are radiation tested at these distances, and when we violate these "standard operating positions" we can be exposed to radiation levels in excess of the FCC exposure limits. Women now place cell phones in their bra or tucked against their abdomen under spandex exercise pants. Men have cell phones in front pockets of jeans. None of these common positions are in accordance with the FCC's regulations.

Letters From US Agencies that Raise Serious Concerns About Outdated FCC Exposure Limits

Radio Frequency Interagency Workgroup Concerns About RF Exposure Limits Gregory Lotz NIOSH 1999 Letter (https://ehtrust.org/wp-content/uploads/2016/04/1999-radiofrequency-interagency-workgroup-letter.pdf) Interagency Radio Frequency Workgroup 2003 Letter from EPA Norbert Hankin on Additional Concerns about RF Exposure Guidelines (https://ehtrust.org/wp-content/uploads/2016/04/2003-Letter-from-the-IARF-Workgroup-to-Chou.pdf) US Department of the Interior Letter 2014 on FCC Guidelines (https://ehtrust.org/wp-content/uploads/2016/04/Department-of-Interior-Feb-2014-letter-on-Birds-and-RF.pdf) EPA 1995 Letter on Development of Guidelines that were never completed as the EPA was defunded on this issue (https://ehtrust.org/wp-content/uploads/2016/04/EPA-Letter-to-Mr.-Smith-by-Ramona-Travato.pdf)

FCC RADIO FREQUENCY GUIDELINES FAQ'S

− How did it happen that these exposure limits are based on decades-old science and have not been updated?

The current FCC exposure limit was adopted by the FCC in 1996. However, based substantially on the IEEE C95.1-1991 but officially ANSI/IEEE C95.1-1992 which is identical as the U.S. government's exposure limit regulation. This means that effectively the standards adopted in 1996 are really from 1991. EHT scientific advisor Lloyd Morgan took a look at the history of the development of the standards and has detailed the key statements in the documents so that you can understand how the guidelines developed. Read it here (https://ehtrust.org/wp-content/uploads/2016/01/ANSIandIEEE-StandardsUSExposuresLimits-AHistoryofTheirCreation.pdf).

+ Why didn't the United States EPA ever develop safety limits for this radiation?

+ Is the government aware of the problems with the FCC guidelines?

+ Will the guidelines ever be assessed, considering they may not protect the public?

+ Are agencies calling on the government to update these FCC limits?

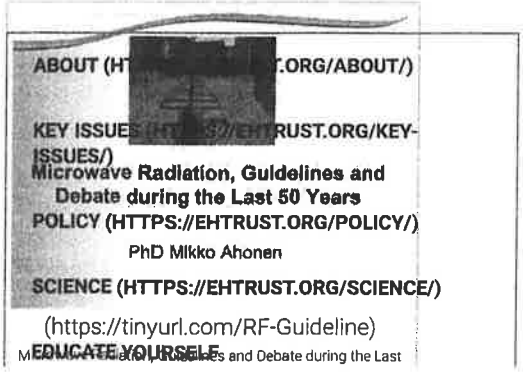
+ I have been told that the RF radiation levels from a proposed cell tower (or from our school's Wi-Fi system) is well below FCC's maximum permissible exposure levels (i.e. FCC compliant) and therefore I should not be concerned. Is there a health risk even at FCC compliant levels?

+ Are the RF limits in all countries thermal like the US? If not, why not?

+ I keep reading that FCC's limits for RF radiation are "thermal" limits. What does this mean?

RESOURCES TO LEARN MORE

ANSI C95.1-1982 Standard (https://ehtrust.org/wp-content/uploads/2015/11/ANSI-National-standards-1982-safety-levels-for-human-exposure.pdf) IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz September 1991 (https://ehtrust.org/wp-content/uploads/2015/11/IEEE-Standard-for-Safety-Levels-with-Respect-to-Human-Exposure-to-Radio-Frequency-Electromagnetic-Fields-3-kHz-to-300-GHz-September-1991-.pdf) Comments on the ANSI and IEEE Standard: EHT scientific advisor Lloyd Morgan took a look at the development of the standards and has detailed the key statements in the documents so that you can understand how the guidelines were improperly set. Please read it here (https://ehtrust.org/wp-content/uploads/2016/01/ANSIandIEEE-StandardsUSExposuresLimits-AHistoryofTheirCreation.pdf). Researcher, PhD Mikko Ahonen put together a slide presentation on the development of the international guidelines that informs our current FCC guidelines. Please take the time to view the slides below.



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Letter to the FCC by Dr. De Kun Li, MD, PhD, MPH on the Inadequacy of FCC guidelines (http://apps.fcc.gov/ecfs/document/view?id=7022311506) Evidence for Inadequacy of the Standards (http://www.bioinitiative.org/report/wp-content/uploads/pdfs/sec04_2012_Evidence_for_Inadequacy_of_the_Standards.pdf) This Chapter of the BioInitiative Report 2012 details the GAO Report, the WHO IARC Classification, President's Cancer Panel Report of 2010, the U.S. Federal Radiofrequency Interagency Working Group conclusions and more. Why the FCC Must Strengthen Radiofrequency Radiation Limits in the U.S. by Joel M. Moskowitz, Ph.D., Director Center for Family and Community Health, The UC Berkeley Prevention Research Center, School of Public Health, University of California, Berkeley November 5, 2013 (http://apps.fcc.gov/ecfs/document/view?id=7520956218) Read Critiques of ICNIRP (International Commission of Non-Ionizing Radiation Protection) (http://www.chronicexposure.org/limitsICNIRP.html) & WHO International EMF Project & the IEEE on Chronic Exposure (http://www.chronicexposure.org/limitsICNIRP.html) The Scientist Magazine: Opinion: Cell Phone Health Risk? Security concerns during the Cold War may have led to the generation of misinformation on the physiological effects of microwave radiation from mobile phones By Scientist and Researcher Allan H. Frey (http://www.the-scientist.com/?articles.view/articleNo/32648/title/Opinion--Cell-Phone-Health-Risk-/)

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RESOURCES ON INTERNATIONAL GUIDELINES

Powerwatch (2010) International Guidance Levels – A Comparison. (http://www.powerwatch.org.uk/gen/intguidance.asp) German Building biology guidance levels, for bedrooms less than 1 μW/m². Based on 10.000 home measurements. (https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwjH4syj7d7MAhWBliwKHeKWCuwQFggjMAE&url=http%3A%2F%2Fw content%2Fuploads%2Frichtwerte-2015-englisch.pdf&usg=AFQjCNERW-rfEVKz7_JWI0Wz0v-79gAesg) ICNIRP – International Commission of Non-Ionizing Radiation Protection – Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz) 1998 (http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf)

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DOCUMENTATION BY US AGENCIES

2014 Letter from the U.S. Department of Interior (https://www.ntia.doc.gov/files/ntia/us_doi_comments.pdf) states, "The electromagnetic radiation standards used by the Federal Communications Commission (FCC) continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today." Read it here. (https://www.ntia.doc.gov/files/ntia/us_doi_comments.pdf) 2002 Letter from Norbert Hankin of the EPA about the FCC guidelines states that children, pregnant women and the elderly were not considered in the regulations and that the regulations were to protect against hearing damage only and did not consider long-term chronic exposure. Read it here. (http://apps.fcc.gov/ecfs/document/view?id=7520941835) 1999 Letter: The U.S. Radiofrequency Interagency Work Group Chief W. Gregory Lotz, Ph.D., at NIOSH (National Institute of Occupational Safety and Health) wrote a letter to Mr. Richard Tell, Chair of the IEEE SCC28 Risk Assessment Work Group, in which they identified 14 issues that "need to be addressed to provide a strong and credible rationale to support RF exposure guidelines." Read it here. (http://www.emrpolicy.org/litigation/case_law/docs/exhibit_a.pdf) 2008 Report: National Academy of Sciences Report "Identification of Research Needs Relating to Adverse Health Effects of Wireless Communication." (http://www.nap.edu/catalog/12036/identification-of-research-needs-relating-to-potential-biological-or-adverse-health-effects-of-wireless-communication)

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Please watch this *must watch* documentary from 2010 that explores the development of the radiofrequency standards.

A FEW PUBLISHED PAPERS ON THE HISTORY OF RF LIMITS

"The Origins of U.S. Safety Standards for Microwave Radiation," (https://science.sciencemag.org/content/208/4449/1230) N.H. Steneck, et al. *Science, 208,* 1230, 1980

Magda Havas Analysis on the Paper #001: Origins of 1966 U.S. Safety Standards for Microwave Radiation (https://magdahavas.com/pick-of-the-week-2-origins-of-1966-u-s-safety-standards-for-microwave-radiation/)

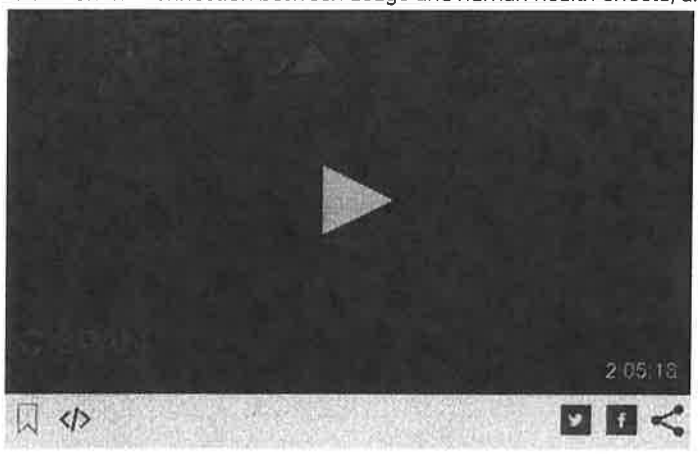
"Early Research on the Biological Effects of Microwave Radiation: 1940-1960. (http://www.magdahavas.com/wp-content/uploads/2010/07/Cook_1980_early_research.pdf)" Cook et al. 1980. Annals of Science 37: 323-351.

ADDITIONAL RESOURCES

EMF Portal: (http://www.emf-portal.de/) The EMF-Portal is an extensive literature database with an inventory of 22,066 publications and 5,327 summaries of individual scientific studies on the effects of electromagnetic fields. Here, scientific studies from journals with a so-called peer-reviewed process are collected, summarized and available free of charge to the user in both German and English. The ICEMS' Monograph, "Non-Thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter", edited by Livio Giuliani and Morando Soffritti for the European Journal of Oncology – Library Vol. 5 of the National Institute for the Study and Control of Cancer and Environmental Diseases "Bernardo Ramazzini", Bologna, Italy, 2010, Part I and Part II. Download the Summary (Adobe Acrobat PDF format) (http://www.icems.eu/papers/SummaryGuilianifeb25th.pdf) Download Part I (Adobe Acrobat PDF format) (http://www.icems.eu/papers/ramazzini_library5_part1.pdf) Download Part II (Adobe Acrobat PDF format) (http://www.icems.eu/papers/ramazzini_library5_part2.pdf) FCC Radio Frequency Safety Webpage (https://www.fcc.gov/general/radio-frequency-safety-0) OSHA Radiofrequency and Microwave Radiation Hazard Locations and Solutions (https://www.osha.gov/SLTC/radiofrequencyradiation/index.html) Occupational Safety and Health Administration (OSHA) page on RFR resources for hazard locations and solutions. Recommended Practice for Measurement of Potentially Hazardous Electromagnetic Fields, RF and Microwave (http://ieeexplore.ieee.org/Xplore/login.jsp?url=/iel1/2897/4704/00182889.pdf?arnumber=182889) Institute of Electrical and Electronics Engineers (IEEE) Standard, IEEE C95.3-2002. Safety Levels with Respect to Human Exposure to Electromagnetic Fields 0-3 kHz (http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1046043) Institute of Electrical and Electronics Engineers (IEEE) Standard, IEEE C95.6, 2002. Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields 3kHz to 3GHz (http://ieeexplore.ieee.org/Xplore/login.jsp?url=/iel5/10830/34126/01626482.pdf?arnumber=1626482) Institute of Electrical and Electronics Engineers (IEEE) Standard, IEEE Std.C95.1, 1999 Edition.

FCC 2008 Testimony on the Health Effects of Cell Phone Use

Expert testimony on the health effects of cell phones. Dr. Herberman, Ellie Marks, Dr. Hoover, Dr. Carpenter spoke about the exponential use of cellphones, the science on the connection between usage and human health effects, and studies looking fro links between usage and various



forms of cancer.

C-SPAN VIDEOS OF CONGRESSIONAL HEARINGS

2001: GAO Report Cell Phones Press Conference (http://www.c-span.org/video/?164408-1/cell-phone-safety-report) Senators Markey and Lieberman spoke to reporters about a Government Accounting Office study of the safety of cell phones and the potential impacts of increased exposure to radio frequency emissions. Because the report did not contain definitive conclusions, they called for greater consumer education and further study of the potential problems. Following their remarks they answered questions from reporters. **2008 Congressional Hearing: Health Effects of Cell Phone Use (http://www.c-span.org/video/?281358-1/health-effects-cell-phone-use)** Witnesses testified about research into cellular telephone use and its potential impact on human health, as well as the potential side effects and consequences of cell phone use. They focused on studies that had examined potential links between cell phones and cancer, and about warnings issued by some groups on cell phone safety. Recent epidemiological studies involving humans suggest that heavy cell phone users of 10 years or more have developed brain tumors on the same side of their heads as where they used to hold their mobile phones. David Carpenter (http://www.c-span.org/person/?1030657), Ronald B. Herberman M.D. (http://www.c-span.org/person/?1000216),Robert Hoover (http://www.c-span.org/person/?1030658), Darrell Issa (http://www.c-span.org/person/?90066), Julius P. Knapp II (http://www.c-span.org/person/?1015467),Ellie Marks (http://www.c-span.org/person/?1030655), Danny "Dan" Lee Burton (http://www.c-span.org/person/?1996), Dennis Kucinich (http://www.c-span.org/person/?45684), Diane Watson (http://www.c-span.org/person/?4372) **2009 Congressional Hearing on Cell Phone Radiation (http://www.c-span.org/video/?288879-1/health-effects-cell-phone-use)** Health Effects of Cell Phone Use Witnesses testified about research into cellular telephone use and its potential impact on human health, as well as the potential side effects and consequences of cell phone use. They focused on studies that had examined potential links between cell phones and cancer, and about warnings issued by some groups on cell phone safety. John Bucher (http://www.c-span.org/person/?1028597), Devra L. Davis (http://www.c-span.org/person/?14854), Linda Erdreich (http://www.c-span.org/person/?9265233), Thomas "Tom" Harkin (http://www.c-span.org/person/?2005), Dariusz Leszczynski (http://www.c-span.org/person/?9265231), Olga Naidenko (http://www.c-span.org/person/?9265234), Mark Pryor (http://www.c-span.org/person/?1002201), Siegal Sadetzki (http://www.c-span.org/person/?9265232), Arlen Specter (http://www.c-span.org/person/?390) **2011: Communicators with Nora Volkow (http://www.c-span.org/video/?299617-1/communicators-nora-volkow)** Dr. Nora Volklow talked about tests conducted by National Institutes of Health (NIH) scientists and the Energy Department's Brookhaven National Laboratory. The test results show that brain chemistry becomes altered after 50 minutes of cell phone usage. Also featuring Kenneth Foster and Devra Davis. **Book Discussion on Disconnect (http://www.c-span.org/video/?296071-1/book-discussion-disconnect)** Devra Davis presented her book Disconnect: The Truth About Cell Phone Radiation, What the Industry Has Done to Hide It, and How to Protect Your Family, published that day by Dutton. She argued that cell phone radiation damages the human body. She said that recently disclosed research shows that cell phones negatively affect human DNA and increase the user's risk of developing memory loss, cancer, and various neurological diseases. Ms. Dutton talked about the industry practices that have hidden the dangers and her recommendations for cell phone use. **Book Discussion on Cell Phones: Invisible Hazards in the Wireless Age (http://www.c-span.org/video/?163734-1/book-discussion-cell-phones-invisible-hazards-wireless-age)** Martin Schram and George Carlo talked about their book Cell Phones: Invisible Hazards In the Wireless Age about Carlos work heading up the WTO Cell Phone Research study that found problems "suppressed" by the Wireless Industry.

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Kalmar in new 5G initiative

News28 Jun 2019byWCN Editorial

Kalmar and Ukkoverkot, a leading private LTE network provider, have signed a two-year cooperation agreement with Nokia to design, build and operate a private LTE network

Nokia brings the digital automation platform that is well suited for mobile machinery and industrial Internet of Things.

A test network reflecting an actual terminal environment will be built for research and development purposes. Machine-to-machine communication will be tested in the new private 4G/LTE (Long Term Evolution) environment and compared against previous wireless technologies with the focus on developing innovative business applications.

This connectivity technique is more reliable and enables more secure communication than Wi-Fi, says Kalmar. Private LTE provides the low latency, high-capacity connectivity combined with edge computing required for time-sensitive critical industrial applications enabling real-time analytics and video-based applications such as machine remote control - key elements of robust digital industrial environments.

Kalmar's technology centre in Tampere, Finland

"We believe the new 5G-ready LTE solution will be an asset to our business, and we look forward to initiating testing in this digital automation environment," said Pekka Yli-Paunu, Director, Research, Kalmar. "The private LTE network will provide the security and real-time video footage needed for reliable remote control of our operations.

"The digital automation platform with its connectivity and application layers makes it possible for us to test new service products and concepts. That gives us the opportunity to demonstrate to our customers how our new services work, which is particularly valuable."

Nokia has already deployed over 1,000 mission-critical networks, and will now draw on decades of experience building some of the biggest and most advanced IP, optical, and wireless networks to benefit industrial cargo handling.

The Nokia-built network will allow for machinery to be connected over reliable private local LTE or 5G networks, enabling automation, robotics, machine learning, analytics, and real-time remote monitoring, which in turn increases cost-efficiency and adds value along the chain. Connections between industrial and safety-critical operators, such as Kalmar's customers, are increasingly customized to meet the customers' needs for capacity, usability, and coverage.

"Kalmar will implement a 5G-ready Nokia Digital Automation platform utilizing the 2.6 GHz band," said Jouko Tuppurainen, Director, Ukkoverkot. "This brings many interesting new business opportunities for digitalization thanks to the reliability, high capacity, low latency, and security - all characteristics of a private LTE network."

Stephan Litjens, General Manager, Nokia Digital Automation, said: "Our digital automation platform brings pervasive mobile broadband coverage for terminals, sensors, cameras and other devices for mission and business critical industrial connectivity and digital transformation.

"Communication is essential for business efficiency and safety in cargo handling, be it between machines or machines and people. We are pleased to collaborate, allowing companies to seize the Industry 4.0 opportunity."

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+ SECTION 6: EVIDENCE FOR GENOTOXIC EFFECTS – RFR AND ELF DNA DAMAGE

+ SECTION 7: EVIDENCE FOR STRESS RESPONSE (STRESS PROTEINS)

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2007

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SECTION 3

The Existing Public Exposure Standards

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August 2007

The US Federal Communications Commission (FCC) Exposure Standard Recommendations

In the United States, the Federal Communications Commission (FCC) enforces limits for both occupational exposures (in the workplace) and public exposures. The exposure limits are variable according to the frequency (in megahertz) and the duration of exposure time (6 minutes for occupational and 30 minutes for public exposures). Table 3.1 show exposure limits for occupational and uncontrolled public access to radiofrequency radiation such as is emitted from AM, FM, television and wireless sources through the air. As an example, 583 microwatts/cm2 (μW/cm2) is the public limit for the 875 MHz cell phone wireless frequency and 1000 μW/cm2 is the limit for PCS frequencies in the 1800 – 1950 MHz range averaged over 30 minutes. The limits in Table 3.1 would pertain to exposures in the vicinity of transmitting antennas (not devices like cell phones, for which exposure limits are shown in Table 3.2).

The FCC is required by the National Environmental Policy Act of 1969 to evaluate the effect of emissions from FCC-regulated transmitters on the quality of the human environment. At the present time there is no federally-mandated radio frequency (RF) exposure standard. However, several non-government organizations, such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers, Inc. (IEEE), and the National Council on Radiation Protection and Measurements (NCRP) have issued recommendations for human exposure to RF electromagnetic fields. The FCC has endorsed these recommendations, and enforces compliance. http://www.fcc.gov/oet/rfsafety/

Table 3.1 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: OET, 1997.

FCC Guidelines for Cell and PCS Phones (and other radiofrequency emitting devices)

Cell phones and portable transmitting devices that operate in the Cellular Radiotelephone Service, the Personal Communications Services (PCS), the Satellite Communications Services, the Maritime Services (ship earth stations only) and the Specialized Mobile Radio (SMR) Service are subject to routine environmental (not health) evaluation for RF exposure prior to equipment authorization or use by the FCC. Section 2.1093 of the FCC's Rules (47 CFR §2.1093) that apply to "portable" devices. For purposes of these requirements a portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user (OET, 1997).

Cell phones and some other wireless communication devices are regulated by the FCC according to their emissions, which depend on the amount of power absorbed into the body. The metric for measurement is specific absorption rate (SAR) and is expressed in watts per kilogram of tissue. The limit for absorption of radiofrequency radiation is limited to 1.6 W/kG within 1 gram of human tissue. This limit has been recommended for change (relaxation) by the IEEE in April of 2006. If adopted by the FCC, this amount of heat or 1.6 W/Kg would be measured over 10 times as much tissue (10 grams) so that far higher heating is possible from these devices over small amounts of tissue (would be far less strict that the current limit, if adopted). More cell phone and related PDA devices would then comply be able with the looser standard, and the public could potentially receive much higher radiofrequency radiation exposures, and it would be in compliance (legal).

"The SAR criteria to be used are specified below and apply for portable devices transmitting in the frequency range from 100 kHz to 6 GHz. The limits used for evaluation are based generally on criteria published by the Institute of Electrical and Electronics Engineers, Inc., (IEEE) for localized specific absorption rate ("SAR") in Section 4.2 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.

These criteria for SAR evaluation are similar to those recommended by the National Council on Radiation Protection and Measurements (NCRP) in "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, Section 17.4.5. Copyright NCRP, 1986, Bethesda, Maryland 20814."

(1) FCC Limits for Occupational/Controlled exposure: 0.4 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 8 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 20 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). Occupational/Controlled limits apply when persons are exposed as a consequence of their

employment provided these persons are fully aware of and exercise control over their exposure. Awareness of exposure can be accomplished by use of warning labels or by specific training or education through appropriate means, such as an RF safety program in a work environment (OET, 1997).

(2) FCC Limits for General Population/Uncontrolled exposure: 0.08 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 1.6 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 4 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). General Population/Uncontrolled limits apply when the general public may be exposed, or when persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or do not exercise control over their exposure. Warning labels placed on consumer devices such as cellular telephones will not be sufficient reason to allow these devices to be evaluated subject to limits for occupational/controlled exposure (OET, 1997).

In the United States, two professional societies - the Institute of Electrical and Electronics Engineers, Inc. (IEEE) and the National Council for Radiation Protection and Measurements (NCRP) develop recommendations for safety standards. . The IEEE charter calls itself the world's leading professional association for the advancement of technology, as well as the instigator of public safety standards. The IEEE recommendations have historically been endorsed by the American National Standards Institute (ANSI) and finally considered by the FCC for implementation. The US Federal Communications Commission (FCC) may then take the recommendations and adopt them as mandatory exposure limits. Several standard-setting processes have occurred like this in the last few decades.

The most recent IEEE recommendations for 3 kHz to 300 GHz were developed in 2006 (IEEE, 2006). Rather than lower the existing limits for radiofrequency and microwave radiation exposure, they greatly increase the exposure limits. This is perplexing since it ignores or discounts a large body of scientific evidence clearly documenting biologically-relevant changes at levels LOWER (much lower) than the existing standards.

ICNIRP Guidelines (International Radiofrequency Guidelines)

In April 1998, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields in the frequency range up to 300 GHz.. These guidelines replaced previous advice issued in 1988 and 1990. The main objective of the ICNIRP Guidelines is to establish guidelines for limiting EMF exposure that will provide protection against known adverse health effects (ICNIRP, 1998). An adverse health effect is defined by ICNIRP as one which causes detectable impairment of the health of the exposed individual or of his or her offspring; a biological effect, on the other hand, may or may not result in an adverse health effect.

The guidelines presented in Table 3.2 apply to occupational and public exposure.

Table 3.2 ICNIRP Basic restrictions for time varying electric and magnetic fields for frequencies up to 10 GHz.

Exposure characteristics	Frequency range	Current density for head and trunk (mA m^{-2})(rms)	Whole-body average SAR (W kg^{-1})	Localized SAR (head and trunk) (W kg^{-1})	Localized SAR (limbs) (W kg^{-1})
Occupational exposure	up to 1 Hz	40	—	—	—
	1–4 Hz	40/*f*	—	—	—
	4 Hz–1 kHz	10	—	—	—
	1–100 kHz	*f*/100	—	—	—
	100 kHz–10 MHz	*f*/100	0.4	10	20
	10 MHz–10 GHz		0.4	10	20
General public exposure	up to 1 Hz	8	—	—	—
	1–4 Hz	8/*f*	—	—	—
	4 Hz–1 kHz	2	—	—	—
	1–100 kHz	*f*/500	—	—	—
	100 kHz–10 MHz	*f*/500	0.08	2	4
	10 MHz–10 GHz		0.08	2	4

Notes:

1. *f* is the frequency in hertz.
2. Because of electrical inhomogeneity of the body, current densities should be averaged over a cross-section of 1 cm^2 perpendicular to the current direction.
3. For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by %2 (~1.414). For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$. For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate basic restriction.
4. All SAR values are to be averaged over any 6-minute period.
5. Localized SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.
6. For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$. Additionally, for pulsed exposures, in the frequency range 0.3 to 10 GHz and for localized exposure of the head, in order to limit or avoid auditory effects caused by thermoelastic expansion, an additional basic restriction is recommended. This is that the SA should not exceed 10 mJ kg^{-1} for workers and 2 mJ kg^{-1} for the general public averaged over 10 g tissue.

In the frequency range from a few Hz to 1 kHz, for levels of induced current density above 100 mA m^{-2}, the thresholds for acute changes in central nervous system excitability and other acute effects such as reversal of the visually evoked potential are exceeded. In view of the safety considerations above, it was decided that, for frequencies in the range 4 Hz to 1 kHz, occupational exposure should be limited to fields that induce current densities less than 10 mA m^{-2}, i.e., to use a safety factor of 10. For the general public an additional factor of 5 is applied, giving a basic exposure restriction of 2 mA m^{-2}. Below 4 Hz and above 1 kHz, the basic restriction on induced current density increases progressively.

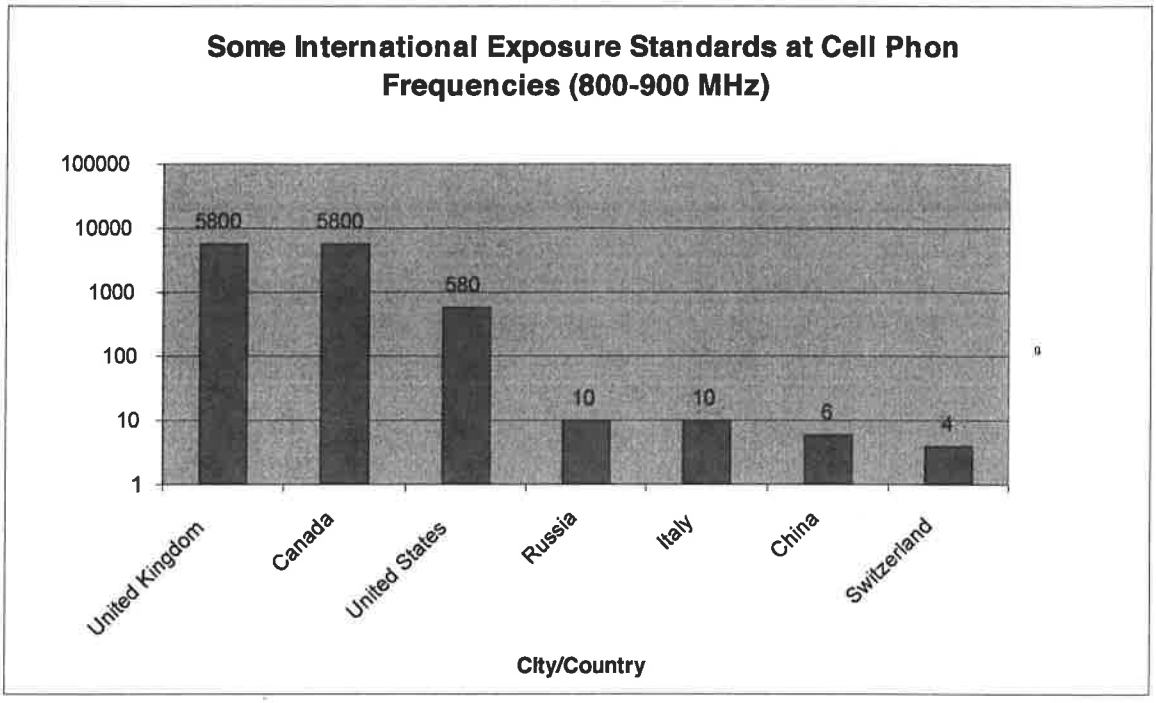
ICNRP maintains that guidelines for limiting exposure have been developed following a thorough review of all published scientific literature (ICNIRP, 1998).

"The criteria applied in the course of the review were designed to evaluate the credibility of the various reported findings (Repacholi and Stolwijk 1991; Repacholi and Cardis 1997); only established effects were used as the basis for the proposed exposure restrictions. Induction of cancer from long-term EMF exposure was not considered to be established, and so these guidelines are based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF. In the case of potential long-term effects of exposure, such as an increased risk of cancer, ICNIRP concluded that available data are insufficient to provide a basis for setting exposure restrictions, although epidemiological research has provided suggestive, but unconvincing, evidence of an association between possible carcinogenic effects and exposure at levels of 50/60 Hz magnetic flux densities substantially lower than those recommended in these guidelines. In-vitro effects of short-term exposure to ELF or ELF amplitude-modulated EMF are summarized. Transient cellular and tissue responses to EMF exposure have been observed, but with no clear exposure–response relationship. These studies are of limited value in the assessment of health effects because many of the responses have not been demonstrated in vivo. Thus, in-vitro studies alone were not deemed to provide data that could serve as a primary basis for assessing possible health effects of EMF. " (ICNIRP, 1998) http://www.icnirp.de

Guidelines and Limits (Other Countries)

On the other hand, some countries in the world have established new, low-intensity based exposure standards that respond to studies reporting effects that do not rely on heating. Consequently, new exposure guidelines are hundreds or thousands of times lower than those of IEEE and ICNIRP. Table 3.3 shows some of the countries that have lowered their limits, for example, in the cell phone frequency range of 800 MHz to 900 MHz. The levels range from 10 microwatts per centimeter squared in Italy and Russia to 4.2 microwatts per centimeter squared in Switzerland. In comparison, the United States and Canada limit such exposures to only 580 microwatts per centimeter squared (at 870 MHz) and then averaged over a time period (meaning that higher exposures are allowed for shorter times, but over a 30 minute period, the average must be 580 microwatts per centimeter squared or less at this frequency). The United Kingdom allows one hundred times this level, or 5800 microwatts per centimeter squared. Higher frequencies have higher safety limits, so that at 1000 MHz, for example, the limit is 1000 microwatts per centimeter squared (in the United States). Each individual frequency in the radiofrequency radiation range needs to be calculated. These are presented as reference points only. Emerging scientific evidence has encouraged some countries to respond by adopting planning targets, or interim action levels that are responsive to low-intensity or non-thermal radiofrequency radiation bioeffects and health impacts.

Table 3.3 Some International Exposure Standards at Cell Phone Frequencies



Professional bodies from technical societies like IEEE and ICNIRP continue to support "thermal-only" guidelines routinely defend doing so a) by omitting or ignoring study results reporting bioeffects and adverse impacts to health and wellbeing from a very large body of peer-reviewed, published science because it is not yet "proof" according to their definitions; b) by defining the proof of "adverse effects" at an impossibly high a bar (scientific proof or causal evidence) so as to freeze action; c) by requiring a conclusive demonstration of both "adverse effect" and risk before admitting low-intensity effects should be taken into account; e) by ignoring low-intensity studies that report bioeffects and health impacts due to modulation; f) by conducting scientific reviews with panels heavily burdened with industry experts and under-represented by public health experts and independent scientists with relevant low-intensity research experience; g) by limiting public participation in standard-setting deliberations; and other techniques that maintain the status quo.

Much of the criticism of the existing standard-setting bodies comes because their contributions are perceived as industry-friendly (more aligned with technology investment and dissemination of new technologies) rather than public health oriented. The view of the Chair of the latest IEEE standard-setting ICES Eleanor Adair is made clear by Osepchuk and Petersen (2003) who write in the abstract of their paper "*her goal and the goal of ICES is to establish rational standards that will make future beneficial applications of RF energy credible to humanity.*" Authors Osepchuk and Petersen note that *"(I)t is important that safety standards be rational and avoid excessive safety margins."* The authors specifically dismiss the body of evidence for low-intensity effects with *"(A)lthough the literature reporting "athermal" bioeffects of exposure to*

microwave/RF energy (other than electrostimulation) is included in the review process, it has been found to be inconsistent and not useful for purposes of standard-setting."

This report addresses the substantial body of evidence reporting low-intensity effects from electromagnetic fields (both power-frequency fields in the ELF range, and radiofrequency/microwave fields at exposure levels that do not involve any heating. It also addresses the inconsistency in the literature quoted as the basis for retaining thermal-only exposure standards (see particularly the Genotoxics Section 6 where half of more of the published papers report negative effects and half positive effects).

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BioInitiative 2012

A Rationale for Biologically-based Exposure Standards for Low-Intensity Electromagnetic Radiation

Report Updated in 2014 and 2017

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SECTION 24

Key Scientific Evidence and Public Health Policy Recommendations

(Supplement 2012)

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I. INTRODUCTION

In public health and environmental policy-making, asking the right questions is a highly evolved art form. It is necessary to periodically look for '*not-so-early-now warnings*' from new science and medical information. At some point it becomes '*old news*' in the real-world process of commercializing new technologies* and is ignored. Precious time is lost if the '*evidence curve*' does not come quickly enough to '*change the rollout curve*' and result in early enough interventions. EMF may be a highly preventable source of disease but not without early enough translation of the science into action. The time for arguing whether EMF health effects exist is over. We know they exist and that they result in human disease.

Asking the right questions and looking for proportionate responses necessarily involves make mid-course corrections guided by new evidence. This is particularly true when the consequences of doing nothing are too great to ignore – because they will affect billions of people in societies around the world. "*While there are many unanswered questions, the cost of doing nothing will result in an increasing number of people, many of them young, developing cancer.*" (Carpenter, 2010).

What questions should be asked now, to move forward on the body of evidence? How much evidence do we need to act? Do we have enough? What standard of evidence should be used to judge (purely scientific vs precautionary public health). What is a relevant biological 'dose'? How long does a biological effect last? Are we accounting for differences among individuals or different types of cells?

Which of the studies are truly measuring chronic exposures (is a one-month or a one-year study really revealing chronic effects; if mid-length studies show no effect, does this tell us anything useful)? Why is it still considered reasonable to base safety standards on time-averaged radiofrequency exposures when the technologies today use pulsed RFR?

*Electronics, the internet, cellular telecommunications, wireless medical technologies, and wireless sensors for energy conservation, electric utilities management, transportation, education, banking and national security.

For example, the collective behavior of neurons is established through synchrony. "*Individual neurons have a time window of tens of milliseconds range for single neurons, but oscillatory coalitions of neurons can expand the effect window of synchronization from hundreds of milliseconds to many seconds*" (Buzsaki, 2006). This means the time span a bioeffect can last long enough to overlap with the next environmental provocation (pulsed RFR in this case) so that repetitive exposures may induce an unending cascade of neurological firing that eventually disrupts normal homeostasis and causes chronically abnormal function in cooperative assemblies of cells like neurons. RFR is bioactive and already classified as a Possible Human Carcinogen but the relevant RFR bursts are camouflaged and their relevant metrics are diluted away by time averaging. Why is it reasonable to use safety standards that were developed to guard against induced currents in tissue (ELF-EMF) or that heat or burn tissue (RFR)?

Briefly stated, here is what we knew in 2007.

- Bioeffects and adverse health effects of chronic exposure to low-intensity (non-thermal) non-ionizing radiation are established.
- Existing FCC and ICNIRP public safety limits are not sufficiently protective of public health.
- The World Health Organization has classified ELF-EMF as a Group 2B Possible Human Carcinogen (2001).
- New, biologically-based public exposure standards are critically needed.
- It is not in the public interest to wait.

Here is what we know in 2012. There is more evidence, over a broader range of studies. The levels of biological responses are extraordinarily low (down to the nanowatt and picowatt power density level).

New studies address fertility and reproduction, fetal and neonatal effects, cognitive and behavioral problems in children and neurological damage. There are more mobile phone base station studies with longer testing periods, much more information on genetic damage and confirmation of increased risk of brain cancers from not one or two

studies, but from many studies and many authors including the World Health Organization's massive 13-country INTERPHONE STUDY (Interphone Study Group, 2010).

There are many studies reporting effects of cell phone radiation (even on standby-mode), wireless laptop exposure, cell phone use by mothers resulting in altered fetal brain development in the offspring, and more evidence that the blood-brain barrier and memory are at risk from cell phone use. There is evidence from human and animal studies that key areas of the brain are negatively affected by RFR at legal levels.

There is better understanding of the important physical and biological factors that make ELF-EMF and RFR potent disruptors of living tissues and basic metabolic processes. More and more, EMF devices are being used for medical treatments in cancer, bone and wound healing and re-tuning the nervous system. Increased depth of evidence in many threads is presented in this report by well-regarded scientists and researchers from around the world. The number of good studies has grown. The exposure levels causing effects are documented to be much lower than in the past. The epidemiological evidence is now showing risks for a variety of adverse health outcomes. All this should be taken seriously by governments, and translated quickly into more protective safety standards, and in the interim, into strong preventative actions, warnings and substitution of safer technologies and redesigned devices.

Bioeffects are clearly established and occur at very low levels of exposure to electromagnetic fields and radiofrequency radiation. Bioeffects can occur in the first few minutes at levels associated with cell and cordless phone use. Bioeffects can also occur from just minutes of exposure to mobile phone masts (cell towers), WI-FI, and wireless utility 'smart' meters that produce whole-body exposure. Chronic base station level exposures can result in illness.

Many of these bioeffects can reasonably be expected to result in adverse health effects if the exposures are prolonged or chronic. This is because they interfere with normal body processes (disrupt homeostasis), prevent the body from healing damaged DNA, produce immune system imbalances, metabolic disruption and lower resistance to disease across multiple pathways. Essential body processes can eventually be disabled by incessant external stresses (from system-wide electrophysiological interference) and lead to pervasive impairment of metabolic and reproductive functions.

What does the WHO IARC Classification of ELF-EMF and RFR as Group 2B Possible Human Carcinogens Mean?

The World Health Organization International Agency for Cancer Research (IARC) designated ELF-EMF as a Group 2B (Possible) Carcinogen in 2001. This is the kind of exposure from power lines, battery switching in cell phone devices, laptop computers and appliances. The World Health Organization specifically reaffirmed its finding that EMF is classifiable as a Group 2B Possible Human Carcinogen in 2006 in their Health Criteria Monograph #238 (WHO, 2007).

World Health Organization International Agency for Research on Cancer (IARC) Cancer Classifications

Group 1	Known Carcinogen
Group 2A	Probable Carcinogen
Group 2B	Possible Human Carcinogen
Group 3	Insufficient Information
Group 4	Not a Carcinogen

In 2011, IARC determined that scientific evidence is sufficient now to classify radiofrequency radiation as a Group 2B Possible Human Carcinogen (Baan et al, 2011). This is the kind of exposure coming from cell and cordless phones, cell towers, WI-FI, wireless laptops, electronic baby monitors and wireless 'smart' utility meters.

So, what does this mean? According to the classification categories, it is again clear IARC did NOT find so little clear and consistent evidence that it should support a finding of "Not A Carcinogen". That would be the valid test that RFR is safe, as best public health experts can judge the evidence. Nor did IARC find that the evidence sufficient so as to make a stronger classification (Probably or Known Carcinogen). Rather, IARC found the evidence supports classification as a "Possible" cancer-causing

agent. That is not a weak or reckless judgment made with few facts. It should be a strong warning to governments to reconsider their safety standards, particularly in light of the billions of people at potential health risk from new wireless technologies. Studies of cell and cordless phones and of wireless whole-body RFR exposures consistently show human health impacts that have become 'epidemiologically visible' (Sections 11 and 21).

ELF-EMF AND RFR ARE CLASSIFIED AS POSSIBLE CANCER-CAUSING AGENTS – WHY ARE GOVERNMENTS NOT ACTING?

The World Health Organization International Agency for Research on Cancer has classified wireless radiofrequency as a Possible Human Carcinogen (May, 2011). The designation applies to low-intensity RFR in general, covering all RFR-emitting devices and exposure sources (cell and cordless phones, WI-FI, wireless laptops, wireless hotspots, electronic baby monitors, wireless classroom access points, wireless antenna facilities, etc). The IARC Panel could have chosen to classify RFR as a Group 4 – Not A Carcinogen if the evidence was clear that RFR is not a cancer-causing agent. It could also have found a Group 3 designation was a good interim choice (Insufficient Evidence). IARC did neither.

II. KEY SCIENTIFIC EVIDENCE (2006- 2012)

Many thousand scientific studies over four decades have provided warnings of serious biological effects and potential health harm from EMF and RFR. About 1800 new, scientific papers published in the last five years report more bioeffects and adverse health effects of EMF and RFR, and are presented in great detail in the BioInitiative Report 2012.

These studies since 2006 give critical support to the argument that current safety standards are grossly inadequate. They cannot be protecting public health if they do not prevent harm to a variety of types of human cells, human sperm and the developing fetus *in-utero*. These are all effects reported today due to cell phone radiation exposures that are both legal and common in daily home, business and school environments. These effects are shown to occur at very low-intensity permissible levels that have become 'typical' for pregnant women, the fetus, the infant, the child, and for adults. Such effects are occurring at hundreds to thousands of times lower intensity exposure levels than the current FCC public safety limits allow. These exposure levels are common in the

environment, but worst in close proximity to wireless devices like cell and cordless phones, 'smart' wireless utility meters, wireless routers, wireless classroom access points and laptops, to baby surveillance devices, and in the first few hundred meters of cell towers. WI-FI levels of RFR and cell phones-on-standby mode are sufficient to cause effects that, if chronic, may be damaging to the health of cellular DNA, reproductive germ cells (sperm) and the male reproductive organs.

Overall, these new studies report abnormal gene transcription (Section 5); genotoxicity and single-and double-strand DNA damage (Section 6); stress proteins because of the fractal RF-antenna like nature of DNA (Section 7); chromatin condensation and loss of DNA repair capacity in human stem cells (Sections 6 and 15); reduction in free-radical scavengers - particularly melatonin (Sections 5, 9, 13, 14, 15, 16 and 17); neurotoxicity in humans and animals (Section 9), carcinogenicity in humans (Sections 11, 12, 13, 14, 15, 16 and 17); serious impacts on human and animal sperm morphology and function (Section 18); effects on offspring behavior (Section 18, 19 and 20); and effects on brain and cranial bone development in the offspring of animals that are exposed to cell phone radiation during pregnancy (Sections 5 and 18). This is only a snapshot of the evidence presented in the BioInitiative 2014 updated report.

Many of these bioeffects are associated with disruption of normal biological functioning in the genes, and in the physiology of the nervous and cardiac systems of the body (brain, blood-brain barrier, heart, vascular system). Sleep disruption (insomnia) is a hallmark bioeffect of RFR. Hypersensitivity disorders like allergies and asthma are reported from exposure to environmental chemicals and to EMF. A pregnant woman's exposure to EMF has been linked to increased asthma and behavioral problems in the human child after *in-utero* exposure. Pregnant mice exposed to cell phone radiation give birth to baby mice with attention disorders, hyperactivity and impaired memory function, similar to effects seen in human babies as reported by Divan et al (2008).

A. Stress, Stress Proteins and DNA as a Fractal Antenna: The word stress invokes different concepts for people, but needs to be understood as a physiological response. BioInitiative author Martin Blank has described how both ELF-EMF and RFR produce stress proteins at very low exposure levels, and why this is only adaptive in the short-

term. Chronic exposures that trigger stress responses (stress proteins) regardless of their environmental cause are mal-adaptive if they go on too long. Any agent (EMF, ionizing radiation, chemicals, heavy metals, etc) that continuously generates stress proteins is not adaptive, and is harmful, if it is a constant provocation.

The work of Martin Blank and Reba Goodman of Columbia University has established that stress proteins are produced by ELF-EMF and RFR at levels far below current safety standards allow. Further, they think DNA is actually a very good fractal RF-antenna which is very sensitive to low doses of EMF, and may induce the cellular processes that result in chronic 'unrelenting' stress. That daily environmental levels of ELF-EMF and RFR can and do throw the human body into stress protein response mode (out of homeostasis) is a fundamental and continuous insult. Chronic exposures can then result in chronic ill-health.

B. Fetal Effects and Fetal Development Studies: Effects on the developing fetus from *in-utero* exposure to cell phone radiation have been observed in both human and animal studies since 2006. Divan et al (2008) found that children born of mothers who used cell phones during pregnancy develop more behavioral problems by the time they have reached school age than children whose mothers did not use cell phones during pregnancy. The July 2008 issue of Epidemiology reports that children whose mothers used cell phones during pregnancy had 25% more emotional problems, 35% more hyperactivity, 49% more conduct problems and 34% more peer problems (Divan et al, 2008).

Aldad et al (2012) showed that cell phone radiation significantly altered fetal brain development and produced ADHD-like behavior in the offspring of pregnant mice. Exposed mice had a dose-dependent impaired glutamatergic synaptic transmission onto Layer V pyramidal neurons of the prefrontal cortex. The authors conclude the behavioral changes were the result of altered neuronal developmental programming *in utero*. Offspring mice were hyperactive and had impaired memory function and behavior problems, much like the human children in Divan et al (2008).

A new study from Greece reports altered development of the cranial bones of the mouse fetus from low intensity (0.6 to 0.9 W/kg) *in-utero* 900 MHz cell phone radiation (Fragopoulou et al, 2009). They report *"our results clearly show that even modest exposure (e.g., 6-min daily for 21 days) is sufficient to interfere with the normal mouse developmental process."*

Other new studies by Fragopoulou et al report that brain astrocyte development followed by proteomic studies is adversely affected by DECT (cordless phone radiation) and mobile phone radiation (Fragopoulou et al, 2012); and that whole body exposure with GSM 900MHz affects spatial memory in mice (Fragopoulou et al, 2010).

FETAL BRAIN DEVELOPMENT MAY BE ALTERED

There is increasing evidence that fetal (*in-utero*) and early childhood exposures to cell phone radiation and wireless technologies in general is a risk factor for hyperactivity, learning disorders and behavioral problems in school.

Neonatal physician Carlo Bellieni of Italy found that heart rate variability is adversely affected in infants hospitalized in isolettes or incubators where ELF-EMF levels are in the 0.8 to 0.9 μT range (8 to 9 mG) (Bellieni, 2008). Infants suffer adverse changes in heart rate variability, similar to adults. He also reported that newborns cared for in the high ELF-EMF environments of isolettes have disrupted melatonin levels (Bellieni et al, 2012a).

C. Studies of Sperm: Several international laboratories have replicated studies showing adverse effects on sperm quality, motility and pathology in men who use and particularly those who wear a cell phone, PDA or pager on their belt or in a pocket (Agarwal et al, 2008; Agarwal et al, 2009; Wdowiak et al, 2007; De Iuliis et al, 2009; Fejes et al, 2005; Aitken et al, 2005; Kumar, 2012). Other studies conclude that usage of cell phones, exposure to cell phone radiation, or storage of a mobile phone close to the testes of human males affect sperm counts, motility, viability and structure (Aitken et al, 2004; Agarwal et al, 2007; Erogul et al., 2006). Animal studies have demonstrated oxidative and DNA damage, pathological changes in the testes of animals, decreased sperm mobility and viability, and other measures of deleterious damage to the male germ line

(Dasdag et al, 1999; Yan et al, 2007; Otitoloju et al, 2010; Salama et al, 2008; Behari et al, 2006; Kumar et al, 2012). There are fewer animal studies that have studied effects of cell phone radiation on female fertility parameters. Panagopoulous et al. 2012 report decreased ovarian development and size of ovaries, and premature cell death of ovarian follicles and nurse cells in *Drosophila melanogaster.* Gul et al (2009) report rats exposed to stand-by level RFR (phones on but not transmitting calls) caused decrease in the number of ovarian follicles in pups born to these exposed dams. Magras and Xenos (1997) reported irreversible infertility in mice after five (5) generations of exposure to RFR at cell phone tower exposure levels of less than one microwatt per centimeter squared (μW/cm2).

Agarwal et al (2009) evaluated the effect of cell phone radiation during talk mode on human sperm samples. The authors found *"radiofrequency electromagnetic waves emitted from cell phones may lead to oxidative stress in human semen. We speculate that keeping the cell phone in a trouser pocket in talk mode may negatively affect spermatozoa and impair male fertility."*

Aitken et al (2005) studied the effect of 900 MHz cell phone radiation on mice (7 days, 12-hr per day at 0.09 W/kg). The authors found statistically significant damage to the mitochondrial genome of epididymal spermatozoa ($p<0.05$).

Avendano et al, 2012 provided evidence that a 4-hr exposure to WI-FI at exceeding low levels (0.5-1.0 μW/cm2) near a laptop computer caused decreased sperm viability and DNA fragmentation in human sperm samples. Avendado says "*(T)o our knowledge, this is the first study to evaluate the direct impact of a laptop use on human spermatozoa. Ex vivo exposure of human spermatozoa to a wireless internet-connected laptop decreased motility and induced DNA fragmentation by a nonthermal effect. We speculate that keeping a laptop connected wirelessly to the internet on the lap near the testes may result in decreased male fertility."*

De Iuliis et al (2009) reported that *"RF-EMR in both the power density and frequency range of mobile phones enhances mitochondrial reactive oxygen species generation by human spermatozoa, decreasing the motility and vitality of these cells*

while stimulating DNA base adduct formation, and ultimately DNA fragmentation." They warned their findings *"have clear implications for the safety of extensive mobile phone use by males of reproductive age, potentially affecting both their fertility and the health and wellbeing of their offspring"* based on damage from a 6-hr exposure to 1800 MHz cell phone radiation in human sperm cells. This 6-hr exposure caused reduced sperm motility and viability and caused a significant increase in reactive oxygen species (free radicals that are associated with oxidative damage to DNA), and the effects were worse with more exposure (a significant dose-response was observed). Atasoy (2012) also questioned the safety of 2400 MHz exposure to those of reproductive age. This study reports that WI-FI internet access devices can damage DNA and reduce DNA repair when the exposures are very low(exposure level of 0.091 W/kg) and chronic; damage can occur even at levels that comply with 802.11 g WI-FI public safety limits.

Behari et al (2006) reported that chronic exposure of rats to cell phone radiation caused double-strand DNA breaks in sperm cells (35 days, 2-hr per day). This study also showed that the mobile radiation exposure at 900 MHz (at 0.9 W/kg) and at 2.45 GHz (at 0.1 W/kg) caused a statistically significant decrease in sperm count and the weight of testes.

Otitoloju et al., (2010) graphically describe sperm head abnormalities in mice exposed for six months to base-station level RF/MW at 70 to 100 nanowatts/cm2 (0.07 – 0.1 μW/cm2). Only 2% of controls but a stunning 39% to 46% of exposed mice had damaged sperm.

> *"The major abnormalities observed were knobbed hook, pin-head and banana-shaped sperm head. The occurrence of sperm head abnormalities was also found to be dose dependent. The implications of the observed increased occurrence of sperm head abnormalities on the reproductive health of humans living in close proximity to GSM base stations were discussed."*

These studies taken together should provide a strong warning that 'normal' use of a cell phone presents risks that warrant strong preventative actions to protect the integrity of the human genome from de novo mutations and loss of fertility across entire male populations of cell phone users. Further, even the much lower exposure levels associated with mobile phone base station (cell tower) RFR levels are deleterious over time.

HUMAN SPERM AND THEIR DNA ARE DAMAGED

Human sperm are damaged by cell phone radiation at very low intensities (0.00034 – 0.07 μW/cm2). There is a veritable flood of new studies reporting sperm damage in humans and animals, leading to substantial concerns for fertility, reproduction and health of the offspring (unrepaired de novo mutations in sperm). Exposure levels are similar to those resulting from wearing a cell phone on the belt, or in the pants pocket, or using a wireless laptop computer on the lap. Sperm lack the ability to repair DNA damage.

D. Human Stem Cell Studies: Markova et al (2010) reported that 915 MHz microwave exposure significantly affects human stem cells. They found that very low-intensity microwave radiation from mobile phones can inhibit DNA repair processes in human stem cells. By placing a mobile phone at one meter distance from human stem cells in petri dishes (SAR = 0.037 W/Kg), they found a significant reduction in 53BP1 foci. These foci are a measure of DNA repair in cells with double strand DNA damage. The damage was greater to stem cells (derived from adipose tissue in humans) than in fibroblasts. Stem cells did not repair over time - and the damage was done within one hour of microwave exposure. Fibroblasts were similarly affected (inhibited 53BP1 foci) but repaired over time. The effects are carrier-frequency dependent. The effects occurred with GSM exposure at 915 MHz, but not at 905 MHz. The failure of DNA repair also occurred at the mobile phone UTMS carrier frequency of 1947 MHz. Analysis of the 53BP1 foci is a sensitive technique to measure double-strand DNA breaks in both unexposed cells and in cells exposed to cytotoxic agents. In the authors' words, "*this represents a direct mechanistic link to epidemiological data showing an association of MW exposure with increased cancer risk.*" The data obtained from human stem cells is of "*utmost relevance for assessment of possible health risks of MW exposure from mobile phones.*" Most, if not all adult tissues and organs including blood, skin and brain contain stem cells. Therefore, "*stem cells like blood cells and fibroblasts are always subjected to exposure from mobile phones.*" With respect to children, because "*almost all organs and tissues possess stem cells and stem cells are more active in children, the possible relationship of chronic MW exposure and various types of tumors and leukemia especially in children should be investigated.*"

Czyz et al (2004) reported that GSM cell phone exposure affected gene expression levels in embryonic stem cells (p53-deficient); and significantly increased heat shock protein HSP 70 production.

HUMAN STEM CELL DNA DOES NOT ADAPT OR REPAIR

Human adipose tissue stem cells lack the ability to repair DNA damage caused by chronic exposure to non-thermal microwaves. Damage to DNA in some other cells may be incompletely repaired.

E. Mobile Phone Base Station (Cell Tower) Studies

Human Studies: Hutter et al (2006) reported that short-term exposure to GSM cell phone radiation resulted in complaints of headache, neurological problems, sleep and concentration problems in adults with 0.01 - 0.05 μW/cm2 exposure levels. Kundi and Hutter (2009) reviewed human effects in fourteen (14) mobile phone base station studies and reported *"(F)rom available evidence it is impossible to delineate a threshold below which no effect occurs, however, given the fact that studies reporting low exposure were invariably negative it is suggested that power densities around 0.5–1 mW/m2 [*0.05 – 0.1 uW/cm2*] must be exceeded in order to observe an effect."*

Buchner and Eger (2012) conducted an eighteen (18) month study to assess changes in stress hormones in 60 persons exposed before and after a mobile phone base station went into operation in the Rimbach village in Germany. The study showed that chronic exposure to base station RF (whole-body) at 0.006 - 0.01 μW/cm2 in humans had significant impacts on stress hormones over time. In the beginning months, adrenaline levels first increased in a dose-dependent fashion according to exposure level ($p < 0.002$) and then decreased below normal levels ($p < 0.005$). Both the average as well as the median adrenaline values increased after the activation of the transmitter and decreased again after one year with exposure levels >0.006 μW/cm2. Chronically ill subjects and children showed especially strong responses; except for some "outliers," no effect was observed in healthy adults (Buchner and Eger, 2012). For dopamine, inverse effects to

those for adrenaline and noradrenaline were observed. The median dopamine levels decreased from 199 to 115 μg/g creatinine between January and July 2004. The fact that the dopamine levels of the study subjects decreased during this period is highly significant ($p<0.0002$). Thereafter, the median increased again: In January 2005, it was at 131 μg/g creatinine, in July of 2005. This increase is also significant between July 2004 and July 2005 ($p<0.05$).

Buchner (2012) indicates that the RFR transmitter induced changes in stress hormones that follow the classic stress syndrome of adaptation, then exhaustion established by Hans Seyle in the 1950's. *"After the stages of alarm and resistance, the last stage of exhaustion sets in. The parameters investigated in the Rimbach study follow this pattern"*.

A long-term 6-yr study assessed the role of exposure to radio frequency radiation (RFR) emitted either from mobiles or base stations and its relations with human's hormone profiles. The study revealed significant RFR effects on pituitary–adrenal axis, resulting in reduction of ACTH, cortisol, thyroid hormones, prolactin in young females, and testosterone levels in males (Eskander et al, 2012). But no direct measurements of RFR power density levels were made, only categories of distance from transmitter.

Oberfeld et al (2004) reported that populations exposed to base stations transmitting cell phone frequencies had more fatigue, depressive tendency, sleeping disorders, concentration difficulties, and cardio-vascular problems reported with exposure to GSM 900/1800 MHz cell phone signal.

Navarro et al (2003) reported that exposure levels of 0.01 - 0.11 μW/cm2 resulted in fatigue, headaches, sleeping problems in populations around mobile phone base stations.

Thomas et al (2008) reported an increase in adult complaints of headaches and concentration difficulties with short-term cell phone use at 0.005 to 0.04 μW/cm2 exposure levels.

Heinrich et al (2010) reported that children and adolescents (8-17 years old) with short-term exposure to base-station level RFR experienced headache, irritation, and concentration difficulties in school. RFR levels were 0.003 - 0.02 μW/cm2.

Thomas et al (2010) reported that RFR levels of 0.003 - 0.02 μW/cm2 resulted in conduct and behavioral problems in children and adolescents (8-17 years old) exposed to short-term cell phone radiation in school.

Mohler et al (2010) reported that adults exposed to 0.005 μW/cm2 cell phone radiation (base-station exposure levels) had sleep disturbances with chronic exposure, but this effect was not significantly increased across the entire population.

Human Studies at Base Station Exposure Levels (Cell Towers)

At least five new cell tower studies with base-station level RFR at levels ranging from 0.003 μW/cm2 to 0.05 uW/cm2 published since 2007 report headaches, concentration difficulties and behavioral problems in children and adolescents; and sleep disturbances, headaches and concentration problems in adults. This is highly consistent with studies done prior to 2007, but the 'effect levels' are significantly lower (dropping from the microwatt to the nanowatt range per square centimeter).

Public safety standards are 1,000 – 10,000 or more times higher than levels now commonly reported in mobile phone base station studies to cause bioeffects.

Sperm studies are showing DNA damage, impaired sperm quality, motility and viability from cell phones on standby mode and wireless laptop use at exposures of 0.00034 μW/cm2 to 0.07 μW/cm2. Several studies report sperm damage effects at 'standby model' cell phone emission levels, which are in the low nanowatt to picowatt per square centimeter range.

F. Electrohypersensitivity (EHS) Studies: McCarty et al (2011) studied electrohypersensitivity in a patient (a female physician). The patient was unable to detect the presence or absence of EMF exposure, largely ruling out the possibility of bias. In multiple trials with the fields either on or not on, the subject experienced and reported temporal pain, feeling of usease, skipped heartbeats, muscle twitches and/or strong headache when the pulsed field (100 ms, duration at 10 Hz) was on, but no or mild symptoms when it was off. Symptoms from continuous fields were less severe than with pulsed fields. The differences between field on and sham exposure were significant at the $p < 0.05$ level. The authors conclude that electromagnetic hypersensitivity is a neurological syndrome, and statistically reliable somatic reactions could be provoked in this patient by exposure to 60-Hz electric fields at 300 volts per meter (V/m). They

conclude *"EMF hypersensitivity can occur as a bona fide environmentally inducible neurological syndrome."* In their response to a letter to the editor of the journal, the authors say: *"(W)e followed an empirical approach and demonstrated a cause-and-effect relationship ($p < 0.05$) under conditions that permitted us to infer the existence of electromagnetic hypersensitivity (EHS), a novel neurological syndrome."* (Marino et al., 2012)

Further, the authors explain the significance of detecting EHS effects by non-linear methods.

> *"The important issue at this point is not whether EMF can produce symptoms (we empirically demonstrated that it can) but rather why this effect historically has been difficult to detect. It occurred to us that EHS has remained elusive because of the way it was studied. The experiments designed to detect EHS had been based on the assumption that if it existed, it was a linear phenomenon, whereas EHS is actually a nonlinear phenomenon." "Our study was designed to detect whether EHS was a linear or nonlinear phenomenon, and we were successful in showing a link between acute EMF exposure and somatic responses ($p < 0.05$). This finding – taken together with the unfailingly negative results of the linear studies – is good evidence that EHS is a nonlinear phenomenon, as we suspected."*

With the exception of the McCarty study there have not been clear demonstrations in controlled circumstances showing that persons reporting to be electrophypersensitive can distinguish whether or not RFR is being applied. There are, however, multiple reports of symptoms experienced by individuals exposed to EMFs in uncontrolled circumstances.

A. Johansson et al (2010) studied symptoms, personality traits and stress in people with mobile phone-related symptoms and electromagnetic hypersensitivity. They reported there is support for a difference between people with symptoms related to specific EMF sources and people with general EHS. The symptoms are anxiety, depression, somatization, exhaustion and stress. The EHS group reported more neurasthenic symptoms.

Two publications on electrohypersensitivity by O. Johansson (2007, 2009) provide an extensive overview of the relevant literature on electrohypersensitivity. Both

publications document symptoms and conditions giving rise to increased sensitivity to ELF-EMF and RFR. The need for new, biologically-based public exposure standards is recommended in both publications, in order to address electrohypersensitivity.

Landgrebe et al (2007) reported that their study of electrosensitive patients showed participants had a reduced intracortical facilitation as compared to two control groups. The EHS group of patients showed altered central nervous system function. In a follow-up study, the authors reported that EHS patients but not controls "*demonstrated significant cognitive and neurobiological alterations pointing to a higher genuine individual vulnerability of electromagnetic hypersensitive patients.*" *(Landgrebe et al, 2008).*

The team of Sandstrom, Hansson Mild and Lyskov produced numerous papers between 1994 and 2003 involving people who are electrosensitive (Lyskov et al, 1995; Lyskov et al, 1998; Sandstrom et al, 1994; Sandstrom et al, 1995; Sandstrom et al, 1997; Sandstrom et al, 2003). Sandstrom et al (2003) presented evidence that heart rate variability is impaired in people with electrical hypersensitivity and showed a dysbalance of the autonomic nervous system. "*EHS patients had a disturbed pattern of circadian rhythms of HRF and showed a relatively 'flat' representation of hourly-recorded spectral power of the HF component of HRV*". This research team also found that *"EHS patients have a dysbalance of the autonomic nervous system (ANS) regulation with a trend to hyper-sympathotonia, as measured by heart rate (HR) and electrodermal activity, and a hyperreactivity to different external physical factors, as measured by brain evoked potentials and sympathetic skin responses to visual and audio stimulation.*" (Lyskov et al, 2001 a,b; Sandstrom et al, 1997). The reports referenced above provide evidence that persons who report being electrosensitive differ from others in having some abnormalities in the autonomic nervous system, reflected in measures such as heart rate variability. At present it remains unclear whether EHS is actually caused by RF/EMF exposure, or rather is a self-identifying syndrome of excessive responsiveness to a variety of stimuli. But given the relatively high percentage of persons reported to be electrosensitive (5% of the general population of Switzerland according to Schreier et al,

2006), with some being severely disabled as a consequence, it is critical that there be more study of this syndrome.

Tuengler and von Klitzing et al (2012) reported EHS people that were tested showed significant changes in regulation of the autonomic nervous system, including changes in capillary blood flow (microcirculation), heart rate variability, and electric skin potentials. The continuous detection of capillary blood flow is an important tool in analyzing the capacity of the autonomic nervous system. In EHS patients, von Klitzing finds that intestinal motility may also be disregulated and show no activity at all for some time after exposure.

G. Effects on the Blood-brain Barrier (BBB): The Lund University (Sweden) team of Leif Salford, Bertil Persson and Henrietta Nittby has done pioneering work on effects of very low level RFR on the human brain's protective lining – the barrier that protects the brain from large molecules and toxins that are in the blood.

THE BLOOD-BRAIN BARRIER IS AT RISK

The BBB is a protective barrier that prevents the flow of toxins into sensitive brain tissue. Increased permeability of the BBB caused by cell phone RFR may result in neuronal damage. Many research studies show that very low intensity exposures to RFR can affect the blood-brain barrier (BBB) (mostly animal studies). Summing up the research, it is more probable than unlikely that non-thermal EMF from cell phones and base stations do have effects upon biology. A single 2-hr exposure to cell phone radiation can result in increased leakage of the BBB, and 50 days after exposure, neuronal damage can be seen, and at the later time point also albumin leakage is demonstrated. *The levels of RFR needed to affect the BBB have been shown to be as low as 0.001 W/kg, or less than holding a mobile phone at arm's length. The US FCC standard is 1.6 W/kg; the ICNIRP standard is 2 W/kg of energy (SAR) into brain tissue from cell/cordless phone use. Thus, BBB effects occur at about 1000 times lower RFR exposure levels than the US and ICNIRP limits allow.* *(Salford, 2012)*

The consequence to modern life is that cell and cordless phone use may cause a pathological leakage of the BBB with very short use periods, and the damage may be long-lasting. Harmful substances may enter the brain. If the damage is ongoing (if cell and cordless phone use continues to occur over months and years), the potential for

harmful effects increases. There is already 'epidemiologically visible' evidence of increased brain cancer risk in humans (Section 11).

Volkow et al (2011a, b) reported increased glucose metabolism in the brain with cell phone use in humans. This important investigation of 47 human subjects used a randomized crossover design and labeled fluorodeoxyglucose to measure the metabolisms of the brain when the cell phone was activated but muted for 50 minutes as compared to not being activated. "*Our study showed that cell phone activation was associated with metabolic increases in brain regions closest to the antenna and that the increases showed a negative linear correlation with distance from the antenna. While the effect was small, the negative correlation of the effect with distance was statistically significant* ($R = -0.91$; $P < .001$). This study is particularly important in that it demonstrates definitively that an active cell phone, placed on the ear as one would normally be used, alters brain metabolic activity, but only in the region close to the cell phone.

H. Brain Cancer Studies: The Orebro University (Sweden) team led by Lennart Hardell, MD, an oncologist and medical researcher, has produced an extraordinary body of work on environmental toxins of several kinds, including the effects of radiofrequency/microwave radiation and cancer. Their 2012 work concludes:

> *"Based on epidemiological studies there is a consistent pattern of increased risk for glioma and acoustic neuroma associated with use of mobile phones and cordless phones. The evidence comes mainly from two study centres, the Hardell group in Sweden and the Interphone Study Group. No consistent pattern of an increased risk is seen for meningioma. A systematic bias in the studies that explains the results would also have been the case for meningioma. The different risk pattern for tumor type strengthens the findings regarding glioma and acoustic neuroma. Meta-analyses of the Hardell group and Interphone studies show an increased risk for glioma and acoustic neuroma. Supportive evidence comes also from anatomical localisation of the tumor to the most exposed area of the brain, cumulative exposure in hours and latency time that all add to the biological relevance of an increased risk. In addition risk calculations based on estimated absorbed dose give strength to the findings.*

In summary:

- *There is reasonable basis to conclude that RF-EMFs are bioactive and have a potential to cause health impacts.*

- *There is a consistent pattern of increased risk for glioma and acoustic neuroma associated with use of wireless phones (mobile phones and cordless phones) mainly based on results from case-control studies from the Hardell group and Interphone Final Study results.*
- *Epidemiological evidence gives that RF-EMF should be classified as a human carcinogen.*
- *Based on our own research and review of other evidence the existing FCC/IEE and ICNIRP public safety limits and reference levels are not adequate to protect public health.*
- *New public health standards and limits are needed.* (Hardell et al, 2012)

I. **Genetic Damage (Genotoxicity Studies):** There are at least several hundred published papers that report EMF affects cellular oxidative processes (oxidative damage). Increased free radical activity and changes in enzymes involved in cellular oxidative processes are the most consistent effects observed in cells and animals after EMF exposure. Aging may make an individual more susceptible to the detrimental effects of ELF EMF from oxidative damage, since anti-oxidants may decline with age. Clearly, the preponderance of genetic studies report DNA damage and failure to repair DNA damage.

> Eighty six (86) new papers on genotoxic effects of RFR published between 2007 and mid-2012 are profiled. Of these, 54 (63%) showed effects and 32 (37%) showed no effects (Lai, 2012)
>
> Forty three (43) new ELF-EMF papers and two static magnetic field papers that report on genotoxic effects of ELF-EMF published between 2007 and mid-2012 are profiled. Of these, 35 (81%) show effects and 8 (19%) show no effect (Lai, 2012).

J. Nervous System Damage: Factors that act directly or indirectly on the nervous system can cause morphological, chemical, or electrical changes in the nervous system that can lead to neurological effects. Both RF and ELF EMF affect neurological functions and behavior in animals and humans.

> One hundred fifty five (155) new papers that report on neurological effects of RFR published between 2007 and mid-2012 are profiled. Of these, 98 (63%) showed effects and 57 (37%) showed no effects.
>
> Sixty nine (69) new ELF-EMF papers (including two static field papers) that report on genotoxic effects of ELF-EMF published between 2007 and mid-2012 are profiled. Of these, 64 (93%) show effects and 5 (7%) show no effect. (Lai, 2012)

L. Children are More Vulnerable: Many studies demonstrate that children are more sensitive to environmental toxins of various kinds (Barouki et al, 2012; Preston, 2004; WHO, 2002; Gee, 2009; Sly and Carpenter, 2012).

> The Presidential Cancer Panel (2010) found that children '*are at special risk due to their smaller body mass and rapid physical development, both of which magnify their vulnerability to known carcinogens, including radiation.*'

> The American Academy of Pediatrics, in a letter to Congressman Dennis Kucinich dated 12 December 2012 states "*Children are disproportionately affected by environmental exposures, including cell phone radiation. The differences in bone density and the amount of fluid in a child's brain compared to an adult's brain could allow children to absorb greater quantities of RF energy deeper into their brains than adults. It is essential that any new standards for cell phones or other wireless devices be based on protecting the youngest and most vulnerable populations to ensure thay are safeguarded through their lifetimes.*"

II. ISSUES AND ANSWERS IN THE EMF DEBATE

Much of the emphasis in the 2007 Bioinititative Report focused on cancer, which is still the best documented disease of concern from exposure to EMF/RF. The evidence that exposure to EMF/RF increases the risk of cancer has only gotten significantly stronger since then, and we have a better, albeit still incomplete, understanding of the mechanisms involved. However, in terms of threshold exposures that result in human disease, new research on male reproduction and neurobehavioral alterations provide evidence for harm at even lower exposure levels. RFR has been shown in this Report to act as an external synchronizer of neural activity, capable of disrupting sleep, circadian rhythms, diurnal hormone fluctuations, brain wave activity and heart rate variability by exposure to artificial electromagnetic signals (as opposed to natural evolutionary frequencies) and to do so at exceedingly low intensities.

Much of the debate over the body of EMF science ignores simple questions that would help to discriminate among studies with apparently conflicting results. Section 15 by Dr. Belyaev is helpful in identifying key factors which must be known and controlled for in experiments (biological variables and physical parameters include bandwidth, frequency, modulation, polarization, intermittence and coherence time of exposure, static

magnetic field, electromagnetic stray fields, sex, age, individual traits, and cell density during exposure). Dr. Andrew Marino emphasizes that detection of EMF/RFR effects require investigation of non-linear phenomena, a critical difference that if ignored, may miss important biological effects (Marino, 2012).

A unifying hypothesis for a plausible biological mechanism to account for very weak field EMF bioeffects other than cancer may lie with weak field interactions of pulsed RFR and ELF-modulated RFR as disrupters of synchronized neural activity. Electrical rhythms in our brains can be influenced by external signals. This is consistent with established weak field effects on coupled biological oscillators in living tissues. Biological systems of the heart, brain and gut are dependent on the cooperative actions of cells that function according to principles of non-linear, coupled biological oscillations for their synchrony, and are dependent on exquisitely timed cues from the environment at vanishingly small levels (Buzsaki, 2006; Strogatz, 2003). The key to synchronization is the joint actions of cells that co-operate electrically - linking populations of biological oscillators that couple together in large arrays and synchronize spontaneously according to the mathematics described for Josephson junctions (Brian Josephson, the 1993 Nobel prize winner for this concept). This concept has been professionally presented in journal articles and also popularized in print by Prof. Steven Strogatz, a mathematician at Cornell University who has written about 'sync' as a fundamental organizing principle for biological systems (Strogatz, 2001; 2003).

> *"Organisms are biochemically dynamic. They are continuously subjected to time-varying conditions in the form of both extrinsic driving from the environment and intrinsic rhythms generated by specialized cellular clocks within the organism itself. Relevant examples of the latter are the cardiac pacemaker located at the sinoatrial node in mammalian hearts and the circadian clock residing at the suprachiasmatic nuclei in mammalian brains. These rhythm generators are composed of thousands of clock cells that are intrinsically diverse but nevertheless manage to function in a coherent oscillatory state. This is the case, for instance, of the circadian oscillations exhibited by the suprachiasmatic nuclei, the period of which is known to be determined by the mean period of the individual neurons making up the circadian clock. The mechanisms by which this collective behavior arises remain to be understood."(Strogatz, 2003)*

Synchronous biological oscillations in cells (pacemaker cells) can be disrupted by artificial, exogenous environmental signals, resulting in desynchronization of neural

activity that regulates critical functions (including metabolism) in the brain, gut and heart and circadian rhythms governing sleep and hormone cycles (Strogatz, 1987). The brain contains a population of oscillators with distributed natural frequencies, which pull one another into synchrony (the circadian pacemaker cells). Strogatz has addressed the unifying mathematics of biological cycles and external factors disrupt these cycles. Buzsaki (2006) says "*rhythms can be altered by a wide variety of agents and that these perturbations must seriously alter brain performance. Rhythms are a robust phenomenon.*"

The heart's natural pacemaker center is the sinoatrial node, a cluster of about 10,000 cells that generate electrical rhythm that commands the rest of the heart to beat. Diseases related to disruption of that synchronization include epilepsy, chronic insomnia, and cardiac arrhythmias (Strogatz, 2003). Some EMF diseases are those where desynchronization of neural activity results in physiological changes that, if chronic, result in chronically disrupted homeostasis, and eventually ill-health and chronic diseases. Such a future burdens health care systems in an irreversible way.

The late Dr. Ross Adey in his last publication in Bioelectromagnetic Medicine (P. Roche and M. Markov, eds. 2004) concluded:

> "*There are major unanswered questions about possible health risks that may arise from exposures to various man-made electromagnetic fields where these human exposures are intermittent, recurrent, and may extend over a significant portion of the lifetime of the individual.*"
>
> "*Epidemiological studies have evaluated ELF and radiofrequency fields as possible risk factors for human health, with historical evidence relating rising risks of such factors as progressive rural electrification, and more recently, to methods of electrical power distribution and utilization in commercial buildings. Appropriate models describing these bioeffects are based in nonequilibrium thermodynamics, with nonlinear electrodynamics as an integral feature. Heating models, based in equilibrium thermodynamics, fail to explain an impressive new frontier of much greater significance. Though incompletely understood, tissue free radical interactions with magnetic fields may extend to zero field levels.*"

Our society appears determined to make everything wireless, and the consequence is to increase cumulative exposure to RFR. Many homes and almost every Starbucks or McDonalds has WiFi. Smart phones, tablets, video iPods and other wireless devices are even given to children as playthings. The result is a significant increase in cumulative RFR exposure of the whole population, but particularly of those who have and use wireless devices for prolonged periods of time. No national or international standard of RFR exposure considers cumulative effects, all being developed to avoid local tissue heating from acute exposures.

The issues around exposure of children to RFR is of critical importance. There is overwhelming evidence that children are more vulnerable than adults to many different exposures (Sly and Carpenter, 2012), including RFR, and that the diseases of greatest concern are cancer and effects on neurodevelopment. Yet parents place RFR baby monitors in cribs, provide very young children with wireless toys, and give cell phones to young children, usually without any knowledge of the potential dangers. A growing concern is the movement to make all student computer laboratories in schools wireless. A wired computer laboratory will not increase RFR exposure, and will provide safe access to the internet.

An urgent example for the need to address the lack of adequate public protection from inadequate safety standards for pulsed RFR exposures is the rapid, global rollout of wireless utility meters ('smart' meters for electricity, gas and water meters). Current safety standard calculations that rely on time-averaging of RFR almost entirely dilute out the power density of RFR levels that are delivered in millisecond bursts, but occur at intervals of every second, or multiple times per second when in use within a wireless mesh network. Said differently, the RFR power density levels are usually legal. While there have been no long term studies of adverse effects of smart meters on human health (primarily because they are so new), there are increasing reports from electrosensitive individuals of harm. Added together, these RFR pulses that now appear to be a highly bioactive agent but are essentially erased or made energetically invisible by time-averaging the pulses as current FCC safety rules mandate.

The wireless meters transmit RF signals like a mini-cell tower antennas in the cell phone radiation frequencies. Currently, they are being deployed in the US and are on the drawing boards around the world including many European countries. The 'smart meter' infrastructure represents the largest single commercial saturation of living space with pulsed RFR yet rolled out by industry. This program places a wireless device (like a mini-mobile phone base station) on the wall, replacing the electromechanical (spinning dial) meter. They will be installed on every home and classroom (every building with an electric meter). Utilities from California to Maine have installed tens of millions already, despite health concerns of experts who already are seeing thousands of health complaints. The wireless meters produce spikes of pulsed radiofrequency radiation on a continuous basis (24/7), and in typical operation, will saturate living space at levels that can be much higher than already reported to cause bioeffects and adverse health effects for some people. These meters, depending on where they are placed relative to occupied space in the home or classroom, can produce RFR exposure levels similar to that within the first 100 feet to 600 feet of a mobile phone base station (cell tower). In the not-so-distant future the plan is to have a wireless device implanted in every household appliance, which will communicate with the smart meter whenever electricity is being used. This will likely make the kitchen a major source of exposure to RFR.

The cumulative RFR burden within any community is largely unknown. Both involuntary sources (like cell towers, smart meters and second-hand radiation from the use of wireless devices by others) plus voluntary exposures from ones' personal use of cell and cordless phones, wireless routers, electronic baby surveillance monitors, wireless security systems, wireless hearing aids, and wireless medical devices like implanted insulin pumps all add up. No one is tallying up the combined exposure levels. Billions of new RFR transmitters from a global smart meter rollout will significantly add to the existing RFR body-burden of pulsed RFR for millions of people. The health concerns are the same as with all other sources of EMF/RFR. Cancer is a serious adverse effect, but damage to male reproduction and central nervous system effects may results from even lower levels of exposure. The work by Strogatz (2001, 2003) and Buzsaki (2006) on weak-field effects on non-linear biological oscillators (brain waves and synchronization of neural activities that regulate body processes) is directly relevant to an understanding

of the profound biological disruptions and health symptoms that continued exposures of pulsed RFR may produce.

The Commons of the Air

Turning to questions of social equity and the individuals' choice not to be exposed to harmful levels of environmental toxins, there has been little inclusion of the public in discussions of wireless radiofrequency exposure. Wireless technologies have become infused in daily habits of billions of people; often choices for wired equivalents are lacking (or those that exist are disappearing). Involuntary exposure to EMF and RFR is becoming more the norm, even where it runs counter to individual choice (second-hand radiation, like second-hand smoke is difficult to avoid).

> *"Wireless technologies drive electromagnetic energy through our air, into and through virtually all indoor and outdoor living environments. The protective air cushion around our planet holds breathable air, buffers us from space radiation, and supports and sustains life in tandem with the natural electromagnetic signature of the earth itself. We are changing this 'commons of the air' in major ways. Wireless signals from broadcast and communications technologies are crowding out and overpowering the natural background. The 'commons of the air' is being altered in unprecedented ways that have enormous consequences for life on earth."(Sage, 2010).*

The rush to 'buy the airwaves' and to market them for commercial purposes is loading '*the commons of the air*' with unsustainable levels of exposure (Sage, 2010). Commercial markets for wireless spectrum successfully lobby government regulators to allocate even more spectrum, once the existing frequencies are allocated. Sage (2010) asks:

> *"Who owns the 'commons of the air'? Who should be allowed to pollute it? What are the limits? On what basis should carrying capacity be defined? Who defines the limits? Do these limits conserve the resource for the future? Do they protect public health and welfare, and the health and well-being of other living things on earth? Who bears the burden of proof of safety or of harm? How should the 'new commons' be managed for the greater good? Do we know enough to act responsibly? Who decides? When should limits be placed on utilization?"*

With no regard to cumulative harm, this commercial rush to buy up wireless spectrum territorial rights has vast implications for public health and well-being. Environmental protections afforded to other natural resources under the National Environmental Policy Act have been ignored. The cumulative impacts and irretrievable commitments on humans, wildlife, and natural resources have never been assessed.

> *"Societies must now define carrying capacity for chronic electromagnetic and wireless exposures. Taking into account the large individual variability to withstand it, new limits must conserve and sustain the 'commons of the air' so that is sustainable for all—and this includes sensitive populations, the young, the elderly, and those with existing sensitivity. Some countries of the world already have surpassed sustainable wireless exposure levels as demonstrated by significant percentages that have already become electrosensitive." (Sage, 2010)*

Homeostasis and Human Health Rights

Chronic exposure to low-intensity RFR and to ELF-modulated RFR at today's environmental levels in many cities will exceed thresholds for increased risk of many diseases and causes of death (Sage and Huttunen, 2012). RFR exposures in daily life alter homeostasis in human beings. These exposures can alter and damage genes, trigger epigenetic changes to gene expression and cause de novo mutations that prevent genetic recovery and healing mechanisms. These exposures may interfere with normal cardiac and brain function; alter circadian rhythms that regulate sleep, healing, and hormone balance ; impair short-term memory, concentration, learning and behavior; provoke aberrant immune, allergic and inflammatory responses in tissues; alter brain metabolism; increase risks for reproductive failure (damage sperm and increase miscarriage risk); and cause cells to produce stress proteins. Exposures now common in home and school environments are likely to be physiologically addictive and the effects are particularly serious in the young (Sage and Huttunen, 2012). This declaration of human health rights below (Sage and Huttunen, 2012) is based on specific reference to health impacts of EMF and RFR that are reasonably well established to occur (Sage and Carpenter, 2009).

Human Health Rights Declaration
Fundamental Human Health Rights ***(Sage and Huttunen, 2012)***

The right to homeostasis in our own bodies.
The right to normal central nervous system function.
The right to natural environmental cues that synchronize our circadian rhythms.
The right to sleep.
The right to heal.
The right to hear.
The right to reproduce.
The right to learn and retain memories.
The right to an intact genome.

If even one of these rights is compromised – placed at risk from involuntary wireless exposures in daily life, it is a breach of human health rights. When many of these human health rights are compromised without the consent of the individual, then the deployment of wireless technologies should be halted and existing exposures reduced or eliminated, in accord with the scientific and public health findings on chronic exposure to low-intensity radiofrequency radiation, and other forms of potentially harmful electromagnetic fields (Sage and Huttunen, 2012)

V. CONCLUSIONS FOR PRUDENT PUBLIC HEALTH PLANNING

Methodology and Approach for Precautionary Action Limits

In 2007, the BioInititive Report chapter on Key Scientific Evidence and Public Health Policy Implications, proposed a specific, interim radiofrequency radiation target level of 0.1 μW/cm2 for cumulative, outdoor RFR exposure (for AM, FM, TV and wireless). It was based on best-available scientific studies to that date. There were few studies prior to 2006 that reported effects at less than 0.1 to 1 μW/cm2 chronic RFR exposures.

In 2009, the journal Pathophysiology produced many peer-reviewed articles in a special two-volume edition on EMF (both ELF-EMF and RFR) essentially publishing the contents of the BioInitiative Report and updating some information. One of these 2009 Pathophysiology papers presented a review of mobile phone base station studies (Kundi and Hutter, 2009). It concluded that the overall studies did not detect effects (headache,

fatigue, tinnitus, concentration difficulties, sleep disruption, etc) at levels of RFR exposure below 0.05 to 0.1 μW/cm2.

New base station-level RFR studies are available in 2012 that can be analyzed to determine if new (and lower) RFR recommendations are warranted. The approach in this chapter relies on "lowest levels at which effects are not seen" akin to the "no observed effect level (NOEL)" used for chemical exposures, as a sufficient basis to establish scientific benchmarks for harm (or alternately, the lowest observed effects level of exposure). It is the province of the science and public health evaluation we do here to report the evidence regardless of what political or strategic complications it may create. An objective presentation of what the studies reveal for 'effects levels' is our goal; not to pre-judge or dilute the evidence because it may present strategic or political hurdles to achieve consensus on policy and regulatory changes. What this report does not intend to do is take into account"how could we do this" or "what would it mean". The purpose is to lay out the science, and make some defensible reductions for factors that studies cannot or do not yet test for, and compensate with deductions for them (safety margins). As interim targets for precautionary action, they will serve as guides for decision-makers who will take up the issues of health, the quality of the future gene pool, social equity and cost.

There is no one study alone that meets impeccable standards for exposure assessment or totally eliminates all possibility for bias, but the constellation of studies together gives adequate support to delineate a 'lowest observed effects level', that in turn, with added safety margins, can serve as a guideline for precautionary action.

A reduction from the BioInitiative 2007 recommendation of 0.1 uW/cm2 (or one-tenth of a microwatt per square centimeter which is the same as 100 nanowatts/cm2) for cumulative outdoor RFR down to something three orders of magnitude lower (in the low nanowatt per square centimeter range) is justified on a public health basis. We use the new scientific evidence documented in this Report to identify 'effect levels' and then apply one or more reduction factors to provide a safety margin. We do note however, even a precautionary action level of several tenths of a nanowatt per square centimeter (or

several hundred picowatts per square centimeter) would still allow for cell phone transmissions (that can operate down to about 0.00003 V/m).

Even so, these levels may need to go lower in the future, as new and better studies are completed. This is what the authors said in 2007 (Carpenter and Sage, 2007, BioInitiative Report) and it remains true today in 2012. We leave room for future studies that may lower today's observed 'effects levels' and should be prepared to accept new information as a guide for new precautionary actions.

Establishing A Scientific Benchmark for 'Lowest Observed Effect Levels'

Studies that provide information at 'new levels of observed effect' have been identified. These serve as scientific benchmarks for possible risk to health and well-being. Next, we indentify reduction factors to compensate for sensitive subpopulations and apply them to the scientific benchmarks (lowest observed effect levels).

A ten-fold reduction factor is warranted (or higher) for studies that report effects from only short-term (i.e., acute) rather than chronic (i.e., long-term) exposures. Longer duration of exposure can cause bioeffects at lower exposures where these effects are NOT seen with shorter (acute) exposures (Belyaev, 1997; Belyaev, 2012). Chronic exposures with longer durations of weeks, months or years is what most populations face with respect to wireless classrooms, wireless offices and locations near base stations.

A second ten-fold reduction (or higher) is justified as a buffer for sensitive populations including children, the elderly and other adult groups that may be ill, already sensitized, in remission or suffer from ailments made worse by physiological stress and insomnia.

Studies which contribute together can reasonably contribute to delineating a new RFR lower effects level are primarily mobile phone (cell phone) base station studies of healthy human populations and studies of sperm damage in men who use and/or wear their wireless devices on or around the belt or pants pocket.

Power Density Studies (Mobile Phone Base Stations and Sperm/Fertility Studies)

A scientific benchmark of 0.003 uW/cm2 or three nanowatts per centimeter squared for 'lowest observed effect level' for RFR is based on mobile phone base station-level studies. The Thomas et al, (2008) study shows effects at a LOEL of 0.005 uW/cm2 on adults exposed to short-term cell phone radiation only (it is not a chronic exposure study). Other studies that are relevant are Thomas et al (2010) with a LOEL of 0.003 uW/cm2 and Heinrich et al (2010) with a LOEL of 0.003 uW/cm2. Both studied mixed child/adolescent populations of students, but have short-term test periods (are not chronic exposure studies) and have LOELs of 0.003 uW/cm2. Buchner et al (2012) shows a 0.006 uW/cm2 'effect level' and tests adult populations, but achieves 'chronic' exposure testing criterion (over 18 months). Applying a ten-fold reduction to compensate for the lack of long-term exposure (to provide a safety buffer for chronic exposure) or for children as a sensitive subpopulation yields a 300 to 600 picowatts per square centimeter precautionary action level. This is also equal to a 0.3 nanowatts to 0.6 nanowatts per square centimeter as a reasonable, precautionary action level.

Of the studies that deal with children and base-station level RFR exposures, none studied children exclusively, so the results may dilute out any apparent effects accruing to the younger test subjects. Thomas et al (2010) is a short-term exposure study of children and adolescents 8 to 17 years in age. Heinrich et al (2010) is a further study of the same population of 8 to 17 year olds over the short-term. A 100-fold reduction could be defended as reasonably conservative in this instance.

Behari et al (2006) provides the one sperm study expressed in power density units with a LOEL of 0.00034 uW/cm2. It is a chronic exposure study. The majority of sperm studies with good exposure information are expressed in SARs (W/kg). These range from LOELs of 0.014 (Kumar et al, 2012) to 0.091 W/kg (Atasoy et al, 2012) to 0.43 W/kg (Salama et al, 2008) to 0.795 W/kg (Panagopoulous et al, 2012) to 0.9 W/kg (Kesari et al, 2012). All the other sperm damage or ovarian damage studies have SARs

of greater than 1.0 W/kg (7 more studies). All are short-term studies. There are more sperm damage studies but without any measurements or other specific exposure information. These are studies that place sperm, or mice, or give prenatal exposures to animals close to sources of cell phone radiation. Such studies give weight to the argument that low-intensity RFR exposures can cause damage, but do not help in delineating LOELs because they have no specific exposure numbers, just distances.

Most of the sperm studies and base station studies which have exposures expressed power density (microwatts per square centimeter) have 'effect' levels in the nanowatt range (0.34 nanowatt/cm2 to 100 nanowatt/cm2)*. They include Behari and Kesari, 2006; Buchner and Eger, 2012; Oberfeld et al, 2004; Thomas et al, 2008, 2010; Heinrich et al, 2010; Navarro et al, 2003; and Otitoloju et al 2010. Avendano et al (2012) report that WI-FI exposure from a 4-hr laptop exposure decreased sperm viability and caused DNA fragmentation in human sperm samples (exposure in petri dishes) at 0.5 to 1.0 uW/cm2. The Kundi-Hutter 2009 Pathophysiology Journal review paper of base station studies through 2006 reports an overall NOEL below 0.05 to 0.1 uW/cm2. Overall, the new 2007-2012 power density studies are reporting 'lowest effects levels' two or three orders of magnitude lower than in 2006, down from the microwatt/cm2 range to the nanowatt/cm2 range.

SAR Studies (Sperm Studies and Ovarian Damage with Cell Phone Radiation Exposures)

Studies on male fertility (adverse effects on sperm, on the testes size and morphology, etc) coming from cell phone-in-the-pocket-on-stand-by-mode and wireless laptop studies provide us with a flood of new data showing very low-intensity effects to guide precautionary actions and to educate the public about potential risks to health, fertility and reproduction.

*The RF Color Charts in this Report are a guide to reported biological effects and those RFR levels reported to cause them.

Sperm and fertility studies with 'effects levels' in the 9 microwatt/kg to 80 milliwatt/kg range are Kumar et al (2012) (male infertility) and Aitken et al (2005) (sperm DNA damage). Sperm studies with 'effect levels' in the 90 to 900 milliwatt/kg range are De Iuliis et al (2009) (human sperm cell damage), Salama et al (2008) (decrease in sperm mobility and concentration), Panagopoulous et al (2012) (ovarian damage) and Kesari et al (2012) (sperm damage). Studies from 1 W/kg to 1.8 W/kg that report sperm or reproductive damage are Gul et al (2009) (toxic effect on ovaries), Agarwal et al (2008) (sperm damage), Agarwal et al (2009) (sperm damage) and Yan et al (2007) (deformed sperm cells, disabled for swimming).

The WI-FI laptop study by Atasoy et al (2012) reports that exposures to laptops estimated at 0.091 W/kg increase DNA damage and reduce DNA repair in damaged sperm, and "*raise questions about safety of radiofrequency exposure from WI-FI internet access dvices for growing organisms of reproductive age, with a potential effect on fertility and integrity of germ lines*."

Altered fetal development in mice exposed to RFR at SARs of 0.3 to 60 milliwatt/kg is reported to result in consequent adverse effects on learning and behavior (Aldad et al, 2012). Fragopoulou et al (2009) reported changes at 600 to 900 milliwatts/kg in mouse embryos.

General Approach to Delineating a Precautionary Action Level

As a methodology, is not necessary or wise to use an averaging approach among studies. The technique itself is too vulnerable to weighting problems by the older studies that did not test for effects at the lowest range of exposures to RFR (or did not have the power to assess effects). Averaging also is insensitive in giving proper visibility to important NEW results at the very low-intensity (nanowatt, picowatt and femtowatt/cm2 range). Even when they are averaged together, these studies contribute vanishingly small influence when averaged together with studies of much higher power density to determine a scientific benchmark for harm.

One limitation of the sperm studies using base station-level RFR exposures is that good estimates of exposure are available if sperm are tested outside the body (in petri dishes), but that does not reflect the more realistic situation of sperm exposed in humans themselves (using or carrying a mobile phone near the testes) where exposure estimates are more difficult to determine. So, it is useful and informative to observe the combined results of both in-vivo and ex-vivo studies as a guide. For base station studies on human populations, the quality of exposure assessments is variable, and in some cases inadequate. Further, very few base station studies are conducted so that test subjects do not know if/when they are subjected to elevated RFR (blinded studies), so that some bias may influence results. People often report more ill effects because they are aware of the exposure (from a nearby base station, for example). These variations in quality across the studies, however, do not offset their usefulness in the aggregate for delineating what the lowest observable effect exposures are, and helping to guide decision-making for public health and precautionary actions.

A further concern is that time-averaging of RFR to give a single numeric recommendation for a precautionary action guideline does not address the critical difference between peak power levels (RFR spikes that occur intermittently) and measurements that hide how high peak power spikes are by dilution. Biological responses can last over seconds of time, or have even longer effects on proteins and enzymes, while the RFR pulses may be in microseconds or milliseconds in duration. It is entirely possible that what causes bioeffects is the high, intermittent RFR spikes that the body perceives and responds to as one continuous, high-power assault. For example, the DECT phone peak power is about 100 times larger than what RFR is measured with time-averaging. A person near a cell tower that produces an RFR measurement of 0.1 microwatts/cm2 is probably getting RFR power density spikes of eight times higher, if one could measure the spikes individually. None of the studies profiled in this section deal with peak power pulses and biological response times that are longer than the 'intermission' between RFR spikes. Thus, precautionary action levels should err on the side of being conservative.

The planning of base stations, and other site evaluations needs to have a scientific benchmark below which effects have not (not yet) been characterized, published or vetted. Then, a reasonable safety buffer should be added - remembering that the design life of such facilities may be 30-50 years long. This is standard procedure for environmental planning constraints.

Health Agencies Should Act Now

Health agencies and regulatory agencies that set public safety standards for ELF-EMF and RFR should act now to adopt new, biologically-relevant safety limits that key to the lowest scientific benchmarks for harm coming from the recent studies, plus a lower safety margin. Existing public safety limits are too high by several orders of magnitude, if prevention of bioeffects and resulting adverse health effects are to be minimized or eliminated. Most safety standards are a thousand times or more too high for healthy populations, and even less effective in protecting sensitive subpopulations.

New, biologically-based public exposure standards are critically needed now and should key to scientific benchmarks for harm, plus a safety margin below that level.

Standard of Evidence for Judging the Science

The standard of evidence for judging the scientific evidence should be based on good public health principles rather than demanding scientific certainty before actions are taken.

Sensitive Populations Require Special Protections

Safety standards for sensitive populations will need to be set at lower levels than for healthy adult populations to protect the developing fetus, the infant and young child, school-age children, the elderly, those with pre-existing chronic diseases, and those with

developed electrical sensitivity (EHS). Men of child-bearing age should not wear wireless devices on their body in order to protect the integrity of sperm DNA. Sperm should be considered a 'sensitive population'. Scientific benchmarks for lowest effect levels should be identified, and applied with additional safety margin reductions to safeguard populations against excessively high exposure to chronic ELF-EMF and RFR.

Protect Children Against Chronic Exposure to Wireless Devices

Strong precautionary action and clear public health warnings are universally warranted for use of cordless and cell phones to help prevent a global epidemic of brain tumors. This is especially important for children, adolescents and young adults, while new safety standards are established and implemented. Children should not use wireless devices except in the case of emergencies, or be exposed on an involuntary and chronic basis to wireless in their living, sleeping or learning environments.

Common Sense Precautionary Measurees are Warranted Now

Common sense measures to limit both ELF-EMF and RFR in the fetus and newborn infant are needed, especially with respect to avoidable exposures like baby monitors in the crib and baby isolettes (incubators) in hospitals that can be modified; and where education of the pregnant mother with respect to laptop computers, mobile phones and other sources of ELF-EMF and RFR are easily instituted.

Wireless laptops and other wireless devices should be strongly discouraged in schools for children of all ages, and wireless systems already installed should be replaced with wired (cable) alternatives. While without question it is important for children to have access to the internet, wired computer laboratories will have no elevated exposure to RFR. What might be lost in flexibility of moving rooms arounds will be more than gained by reducing exposure to RFR if wired connections, rather than wireless, are used. Pregnant women should be strongly cautioned not to use wireless devices during pregnancy. If a school already has wireless facilities, classrooms without wireless should

be made available to students, teachers and staff during the transition if sensitivities to EMF are reported by the individual. Special education classroom teaching environments should offer wired teaching environments (not wireless), nor should they be exposed to off-site wireless radiofrequency radiation from other sources that elevate interior levels for children.

Special Protections for the Integrity of the Genome and Reproduction

Reducing life-long health risks should begin in the earliest stages of embryonic and fetal development. Development pace is accelerated for the infant and very young child compared to adults, and is not complete in young people (as far as brain and nervous system maturation) until the early 20's. Windows of critical development mean that risk factors once laid down in the cells, or in epigenetic changes in the genome may have grave and life-long consequences for health or illness for every individual, and furthermore these genetic and epigenetic changes may be passed to the next generation. All relevant environmental conditions, including biologically active exposures to EMF and RFR that can degrade the human genome, and impair normal health and development of all species including humans - should be given weight in defining and implementing strong precautionary actions now to protect public health. The consequence of ignoring clear evidence of large-scale health risks to global populations, when the risk factors are largely avoidable or preventable is too high a risk to take.

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SECTION 25

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Important Bird Areas

Pier 400 Tern Colony (formerly Terminal Island)

California

Not a natural island, but a 15.7 acre fenced area on Pier 400, part of Terminal Island, in the Los Angeles Harbor that is maintained, prepared and monitored annually by the Port of Los Angeles for the Least Tern. The nesting site was created, along with the entire Pier 400 peninsula, of material dredged from the Los Angeles Harbor from 1995 through 2003; the remained of Pier 400 is now a shipping container terminal. Like Brooks Island and Alameda NAS in San Francisco Bay, the site has been used by the Least Tern for nesting since it was created in 1997.

Updated December 2008

Ornithological Summary

With roughly 200 pairs in 2001, this site protects a significant proportion of the global population of California Least Tern. In addition to Least Terns, in previous years, Pier 400 was also used for nesting by Caspian Tern, Elegant Tern, Royal Tern, and Black Skimmer, some of which are California Species of Special Concern. These species nested within the Pier 400 IBA, as well as areas on dredge fill north of the Least Tern site prior to the paving of the container terminal. However, in late April 2005, Caspian and Elegant Terns abandoned their nests following a nocturnal predation event, believed to be an owl (three Elegant Tern carcasses were found the next day.) The birds failed to return that year or in subsequent years. In 2005, both species apparently relocated to Bolsa Chica (part of the Orange Coast Wetlands IBA), as evidenced by the subsequent increase in nest numbers there. The availability of nesting sites at Bolsa Chica has likely deterred their return to Pier 400 in current years. Caspian Terns and Elegant Terns, however, are often seen foraging in the Los Angeles Harbor. (K. Keane, via email.)

Help us learn more about the birds at this IBA! Enter your birding data online at Calfornia eBird! (http://ebird.org/california/)

Ownership

This man-made island is located within Los Angeles Harbor.

Habitat

Not a natural island, but a 15.7 acre fenced area on Pier 400, part of Terminal Island, in the Los Angeles Harbor that is maintained, prepared and monitored annually by the Port of Los Angeles for the Least Tern. The nesting site was created, along with the entire Pier 400 peninsula, of material dredged from the Los Angeles Harbor from 1995 through 2003; the remained of Pier 400 is now a shipping container terminal.

Share this Important Bird Area

Birds in This Area

Least Tern
Sternula antillarum

Royal Tern
Thalasseus maximus

Black Skimmer

Caspian Tern

Elegant Tern

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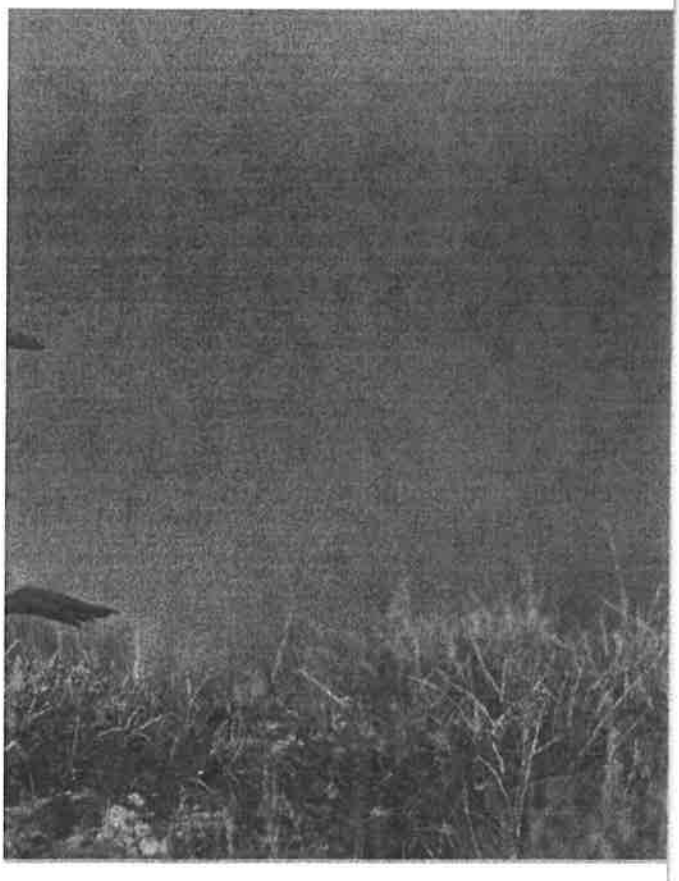

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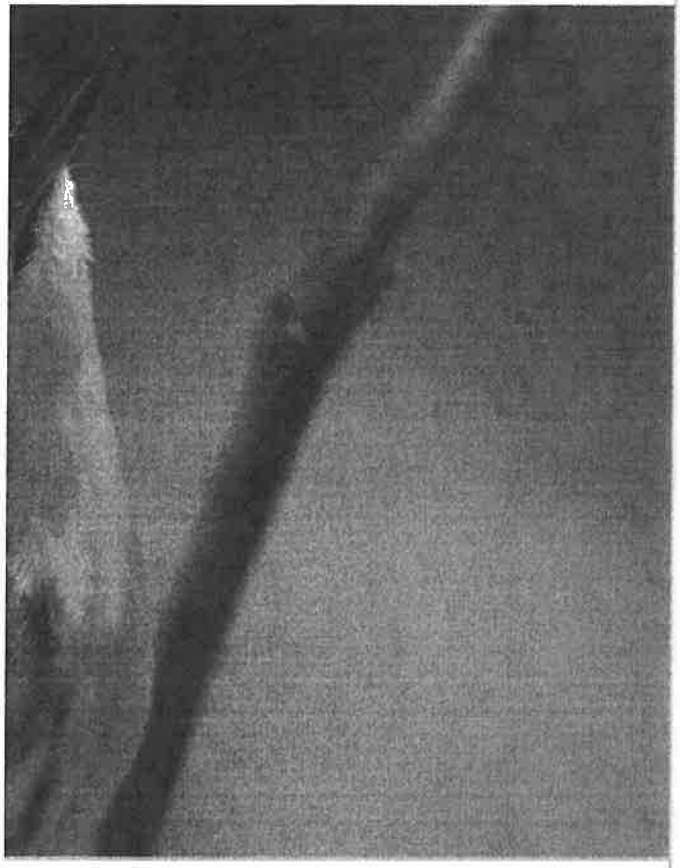

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SECTION 3

The Existing Public Exposure Standards

Cindy Sage, MA

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Prepared for the BioInitiative Working Group

August 2007

The US Federal Communications Commission (FCC) Exposure Standard Recommendations

In the United States, the Federal Communications Commission (FCC) enforces limits for both occupational exposures (in the workplace) and public exposures. The exposure limits are variable according to the frequency (in megahertz) and the duration of exposure time (6 minutes for occupational and 30 minutes for public exposures). Table 3.1 show exposure limits for occupational and uncontrolled public access to radiofrequency radiation such as is emitted from AM, FM, television and wireless sources through the air. As an example, 583 microwatts/cm2 (μW/cm2) is the public limit for the 875 MHz cell phone wireless frequency and 1000 μW/cm2 is the limit for PCS frequencies in the 1800 – 1950 MHz range averaged over 30 minutes. The limits in Table 3.1 would pertain to exposures in the vicinity of transmitting antennas (not devices like cell phones, for which exposure limits are shown in Table 3.2).

The FCC is required by the National Environmental Policy Act of 1969 to evaluate the effect of emissions from FCC-regulated transmitters on the quality of the human environment. At the present time there is no federally-mandated radio frequency (RF) exposure standard. However, several non-government organizations, such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers, Inc. (IEEE), and the National Council on Radiation Protection and Measurements (NCRP) have issued recommendations for human exposure to RF electromagnetic fields. The FCC has endorsed these recommendations, and enforces compliance. http://www.fcc.gov/oet/rfsafety/

Table 3.1 **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: OET, 1997.

FCC Guidelines for Cell and PCS Phones (and other radiofrequency emitting devices)

Cell phones and portable transmitting devices that operate in the Cellular Radiotelephone Service, the Personal Communications Services (PCS), the Satellite Communications Services, the Maritime Services (ship earth stations only) and the Specialized Mobile Radio (SMR) Service are subject to routine environmental (not health) evaluation for RF exposure prior to equipment authorization or use by the FCC. Section 2.1093 of the FCC's Rules (47 CFR §2.1093) that apply to "portable" devices. For purposes of these requirements a portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user (OET, 1997).

Cell phones and some other wireless communication devices are regulated by the FCC according to their emissions, which depend on the amount of power absorbed into the body. The metric for measurement is specific absorption rate (SAR) and is expressed in watts per kilogram of tissue. The limit for absorption of radiofrequency radiation is limited to 1.6 W/kG within 1 gram of human tissue. This limit has been recommended for change (relaxation) by the IEEE in April of 2006. If adopted by the FCC, this amount of heat or 1.6 W/Kg would be measured over 10 times as much tissue (10 grams) so that far higher heating is possible from these devices over small amounts of tissue (would be far less strict that the current limit, if adopted). More cell phone and related PDA devices would then comply be able with the looser standard, and the public could potentially receive much higher radiofrequency radiation exposures, and it would be in compliance (legal).

"The SAR criteria to be used are specified below and apply for portable devices transmitting in the frequency range from 100 kHz to 6 GHz. The limits used for evaluation are based generally on criteria published by the Institute of Electrical and Electronics Engineers, Inc., (IEEE) for localized specific absorption rate ("SAR") in Section 4.2 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.

These criteria for SAR evaluation are similar to those recommended by the National Council on Radiation Protection and Measurements (NCRP) in "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86, Section 17.4.5. Copyright NCRP, 1986, Bethesda, Maryland 20814."

(1) FCC Limits for Occupational/Controlled exposure: 0.4 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 8 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 20 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). Occupational/Controlled limits apply when persons are exposed as a consequence of their

employment provided these persons are fully aware of and exercise control over their exposure. Awareness of exposure can be accomplished by use of warning labels or by specific training or education through appropriate means, such as an RF safety program in a work environment (OET, 1997).

(2) FCC Limits for General Population/Uncontrolled exposure: 0.08 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 1.6 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 4 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). General Population/Uncontrolled limits apply when the general public may be exposed, or when persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or do not exercise control over their exposure. Warning labels placed on consumer devices such as cellular telephones will not be sufficient reason to allow these devices to be evaluated subject to limits for occupational/controlled exposure (OET, 1997).

In the United States, two professional societies - the Institute of Electrical and Electronics Engineers, Inc. (IEEE) and the National Council for Radiation Protection and Measurements (NCRP) develop recommendations for safety standards. . The IEEE charter calls itself the world's leading professional association for the advancement of technology, as well as the instigator of public safety standards. The IEEE recommendations have historically been endorsed by the American National Standards Institute (ANSI) and finally considered by the FCC for implementation. The US Federal Communications Commission (FCC) may then take the recommendations and adopt them as mandatory exposure limits. Several standard-setting processes have occurred like this in the last few decades.

The most recent IEEE recommendations for 3 kHz to 300 GHz were developed in 2006 (IEEE, 2006). Rather than lower the existing limits for radiofrequency and microwave radiation exposure, they greatly increase the exposure limits. This is perplexing since it ignores or discounts a large body of scientific evidence clearly documenting biologically-relevant changes at levels LOWER (much lower) than the existing standards.

ICNIRP Guidelines (International Radiofrequency Guidelines)

In April 1998, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields in the frequency range up to 300 GHz.. These guidelines replaced previous advice issued in 1988 and 1990. The main objective of the ICNIRP Guidelines is to establish guidelines for limiting EMF exposure that will provide protection against known adverse health effects (ICNIRP, 1998). An adverse health effect is defined by ICNIRP as one which causes detectable impairment of the health of the exposed individual or of his or her offspring; a biological effect, on the other hand, may or may not result in an adverse health effect.

The guidelines presented in Table 3.2 apply to occupational and public exposure.

Table 3.2 ICNIRP Basic restrictions for time varying electric and magnetic fields for frequencies up to 10 GHz.

Exposure characteristics	Frequency range	Current density for head and trunk (mA m^{-2})(rms)	Whole-body average SAR (W kg^{-1})	Localized SAR (head and trunk) (W kg^{-1})	Localized SAR (limbs) (W kg^{-1})
Occupational exposure	up to 1 Hz	40	—	—	—
	1–4 Hz	40/*f*	—	—	—
	4 Hz–1 kHz	10	—	—	—
	1–100 kHz	*f*/100	—	—	—
	100 kHz–10 MHz	*f*/100	0.4	10	20
	10 MHz–10 GHz		0.4	10	20
General public exposure	up to 1 Hz	8	—	—	—
	1–4 Hz	8/*f*	—	—	—
	4 Hz–1 kHz	2	—	—	—
	1–100 kHz	*f*/500	—	—	—
	100 kHz–10 MHz	*f*/500	0.08	2	4
	10 MHz–10 GHz		0.08	2	4

Notes:

1. *f* is the frequency in hertz.
2. Because of electrical inhomogeneity of the body, current densities should be averaged over a cross-section of 1 cm^2 perpendicular to the current direction.
3. For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by %2 (~1.414). For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$. For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate basic restriction.
4. All SAR values are to be averaged over any 6-minute period.
5. Localized SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.
6. For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$. Additionally, for pulsed exposures, in the frequency range 0.3 to 10 GHz and for localized exposure of the head, in order to limit or avoid auditory effects caused by thermoelastic expansion, an additional basic restriction is recommended. This is that the SA should not exceed 10 mJ kg^{-1} for workers and 2 mJ kg^{-1} for the general public averaged over 10 g tissue.

In the frequency range from a few Hz to 1 kHz, for levels of induced current density above 100 mA m^{-2}, the thresholds for acute changes in central nervous system excitability and other acute effects such as reversal of the visually evoked potential are exceeded. In view of the safety considerations above, it was decided that, for frequencies in the range 4 Hz to 1 kHz, occupational exposure should be limited to fields that induce current densities less than 10 mA m^{-2}, i.e., to use a safety factor of 10. For the general public an additional factor of 5 is applied, giving a basic exposure restriction of 2 mA m^{-2}. Below 4 Hz and above 1 kHz, the basic restriction on induced current density increases progressively.

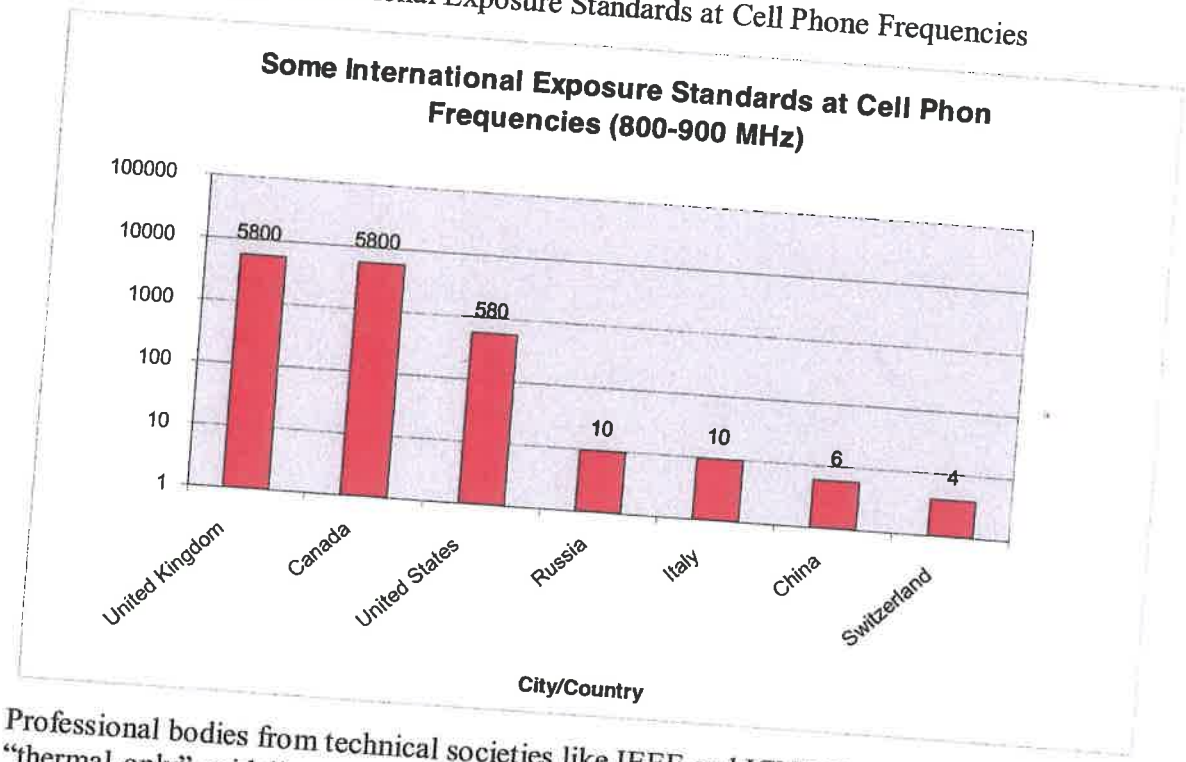
ICNRP maintains that guidelines for limiting exposure have been developed following a thorough review of all published scientific literature (ICNIRP, 1998).

"The criteria applied in the course of the review were designed to evaluate the credibility of the various reported findings (Repacholi and Stolwijk 1991; Repacholi and Cardis 1997); only established effects were used as the basis for the proposed exposure restrictions. Induction of cancer from long-term EMF exposure was not considered to be established, and so these guidelines are based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF. In the case of potential long-term effects of exposure, such as an increased risk of cancer, ICNIRP concluded that available data are insufficient to provide a basis for setting exposure restrictions, although epidemiological research has provided suggestive, but unconvincing, evidence of an association between possible carcinogenic effects and exposure at levels of 50/60 Hz magnetic flux densities substantially lower than those recommended in these guidelines. In-vitro effects of short-term exposure to ELF or ELF amplitude-modulated EMF are summarized. Transient cellular and tissue responses to EMF exposure have been observed, but with no clear exposure–response relationship. These studies are of limited value in the assessment of health effects because many of the responses have not been demonstrated in vivo. Thus, in-vitro studies alone were not deemed to provide data that could serve as a primary basis for assessing possible health effects of EMF. " (ICNIRP, 1998) http://www.icnirp.de

Guidelines and Limits (Other Countries)

On the other hand, some countries in the world have established new, low-intensity based exposure standards that respond to studies reporting effects that do not rely on heating. Consequently, new exposure guidelines are hundreds or thousands of times lower than those of IEEE and ICNIRP. Table 3.3 shows some of the countries that have lowered their limits, for example, in the cell phone frequency range of 800 MHz to 900 MHz. The levels range from 10 microwatts per centimeter squared in Italy and Russia to 4.2 microwatts per centimeter squared in Switzerland. In comparison, the United States and Canada limit such exposures to only 580 microwatts per centimeter squared (at 870 MHz) and then averaged over a time period (meaning that higher exposures are allowed for shorter times, but over a 30 minute period, the average must be 580 microwatts per centimeter squared or less at this frequency). The United Kingdom allows one hundred times this level, or 5800 microwatts per centimeter squared. Higher frequencies have higher safety limits, so that at 1000 MHz, for example, the limit is 1000 microwatts per centimeter squared (in the United States). Each individual frequency in the radiofrequency radiation range needs to be calculated. These are presented as reference points only. Emerging scientific evidence has encouraged some countries to respond by adopting planning targets, or interim action levels that are responsive to low-intensity or non-thermal radiofrequency radiation bioeffects and health impacts.

Table 3.3 Some International Exposure Standards at Cell Phone Frequencies



Professional bodies from technical societies like IEEE and ICNIRP continue to support "thermal-only" guidelines routinely defend doing so a) by omitting or ignoring study results reporting bioeffects and adverse impacts to health and wellbeing from a very large body of peer-reviewed, published science because it is not yet "proof" according to their definitions; b) by defining the proof of "adverse effects" at an impossibly high a bar (scientific proof or causal evidence) so as to freeze action; c) by requiring a conclusive demonstration of both "adverse effect" and risk before admitting low-intensity effects should be taken into account; e) by ignoring low-intensity studies that report bioeffects and health impacts due to modulation; f) by conducting scientific reviews with panels heavily burdened with industry experts and under-represented by public health experts and independent scientists with relevant low-intensity research experience; g) by limiting public participation in standard-setting deliberations; and other techniques that maintain the status quo.

Much of the criticism of the existing standard-setting bodies comes because their contributions are perceived as industry-friendly (more aligned with technology investment and dissemination of new technologies) rather than public health oriented. The view of the Chair of the latest IEEE standard-setting ICES Eleanor Adair is made clear by Osepchuk and Petersen (2003) who write in the abstract of their paper "*her goal and the goal of ICES is to establish rational standards that will make future beneficial applications of RF energy credible to humanity.*" Authors Osepchuk and Petersen note that "*(I)t is important that safety standards be rational and avoid excessive safety margins.*" The authors specifically dismiss the body of evidence for low-intensity effects with "*(A)lthough the literature reporting "athermal" bioeffects of exposure to*

microwave/RF energy (other than electrostimulation) is included in the review process, it has been found to be inconsistent and not useful for purposes of standard-setting."

This report addresses the substantial body of evidence reporting low-intensity effects from electromagnetic fields (both power-frequency fields in the ELF range, and radiofrequency/microwave fields at exposure levels that do not involve any heating. It also addresses the inconsistency in the literature quoted as the basis for retaining thermal-only exposure standards (see particularly the Genotoxics Section 6 where half of more of the published papers report negative effects and half positive effects).

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Osepchuk JM Petersen RC. 2003. Historical Review of RF Exposure Standards and the International Committee on Electromagnetic Safety (ICES). Bioelectromagnetics Supplement 6:S7-16. Osepchuk is a former employee of Raytheon. Petersen is a former employee of Bell Labs and Lucent Technologies. Both are independent industry consultants in their retirement.

SECTION 4

Evidence for Inadequacy of the Standards

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I. Introduction

Evidence for judging the adequacy (or inadequacy) of the existing ICNIRP and IEEE C95.1 radiofrequency radiation standards can be taken from many relevant sources. The ICNIRP standards are similar to the IEEE (except for the new C95.1 -2006) revisions by IEEE SC-4), and these discussions can be used to evaluate both sets of public exposure standards for adequacy (or inadequacy).

An important screen for assessment of how review bodies conduct their science reviews and resulting conclusions on the adequacy of ELF and RF exposure limits depends on embedded assumptions. The singularly most important embedded assumption is whether these bodies assume from the beginning that only conclusive scientific evidence (proof) will be sufficient to warrant change; or whether actions should be taken on the basis of a growing body of evidence which provides early but consequential warning of (but not yet proof) of possible risks.

As a result of current international research and scientific discussion on whether the prevailing RF and ELF standards are adequate for protection of public health, there are many recent developments prior to 2007 to provide valuable background on the uncertainty about whether current standards adequately protect the public. Since 2007, there are important new milestone publications that underscore the critical need to update public safety limits. These newer documents calling for review and updating are based on a deluge of new scientific studies reporting effects at non-thermal, low-intensity ELF and RF exposure levels. There is little doubt that bioeffects and adverse health effects are occurring at lower-than-safety limit levels, meaning the existing protections are inadequate.

II. United States Government Accountability Office

The US Government Accountability Office published a report in 2012 urging the US Federal Communications Commission to revisit the outdated safety standards for the exposures from wireless devices. (US GAO, 2012)

The rapid adoption of mobile phones has occurred amidst controversy over whether the technology poses a risk to human health as a result of long-term exposure to RF energy from mobile phone use. FCC and FDA share regulatory responsibilities for mobile phones. GAO was asked to examine several issues related to mobile phone health effects and regulation. Specifically, this report addresses:

> (1) what is known about the health effects of RF energy from mobile phones and what are current research activities,
> (2) how FCC set the RF energy exposure limit for mobile phones, and
> (3) federal agency and industry actions to inform the public about health issues related to mobile phones, among other things.

GAO reviewed scientific research; interviewed experts in fields such as public health and engineering, officials from federal agencies, and representatives of academic institutions, consumer groups, and the mobile phone industry; reviewed mobile phone testing and certification regulations and guidance; and reviewed relevant federal agency websites and mobile phone user manuals.

The Report noted that the FCC's RF energy exposure limit may not reflect the latest research. Redundant and overlapping jurisdiction over the setting of public safety limits is highlighted where the GAO Report notes:

> *"FCC told GAO that it relies on the guidance of federal health and safety agencies when determining the RF energy exposure limit, and to date, none of these agencies have advised FCC to change the limit. However, FCC has not formally asked these agencies for a reassessment. By not formally reassessing it's current limit, FCC cannot ensure it is using a limit that reflects the latest research on RF energy exposure. FCC has also not reassessed it's testing requirements to ensure that they identify the maximum RF energy exposure a user could experience. Some consumers may use mobile phones against the body, which FCC does not currently test, and could result in RF energy exposure higher than the FCC limit." (US GAO, 2012)*

The GAO Report recommends to the FCC that it formally reassess, and, if appropriate, change it's current RF energy exposure limit and mobile phone testing requirements related to likely usage configurations, particularly when phones are held against the body.

FCC noted that a draft document that is now under consideration by the FCC has the potential to address GAO's recommendations. (US GAO, 2012)

III. International Agency for Research on Cancer - World Health Organization Classifies Radiofrequency Radiation as 2B Possible Human Carcinogen

In 2011, a group of 30 researchers, scientists and medical doctors were invited to participate in an assessment of the scientific literature on radiofrequency radiation carcinogenicity in Lyon, France. Under the auspices of IARC, they conducted a comprehensive scientific assessment of RF studies and determined:

> *"In view of the limited evidence in humans and in experimental animals, the Working Group classified RF- EMF as "possibly carcinogenic to humans" (Group 2B). This evaluation was supported by a large majority of Working Group members."* (Baan et al, 2011)
>
> *"(T)he Working Group concluded that the (Interphone Final Report) findings could not be dismissed as reflecting bias alone, and that a causal interpretation between mobile phone RF-EMF exposure and glioma is possible. A similar conclusion was drawn from these two studies for acoustic neuroma, although the case numbers were substantially smaller than for glioma."* (Baan et al, 2011)

It is important to recognize that the IARC RF Working Group did not find the evidence insufficient to classify (Group 3) or not a carcinogen (Group 4). Both of these possible outcomes to the scientific assessment could have rendered a substantially weaker conclusion. Where there has been the necessity of a virtual scientific paradigm shift to accommodate ANY consideration of both ELF-EMF and RFR to the status where legitimate scientific attention is achieved is a notable achievement. There is a very high bar set to show that non-chemical carcinogens warrant IARC carcinogenicity evaluation - it greatly exceeds that necessary for chemicals and other toxins.

IV. World Health Organization *INTERPHONE* Study on Mobile Phone Cancer Risk

In 2010, the World Health Organization released the final results of it's investigation on

cell phones and cancer. (INTERPHONE Study Group, 2010) The ten-year long World Health Organization *INTERPHONE Study* confirms previous reports showing what many experts have warned – that regular use of a cell phone by adults can significantly increase the risk of glioma by 40% with 1640 hours or more of use (this is about one-half hour per day over ten years). Tumors were more likely to occur on the side of the head most used for calling. The risk increases to 96% for adults with ipsilateral cell phone use (when the cell phone is used predominantly on one side of the head). The study appears in the International Journal of Epidemiology. Thirteen teams from countries around the world combined their results. Only the glioma findings were released (final results on acoustic neuroma and parotid tumors are not yet published.

A comprehensive and technically reliable description of the *INTERPHONE* study findings is provided within the International Agency for Research on Cancer, 2011 RF Monograph as part of the publication in Lancet Oncology on IARC's classification of radiofrequency radiation as a 2B Possible Human Carcinogen. Results of the *INTERPHONE* Study were highly scrutinized by IARC, and influenced the classification of RF based on the cell phone-brain cancer findings of *INTERPHONE*.

From Baan et al, 2011:

> *"The INTERPHONE study, a multi-centre case-control study, is the largest investigation so far of mobile phone use and brain tumours, including glioma, acoustic neuroma, and meningioma.The pooled analysis included 2708 glioma cases and 2972controls(participation rates64% and 53%, respectively). Comparing those who ever used mobile phones with those who never did yielded an odds ratio (OR) of 0·81 (95% CI 0·70–0·94). In terms of cumulative call time, ORs were uniformly below or close to unity for all deciles of exposure except the highest decile (>1640 h of use), for which the OR for glioma was 1·40 (95% CI 1·03–1·89). There was suggestion of an increased risk for ipsilateral exposure(on the same side of the head as the tumour) and for tumours in the temporal lobe, where RF exposure is highest. Associations between glioma and cumulative specific energy absorbed at the tumour location were examined in a subset of 553 cases that had estimated RF doses.10 The OR for glioma increased with increasing RF dose for exposures 7 years or more before diagnosis, whereas there was no association with estimated dose for exposures less than 7 years before diagnosis.*
>
> *A Swedish research group did a pooled analysis of two very similar studies of associations between mobile and cordless phone use and glioma, acoustic neuroma, and meningioma.9 The analysis included 1148 glioma cases (ascertained 1997–2003) and 2438 controls,obtained through cancer and population registries,*

respectively. Self-administered mailed questionnaires were followed by telephone interviews to obtain information on the exposures and covariates of interest, including use of mobile and cordless phones (response rates 85% and 84%, respectively). Participants who had used a mobile phone for more than 1 year had an OR for glioma of 1.3 (95% CI 1·1–1·6). The OR increased with increasing time since first use and with total call time, reaching 3.2 (2·0–5·1) for more than 2000 h of use. Ipsilateral use of the mobile phone was associated with higher risk. Similar findings were reported for use of cordless phones.

Although both the INTERPHONE study and the Swedish pooled analysis are susceptible to bias—due to recall error and selection for participation— the Working Group concluded that the findings could not be dismissed as reflecting bias alone, and that a causal interpretation between mobile phone RF-EMF exposure and glioma is possible. A similar conclusion was drawn from these two studies for acoustic neuroma, although the case numbers were substantially smaller than for glioma. Additionally, a study from Japan (11) found some evidence of an increased risk for acoustic neuroma associated with ipsilateral mobile phone use.

(Baan et al, 2011)

No that no increased risk was detected overall. But this is not unexpected. No exposures to carcinogens that cause solid tumors like brain cancer or lung cancers, for example from tobacco and asbestos have ever been shown to significantly increase cancer risk in people with such short duration of exposure. The latency period for brain cancer is 15-30 years.

The final INTERPHONE results support findings of several research groups who have published studies reporting that continuing use of a mobile phone increases risk of brain cancer. We would not expect to see substantially increased brain tumor risk for most cancer-causing agents except in the longer term (10 year and longer) as is the case here in the population of regular cell phone users. Further, the participants included in this study were 30-59 years old, excluding younger and older users. Use of cordless phones was neglected in the analysis. Radiofrequency radiation from some cordless phones can be as high as mobile phones in some countries, so excluding such use would underestimate the risk for brain tumors and other cancers.

For public health experts and members of the public who looked to IARC for further clarification of the scope of this 2B Possible Human Carcinogen designation, Dr. Baan replied to informal queries that:

"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 radiofrequency part of the electromagnetic spectrum, including the radiation emitted by base-station antennas, radio/ TV towers, radar, Wi-Fi, smart meters, etc." (Personal communication of Dr. Robert Baan to Connie Hudson, August 29, 2011)

V. President's Cancer Panel Report of 2010

The United States President's Cancer Panel Report (2010) includes important and unprecedented recognition of non-ionizing radiation as a possible carcinogen deserving of further research and possible public health action. The Report found "the true burden of environmentally induced cancers has been grossly underestimated" and strongly urged action to reduce peoples' widespread exposures to carcinogens. The 240-page report issued for 2008-2009 by a panel of experts that report to the US president indicate that environmental factors are underestimated in cancer prevention. The Report specifically addresses the link between cell phones and cancer. The Panel recommends that people reduce their cell phone exposure, even when absolute proof of harm is not yet available.

Research Recommended by Presidents Cancer Panel

- Resolve controversies regarding the safety or harm of low doses of various forms of radiation in adults and children. Identify circumstances under which low- dose radiation may have a hormetic effect.

- Develop radiation dose and risk estimates that better reflect the current and future U.S. population. Existing dose and risk estimates have been based on adult males; estimates should account for population diversity, including children. In addition, develop medical radiation risk estimates that are not based on acute doses received by atomic bomb survivors.

- Expand research on possible harmful effects of cell phone use, especially in children. Cell phone use still is relatively recent, and studies to date have had mixed findings; most involve users of older equipment. Findings from cohort studies now underway are anticipated, but longer-term studies of individuals using current equipment are needed.

- Conduct additional research on possible links between electromagnetic fields (EMF) and cancer; identify mechanism(s) of EMF carcinogenesis.

- Monitor changing patterns of radiation exposure.

- Raise the priority of and investment in research to develop non-toxic products anD processes.

- Develop, test, and evaluate prevention communication strategies and interventions, especially in high-risk occupations and populations.

(National Cancer Institute, 2010)

VI. World Health Organization Research Agenda for Radiofrequency Fields (2010)

In 2010, the WHO produced a research agenda to address growing scientific questions and public concern about health effects of radiofrequency radiation, particularly with the explosive rise in exposures from new telecommunications technologies. It replaced a 2006 research agenda developed by the International EMF Project.

> *"Telecommunication technologies based on radiofrequency (RF) transmission, such as radio and television, have been in widespread use for many decades. However, there are numerous new applications for the broadcast and reception of RF waves and the use of RF devices such as mobile phones is now ubiquitous.*
>
> ***The attendant increased public exposure to RF fields has made its effects on human health a topic of concern for scientists and the general public.***
>
> *(emphasis added)*
>
> *To respond to these concerns, an important research effort has been mounted over the past decade and many specific questions about potential health effects of RF fields have already been investigated by scientists around the world. Nonetheless, several areas still warrant further investigation and the rapid evolution of technology in this field is raising new questions."* *(WHO, 2010)*
>
> *"This Research Agenda is developed ahead of the major hazard/health risk evalu-*

ations that the IARC and WHO are due to carry out over the next two years. It focuses on identifying short- and long-term research needs that will enable more complete health risk assessments to be undertaken and communicated more effectively to the public."

(WHO, 2010)

Recommendations of the WHO Research Agenda for Radiofrequency Fields are as follows. This section is necessarily extensive to document the advice of experts at WHO by 2010 in recognizing radiofrequency radiation has the potential to result in global health impacts; even if very slow to implement precautionary advice to the European Commission and member countries.

Priority: Epidemiology

High - Prospective cohort studies of children and adolescents with outcomes including behavioural and neurological disorders and cancer

Rationale: As yet, little research has been conducted in children and adolescents and it is still an open question whether children are more susceptible to Rf EMF since the brain continues to develop during childhood and adolescence. also, children are starting to use mobile phones at a younger age. given the existence of large-scale cohort studies of mothers and children with follow-up started during or before pregnancy, an Rf sources component could be added at a reasonably low cost. Billing records for mobile phones are not valid for children, therefore the prospective collection of exposure data is needed. for neuropsychological studies, one challenge is to distinguish the "training" of motor and neu- ropsychological skills caused by the use of a mobile phone from the effects of the Rf field. any future study should try to address this issue. in any case it should be of longitudinal design, thereby allowing the study of several outcomes and changes in technology and the use of mobile phones as well as other sources of Rf eMf exposure, such as wireless laptops.

High - Monitoring of brain tumour incidence trends through well-established population-based cancer registries, if possible combined with population exposure data

Rationale: If there is a substantial risk associated with mobile phone use, it should be observable in data sources of good quality. such time trend analyses can be performed quite quickly and inexpensively. By using modern statistical techniques for analysing popu- lation data it should be possible to link changes in exposure prevalence in the population to the incidence of brain tumours and, if high-quality surveillance data are available, the incidence of other diseases at the population level. given the shortcomings in the exposure assessment and participation of previous studies based on individual data, an ecological study would have benefits that may outweigh its limitations.

Other - case-control studies of neurological diseases provided that objective exposure data and confounder data are available and reasonable participation is achieved

Rationale: Neurological endpoints, such as alzheimer disease and Parkinson disease, may be as biologically plausible as brain cancer and an increased risk would have a major public health impact. This study could give an early warning sign that can be elaborated further in the prospective cohort studies. an analysis of time-trends in neurological disease could also serve as an early warning sign. However, a feasibility study would be necessary in order to determine whether a good quality case-control study could be carried out.

Priority: Human studies

High - further RF EMf provocation studies on children of different ages

Rationale: current research has focused primarily on adolescents; very little is known about possible effects in younger children. longitudinal testing at different ages, for example by studying children already participating in current cohort studies, is recommended. This would allow consideration of the influence of potentially confounding factors such as lifestyle.

High - Provocation studies to identify neurobiological mechanisms underlying possible effects of RF on brain function, including sleep and resting EEG

Rationale: These studies should include validation of these effects using a range of brain imaging methods. They should also include studies investigating possible thresholds and dose-response relationships at higher exposure levels such as those encountered during occupational exposure.

Priority: Animal studies

High - Effects of early-life and prenatal RF exposure on development and behaviour

Rationale: There is still a paucity of information concerning the effects of prenatal and early life exposure to RF EMf on subsequent development and behaviour. Such studies are regarded as important because of the widespread use of mobile phones by children and the increasing exposure to other RF sources such as wireless local area networks (Wlans) and the reported effects of RF EMf on the adult EEG. further study is required which should include partial (head only) exposure to mobile phones at relatively high specific absorption rate (SAR) levels.

High - effects of RF exposure on ageing and neurodegenerative diseases

Rationale: age-related diseases, especially neurodegenerative diseases of the brain such as alzheimer disease and Parkinson disease, are increasingly prevalent and are therefore an important public health issue. Mobile phone use typically involves repeated Rf eMf

exposure of the brain; a recent study has suggested that this type of exposure could affect alzheimer disease in a transgenic mouse model for this condition (arendash et al., 2010). There are a few ongoing studies of possible Rf eMf effects on neurodegenerative diseases but further studies are required to investigate this subject more fully.

Other research needs - Effects of RF exposure on reproductive organs

Rationale: The available data concerning possible effects of Rf eMf from mobile phones on male fertility are inconsistent and their quality and exposure assessments are weak. in vivo studies on fertility should consider effects on both males and females and investigate a range of relevant endpoints including Rf eMf effects on the development and function of the endocrine system.

Priority: Cellular studies

Other - Identify optimal sets of experimental tests to detect cellular response after exposure to new RF technologies and co-exposures of RF EMF with environmental agents

Rationale: a number of in vitro studies investigating the effects of exposure to mobile phone frequencies/signals, or co-exposures of RF EMf with chemical or physical agents, have been published in the last fifteen years. Results obtained have been inconsistent and contradictory, not least because of the use of a large variety of cell types and study approaches. a set of highly sensitive, well-harmonized cellular and molecular methods should be developed in order to screen the toxic potential of new types of RF signals used in new technologies and of co-exposures of RF EMf and environmental agents – especially those suspected to have toxic effects. This research must be multicentred in order to allow the widest possible acceptance and application of this screening tool.

Other - further studies on the influence of genetic background and cell type: possible effects of mobile phone type Rf exposure on a variety of cell types using newer, more sensitive methods less susceptible to artefact and/or bias

Rationale: More rigorous quantitative methods should be employed in the evaluation of positive results that suggest a specific cell type response, e.g. of embryonic cells (Czyz et al., 2004; Franzellitti et al., 2010), raising the possibility that RF impacts specific cell subpopulations or cell types. These studies should include a variety of cell types such as stem cells and cells with altered genetic backgrounds.

Priority: Mechanisms: none

Priority: Dosimetry

High - Assess characteristic RF EMF emissions, exposure scenarios and corresponding exposure levels for new and emerging RF technologies; also for changes in the use of established technologies

Rationale: The work should address the latest developments in areas such as mobile/cordless phones, wireless data networking, asset tracking and identification, wireless transfer of electrical power and body imaging/scanners. it should also consider the possible combined effect of exposure to multiple sources. This will allow exposures from new devices/scenarios to be compared with those that are more familiar and with exposure guidelines for risk communication purposes. This information will also be of value for exposure assessment in epidemiological studies and in the design of biological exposure systems.

High - quantify personal exposures from a range of RF sources and identify the determinants of exposure in the general population

Rationale: The quantification of personal exposure from a range of RF sources will provide valuable information for risk assessment and communication, and for the development of future epidemiological research. it is particularly useful for global exposure assessment in view of the upcoming WHO health risk assessment. The study will also provide baseline data for identification of any changes in the level of exposure and the dominant contributing factors over time. subgroup analyses should be carried out to identify any influence from demographic aspects of the user as well as the microenvironment in which the exposure occurs. exposure metrics should also be considered, especially in combining localized exposures from body-worn devices and whole-body exposures.

Other research needs - Monitoring of personal exposure of Rf workers

Rationale: The exposure patterns of both workers and the general public change continuously, mainly due to the development of new RF technologies. However, workers encounter industrial sources and exposure situations that lead to much higher energy deposition in the body. When epidemiological studies on RF workers are performed, it is imperative to monitor adequately their RF exposure. new instruments are needed to address the lack of adequate measurement tools for evaluating this type of exposure e.g. portable devices suitable for measuring different frequencies and waveforms. in addition, a study of the feasibility of monitoring the personal exposure of RF workers is required for future epidemiological studies. such studies would be facilitated by the production of a job exposure matrix (JeM) for RF workers – in which job designations can be characterized by their exposure.

(WHO, 2010)

VII. National Academy of Sciences, National Research Council (2008)

The U.S. Food and Drug Administration (FDA) of the Department of Health and Human Services asked the National Academies to organize a workshop of national and international experts to identify research needs and gaps in knowledge of biological effects and adverse health outcomes of exposure to radiofrequency (RF) energy from wireless communications devices. To accomplish this task, the National Academies appointed a seven member committee to plan the workshop.1

Following the workshop, the committee was asked to issue a report based on the presentations and discussions at the workshop that identified research needs and current gaps in knowledge. The committee's task did not include the evaluation of health effects or the generation of recommendations relating to how the identified research needs should be met.

For the purposes of this report, the committee defines research needs as research that will increase our understanding of the potential adverse effects of RF energy on humans. Research gaps are defined as areas of research where the committee judges that scientific data that have potential value are presently lacking, but that closing of these gaps is either ongoing and results should be awaited before judgments are made on further research needs, or the gaps are not judged by the committee to be of as high a priority with respect to directly addressing health concerns at this time.

1. Committee on Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communications Devices.

These needs and gaps are committee judgments derived from the workshop presentations and discussions, and the report does not necessarily reflect the views of the FDA, individual workshop speakers, or other workshop participants.

The committee judged that important research needs included, in order of appearance in the text, the following:

- Characterization of exposure to juveniles, children, pregnant women, and fetuses from personal wireless devices and RF fields from base station antennas.

- Characterization of radiated electromagnetic fields for typical multiple- element base station antennas and exposures to affected individuals.

- Characterization of the dosimetry of evolving antenna configurations for cell phones and text messaging devices.

- Prospective epidemiologic cohort studies of children and pregnant women.

- Epidemiologic case-control studies and childhood cancers, including brain cancer.

- Prospective epidemiologic cohort studies of adults in a general population and retrospective cohorts with medium to high occupational exposures.

- Human laboratory studies that focus on possible adverse effects on electroencephalography2 activity and that include a sufficient number of subjects.

- Investigation of the effect of RF electromagnetic fields on neural networks.

- Evaluation of doses occurring on the microscopic level.

- Additional experimental research focused on the identification of potential biophysical and biochemical/molecular mechanisms of RF action.

(NAS-NRC, 2008)

VIII. World Health Organization Draft Framework for Electromagnetic Fields

The International EMF Project was established by WHO in 1996. Its mission was to *"pool resources and knowledge concerning the effects of exposure to EMF and make a concerted effort to identify gaps in knowledge, recommend focused research programmes that allow better health risk assessments to be made, conduct updated critical reviews of the scientific literature, and work towards an international consensus and solutions on the health concerns."* (WHO September 1996 Press Release - Welcome to the International EMF Project)

The stated role of the WHO Precautionary Framework on EMF Health Risk Research (Radiation and Environment Health) has termed its objectives as follows;

- to anticipate and respond to possible threats before introduction of an agent or technology
- to address public concerns that an uncertain health risk is minimized after introduction of an agent
- to develop and select options proportional to the degree of scientific certainty, the severity of harm, the size and nature of the affected population and the cost.

The role of WHO is advisory only to the countries of Europe but it is an important function and can significantly affect decision-making on public health issues. It provides analysis and recommendations on various topics of health and environment, for consideration by member countries of the EU. Given the EU Article 174 policy requires a precautionary approach to judging health and environmental risks, and given that the charter of WHO is to serve the needs of the EU, one would think it essential that the WHO EMF Program health criteria results should be guided by and tailored to compliance with Article 174. This needs to occur in the assessment of the scientific literature (e.g., not requiring studies to provide scientific proof or causal scientific evidence but paying attention to and acting on the evidence, and the trend of the evidence at hand) and in its environmental health criteria recommendations. If the WHO EMF Program instead chooses to use the definitions of adverse impact and risk based on reacting to nothing short of conclusive scientific evidence, it fails to comply with the over-arching EU principle of health.

The World Health Organization has issued a draft framework to address the adequacy of scientific information, and accepted definitions of bioeffects, adverse health effect and hazard (WHO EMF Program Framework for Developing EMF Standards, Draft, October 2003). These definitions are not subject to the whim of organizations preparing public exposure standard recommendations. The WHO definition states that:

> "(A)nnoyance or discomforts caused by EMF exposure may not be pathological per se, but, if substantiated, can affect the physical and mental well-being of a

person and the resultant effect may be considered as an adverse health effect. A health effect is thus defined as a biological effect that is detrimental to health or well-being. According to the WHO Constitution, health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." www.who.int/peh-emf

IX. The European Union Treaties Article 174

The EU policy (Article 174-2) requires that the precautionary principle be the basis for environmental protection for the public, and that protecting public health and taking preventative action before certainty of harm is proven is the foundation of the Precautionary Principle. It is directly counter to the principles used by ICNIRP and IEEE in developing their recommendations for exposure standards. Both bodies require proof of adverse effect and risk before amending the exposure standards; this Treaty requires action to protect the public when a reasonable suspicion of risk exists (precautionary action).

Article 174 (2) [ex Article 130r]

1. Community policy on the environment shall contribute to pursuit of the following objectives:
—preserving, protecting and improving the quality of the environment;
—protecting human health;
—prudent and rational utilisation of natural resources;
—promoting measures at international level to deal with regional or worldwide environmental problems.

2. Community policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Community. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay. In this context, harmonization measures answering environmental protection requirements shall include, where appropriate, as a safeguard clause allowing Member States to take provisional measures, for non-economic environmental reasons, subject to a Community inspection procedure.

3. In preparing its policy on the environment, the Community shall take account of:

—available scientific and technical data;
—environmental conditions in the various regions of the Community;

—the potential benefits and costs of action or lack of action;
—the economic and social development of the Community as a whole and the balanced development of its regions.

http://www.law.harvard.edu/library/services/research/guides/international/eu/eu_legal_research_treaties.php

X. WHO ELF Environmental Health Criteria Monograph, June 2007

In 2007. the WHO EMF Program released its ELF Health Criteria Monograph and held a workshop in Geneva, Switzerland June 20-21st.

ELF Health Criteria Monograph

12.6 Conclusions

Acute biological effects have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines exist that have addressed this issue. Compliance with these guidelines provides adequate protection.

Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. ***However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted.*** (emphasis added).

The Monograph finds no reason to change the designation of EMF as a 2B (Possible) Human Carcinogen as defined by the International Agency for Cancer Research (IARC). In finding that ELF-EMF is classifiable as a possible carcinogen, it is inconsistent to conclude that no change in the exposure limits is warranted. If the Monograph confirms, as other review bodies have, that childhood leukemia occurs at least as low as the 3 mG to 4 mG exposure range, then ICNIRP limits of 1000 mG for 50 Hz and 60 Hz ELF exposures are clearly too high and pose a risk to the health of children.

The WHO Fact Sheet summarizes some of the Monograph findings but adds further recommendations.

"Potential long-term effects"

Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans. This classification was based on pooled analyses of epidemiological studies demonstrating a consistent

pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT. ***The Task Group concluded that additional studies since then do not alter the status of this classification."*** *(emphasis added)*

"International exposure guidelines"

"Health effects related to short-term, high-level exposure have been established and form the basis of two international exposure limit guidelines (ICNIRP, 1998; IEEE, 2002). At present, these bodies consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering these quantitative exposure limits."

"Regarding long-term effects, given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, the benefits of exposure reduction on health are unclear. In view of this situation, the following recommendations are given:

> *1) Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure. Through the ELF risk assessment process, gaps in knowledge have been identified and these form the basis of a new research agenda.*
>
> *2) Member States are encouraged to establish effective and open communication programmes with all stakeholders to enable informed decision-making. These may include improving coordination and consultation among industry, local government, and citizens in the planning process for ELF EMF-emitting facilities.*
>
> *3) When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted."*

The last bullet in the WHO ELF Fact Sheet does not come from the Monograph, nor is it consistent with conclusions of the Monograph. The Monograph does call for prudent avoidance measures, one of which could reasonably be to establish numeric planning targets or interim limits for new and upgraded transmission lines and appliances used by children, for example. Countries should not be dissuaded by WHO staff, who unlike the authors of the Monograph, go too far in defining appropriate boundaries for countries that may wish to implement prudent avoidance in ways that best suit their population needs, expectations and resources. www.who.int/peh-emf/project/en

XI. World Health Organization Report on Children's Health and Environment

Environmental Issue Report Number 29 from the World Health Organization (2002) cautions about the effects of radiofrequency radiation on children's health. As part of a publication on "Children's Health and Environment: A Review of Evidence" the World Health Organization (WHO) wrote:

> *"The possible adverse health effects in children associated with radiofrequency fields have not been fully investigated."*
>
> *"Because there are suggestions that RF exposure may be more hazardous for the fetus and child due to their greater susceptibility, prudent avoidance is one approach to keeping children's exposure as low as possible."*
>
> *"Further research is needed to clarify the potential risks of ELF-EMF and radiofrequency fields for children's health."*

XII. International Agency for Research on Cancer (IARC)

A 2001 report by the WHO International Agency for Research on Cancer (IARC) concluded that ELF-EMF power frequency fields are a Category 2B (Possible) Human Carcinogen. These are power-frequency electromagnetic fields (50-Hz and 60-Hz electric power frequency fields).

The World Health Organization (WHO) is conducting the International Electromagnetic Fields (EMF) Project to assess health and environmental effects of exposure to static and time varying electric and magnetic fields in the frequency range of 1 – 300 gigahertz (GHz). Project goals include the development of international guidelines on exposure limits. This work will address radio and television broadcast towers, wireless communications transmission and telecommunications facilities, and associated devices such as mobile phones, medical and industrial equipment, and radars. It is a multi-year program that began in 1996 and will end in 2005. www.who.int/peh-emf

XIII. SCENIHR Opinion (European Commission Study of EMF and Human Health)

An independent Scientific Committee on newly emerging risks commissioned by the European Union released an update of its 2001 opinion on electromagnetic fields and human health in 2007. "The Committed addressed questions related to potential risks associated with interaction of risk factors, synergistic effects, cumulative effects, anti-microbial resistance, new technologies such as nanotechnologies, medical devices, tissue engineeringm blood products, fertility reduction, cancer of endocrine organs, physical hazards such as noise and electromagnetic fields and methodologies for assessing new risks." SCENIHR, 2007

SCENIHR Conclusions on Extremely low frequency fields (ELF fields)

> The previous conclusion that ELF magnetic fields are possibly carcinogenic, chiefly based on childhood leukaemia results, is still valid. There is no generally accepted mechanism to explain how ELF magnetic field exposure may cause leukaemia.
>
> For breast cancer and cardiovascular disease, recent research has indicated that an association is unlikely. For neurodegenerative diseases and brain tumours, the link to ELF fields remains uncertain. A relation between ELF fields and symptoms (sometimes referred to as electromagnetic hypersensitivity) has not been demonstrated.

SCENIHR Conclusions on Radiofrequency Radiation fields (RF fields)

> Since the adoption of the 2001 opinion, extensive research has been conducted regarding possible health effects of exposure to low intensity RF fields. This research has investigated a variety of possible effects and has included epidemiologic, in vivo, and in vitro research. The overall epidemiologic evidence suggests that mobile phone use of less than 10 years does not pose any increased risk of brain tumour or acoustic neuroma. For longer use, data are sparse, since only some recent studies have reasonably large numbers of long-term users. Any conclusion therefore is uncertain and tentative. From the available data, however, it does appear that there is no increased risk for brain tumours in long-term users, with the exception of acoustic neuroma for which there is limited evidence of a weak association. Results of the so-called Interphone study will provide more insight, but it cannot be ruled out that some questions will remain open.

SCENIHR Conclusions on Sensitivity of Children

> Concerns about the potential vulnerability of children to RF fields have been

raised because of the potentially greater susceptibility of their developing nervous system; in addition, their brain tissue is more conductive than that of adults since it has a higher water content and ion concentration, RF penetration is greater relative to head size, and they have a greater absorption of RF energy in the tissues of the head at mobile telephone frequencies. Finally, they will have a longer lifetime exposure.

Few relevant epidemiological or laboratory studies have addressed the possible effects of RF field exposure on children. Owing to widespread use of mobile phones among children and adolescents and relatively high exposures to the brain, investigation of the potential effect of RF fields in the development of childhood brain tumour is warranted. The characteristics of mobile phone use among children, their potential biological vulnerability and longer lifetime exposure make extrapolation from adult studies problematic.

There is an ongoing debate on possible differences in RF absorption between children and adults during mobile phone usage, e.g. due to differences in anatomy (Wiart et al. 2005, Christ and Kuster, 2005). Several scientific questions like possible differences of the dielectric tissue parameters remain open. The anatomical development of the nervous system is finished around 2 years of age, when children do not yet use mobile phones although baby phones have recently been introduced. Functional development, however, continues up to adult age and could be disturbed by RF fields.

XIV. Health Protection Agency (Formerly the NRPB - United Kingdom)

The National Radiation Protection Board or NRPB (2004) concluded, based on a review of the scientific evidence, that the most coherent and plausible basis from which guidance could be developed on exposures to ELF concerned weak electric field interactions in the brain and CNS (NRPB, 2004). A cautious approach was used to indicate thresholds for possible adverse health effects.

"Health Effects - It was concluded from the review of scientific evidence (NRPB, 2004b) that the most coherent and plausible basis from which guidance could be developed on exposures to ELF EMFs concerned weak electric field interactions in the brain and CNS (NRPB, 2004). A cautious approach was used to indicate thresholds for possible adverse health effects."

"The brain and nervous system operate using highly complex patterns of electrical signals. Therefore, the basic restrictions are designed to limit the

electric fields and current densities in these tissues so as to not adversely affect their normal functioning. The adverse effects that might occur cannot easily be characterized according to presenting signs or symptoms of disease or injury. They represent potential changes to mental processes such as attention and memory, as well as to regulatory functions with in the body. Thus, the basic restrictions should not be regarded as precisely determined values below which no adverse health effects can occur and above which clearly discernible effects will happen. The do, however, indicate an increasing likelihood of effects occurring as exposure increases above the basic restriction values."

*"From the results of the epidemiological investigations, there remain concerns about a possible increased risk of child leukaemia associated with exposure to magnetic fields above about 0.4 uT (*4 mG*). In this regard, it is important to consider the possible need for further precautionary measures."*

This recent statement by the UK Health Protection Agency clearly indicates that the current guidelines may not be protective of public health. Yet, the reference levels used in the United Kingdom remain at 5000 mG for 50 Hz power frequency fields for occupational exposure and 1000 mG for public exposure.

XV. US Government Radiofrequency Interagency Working Group Guidelines Statement

The United States Radiofrequency Interagency Working Group (RFIAWG) cited concerns about current federal standards for public exposure to radiofrequency radiation in 1999 (Lotz, 1999 for the Radiofrequency Interagency Working Group)

"Studies continue to be published describing biological responses to nonthermal ELF-modulated RF radiation exposures that are not produced by CW (unmodulated) radiation. These studies have resulted in concern that 'exposure guidelines based on thermal effects, and using information and concepts (time-averaged dosimetry, uncertainty factors) that mask any differences between intensity-modulated RF radiation exposure and CW exposure, do not directly address public exposures, and therefore may not adequately protect the public."

The United States government Federal Radiofrequency Interagency Working Group has reviewed the existing ANSI/IEEE RF thermal-based exposure standard upon which the FCC limit is based. This Working Group was made up of representatives from the US government's National Institute for Occupational Safety and Health (NIOSH), the

Federal Communications Commission (FCC), Occupational Health and Safety Administration (OSHA), the Environmental Protection Agency (US EPA), the National Telecommunication and Information Administration, and the US Food and Drug Administration (FDA).

On June 17, 1999, the RFIAWG issued a Guidelines Statement that concluded the present RF standard "may not adequately protect the public". The RFIAWG identified fourteen (14) issues that they believe are needed in the planned revisions of ANSI/IEEE RF exposure guidelines including "to provide a strong and credible rationale to support RF exposure guidelines". In particular, the RFIAWG criticized the existing standards as not taking into account chronic, as opposed to acute exposures, modulated or pulsed radiation (digital or pulsed RF is proposed at this site), time-averaged measurements that may erase the unique characteristics of an intensity-modulated RF radiation that may be responsible for reported biologic effects, and stated the need for a comprehensive review of long-term, low-level exposure studies, neurological-behavioral effects and micronucleus assay studies (showing genetic damage from low-level RF).

The existing federal standards may not be protective of public health in critical areas. The areas of improvement where changes are needed include: a) selection of an adverse effect level for chronic exposures not based on tissue heating and considering modulation effects; b) recognition of different safety criteria for acute and chronic exposures at non-thermal or low-intensity levels; c) recognition of deficiencies in using time-averaged measurements of RF that does not differentiate between intensity-modulated RF and continuous wave (CW) exposure, and *therefore may not adequately protect the public.*

As of 2007, requests to the RFIAWG on whether these issues have been satisfactorily resolved in the new 2006 IEEE recommendations for RF public safety limits have gone unanswered (BioInitiative Working Group, 2007).

XVI. United Kingdom - Parliament Independent Expert Group Report (Stewart Report)

The Parliament of the United Kingdom commissioned a scientific study group to evaluate the evidence for RF health and public safety concerns. In May of 2000, the United Kingdom Independent Expert Group on Mobile Phones issued a report underscoring concern that standards are not protective of public health related to both mobile phone use and exposure to wireless communication antennas.

Conclusions and recommendations from the Stewart Report (for Sir William Stewart) indicated that the Group has some reservation about continued wireless technology expansion without more consideration of planning, zoning and potential public health concerns. Further, the Report acknowledges significant public concern over community siting of mobile phone and other communication antennas in residential areas and near schools and hospitals.

> *"Children may be more vulnerable because of their developing nervous system, the greater absorption of energy in the tissue of the head and a longer lifetime of exposure."*
>
> *"The siting of base stations in residential areas can cause considerable concern and distress. These include schools, residential areas and hospitals."*
>
> *" There may be indirect health risks from living near base stations with a need for mobile phone operators to consult the public when installing base stations."*
>
> *"Monitoring should be expecially strict near schools, and that emissions of greatest intensity should not fall within school grounds."*
>
> *"The report recommends "a register of occupationally exposed workers be established and that cancer risks and mortality should be examined to determine whether there are any harmful effects."*
> (IEGMP, 2000)

XVII. Food and Drug Administration (US FDA)

The Food and Drug Administration announced on March 28, 2007 it is contracting with the National Academy of Science to conduct a symposium and issue a report on additional research needs related to possible health effects associated with exposure to radio frequency energy similar to those emitted by wireless communication devices. The National Academy of Sciences will organize an open meeting of national and international experts to discuss the research conducted to date, knowledge gaps, and additional research needed to fill those gaps. The workshop will consider the scientific literature and ongoing research from an international perspective in order to avoid duplication, and in recognition of the international nature of the scientific community and of the wireless industry.

Funding for the project will come from a Cooperative Research and Development Agreement (CRADA) between the Food and Drug Administration's Center for Devices and Radiological Health and the Cellular Telecommunications and Internet Association (CTIA).

http://www.fda.gov/cellphones/index.html

XVIII. National Institutes for Health - National Toxicology Program

The National Toxicology Program (NTP) is a part of the National Institute for Environmental Health Sciences, National Institutes for Health. Public and agency comment has been solicited on whether to add radiofrequency radiation to its list of substances to be tested by NTP as carcinogens. In February 2000 the FDA made a recommendation to the NPT urging that RF be tested for carcinogenicity (www.fda.gov.us). The recommendation is based in part on written testimony stating:

> *" Animal experiments are crucial because meaningful data will not be available from epidemiological studies for many years due to the long latency period between exposure to a carcinogen and the diagnosis of a tumor.*
>
> *"There is currently insufficient scientific basis for concluding either that wireless communication technologies are safe or that they pose a risk to millions of users."*

"FCC radiofrequency radiation guidelines are based on protection from acute injury from thermal effects of RF exposure and may not be protective *against any non-thermal effects of chronic exposures."*

In March of 2003, the National Toxicology Program issued a Fact Sheet regarding its toxicology and carcinogenicity testing of radiofrequency/microwave radiation. These studies will evaluate radiofrequency radiation in the cellular frequencies.

"The existing exposure guidelines are based on protection from acute injury from thermal effects of RF exposure. Current data are insufficient to draw definitive conclusions concerning the adequacy of these guidelines to be protective against any non-thermal effects of chronic exposures. "

XIX. US Food and Drug Administration

In February of 2000, Russell D. Owen, Chief of the Radiation Biology Branch of the Center for Devices and Radiological Health, US Food and Drug Administration (FDA) commented that there is:

"currently insufficient scientific basis for concluding whether wireless communication technologies pose any health risk."

"Little is known about the possible health effects of repeated or long-term exposures to low level RF of the sort emitted by such devices."

"Some animal studies suggest the possibility for such low-level exposures to increase the risk of cancer..."

Dr. Owen's comments are directed to users of cell phones, but the same questions are pertinent for long-term RF exposure to radiofrequency radiation for the larger broadcast transmissions of television, radio and wireless communications (Epidemiology Vol. 1, No. 2 March 2000 Commentary). The Food and Drug Administration signed an agreement (CRADA agreement) to provide funding for immediate research into RF health effects, to be funded by the Cellular Telephone Industry of America. The FDA no longer assures the safety of users. No completion date has been set.

XX. National Academy of Sciences - National Research Council

An Assessment of Non-Lethal Weapons Science and Technology by the Naval Studies Board, Division of Engineering and Physical Sciences (National Academies Press (2002) has produced a report that confirms the existence of non-thermal bioeffects from information transmitted by radiofrequency radiation at low intensities that cannot act by tissue heating (prepublication copy, page 2-13).

In this report, the section on Directed-Energy Non-Lethal Weapons it states that:

"The first radiofrequency non-lethal weapons, VMADS, is based on a biophysical susceptibility known empirically for decades. More in-depth health effects studies were launched only after the decision was made to develop that capability as a weapon. The heating action of RF signals is well understood and can be the basis for several additional directed-energy weapons. Leap-ahead non-lethal weapons technologies will probably be based on more subtle human/RF interactions in which the signal information within the RF exposure causes an effect other than simply heating: for example, stun, seizure, startle and decreased spontaneous activity. Recent developments in the technology are leading to ultrawideband, very high peak power and ultrashort signal capabilities, suggesting the the phase space to be explored for subtle, uyet potentially effective non-thermal biophysical susceptibilities is vast. Advances will require a dedicated effort to identify useful susceptibilities."

Page 2-13 of the prepublication report (emphasis added)

This admission by the Naval Studies Board confirms several critical issues with respect to non-thermal or low-intensity RF exposures. First, it confirms the existence of bioeffects from non-thermal exposure levels of RF. Second, it identifies that some of these non-thermal effects can be weaponized with bioeffects that are incontrovertibly adverse to health (stun, seizure, startle, decreased spontaneous activity). Third, it confirms that there has been knowledge for decades about the susceptibility of human beings to non-thermal levels of RF exposure. Fourth, it provides confirmation of the concept that radiofrequency interacts with humans based on the RF information content (signal information) rather than heating, so it can occur at subtle energy levels, not at high levels associated with tissue heating. Finally, the report indicates that a dedicated scientific research effort is needed to really understand and refine non-thermal RF as a weapon, but it is promising enough for continued federal funding.

XXI. The IEEE (United States)

IEEE ICES SCC-28 SC-4 Subcommittee (Radiofrequency/Microwave Radiation)

Members of the ICES SCC-28 SC-4 committee presented their views and justifications in a Supplement to the Bioelectromagnetics Journal (2003). It offers a window into the thinking that continues to support thermal-only risks, and on which the current United States IEEE recommendations have been made. The United States Federal Communications Commission (FCC) has historically based its federally-mandated public and occupational exposure standards on the recommendations of the IEEE.

Radiofrequency/Microwave Radiation

IEEE's original biological benchmark for setting human exposure standards (on which most contemporary human standards are based) is disruption of food-motivated learned behavior in subject animals. For RF, it was based on short, high intensity RF exposures that were sufficient to result in changes in animal behavior.

> *"The biological endpoint on which most contemporary standards are based is disruption of food- motivated learned behavior in subject animals. The threshold SAR for behavioral disruption has been found to reliably occur between 3 and 9 W/kg across a number of animal species and frequencies; a whole-body average SAR of 4 W/kg is considered the threshold below which adverse effects would not be expected. To ensure a margin of safety, the threshold SAR is reduced by a safety factor of 10 and 50 to yield basic restrictions of 0.4 W/kg and 0.08 W/kg for exposures in controlled (occupational) and uncontrolled (public) environments, respectively." (Osepchuk and Petersen, 2003).*

The development of public exposure standards for RF is thus based on acute, but not chronic exposures, fails to take into account intermittent exposures, fails to consider special impacts of pulsed RF and ELF-modulated RF, and fails to take into account bioeffects from long-term, low-intensity exposures that may lead to adverse health impacts over time.

XXII. BEMS Supplement 6 (Journal of the Bioelectromagnetics Society)

BEMS Supplement 6 was prepared in support of the IEEE SC-4 committee RF recommendations. In explaining and defending revised recommendations on RF limits contained within C.95.1, some key members took out space in Bioelectromagnetics (the Journal of the Bioelectromagnetic Society) to present papers ostensibly justifying a relaxation of the existing IEEE RF standards, rather than making the standards more conservative to reflect the emerging scientific evidence for both bioeffects and adverse health impacts.

Several clues are contained in the BEMS Supplement 6 to understand how the SC-4 IEEE C.95 revision working group and the ICES could arrive at a decision to not to recommend tighter limits on RF exposure. Not one but two definitions of "adverse effect" are described, one by Osepchuk/Petersen (2003) and another by the working group itself (D'Andrea et al, 2003). Both set a very high bar for demonstration of proof, and both are ignored in the final recommendations by the SC-4 Subcommittee.

Second, many of the findings presented in the papers by individual authors in the BEMS Supplement 6 do report that RF exposures are linked to bioeffects and to adverse effects; but these findings are evidently ignored or dismissed by the SC-4 Subcommittee, ICES and by the eventual adoption of these recommendations by the full IEEE membership (in 2006). Even with a very high bar of evidence set by the SC-4 Subcommittee (and two somewhat conflicting definitions of adverse effect against which all scientific papers were reviewed and analyzed); there is clear sign that the "deal was done' regardless of even some of the key Subcommittee member findings reporting such effects at exposure levels below the existing limits.* sidebar

The SC-4 Subcommittee has developed a new and highly limited definition on RF effects, adverse effects and hazards that is counter to the WHO Constitution Principle on Health. The definition as presented by D'Andrea et al (2003, page S138) is based on the SC-4 IEEE C.95 revision working group definition of adverse effect:

"An adverse effect is a biological effect characterized by a harmful change in health. For example, such changes can include organic disease, impaired mental function, behavioral disfunction, reduced longevity, and defective or deficient reproduction. Adverse effects do not include: biological effects without detrimental health effect, changes in subjective feelings of well-being that are a result of anxiety about RF effects or impacts of RF infrastructure that are not related to RF emissions, or indirect effects caused by electromagnetic interference with electronic devices. An adverse effects exposure level is the condition or set of conditions under which an electric, magnetic or electromagnetic field has an adverse effect."

Further, the working group extended its definition to include that of Michaelson and Lin (1987) which states:

"If an effect is of such an intense nature that it compromises the individual's ability to function properly or overcomes the recovery capability of the individual, then the 'effect' may be considered a hazard. In any discussion of the potential for 'biological effects' from exposure to electromagnetic energies we must first determine whether any 'effect' can be shown; and then determine whether such an observed 'effect' is hazardous."

The definition of adverse effect according to Osepchuk and Petersen (2003) reported in the same BEMS Supplement 6 is:

"An adverse biological response is considered any biochemical change, functional impairment, or pathological lesion that could impair performance and reduce the ability of an organism to respond to additional challenge. Adverse biological responses should be distinguished from biological responses in general, which could be adaptive or compensatory, harmful, or beneficial. "

In contrast, the World Health Organization draft framework has accepted definitions of bioeffect, adverse health effect and hazard (WHO EMF Program Framework for Developing EMF Standards, Draft, October 2003). These definitions are not subject to the whim of organizations preparing public exposure standard recommendations. The WHO definition states that:

"(A)nnoyance or discomforts caused by EMF exposure may not be pathological per se, but, if substantiated, can affect the physical and mental well-being of a person and the resultant effect may be considered as an adverse health effect. A health effect is thus defined as a biological effect that is detrimental to health or well-being. According to the WHO Constitution, health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."

The SC-4 definitions require proof that RF has caused organic disease or other cited

effects that qualify. The burden of proof is ultimately shifted to the public, that bears the burden of unacknowledged health effects and diseases, where the only remedy is proof of illness over a large population of affected individuals, over a significant amount of time, and finally, delays until revisions of the standards can be implemented. The results of studies and reviews in the BEMS Supplement 6 already acknowledge the existence of bioeffects and adverse effects that occur at non-thermal exposure levels (below current FCC and ICNIRP standards that are supposedly protective of public health. However, they go on to ignore their own findings, and posit in advance that adverse effects seen today will, even with chronic exposure, not conclusively reveal disease or dysfunction tomorrow at exposure levels below the existing standards.

Sidebar: Quotes from BEMS Supplement 6

a) Studies and reviews where bioeffects likely to lead to adverse health effects with chronic exposure are reported;
b) adverse effects which are already documented;
c) studies where non-thermal RF effects are reported and unexplained;
d) effects are occurring below current exposure limits, and
e) conclusions by authors they cannot draw conclusions about hazards to human health

These quotes appear in articles presented by the IEEE SC-4 Subcommittee in BEMS Supplement 6. Despite these acknowledged gaps in information, lack of consistency in studies, abundant conflicting evidence documenting low level RF effects that can resulting serious adverse health impacts (DNA damage, cognitive impairment, neurological deficits, cancer, etc), and other clear instances of denial of ability to predict human health outcomes, the IEEE SC-4 Subcommittee has proposed recommendations to relax the existing limits.

XXIII. Proceedings of the NATO Advanced Research Workshop – Mechanisms of the Biological Effect on Extra High Power Pulses (EHPP) and UNESCO/WHO/IUPAB Seminar "Molecular and Cellular Mechanisms of Biological Effects of EMF" held March 2005, Yerevan, Armenia.

The proceedings conclude that "*the authors agreed with one main conclusion from these meeting(s): that in the future worldwide harmonization of standards have to be based on biological responses, rather than computed values*". The authors included 47 scientists, engineers, physicians and policy makers from 21 countries from Europe, North and South America, and Asia.

> *"The ICNIRP Guidelines for radiofrequency electromagnetic exposure are based only on thermal effects, and completely neglects the possibility of non-thermal effect."*
>
> *"The guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) specify the quantative characteristics of EMF used to specify the basic restrictions are current density, specific absorption rate (SAR) and power density, i.e., the energetic characteristics of EMF. However, experimental data on energy-dependency of biological effects by EMF have shown that the SAR approach, very often, neither adequately describes or explains the real value of EMF-induced biological effects on cells and organisms, for at least two reasons: a) the non-linear character of EMF-induced bioeffects due to the existence of amplitude, frequency and 'exposure time-windows' and b) EMF-induced bioeffects significantly depend on physical and chemical composition of the surrounding medium."* (Preface pages XI – XIII).

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SECTION 6

Genetic Effects of Non-Ionizing Electromagnetic Fields

2014 Supplement

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I. INTRODUCTION

The following is an update of information and abstracts on research papers published since 2006/2007 on the genetic effects of nonionizing electromagnetic fields (EMF) in the radiofrequency (RF) and extremely-low frequency (ELF) ranges. Two static magnetic field papers (Jouni et al. 2012; Wang et al., 2009) are also included. Where additional information is relevant, some earlier papers, or papers not specifically related to genetic effects, are also included with citations contained within the discussion below. A list of abstracts, with summary sentences underlined for reader convenience, can be found at the end of this paper.

Analysis of these recent publications shows that there are more papers reporting effects than no effect.

In summary, the new radiofrequency studies report that 65% of genetic studies show effects and 35% do not show effects. **[Effects = 74 (65%) No Effects = 40 (35%)]**

In summary, the new ELF-EMF studies report that 82% of genetic studies show effects and 18% do not show effects **[Effects= 49 (83%) No Effects= 10 (17%)]**

Appendix A has references and abstracts for the RFR literature. Appendix B has references and abstracts for the ELF-EMF literature.

II. GENOTOXIC EFFECTS OF RADIOFREQUENCY RADIATION (RFR) AND OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS (ELF-EMF) (2007-2014)

The following is an update of information and abstracts on research papers published since 2006/2007 on the genetic effects of nonionizing electromagnetic fields (EMF) in the radiofrequency (RF) and extremely-low frequency (ELF) ranges. Two static magnetic field papers (Jouni et al. 2012; Wang et al., 2009) are also included. Where additional information is relevant, some earlier papers, or papers not specifically related to genetic effects, are also included with citations contained within the discussion below. A list of abstracts, with summary sentences underlined for reader convenience, can be found at the end of this paper.

Analysis of these recent publications shows that there are more papers reporting effects than no effect. With E representing a biological effect, and NE representing no biological effects, the recent literature finds RFR-genetic effects at: E=74 publications (65%); NE=40 publications (35%); and ELF-genetic effects at: E=49 (83%); NE=10 (17%).

Discussion

1. The effects of both RF and ELF fields are very similar. This is surprising because the energies carried by these EMFs are billions of folds different. An explanation for similar genetic effects has been provided by a recent paper by Blank and Goodman (Blank M, Goodman R. DNA is a fractal antenna in electromagnetic fields. Int. J. Radiat. Biol. 87(4):409-415, 2011) in which they stated that '...the wide frequency range of interaction with EMF is the functional characteristic of a fractal antenna, and DNA appears to possess the two structural characteristics of fractal antennas, electronic conduction and self symmetry.' However, similarities in effects between ELF and RF fields have also been reported in studies of other physiological processes, e.g., neurochemical and behavioral effects (Cf. Lai, H., Carino, M.A., Horita, A. and Guy, A.W. Opioid receptor subtypes that mediate a microwave-induced decrease in central cholinergic activity in the rat. Bioelectromagnetics 13:237-246, 1992; Lai, H. and Carino, M.A. Intracerebroventricular injections of mu and delta-opiate receptor antagonists block 60-Hz magnetic field-induced decreases in cholinergic activity in the frontal cortex and hippocampus of the rat. Bioelectromagnetics 19:433-437, 1998; Lai, H., Carino, M.A. and Ushijima, I. Acute exposure to a 60 Hz magnetic field affects rats' performance in the water maze. Bioelectromagnetics 19:117-122, 1998; Wang, B.M. and Lai, H. Acute exposure to pulsed 2450-MHz microwaves affects water maze learning in the rat. Bioelectromagnetics 21:52-56, 2000.) Thus, there is a basic interaction mechanism of biological tissues with electromagnetic fields that is independent of frequency.
   Many studies have implicated the involvement of free radical processes in the genetic effects of EMF: ELF-EMF (Butdak et al., 2012; Jouni et al., 2012; Luukkonen et al., 2014; Tiwari et al.,2014); RFR (Agarwal et al., 2009; Atasoy et al., 2012; Burlaka et al., 2013; Campisi et al., 2010; De Iuliis et al., 2009; Esmekaya et al., 2011; Ferreira et al., 2006; Gajski and Garaj-Vrhovac, 2009; Garaj-Vrhovac et al., 2011; Guler et al., 2010, 2012; Kesari and Behari, 2009; Kesari et al., 2010; Khalil et al., 2012; Kumar et al., 2010; Liu et al., 2013a,b; Luukkonan et al., 2009; Tomruk et al., 2010; Tkalec et al., 2013; Wu et al., 2008; Xu et al., 2010; Yao et al., 2003). Increase in free radical activity and changes in enzymes involved in cellular oxidative processes are the most consistent effects observed in cells and animals after EMF exposure. However, they are reports indicating that EMF could induce genetic effects without the involvement of free radicals (ELF- Alcaraz et al., 2013; RFR- Ferreira et al., 2006; Furtado-Filho et al., 2013) and increase in free radical after EMF exposure did not lead to genetic effects (Frahm et al., 2006). There are at least a couple of hundred published papers on the effects of EMF exposure on cellular oxidative processes. Many biological effects of EMF can be explained by intracellular changes in oxidative status, including the genetic effects reported in this review.

2. An important observation of the studies is that EMF can interact with other entities and synergistically cause genetic effects. These entities include: ELF-EMF- cisplastin (Buldak et al., 2012; El-Bialy et al., 2013), bleomycin (Cho et al., 2007), gadolinium (Cho et al., 2014); hydrogen peroxide and methyl methane sulfonate (Koyama et al., 2008), menadione (Luukkonan et al., 2011, 2014; Markkanen et al., 2008), ionizing radiation (Mairs et al., 2007; Journi et al., 2012 Yoon et al., 2014); RFR- chemical

mutagens (Baohong et al., 2005), clastogens (Kim et al., 2008), x-rays (Manti et al., 2008), ultraviolet ray (Baohong et al., 2007), aphidicolin (Tiwari et al., 2008), picrotoxin (López-Martín et al., 2009), doxorubicin (Zhijian et al., 2010), and incoherent electromagnetic noise (Wu et al., 2008; Yao et al., 2008). Most of the compounds that interact with EMF are mutagens. This is important because in real life situations, a person is usually exposed to many different environmental factors simultaneously. Synergism of these factors with EMF should be considered more seriously.

3. Several long term/repeated exposure papers are included in this update: ELF-EMF (Borhani et al., 2011; Cuccurazzu et al., 2010; Erdal et al., 2007; Fedrowitz and Loscher, 2012; Mariucci et al., 2010; Panagopoulous et al., 2013; Udroiu et al., 2006), and RFR (Asasoy et al., 2012; Atli Serkeroglu et al., 2013; Burlaka et al., 2013; Chavdoula et al., 2010; Deshmukh et al., 2013; Ferreira et al., 2006; Garaj-Vrhovac et al., 2011; Guler et al., 2010, 2012; Kesari and Behari, 2009; Kesari et al., 2010; Lakshmi et al., 2010; Paulraj and Behari, 2006; Tomruk et al., 2010; Yan et al., 2008). These data are important in the understanding of the biological effects of EMF exposure in real life situation, since human environmental EMF exposure is both chronic and intermittent. Within these long-term exposure studies, there are several that investigated the effect of EMF exposure on developing animals (ELF-EMF: Borhani et al., 2011; Cuccurazzu et al., 2010; Panagopoulous et al., 2013; Udroiu et al., 2006, RFR: Burlaka et al., 2013; Ferreira et al., 2006; Guler et al., 2010, 2012; Serkeroglu et al., 2013; Tomruk et al., 2010; Zalata et al., In press). Data of effects of EMF exposure on growth and development of young animals are urgently needed. There are several studies indicating that RFR may affect reproduction, particularly with effects on sperm physiology and DNA (Agarwal et al., 2009; Atasoy et al., 2012; Avendano et al., 2012; Chavdoula et al., 2010; de Iuliis et al., 2009; Liu et al., 2013b; Panagopoulous et al., 2007). Similar effects of ELF-EMF on sperm have also been reported, e.g., Hong R, Zhang Y, Liu Y, Weng EQ. Effects of extremely low frequency electromagnetic fields on DNA of testicular cells and sperm chromatin structure in mice. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 23(6):414-417, 2005; Iorio R, Scrimaglio R, Rantucci E, Delle Monache S, Di Gaetano A, Finetti N, Francavilla F, Santucci R, Tettamanti E, Colonna R. A preliminary study of oscillating electromagnetic field effects on human spermatozoon motility. Bioelectromagnetics. 28(1):72-75, 2007; Iorio R, Delle Monache S, Bennato F, Di Bartolomeo C, Scrimaglio R, Cinque B, Colonna RC. Involvement of mitochondrial activity in mediating ELF-EMF stimulatory effect on human sperm motility. Bioelectromagnetics. 32(1):15-27, 2011.

4. Another area that needs more research is the biological effects of low-intensity exposure. This is particularly true for ELF-EMF, since intensities of ELF-EMF in the environment are in microtesla (μT) levels. There are many studies on biological effects of low-intensity RFR (see Table 1 in Levitt, B.B. and Lai, H. Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. Environ. Rev. 18:369-395, 2010.) However, most cell and animal studies in ELF-EMF used fields in the millitesla (mT) level. Exceptions are the study of Sarimov et al. (2011) listed below in the reference section and the study of de Bruyn and de Jager (2010) (de Bruyn L and de Jager L. Effect of long-term exposure to a randomly varied 50

Hz power frequency magnetic field on the fertility of the mouse. Electromag. Biol. Med. 29(1-2):52-61, 2010).

5. Two other important findings of these recent studies are that the effects of EMF are shown to be waveform specific and cell-type specific. Regarding waveform specificity, Campisi et al. (2010) reported increases in free radical activity and DNA fragmentation in brain cells after acute exposure to a 50-Hz amplitude-modulated 900-MHz RFR, whereas a continuous-wave 9000-MHz field produced no effect. Franzellitti et al. (2010) showed increased DNA strand breaks in trophoblasts after exposure to a 217-Hz modulated 1.8 GHz-RFR, but a continuous-wave field of the same carrier frequency was without effect. Tkalec et al (2013) reported that AM-modulated (1 KHz sinusoidal) 900-MHz RFR is more potent than non-modulated field in causing DNA damage in coelomocytes of exposed earthworms. Luukkonen et al. (2009) reported a continuous-wave 872-MHz RFR increased chemically-induced DNA strand breaks and free radicals in human neuroblastoma cells, whereas a GSM-modulated 872-MHz field had no significant effect. Zhang et al. (2008) found that gene expression in rat neurons is more sensitive to intermittent than continuous exposure to a 1.8 GHz-RFR. López-Martín et al. (2009) found that GSM and unmodulated RFR caused different effects on c-Fos gene expression in the rat brain. Regarding cell-type specificity, Nylund and Leszczynski (2006) and Remondini et al. (2006) reported different patterns of gene expression in different types of cells after exposure to RFR. Zhao et al. (2007) found than neurons are more sensitive to a 1.9 GHz cell phone radiation than astrocytes. Schwarz et al. (2008) reported DNA strand breaks and micronucleus formation in human fibroblasts, but not in lymphocytes, after exposure to a 1950-MHz UMTS field. Furthermore, Xu et al (2013) found DNA damages in some cell types and not in others after exposure to 1800-MHz RFR. Valbonesi et at. (2014) reported that HSP70 expression and MAPK signaling pathways in PC12 cells were affected by GSM-217 Hz signal and not by CW or GSM-talk signals. In ELF-EM research, Giorgi et al. (2011) found that DNA transposition in E. coli was *decreased* after exposure to a sinusoidal magnetic field and *increased* after exposure to a pulsed magnetic field. Kim et al. (2012) described DNA strand breaks in human fibroblasts after exposure to ELF magnetic field. They found that the pattern of changes depended on the eddy current and Lorentz force in the field. Nahab et al. (2007) reported that a square-continuous ELF magnetic field was more effective than sinusoidal-continuous or pulsed field in inducing sister chromatid exchange in human lymphocytes. These findings underscore the complicity of interaction of EMF with biological tissues and may partially explain why effects were observed in some studies and not others. It is essential to understand why and how certain wave-characteristics of an EMF are more effective than other characteristics in causing biological effects, and why certain types of cells are more susceptible to the effect of EMF? That there are different biological effects elicited by different EMF wave characteristics is critical proof for the existence of nonthermal effects.

6. Many biological/health effects have been reported in cells and animals after exposure to EMFs in both the ELF and RF ranges. (Sixty-five percent of the RFR papers and 82% of the ELF-EMF papers in the publication list below reported effects.) It is highly dishonest for a scientist to summarily deny the existence of biological effects of EMF. A

biological effect of EMF can be detrimental to health, but can also be turned into a beneficial means for the treatment of human diseases. Denying any effects hampers the development of electromagnetic treatments for diseases. Examples of possible clinical uses of EMF are: Alzheimer's disease (Arendash GW, Sanchez-Ramos J, Mori T, Mamcarz M, Lin X, Runfeldt M, Wang L, Zhang G, Sava V, Tan J, Cao C. Electromagnetic field treatment protects against and reverses cognitive impairment in Alzheimer's disease mice. J Alzheimers Dis. 19(1):191-210, 2010); Parkinson's disease (Wang Z, Che PL, Du J, Ha B, Yarema KJ. Static magnetic field exposure reproduces cellular effects of the Parkinson's disease drug candidate ZM241385. PLoS One. 5(11):e13883, 2010); bone regeneration (Lee HM, Kwon UH, Kim H, Kim HJ, Kim B, Park JO, Moon ES, Moon SH. Pulsed eltromagnetic field stimulates cellular proliferation in human intervertebral disc cells. Yonsei Med. J. 51(6):954-959, 2010); cancer treatment (Costa FP, de Oliveira AC, Meirelles R, Machado MC, Zanesco T, Surjan R, Chammas MC, de Souza Rocha M, Morgan D, Cantor A, Zimmerman J, Brezovich I, Kuster N, Barbault A, Pasche B. Treatment of advanced hepatocellular carcinoma with very low levels of amplitude-modulated electromagnetic fields. Br. J. Cancer. 105(5):640-648, 2011), and tissue regeneration (Gaetani R, Ledda M, Barile L, Chimenti I, De Carlo F, Forte E, Ionta V, Giuliani L, D'Emilia E, Frati G, Miraldi F, Pozzi D, Messina E, Grimaldi S, Giacomello A, Lisi A. Differentiation of human adult cardiac stem cells exposed to extremely low-frequency electromagnetic fields. Cardiovasc. Res. 82(3):411-420, 2009).

7. It must be pointed out that, consistent with previous research, not very much of the cellular and animal genetic research data directly indicate that EMF (both RF and ELF EMF) is a carcinogen. However, the data show that EMF can possibly alter genetic functions and thus it is advisable that one should limit one's exposure to EMF.

APPENDIX A - ABSTRACTS ON GENETIC EFFECTS OF RADIOFREQUENCY AND CELL PHONE RADIATION (2007-2014)

Below is a key to abbreviations used throughout the following list of abstracts for recent papers published since 2006 and serve as my comments to help the reader quickly identify the significance of each work. The summary sentences by each author are underlined. The list is divided into RF effects papers, and ELF effects papers.

(E- effect observed; NE- no effect observed) (LE- long term exposure; GT- genotoxic effect, e.g., DNA damage, micronucleus formation, chromosome alterations; GE- gene expression; HU- human study; OX- oxidative effects, i.e., involvement of free radicals and oxidative enzymes; IA- interaction with other factors to cause genetic effects; DE- effects on developing animals; RP- reproduction, e.g., sperm damage; EH- compared with electro-hypersensitive subjects; WS- waveform specific effect, e.g., modulation and frequency; CS- cell type specific effect).

(E) **Agarwal A, Desai NR, Makker K, Varghese A, Mouradi R, Sabanegh E, Sharma R. Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. Fertil Steril 92 1318-1325, 2009. (GT, RP, OX)**

OBJECTIVE: To evaluate effects of cellular phone radiofrequency electromagnetic waves (RF-EMW) during talk mode on unprocessed (neat) ejaculated human semen. DESIGN: Prospective pilot study. SETTING: Center for reproductive medicine laboratory in tertiary hospital setting. SAMPLES: Neat semen samples from normal healthy donors (n = 23) and infertile patients (n = 9). INTERVENTION(S): After liquefaction, neat semen samples were divided into two aliquots. One aliquot (experimental) from each patient was exposed to cellular phone radiation (in talk mode) for 1 h, and the second aliquot (unexposed) served as the control sample under identical conditions. MAIN OUTCOME MEASURE(S): Evaluation of sperm parameters (motility, viability), reactive oxygen species (ROS), total antioxidant capacity (TAC) of semen, ROS-TAC score, and sperm DNA damage. RESULT(S): Samples exposed to RF-EMW showed a significant decrease in sperm motility and viability, increase in ROS level, and decrease in ROS-TAC score. Levels of TAC and DNA damage showed no significant differences from the unexposed group. CONCLUSION(S): Radiofrequency electromagnetic waves emitted from cell phones may lead to oxidative stress in human semen. We speculate that keeping the cell phone in a trouser pocket in talk mode may negatively affect spermatozoa and impair male fertility.

(E) **Atasoy HI, Gunal MY, Atasoy P, Elgun S, Bugdayci G. Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices.J Pediatr Urol. 2012 Mar 30. [Epub ahead of print]** (GT, **OX, LE, RP)**

OBJECTIVE: To investigate effects on rat testes of radiofrequency radiation emitted from indoor Wi-Fi Internet access devices using 802.11.g wireless standards. METHODS: Ten Wistar albino male rats were divided into experimental and control groups, with five rats per group. Standard wireless gateways communicating at 2.437 GHz were used as radiofrequency wave sources. The experimental group was exposed to radiofrequency energy for 24 h a day for 20 weeks. The rats were sacrificed at the end of the study. Intracardiac blood was sampled for serum 8-hydroxy-2'-deoxyguanosine levels. Testes were removed and examined histologically and immunohistochemically. Testis tissues were analyzed for malondialdehyde levels and prooxidant-antioxidant enzyme activities. RESULTS: We observed significant increases in serum 8-hydroxy-2'-deoxyguanosine levels and 8-hydroxyguanosine staining in the testes of the experimental group indicating DNA damage due to exposure ($p < 0.05$). We also found decreased levels of catalase and glutathione peroxidase activity in the experimental group, which may have been due to radiofrequency effects on enzyme activity ($p < 0.05$). CONCLUSIONS: These findings raise questions about the safety of radiofrequency exposure from Wi-Fi Internet access devices for growing organisms of reproductive age, with a potential effect on both fertility and the integrity of germ cells.

(E) Atlı Şekeroğlu Z, Akar A, Sekeroğlu V. Evaluation of the cytogenotoxic damage in immature and mature rats exposed to 900 MHz radio frequency electromagnetic fields. Int J Radiat Biol. 89(11):985-992, 2013. [Epub ahead of print] (GT, DE, LE)

Abstract Purpose: One of the most important issues regarding radio frequency electromagnetic fields (RF-EMF) is their effect on genetic material. Therefore, we investigated the cytogenotoxic effects of 900 MHz radio frequency electromagnetic fields (RF-EMF) and the effect of a recovery period after exposure to RF-EMF on bone marrow cells of immature and mature rats. Materials and methods: The immature and mature rats in treatment groups were exposed to RF-EMF for 2 h/day for 45 days. Average electrical field values for immature and mature rats were 28.1±4.8 V/m and 20.0±3.2 V/m, respectively. Whole-body specific absorption rate (SAR) values for immature and mature rats were in the range of 0.38-0.78 W/kg, and 0.31-0.52 W/kg during the 45 days, respectively. Two recovery groups were kept for 15 days after RF-EMF exposure. Results: Significant differences were observed in chromosome aberrations (CA), micronucleus (MN) frequency, mitotic index (MI) and ratio of polychromatic erythrocytes (PCE) in all treatment and recovery groups. The cytogenotoxic damage in immature rats was statistically higher than the mature rats. The recovery period did not reduce the damage to the same extent as the corresponding control groups. Conclusions: The exposure of RF-EMF leads to cytotoxic and genotoxic damage in immature and mature rats. More sensitive studies are required to elucidate the possible carcinogenic risk of EMF exposure in humans, especially children.

(E) Avendaño C, Mata A, Sanchez Sarmiento CA, Doncel GF. Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. FertilSteril 97:39-45, 2012. (GT, RP)

OBJECTIVE: To evaluate the effects of laptop computers connected to local area networks wirelessly (Wi-Fi) on human spermatozoa. DESIGN: Prospective in vitro study. SETTING: Center for reproductive medicine. PATIENT(S): Semen samples from 29 healthy donors. INTERVENTION(S): Motile sperm were selected by swim up. Each sperm suspension was divided into two aliquots. One sperm aliquot (experimental) from each patient was exposed to an

internet-connected laptop by Wi-Fi for 4 hours, whereas the second aliquot (unexposed) was used as control, incubated under identical conditions without being exposed to the laptop. MAIN OUTCOME MEASURE(S): Evaluation of sperm motility, viability, and DNA fragmentation. RESULT(S): Donor sperm samples, mostly normozoospermic, exposed ex vivo during 4 hours to a wireless internet-connected laptop showed a significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation. Levels of dead sperm showed no significant differences between the two groups. CONCLUSION(S): To our knowledge, this is the first study to evaluate the direct impact of laptop use on human spermatozoa. Ex vivo exposure of human spermatozoa to a wireless internet-connected laptop decreased motility and induced DNA fragmentation by a nonthermal effect. We speculate that keeping a laptop connected wirelessly to the internet on the lap near the testes may result in decreased male fertility. Further in vitro and in vivo studies are needed to prove this contention.

(E) **Baohong Wang, Jiliang H, Lifen J, Deqiang L, Wei Z, Jianlin L, Hongping D. Studying the synergistic damage effects induced by 1.8 GHz radiofrequency field radiation (RFR) with four chemical mutagens on human lymphocyte DNA using comet assay in vitro. Mutat Res 578:149-57, 2005.** (GT, IA)

The aim of this investigation was to study the synergistic DNA damage effects in human lymphocytes induced by 1.8GHz radiofrequency field radiation (RFR, SAR of 3W/kg) with four chemical mutagens, i.e. mitomycin C (MMC, DNA crosslinker), bleomycin (BLM, radiomimetic agent), methyl methanesulfonate (MMS, alkylating agent), and 4-nitroquinoline-1-oxide (4NQO, UV-mimetic agent). The DNA damage of lymphocytes exposed to RFR and/or with chemical mutagens was detected at two incubation time (0 or 21h) after treatment with comet assay in vitro. Three combinative exposure ways were used. Cells were exposed to RFR and chemical mutagens for 2 and 3h, respectively. Tail length (TL) and tail moment (TM) were utilized as DNA damage indexes. The results showed no difference of DNA damage indexes between RFR group and control group at 0 and 21h incubation after exposure (P>0.05). There were significant difference of DNA damage indexes between MMC group and RFR+MMC co-exposure group at 0 and 21h incubation after treatment (P<0.01). Also the significant difference of DNA damage indexes between 4NQO group and RFR+4NQO co-exposure group at 0 and 21h incubation after treatment was observed (P<0.05 or P<0.01). The DNA damage in RFR+BLM co-exposure groups and RFR+MMS co-exposure groups was not significantly increased, as compared with corresponding BLM and MMS groups (P>0.05). The experimental results indicated 1.8GHz RFR (SAR, 3W/kg) for 2h did not induce the human lymphocyte DNA damage effects in vitro, but could enhance the human lymphocyte DNA damage effects induced by MMC and 4NQO. The synergistic DNA damage effects of 1.8GHz RFR with BLM or MMS were not obvious.

(E) **Baohong W, Lifen J, Lanjuan L, Jianlin L, Deqiang L, Wei Z, Jiliang H.Evaluating the combinative effects on human lymphocyte DNA damage induced by ultraviolet ray C plus 1.8GHz microwaves using comet assay in vitro. Toxicology. 232(3):311-316, 2007.** (GT, IA)

The objective of this study was to observe whether 1.8GHz microwaves (MW) (SAR, 3 W/kg) exposure can influence human lymphocyte DNA damage induced by ultraviolet ray C (UVC). The lymphocytes, which were from three young healthy donors, were exposed to 254 nm UVC at the doses of 0.25, 0.5, 0.75, 1.0, 1.5 and 2.0 J m(-2), respectively. The lymphocytes were irradiated by 1.8GHz MW (SAR, 3 W/kg) for 0, 1.5 and 4 h. The combinative exposure of UVC

plus MW was conducted. The treated cells were incubated for 0, 1.5 and 4 h. Finally, comet assay was used to measure DNA damage of above treated lymphocytes. The results indicated that the difference of DNA damage induced between MW group and control group was not significant (P>0.05). The MTLs induced by UVC were 1.71+/-0.09, 2.02+/-0.08, 2.27+/-0.17, 2.27+/-0.06, 2.25+/-0.12, 2.24+/-0.11 microm, respectively, which were significantly higher than that (0.96+/-0.05 microm) of control (P<0.01). MTLs of some sub-groups in combinative exposure groups at 1.5-h incubation were significantly lower that those of corresponding UVC sub-groups (P<0.01 or P<0.05). However, MTLs of some sub-groups in combinative exposure groups at 4-h incubation were significantly higher that those of corresponding UVC sub-groups (P<0.01 or P<0.05). In this experiment it was found that 1.8GHz (SAR, 3 W/kg) MW exposure for 1.5 and 4 h did not enhance significantly human lymphocyte DNA damage, but could reduce and increase DNA damage of human lymphocytes induced by UVC at 1.5-h and 4-h incubation, respectively.

(E) Belyaev IY, Hillert L, Protopopova M, Tamm C, Malmgren LO, Persson BR, Selivanova G, Harms-Ringdahl M. 915 MHz microwaves and 50 Hz magnetic field affect chromatin conformation and 53BP1 foci in human lymphocytes from hypersensitive and healthy persons. Bioelectromagnetics 26:173-184, 2005. (GT, EH)

We used exposure to microwaves from a global system for mobile communication (GSM) mobile phone (915 MHz, specific absorption rate (SAR) 37 mW/kg) and power frequency magnetic field (50 Hz, 15 muT peak value) to investigate the response of lymphocytes from healthy subjects and from persons reporting hypersensitivity to electromagnetic field (EMF). The hypersensitive and healthy donors were matched by gender and age and the data were analyzed blind to treatment condition. The changes in chromatin conformation were measured with the method of anomalous viscosity time dependencies (AVTD). 53BP1 protein, which has been shown to colocalize in foci with DNA double strand breaks (DSBs), was analyzed by immunostaining in situ. Exposure at room temperature to either 915 MHz or 50 Hz resulted in significant condensation of chromatin, shown as AVTD changes, which was similar to the effect of heat shock at 41 degrees C. No significant differences in responses between normal and hypersensitive subjects were detected. Neither 915 MHz nor 50 Hz exposure induced 53BP1 foci. On the contrary, a distinct decrease in background level of 53BP1 signaling was observed upon these exposures as well as after heat shock treatments. This decrease correlated with the AVTD data and may indicate decrease in accessibility of 53BP1 to antibodies because of stress-induced chromatin condensation. Apoptosis was determined by morphological changes and by apoptotic fragmentation of DNA as analyzed by pulsed-field gel electrophoresis (PFGE). No apoptosis was induced by exposure to 50 Hz and 915 MHz microwaves. In conclusion, 50 Hz magnetic field and 915 MHz microwaves under specified conditions of exposure induced comparable responses in lymphocytes from healthy and hypersensitive donors that were similar but not identical to stress response induced by heat shock.

(E) Belyaev IY, Koch CB, Terenius O, Roxstrom-Lindquist K, Malmgren LO, H Sommer W, Salford LG, Persson BR. Exposure of rat brain to 915 MHz GSM microwaves induces changes in gene expression but not double stranded DNA breaks or effects on chromatin conformation. Bioelectromagnetics 27:295-306, 2006. (GE)

We investigated whether exposure of rat brain to microwaves (MWs) of global system for mobile communication (GSM) induces DNA breaks, changes in chromatin conformation and in gene expression. An exposure installation was used based on a test mobile phone employing a GSM signal at 915 MHz, all standard modulations included, output power level in pulses 2 W, specific absorption rate (SAR) 0.4 mW/g. Rats were exposed or sham exposed to MWs during 2 h. After exposure, cell suspensions were prepared from brain samples, as well as from spleen and thymus. For analysis of gene expression patterns, total RNA was extracted from cerebellum. Changes in chromatin conformation, which are indicative of stress response and genotoxic effects, were measured by the method of anomalous viscosity time dependencies (AVTD). DNA double strand breaks (DSBs) were analyzed by pulsed-field gel electrophoresis (PFGE). Effects of MW exposure were observed on neither conformation of chromatin nor DNA DSBs. Gene expression profiles were obtained by Affymetrix U34 GeneChips representing 8800 rat genes and analyzed with the Affymetrix Microarray Suite (MAS) 5.0 software. In cerebellum from all exposed animals, 11 genes were upregulated in a range of 1.34-2.74 fold and one gene was downregulated 0.48-fold ($P < .0025$). The induced genes encode proteins with diverse functions including neurotransmitter regulation, blood-brain barrier (BBB), and melatonin production. The data shows that GSM MWs at 915 MHz did not induce PFGE-detectable DNA double stranded breaks or changes in chromatin conformation, but affected expression of genes in rat brain cells

(E) **Belyaev IY, Markovà E, Hillert L, Malmgren LO, Persson BR. Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes. Bioelectromagnetics 30:129-41, 2009.** (GT, EH)

We have recently described frequency-dependent effects of mobile phone microwaves (MWs) of global system for mobile communication (GSM) on human lymphocytes from persons reporting hypersensitivity to electromagnetic fields and healthy persons. Contrary to GSM, universal global telecommunications system (UMTS) mobile phones emit wide-band MW signals. Hypothetically, UMTS MWs may result in higher biological effects compared to GSM signal because of eventual "effective" frequencies within the wideband. Here, we report for the first time that UMTS MWs affect chromatin and inhibit formation of DNA double-strand breaks co-localizing 53BP1/gamma-H2AX DNA repair foci in human lymphocytes from hypersensitive and healthy persons and confirm that effects of GSM MWs depend on carrier frequency. Remarkably, the effects of MWs on 53BP1/gamma-H2AX foci persisted up to 72 h following exposure of cells, even longer than the stress response following heat shock. The data are in line with the hypothesis that the type of signal, UMTS MWs, may have higher biological efficiency and possibly larger health risk effects compared to GSM radiation emissions. No significant differences in effects between groups of healthy and hypersensitive subjects were observed, except for the effects of UMTS MWs and GSM-915 MHz MWs on the formation of the DNA repair foci, which were different for hypersensitive ($P < 0.02$[53BP1]//0.01[gamma-H2AX]) but not for control subjects ($P > 0.05$). The non-parametric statistics used here did not indicate specificity of the differences revealed between the effects of GSM and UMTS MWs on cells from hypersensitive subjects and more data are needed to study the nature of these differences.

(NE) **Bourthoumieu S, Joubert V, Marin B, Collin A, Leveque P, Terro F, Yardin C. Cytogenetic studies in human cells exposed in vitro to GSM-900 MHz radiofrequency radiation using R-banded karyotyping. Radiat Res 174:712-718, 2010.** (GT)

It is important to determine the possible effects of exposure to radiofrequency (RF) radiation on the genetic material of cells since damage to the DNA of somatic cells may be linked to cancer development or cell death and damage to germ cells may lead to genetic damage in next and subsequent generations. The objective of this study was to investigate whether exposure to radiofrequency radiation similar to that emitted by mobile phones of second-generation standard Global System for Mobile Communication (GSM) induces genotoxic effects in cultured human cells. The cytogenetic effects of GSM-900 MHz (GSM-900) RF radiation were investigated using R-banded karyotyping after in vitro exposure of human cells (amniotic cells) for 24 h. The average specific absorption rate (SAR) was 0.25 W/kg. The exposures were carried out in wire-patch cells (WPCs) under strictly controlled conditions of temperature. The genotoxic effect was assessed immediately or 24 h after exposure using four different samples. One hundred metaphase cells were analyzed per assay. Positive controls were provided by using bleomycin. We found no direct cytogenetic effects of GSM-900 either 0 h or 24 h after exposure. To the best of our knowledge, our work is the first to study genotoxicity using complete R-banded karyotyping, which allows visualizing all the chromosomal rearrangements, either numerical or structural.

(NE) Bourthoumieu S, Terro F, Leveque P, Collin A, Joubert V, Yardin C. Aneuploidy studies in human cells exposed in vitro to GSM-900 MHz radiofrequency radiation using FISH. Int J Radiat Biol 87:400-408, 2011. (GT)

PURPOSE: Since previous research found an increase in the rate of aneuploidies in human lymphocytes exposed to radiofrequencies, it seems important to perform further studies. The objective of this study was then to investigate whether the exposure to RF (radiofrequency) radiation similar to that emitted by mobile phones of a second generation standard, i.e., Global System for Mobile communication (GSM) may induce aneuploidy in cultured human cells. MATERIALS AND METHODS: The potential induction of genomic instability by GSM-900 MHz radiofrequency (GSM-900) was investigated after in vitro exposure of human amniotic cells for 24 h to average-specific absorption rates (SAR) of 0.25, 1, 2 and 4 W/kg in the temperature range of 36.3-39.7°C. The exposures were carried out in a wire-patch cell (WPC). The rate of aneuploidy of chromosomes 11 and 17 was determined by interphase FISH (Fluorescence In Situ Hybridisation) immediately after independent exposure of three different donors for 24 h. At least 100 interphase cells were analysed per assay. RESULTS: No significant change in the rate of aneuploidy of chromosomes 11 and 17 was found following exposure to GSM-900 for 24 h at average SAR up to 4 W/kg. CONCLUSION: Our study did not show any in vitro aneuploidogenic effect of GSM using FISH and is not in agreement with the results of previous research.

(NE) Bourthoumieu S, Magnaudeix A, Terro F, Leveque P, Collin A, Yardin C. Study of p53 expression and post-transcriptional modifications after GSM-900 radiofrequency exposure of human amniotic cells. Bioelectromagnetics. 2012 Jul 5. doi: 10.1002/bem.21744. [Epub ahead of print] (GE)

The potential effects of radiofrequency (RF) exposure on the genetic material of cells are very important to determine since genome instability of somatic cells may be linked to cancer development. In response to genetic damage, the p53 protein is activated and can induce cell cycle arrest allowing more time for DNA repair or elimination of damaged cells through

apoptosis. The objective of this study was to investigate whether the exposure to RF electromagnetic fields, similar to those emitted by mobile phones of the second generation standard, Global System for Mobile Communications (GSM), may induce expression of the p53 protein and its activation by post-translational modifications in cultured human cells. The potential induction of p53 expression and activation by GSM-900 was investigated after in vitro exposure of human amniotic cells for 24 h to average specific absorption rates (SARs) of 0.25, 1, 2, and 4 W/kg in the temperature range of 36.3-39.7 °C. The exposures were carried out using a wire-patch cell (WPC) under strictly controlled conditions of temperature. Expression and activation of p53 by phosphorylation at serine 15 and 37 were studied using Western blot assay immediately after three independent exposures of cell cultures provided from three different donors. Bleomycin-exposed cells were used as a positive control. According to our results, no significant changes in the expression and activation of the p53 protein by phosphorylation at serine 15 and 37 were found following exposure to GSM-900 for 24 h at average SARs up to 4 W/kg in human embryonic cells.

(E) Burlaka A, Tsybulin O, Sidorik E, Lukin S, Polishuk V, Tsehmistrenko S, Yakymenko I. Overproduction of free radical species in embryonal cells exposed to low intensity radiofrequency radiation. Exp Oncol. 35(3):219-225, 2013. (GT, LE, DE, OX)

Aim: Long-term exposure of humans to low intensity radiofrequency electromagnetic radiation (RF-EMR) leads to a statistically significant increase in tumor incidence. Mechanisms of such the effects are unclear, but features of oxidative stress in living cells under RF-EMR exposure were previously reported. Our study aims to assess a production of initial free radical species, which lead to oxidative stress in the cell. Materials and Methods: Embryos of Japanese quails were exposed in ovo to extremely low intensity RF-EMR of GSM 900 MHz (0.25 μW/cm2) during 158-360 h discontinuously (48 c - ON, 12 c - OFF) before and in the initial stages of development. The levels of superoxide (O2·-), nitrogen oxide (NO·), thiobarbituric acid reactive substances (TBARS), 8-oxo-2'-deoxyguanosine (8-oxo-dG) and antioxidant enzymes' activities were assessed in cells/tissues of 38-h, 5- and 10-day RF-EMR exposed and unexposed embryos. Results: The exposure resulted in a significant persistent overproduction of superoxide and nitrogen oxide in embryo cells during all period of analyses. As a result, significantly increased levels of TBARS and 8-oxo-dG followed by significantly decreased levels of superoxide dismutase and catalase activities were developed in the exposed embryo cells. Conclusion: Exposure of developing quail embryos to extremely low intensity RF-EMR of GSM 900 MHz during at least one hundred and fifty-eight hours leads to a significant overproduction of free radicals/reactive oxygen species and oxidative damage of DNA in embryo cells. These oxidative changes may lead to pathologies up to oncogenic transformation of cells.

(E) Buttiglione M, Roca L, Montemurno E, Vitiello F, Capozzi V, Cibelli G. Radiofrequency radiation (900 MHz) induces Egr-1 gene expression and affects cell-cycle control in human neuroblastoma cells. J Cell Physiol. 213(3):759-767, 2007. (GE)

Many environmental signals, including ionizing radiation and UV rays, induce activation of Egr-1 gene, thus affecting cell growth and apoptosis. The paucity and the controversial knowledge about the effect of electromagnetic fields (EMF) exposure of nerve cells prompted us to investigate the bioeffects of radiofrequency (RF) radiation on SH-SY5Y neuroblastoma cells. The effect of a modulated RF field of 900 MHz, generated by a wire patch cell (WPC) antenna

exposure system on Egr-1 gene expression, was studied as a function of time. Short-term exposures induced a transient increase in Egr-1 mRNA level paralleled with activation of the MAPK subtypes ERK1/2 and SAPK/JNK. The effects of RF radiations on cell growth rate and apoptosis were also studied. Exposure to RF radiation had an anti-proliferative activity in SH-SY5Y cells with a significant effect observed at 24 h. RF radiation impaired cell cycle progression, reaching a significant G2-M arrest. In addition, the appearance of the sub-G1 peak, a hallmark of apoptosis, was highlighted after a 24-h exposure, together with a significant decrease in mRNA levels of Bcl-2 and survivin genes, both interfering with signaling between G2-M arrest and apoptosis. Our results provide evidence that exposure to a 900 MHz-modulated RF radiation affect both Egr-1 gene expression and cell regulatory functions, involving apoptosis inhibitors like Bcl-2 and survivin, thus providing important insights into a potentially broad mechanism for controlling in vitro cell viability.

(E) Cam ST, Seyhan N. Single-strand DNA breaks in human hair root cells exposed to mobile phone radiation. Int J Radiat Biol 88(5):420-424, 2012 (GT, HU)

Purpose: To analyze the short term effects of radiofrequency radiation (RFR) exposure on genomic deoxyribonucleic acid (DNA) of human hair root cells. Subjects and methods: Hair samples were collected from 8 healthy human subjects immediately before and after using a 900-MHz GSM (Global System for Mobile Communications) mobile phone for 15 and 30 minutes. Single-strand DNA breaks of hair root cells from the samples were determined using the 'comet assay'. Results: The data showed that talking on a mobile phone for 15 or 30 minutes significantly increased ($p < .05$) single-strand DNA breaks in cells of hair roots close to the phone. Comparing the 15-min and 30-min data using the paired t-test also showed that significantly more damages resulted after 30 minutes than after 15 minutes of phone use. Conclusions: A short-term exposure (15 and 30 minutes) to RFR (900-MHz) from a mobile phone caused a significant increase in DNA single-strand breaks in human hair root cells located around the ear which is used for the phone calls.

(E) Campisi A, Gulino M, Acquaviva R, Bellia P, Raciti G, Grasso R, Musumeci F, Vanella A, Triglia A. Reactive oxygen species levels and DNA fragmentation on astrocytes in primary culture after acute exposure to low intensity microwave electromagnetic field. Neurosci Lett 473:52-55. 2010. (GT, OX, WS)

The exposure of primary rat neocortical astroglial cell cultures to acute electromagnetic fields (EMF) in the microwave range was studied. Differentiated astroglial cell cultures at 14 days in vitro were exposed for 5, 10, or 20 min to either 900 MHz continuous waves or 900 MHz waves modulated in amplitude at 50 Hz using a sinusoidal waveform and 100% modulation index. The strength of the electric field (rms value) at the sample position was 10V/m. No change in cellular viability evaluated by MTT test and lactate dehydrogenase release was observed. A significant increase in ROS levels and DNA fragmentation was found only after exposure of the astrocytes to modulated EMF for 20 min. No evident effects were detected when shorter time intervals or continuous waves were used. The irradiation conditions allowed the exclusion of any possible thermal effect. Our data demonstrate, for the first time, that even acute exposure to low intensity EMF induces ROS production and DNA fragmentation in astrocytes in primary cultures, which also represent the principal target of modulated EMF. Our findings also suggest the hypothesis that the effects could be due to hyperstimulation of the glutamate receptors, which play a crucial

role in acute and chronic brain damage. Furthermore, the results show the importance of the amplitude modulation in the interaction between EMF and neocortical astrocytes.

(E) 1 **Cervellati F, Valacchi G, Lunghi L, Fabbri E, Valbonesi P, Marci R, Biondi C, Vesce F. 17-β-estradiol counteracts the effects of high frequency electromagnetic fields on trophoblastic connexins and integrins. Oxid Med Cell Longev. 2013;2013:280850. doi: 10.1155/2013/280850.** (GE)

We investigated the effect of high-frequency electromagnetic fields (HF-EMFs) and 17-β-estradiol on connexins (Cxs), integrins (Ints), and estrogen receptor (ER) expression, as well as on ultrastructure of trophoblast-derived HTR-8/SVneo cells. HF-EMF, 17-β-estradiol, and their combination induced an increase of Cx40 and Cx43 mRNA expression. HF-EMF decreased Int alpha1 and β 1 mRNA levels but enhanced Int alpha5 mRNA expression. All the Ints mRNA expressions were increased by 17-β-estradiol and exposure to both stimuli. ER-β mRNA was reduced by HF-EMF but augmented by 17-β-estradiol alone or with HF-EMF. ER-β immunofluorescence showed a cytoplasmic localization in sham and HF-EMF exposed cells which became nuclear after treatment with hormone or both stimuli. Electron microscopy evidenced a loss of cellular contact in exposed cells which appeared counteracted by 17-β-estradiol. We demonstrate that 17-β-estradiol modulates Cxs and Ints as well as ER-β expression induced by HF-EMF, suggesting an influence of both stimuli on trophoblast differentiation and migration.

(NE) **Chang SK, Choi JS, Gil HW, Yang JO, Lee EY, Jeon YS, Lee ZW, Lee M, Hong MY, Ho Son T, Hong SY. Genotoxicity evaluation of electromagnetic fields generated by 835-MHz mobile phone frequency band. Eur J Cancer Prev 14:175-179, 2005.** (GT, IA) **(Some interaction effects with chemicals are reported in this paper.)**

It is still unclear whether the exposure to electromagnetic fields (EMFs) generated by mobile phone radiation is directly linked to cancer. We examined the biological effects of an EMF at 835 MHz, the most widely used communication frequency band in Korean CDMA mobile phone networks, on bacterial reverse mutation (Ames assay) and DNA stability (in vitro DNA degradation). In the Ames assay, tester strains alone or combined with positive mutagen were applied in an artificial mobile phone frequency EMF generator with continuous waveform at a specific absorption rate (SAR) of 4 W/kg for 48 h. In the presence of the 835-MHz EMF radiation, incubation with positive mutagen 4-nitroquinoline-1-oxide and cumene hydroxide further increased the mutation rate in Escherichia coli WP2 and TA102, respectively, while the contrary results in Salmonella typhimurium TA98 and TA1535 treated with 4-nitroquinoline-1-oxide and sodium azide, respectively, were shown as antimutagenic. However, these mutagenic or co-mutagenic effects of 835-MHz radiation were not significantly repeated in other relevant strains with same mutation type. In the DNA degradation test, the exposure to 835-MHz EMF did not change the rate of degradation observed using plasmid pBluescriptSK(+) as an indicator. Thus, we suggest that 835-MHz EMF under the conditions of our study neither affected the reverse mutation frequency nor accelerated DNA degradation in vitro.

(NE) **Chauhan V, Mariampillai A, Bellier PV, Qutob SS, Gajda GB, Lemay E, Thansandote A, McNamee JP. Gene expression analysis of a human lymphoblastoma cell**

line exposed in vitro to an intermittent 1.9 GHz pulse-modulated radiofrequency field. Radiat Res. 165(4):424-429, 2006. (GE)

This study was designed to determine whether radiofrequency (RF) fields of the type used for wireless communications could elicit a cellular stress response. As general indicators of a cellular stress response, we monitored changes in proto-oncogene and heat-shock protein expression. Exponentially growing human lymphoblastoma cells (TK6) were exposed to 1.9 GHz pulse-modulated RF fields at average specific absorption rates (SARs) of 1 and 10 W/kg. Perturbations in the expression levels of the proto-oncogenes FOS, JUN and MYC after exposure to sham and RF fields were assessed by real-time RT-PCR. In addition, the transcript levels of the cellular stress proteins HSP27 and inducible HSP70 were also monitored. We demonstrated that transcript levels of these genes in RF-field-exposed cells showed no significant difference in relation to the sham treatment group. However, concurrent positive (heat-shock) control samples displayed a significant elevation in the expression of HSP27, HSP70, FOS and JUN. Conversely, the levels of MYC mRNA were found to decline in the positive (heat-shock) control. In conclusion, our study found no evidence that the 1.9 GHz RF-field exposure caused a general stress response in TK6 cells under our experimental conditions.

(NE) Chauhan V, Mariampillai A, Gajda GB, Thansandote A, McNamee JP. Analysis of proto-oncogene and heat-shock protein gene expression in human derived cell-lines exposed in vitro to an intermittent 1.9 GHz pulse-modulated radiofrequency field. Int J Radiat Biol. 82(5):347-354, 2006. (GE)

Purpose: Several studies have reported that radiofrequency (RF) fields, as emitted by mobile phones, may cause changes in gene expression in cultured human cell-lines. The current study was undertaken to evaluate this possibility in two human-derived immune cell-lines.Materials and methods: HL-60 and Mono-Mac-6 (MM6) cells were individually exposed to intermittent (5 min on, 10 min off) 1.9 GHz pulse-modulated RF fields at a average specific absorption rate (SAR) of 1 and 10 W/kg at 37 +/- 0.5 degrees C for 6 h. Concurrent negative and positive (heat-shock for 1 h at 43 degrees C) controls were conducted with each experiment. Immediately following RF field exposure (T = 6 h) and 18 h post-exposure (T = 24 h), cell pellets were collected from each of the culture dishes and analyzed for transcript levels of proto-oncogenes (c-jun, c-myc and c-fos) and the stress-related genes (heat shock proteins (HSP) HSP27 and HSP70B) by quantitative reverse transcriptase polymerase chain reaction (RT-PCR).Results: No significant effects were observed in mRNA expression of HSP27, HSP70, c-jun, c-myc or c-fos between the sham and RF-exposed groups, in either of the two cell-lines. However, the positive (heat-shock) control group displayed a significant elevation in the expression of HSP27, HSP70, c-fos and c-jun in both cell-lines at T = 6 and 24 h, relative to the sham and negative control groups.Conclusion: This study found no evidence that exposure of cells to non-thermalizing levels of 1.9 GHz pulse-modulated RF fields can cause any detectable change in stress-related gene expression.

(NE) Chauhan V, Qutob SS, Lui S, Mariampillai A, Bellier PV, Yauk CL, Douglas GR, Williams A, McNamee JP. Analysis of gene expression in two human-derived cell lines exposed in vitro to a 1.9 GHz pulse-modulated radiofrequency field. Proteomics. 7(21):3896-3905, 2007. (GE)

There is considerable controversy surrounding the biological effects of radiofrequency (RF) fields, as emitted by mobile phones. Previous work from our laboratory has shown no effect related to the exposure of 1.9 GHz pulse-modulated RF fields on the expression of 22,000 genes in a human glioblastoma-derived cell-line (U87MG) at 6 h following a 4 h RF field exposure period. As a follow-up to this study, we have now examined the effect of RF field exposure on the possible expression of late onset genes in U87MG cells after a 24 h RF exposure period. In addition, a human monocyte-derived cell-line (Mono-Mac-6, MM6) was exposed to intermittent (5 min ON, 10 min OFF) RF fields for 6 h and then gene expression was assessed immediately after exposure and at 18 h postexposure. Both cell lines were exposed to 1.9 GHz pulse-modulated RF fields for 6 or 24 h at specific absorption rates (SARs) of 0.1-10.0 W/kg. In support of our previous results, we found no evidence that nonthermal RF field exposure could alter gene expression in either cultured U87MG or MM6 cells, relative to nonirradiated control groups. However, exposure of both cell-lines to heat-shock conditions (43 degrees C for 1 h) caused an alteration in the expression of a number of well-characterized heat-shock proteins.

(E) **Chavdoula ED, Panagopoulos DJ, Margaritis LH. Comparison of biological effects between continuous and intermittent exposure to GSM-900-MHz mobile phone radiation: detection of apoptotic cell-death features. Mutat Res 700:51-61, 2010.** (RP, LE, GT)

In the present study we used a 6-min daily exposure of dipteran flies, Drosophila melanogaster, to GSM-900 MHz (Global System for Mobile Telecommunications) mobile phone electromagnetic radiation (EMR), to compare the effects between the continuous and four different intermittent exposures of 6min total duration, and also to test whether intermittent exposure provides any cumulative effects on the insect's reproductive capacity as well as on the induction of apoptotic cell death. According to our previous experiments, a 6-min continuous exposure per day for five days to GSM-900 MHz and DCS-1800 MHz (Digital Cellular System) mobile phone radiation, brought about a large decrease in the insect's reproductive capacity, as defined by the number of F pupae. This decrease was found to be non thermal and correlated with an increased percentage of induced fragmented DNA in the egg chambers' cells at early- and mid-oogenesis. In the present experiments we show that intermittent exposure also decreases the reproductive capacity and alters the actin cytoskeleton network of the egg chambers, another known aspect of cell death that was not investigated in previous experiments, and that the effect is also due to DNA fragmentation. Intermittent exposures with 10-min intervals between exposure sessions proved to be almost equally effective as continuous exposure of the same total duration, whereas longer intervals between the exposures seemed to allow the organism the time required to recover and partly overcome the above-mentioned effects of the GSM exposure.

(E) **Chen G, Lu D, Chiang H, Leszczynski D, Xu Z. Using model organism Saccharomyces cerevisiae to evaluate the effects of ELF-MF and RF-EMF exposure on global gene expression. Bioelectromagnetics. 33(7):550-560, 2012 .** (GE)

The potential health hazard of exposure to electromagnetic fields (EMF) continues to cause public concern. However, the possibility of biological and health effects of exposure to EMF remains controversial and their biophysical mechanisms are unknown. In the present study, we used Saccharomyces cerevisiae to identify genes responding to extremely low frequency magnetic fields (ELF-MF) and to radiofrequency EMF (RF-EMF) exposures. The yeast cells were exposed for 6 h to either 0.4 mT 50 Hz ELF-MF or 1800 MHz RF-EMF at a specific

absorption rate of 4.7 W/kg. Gene expression was analyzed by microarray screening and confirmed using real-time reverse transcription-polymerase chain reaction (RT-PCR). We were unable to confirm microarray-detected changes in three of the ELF-MF responsive candidate genes using RT-PCR ($P > 0.05$). On the other hand, out of the 40 potential RF-EMF responsive genes, only the expressions of structural maintenance of chromosomes 3 (SMC3) and aquaporin 2 (AQY2 (m)) were confirmed, while three other genes, that is, halotolerance protein 9 (HAL9), yet another kinase 1 (YAK1) and one function-unknown gene (open reading frame: YJL171C), showed opposite changes in expression compared to the microarray data ($P < 0.05$). In conclusion, the results of this study suggest that the yeast cells did not alter gene expression in response to 50 Hz ELF-MF and that the response to RF-EMF is limited to only a very small number of genes. The possible biological consequences of the gene expression changes induced by RF-EMF await further investigation. 1

(E) De Iuliis GN, Newey RJ, King BV, Aitken RJ. Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro. PLoS One 4:e6446, 2009. (GT, OX, RP)

BACKGROUND: In recent times there has been some controversy over the impact of electromagnetic radiation on human health. The significance of mobile phone radiation on male reproduction is a key element of this debate since several studies have suggested a relationship between mobile phone use and semen quality. The potential mechanisms involved have not been established, however, human spermatozoa are known to be particularly vulnerable to oxidative stress by virtue of the abundant availability of substrates for free radical attack and the lack of cytoplasmic space to accommodate antioxidant enzymes. Moreover, the induction of oxidative stress in these cells not only perturbs their capacity for fertilization but also contributes to sperm DNA damage. The latter has, in turn, been linked with poor fertility, an increased incidence of miscarriage and morbidity in the offspring, including childhood cancer. In light of these associations, we have analyzed the influence of RF-EMR on the cell biology of human spermatozoa in vitro. PRINCIPAL FINDINGS: Purified human spermatozoa were exposed to radio-frequency electromagnetic radiation (RF-EMR) tuned to 1.8 GHz and covering a range of specific absorption rates (SAR) from 0.4 W/kg to 27.5 W/kg. In step with increasing SAR, motility and vitality were significantly reduced after RF-EMR exposure, while the mitochondrial generation of reactive oxygen species and DNA fragmentation were significantly elevated ($P<0.001$). Furthermore, we also observed highly significant relationships between SAR, the oxidative DNA damage bio-marker, 8-OH-dG, and DNA fragmentation after RF-EMR exposure. CONCLUSIONS: RF-EMR in both the power density and frequency range of mobile phones enhances mitochondrial reactive oxygen species generation by human spermatozoa, decreasing the motility and vitality of these cells while stimulating DNA base adduct formation and, ultimately DNA fragmentation. These findings have clear implications for the safety of extensive mobile phone use by males of reproductive age, potentially affecting both their fertility and the health and wellbeing of their offspring.

(E) **Del Vecchio G, Giuliani A, Fernandez M, Mesirca P, Bersani F, Pinto R, Ardoino L, Lovisolo GA, Giardino L, Calzà L. Continuous exposure to 900MHz GSM-modulated EMF alters morphological maturation of neural cells. Neurosci Lett. 455(3):173-177, 2009.** (GE, DE)

The effects of radiofrequency electromagnetic field (RF-EMF) exposure on neuronal phenotype maturation have been studied in two different in vitro models: murine SN56 cholinergic cell line and rat primary cortical neurons. The samples were exposed at a dose of 1W/kg at 900 MHz GSM modulated. The phenotype analysis was carried out at 48 and 72 h (24 and 48 h of SN56 cell line differentiation) or at 24, 72, 120 h (2, 4 and 6 days in vitro for cortical neurons) of exposure, on live and immunolabeled neurons, and included the morphological study of neurite emission, outgrowth and branching. Moreover, cortical neurons were studied to detect alterations in the expression pattern of cytoskeleton regulating factors, e.g. beta-thymosin, and of early genes, e.g. c-Fos and c-Jun through real-time PCR on mRNA extracted after 24h exposure to EMF. We found that RF-EMF exposure reduced the number of neurites generated by both cell systems, and this alteration correlates to increased expression of beta-thymosin mRNA.

(E) Deshmukh PS, Megha K, Banerjee BD, Ahmed RS, Chandna S, Abegaonkar MP, Tripathi AK. Detection of Low Level Microwave Radiation Induced Deoxyribonucleic Acid Damage Vis-à-vis Genotoxicity in Brain of Fischer Rats. Toxicol Int. 20(1):19-24, 2013. (GT, LE)

BACKGROUND: Non-ionizing radiofrequency radiation has been increasingly used in industry, commerce, medicine and especially in mobile phone technology and has become a matter of serious concern in present time. OBJECTIVE: The present study was designed to investigate the possible deoxyribonucleic acid (DNA) damaging effects of low-level microwave radiation in brain of Fischer rats. MATERIALS AND METHODS: Experiments were performed on male Fischer rats exposed to microwave radiation for 30 days at three different frequencies: 900, 1800 and 2450 MHz. Animals were divided into 4 groups: Group I (Sham exposed): Animals not exposed to microwave radiation but kept under same conditions as that of other groups, Group II: Animals exposed to microwave radiation at frequency 900 MHz at specific absorption rate (SAR) 5.953 × 10(-4) W/kg, Group III: Animals exposed to 1800 MHz at SAR 5.835 × 10(-4) W/kg and Group IV: Animals exposed to 2450 MHz at SAR 6.672 × 10(-4) W/kg. At the end of the exposure period animals were sacrificed immediately and DNA damage in brain tissue was assessed using alkaline comet assay. RESULTS: In the present study, we demonstrated DNA damaging effects of low level microwave radiation in brain. CONCLUSION: We concluded that low SAR microwave radiation exposure at these frequencies may induce DNA strand breaks in brain tissue.

(E) Engelmann JC, Deeken R, Müller T, Nimtz G, Roelfsema MR, Hedrich R. Is gene activity in plant cells affected by UMTS-irradiation? A whole genome approach. Adv Appl Bioinform Chem. 1:71-83, 2008. (GE)

Mobile phone technology makes use of radio frequency (RF) electromagnetic fields transmitted through a dense network of base stations in Europe. Possible harmful effects of RF fields on humans and animals are discussed, but their effect on plants has received little attention. In search for physiological processes of plant cells sensitive to RF fields, cell suspension cultures of Arabidopsis thaliana were exposed for 24 h to a RF field protocol representing typical microwave exposition in an urban environment. mRNA of exposed cultures and controls was used to hybridize Affymetrix-ATH1 whole genome microarrays. Differential expression analysis revealed significant changes in transcription of 10 genes, but they did not exceed a fold change

of 2.5. Besides that 3 of them are dark-inducible, their functions do not point to any known responses of plants to environmental stimuli. The changes in transcription of these genes were compared with published microarray datasets and revealed a weak similarity of the microwave to light treatment experiments. Considering the large changes described in published experiments, it is questionable if the small alterations caused by a 24 h continuous microwave exposure would have any impact on the growth and reproduction of whole plants.

(E) Esmekaya MA, Aytekin E, Ozgur E, Güler G, Ergun MA, Omeroğlu S, Seyhan N. Mutagenic and morphologic impacts of 1.8GHz radiofrequency radiation on human peripheral blood lymphocytes (hPBLs) and possible protective role of pre-treatment with Ginkgo biloba (EGb 761). Sci Total Environ. 410-411:59-64, 2011. (GT, OX)

The mutagenic and morphologic effects of 1.8GHz Global System for Mobile Communications (GSM) modulated RF (radiofrequency) radiation alone and in combination with Ginkgo biloba (EGb 761) pre-treatment in human peripheral blood lymphocytes (hPBLs) were investigated in this study using Sister Chromatid Exchange (SCE) and electron microscopy. Cell viability was assessed with 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide (MTT) reduction assay. The lymphocyte cultures were exposed to GSM modulated RF radiation at 1.8GHz for 6, 8, 24 and 48h with and without EGb 761. We observed morphological changes in pulse-modulated RF radiated lymphocytes. Longer exposure periods led to destruction of organelle and nucleus structures. Chromatin change and the loss of mitochondrial crista occurred in cells exposed to RF for 8h and 24h and were more pronounced in cells exposed for 48h. Cytoplasmic lysis and destruction of membrane integrity of cells and nuclei were also seen in 48h RF exposed cells. There was a significant increase ($p<0.05$) in SCE frequency in RF exposed lymphocytes compared to sham controls. EGb 761 pre-treatment significantly decreased SCE from RF radiation. RF radiation also inhibited cell viability in a time dependent manner. The inhibitory effects of RF radiation on the growth of lymphoctes were marked in longer exposure periods. EGb 761 pre-treatment significantly increased cell viability in RF+EGb 761 treated groups at 8 and 24h when compared to RF exposed groups alone. The results of our study showed that RF radiation affects cell morphology, increases SCE and inhibits cell proliferation. However, EGb 761 has a protective role against RF induced mutagenity. We concluded that RF radiation induces chromosomal damage in hPBLs but this damage may be reduced by EGb 761 pre-treatment.

(NE) Falzone N, Huyser C, Franken DR, Leszczynski D. Mobile phone radiation does not induce pro-apoptosis effects in human spermatozoa. Radiat Res 174:169-176, 2010. (GT, OX)

Abstract Recent reports suggest that mobile phone radiation may diminish male fertility. However, the effects of this radiation on human spermatozoa are largely unknown. The present study examined effects of the radiation on induction of apoptosis-related properties in human spermatozoa. Ejaculated, density-purified, highly motile human spermatozoa were exposed to mobile phone radiation at specific absorption rates (SARs) of 2.0 and 5.7 W/kg. At various times after exposure, flow cytometry was used to examine caspase 3 activity, externalization of phosphatidylserine (PS), induction of DNA strand breaks, and generation of reactive oxygen species. Mobile phone radiation had no statistically significant effect on any of the parameters

studied. This suggests that the impairment of fertility reported in some studies was not caused by the induction of apoptosis in spermatozoa.

(E) Ferreira AR, Knakievicz T, de Bittencourt Pasquali MA, Gelain DP, Dal-Pizzol F, Fernandez CE, de Almeida de Salles AA, Ferreira HB, Moreira JC. Ultra high frequency-electromagnetic field irradiation during pregnancy leads to an increase in erythrocytes micronuclei incidence in rat offspring. Life Sci 80: 43-50, 2006. (GT, OX, LE, DE)

Mobile telephones and their base stations are an important ultra high frequency-electromagnetic field (UHF-EMF) source and their utilization is increasing all over the world. Epidemiological studies suggested that low energy UHF-EMF emitted from a cellular telephone may cause biological effects, such as DNA damage and changes on oxidative metabolism. An in vivo mammalian cytogenetic test, the micronucleus (MN) assay, was used to investigate the occurrence of chromosomal damage in erythrocytes from rat offspring exposed to a non-thermal UHF-EMF from a cellular phone during their embryogenesis; the irradiated group showed a significant increase in MN occurrence. In order to investigate if UHF-EMF could also alter oxidative parameters in the peripheral blood and in the liver - an important hematopoietic tissue in rat embryos and newborns - we also measured the activity of antioxidant enzymes, quantified total sulfhydryl content, protein carbonyl groups, thiobarbituric acid-reactive species and total non-enzymatic antioxidant defense. No significant differences were found in any oxidative parameter of offspring blood and liver. The average number of pups in each litter has also not been significantly altered. Our results suggest that, under our experimental conditions, UHF-EMF is able to induce a genotoxic response in hematopoietic tissue during the embryogenesis through an unknown mechanism.

(NE) Finnie JW, Cai Z, Blumbergs PC, Manavis J, Kuchel TR. Expression of the immediate early gene, c-fos, in fetal brain after whole of gestation exposure of pregnant mice to global system for mobile communication microwaves. Pathology. 38(4):333-335, 2006. (GE, DE)

AIMS: To study immediate early gene, c-fos, expression as a marker of neural stress after whole of gestation exposure of the fetal mouse brain to mobile telephone-type radiofrequency fields. METHODS: Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Pregnant control mice were sham-exposed or freely mobile in a cage without further restraint. Immediately prior to parturition on gestational day 19, fetal heads were collected, fixed in 4% paraformaldehyde and paraffin embedded. Any stress response in the brain was detected by c-fos immunohistochemistry in the cerebral cortex, basal ganglia, thalamus, hippocampus, midbrain, cerebellum and medulla. RESULTS: c-fos expression was of limited, but consistent, neuroanatomical distribution and there was no difference in immunoreactivity between exposed and control brains. CONCLUSION: In this animal model, no stress response was detected in the fetal brain using c-fos immunohistochemistry after whole of gestation exposure to mobile telephony.

(E) Franzellitti S, Valbonesi P, Ciancaglini N, Biondi C, Contin A, Bersani F, Fabbri E. Transient DNA damage induced by high-frequency electromagnetic fields (GSM 1.8 GHz)

in the human trophoblast HTR-8/SVneo cell line evaluated with the alkaline comet assay. Mutat Res 683(1-2):35-42, 2010. (GT, WS)

One of the most controversial issue regarding high-frequency electromagnetic fields (HF-EMF) is their putative capacity to affect DNA integrity. This is of particular concern due to the increasing use of HF-EMF in communication technologies, including mobile phones. Although epidemiological studies report no detrimental effects on human health, the possible disturbance generated by HF-EMF on cell physiology remains controversial. In addition, the question remains as to whether cells are able to compensate their potential effects. We have previously reported that a 1-h exposure to amplitude-modulated 1.8 GHz sinusoidal waves (GSM-217 Hz, SAR=2 W/kg) largely used in mobile telephony did not cause increased levels of primary DNA damage in human trophoblast HTR-8/SVneo cells. Nevertheless, further investigations on trophoblast cell responses after exposure to GSM signals of different types and durations were considered of interest. In the present work, HTR-8/SVneo cells were exposed for 4, 16 or 24h to 1.8 GHz continuous wave (CW) and different GSM signals, namely GSM-217 Hz and GSM-Talk (intermittent exposure: 5 min field on, 10 min field off). The alkaline comet assay was used to evaluate primary DNA damages and/or strand breaks due to uncompleted repair processes in HF-EMF exposed samples. The amplitude-modulated signals GSM-217 Hz and GSM-Talk induced a significant increase in comet parameters in trophoblast cells after 16 and 24h of exposure, while the un-modulated CW was ineffective. However, alterations were rapidly recovered and the DNA integrity of HF-EMF exposed cells was similar to that of sham-exposed cells within 2h of recovery in the absence irradiation. Our data suggest that HF-EMF with a carrier frequency and modulation scheme typical of the GSM signal may affect the DNA integrity.

(E) Furtado-Filho OV, Borba JB, Dallegrave A, Pizzolato TM, Henriques JA, Moreira JC, Saffi J. Effect of 950 MHz UHF electromagnetic radiation on biomarkers of oxidative damage, metabolism of UFA and antioxidants in the livers of young rats of different ages. Int J Radiat Biol. 2013 Jul 25. [Epub ahead of print] (LE, GT, OX)

Purpose: To assess the effect of 950 MHz ultra-high-frequency electromagnetic radiation (UHF EMR) on biomarkers of oxidative damage, as well as to verify the concentration of unsaturated fatty acids (UFA) and the expression of the catalase in the livers of rats of different ages. Materials and methods: Twelve rats were equally divided into two groups as controls (CR) and exposed (ER), for each age (0, 6, 15 and 30 days). Radiation exposure lasted half an hour per day for up to 51 days (21 days of gestation and 6, 15 or 30 days of life outside the womb). The specific absorption rate (SAR) ranged from 1.3-1.0 W/kg. The damage to lipids, proteins and DNA was verified by thiobarbituric acid reactive substances (TBARS), protein carbonyls and comets, respectively. UFA were determined by gas chromatography with a flame ionization detector. The expression of catalase was by Western blotting. Results: The neonates had low levels of TBARS and concentrations of UFA after exposure. There was no age difference in the accumulation of protein carbonyls for any age. The DNA damage of ER 15 or 30 days was different. The exposed neonates exhibited lower expression of catalase. Conclusions: 950 MHz UHF EMR does not cause oxidative stress (OS), and it is not genotoxic to the livers of neonates or those of 6 and 15 day old rats, but it changes the concentrations of polyunsaturated fatty acid (PUFA) in neonates. For rats of 30 days, no OS, but it is genotoxic to the livers of ER to total body irradiation.

(E) Gajski G, Garaj-Vrhovac V. Radioprotective effects of honeybee venom (Apismellifera) against 915-MHz microwave radiation-induced DNA damage in wistar rat lymphocytes: in vitro study. Int J Toxicol 28:88-98, 2009. (GT, OX)

The aim of this study is to investigate the radioprotective effect of bee venom against DNA damage induced by 915-MHz microwave radiation (specific absorption rate of 0.6 W/kg) in Wistar rats. Whole blood lymphocytes of Wistar rats are treated with 1 microg/mL bee venom 4 hours prior to and immediately before irradiation. Standard and formamidopyrimidine-DNA glycosylase (Fpg)-modified comet assays are used to assess basal and oxidative DNA damage produced by reactive oxygen species. Bee venom shows a decrease in DNA damage compared with irradiated samples. Parameters of Fpg-modified comet assay are statistically different from controls, making this assay more sensitive and suggesting that oxidative stress is a possible mechanism of DNA damage induction. Bee venom is demonstrated to have a radioprotective effect against basal and oxidative DNA damage. Furthermore, bee venom is not genotoxic and does not produce oxidative damage in the low concentrations used in this study.

(E) Gandhi G, Anita, Genetic damage in mobile phone users: some preliminary findings. Ind J Hum Genet 11:99-104, 2005. (GT, HU)

BACKGROUND: The impact of microwave (MW)/radio frequency radiation (RFR) on important biological parameters is probably more than a simply thermal one. Exposure to radio frequency (RF) signals generated by the use of cellular telephones have increased dramatically and reported to affect physiological, neurological, cognitive and behavioural changes and to induce, initiate and promote carcinogenesis. Genotoxicity of RFR has also been reported in various test systems after in vitro and/or in vivo exposure but none in mobile phone users. AIMS: In the present study, DNA and chromosomal damage investigations were carried out on the peripheral blood lymphocytes of individuals using mobile phones, being exposed to MW frequency ranging from 800 to 2000 MHz. METHODS: DNA damage was assessed using the single cell gel electrophoresis assay and aneugenic and clastogenic damage by the in vivo capillary blood micronucleus test (MNT) in a total of 24 mobile phone users. RESULTS: Mean comet tail length (26.76 ± 0.054 mm; 39.75% of cells damaged) in mobile phone users was highly significant from that in the control group. The in vivo capillary blood MNT also revealed highly significant (0.25) frequency of micronucleated (MNd) cells. CONCLUSIONS: These results highlight a correlation between mobile phone use (exposure to RFR) and genetic damage and require interim public health actions in the wake of widespread use of mobile telephony.

(E) Gandhi G, Singh P. Cytogenetic damage in mobile phone users: preliminary data. Int J Hum Genet 5:259-265, 2005. (GT, HU)

Mobile telephones, sometimes called cellular (cell) phones or handies, are now an integral part of modern life. The mobile phone handsets are low-powered radiofrequency transmitters, emitting maximum powers in the range of 0.2 to 0.6 watts. Scientific concenrns have increased sufficiently over the possible hazard to health from using cell phones. The reported adverse health effects include physiological, behavioural and cognitive changes as well as tumour formation and genetic damage. However findings are controversial and no consensus exists. Genotoxicity has been observed either in lower organisms or in vitro studies. The aim of the present study hence was to detect any cytogenertic damage in mobile phone users by analysing short term peripheral lymphocyte cultures for chromosomal aberrations and the buccal mucosal

cells for micronuclei (aneugenicity and clastogenicity). The results revealed increased number of micronucleated buccal cells and cytological abnormalities in cultured lymphocytes indicating the genotoxic response from mobile phone use.

(E) Garaj-Vrhovac V, Gajski G, Pažanin S, Sarolić A, Domijan AM, Flajs D, Peraica M. Assessment of cytogenetic damage and oxidative stress in personnel occupationally exposed to the pulsed microwave radiation of marine radar equipment. Int J Hyg Environ Health. 4(1):59-65, 2011. (GT, HU, OX)

Due to increased usage of microwave radiation, there are concerns of its adverse effect in today's society. Keeping this in view, study was aimed at workers occupationally exposed to pulsed microwave radiation, originating from marine radars. Electromagnetic field strength was measured at assigned marine radar frequencies (3 GHz, 5.5 GHz and 9.4 GHz) and corresponding specific absorption rate values were determined. Parameters of the comet assay and micronucleus test were studied both in the exposed workers and in corresponding unexposed subjects. Differences between mean tail intensity (0.67 vs. 1.22) and moment (0.08 vs. 0.16) as comet assay parameters and micronucleus test parameters (micronuclei, nucleoplasmic bridges and nuclear buds) were statistically significant between the two examined groups, suggesting that cytogenetic alterations occurred after microwave exposure. Concentrations of glutathione and malondialdehyde were measured spectrophotometrically and using high performance liquid chromatography. The glutathione concentration in exposed group was significantly lower than in controls (1.24 vs. 0.53) whereas the concentration of malondialdehyde was significantly higher (1.74 vs. 3.17), indicating oxidative stress. Results suggests that pulsed microwaves from working environment can be the cause of genetic and cell alterations and that oxidative stress can be one of the possible mechanisms of DNA and cell damage.

(E) Guler G, Tomruk A, Ozgur E, Seyhan N.The effect of radiofrequency radiation on DNA and lipid damage in non-pregnant and pregnant rabbits and their newborns. Gen Physiol Biophys 29:59-66, 2010. (GT, OX, LE, DE)

The concerns of people on possible adverse health effects of radiofrequency radiation (RFR) generated from mobile phones as well as their supporting transmitters (base stations) have increased markedly. RFR effect on oversensitive people, such as pregnant women and their developing fetuses, and older people is another source of concern that should be considered. In this study, oxidative DNA damage and lipid peroxidation levels in the brain tissue of pregnant and non-pregnant New Zealand White rabbits and their newborns exposed to RFR were investigated. Thirteen-month-old rabbits were studied in four groups as non-pregnant-control, non-pregnant-RFR exposed, pregnant-control and pregnant-RFR exposed. They were exposed to RFR (1800 MHz GSM; 14 V/m as reference level) for 15 min/day during 7 days. Malondialdehyde (MDA) and 8-hydroxy-2'-deoxyguanosine (8-OHdG) levels were analyzed. MDA and 8-OHdG levels of non-pregnant and pregnant-RFR exposed animals significantly increased with respect to controls ($p < 0.001$, Mann-Whitney test). No difference was found in the newborns ($p > 0.05$, Mann-Whitney). There exist very few experimental studies on the effects of RFR during pregnancy. It would be beneficial to increase the number of these studies in order to establish international standards for the protection of pregnant women from RFR.

(E) Güler G, Tomruk A, Ozgur E, Sahin D, Sepici A, Altan N, Seyhan N. The effect of radiofrequency radiation on DNA and lipid damage in female and male infant rabbits. Int J Radiat Biol. 88(4):367-373, 2012. (LE, GT, OX, DE)

PURPOSE: We aimed to design a prolonged radiofrequency (RF) radiation exposure and investigate in an animal model, possible bio-effects of RF radiation on the ongoing developmental stages of children from conception to childhood. **MATERIALS AND METHODS:** A total of 72 New Zealand female and male white rabbits aged one month were used. Females were exposed to RF radiation for 15 min/day during 7 days, whereas males were exposed to the same level of radiation for 15 min/day during 14 days. Thirty-six female and 36 male infant rabbits were randomly divided into four groups: Group I [Intrauterine (IU) exposure (-); Extrauterine (EU) exposure (-)]: Sham exposure which means rabbits were exposed to 1800 MHz Global System for Mobile Telecommunication (GSM)-like RF signals neither in the IU nor in the EU periods. Group II [IU exposure (-); EU exposure (+)]: Infant rabbits were exposed to 1800 MHz GSM-like RF signals when they reached one month of age. Group III [IU exposure (+); EU exposure (-)]: Infant rabbits were exposed to 1800 MHz GSM-like RF signals in the IU period (between 15th and 22nd days of the gestational period). Group IV [IU exposure (+); EU exposure (+)]: Infant rabbits were exposed to 1800 MHz GSM-like RF signals both in the IU period (between 15th and 22nd days of the gestational period) and in the EU period when they reached one month of age. Biochemical analysis for lipid peroxidation and DNA damage were carried out in the livers of all rabbits. **RESULTS:** Lipid peroxidation levels in the liver tissues of female and male infant rabbits increased under RF radiation exposure. Liver 8-hydroxy-2'-deoxyguanosine (8-OHdG) levels of female rabbits exposed to RF radiation were also found to increase when compared with the levels of non-exposed infants. However, there were no changes in liver 8-OHdG levels of male rabbits under RF exposure. **CONCLUSION:** Consequently, it can be concluded that GSM-like RF radiation may induce biochemical changes by increasing free radical attacks to structural biomolecules in the rabbit as an experimental animal model.

(NE) Gurbuz N, Sirav B, Yuvaci HU, Turhan N, Coskun ZK, Seyhan N. Is there any possible genotoxic effect in exfoliated bladder cells of rat under the exposure of 1800 MHz GSM-like modulated radio frequency radiation (RFR)? Electromagn Biol Med. 29(3):98-104, 2010. (LE, GT)

People are exposed to many carcinogenic and mutagenic chemicals in their everyday lives. These include antineoplastic drugs, Polycyclic aromatic hydrocarbons (PAH)s, aromatic amines, nitrosamines, metals, and electromagnetic radiation. Based on the state of knowledge acquired during the last 50 years of research on possible biological effects of electromagnetic fields (EMF), the majority of the scientific community is convinced that exposure to EMF below the existing security limits does not cause a risk to the health of the general public. However, this position is questioned by others, who are of the opinion that the available research data are contradictory or inconsistent and, therefore, unreliable. In this study, we aimed to investigate if there is any effect of 1800 MHz GSM modulated radio frequency radiation (RFR) on the number of micronucleus in exfoliated bladder cells of rat which will be informative about the genotoxic damage. Exposure period was 20 min/day, 5 days/week during a month. Six female Wistar rats were used for two groups: Group I (n=6): controls; Group II (n=6): 1.8 GHz exposed animals.

1800 MHz RFR did not showed a significant MN frequencies in rat bladder cells when compared with the control group (p>0.05). 1800 MHz RFR-exposed animals did not produce any genotoxic effect when compared with the control group (p>0.05). Kinetic studies are important for any biomarker, especially those in which tissue differentiation and maturation processes will heavily influence the time between induction of damage and collection of damaged cells for micronucleus analysis.

(NE) **Gurbuz N, Sirav B, Colbay M, Yetkin I, Seyhan N. No genotoxic effect in exfoliated bladder cells of rat under the exposure of 1800 and 2100-MHz radio frequency radiation. Electromagn Biol Med. 2013 Nov 27. [Epub ahead of print]** (GT, LE)

Abstract In this study, we aimed to investigate the effects of 1800 and 2100 MHz Radio Frequency (RF) radiation on the number of micronucleus (MN) in exfoliated bladder cells of rat which shows the genotoxic damage. Exposure period was 30 min/day, 6 days/week for a month and two months exposure periods. Thirty male wistar albino rats were used for five groups: Group I (n = 6): 1800 MHz RF exposed animals for one month, Group II (n = 6): 2100 MHz RF exposed animals for one month, Group III (n = 6): 2100 MHz RF exposed for two months, Group IV (n = 6): control group for one month, Group V (n = 6): control group for two months. Rats of the control groups were housed in their home cages during the entire experimental period without subjecting to any experimental manipulation. 1800 and 2100 MHz RF exposures did not result in any significant MN frequencies in rat bladder cells with respect to the control groups (p > 0.05). There was no statistically significant difference between 2100 MHz RF exposed groups, either. Further studies are needed to demonstrate if there is any genotoxic effect, micronucleus formation in other tissues of rats.

(NE) **Hansteen IL, Lågeide L, Clausen KO, Haugan V, Svendsen M, Eriksen JG, Skiaker R, Hauger E, Vistnes AI, Kure EH. Cytogenetic effects of 18.0 and 16.5 GHz microwave radiation on human lymphocytes in vitro. Anticancer Res 29:2885-2892, 2009.** (GT, IA, WS)

BACKGROUND: There are few cell studies on the direct genotoxic effects of microwave radiation. In this study, cytogenetic effects of microwave radiation alone or in combination with mitomycin C (MMC) were investigated. MATERIALS AND METHODS: Lymphocytes from two smoking and four non-smoking donors were exposed for 53 hours in vitro to 1.0 W/m continuous-wave radiation at 18.0 GHz or 10 W/m pulsed-wave at 16.5 GHz, alone or in combination with MMC. DNA synthesis and repair were inhibited in vitro in some cultures. RESULTS: No synergistic effect was observed in cells exposed to combinations of microwave radiation and in vitro exposure to MMC, or to cells pre-exposed in vivo to tobacco smoke. For the 16.5 GHz pulsed exposure, a non-significant trend consisting of an increase in aberration frequencies with microwave radiation was shown for the DNA synthesis and repair inhibited cultures both with and without MMC. CONCLUSION: Neither 18.0 GHz continuous-wave nor 16.5 GHz pulsed-wave exposure to human lymphocytes in vitro induced statistically significant increases in chromosomal aberration frequencies. 16.5 GHz pulsed-wave exposure requires further documentation before a true negative conclusion can be drawn.

(NE) **Hansteen IL, Clausen KO, Haugan V, Svendsen M, Svendsen MV, Eriksen JG, Skiaker R, Hauger E, Lågeide L, Vistnes AI, Kure EH. Cytogenetic effects of exposure to**

2.3 GHz radiofrequency radiation on human lymphocytes in vitro. Anticancer Res 29:4323-4330, 2009. (GT, IA)

BACKGROUND: No previous in vitro studies have tested radio frequency radiation for at least one full cell cycle in culture. The aim was to test if exposure used in mobile phones and wireless network technologies would induce DNA damage in cultured human lymphocytes with and without a known clastogen. MATERIALS AND METHODS: Lymphocytes from six donors were exposed to 2.3 GHz, 10 W/m continuous waves, or 2.3 GHz, 10 W/m pulsed waves (200 Hz pulse frequency, 50% duty cycle). Mitomycin C was added to half of the cultures. DNA synthesis and repair were inhibited in one experiment. RESULTS: No statistically significant differences were observed between control and exposed cultures. A weak trend for more chromosomal damage with the interaction of pulsed fields with mitomycin C compared to a constant field was observed. CONCLUSION: Exposure during the whole cell cycle in inhibited cultures did not resulted in significant differences in chromosomal aberrations as compared to controls.

(E) Hekmat A, Saboury AA, Moosavi-Movahedi AA. The toxic effects of mobile phone radiofrequency (940MHz) on the structure of calf thymus DNA. Ecotoxicol Environ Saf. 2012 Nov 16. pii: S0147-6513(12)00368-5. doi: 10.1016/j.ecoenv.2012.10.016. [Epub ahead of print] (GT)

Currently, the biological effects of nonionizing electromagnetic fields (EMFs) including radiofrequency (RF) radiation have been the subject of numerous experimental and theoretical studies. The aim of this study is to evaluate the possible biological effects of mobile phone RF (940MHz, 15V/m and SAR=40mW/kg) on the structure of calf thymus DNA (ct DNA) immediately after exposure and 2h after 45min exposure via diverse range of spectroscopic instruments. The UV-vis and circular dichroism (CD) experiments depict that mobile phone EMFs can remarkably cause disturbance on ct DNA structure. In addition, the DNA samples, immediately after exposure and 2h after 45min exposure, are relatively thermally unstable compared to the DNA solution, which was placed in a small shielded box (unexposed ct DNA). Furthermore, the exposed DNA samples (the DNA samples that were exposed to 940MHz EMF) have more fluorescence emission when compared with the unexposed DNA, which may have occurred attributable to expansion of the exposed DNA structure. The results of dynamic light scattering (DLS) and zeta potential experiments demonstrate that RF-EMFs lead to increment in the surface charge and size of DNA. The structure of DNA immediately after exposure is not significantly different from the DNA sample 2h after 45min exposure. In other words, the EMF-induced conformational changes are irreversible. Collectively, our results reveal that 940MHz can alter the structure of DNA. The displacement of electrons in DNA by EMFs may lead to conformational changes of DNA and DNA disaggregation. Results from this study could have an important implication on the health effects of RF-EMFs exposure. In addition, this finding could proffer a novel strategy for the development of next generation of mobile phone.

(NE) Hintzsche H, Stopper H. Micronucleus frequency in buccal mucosa cells of mobile phone users. Toxicol Lett. 193(1):124-130, 2010. (GT, HU)

Mobile phones are being used extensively throughout the world, with more than four billion accounts existing in 2009. This technology applies electromagnetic radiation in the microwave

range. Health effects of this radiation have been subject of debate for a long time, both within the scientific community and within the general public. This study investigated the effect of mobile phone use on genomic instability of the human oral cavity's mucosa cells. 131 Individuals donated buccal mucosa cells extracted by slightly scraping the oral cavity with a cotton swab. Every participant filled out a questionnaire about mobile phone use including duration of weekly use, overall period of exposure and headset usage. 13 Individuals did not use mobile phones at all, 85 reported using the mobile phone for three hours per week or less, and 33 reported use of more than three hours per week. Additionally, information on age, gender, body weight, smoking status, medication and nutrition was retrieved. For staining of the cells a procedure using alpha-tubulin-antibody and chromomycin A(3) was applied. Micronuclei and other markers were evaluated in 1000 cells per individual at the microscope. A second scorer counted another 1000 cells, resulting in 2000 analyzed cells per individual. Mobile phone use did not lead to a significantly increased frequency of micronuclei.

(NE) Hintzsche H, Jastrow C, Kleine-Ostmann T, Schrader T, Stopper H. 900 MHz radiation does not induce micronucleus formation in different cell types. Mutagenesis. 27(4):477-483, 2012 . (GT)

The exposure of the population to non-ionising electromagnetic radiation is still increasing, mainly due to mobile communication. Whether low-intensity electromagnetic fields can cause other effects apart from heating has been a subject of debate. One of the effects, which were proposed to be caused by mobile phone radiation, is the occurrence of mitotic disturbances. The aim of this study was to investigate possible consequences of these mitotic disturbances as manifest genomic damage, i.e. micronucleus induction. Cells were irradiated at a frequency of 900 MHz, which is located in one of the main frequency bands applied for mobile communication. Two cell types were used, HaCaT cells as human cells and A(L) cells (human-hamster hybrid cells), in which mitotic disturbances had been reported to occur. After different post-exposure incubation periods, cells were fixed and micronucleus frequencies were evaluated. Both cell types did not show any genomic damage after exposure. To adapt the protocol for the micronucleus test into the direction of the protocol for mitotic disturbances, the post-exposure incubation period was reduced and exposure time was extended to one cell cycle length. This did not result in any increase of the genomic damage. In conclusion, micronucleus induction was not observed as a consequence of exposure to non-ionising radiation, even though this agent was reported to cause mitotic disturbances under similar experimental conditions.

(NE) Hirose H, Sakuma N, Kaji N, Suhara T, Sekijima M, Nojima T, Miyakoshi J. Phosphorylation and gene expression of p53 are not affected in human cells exposed to 2.1425 GHz band CW or W-CDMA modulated radiation allocated to mobile radio base stations. Bioelectromagnetics 27:494-504, 2006.

SECTION 10

Effects of Electromagnetic Fields From Wireless Communication upon the Blood-Brain Barrier

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I. INTRODUCTION

The Blood-Brain Barrier

Some organs of crucial importance for the function of our bodies are protected from exposure to potentially harmful compounds in the blood. Thus the brain, the eyes (which are protrusions of the brain), the testes and the follicles of the ovaries have special barriers between the capillaries and the tissue. In the normal brain, the passage of compounds over this barrier, the Blood-Brain Barrier (BBB), is highly restricted.

The BBB is a hydrophobic barrier formed by the vascular endothelial cells of the capillaries in the brain with tight junctions between them leaving no openings between the vessel lumen and the surrounding brain. The existence of the mammalian BBB was discovered in the late 19th century by the German bacteriologist Paul Ehrlich and his student, Edwin Goldman. Paul Ehrlich found, that when he injected dyes into the systemic blood circulation, the brain tissue did not take up any of the stain. A barrier surrounding the brain tissue at the site of the brain micro vessels seemed to be a logic explanation to these findings.

There is scientific evidence that the BBB exists not only in vertebrates, but also in insects (1), crustaceans and cephalopod molluscs (such as the cuttlefish) (2) and in elasmobranchs (cartilaginous fishes such as sharks) (3) and helices (landsnails) (4), maintaining ionic integrity of the neuronal bathing fluid.

The BBB seems to be present very early in the foetal development. Also, at an early stage, there seems to be a cerebrospinal fluid barrier, which excludes cerebrospinal fluid (CST) protein from the brain extracellular space (5).

BBB Anatomy and Physiology

The tight junctions of the BBB 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 (6). An important part is

the binding of claudin proteins on opposing membranes, where claudin-5 in particular is crucial in the BBB (7). 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 (see Figure 1).

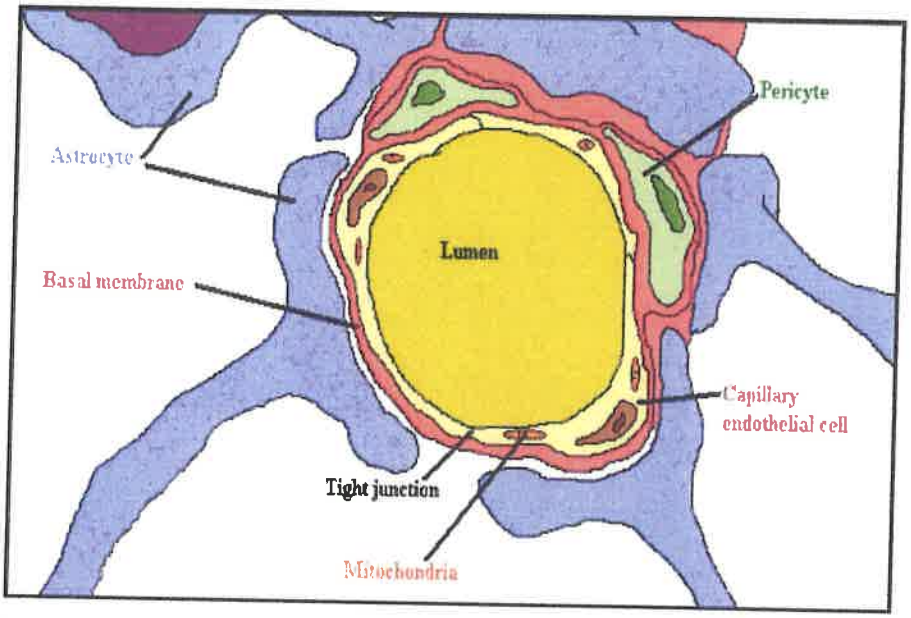


Fig. 1. The mammalian BBB

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% o the capillary surface (8), seem to be in a position to significantly contribute to central nervous system (CNS) immune mechanisms (9). 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 (9). Additionally, the pericytes 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 (9).

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 (10). All this speaks in favour 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. Firstly, the tight junctions and low number of pinocytotic vesicles guarantee that proteins cannot pass freely into the brain parenchyma.
Secondly, 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. Thirdly, the BBB has a capacity to metabolize certain solutes, such as drugs and nutrients (11). Fourthly, 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 (12).

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 (12).

It is important to have information on possible differences between homo and other mammals. The mammalian brain at large seems to have a uniform anatomy of its BBB constituents

preserved through the evolution, and very little information about differences between mammalian species has been available. However, recently very interesting observations have been published. Humans have evolved protoplasmic astrocytes that are both larger (27-fold greater volume) and far more elaborate than their rodent counterparts. These astrocytes reside near blood vessels, and their processes contribute to the BBB (13). When the end feet of human and rodent protoplasmic astrocytes are compared, it is shown that nearly all astrocytes in both species contact the vasculature, but in the human brain, the end feet completely encompass the vessels while the rodent astrocytes form rosettes of end feet around the vasculature. The number of mithochondria is however equally abundant in human and rodent end feet (14).

Comparisons between mammalian species concerning enzymatic functions in the BBB are few in number. Similarities are described: mouse *vs* human (15) and rat *vs* human (16), while differences are demonstrated between rodent and dog BBB leading to the conclusion that the canine BBB may be preferable to that of the rat as a model for studies of glucose transport relevant to human brain (17).

In summary, the BBB serves as a regulatory system that stabilizes and optimizes the fluid environment of the brain's intracellular compartment (18-20). 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.

II. DISRUPTION OF THE BLOOD-BRAIN BARRIER

The normal selective permeability of the BBB can be altered in several pathological conditions such as epileptic seizures (21) or extreme hypertension (22)and also transient openings of the BBB might lead to permanent tissue damage (22). 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 (23), 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 (23).

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.

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. (25) found increases in the BBB permeability of rats to fluorescein after 30 min of exposure to both pulsed and continuous waves (CWs) at 1.2GHz with average power densities of $0.2mW/cm^2$. Similar observations were made in a study with 180 animals by Oscar and Hawkins (26). Exposure of anaesthetized rats for 20 min to 1.3GHz of pulsed EMFs with average power densities of $0.3mW/cm^2$ resulted in leakage of 14C-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. (27) 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 (26) might be of less magnitude than originally thought (Table 1).

Effects of Radiofrequency/Microwave Radiation upon the BBB – A summary of Previous Studies

Table 1. BBB permeability after EMF exposure. (From Nittby et al. (24))

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 hours	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	Yes	1002 Fischer	Albumin extravasation	

				average whole-body		344 rats		
Salford et al. 2003	915	GSM	2 hours	0.002-0.2 W/kg	Yes		Albumin extravasation and dark neurons	Effect was seen 50 days after the exposure
Eberhardt et al. 2008	915	GSM	2 hours	0.0002-0.2 W/kg	Yes	96 Fischer 344 rats	Albumin extravasation and dark neurons	Albumin extravasation 14 days after exposure, dark neurons 28 days after exposure
Mobile phone exposure								
Fritze et al. 1997	900	GSM	4 hours	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 hours	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

Neubauer et al. 1990	2450	100 pps	30-120 min	Average 2 W/kg	Yes		Rhodamine-ferritin complex	of 0.5 and 2.0 W/kg No leakage at 1 W/kg at short-term exposure of 15 min
Tsurita et al. 2000	1439	TDMA	1 hour 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 hour	Whole-body of 4 W/kg	No	60 mice	Albumin extravasation	
Finnie et al. 2002	900	GSM	1 hour daily, 5 days a week for 104 weeks	Average whole-body 0.25; 1.0; 2.0 and 4.0 W/kg	No	207 mice	Albumin extravasation	
Franke et al. 2005b	1800	GSM	1 to 5 days	Average 0.3 W/kg	No		Sucrose permeation	In vitro model of BBB
Schirmacher et al. 2000	1800	GSM	4 days	Average 0.3 W/kg	No		Sucrose permeation	In vitro model of BBB
Franke et al. 2005a	1966	UMTS	1 to 3 days	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 Hawksins 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)
Ward et al. 1982	2450	CW	30 min	10-30 mW/ cm^2	No	Rats	Sucrose and inulin	
Ward and Ali 1985	1700	CW and 1000 pps	30 min	0.1 W/kg	No	Rats	Sucrose and inulin	
Albert and	2450	CW	2 hours	2.5 W/kg	Yes	80 Chinese	Horseradish peroxidase	Reversible

Kerns 1981						hamsters		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	
Williams et al. 1984c	2450	CW	30-90 min	13 W/kg	No	24 Fischer 344 rats	Sucrose	
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.	65	23 min x 2	0.15 T static	Yes	43	Diethylenetriaminepentaacetic	Standard MRI

1990			magnetic field		Sprague Dawley rats	acid (DTPA)	procedure
Prato et al. 1994		23 min x 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 hours daily for 21 days	0.005T	Yes	34 Wistar rats	Evans-blue	BBB disruption in diabetic rats, but not in normoglycemic rats

In an attempt to repeat the findings of Oscar and Hawkins (26), Preston et al. (28) found no increase in the uptake of 14C-mannitol in anaesthetised rats after 2450MHz CW exposure for 30 min at power densities of 0.1 to 30mW/cm^2. Preston et al. further concluded that the increased BBB permeability, which had been observed by Oscar and Hawkins (26) 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) (29), 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. (29) tried to replicate also the findings of Frey et al. (25), 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. (25) (30).

No alteration of BBB permeation of 14C-sucrose and 3H-inulin was found by Ward et al. (31)after exposure of anaesthetised rats to CW at 2450MHz for 30 min at power densities of 0, 10, 20, or 30 mW/cm^2 after correction for thermal effects. Similarly, Ward and Ali (32) observed no permeation after 1.7GHz exposure at SAR of 0.1 W/kg, using the same exposure duration and injected tracers as Ward et al. (31). Absence of EMF induced BBB permeability was also reported by Gruenau et al. (33), after injection of 14C-sucrose in conscious rats and exposure 30 min pulsed energy (2.8GHz at 0, 1, 5, 10, or 15mW/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 (34), who exposed un-anaesthetised Chinese hamsters to 2,450MHz 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 by Lin and Lin (35), using Evans blue and sodium fluorescein as indicators of BBB permeation, showed that 20 min of 2,450MHz 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 (36), no permeation of Evans blue could be observed after exposure to 2,450MHzB 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 (37).

In a series of EMF exposures at 2,450MHz CW, Williams et al. (38-40) 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 (38) were found only in the brains of conscious rats made considerably hyperthermic by exposure to ambient heat for 90 min or 2,450MHz 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 (41) —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 (42). 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 (43-46) need to be considered from another point of view, as 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 radiofrequency field, and time-varying magnetic field. Shivers et al. (47) 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 to horseradish peroxidase (HRP) in anaesthetised rats. 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 (48)while others contradicted (49, 50) the initial findings made by Shivers et al. (47). 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 (48). 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. (50) found no significant permeation of blood-borne 14C-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. (50) compared the lack of BBB leakage in their study to the MRI induced leakage which had been observed by Shivers et al. (47), 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 (51) 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 also altered by exposure to MRI at 1.5T for 23 min in 2 subsequent exposure sessions (52).

Studies by the Lund Group

Two of us found these observations highly interesting:

- the neurosurgeon (LGS) in the hope to utilize possible applications of EMF to make the blood-brain barrier (BBB) more penetrable to chemotherapy, in order to treat brain cancers more effectively. An intact BBB keeps out chemotherapy agents, allowing cancer cells to hide behind the BBB.

- the radiophysicist (BRRP) interested in possible adverse effects of the MRI technique.

After a visit to Shivers' group in London Ontario in 1988, we started work in Lund in 1988, studying the effects of MRI on rat brain and we found, by the use of Evans Blue, the same increased permeability over BBB for albumin (53).

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 of albumin with rabbit antibodies (see Figure 2 and 3) and rabbit anti-human fibrinogen.

Figure 2. Albumin extravasation in rat brain (material from Persson et al. 1997)(54).
Left: control brain with albumin staining in hypothalamus, which serves as an inbuilt-control of the staining method, since the hypothalamus lacks BBB, and one occasional staining.
Right: Brain of EMF exposed rat, with multiple albumin positive foci.

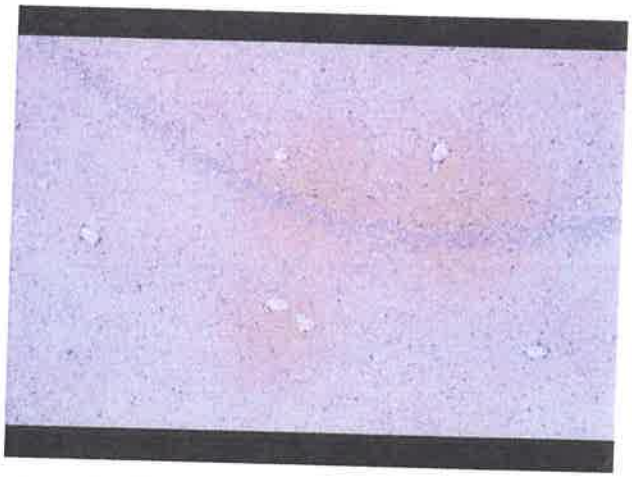


Figure 3. Albumin extravasation around vessels in the brain of an EMF exposed rat.

The work by Blackman et al. (55, 56) ~~made the ground~~ laid the groundwork for studies on the frequency modulation 16 Hz and its ~~harmonies~~ harmonics 4 and 8 Hz. A carrier wave of 915 MHz was used. At the suggestion of Östen Mäkitalo (Telia), a pioneer in mobile phone

development, who introduced 50 Hz (DUX) and 217 Hz (GSM) modulation in new digital wireless communication systems, we also included theses frequencies. This paralleled the first BBB study results that were published in 1992-1994 (57-59).

The result of our continued work, comprising more than 1000 animals, 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% (for results see Figure 4) (54).

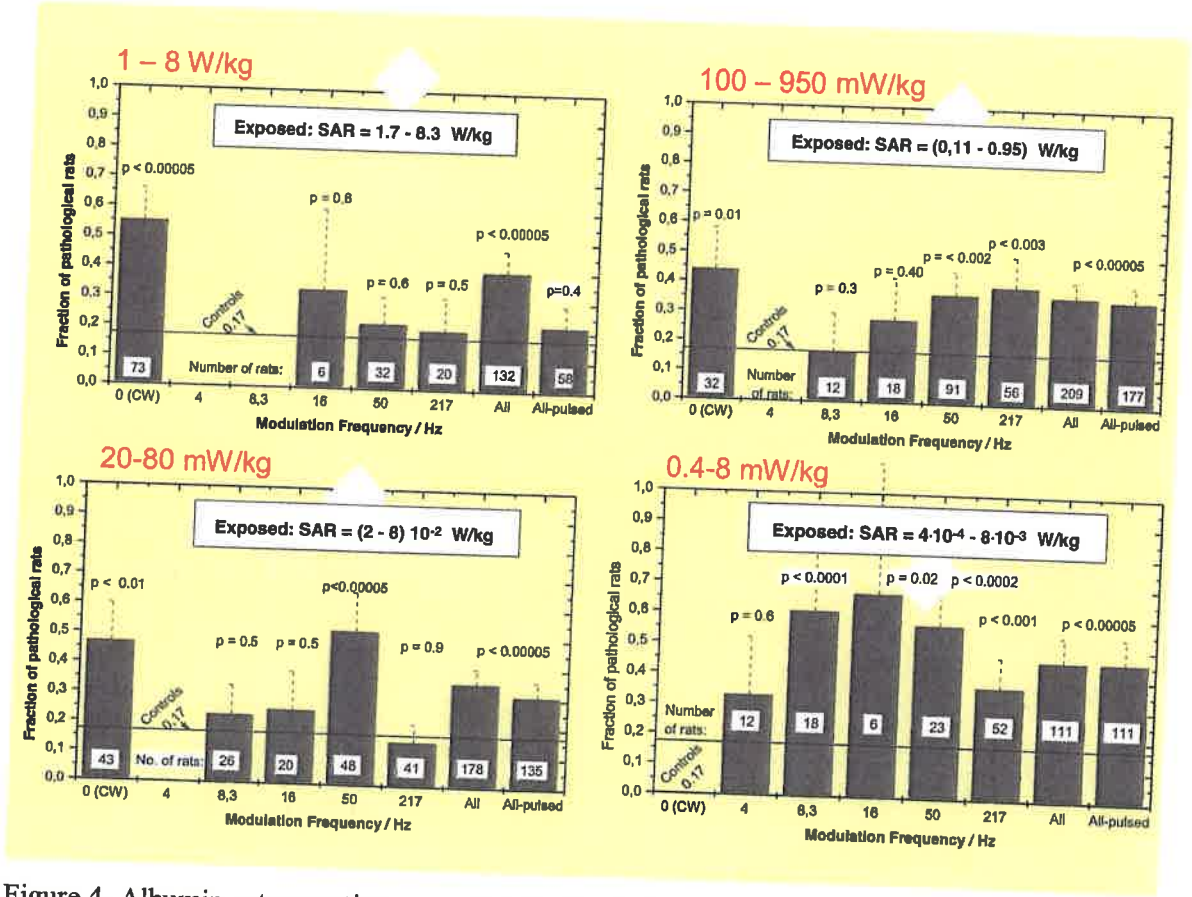


Figure 4. Albumin extravasation score as a result of EMF exposure (results from the study by Persson et al. (54)).

The fact that sham-exposed control animals also show some amount of albumin extravasation (see Figure 4), 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 (54).

Another conclusion from the 1997 study is that the number of pathological leakages in exposed animals is more frequent, and also more severe, per animal compared to the controls. This is an interesting observation as the prevailing opinion is that pulse modulated electromagnetic fields are more potent in causing biological effects.

In a statistical re-evaluation of our material published in 1997, where only exposed rats with a matched unexposed control rat are included, we found for the most interesting modulation frequency 217 Hz, i.e. that of GSM, that at SAR-values of 0.2 to 4 mW/kg 48 exposed rats had a significantly increased albumin leakage ($p < 0.001$) as compared their 48 matched controls. On the other hand, SAR-values of 25-50 mW/kg, gave no significant difference between 22 exposed rats *vs* their matched controls (Wilcoxon's Rank Test, 2-sided p-value) (60).

In all our earlier studies we showed albumin extravasation immediately after exposure as described above. In later years we have performed a series of experiments where the animals were allowed to survive for 7 days (61), 14 days, 28 days (62) or 50 days (63) after one single 2-hour exposure to the radiation from a GSM mobile phone. All were exposed in TEM-cells to a 915 MHz carrier wave as described below. The peak power output from the GSM mobile phone fed into the TEM-cells was 1 mW, 10 mW, 100 mW and 1000 mW per cell respectively for the 7-14-28-days survival animals, resulting in average whole-body SAR of 0.12 mW/kg, 1.2 mW/kg, 12 mW/kg and 120 mW/kg for four different exposure groups SAR-values of 2, 20 and 200 mW/kg mW/kg for 2 hours for the 50-days survival animals.

Albumin extravasation over the BBB after GSM exposure seemed to be time-dependent, with significantly increased albumin in the brain parenchyma of the rats, which had survived for 7 and 14 days, but not for those surviving 28 days. After 50 days, albumin extravasation was

significantly increased again, with albumin-positive foci around the finer blood vessels in white and gray matter of the exposed animals.

In connection to the albumin passage over the BBB, albumin also spread in the surrounding brain tissue. A significantly increased uptake of albumin in the cytoplasm of neurons could be seen in the GSM exposed animals surviving 7 and 14 days after exposure, but not in those surviving 28 or 50 days.

Neuronal uptake

Extravasated albumin rapidly diffused down to, and beyond, concentrations possible to demonstrate accurately immunohistologically. However, the initial albumin leakage into the brain tissue (seen within hours in ~40% of exposed animals in our previous studies) most likely started a vicious circle of further BBB opening.

It has been postulated that albumin is the most likely neurotoxin in serum (64). Hassel et al. (65) have demonstrated that injection of albumin into the brain parenchyma of rats gives rise to neuronal damage. When 25 µl 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. It also causes leakage of endogenous albumin in and around the area of neuronal damage. Albumin in the dose 10 mg/ml is approximately equivalent to 25% of the serum concentration.
It is less likely that the albumin leakage demonstrated in our experiments locally reaches such concentrations. However, we have seen that in the animals surviving 28 and 50 days after 2 hours of GSM exposure, there was a significantly increased incidence of neuronal damage as compared to the sham controls. In the 7-days and 14-days survival animals, on the other hand, no such increase of neuronal damage was seen.

In the 50-days post-exposure survival study, a 2 h exposure to GSM at SAR values 200, 20, and 2 mW/kg resulted in a significant ($p = 0.002$) neuronal damage in rat brains of the exposed animals as compared to the controls 50 days after the exposure occasion (Salford et al., 2003)(63). We have followed up this observation, as mentioned above, in a study where 96 animals were sacrificed 14 and 28 days respectively after an exposure for 2 h to GSM mobile phone electromagnetic fields at SAR values 0 (controls), 0.12, 1.2, 12 and 120 mW/kg. Significant neuronal damage is seen after 28 days and albumin leakage after 14. Our

findings may support the hypothesis that albumin leakage into the brain is the cause for the neuronal damage observed after 28 and 50 days (62).

The damaged neurons in the above mentioned studies took the shape of so-called dark neurons. Three main characteristics of the damaged dark neurons have been proposed (66): (i) irregular cellular outlines, (ii) increased chromatin density in the nucleus and cytoplasm and (iii) intensely and homogenously stained nucleus. The damaged dark neurons found in the 50 days-survival animals were investigated regarding signs of apoptotic markers, but we found no positive staining for Caspase-3, a marker for apoptosis (Bexell et al. unpublished results). However, the albumin leakage out in the neuropil in connection to EMF exposure might start other deleterious processes, leading to the formation of the dark neurons.

A group in Turkey performed similar experiments. However, also the presumed protective effects of the antioxidant Ginko biloba (Gb) were examined by Ilhan et al. (67). About 22 female Wistar rats were exposed to a 900 MHz electromagnetic GSM near-field signal for 1 h a day for 7 days. In the GSM only group, the pathological examination revealed scattered and grouped dark neurons in all locations, but especially in the cortex, hippocampus and basal ganglia, mixed in among normal neurons. A combined non-parametric test for the four groups revealed that the distributions of scores differed significantly between the control and the GSM only exposure group ($p < 0.01$).

Long-term study, including studies of memory and behaviour

In a recent long-term study from our laboratory, rats were exposed to GSM radiation 2 hours weekly during 55 weeks (two different exposure groups with 0.6 mW/kg and 60 mW/kg at the initiation of the exposure period). After this protracted exposure, behaviour and memory of the exposed animals were tested. Whereas the behaviour of the animals was not affected, the GSM exposed rats had significantly impaired episodic memory as compared to the sham controls (68). After the finalization of these tests, that is 5-7 weeks after the last exposure, the animals were sacrificed by perfusion fixation. Albumin extravasation, an indicator of BBB leakage, was increased in about 1 animal in each group of low GSM exposed, high GSM exposed, sham exposed and cage control rats. About 40 % of the animals had neuronal damage. GFAP staining, as an indicator of glial reaction, revealed positive results in 31-69 % of the animals for different groups and the aggregation product lipofuscin was increased in

44-71 % of the animals for different groups. With the Gallyas staining (aiming at cytoskeletal structures), no changes were seen. When comparing the results between the different groups, it turned out that there was no statistically significant difference for any of these parameters due to GSM exposure (69). When comparing these findings to those from animals which had been exposed only once for 2 hours, it seems likely that during the 55 weeks of repeated exposure, albumin leakage at an initial stage of the experimental period might have been absorbed after some time, and that at a certain, but unknown, time point during this protracted, more than 1 year long-exposure period, some adaptation process might have been activated. However, this could not compensate for cognitive alterations, demonstrated by the episodic memory tests.

TEM-cells

In the majority of our studies, EMF exposure of the animals has been performed in transverse electromagnetic transmission line chambers (TEM-cells, see Figure 5) (53, 54, 59, 61-63, 68-71). 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. (72)) 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.

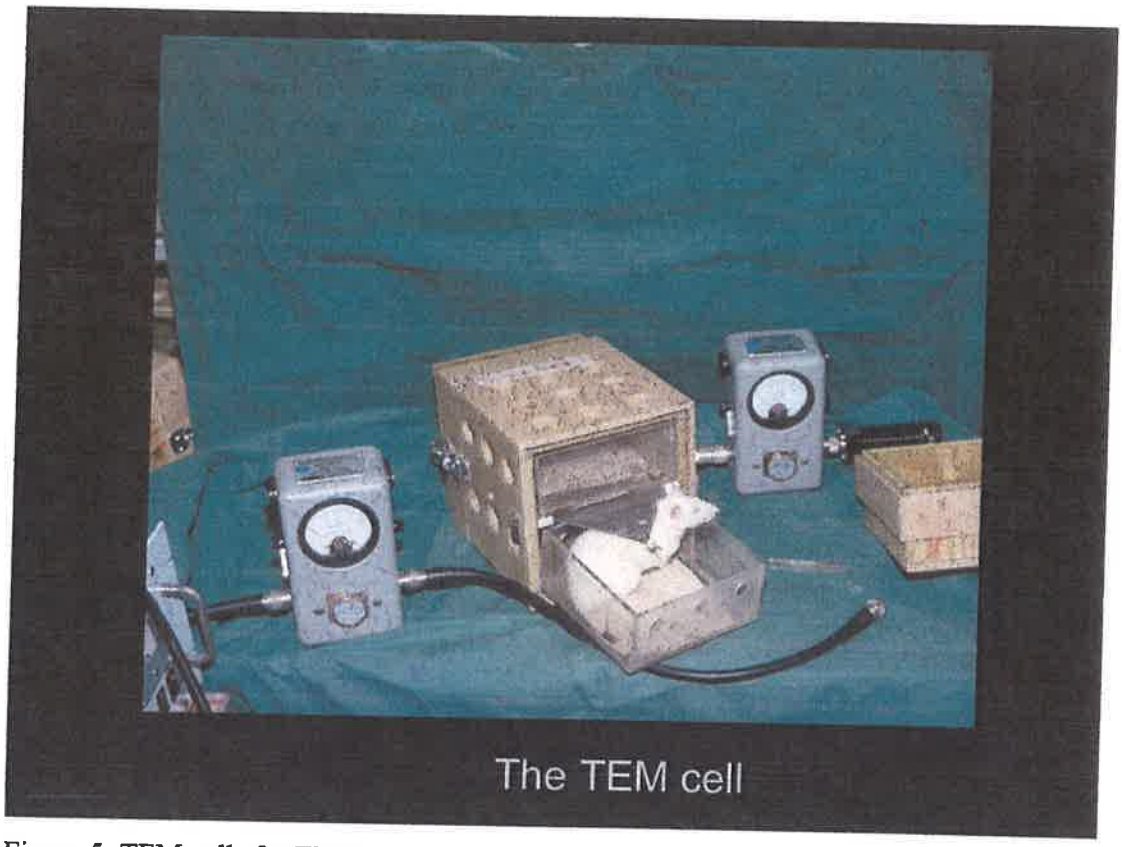


Figure 5. TEM-cells for EMF exposure.

GSM-1800 modulated and CW microwaves in an anechoic chamber

In Lund we have also utilized an anechoic chamber for studies on microwaves from a real GSM-1800 mobile telephone, which were amplified and transferred to a dipole antenna in the anechoic chamber. The output power was varied to study the effect of various SAR values. In a series of 65 rats exposed for 2 h with 1800-GSM at SAR: 0.027 mW/kg, and 12 rats exposed for 2 h with continuous wave, we found significantly increased albumin leakage (see figure 6) as compared to 103 control rats ($p<0,03$ and $p<0,02$, respectively). (Unpublished results).

Figure 6.

Pathological leakage around vessels demonstrated by immunostaining against albumin. Fischer 344 rat exposed for 2 h with 1800-GSM at SAR: 0.027 mW/kg

Other 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 by Fritze et al. (73), 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. (20)).

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 by Töre et al. (74, 75). 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. (74, 75) concluded that the pressure variations (100–130mm 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. (74, 75). 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 2.45GHz EMFs at average power densities of

2 W/kg by Neubauer et al. (76). 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 1,439MHz 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 by Tsurita et al.(77). 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 1,439MHz exposure for 90 min/d for 1–2 weeks at average brain power densities of either 2 or 6W/kg by Kuribayashi et al.(78). A total number of 40 animals were included in the study.

Finnie et al. (79) 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. (80) continued to investigate more long-lasting exposure effects. In a series of experiments, a total of 207 mice were exposed 60 min daily, 5 days per week for 104 weeks at average whole body SARs of 0.25, 1.0, 2.0, and 4.0W/kg. This led 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 to correspondence in the same journal (81), the authors presented the original data from the long-term study in one table, from which

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.

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 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 histopathological examinations of the brains are not uncomplicated. Some laboratories that have tried to replicate our studies have not been able to demonstrate the albumin leakage. We have recently had problems with the albumin staining due to change of suppliers of avidin, biotin, serum and antibodies. The lateral hypothalamic nuclei in the immediate vicinity of the third ventricle are well known for their normally insufficient BBB. This has served as an inbuilt control of adequate albumin staining in all our experiments since 1990. In our study on combined effects of RF- and ELF-EMF, for the first time, we could not demonstrate albumin extravasation in basal hypothalamus. Not until our third attempt with new staining material, we got our positive control and could also demonstrate albumin leakage in the exposed brains (61).

The biological effects of RF exposure depend on many parameters, such as mean power level and the time variations of the power (82) 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 (54, 63). 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.

Other Studies on BBB permeability and neuronal damage

As has been mentioned above (p. 26) Ilhan et al. (67), in 2004 reported neuronal damage in female Wistar rats, which had been exposed to a 900 MHz electromagnetic GSM near-field signal for 1 h. a day for 7 days. They found scattered and grouped dark neurons in the cortex, hippocampus and basal ganglia, mixed in among normal neurons. A combined non-parametric test for the four groups revealed that the distributions of scores differed significantly between the control and the GSM only exposure group ($p < 0.01$).

Later, Masuda et al. (83) tried to replicate the findings by our group of albumin extravasation and dark neurons. F344 rats (n=64) were exposed to 915 MHz signals for 2 hours (SAR of 0, 0.02, 0.2 and 2 W/kg), and albumin extravasation and dark neurons were investigated 14 and 50 days after the exposure. No albumin extravasation was seen, neither in control or exposed rats, and no difference in the occurrence of dark neurons could be found due to EMF exposure. An interesting difference as compared to the studies by Salford et al. mentioned above, was that animals, after perfusion fixation, were left in a 4°C storage for 18 hours before the brains were removed. The question is whether this might have led to dilution of the very sensitive albumin extravasation, which is often more pronounced in the circumventrical organs as compared to the brain extravasates (personal communications with our neuropathologist Arne Brun). This might explain the fact, that no albumin extravasation could be seen in neither the cage control animals, the shams or the GSM exposed animals.

Another study by Mason and his group at Brooks Airforce Resarch Laboratory, San Antonio, also tried to confirm our findings of albumin extravastion by using the same type of TEM-cells for EMF Exposure (84), although the exposure parameters where somewhat different with only 30-min exposure, including only male rats of the Fischer 344 CD-VAF strain and utilizing only the upper compartment of the TEM cells. Exposure was at whole-body SAR values of 0.002 to 20 W/kg. Regarding extracellular albumin accumulation, the results were

not formally analyzed, as motivated by too low scores of albumin. Regarding intracellular albumin uptake, no significant difference between the different groups was reported. However, as presented in the paper by McQuade et al.(84), at the lowest SAR of 1.8 mW/kg at 16 Hz, of 33 exposed rats, 11 had 2 or 3 positivities (33% of the animals) and 22 had none or 1 positivity. In the sham animals, 18% were positive and among the cage controls only 12%. These results are reminiscent of prior work by the Lund group reporting that 17% of the sham animals had some albumin leakage, while only at the most 50% of the identical and equally handled, but RF exposed animals displayed albumin extravasation (60).

In a third study aiming to replicate the Lund findings of dark neurons, a group in Bordeaux (85) exposed 14 weeks old Fischer 344 rats (which, however, were restrained in a rocket-type exposure setup), to the GSM-900 signal for 2 h at various brain-averaged SARs (0, 0.14 and 2.0 W/kg). Eight rats were included in each of these groups.
Albumin leakage and neuronal degeneration was evaluated 14 and 50 days after exposure. It was reported that no statistically significant albumin leakage was observed and that neuronal degeneration assessed using cresyl-violet or the more specific marker Fluoro-Jade B, was not significantly different among the tested groups. Here we want to point out that the Bordeaux group makes a major deviation from the way we have evaluated the occurrence of dark neurons in the tissue slices. While we counted the overall number of dark neurons, de Gannes et al. (85) chose to subdivide the slices into 12 different small regions, which were compared individually to each other (fig 3 in the publication). This gave the effect that a clear overall difference in number of observed dark neurons between animals 50 days after exposure to 2 W/kg for two hours versus sham exposed, disappeared in the statistics. On the contrary, if all the numerical values for the bars representing the scored dark neurons observed in each brain zone and region 50 days after exposure to 2 W/kg are compared to all those of the sham animals, a highly significant difference (Kruskall-Wallis) between animals exposed to 2 W/kg and sham is demonstrated (Mann-Whitney) $p = 0.003$! This is in concordance with the Lund experience!

Indirect studies and studies on the blood cerebrospinal fluid barrier

The integrity of the BBB has also been investigated indirectly. Cosquer et al. (86) treated rats with the muscarinic antagonist scopolamine methylbromide, which is known to induce

memory impairments, followed by EMF exposure at 2.45GHz for 45 min at average whole body SARs of 2W/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.

Ushiyama et al. (87) investigated the effects on the blood cerebrospinal fluid barrier after RF-EMF exposure. 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 1.5GHz RFs during 30 min at SAR-values of 0.5, 2.0, 9.5W/kg for adult rats and 0.6, 2.2, 10.4W/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 a recent study, the permeability of the human BBB after mobile phone exposure was assessed measuring blood levels of S100B and transthyretin in human volunteers by Söderqvist et al. (88). S100B is a calcium-binding protein, and it has been shown to be increased in serum after damage to the BBB. Transthyretin, also known as pre-albumin, is synthesised both in the liver and the choroid plexus. 30 min of GSM-900-like exposure at SAR-values of 1 W/kg was used. No difference was seen regarding S100, but transthyretin was increased 60 min after the termination of exposure as compared to the control situation. The concentrations of S100B and transthyretin were also analysed 30 min prior to provocation and after 30 min rest, showing a decrease after 30 min rest, which was suggested, might be due to less stress after the 30 min rest. Thus, it is interesting that despite this decline, which might be due to relaxation, still an increase in thransthyretin could be measured 30 min after exposure. It was also put forward, that it could not be excluded that the thransthyretin rise might be a compensation to the previous decrease, and that new studies including more participants and also a sham group would be needed.

We have in the past investigated whether MW exposure, CW and at different SAR levels might enhance S-100 protein levels in the blood of a large proportion of our rats. We could conclude that no significant differences were seen (see Figure 7 below) (to be published).

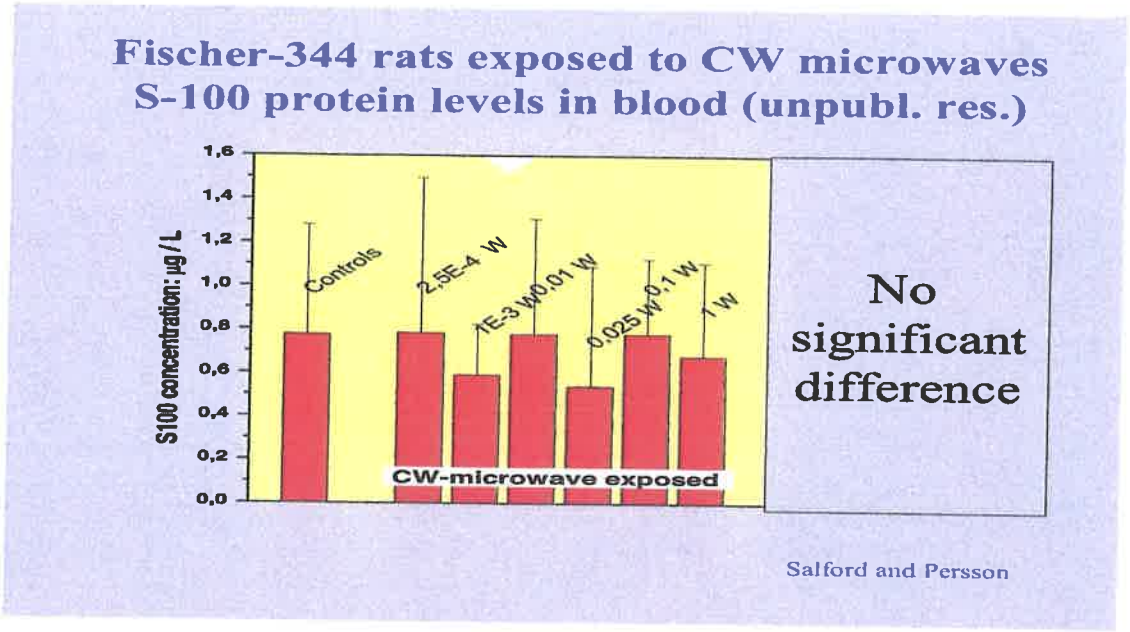


Figure 7. S-100 in the blood of rats after EMF exposure (to be published in Acta Scientiarum Lundensia).

In another study, by Sirav and Seyhan (89), exposure to CW EMFs at 900 and 1,800 MHz for 20 min, increased the BBB permeability of male but not female rats. Evans blue dye, which binds to serum albumin after injection, was used to quantitatively measure BBB permeability. A strength of this study, was the ability to objectively quantify the Evans blue uptake in the brain. The finding that only male, and not female rats, are affected, is however not fully addressed.

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. (90), 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 14C-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 (91). The modified BBB model had a higher general tightness. It was speculated that at a higher original BBB permeability, which was

present in the first study by Schirmacher et al. (90), the cultures were more susceptible to the RF EMFs. 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 (92).

In the search after the mechanism underlying non thermal EMF effects, Leszczynski et al. (93) 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.

Further perspectives of the importance of the BBB including the human situation

BBB in the Context of Alzheimer's Disease and the findings by the Zlokovic Group

The BBB, as mentioned previously, is of essential role for maintaining an accurate brain function. As described by Zlokovic (94), in a review regarding BBB in correlation to neurodegenerative disorders, BBB breakdown can be due to tight junction disruption, alterations of angiogenesis or vessel regression, hypoperfusion, inflammatory response and alterations of the transport of molecules across the BBB (94). Further, as Zlokovic hypothesises, this might contribute to neurodegenerative disorders, such as Alzheimer's disease (AD), Parkinson's disease, multiple sclerosis and amyotrophic lateral sclerosis.

In the review by Zlokovic (94), a neurovascular disease pathway is presented, regarding possible genesis of AD, where it is suggested that changes in vascular genes and receptors in brain capillaries and small arteries might disrupt BBB functions, leading to an accumulation

of amyloid beta (Aβ), a neuroinflammatory response and BBB breakdown and further on accumulation of Aβ, loss of the BBB to clear Aβ (due to affected synaptic transmission, neuronal injury and recruitment of microglia) and secretion of proinflammatory cytokines. Ultimately, this is suggested to lead to disappearance of the capillary unit, increasing Aβ deposits and synaptic and neuronal loss (94).

This observation might explain how vascular disease contributes to Alzheimer's disease (AD) risk; the heterogeneity of AD; and supports the idea that exclusively focusing on amyloid is likely to be disappointing.

Neuronal injury resulting from vascular defects that are not related to amyloid-beta but is related to damage results from a breakdown of the blood-brain barrier and a reduction in blood flow (94). Although Amyloid beta definitely has an important role in Alzheimer's disease it's very important to investigate other leads, perhaps where amyloid-beta isn't as centrally involved.

Human apolipoprotein E has three isoforms: APOE2, APOE3 and APOE4. APOE4 is a major genetic risk factor for Alzheimer's disease and is associated with Down's syndrome dementia and poor neurological outcome after traumatic brain injury and haemorrhage. Neurovascular dysfunction is present in normal APOE4 carriers and individuals with APOE4-associated disorders. In mice, lack of APOE leads to blood-brain barrier (BBB) breakdown, whereas APOE4 increases BBB susceptibility to injury. How APOE genotype affects brain microcirculation remains elusive. Using different APOE transgenic mice, including mice with ablation and/or inhibition of cyclophilin A (CypA), it has been shown show that expression of APOE4 and lack of murine APOE, but not APOE2 and APOE3, leads to BBB breakdown by activating a proinflammatory CypA-nuclear factor-kappa B-matrix-metalloproteinase-9 pathway in pericytes. These findings suggest that CypA is a key target for treating APOE4-mediated neurovascular injury and the resulting neuronal dysfunction and degeneration. The data reviewed above support an essential role of neurovascular and BBB mechanisms in contributing to both, onset and progression of AD (95, 96).

BBB in the context of Alzheimer's Disease – Importance of EMF Exposure

In this context, the findings of Arendash et al., that long-term EMF reduced brain Aβ deposition through Aβ anti-aggregation actions in AD mice, are highly interesting (97). It was also found, by Mori and Arendash et al., that long-term exposure to high frequency EMF treatment prevented cognitive impairment in AD transgenic (Tg) mice and improved memory in normal mice and that an increase in neuronal activity could be observed in the EMF exposed groups (98). Furthermore, it was found by the group that EMF treatment enhances brain mitochondrial functions in AD Tg as well as normal mice and that no increase in brain temperature could be found in connection to the EMF exposure (99). An interesting aspect in this context, is the role of mitochondria for many cellular functions, including reactive oxygen species generation, apoptosis, and $Ca2^{+}$ homeostasis as was mentioned by Dragicevic et al. and reviewed by Nicholls (99, 100).

In the first mentioned study by Arendash et al. (97), mice were EMF exposed with start at young age or at adult age. In the young-age group, 24 mice were divided into 4 subgroups: n=6 were Tg controls, n=6 were Tg animals treated with EMF, n=6 were non-transgenic (NT) controls and n=6 were NT animals treated with EMF. 2.5, 4-5 and 6-7 months after daily GSM-900 EMF exposure (two 1-hour sessions daily, at SAR 0.25 W/kg), the animals were evaluated by cognitive tests. At the end of the study, Aβ in the brains was evaluated by immunohistochemistry. No effect on cognitive functions was observed after 2 months of exposure. However, for the Tg+EMF mice with start of EMF exposure at young age, the cognitive function was maintained after 6-7 months of exposure, while it deteriorated in the Tg group. In a final task for NT mice after 7 months of EMF, the EMF actually improved the mnemonic function. In the adult-age group, Tg animals had impaired cognitive functions at the age of 4 months. 28 Tg and NT mice were included. After long-term EMF exposure (2, 5 and 8 months) the memory was tested. While 2 months of EMF exposure had no effect, 5 months of exposure had positive effects only on NT mice, and 8 months of exposure had beneficial effects for the Tg mice, with better results in the Tg+EMF group as compared to the Tg controls. Also the NT+EMF mice had an improved function as compared to NT controls after 8 months. Staining for Aβ revealed lower values on both hippocampus and the entorhinal cortex in the Tg+EMF group as compared to the Tg control group. Hippocampal

tissue from Tg mice were then exposed to EMF for 4 days, after which it was shown that the Aβ amount had decreased as compared to non-exposed control tissue. It was also reported that a ±1° temperature increase was observed in EMF exposed animals during exposure, but not in between exposure sessions (97).

In the study by Mori and Arendash (98), n=6 mice were Tg controls, carrying the mutant APPK670N , n=10 mice were Tg treated with EMF, n=4 mice were NT controls and n=5 mice were NT treated with EMF. EMF exposed animals were placed in a Faraday cage, receiving two 2-hour periods of EMF treatment at GSM-900 frequencies, pulse modulated at SAR 0.25-1.05 W/kg. The neuronal expression of c-Fos was taken as an indicator of neuronal activity. With immunohistochemistry, it was found that c-Fos was increased in both the NT+EMF group, as well as in the Tg+EMF group in the entorhinal cortex. However, only this one brain region was analyzed, since c-Fos expression was too low in other regions, which the authors hypothesised might be due to that c-Fos in an early response gene, and that at a certain time after stimulation, when the animals were sacrificed, the expression had already declined in other regions, such as hippocampus. In a cognitive test (Y-maze), it was found that EMF improved the performance in both NT and Tg group as compared to untreated controls. It should also be noted, that despite the very interesting findings, the number of included animals is quite small (98).

EMF and ^{18}FDG Uptake – Recent Studies

The question whether EMF exposure from mobile phones has neuronal effects in the human situation was recently addressed by an American research group led by Volkow et al., conducting a PET study on ^{18}F-fluorodeoxyglucose (^{18}FDG) uptake (101). Though PET-studies on humans in correlation to EMF exposure have also been previously made, the purpose of this study was to extend the study material and use the more direct measure of brain glucose metabolism by the uptake of ^{18}FDG instead of the previously used CBF (cerebral blood flow) measure, which might be a more indirect sign of neuronal activity and also reflect short-term alterations (60s) as compared to the more long-lasting ones observed with ^{18}FDG (suggested to be in the range of 30 min). ^{18}FDG is actively transported across the BBB into the cells, where it is phosphorylated, and is, among others, used as a prognostic value for following low-grade brain tumours, where an increased uptake in previously low-

grade tumours is an indicator of anaplastic transformation (for review into the topic of ^{18}FDG and brain tumours (102).

(space)

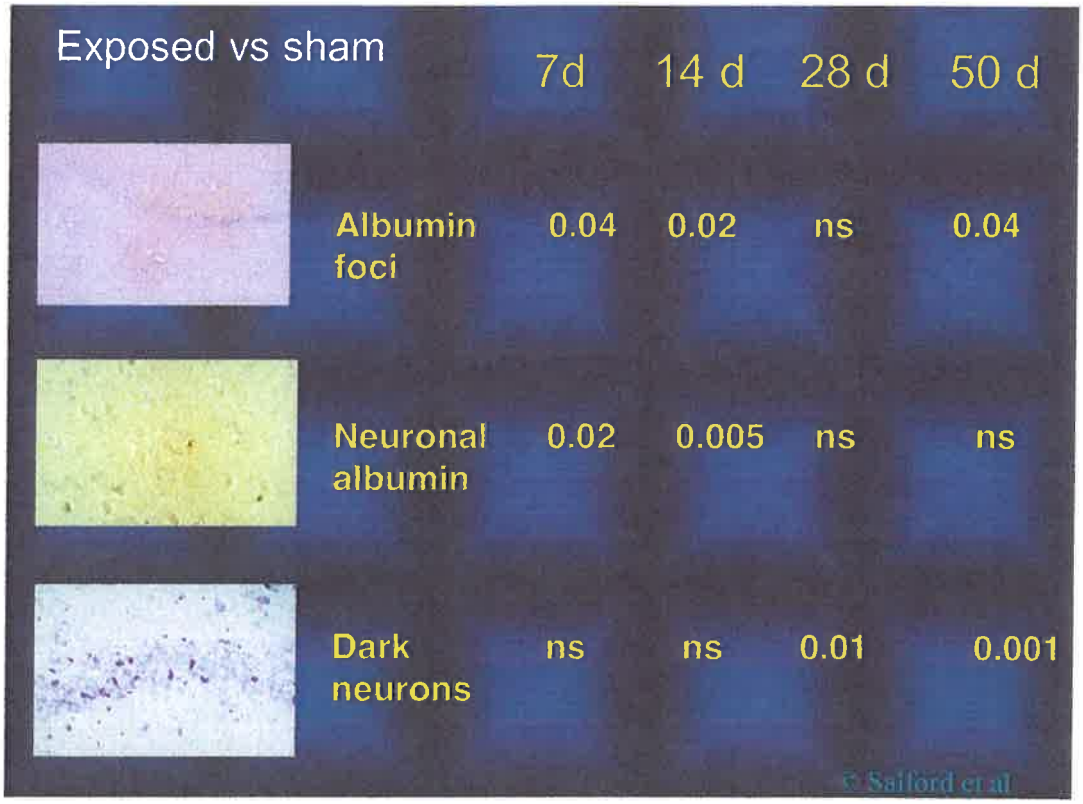
In the study by Volkow et al. (101), in total, 47 persons were involved, and effects upon brain glucose metabolism of EMF exposure were evaluated using PET with injection of ^{18}FDG. PET scans were performed both with and without EMF exposure (50 min of GSM-900 with maximum SAR of 0.901 W/kg), and the participants were blinded to the exposure situation. Whereas whole-brain metabolism was not affected, there were regional differences, in the right orbitofrontal cortex and the lower part of the right superior temporal gyrus (that is, the same side as the mobile phone was placed at) with increased metabolism in the exposure situation of about 7% as compared to control. There was a positive correlation between the strength of the E-field from the phones and the brain activation. Interestingly, it was hypothesized that RF-EMF exposure might increase the excitability of brain neurons.

Following the study by Volkow et al. (101), Kwon et al. (103) also investigated effects of GSM-900 exposure upon brain ^{18}FDG uptake. Thirteen persons were exposed to GSM-900 for 30 minutes to the right side of the head, and all subjects were also sham-exposed, and blinded to the exposure situation (SAR-values of maximum 0.74 W/kg in the head and 0.23 W/kg in the brain tissue). Contrary to the findings of Volkow et al. (101), the study by Kwon et al. (103) demonstrated a decrease in brain ^{18}FDG uptake after GSM-900 exposure, with decreased uptake values in the temporoparietal junction. A volume-of-interest analysis focused upon the right temporal lobe, showed a decreased ^{18}FDG uptake in the anterior inferior temporal cortex. No effects on task performance were found, and no correlation between temperature or ^{18}FDG uptake (a temperature increase of <0.21°C was found on the skin on the exposed side of the head) (103).

In the animal situation, Frilot et al. investigated the effect of ELF magnetic field exposure (2.5 G at 60 Hz) upon ^{18}FDG uptake in rats, comparing uptake with and without EMF exposure. An increased glucose uptake was found in the hindbrain when the field was orthogonally to the sagittal plane, but not when the angle varied randomly between the field and sagittal plane. These effects were hypothesized to be coupled to induction of electric field on the gate of ion channels (104).

Possible connection between BBB leakage and nerve cell injury

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 (105). Much speaks in favour 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 (Figure 8).



Exposed vs sham	7d	14 d	28 d	50 d
Albumin foci	0.04	0.02	ns	0.04
Neuronal albumin	0.02	0.005	ns	ns
Dark neurons	ns	ns	0.01	0.001

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Figure 8. Results from the Lund group (61-63)

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 favour 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 (106) in the stroke

prone hypertensive rat (105); and in acute hypertension by aortic compression in rats (22). Furthermore, it has been shown in other laboratories that epileptic seizures cause extravasation of plasma into brain parenchyma (21), and in the clinical situation the cerebellar Purkinje cells are heavily exposed to plasma constituents and degenerate in epileptic patients . There are indications that an already disrupted BBB is more sensitive to the RF fields than an intact BBB (74, 91). It has been stated by other researchers that albumin is the most likely neurotoxin in serum (64). It has been 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 axonal severe damage (65). 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.

Possible mechanisms

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 as described by Nittby et al. (107). 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 up-regulated 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 (7).

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 (108). As an example of this, it was reported by Chan et al.(109), 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 might exert its effects, has been proposed (110). 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 signalling 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 bio-membranes has been studied (111) and $Ca2^{+}$-efflux over plasma membranes has been observed in plasma vesicles from spinach exposed to ELF magnetic fields (112). 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 (113), 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 $Ca2^{+}$-channels, are one of the targets. More recently, new models for the interaction between magnetic fields and hydrogen nuclei also have been proposed.

EMF-induced $Ca2^{+}$-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 $Ca2^{+}$ should mediate these changes, thereby resulting in measurable alterations of intracellular $Ca2^{+}$-levels in brain capillary cells after exposure to BBB-disrupting agents (108).

Another hypothesis is that EMF-induced intracellular $Ca2^{+}$-alterations might affect Ets genes, which are transcription factors expressed in different tissues (114). 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.

EMF induced BBB permeability – with the aim of medical use

In the attempt to further try to understand the underlying mechanisms of the RF effects, we recently undertook a study upon snail nociception, with 1-hour GSM-1800 exposure of the land snail *H. pomatia*. This revealed, that the exposure induced analgesia in the snail model, with a significantly increased latency of reaction when placed on a hot plate, as compared to when only sham exposed. The vast knowledge about the physiology of the snail, its neurotransmission systems and it simplicity as compared the mammals may provide a tool for successful continued search for the mechanisms behind the effects of the GSM EMF upon biology (115).

In a recent study by Kuo et al (116), it was described how EMFs might be utilized to facilitate transport across the BBB. In an *in vitro* model, human micro-vascular endothelial cells were co-cultured with human astrocytes. Effects of EMF upon P-glycoprotein (P-gp) and multi-drug resistance -associated proteins (MRP) were tested in connection to treatment with anti-retroviral drugs, where the MRPs and P-gp are known to play an important role in multidrug resistance, which is encountered in carcinomas and therapies for acquired immune-deficiency (Kuo et al. 2012). With increasing EMF frequencies up to 900 MHz (both 715MHz and 900 MHz), the endocytotic uptake of calcein was increased (5mW, square wave with amplitude modulation at 20 MHz for 4 hours). Treatment with EMF could also inhibit expression of MRP and P-gp after treatment with anti-retroviral drugs, indicating that it might be useful in order to deliver antiretroviral proteins into the brain, by decreasing the efflux of the drugs due to the MRPs and P-gl.

Kuo et al. (117) also showed that EMF exposure (915 MHz EMFs at 5 mW with 20 MHz amplitude modulation for 4 hours) in combination with cationic solid lipid nanoparticles (CSLNs) could increase the transport of the antiretroviral drug Saquinavir 22-fold across human brain-microvascular endothelial cells (as compared to a 17-fold increase when only CSLNs were used).

Conclusions

In this review, we have reported the results of our group's research during the last 24 years, and the results of similar, but seldom identical, experiments of several other groups around the world. When summing up what we have described here, we are convinced that RF electromagnetic fields have effects upon biology, and we believe that it is more probable than unlikely, that non-thermal electromagnetic fields from mobile phones and base stations do have effects also upon the human brain. However, in this context, it is also important to point out, that the studies from our laboratory, as well as most studies presented above and available in literature, have been performed using animals and not humans. Thus no definitive conclusions can be drawn regarding effects of mobile phone use upon the human BBB.

However, studies in humans utilizing radiopharmaceuticals have been performed by Volkow et al. (101) upon brain glucose metabolism, and as was described by Saha et al. (118) already in 1994, studies with PET or SPECT and radiopharmaceuticals are used in brain imaging.

Further, a tool to directly study the human BBB has recently been described (119). It is based upon a non-radioactive methodology for *in vivo* non-invasive, real-time imaging of BBB permeability for conventional drugs, using nitroxyl radicals as spin-labels and MRI. In this connection, it should be mentioned though, that MRI has the drawback of possibly itself influence upon the results.

Based upon what has been presented here, we feel that the WHO IARC classification of RFR at the level 2B is adequate at present.

The question whether existing FCC/IEE and/or ICNIRP public safety limits and reference levels are adequate to protect the public is not easily answered. The reported studies on EMF induced BBB disruption have shown partially contradictory results from different laboratories. However, the fact that an abundance of studies do show effects is an important warning. This is true even if it can be summarized that the effects most often are weak and are seen in about 40% of the exposed animals.

However, we have stressed the following opinion in several publications during the past years: - "*The intense use of mobile phones, not least by youngsters, is a serious memento. A neuronal damage may not have immediately demonstrable consequences, even if repeated. It may, however, in the long run, result in reduced brain reserve capacity that might be unveiled by other later neuronal disease or even the wear and tear of ageing. We can not exclude that after some decades of (often), daily use, a whole generation of users, may suffer negative effects such as autoimmune and neuro-degenerative diseases maybe already in their middle age*".

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. These very low SAR-values, such as 1 mW/kg, 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. Further, when a mobile phone operating at 915 MHz (and its antenna) is held 1.4 cm from the human head, the very low SAR levels of 10 mW/kg exist in deep-lying parts of the human brain such as the basal ganglia, and the power density of 1 mW/kg and less is absorbed in thalamus bilaterally.

With this information as a background, it is difficult to recommend safety limits as the function of existing mobile systems might not allow for limits that produce SAR levels below 1 or 0,1 mW/kg in the human brain, which are reported to cause a pathological leakage of the BBB and to neuronal damage.

Demonstrated effects on the BBB, as well as a series of other effects upon biology (120) have given rise to scientific concern and to public anxiety. It is up to the society and our politicians 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.

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ABB

Press release | Zurich, Switzerland, 14 November 2018

Nokia, ABB and Kalmar conduct industry's first trial with ultra-reliable low-latency 5G technology for electricity grid and harbor automation

- Trial leverages ultra-low-latency capabilities of 5G within the research project called WIVE (Wireless for Verticals), part of the 5G Test Network Finland

- Project with ABB and Kalmar used Nokia's ultra-reliable low latency communication (URLLC) prototype for the first 'real-world' industrial trials

Nokia, ABB and Kalmar, part of Cargotec, today announced that they have successfully conducted industrial trials that leverage the low latency capabilities of 5G to support time-critical applications and enhance protection and efficiency in a smart electricity grid and in harbor automation. The

trials, conducted as part of the Wireless for Verticals (WIVE) research project, represent one of the first real-world applications of time-critical 5G applications on electricity grid and harbor automation.

URLLC (ultra-reliable low latency communications) has been identified as one of the three main usage scenarios for 5G due to its ability to transmit data, within a few milliseconds or less, with high reliability. The 3rd Generation Partnership Project (3GPP) has standardized the first version of URLLC solutions as part of the Rel-15 New Radio (NR) work.

In the first trial, Nokia and ABB demonstrated how URLLC technology can be applied to protection applications in medium-voltage distribution networks. It is of the utmost importance that severe faults are cleared immediately to keep the distribution network running, guaranteeing the safety of personnel and avoiding damage to equipment. The trial confirmed that 5G/URLLC fulfils latency requirements set by protection applications.

In the second trial, Nokia and Kalmar successfully demonstrated the ability of URLLC technology to advance container yard automation. Reliable and low-latency messages are required, for example, in safety related messages.

"Managing power distribution networks with an increasing amount of distributed energy resources and an increasing need of flexibility requires advanced technology for protection, control and monitoring. The 5G URLLC technology provides an affordable communication platform for deployment of these advanced technologies. The results of the WIVE project are encouraging for future utility-scale implementation of 5G," said Petri Hovila, program manager at ABB.

Automation research director Pekka Yli-Paunu from Kalmar, part of Cargotec, said: "Network slicing in 5G networks brings a higher level of predictability and control for our safety-related applications. 5G connection should work at the same level of reliability, latency, and bandwidth as cables, and its management should be simple enough."

Mikko Uusitalo, head of wireless advanced technologies research at Nokia said: "Industry collaboration is essential in fostering innovation around 5G and for enabling different industries to take full advantage of the promises of 5G, especially the low latency combined with high reliability. The WIVE project has provided us with greater insight into the requirements and opportunities for

experimentation to test our solutions. In this project, Nokia created concepts of how to make 5G URLLC possible and implemented some of these technologies as a prototype that has been tested. It is great to see the solutions moving towards reality."

Tomi Sarajisto, research manager from Telia Company's emerging businesses unit Division X said: "Within the WIVE project we are working with the participating companies to accelerate the industrial revolution in Finland. Telia has explored new areas where 5G solutions will most likely produce breakthroughs in introducing new, more effective processes. In the trials we have studied how lightning-fast 5G will advance electricity grid infrastructure protection and harbor automation."

"Aalto University has been studying opportunities of 5G technologies in smart grids. A particular focus has been on protection and fault location applications and in packet core performance. We are thrilled about the economic potential that 5G technologies bring to the industrial internet, where low latency and reliable communications are key to elements like safety and automation, remote control of moving machines and distributed green power generation and storage," said Raimo Kantola, professor at Aalto University Department of Communications and Networking.

"VTT has examined URLLC requirements for different vertical use cases, and utilized 5G Test Network Finland testbed facilities to both implement and validate different URLLC solutions. Within the project, VTT has collaborated with WIVE partners to build a latency measurement setup to test and develop communication-critical components already in their prototyping stage for grid protection and container yard automation," states Seppo Horsmanheimo, principal scientist at VTT.

The WIVE project is co-funded by Business Finland and involves several industry research units and academic partners such as Nokia, Teleste, Telia, ABB, Kalmar, the Finnish Broadcasting Company (YLE), Digita, regulator FICORA, key Finnish universities as well as VTT Technical Research Centre of Finland.

Read more about the WIVE project from the https://wive.turkuamk.fi/

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Kalmar Asserts the Revolutionary Potential of 5G

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Following a trial of 5G applications to test the network's reliability, capacity, speed and security, Kalmar's Director of Automation Research Pekka Yli-Paunu has reviewed the initiative.

Expectations for the increased implementation of 5G technology have been high, and the next phase of mobile connectivity is expected to support a variety of near future use cases, as well as boosting the development of the logistics sector.

Working in collaboration with Nokia, Kalmar's trial demonstrated the ability of URLLC (https://www.porttechnology.org/news/kalmar_abb_and_nokia_trial_5g_applications#kalmar_global) (ultra-reliable low latency communications) technology to advance container yard automation.

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View Kalmar's automated solutions for ports and terminals in PTI's Supplier Directory (https://www.porttechnology.org/directory/kalmar_global)

Yli-Paunu commented: "Thanks to the trial with Nokia, we were able to build a technology road map to 5G, to see how to proceed towards it and when to take certain steps."

According to Kalmar's review, the case study of an automated rubber-tyred gantry crane (RTG) yielded practical insight into the industry's requirements for 5G technology.

Director of Automation Research, Pekka Yli-Paunu (Photo Credit: Kalmar)

"RTG is equipped with multiple cameras, and video data takes a lot of bandwidth. Remote control means there is a need for low and predictable latency.

"On the other hand, advances in connectivity give us the opportunity to develop the next generation of remote control that may utilise, not only video, but audio and haptics as well."

The full potential of 5G is significant, the technology able to fulfil requirements of reliability, security, speed and bandwidth, even when different applications have varying demands.

Peter Söderberg, Kalmar, discusses eco-efficient terminal operations in a recent Port Technology technical paper (https://www.porttechnology.org/technical_papers/eco_efficiency_in_terminal_operations#kalmar_global)

Yli-Paunu has predicted that 5G will be the industrial standard of the future, combining terrestrial and mobile networks.

The automation expert also discussed how virtual networks, or "slices", will operate under 5G: "When a terminal tractor is connected to a specific slice, for example, its activities are easily and accurately monitored in all circumstances. That adds to the overall safety and operational efficiency of a port."

Sliced networks, powered by 5G, support both human and machine communications, enabling smart cargo handling as a result.

Read more:

- **Nokia Drives Digitalization at Finland Terminal (https://www.porttechnology.org/news/nokia_drives_digitalization_at_finland_terminal)**

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KALMAR

10 January 2019 Reading time 3 minutes

PEOPLE · CONTAINER HANDLING AUTOMATION INTELLIGENT SYSTEMS R&D

Kalmar moves towards 5G

In the future, 5G will fulfil port automation needs for reliability, capacity, speed and security. Kalmar has successfully conducted one of the industry's first trials with ultra-reliable, low-latency 5G technology in collaboration with Nokia.

Pekka Yli-Paunu, Director of Automation Research at Kalmar, reviews the trial with satisfaction. Expectations for 5G technology have been high in the field of cargo handling, and now they are backed up by test results. 5G supports a wide

variety of near future use cases and boosts development of applications in the logistics sector.

Yli-Paunu explains: "Thanks to the trial with Nokia, we were able to build a technology road map to 5G, to see how to proceed towards it and when to take certain steps."

In the joint trial, Nokia and Kalmar successfully demonstrated the ability of URLLC (ultra-reliable low latency communications) technology to advance container yard automation. The trial was carried out at Kalmar's Technology and Competence Centre test yard in Tampere, Finland. A case study of an automated rubber-tyred gantry crane (RTG) yielded practical insight into the industry's requirements for 5G technology.

"RTG is equipped with multiple cameras, and video data takes a lot of bandwidth. Remote control means there is a need for low and predictable latency," Yli-Paunu says. "On the other hand, advances in connectivity give us the opportunity to develop the next generation of remote control that may utilise, not only video, but audio and haptics as well."

Safer and more reliable communications

All automated port operations rely on real-time connectivity. Once 5G reaches its full potential, it should fulfil the needs for reliability, security, speed and bandwidth, even when different applications have varying requirements. Meanwhile, there will be useful wireless solutions with 4G LTE and WiFi, and Kalmar is exploring these as well. But, as Yli-Paunu points out, 5G will be the industrial standard of the future and a concept that combines terrestrial and mobile networks.

One major change that 5G is bringing is the ability to partition the network into virtual networks, so-called slices. For example, a private network can be deployed to cover a port area and customised to meet various application needs. "When a terminal tractor is connected to a specific slice, for example, its activities are easily and accurately monitored in all circumstances. That adds to the overall safety and operational efficiency of a port," says Yli-Paunu.

A sliced private 5G network supports both human and machine communications and enables smarter cargo handling unlike any technology seen before.

"Kalmar is a dream come true for a person who is truly interested in technology."

An engineer's dream

The joint trial of Kalmar and Nokia is part of a much larger research project, *Wireless for Verticals*, involving several industry research units and academic partners. Yli-Paunu sees that as an excellent opportunity for networking, getting fresh ideas for the future, and for co-shaping the standard.

"A diversified network is a valuable asset to our research team for keeping our finger on the pulse of technological development. At the moment, we are very interested in measurement techniques in the automotive industry and XR technologies."

Trialling 5G combines elements that make an engineer's life interesting: new technologies, useful solutions that solve customers' challenges, and in the future, new scenarios created by IoT and Industry 4.0.

Yli-Paunu sees his work as an exciting adventure in technological development and making things ever better. "Kalmar is a dream come true for a person who is truly interested in technology. The systems and devices you design become real and make big machines work – maybe even in front of your very eyes in our test yard!"

Pekka Yli-Paunu
Age: 56
Education: Licentiate in Technology, Automation & Hydraulics.
Primary work experience: 16 years of automation R&D at Cargotec and Kalmar, CEO in an engineering office, and several years as a research scientist at VTT, The Technical Research Centre of Finland.
Family: wife and son.
Hobbies: Sailing, boat DIY and maintenance, including technical devices – that's plenty to do all year round!

Themes in this article

Collaboration Technology

Comments

Finland ironically becomes latest front in global 5G health battle

• Jeremy Horwitz
4 months ago

Nokia's offices in Espoo, Finland, July 28, 2015.

Finland has played a large role in developing and deploying 5G cellular technologies. Now a small group of Finnish citizens is trying to stop the spread of 5G base stations, suggesting that their higher levels of electromagnetic radiation may threaten human health.

Currently backed by over 2,300 supporters, Helena Ertz's petition(translated) asks Finland's government to completely ban "5G technology" on one key ground: 5G base stations are more densely placed than their 4G predecessors, increasing citizens' exposure to potentially dangerous radiation. The petition also posits that "the frequencies used by 5G technology are harmful to health," a claim Ertz says has been brushed aside, despite support from scientists and doctors in multiple countries.

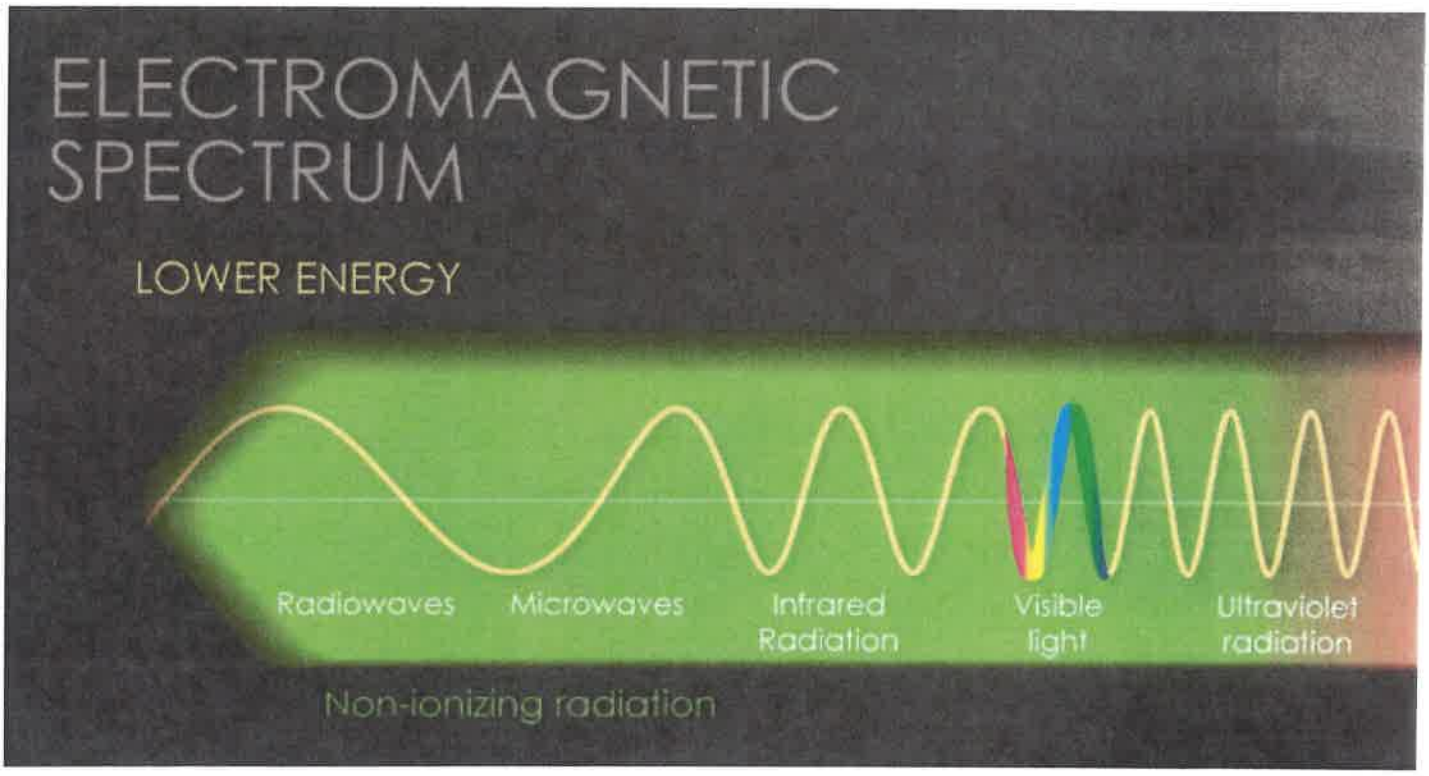
The Finnish petition isn't the first effort to halt 5G network rollouts, but it's ironic given the country's historic involvement in creating new cellular technologies. Since Finnish citizens have been among the first to be exposed to every prior generation of cellular technology — including experimental ones — there have been endless opportunities to raise concerns before now.

Spurred by Nokia, the University of Oulu, and Finland's government, Finnish engineers have been involved in developing cellular phones for decades. They were among the first to test 5G networks, a years-long process, and have already started work on next-generation 6G cellular technology. Last June, Finnish carrier Elisa became one of the world's first carriers to launch a commercial 5G

network, another illustration of the small country's outsized role in moving cellular standards forward.

Despite the push to quickly open 5G networks around the world, small groups in some European and U.S. cities have recently called for bans or delays pending research into the potential health impacts of the new cellular technologies. These health-focused movements are generally but not always separate from efforts to stop or slow down 5G rollouts based on local aesthetic concerns or loss of zoning revenues.

Thus-far unproven claims suggest that 5G's new millimeter wave signals or increased concentrations of mid-range (sub-6GHz) radio waves could damage human cellular structures. The Finnish petition claims that 2G, 3G, 4G, and Wi-Fi have already impacted human brains, increased cancer risks, and reduced fertility. Stronger 5G signals can increase these effects, it adds.



These claims have largely been dismissed by both electronic engineers and governments. Radio waves are believed to be non-ionizing — incapable of deep penetration into the body or changing cellular structures, apart from generating heat — which is the reason radios, televisions, and cell phones have become internationally ubiquitous over the years. People have tolerated higher-frequency emissions from microwave ovens, satellites, and airport body scanners for years, seemingly without health impacts.

But the debate over wireless radiation isn't over. Prior to the rollout of 5G, government agencies such as the U.S. Centers for Disease Control and Prevention took a "wait and see" approach, suggesting that additional research is needed to conclusively determine whether cellular devices can impact users' health — but hasn't called for cell phones to be banned as research continues. By contrast, the Finnish petitioners are demanding a 5G ban, then a thorough study of wireless radiation impacts, followed by clear limits on the exposure of electromagnetic radiation in common spaces.

Whether Finland's government will act on the petition remains to be seen: 50,000 signatures are needed to force the parliament to officially consider it, and it's at less than 5 percent of that level now. A $20,000 Kickstarter campaign to get the U.S. government to research and publicize the supposed health effects of 5G currently has 14 days left to get beyond its current $2 of support from two backers.

Environment

Does cellphone use kill birds? Experts weigh in on idea promoted by Shankar's '2.0'

Across the country, we're seeing migratory birds crash landing into poles and fences in urban localities - are cellphones the reason?

Priyanka Thirumurthy
Tuesday, December 04, 2018 - 15:22

Screenshot from YouTube/Gazab Wood

Avian and exotic animal specialist Dr. Rina Dev has been a practicing veterinarian for over a decade now in India's financial capital and has always maintained that her feathered patients are superior in intelligence to even canines. But over the last five years, Rina has been witnessing a strange and worrisome phenomenon in Mumbai. Several migratory birds that pass over the city in winter have been crash landing into populated areas and even industrial zones, far removed from forests or water bodies where they traditionally halt.

"I get at least three pallid scops owls in my clinic every single week and the latest one was found in an industrial area in Andheri East," reveals Dr. Rina. "They are crashing into buildings and poles. Their behaviour is far from normal," she adds.

And close to 1000 kilometres from Mumbai, in the garden city of Bengaluru, Jayanthi Kallam, the co-founder of the Avian and Reptile rehabilitation centre narrates a similar ordeal. For three years now, the Indian Pitta which migrates from the Himalayas to Sri Lanka, has been found disoriented and weak in the lawns of homes in Karnataka's capital city.

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"They migrate in September and October and sighting is very rare," says Jayanthi. "But this year, we found at least 12 birds that had lost their way. Why were they bumping into poles and why were they flying so low in populated areas has become a matter of concern," she adds.

Across India, rescuers and experts in the avian field are recounting similar abnormal behaviour amongst birds flying through cities. And what was a daily subject of conversation for only those concerned with the field of ornithology has now entered public domain, following the release of director Shankar's 2.0, starring actors Rajinikanth and Akshay Kumar in lead roles.

In the film, Akshay plays the role of an ornithologist who attempts to make the public aware of the effect of electromagnetic field radiation (EMF) from cellphone towers on the avian species. Scenes in the film show birds crashing to their deaths due to disorientation. It holds no punches and has created a flutter amongst audiences across the country, with its message - radiation from cellphone towers is killing birds.

'Everyone with a cellphone is a murderer'

This is the claim that Pakshirajan (Akshay Kumar's character), a cellphone snatching "evil aura", wildly declares. In a flashback sequence ahead of the interval in the movie, the "aura", which is out to destroy cellphone towers, recalls how he was once a kind and gentle ornithologist. As the years pass, a cellphone tower is set up near his home and he notices birds behaving strangely in the sanctuary he has built for them. They smash into fences, come crashing into the ground and even face severe reproductive issues. He appeals to multiple government authorities, all the while stating that it is the increasing presence of electromagnetic field radiation that is causing the death of birds. He points that if we do not put an end to it, the end of humanity will soon be upon us.

According to the National institute of Environmental Health and Sciences, electric and magnetic fields (EMFs) are invisible areas of energy, often referred to as radiation, that are associated with the use of electrical power and various forms of natural and human-made lighting. EMFs are typically grouped into one of two categories by their frequency - Non-ionizing, which means low-level radiation and is generally perceived as harmless to humans, and Ionizing, which is high-level radiation and has the potential for cellular and DNA damage.

Many experts have pointed out that cellphone towers emit non-ionised radiation that is different from nuclear radiation or even the waves you are exposed to while getting an X-ray done. While these rays cannot penetrate deep into the cells of humans or affect molecular structure, they create very stressful situations for birds in urban areas (where there is a larger concentration of towers).

But stakeholders in India's massive cellular industry wouldn't hear any of it. Two days ahead of the movie's release, the Cellular Operations Association of India had written to the Central Board of Film Certification (CBFC) over the film's depiction of mobile phones. According to a complaint letter by the 'non-governmental society' that is 'dedicated to the advancement of modern communication', the film "falsely depicts mobile phones and mobile towers as harmful to living creatures and the environment including birds and human beings, on account of electromagnetic field (EMF) emissions from them."

The association even claims that the depiction of mobile services and towers is 'false, based on no evidence and wholly fictional'. But studies conducted both abroad and in India, show that there is definitely reason to be concerned.

What does science say?

As recent as May 2018, an analysis of 97 studies by the EU-funded review body EKLIPSE concluded that radiation from cellphone towers, phone masts, WiFi and broadcast transmitters is a potential risk to insect and bird orientation and plant health. The report found that the magnetic orientation of birds, mammals and invertebrates such as insects and spiders could be disrupted by EMR. Authors of the review have stressed on the need to strengthen the scientific basis of knowledge on EMR and its impact of wildlife. In fact, 237 scientists have reportedly appealed to the United Nations through a petition, asking them to take risks posed by electromagnetic radiation more seriously.

Closer home, an expert group was formed by the Ministry of Environment and Forestto study the possible impacts of communication towers on wildlife, including birds and bees. It pointed out that India is likely to become one of the world's largest markets for cellphones and was devoid of any policy on infrastructure development and location of cell phone towers. They studied 919 reports on the effects of EMF, with 81% of the reports cataloguing effects on humans, 3% recording effect on birds and just 2% on wildlife. But even in the 30 existing studies, 23 concluded that EMF had a negative impact on birds while 6 out of 7 studies concluded negative impact on bees.

The observations made on impact on birds include that they are at higher risk of radiation exposure due their ability to fly, that EMR affects their ability to recover from acute physiological stressors, radiation causes acute physiological stressors, potential physiological and behavioural repercussions and malformation in embryos.

Jayanthi Kallam further points out that the feathers of birds act as receptors of high levels of EMF.

"When exposed to high EMF, these birds receive a small electric shock that can impact their flight and even the path they take. Birds use magnetic navigation to travel, but then contrasting magnetic fields present in the atmosphere will leave them completely disoriented," she points out. "In urban areas they are already exposed to high levels of noise and air pollution. Increased levels of EMF could just be the straw that broke the camel's back," she adds.

Or in this case, as per the MoEF study, it could be the reason we do not see sparrows in our cities any more.

"Reproductive and co-ordination problems and aggressive behavior has also been observed in birds such as sparrows (due to EMF) (Balmori, 2005). General methodology used for such study was, from each area, all sparrows were counted in addition to the mean electric field strength (Everaert & Bauwens, 2007). In similar studies in India, population of Passer domesticus was found fast disappearing from areas contaminated with electromagnetic waves arising out of increased number of cell phones, in Bhopal, Nagpur, Jabalpur, Ujjain, Gwaliar, Chhindwara, Indore & Betul (Dongre & Verma, 2009). It was also observed that when 50 eggs of House Sparrow, exposed to electromagnetic radiation (EMR) for durations of five minutes to 30 minutes, all the 50 embryos were found damaged in a study carried out by the Centre for Environment and Vocational Studies of Punjab University (Kumar 2010, Ram 2008)," reads the report.

In bees, studies have linked electromagnetic radiations with an unusual phenomenon known as 'Colony Collapse Disorder'. Colony Collapse Disorder (CCD) occurs when a 'hive's inhabitants suddenly disappear, leaving only queens, eggs and a few immature workers. The vanished bees are never found, but thought to die alone, far from home. The theory is that radiation from mobile phones interferes with bees' navigation systems, preventing them from finding their way back to their hives'. Bees are considered crucial to sustaining human population on this planet.

But Asad Rahmani, former director of Bombay Natural History Society, who also chaired the commitee that came out with report, expresses doubt over these studies.

In an interview to Deccan Herald he has said, "People feel because of cell phone and mobile tower radiation, the number of house sparrows are on a decline. But the feeling is not science. There is no scientific proof between electromagnetic radiation and absence of sparrows. In the countryside there is no dearth of house sparrows. And if radiation is the culprit, then why are pigeons still around in the cities?"

Rahmani acknowledged that there were several gaps in their study and said, "Our study was a baseline one, with information collected from various parts of India. However, we did not do experiments. To collect data, we would have had to take a fixed sample size, in this case, live birds, and subject them to radiation and then monitor changes in their body. But we did not do this."

Ornithologist Mohammad Dilawar who has studied house sparrows extensively and was a member of the expert committee, points out that EMF radiation could be a factor affecting sparrows. But he also adds that there could be other reasons.

"Studies abroad have conclusively proved that when the number of cellphones in an area increase, the number of sparrows decrease and vice-versa. However, in India, the topic has not been studied well. In the 2011 MoEF study, we had said that EMR could be one of the reasons why sparrows were vanishing but not the only reason. Other reasons include lack of nests and food," he told Down To Earth, following the release of the film. "But if this is what the plot of the movie is about, then it is a good thing that popular cinema has started talking about electromagnetic radiation or EMR. EMR is an invisible kind of pollution. So far, we have seen other kinds of pollution being depicted in documentaries and popular cinema, but not EMR," he said.

Physicists whom TNM contacted also maintained that current data available on the subject did not provide conclusive information on the adverse effects of EMF radiation.

The 2011 report too highlights the need to conduct more studies in this area of EMF radiation and the effects it has on wildlife. It suggests that EMF should be recognised as a pollutant and regular auditing should be conducted in urban localities/educational/hospital/industrial/residential/recreational premises and around the protected areas and ecologically sensitive areas. It also stressed on the need to introduce a law for the protection of urban flora and fauna from emerging threats like EMF, as conservation issues in urban areas are different from wildlife habitats. It further calls for independent monitoring of radiation levels and overall health of the community to be conducted. It specifically focused on monitoring animal mortality.

7 years later, little has been achieved

Director Shankar is not the first member of the film industry to raise an alarm in regard to EMF radiation pollution. As early as 2013, Bollywood actor Juhi Chawla came out in public to protest against the setting up of mobile towers in residential areas. She shared her fear of illnesses that could be caused because of EMF radiation from a tower set up at a government guest house near her home. She filed a case and it is currently pending in Supreme Court. Five years later, however, there has been no change on ground.

In February this year, the actor-cum-movie producer wrote a letter to Maharashtra Chief Minister Devendra Fadnavis, cautioning against the health hazards due to EMF radiation from mobile tower antennas and WiFi hotspots. She further sought to know whether the Centre, which is implementing 5G to achieve the objectives of Digital India, has done enough research on the new technology.

Dr. Rina Dev points out that the MoEF is responsible for ensuring that these studies are conducted immediately.

"Flamingos that are flying in from Siberia are crash landing in Mumbai. Unless we conduct studies backed by the government, we will not be in a position to understand what exactly is happening," she points out.

Jayanthi meanwhile says that time is of essence and that EMF radiation cannot be ruled out merely because only birds and insects seem to be affected.

"The same was thought of pesticides. We saw it first affect insects, then birds and finally we saw what happened to humans who ate food sprayed with the chemical. And now we are all trying to switch to organic produce," she says. "In the case of EMF, we need to recognise its danger with thorough studies and counter it before we can see the adverse effects it will have on human beings."