



Safety Issues of Radiofrequency Exposure

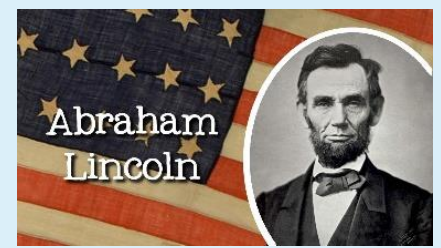
Dr. C-K. Chou*
TC95 Chairman

International Committee on Electromagnetic Safety (ICES)
Institute of Electrical and Electronics Engineers (IEEE)
Piscataway, NJ, USA





Know the facts



LET THE PEOPLE KNOW THE FACTS
AND THE COUNTRY WILL BE SAFE.

ABRAHAM LINCOLN

On a wall inside the "Chicago Tribune" downtown building

In science, what is a fact?

Can you prove it? (hypothesis testing)

Is it always true? (repeatability, consistency, know why)





Outline

- History of the issues
- Key concepts
- Research (examples)
- Standards
- Regulations
- Conclusions
- Q&A



A Global Issue



History of the issues



RF Sources (year)

- Radar (50-60's)
- Radio and TV Broadcasting (60-70's)
- Microwave Oven (70-80's)
- Police Radar (80's)
- Wireless Communication (90's - ?)
(mobile phones, base stations, Wi-Fi, WiMAX, smart meters, RFID, etc.)
- Wireless power transmission (2011-?)





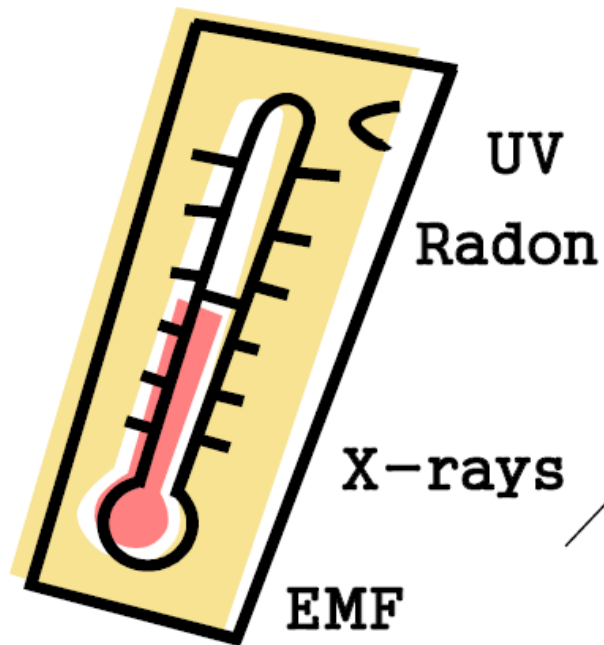
Common understanding (mainly from media or internet)



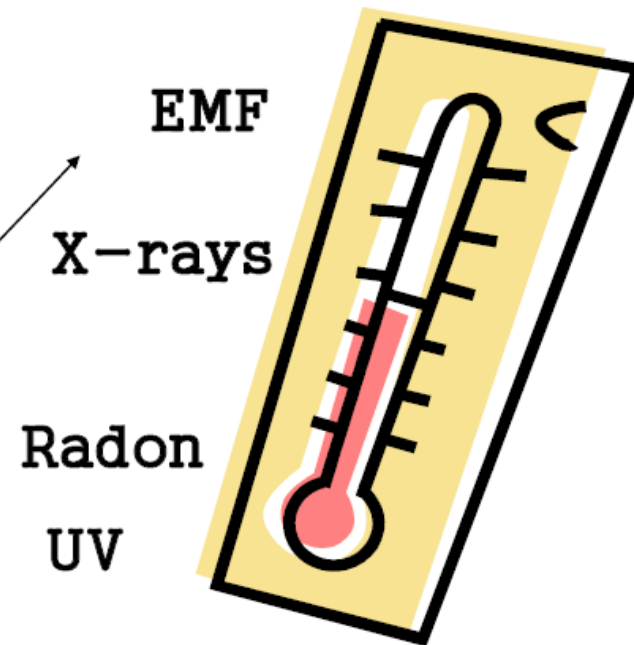
- Microwave (RF) radiation is dangerous
- We don't have enough understanding of its effects
- Many reports show non-thermal effects
- Radiation can cause cancer, and many other diseases
- The standards are not protective
- Need precautionary measures to be safe than sorry

Radiation

Public Health



Public Concern





Root of Concerns: “Radiation”

RF Exposure



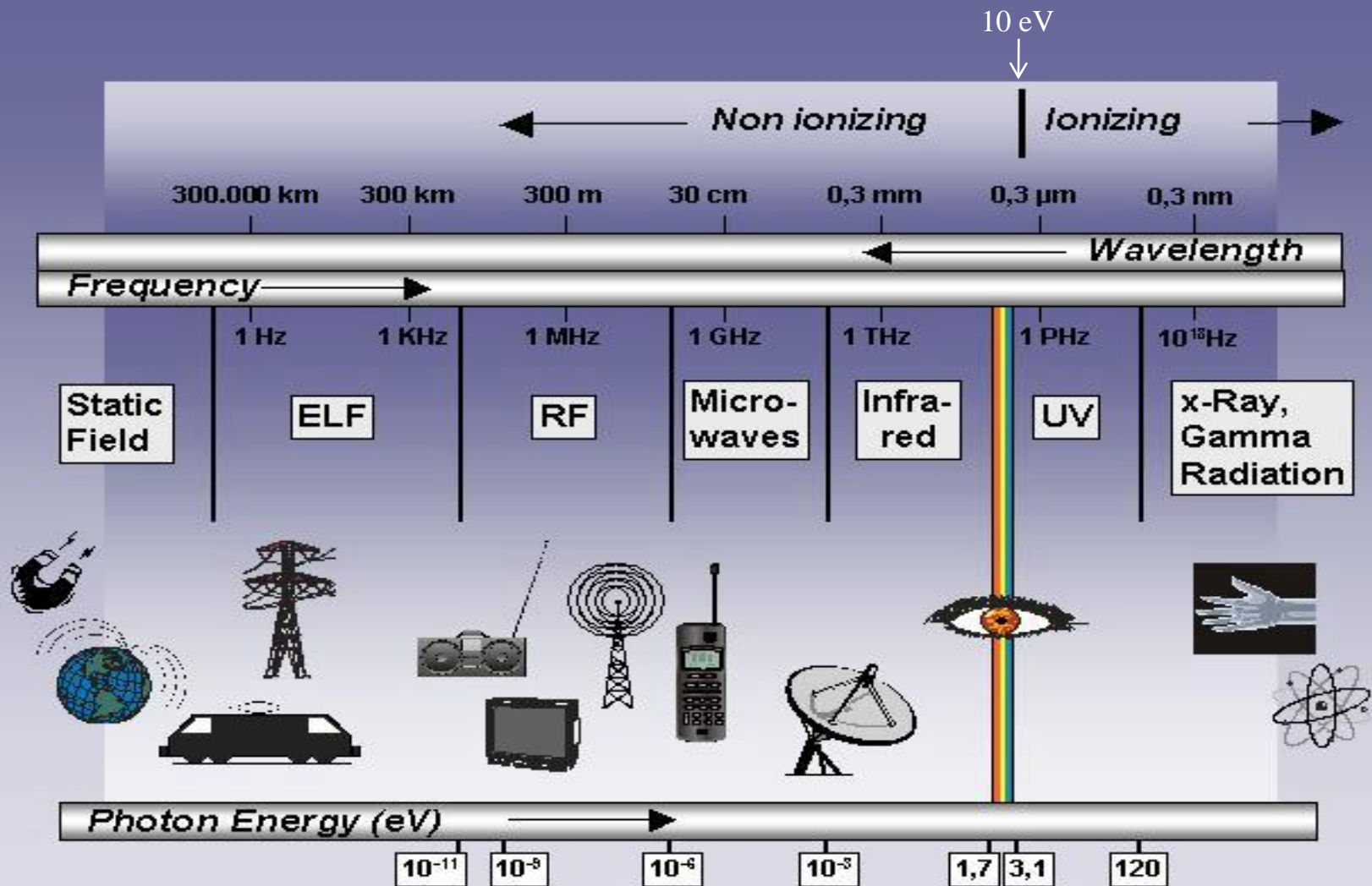
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Nuclear Radiation



X

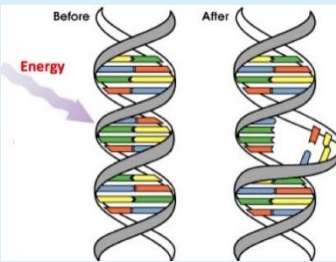






Ionizing vs. Non-Ionizing Energy

➤ Ionizing



- Sufficient energy to alter chemical bonds and atomic structures
- Confirmed health effects include genetic damage
- Effects can occur from cumulative exposure

➤ Non-ionizing (including RF)



- Lower energy, insufficient to cause effects like those above
- Only confirmed RF health effects relate to tissue heating at levels well above limits for wireless communication
- No known chronic/cumulative effects



Steps to address safety concerns

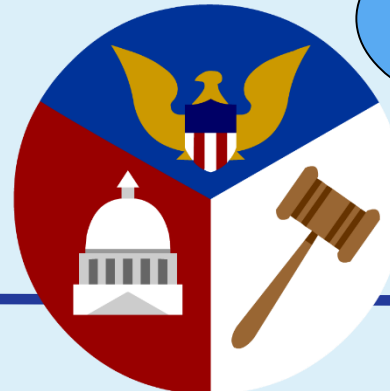
Scientific
research



Peer-reviewed
publication

Consensus
standards

Regulations



C95.1™



IEEE Standard for Safety Levels with
Respect to Human Exposure to Radio
Frequency Electromagnetic Fields,
3 kHz to 300 GHz

Sponsored by the
IEEE International Committee on Electromagnetic Safety (SCC39)

IEEE
3 Park Avenue
New York, NY 10016-5957, USA
12 April 2006

IEEE Std C95.1™-2005
(Revision of IEEE Std C95.1-1991)





Study Strengths and Weaknesses

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



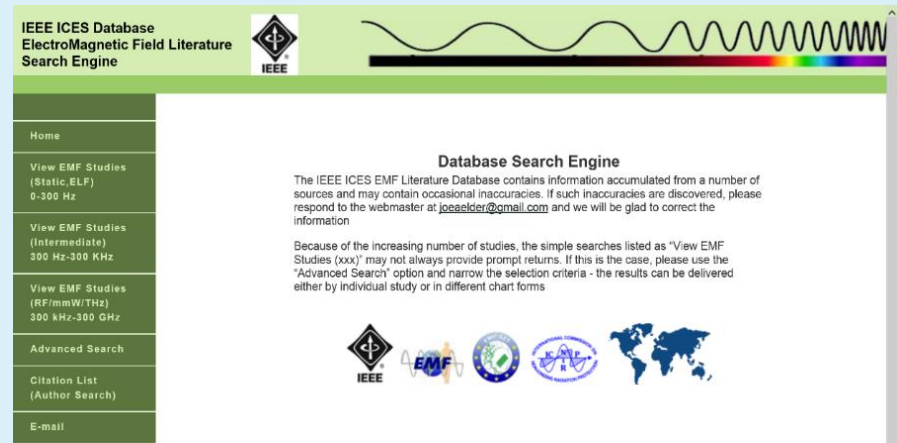


Extensive Research Database

- The biological effects of RF exposure have been studied for about **70** years.
- Current IEEE EMF database contains 6839 entries, of which **3684** are relevant to biological effects of RF exposure (September 11, 2018)



<http://ieee-emf.com/>





Mobile Telephony Related Studies

Study Type	Published
Epidemiology	519
Human	410
Animal	567
<i>In Vitro</i>	385
Engineering	1166
Total	3038



IEEE EMF Database (September 11, 2018)





WHO Comment on Database (2016)



- “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

<http://www.who.int/peh-emf/about/WhatisEMF/en/index1.html>



Quality of Science (Established vs. Possible)



↑
Increasing validity

A	Confirmed and Established Science	
B	Unconfirmed report (could be useful)	?
C	Unconfirmed report contradicts A	?
D	Unconfirmed report with clear flaws and artifacts	?
E	Junk report in peer-reviewed literature	?
F	Junk report in non-peer-reviewed literature	?

Facts

Opinions

Adapted from Osepchuk [2004]

“Good science is never outdated.” -- Herman P. Schwan



Biological Complexity

❖ In vivo study

- Species
- Strain
- Sex
- Age
- Extrapolation from animal to humans



❖ In vitro study

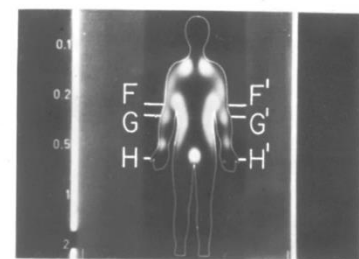
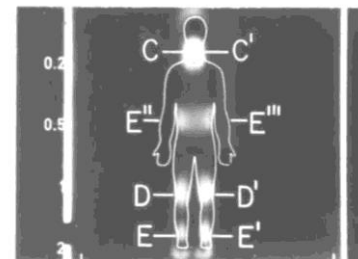
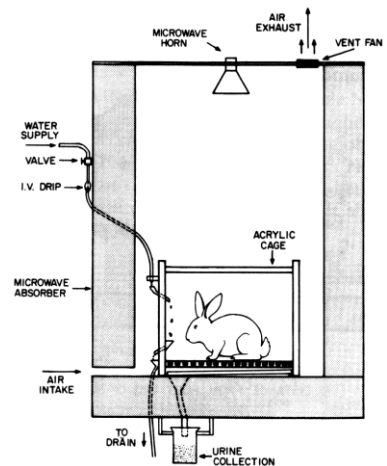
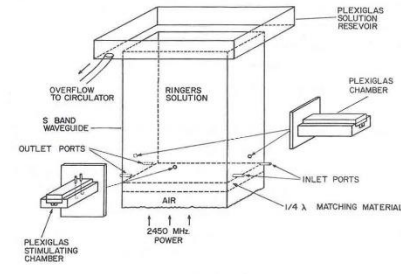
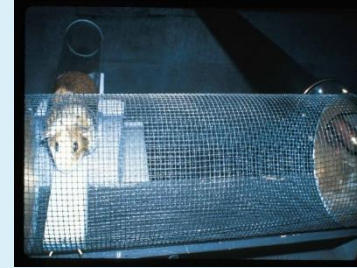
- Monolayer
- Cell suspension
- Isolated tissue
- Extrapolation to in vivo



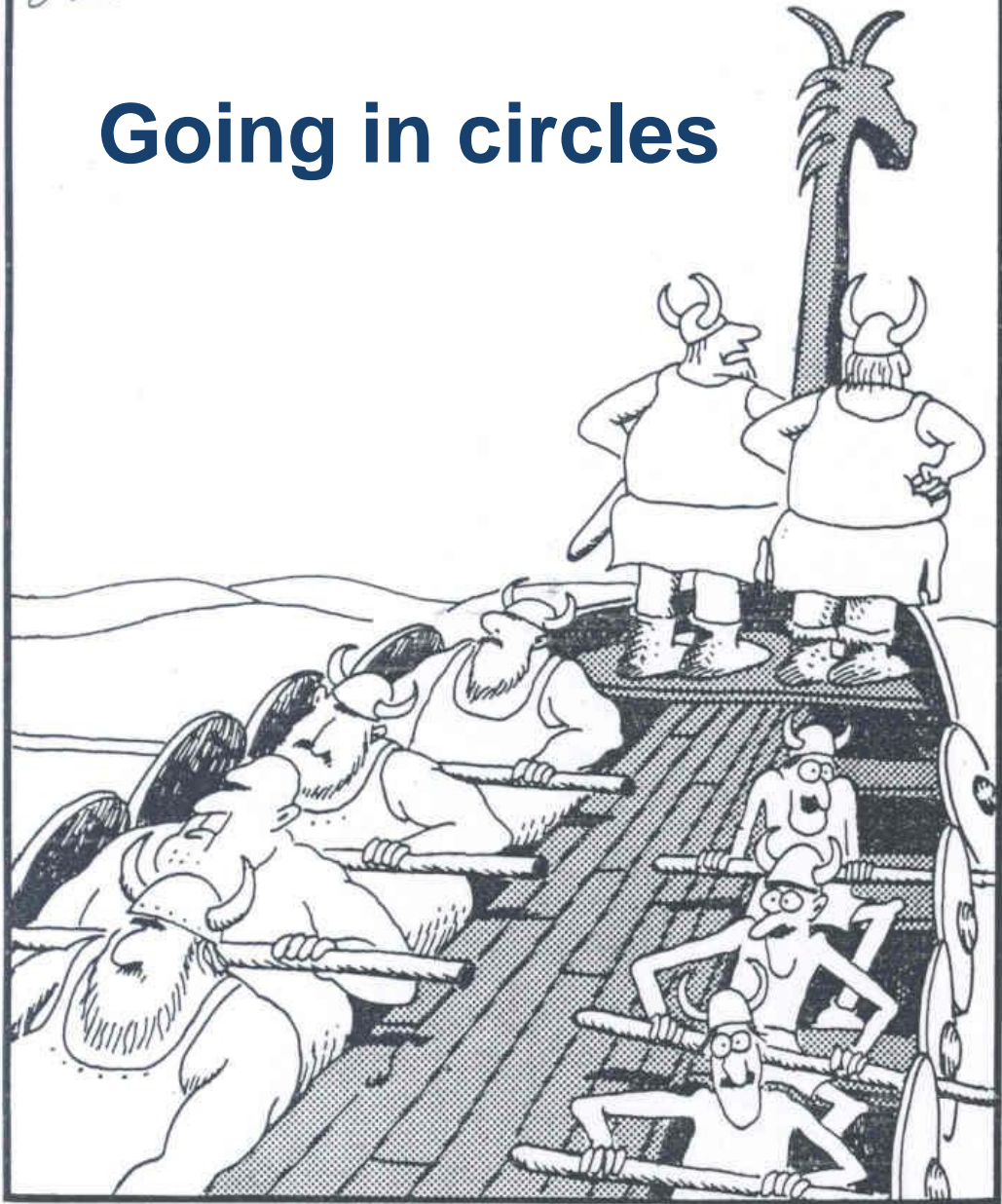


Engineering Complexity

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



Going in circles



"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



IEEE ICES



Validity of studies

- ❖ Scientific studies must be repeatable, consistent, and confirmable
- ❖ Unique findings are not scientific (unlike in art)
- ❖ Any observed effects must have a reason (make sense)
- ❖ Scientists have the responsibility to ensure that their findings are robust before publication

(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.)





IARC: International Agency for Research on Cancer

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

- IARC has so far classified 1006* agents, mixtures and exposures based on the strength of scientific evidence of their **potential** as human cancer hazards
- IARC assigns one of 5 classification groups:
 - 1 known carcinogen (120)
 - 2A probable carcinogen (82) (red meat)
 - 2B **possible** carcinogen (302)
 - 3 not classifiable (501)
 - 4 probably not a carcinogen (1)
- The IARC evaluation deals only with the hazard, not the risk
- **2B includes ELF magnetic fields and RF exposures**



* As of September 11, 2018



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.”*

**WHO Reviewed October 2014*



American Cancer Statistics (2018)

brain and other nervous system tumors

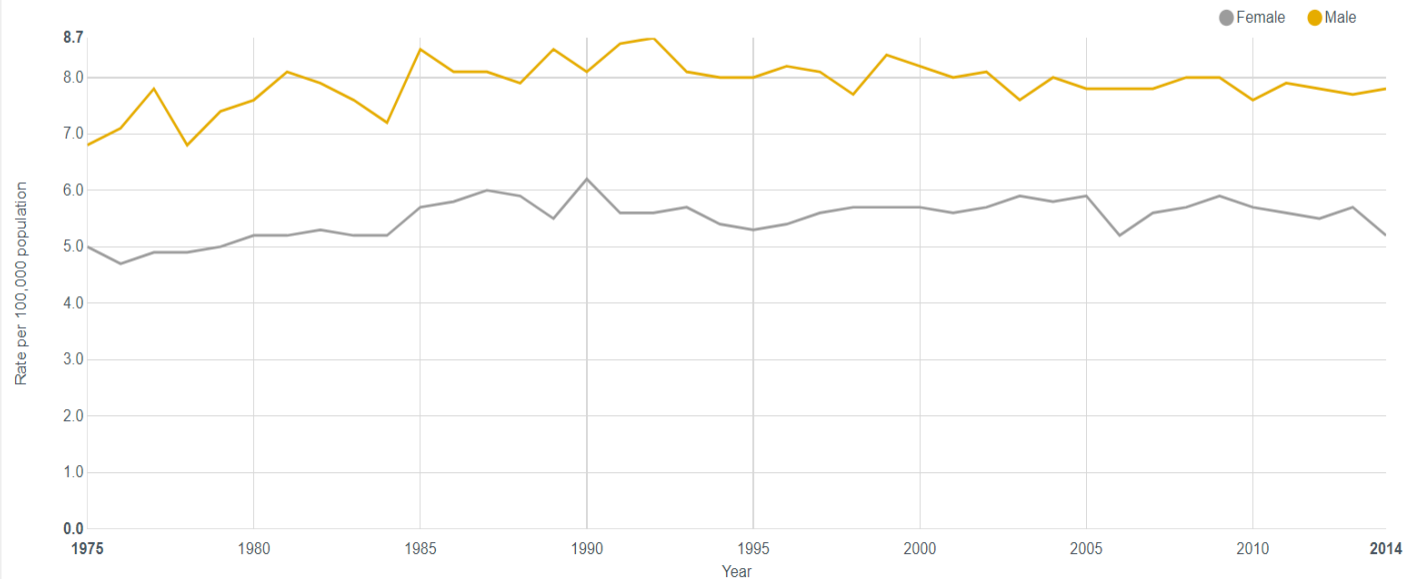


INCIDENCE AND DEATH RATES

TOOLS ▾

Trends in incidence rates, 1975-2014

Brain and other nervous system, by sex



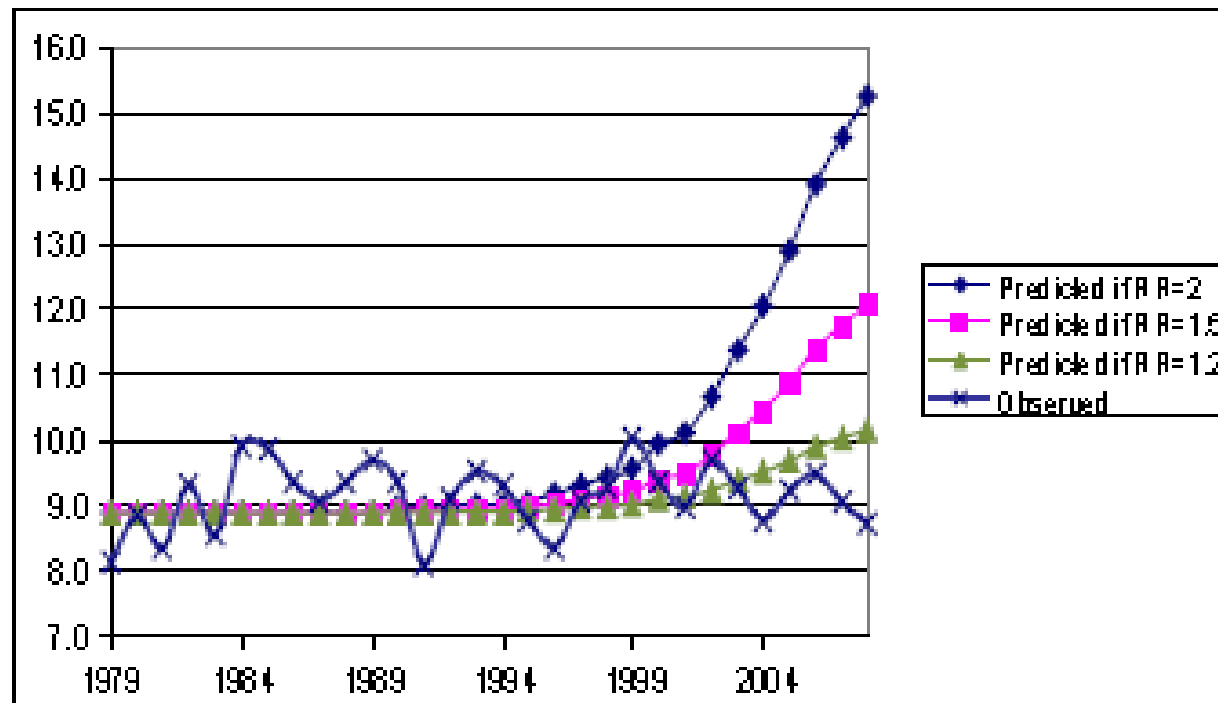
Per 100,000, age adjusted to the 2000 US standard population.

Data sources: Surveillance, Epidemiology, and End Results (SEER) 9 registries, National Cancer Institute, 2017



Increase in brain tumour rates?

All users at increased risk after 10 years



Glioma

International Agency for Research on Cancer

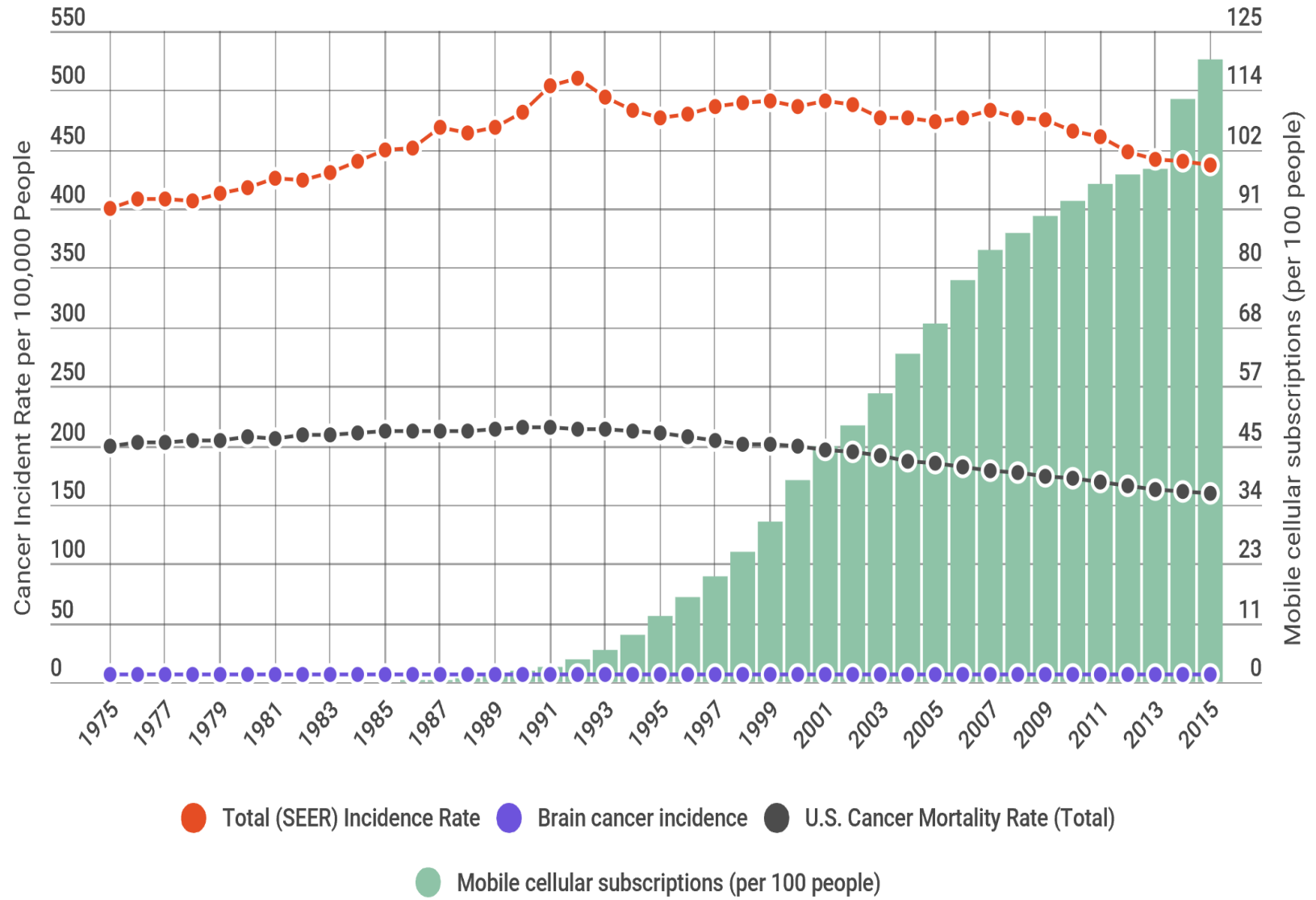


Deltour et al., Epidemiology, 2012

Little et al., BMJ, 2012



U.S. incidences of cancer and cellular subscriptions





Electrohypersensitivity EHS

- EMF Refuge Zone in France



- “Wi-Fi refuge” shelter in mountains of Green Bank, West Virginia, USA



EHS or IEI



- World Health Organization:
Fact Sheet #296 (2005)
 - A more general term for sensitivity to environmental factors is *Idiopathic Environmental Intolerance (IEI)*.
 - EHS has no clear diagnostic criteria and there is *no scientific basis to link EHS symptoms to EMF exposure*.
- European Union: On November 16-17, 2011 the European Commission hosted an international scientific conference on electromagnetic fields (EMF) and health in Brussels.
 - The *nocebo effect* (an ill effect caused by the suggestion or belief that something is harmful) is a major contributor to EHS.





Recent EHS study

The results of ELF-MF exposure and symptoms from a Dutch crosssectional survey of **5933 adults** have been described (Baliatsas et al., 2015)

- ❖ **None of the modelled RF-EMF exposure sources was related to the occurrence of symptoms**, whereas consistent associations of self-reported RF-EMF exposure with all symptoms were observed.

BALIATSAS et al. Actual and perceived exposure to electromagnetic fields and non-specific physical symptoms: an epidemiological study based on self-reported data and electronic medical records. Int J Hyg Environ Health, 218, 331-44., 2015.





Expert Reviews (2010-2018)

Statements from Governments and Expert Panels
Concerning Health Effects and Safe Exposure Levels
of Radiofrequency Energy (70 citations)

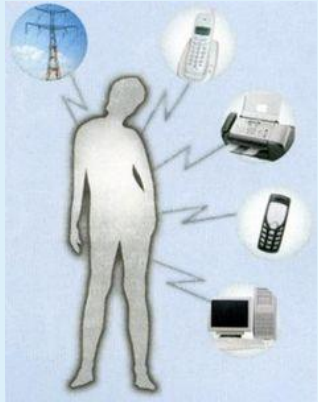
<http://www.ices-emfsafety.org/expert-reviews/>

Adverse health effects have not been confirmed for RF exposures that comply with contemporary science-based safety guidelines, such as those developed by ICNIRP and IEEE/ICES.





Three Types of RF Safety Standards



- ❖ Exposure standards for limiting human exposures
 - Two tiers
 - General public
 - Occupational (in controlled environments)
- ❖ Assessment standards 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 appointed experts, no industry representatives
 - endorsed by WHO



- **IEEE-ICES** (International Committee on Electromagnetic Safety) TC95
 - large committee open to anyone with a material interest
 - about 130 members from 29 countries
 - open consensus process





Who set RF Assessment standards?

❖ International Electrotechnical Commission (IEC)



- Close to 20,000 experts from industry, commerce, government, test and research labs, academia and consumer groups participate in IEC Standardization work.

❖ IEEE ICES TC34

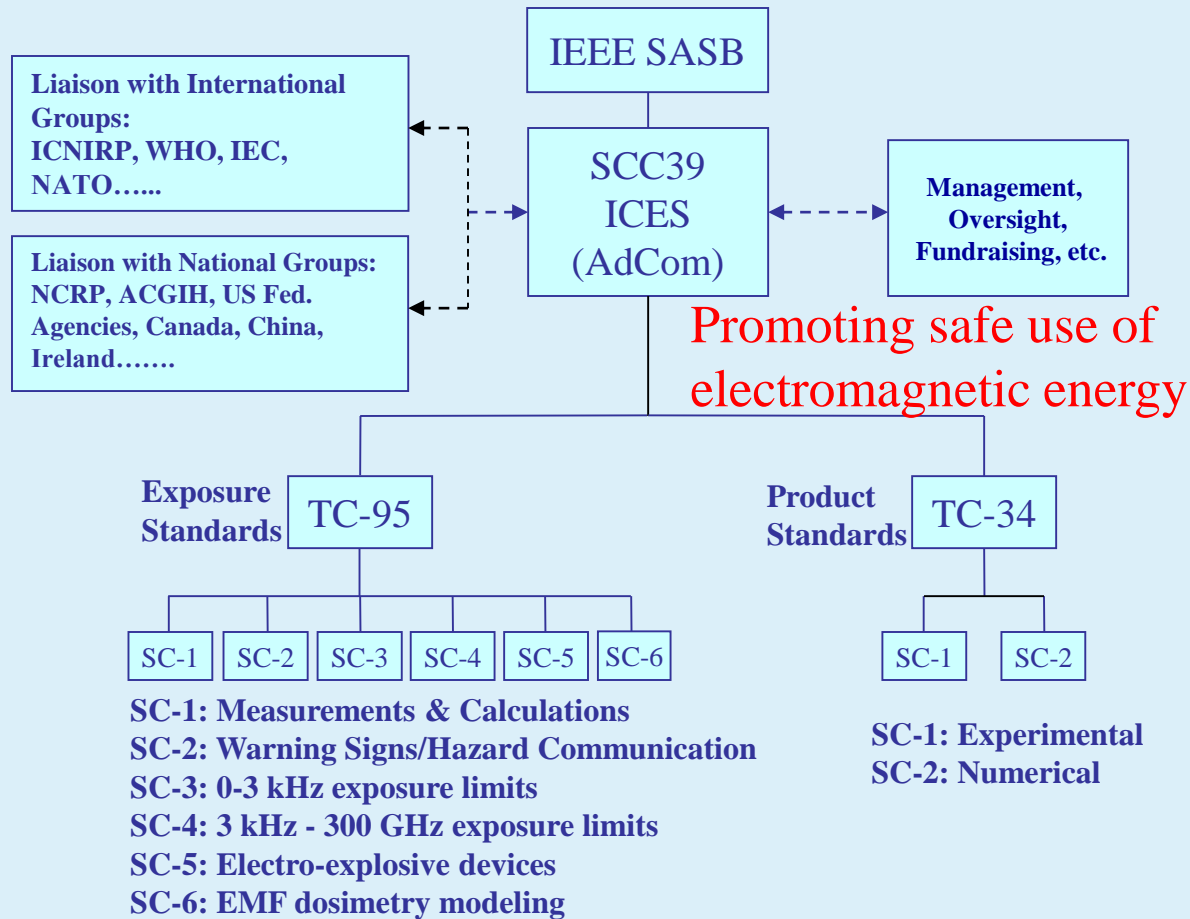


- IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity, with 426,000 members in more than 160 countries.





ICES as the Focal Point in the Global Program for EME Safety Standards





IEEE Exposure Standards History

1960: USASI C95 Radiation Hazards Project and Committee chartered

1966: USAS **C95.1-1966**

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

2018: IEEE C95.1-2018 (0-300 GHz) **to be approved by IEEE**





Weight of evidence

IEEE committee reviewed*:

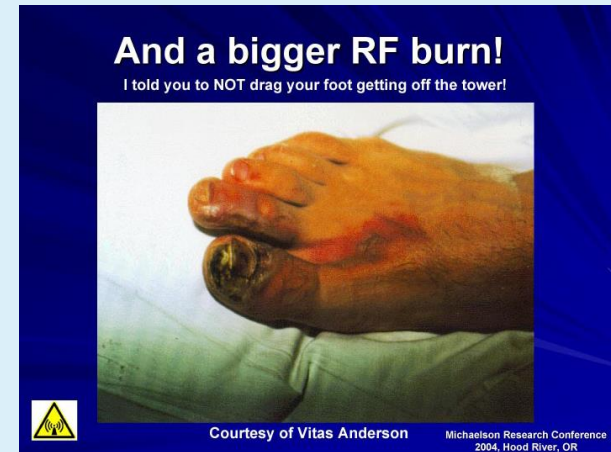
- Quality of test methods
- Size and power of the study designs
- Consistency of results across studies
- Biological plausibility of dose-response relationships
- Statistical associations



***Reviewed all literature (including both positive and negative effects, thermal and non-thermal effects)**

Risk profile for adverse effects (C95.1-2005)

1. RF shocks and burns
2. Localized RF heating effects
3. Surface heating effects
4. Whole body heating effects
5. Microwave hearing effects
6. Low-level effects
(previously 'non-thermal effects')





Low-level effects ? (2018 C95.1 revision)

- 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.
- The relevance of reported low-level effects to health remains speculative.

Inappropriate for standard setting.



Safety factors

[SAR applies 100 kHz- 3 GHz]

- **Whole body averaged**
Behavioral effects in animals over many frequencies, threshold at 4 W/kg
10X - 0.4 W/kg for upper tier
50X - 0.08 W/kg for lower tier
- **Localized exposure** (averaged in 10 g)
Cataract observed in rabbits, threshold at 100 W/kg
10X – 10 W/kg for upper tier
50X – 2 W/kg for lower tier



IEEE Std. C95.1-2005

pp 1-250



IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

Sponsored by the
IEEE International Committee on Electromagnetic Safety (SCC39)

C95.1TM

IEEE
3 Park Avenue
New York, NY 10016-5997, USA
19 April 2006

IEEE Std C95.1TM-2005
(Revision of IEEE Std C95.1-1991)





IEEE Std. C95.1-2345-2014

pp 1-57

IEEE Standard for Military Workplaces—Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz

IEEE Technical Committee 95

Sponsored by the
IEEE International Committee on Electromagnetic Safety (SCC39)

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

IEEE Std C95.1-2345™-2014





C95.1 revision is in final IEEE voting

PC95.1™/D3.4 Draft Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz

Sponsor

TC95

of the

IEEE SCC39 International Committee on Electromagnetic Safety (ICES)

Approved <Date Approved>

IEEE-SA Standards Board

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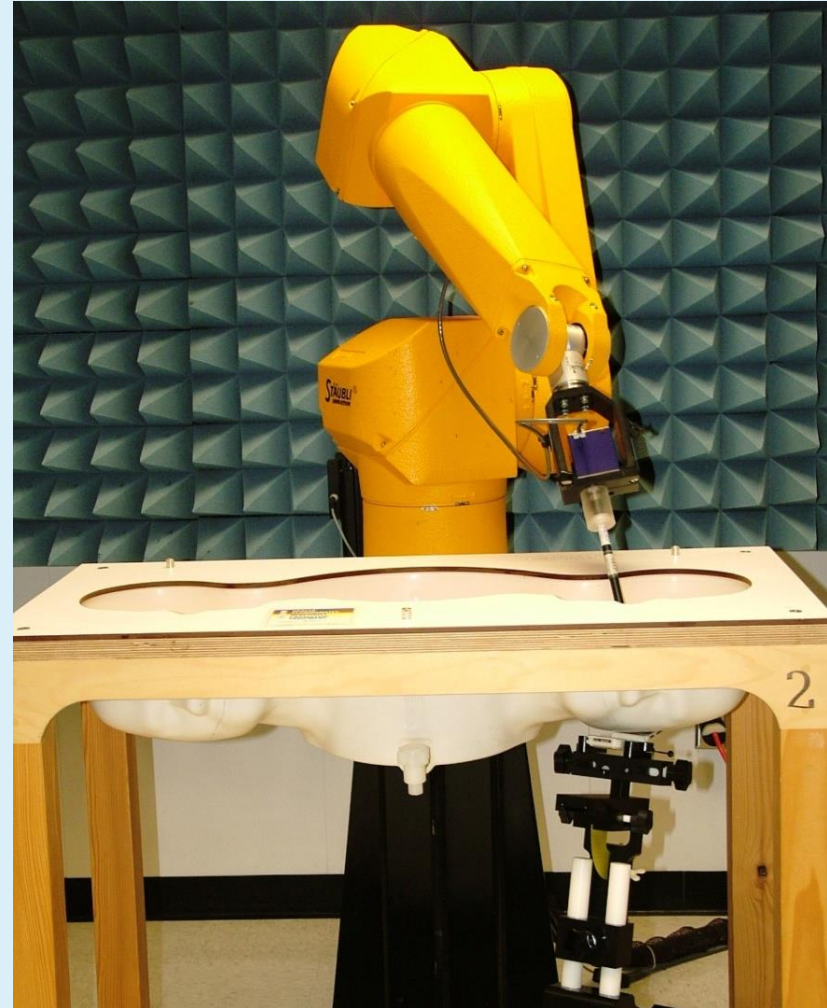
445 Hoes Lane

Piscataway, NJ 08854, USA



Experimental methods for mobile phone compliance test

- ❖ Revised IEEE 1528-2013 to address 0.3 - 6 GHz measurement methods
- ❖ Collaborates with IEC 62209-1:2016 measurements 0.3 – 6 GHz
- ❖ *Efforts to develop IEC/IEEE dual logo standard*





ICES exposure and assessment standards

Number	Year	Expiration Date	Approval Date
1460	1996	12/31/2018	12/10/1996
1528	2013	12/31/2023	06/14/2013
1528.a	2005	12/31/2018	09/22/2005
C95.1	2005	12/31/2018	10/03/2005
C95.1a	2010	02/02/2020	02/02/2010
C95.1-2345	2014	12/31/2024	05/16/2014
C95.2	1999	12/31/2018	09/16/1999
C95.3	2002	12/31/2018	12/11/2002
C95.3.1	2010	03/25/2020	03/25/2010
C95.4	2002	12/31/2018	11/11/2002
C95.6	2002	12/31/2018	09/12/2002
C95.7	2014	12/31/2024	06/13/2014

* At the end of 10 years, IEEE standards must be reaffirmed, revised or withdrawn





Free IEEE C95 Safety Standards

Get IEEE C95™ STANDARDS: Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields <http://standards.ieee.org/about/get/index.html>

- **IEEE C95.1™-2005**
Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
- **IEEE C95.1a™-2010**
Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Field, 3 kHz to 300 GHz. Amendment 1: Specifies Ceiling Limits for Induced & Contact Current
- **IEEE C95.1-2345™-2014**
Military Workplaces--Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz
- **IEEE C95.2™-1999**
IEEE Standard for Radio-Frequency Energy and Current-Flow Symbols
- **IEEE C95.3™-2002**
Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz-300 GHz
- **IEEE C95.3.1™-2010**
Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 100 kHz
- **IEEE C95.4™-2002**
IEEE Recommended Practice for Determining Safe Distances From Radio Frequency Transmitting Antennas When Using Electric Blasting Caps During Explosive Operations
- **IEEE C95.6™-2002 (R2007)**
Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz
- **IEEE C95.7™-2014**
Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz

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

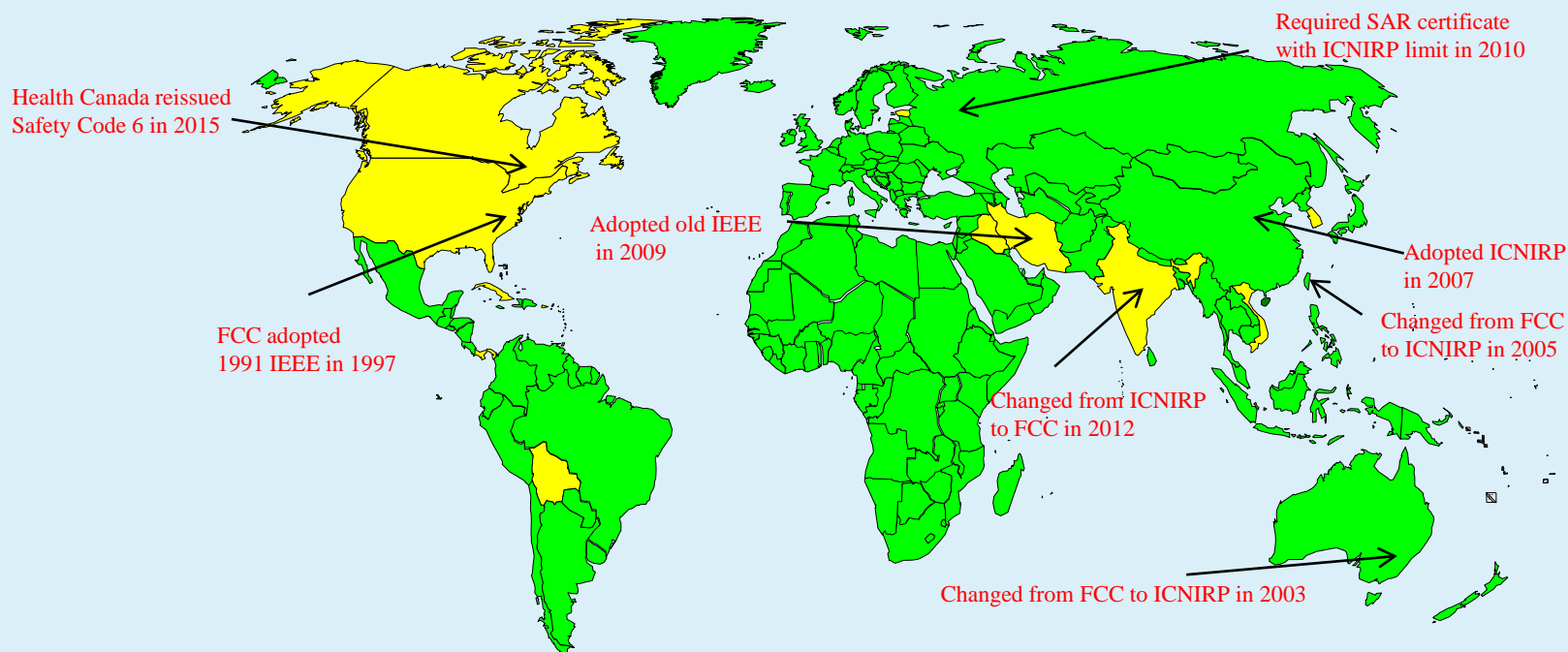




Regulations



Regulatory Status of Localized “peak” SAR Standards for Portable Devices



- ICNIRP mandatory or accepted products (2/10 W/kg over 10 g)
- 1991 IEEE mandatory: USA, Bolivia, Canada, Cuba, India, Iran, Iraq, Panama, South Korea, Vietnam (1.6/8 W/kg over 1 g)



Whole body exposure limits for antenna sites



ICNIRP 1998 ■ FCC 1996 ■ other ■ unknown ■

Note: Information from public sources except where indicated.

Last updated: 10 November 2016



<http://www.gsma.com/publicpolicy/mobile-and-health/networks-map>



Whole body exposure limits for antenna sites

- ICNIRP Guidelines (124 countries and territories)

Albania, Argentina, Armenia, Australia, Austria, Bahrain, 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)

Belgium, Chile, Greece, India, Israel, Italy, Liechtenstein, Switzerland (precautionary)





Worldwide Harmonization of RF standards

- One RF exposure standard
 - IEEE C95.1/ICNIRP guidelines (Harmonized on major issues and limits)
 - Converge of science based standards
- One portable device SAR measurement standard
 - IEC 62209-1/IEEE 1528 (at ear) (Totally harmonized)
 - IEC 62209-2 (at body, and in front of face)
- Other portable and mobile devices SAR computational standards
 - IEC and IEEE close collaboration, Dual logo
- One base station measurement standard
 - IEC 62232

“One sun in the sky”



***A world-wide harmonized exposure standard would be desirable.**





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

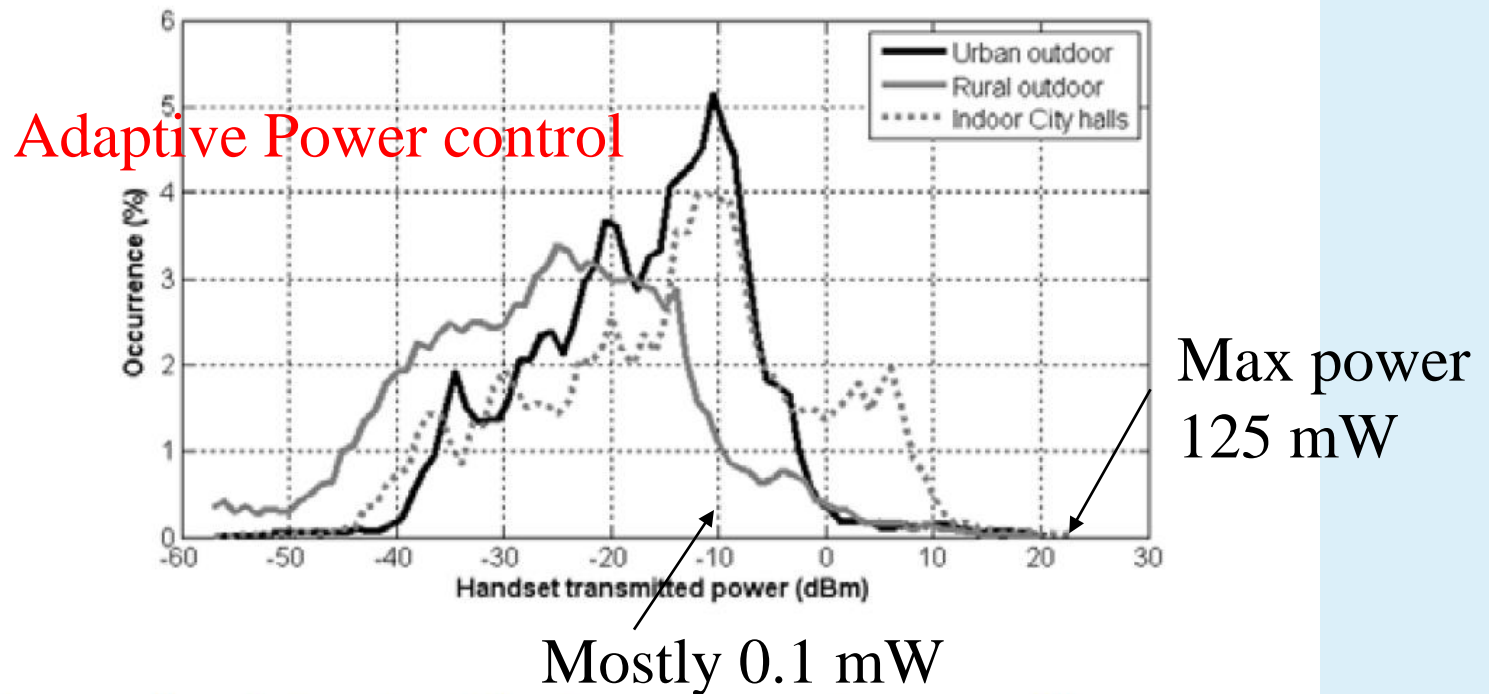
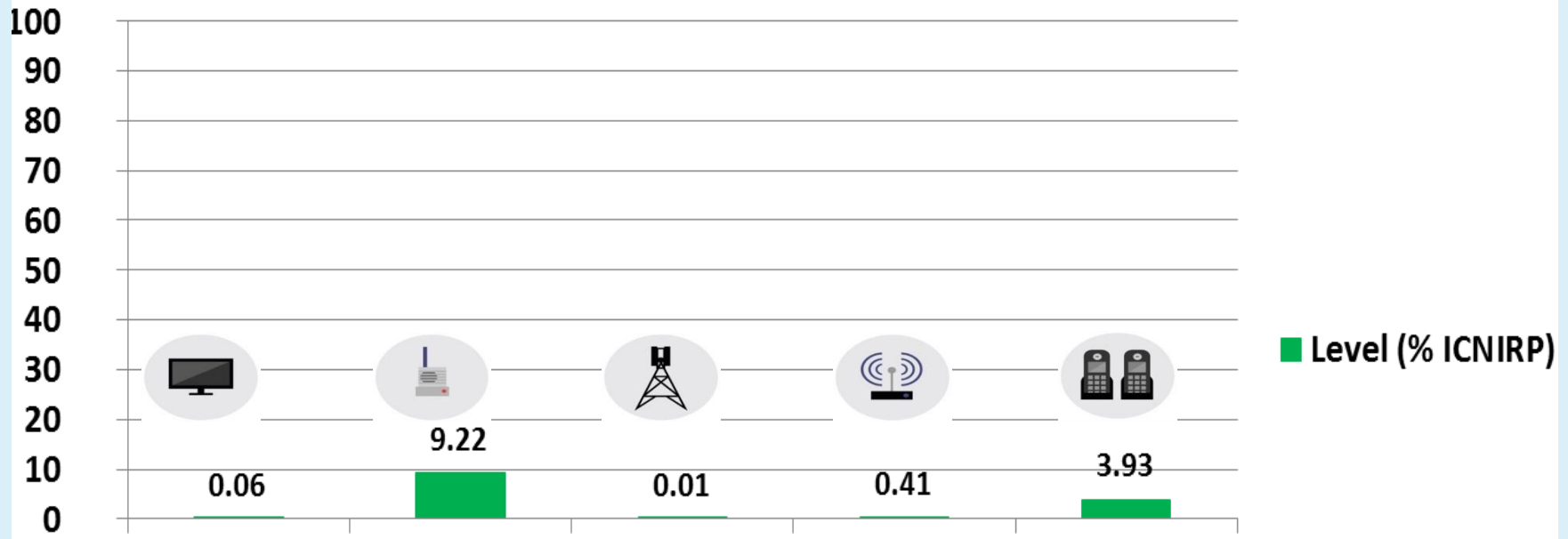


Fig. 3. Distribution of mobile phone transmitted power in different areas.



Mobile levels similar to other radio sources



Average urban, TV and radio

Baby monitors (20 cm)

Average urban, base stations

WLAN access point (20 cm)

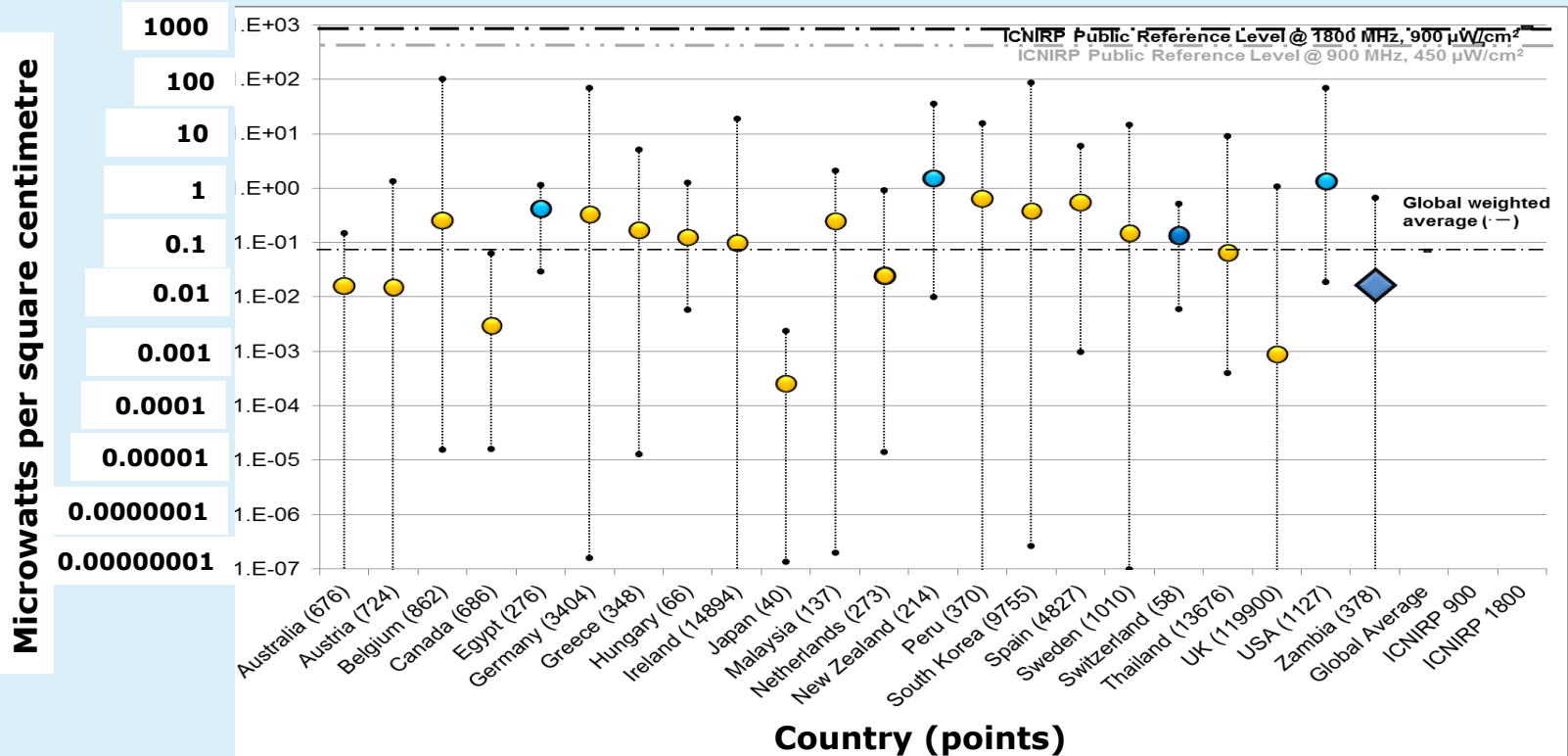
DECT cordless phone (20 cm)

Based on [Valberg et al., 2007](#)





Exposure similar for all countries



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

Based on [Rowley and Joyner, 2012](#)





Rooftop Antennas



Residential and office building RF exposures are in general lower than 1% of ICNIRP or IEEE limits, similar to radio and TV broadcast exposure level.

Rooftop antenna installation is safe.





Example: antennas on a pole



Compliance range

Outside the green regions,
exposure is below ICNIRP limits.

20 watts
3G, 2100 MHz



Definitely, there are big effects!

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



Not RF effects

It's improper use of the device!



Established Scientific Understanding (in green)

- ❖ Microwave radiation is dangerous
- ✓ Only when at high intensity
- ❖ We don't have enough understanding of its effects
- ✓ 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





Conclusions

- Radiofrequency electromagnetic exposure is very different from nuclear radiation.
- 70 years of research shows the only established adverse health effect of RF energy (above 100 kHz) is thermal effect.
- 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 safety guidelines or exposure standards (ICNIRP, IEEE).
- Ordinary exposures are very low. Unnecessary worry can cause nocebo effects.



Built on Solid Rocks (Established Effects)

Thank You



(Possible Effects)

Contact:
ck.chou@ieee.org



National Toxicology Program (NTP) Study on rats (2016)



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 ($p < 0.05$)

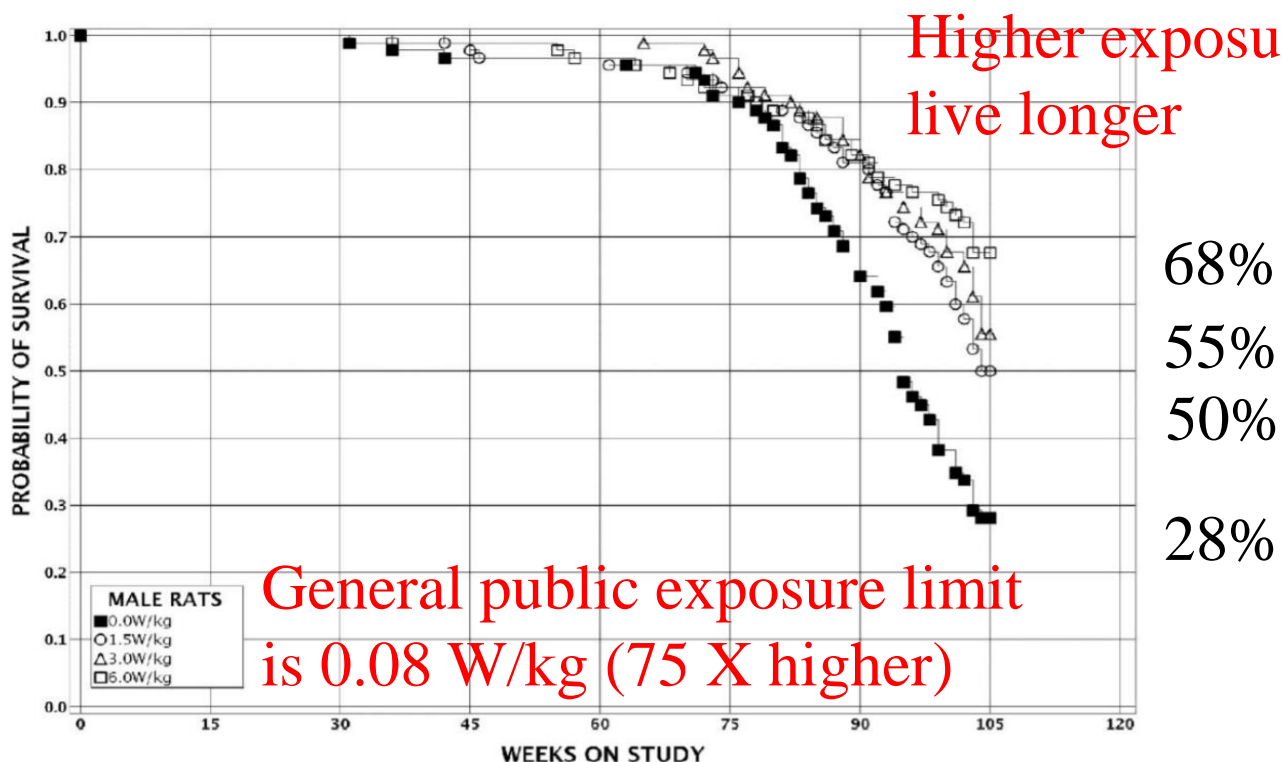




NTP study (2016)



Survival in male rats exposed to GSM RFR



- Greater survival in all groups of exposed males compared to controls

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ICNIRP Note (September 4, 2018)

RECENT ANIMAL CARCINOGENESIS STUDIES

<https://www.icnirp.org/cms/upload/publications/ICNIRPnote2018.pdf>

- ❖ “Two recent animal studies investigating the carcinogenic potential of long-term exposure to radiofrequency electromagnetic fields (EMFs) associated with mobile phones have been released: one by the U.S. **National Toxicology Program** and the other from the **Ramazzini Institute**.”
- ❖ “However, both studies have **inconsistencies and limitations** that affect the usefulness of their results for setting exposure guidelines, and both need to be considered within the context of other animal and human carcinogenicity research.”
- ❖ “Overall, based on the considerations outlined below, ICNIRP concludes that **these studies do not provide a reliable basis for revising the existing radiofrequency exposure guidelines**.”

