

Distinguished Lecture

RF Safety Issues: why so controversial?

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*Speaking as an individual and not for the IEEE

Outline

- History of the issues
- Controversies
- Key concepts
- Research
- Publication
- Standards
- Regulations
- Risk communication
- Conclusions
- Q&A

History of the RF safety issues

RF Sources (year)



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Radio and TV Broadcasting (60-70's)

Microwave Oven (70-80's)

Police Radar (80's)

Wireless Communication (90's - ?)

(mobile phones 2-5 G, base stations, Wi-Fi,

WiMAX, smart meters, RFID, etc.)

•Wireless power transmission (2012-?)













Common understanding (mainly from media)





- We don't have enough understanding of its effects
- Many reports show non-thermal effects
- Radiation can cause cancer, and many other diseases
- The standards are not protective
- Need precautionary measures to be safe than sorry

Established Scientific Understanding (in green)

- Microwave (RF) radiation is dangerous
- Only when at high intensity
- We don't have enough understanding of its effects
- ✓ There have been 70 years of research
- Many reports show non-thermal effects
- Either not repeatable or no proven health effects
- It can cause cancer, and many other diseases
- ✓ No proof and no mechanism other than heating
- The standards are not protective
- ✓ Worldwide expert groups and health authorities agree they are
- Need precautionary measure to be safe than sorry
- Safety standards already have large safety margins





What are the causes of the controversies ?

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Root of Concerns: "Radiation"



10 eV Non ionizing Ionizing 300.000 km 300 km 300 m 30 cm 0,3 mm 0,3 µm 0,3 nm Wavelength -Frequency--1 Hz 1 KHz 1 MHz 1 GHz 1 THZ 1 PHz 10¹⁸Hz Micro-Static Infrax-Ray, ELF RF UV Gamma Field waves red Radiation (*** Photon Energy (eV) • 10-6 10-8 1,7 3,1 120 10-9 10-11

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Ionizing vs. Non-Ionizing Energy

- Ionizing

Damage DNA

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- Sufficient energy to alter chemical bonds and atomic structures
- Confirmed health effects include genetic damage
- Effects can occur from cumulative exposures
- Research since early 1900

- Non-ionizing (including RF)
 - Lower photon energy, insufficient to cause effects like those above
 - o Only confirmed RF health effects relate to tissue heating at levels well
 - above limits for wireless communication
 - No known chronic/cumulative effects
 - Research since the end of WWII (~1950)

Diathermy since 1946

Steps to address safety concerns



Research: Study Strengths and Weaknesses

- <u>Epidemiological studies:</u> (Greatest weighting WHO, IARC)
 - Distribution of disease in human populations and factors affecting disease
 - BUT can be subject to bias and confounding factors
- Human studies:
- Response of people to an agent such as RF
- BUT short-term exposure and selection (usually healthy volunteers)
- Animal studies:
- Responses of mammals to an agent such as RF
- BUT differences in metabolism, physiology, lifespan, etc
- In vitro studies:

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- (Least weight)
- Rapid inexpensive testing for possible interaction mechanisms
- BUT simple systems may not be applicable to whole organism

WHO Comment on Database (2021)



EMF biological effects or health effects?

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 "Scientific knowledge in this area is now more extensive than for most chemicals."

"....current evidence does not confirm the existence of any health consequences from exposure to low level* electromagnetic fields."
*Low level means below the current international exposure guidelines

https://www.who.int/news-room/q-a-detail/radiation-electromagnetic-fields

Quality of Science (Established vs. Possible) (Facts vs. Opinions)



Adapted from Osepchuk [2004]

"Good science is never outdated." -- Herman P. Schwan

Fact: it can be proven, and must be always true.

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Professor Arthur W. Guy

Jack Anderson Journalist 1970 reported on US Embassy in Moscow

> Part 1 effects on isolated nervous tissues (clarify Soviet studies in 1964)

Part 2 microwave auditory effects (clarify American studies before 1971) THE EFFECTS OF ELECTROMAGNETIC FIELDS ON

THE NERVOUS SYSTEM

CHUNG-KWANG CHOU

by



A dissertation submitted in partial fulfillment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY

UNIVERSITY OF WASHINGTON

1975

(Chairman of Supervisory Committee) Approved by

Department Electrical Engineering

(Departmental Faculty sponsoring candidate)

August 15, 1975 Date

Biological Complexity (subjects used at UW and City of Hope)

- In vivo study
 - Species

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- Strain
- Sex
- Age







- Extrapolation from animal to humans
- In vitro study
 - Monolayer
 - Cell suspension
 - Isolated tissue
 - Extrapolation to in vivo











Engineering Complexity (at UW and Motorola)

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- Exposure systems
- Far Field
- Near Field
- Dosimetry
- Resonance
- Modulation
 - CW, Pulsed
 - AM, FM, TDMA, CDMA, LTE, 5G
- Experimental Artifacts
- Temperature Control

















H field

Chou et al. Radio Frequency Electromagnetic Exposure:

May 4, 2021

A Tutorial Review on Experimental Dosimetry. Bioelectromagnetics 17(3):195-208, 1996.



"I've got it, too, Omar . . . a strange feeling like we've just been going in circles." Unbalanced research ability in either biological science or engineering expertise (or both are weak) makes dealing with the complexities difficult

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Examples of Research Controversy

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Bioelectromagnetics 4:63–77 (1983)

Chronic Exposure of Rabbits to 0.5 and 5 mW/cm² 2450-MHz CW Microwave Radiation

Chung-Kwang Chou, Arthur W. Guy, Lucinda E. Borneman, Lawrence L. Kunz, and Piro Kramar

Department of Rehabilitation Medicine, Bioelectromagnetics Research Laboratory (C.-K.C., A.W.G., L.E.B., L.L.K), and Department of Ophthalmology (P.K.), University of Washington School of Medicine, Seattle

US-USSR exchange program research

Soviet group reported effects on cytochemical and immunological functions of rats at 10 µW/cm²

US group found no effect other than the food consumption in rabbits exposed at 5 mW/cm²



Fig. 7. Food consumption of rabbits exposed to 2450-MHz fields at 5.0 mW/cm².

Behavior effect study on rats

Korbel, S. F., Thompson, W. D. (1965). Behavioral effects of stimulation by UHF radio fields II. Psych. Rep. 17:592–602.

Dosimetry study to reveal what actually happened

1 mW/cm² Induced behavioral effect



Up to 185 W/kg !



THROUGH LINE A 277 W/20 SEC PEAK ABSORPTION 5.13 mW/cm³



THROUGH LINE C 278W/7SI PEAK ABSORPTION 14.10mW/c



THROUGH LINE B 278W/IO SEC PEAK ABSORPTION 7.37mW/cm³ LINE I 3 LEGS IN CONTACT



THROUGH LINE D 277 W/10 S PEAK ABSORPTION 7.16 mW

Guy, A. W., Korbel, S. F. (1972). Dosimetry studies on UHF cavity exposure chamber for rodents. Summaries of papers presented at The 1972 Power Symposium, Ottawa (Canada)







Brain Research 904 (2001) 43-53

www.elsevier.com/locate/bres

Research report

Effects of low intensity radiofrequency electromagnetic fields on electrical activity in rat hippocampal slices

John E.H. Tattersall^a,*, Iain R. Scott^a, Sebastien J. Wood^a, Julia J. Nettell^a, Michael K. Bevir^b, Zhou Wang^c, Nalinda P. Somasiri^c, Xiaodong Chen^c

^aBiomedical Sciences Department, CBD Porton Down, Salisbury SP4 0JQ, UK ^bPoynting High Voltage Ltd, 4 Harrier Park, Hawksworth, Didcot OX11 7PL, UK ^cDepartment of Electronic Engineering, Queen Mary and Westfield College, London E1 4NS, UK

Accepted 20 March 2001



Figure 3. Effects shown on the left were verified to be caused by a metallic electrodeinduced heating (horizontal bar for RF exposure) [John Tattersall IEEE TC95 presentation in London, Minutes of the March 2007 meeting Attachment 8, http://www.icesemfsafety.org/meetings_archive.php].



Repacholi M. H., Basten A., Gebski V., Noonan D., Finnie J., Harris A. W. LYMPHOMAS IN Eu-Pim1 TRANSGENIC MICE EXPOSED TO PULSED 900 MHz ELECTROMAGNETIC FIELDS. Radiat. Res., Vol. 147, Pg. 631 - 640, 1997

Used a better controlled exposure system, effects not observed



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Developed by Motorola

- The findings showed that long-term exposures of lymphomaprone mice to 898.4 MHz GSM radiofrequency (RF) radiation at SARs of 0.25, 1.0, 2.0 and 4.0 W/kg had no significant effects when compared to sham-irradiated animals.
- A previous study reported that long-term exposure of lymphoma-prone mice to one exposure level of 900 MHz RF radiation significantly increased the incidence of non-lymphoblastic lymphomas when compared to sham-irradiated animals.

Utteridge TD, Gebski V, Finnie JW, Vernon-Roberts B, Kuchel TR. 2002. Long-term exposure of Em-Pim1 transgenic mice to 898.4 MHz microwaves does not increase lymphoma incidence. Radiat Res 158:357–364.



University of Washington

Life time exposure of 200 rats to pulsed RF fields

[Chou et al., 1992]



Incidence of neoplasia

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Exposed		<u>Sham</u>		
В	Μ	В	Μ	B: Benign tumor
62	18*	53	5*	M: Metastatic malignancy

*A statistically significant increase of primary malignancies in exposed rats vs. incidence in controls is a provocative finding, but the biological significance of this effect in the absence of truncated longevity is conjectural.

Chou et al. Long-term low-level microwave irradiation of rats, Bioelectromagnetics, Vol. 13, Pg. 469 - 496, 1992

Cancer increase not confirmed in two follow-up mice studies funded by Air Force

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Toler et al. "Long-term, low-level exposure of mice prone to mammary tumors to 435 MHz radiofrequency radiation" Radiat. Res., 148: 227-234, 1997

Frei et al. "Chronic Exposure of Cancer-Prone Mice to Low-Level 2450 MHz Radiofrequency Radiation". Bioelectromagnetics 19:20-31, 1998

National Toxicology Program (NTP) Study on Male Rats (2018)



Pathology findings – Brain

Hyperplastic Brain Lesions in Male Rats

	Control	GSM Modulation			CDMA Modulation		
	0 W/kg	1.5 W/kg	3.0 W/kg	6.0 W/kg	1.5 W/kg	3.0 W/kg	6.0 W/kg
Number examined	90	90	90	90	90	90	90
Malignant glioma [‡]	0*	3 (3.3%)	3 (3.3%)	2 (2.2%)	0	0	3 (3.3%)
Glial cell hyperplasia	0	2 (2.2%)	3 (3.3%)	1 (1.1%)	2 (2.2%)	0	2 (2.2%)

[‡] Historical control incidence in NTP studies: 11/550 (2.0%), range 0-8%

* Significant SAR-dependent trend for CDMA exposures by poly-6 (p < 0.05)

National Toxicology Program (NTP) Study on male rats (2018)



Pathology findings – Heart

Hyperplastic Heart Lesions in Male Rats

	Control	GSM Modulation			CDMA Modulation		
	0 W/kg	1.5 W/kg	3.0 W/kg	6.0 W/kg	1.5 W/kg	3.0 W/kg	6.0 W/kg
Number examined	90	90	90	90	90	90	90
Schwannoma [‡]	0*	2 (2.2%)	1 (1.1%)	5 (5.5%)	2 (2.2%)	3 (3.3%)	6** (6.6%)
Schwann cell hyperplasia	0	1 (1.1%)	0	0	0	0	3 (3.3%)

[‡] Historical control incidence in NTP studies: 9/699 (1.3%), range 0-6%

* Significant SAR-dependent trend for GSM and CDMA exposures by poly-3 (p < 0.05)

** Significant different than controls poly-3 (p < 0.05)

NTP study (2018)





Greater survival in all groups of exposed males compared to controls

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Korea and Japan are conducting a NTP validation joint study

- whole-body average SAR of 4 W/kg at 900 MHz (CDMA) for 70 male rats each country
- Long term exposure is ongoing

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Dec 2023 is the end of the 5 year study

Bioelectromagnetics Supplement 6:S101 – S106 (2003)

Survival and Cancer in Laboratory Mammals Exposed to Radiofrequency Energy

Joe A. Elder*

Motorola Florida Research Laboratories, Ft. Lauderdale, Florida

This article is a review of the effects of radiofrequency (RF) energy on (1) survival and (2) cancer in the same animal populations having survival data. The literature consisted of 18 studies with survival data, and 16 of these have information on cancer. In one study, a significant decrease in lifespan was observed at 6.8 W/kg but not at 2 W/kg. Thermal stress appears to be the causal factor for the effect on lifespan because the higher dose rate, unlike the lower dose rate, was estimated to increase body temperature significantly. The finding that the lower level was without effect is consistent with the results of a number of recent studies showing that long term, low level exposure to RF energy did not affect survival adversely. Many of these recent studies addressed the cancer issue by histopathological analysis of many organs and tissues following exposure up to 2 years, the average lifetime of rats and mice. Some investigations examined the effect of RF fields from mobile phones on brain cancer, including the progression of chemically induced brain cancer. The results demonstrate that RF exposure did not adversely affect cancer incidence at whole body specific absorption rates (SARs) ≤ 4 W/kg and brain SARs ≤ 2.3 W/kg. The weight-of-evidence of these 18 studies shows that long term, low level exposure to RF energy does not adversely affect survival and cancer in laboratory mammals. Bioelectromagnetics Supplement 6:S101–S106, 2003. © 2003 Wiley-Liss, Inc.

Need an update on long term studies

Brain and Other Nervous System Cancer







Glioma incidence, Sweden 1970-2017, men, 20-39 and 40-69 years



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IARC: International Agency for Research on Cancer

IARC is an agency of the World Health Organization (WHO)

- IARC has so far classified 1027* agents, mixtures and exposures based on the strength of scientific evidence of their potential as human cancer hazards
 - The IARC evaluation deals only with the hazard, not the risk

IARC assigns one of <u>4 classification groups</u>:

- 1 <u>known</u> carcinogen (121) _____
- 2A <u>probable</u> carcinogen (89)
- 2B possible carcinogen (318)
- o 3 <u>not classifiable</u> (499)

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2B: Power line magnetic fields and RF fields



Statements from WHO

WHO (June 22, 2011) Fact Sheet #193* "Electromagnetic fields and public health: mobile phones" http://www.who.int/mediacentre/factsheets/fs193/en/index. html

Are there any health effects?

"A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use."

*Reviewed October 2014

Expert Reviews (2010-2021)

Statements from Governments and Expert Panels Concerning Health Effects and Safe Exposure Levels of Radiofrequency Energy (86 citations)

<u>http://www.ices-emfsafety.org/expert-reviews/</u>

No adverse health effects have been confirmed below the current international RF safety guidelines or exposure standards (ICNIRP, IEEE).

Expert Reviews

Statements from Governments and Expert Panels Concerning Health Effects and Safe Exposure Levels of Radiofrequency Energy (2010-2021)

86. Swedish Radiation Safety Authority (2021)

Research on EMF & Health Risks

https://www.stralsakerhetsmyndigheten.se/contentassets/fce87121bd5e47ca95ad16d93d03f638/recentresearch-on-emf-and-health-risk

 "No new established causal relationships between EMF exposure and health risks have been identified. New research on brain tumors and mobile phone use is in line with previous research suggesting mostly an absence of risk."

Controversy in Research

- Ionizing radiation research methods have been used for nonionizing radiation (without knowing the complicated dosimetry)
- Scientific studies must be repeatable, and consistent
- Unique findings are not scientific (unlike in art)
 - Any observed effects must have a reason (must be repeatable before one can find out why)

(Old saying: It is easy for one man to throw a big rock into a well, but it will take 10 people and a long time to get it out.)



Problems in Publication

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- Some cultures publish only positive effect papers
- Some journals are biased in publishing only positive effect papers
- Many journals do not have reviewers with expertise in this field
- Many published papers do not have enough details for evaluation or replication
- Many peer-reviewed papers are not useful for standard setting, often due to inadequate attention to engineering or biological details or both.

Example of a published study

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- In 2003, during a visit to the Tel-Aviv University to observe an experiment, which researchers claimed to have found RF non-thermal effects on cells.
- A 4 °C temperature gradient was observed in the culture media.
- The paper was published in the Bioelectromagnetics Journal (Mashevich et al., 2003).
- The paper received the second place award from the Society for the most influential journal paper in 2008.

Bioelectromagnetics 24:82–90 (2003)

Exposure of Human Peripheral Blood Lymphocytes to Electromagnetic Fields Associated With Cellular Phones Leads to Chromosomal Instability

Maya Mashevich,^{1,3} Dan Folkman,² Amit Kesar,² Alexander Barbul,³ Rafi Korenstein,³* Eli Jerby,² and Lydia Avivi¹

> ¹Department of Human Genetics and Molecular Medicine, Tel-Aviv University, Tel-Aviv, Israel ²Department of Electrical Engineering-Physical Electronics, Tel-Aviv University, Tel-Aviv, Israel ³Department of Physiology and Pharmacology, Tel-Aviv University, Tel-Aviv, Israel

May 4, 2021



Based on science
Protective
Practical to implement

Three Types of RF Safety Standards

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- Two tiers
 - General public
 - Occupational (in controlled environments)
- <u>Assessment standards</u> for radiating source compliance
 - Measurements
 - Computations



Interference standards with medical devices



Who Set RF Exposure Standards?

ICNIRP

(International Commission on Non-Ionizing Radiation Protection)

- guidelines developed by a committee of 14 elected experts, no industry representatives
- formally recognized by WHO





IEEE-ICES

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(International Committee on Electromagnetic Safety) TC95

- large committee open to anyone with a material interest
- about 130 members from 29 countries
- open consensus process



ICNIRP Guidelines on EMF Exposures

 For limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz)

Health Physics 99(6):818-836; 2010

For limiting exposure to electromagnetic fields (100 kHz - 300 GHz)
 Health Physics 118(5): 483–524; 2020

IEEE Exposure Standards History

1960: USASI C95 Radiation Hazards Project and Committee chartered 1966: USAS C95.1-1966 (2 pages) 10 mW/cm² (10 MHz to 100 GHz) based on simple thermal model 1974: ANSI C95.1-1974 (limits for E² and H²) 1982: ANSI C95.1-1982 (incorporates dosimetry) 1991: IEEE C95.1-1991 (two tiers – reaffirmed 1997) 2002: IEEE C95.6-2002 (0-3 kHz) 2006: IEEE C95.1-2005 published on April 19, 2006 (comprehensive revision, 250 pages, 1143 ref.) 2014: IEEE C95.1-2345-2014 (0-300 GHz) (NATO/IEEE agreement) 2015: NATO adopted C95.1-2345-2014 2019: IEEE C95.1-2019 (0-300 GHz) published on October 4, 2019 (310 pages, 1550 ref.)

IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz

IEEE Std. C95.1-2019 pp 1-310

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IEEE Standards Coordinating Committee 39

Developed by the IEEE International Committee on Electromagnetic Safety

IEEE 3 Park Avenue New York, NY 10016-5997 USA

IEEE Std C95.1[™]-2019 (Revision of IEEE Std C95.1-2005/ Incorporates IEEE Std C95.1-2019/Cor 1-2019)

Risk profile for adverse effects (C95.1-2019)

RF shocks and burns
 Localized RF heating effects
 Surface heating effects
 Whole body heating effects
 Microwave hearing effects
 Low-level effects

 (previously 'non-thermal effects')

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On page 107:

- Despite about 70 years of RF research, low-level biological effects have not been established.
- No theoretical mechanism has been established that supports the existence of any effect characterized by trivial heating other than microwave hearing.
- Moreover, the relevance of reported low-level effects to health remains speculative.

Free IEEE Safety Standards

Get IEEE C95[™] STANDARDS: Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields

https://ieeexplore.ieee.org/browse/standards/get-program/page/series?id=82

- <u>C95.1-2019/Cor 2-2020</u> IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz - Corrigenda 2
- <u>C95.1-2019</u> IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz
- <u>C95.1-2345-2014</u> IEEE Standard for Military Workplaces--Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz
- <u>C95.2-2018</u> IEEE Standard for Radio-Frequency Energy and Current-Flow Symbols
- <u>C95.3-2002</u> IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz-300 GHz
- <u>C95.3.1-2010</u> IEEE Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 100 kHz
- <u>C95.7-2014</u> IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz

Sponsored by the United States Navy, Air Force, and Army.

Other organizations

- International Commission for Electromagnetic Safety (ICEMS) advocates protection of the public health from electromagnetic fields and develops the scientific basis and strategies for assessment, prevention, management and communication of risk, based on the precautionary principle (web posted 3 resolutions)
- BioInitiative Report promotes low exposure limits to avoid possible biological effects as a precautionary measure (2012 report suggests 0.3 nW/cm² as a precautionary action level)

Controversy on standards

- ICNIRP guidelines and IEEE standard have differences in lower frequencies. Higher frequencies mostly harmonized.
- Harmonization between the two is continuing.
- Activist groups continually promote precautionary principle and demand for lower exposure limits to avoid possible biological effects.

Regulations: Two approaches of protection

- Established Adverse Health Effects
- Possible Biological Effects

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Determination of exposure limits using the hazard threshold and possible biological effect approaches (Repacholi, 1983)



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Example of the two different approaches



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- "The general approach to public health protection and setting exposure limits by previous Soviet and current Russian committees is that people should not have to compensate for any effects produced by RF exposure, even though they are not shown to be adverse to health (pathological)."
- "Exposure limits are then set that do not cause any possible biological consequence among the population (regardless of age or gender) that could be detected by modern methods during the RF exposure period or long after it has finished."
- This is an important difference from the approach used by the IEEE and ICNIRP.

Repacholi M., Grigoriev Y., Buschmann J., Pioli C. "Scientific basis for the Soviet and Russian radiofrequency standards for the general public." Bioelectromagnetics, 33, 623 - 633, 2012.

Regulatory Status of Localized "peak" SAR Standards for Portable Devices



W/kg over 1 g)

Hover over the map for additional country specific RF limit information. Whole body exposure limits for antenna sites

ICNIRP 1998 📕 FCC 1996 📕 other 📕 unknown 🔳

http://www.gsma.com/publicpolicy/mobile-and-health/networks-map Note: Information from public sources except where indicated.

Last updated: 24 April 2016

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GSMA

Whole body exposure limits for antenna sites

ICNIRP Guidelines (125 countries and territories)

Albania, Argentina, Armenia, Australia, Austria, Bahrain, Bangladesh, Botswana, Brazil, Cambodia, Cameroon, Cape Verde, Central African Republic, Colombia, Costa Rica, Côte d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, Estonia, Faroe Islands, Falkland Islands (Malvinas), Finland, France, French Guiana, French Polynesia, Germany, Ghana, Greenland, Guadeloupe, Guatemala, Guinea-Bissau, Honduras, Hong Kong SAR, Hungary, Iceland, Iran (Islamic Republic of), Iraq, Ireland, Japan, Jordan, Kenya, Korea, Republic of (South), Kuwait, Latvia, Lebanon, Madagascar, Malaysia, Mali, Malta, Martinique, Mauritania, Mauritius, Mexico, Moldova, Namibia, Nepal, Netherlands, New Caledonia, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Palestinian National Authority, Panama, Paraguay, Peru, Philippines, Portugal, Qatar, Réunion, Romania, Rwanda, Saudi Arabia, Senegal, Singapore, South Africa, Spain, Sri Lanka, St. Helena, St. Pierre and Miquelon, Suriname, Svalbard, Sweden, Taiwan, Thailand, Tunisia, Uganda, United Arab Emirates, United Kingdom, United Republic of Tanzania, Uruguay, Vanuatu, Venezuela, Wallis and Futuna Islands, Zambia, etc.

IEEE/NCRP standard (11 follow FCC)

American Samoa, Bolivia, Federated States of Micronesia, Guam, Iraq, Marshall Islands, Northern Mariana Islands, Palau, Puerto Rico, United States of America, United States Virgin Islands

Below ICNIRP and IEEE

Belarus, Bulgaria, China, Lithuania, Poland, Russia (Soviet influence) (Limits do not apply to military personnel) Belgium, Chile, Greece, India, Israel, Italy, Liechtenstein, Switzerland (precautionary)

Details see: http://www.gsma.com/publicpolicy/mobile-and-health/networks-map

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Controversy in Regulations

- When agendas and factors other than science become a part of the decision making process, large disparities among regulations can be expected, as has happened in the world.
- Standards and regulations should be based on science with rationally defensible safety factors included to account for uncertainties and differences among populations.
- Non-scientifically based factors should not be included since these usually lead to arbitrary exposure limits.

Risk Communication

Wireless communication technology is complex
Inability of science to "prove safety" for anything
Precautionary recommendations can increase concerns.

WHO recommends against arbitrary precautionary levels.

Differences between Science and Media

Science	Media
Consensus	Conflicts
Truth	"News"
General Laws	Stories
to be continued	



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Problems in Media Communication

- Media reports on EME issues often are not verified and reviewed, unlike scientific journals.
- Statements often from outspoken so called "Experts"
- "Spot light" reporting, not "weight of evidence"
- Need to attract audience
- Misinformation propagates fast and continuously
- Corrections do not make the news
- General public acquire knowledge from media and NOT from scientific journals
- Scientists have an overall responsibility to ensure their findings are robust before publication, and not to mislead the media.



O. P. Gandhi, G. Lazzi, C.M. Furse, "Electromagnetic Absorption in the Human Head and Neck for Mobile Telephones at 835 and 1900 MHz," *IEEE Trans. Microwave Theory and Techniques*, 44:1884-1897, 1996.

SAR in plane of antenna feed point as published by Gandhi, Oct. 1996



Conclusion: Deeper penetration and higher absorption in smaller heads

This figure is heavily cited by activists for protecting children.

INSTITUTE OF PHYSICS PUBLISHING

PHYSICS IN MEDICINE AND BIOLOGY

Phys. Med. Biol. 47 (2002) 1501-1518

PII: S0031-9155(02)30727-9

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Some present problems and a proposed experimental phantom for SAR compliance testing of cellular telephones at 835 and 1900 MHz

Om P Gandhi and Gang Kang



Near field coupling: patterns should be similar

No activists use this corrected figure

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Relationship between Policies and Public Concern



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Mobile Telephony RF Exposures



Actual handset transmitted power

• Gati et al., Exposure induced by WCDMA mobiles phones in operating networks, IEEE Transactions on Wireless Communications, 8(12):5723-5727, December 2009. IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 8, NO. 12, DECEMBER 2009



4G and 5G mobile phones



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Exposure similar for all countries

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Global average more than 5,500 times below limit values.

Based on Rowley and Joyner, 2012

5G basestation compliance



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Out of more than 13 million samples collected over 24 h, the maximum time-averaged power per beam direction was found to be well-below the theoretical maximum and lower than what was predicted by the existing statistical models.

Divide Colombi *, Paramananda Joshi, Bo Xu , Fatemeh Ghasemifard , Vignesh Narasaraju and Christer Törnevik Analysis of the Actual Power and EMF Exposure from Base Stations in a Commercial 5G Network Appl. Sci. 2020, 10, 5280; doi:10.3390/app10155280

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Definitely, there are big effects!

1.6 million accidents per year in US are related to mobile phone use



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Not RF effects

It's improper use of the device!

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- RF bioeffect research is difficult, due to required biological and engineering expertise.
- Publication quality varies, with few confirmed health effects.
- What research results are to be used for exposure limits (established health effects vs possible biological effects).
- Governments regulations often include political considerations.
- Risk communication by media more on spot light of unusual reports.
- General public are confused by the conflicting scientific reports, unharmonized standards and regulations.

My 50 years in RF Safety research and standards

- Radiofrequency electromagnetic exposure is very different from nuclear radiation.
- 70 years of research shows excessive thermal effect is an established adverse health effect of RF energy (above 100 kHz).
- International exposure (with large safety margins) and assessment standards are available to provide protection.
- A large number of expert scientific reviews have concluded that no adverse health effects have been confirmed below the current international RF exposure limits (ICNIRP, IEEE).
- Ordinary exposures are very low. Unnecessary worry can cause nocebo effects.

My hope: More facts, less opinions

If scientists would discuss EMF safety issues based on validated scientific facts and not on unreproducible possible effects and opinions, the controversy would be minimized or resolved.



Knowing what you know and what you don't know, that is knowledge.

Thank you ck.chou@ieee.org

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