IEEE Oakland/East Bay
Life Members Affinity Group

Safety Issues of Radiofrequency Exposure

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IEEE ICES

*Speaking as an individual and not for the IEEE

Outline

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

A Global Issue

History of the issues

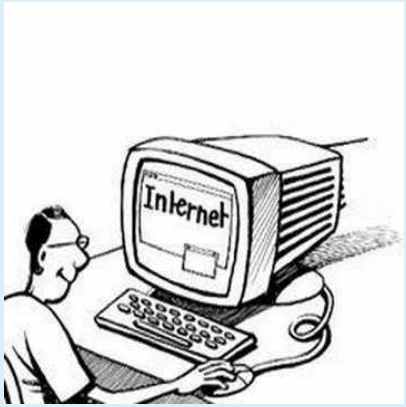
RF Sources (year)

- 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 (2012-?)

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

Internet information on microwave ovens

TOP 5 Reasons Not To Use A Microwave

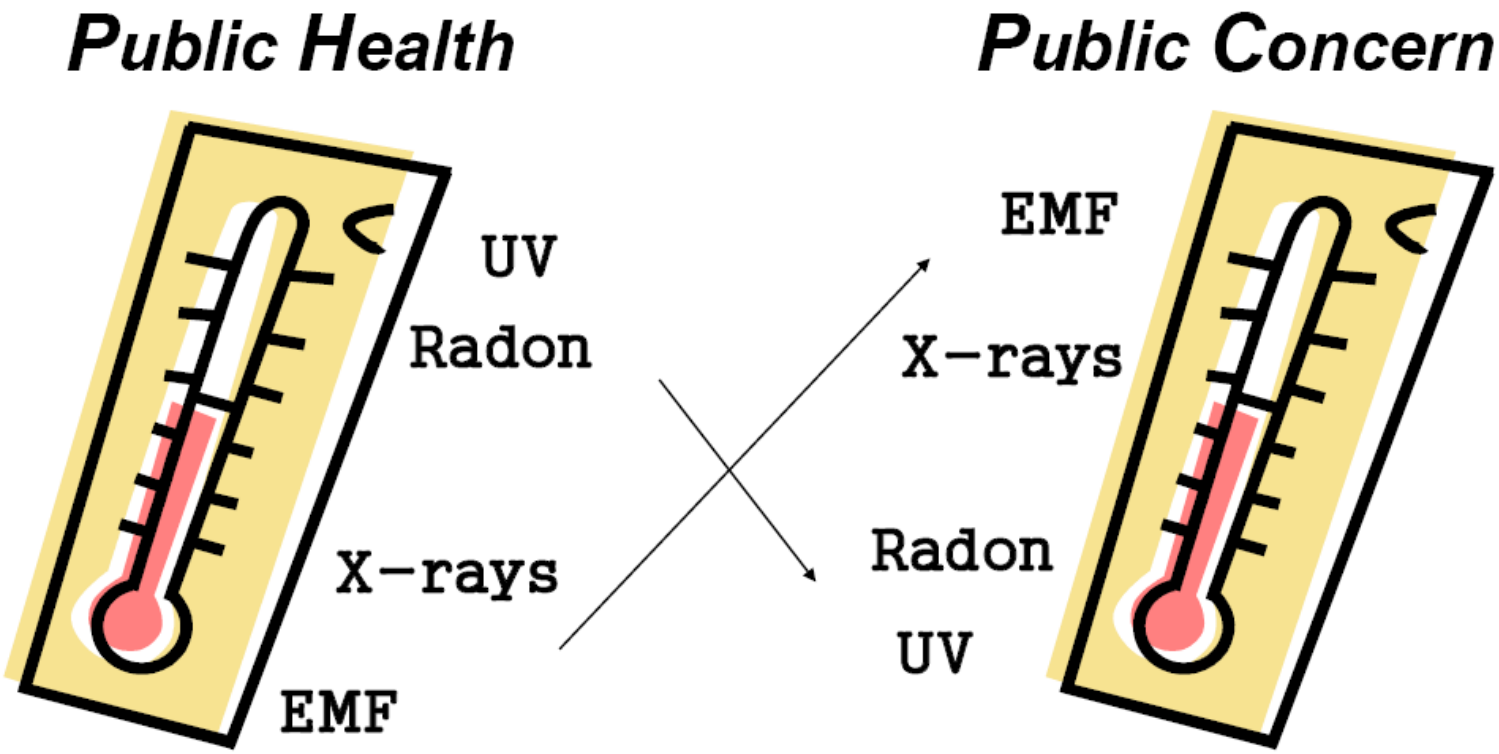
1. Microwaves were never thoroughly researched before adoption
2. Microwaves destroy the nutrient value of your food
3. Microwaves create carcinogenic compounds in certain foods
4. Microwaves provide unnecessary daily exposure to radiation
5. Microwaves can create severe health issues

Important Tips to Remember....

- Eat raw foods at every meal
- Thaw freezer items in fridge before heating
- Heat foods safely using a steamer or in a 200-250 degree oven
- Choose restaurants that do not use microwaves

More info @ foodbabe.com

Radiation

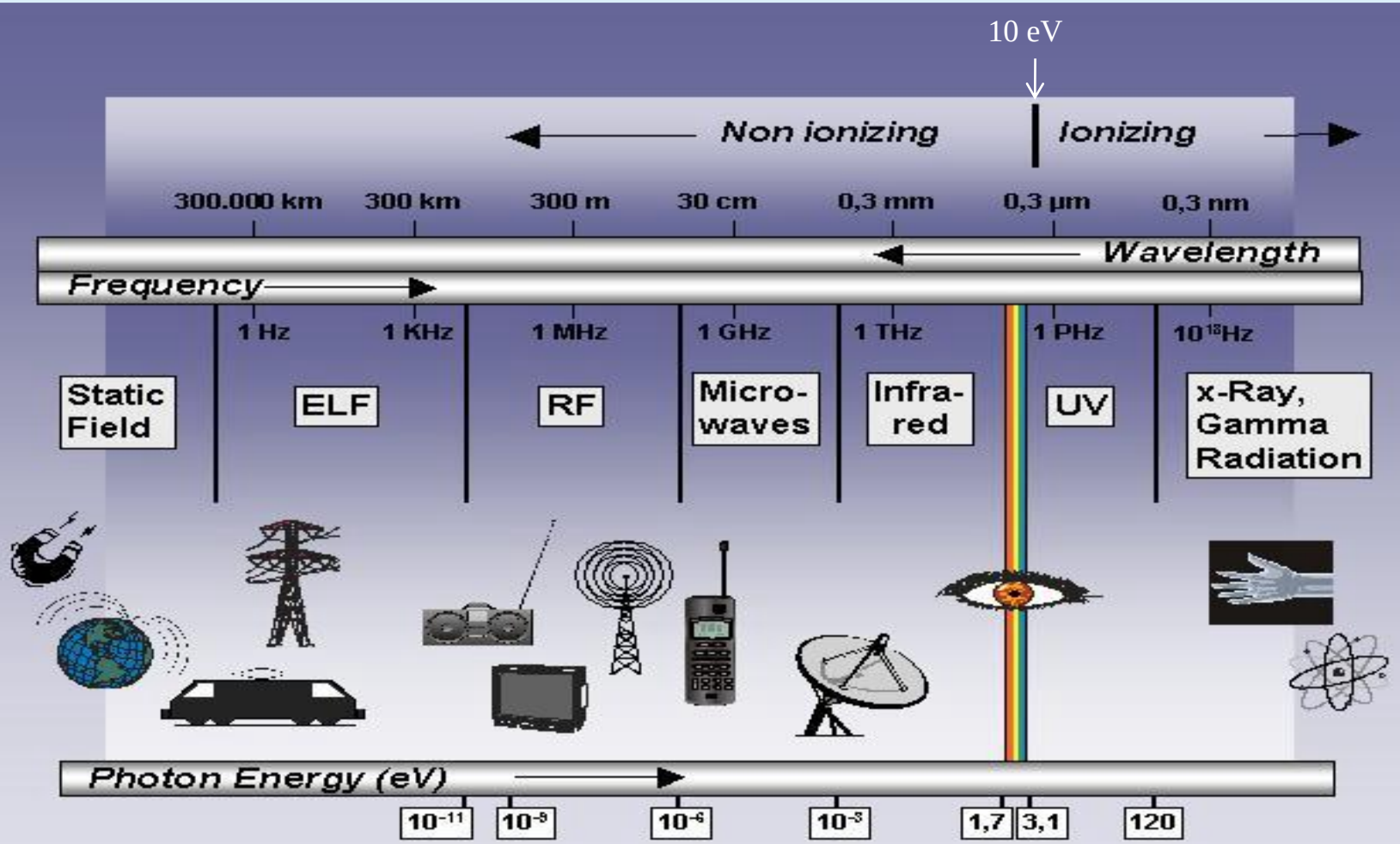

Public Health
Public Concern
UV
Radon
X-rays
EMF
EMF
X-rays
Radon
UV

Roots of Concern: “Radiation”

RF Exposure

≠

Nuclear 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
Static Field
ELF
RF
Micro-waves
Infra-red
UV
x-Ray, Gamma Radiation
Photon Energy (eV)
10⁻¹¹
10⁻⁹
10⁻⁶
10⁻³
1,7
3,1
120

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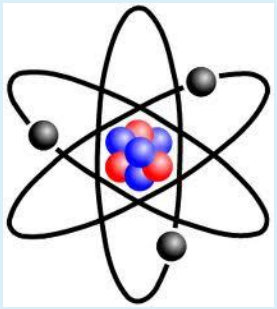
Ionizing vs. Non-Ionizing Energy



- **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

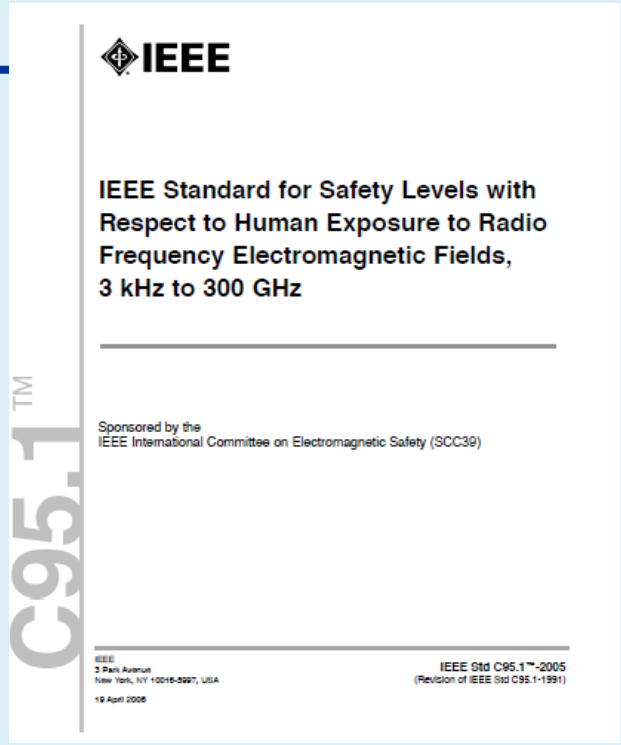
Steps to address safety concerns

Scientific research

Peer-reviewed publication

Consensus standards

Regulations

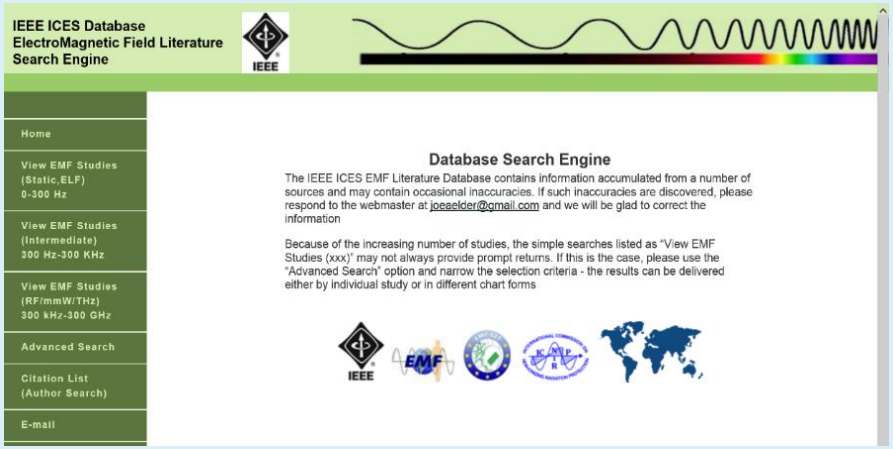


Extensive Research Database

- The biological effects of RF exposure have been studied for more than 60 years.

- Current IEEE EMF database contains 6358 entries, of which 3483 are relevant to biological effects of RF exposure (September 13, 2016)

http://ieee-emf.com/



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

Mobile Telephony Related Studies

Study Type	Published
Epidemiology	452
Human	372
Animal	493
In Vitro	359
Engineering	1064
Total	2740

IEEE EMF Database (September 13, 2016)

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	?

Adapted from Osepchuk [2004]

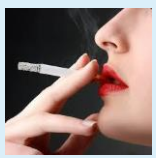
"Good science is never outdated." -- Herman P. Schwan

IARC: International Agency for Research on Cancer

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

- IARC has so far classified 990* 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 (118)
  - 2A probable carcinogen (80)
  - 2B possible carcinogen (289)
  - 3 not classifiable (502)
  - 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 13, 2016

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*

Statements from ICNIRP

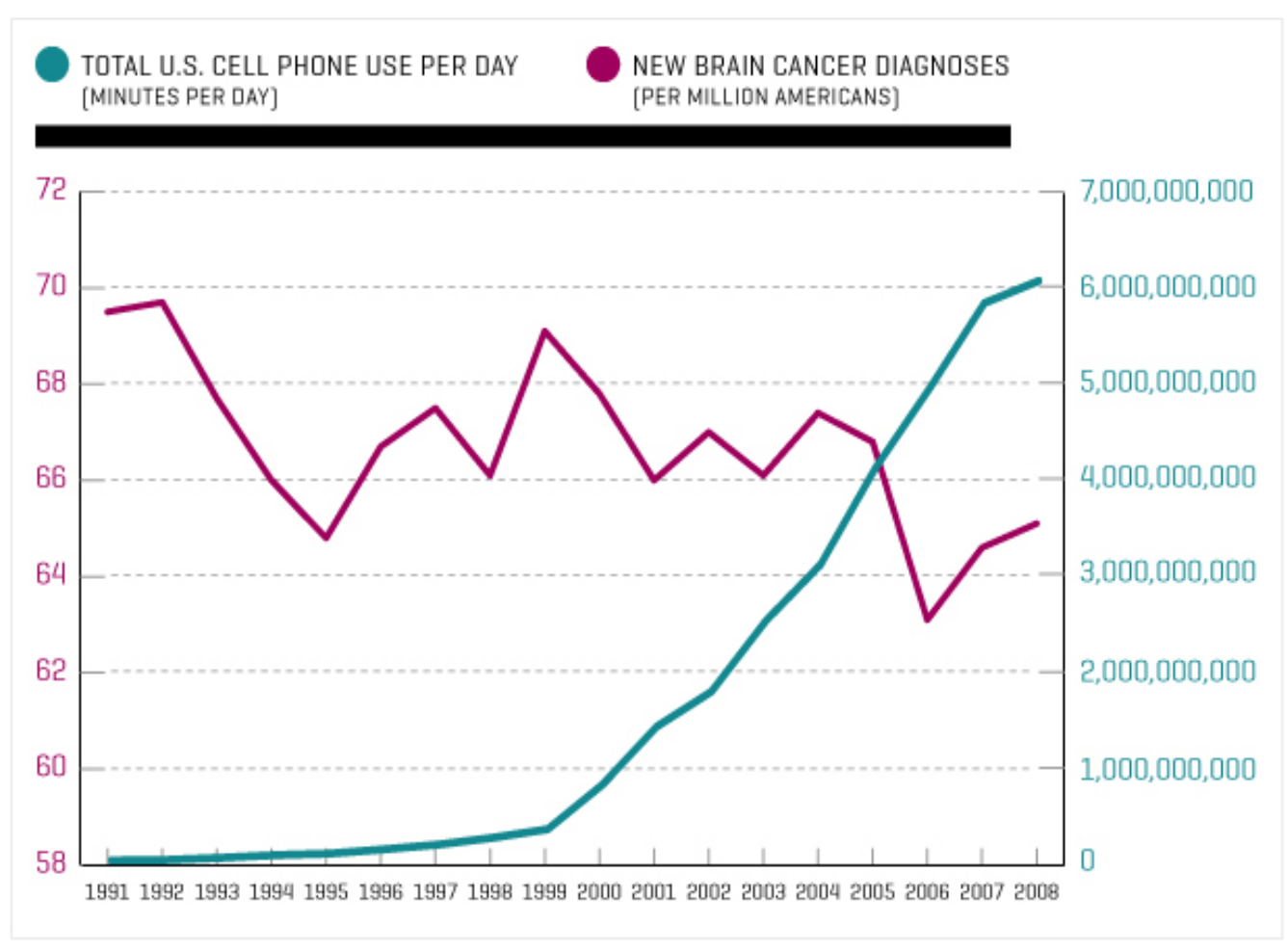
International Commission on Non-Ionizing Radiation Protection (July 1, 2011)
"Mobile Phones, Brain Tumours and the Interphone Study: Where Are We Now?" http://ehp03.niehs.nih.gov/article/info%3Adoi%2F10.1289%2Fehp.1103693

- "*In summary, Interphone and the literature overall have methodological deficiencies but do not demonstrate greater risk of either glioma or meningioma with longer or greater use of mobile phones, although the longest period since first use examined is <15 years*."
- "*Although there remains some uncertainty, the trend in the accumulating evidence is increasingly against the hypothesis that mobile phone use can cause brain tumours in adults*."

30-Year Brain Cancer Trends

- **New Zealand:** "*..there has been no consistent increase in incidence rates of primary brain cancers*." during 1995-2010 (2015).
- **Taiwan:** "*we do not detect any correlation between the morbidity/mortality of malignant brain tumors and cell phone use in Taiwan."* (2013)
- **UK:** Examined time trends in brain cancer incidence rates in England from 1998 to 2007, "*Increases in incidence should have begun to appear in cancer registry data if mobile phone use had an important impact on the cancer risk."* (2011)
- **United States: "***these incidence data do not provide support to the view that cellular phone use causes brain cancer*" (2010)
- **Scandinavia**: *"…No change in incidence trends were observed from 1998 to 2003, the time when possible associations between mobile phone use and cancer risk would be informative about an induction period of 5-10 years."* (2009)
- **Switzerland:** *"…after the introduction of mobile phone…brain tumour mortality rates remained stable in all age groups.."* (2007)

US Brain Cancer Rate vs. Cell Phone Use



US National Cancer Institute (2015)

Annual Report to the Nation on the Status of Cancer, 1975 -2011

- With regard to brain cancer [a category that also includes other nervous system cancer types], during the most recent 10-year period (2002-2011) mortality rates decreased among women and remained stable among men. During that same time period, brain cancer incidence rates remained stable among women and decreased among men [during the most recent 5-year period of 2007-2011, brain cancer incidence rates decreased among women].

Brain tumor incidence data (Netherlands)

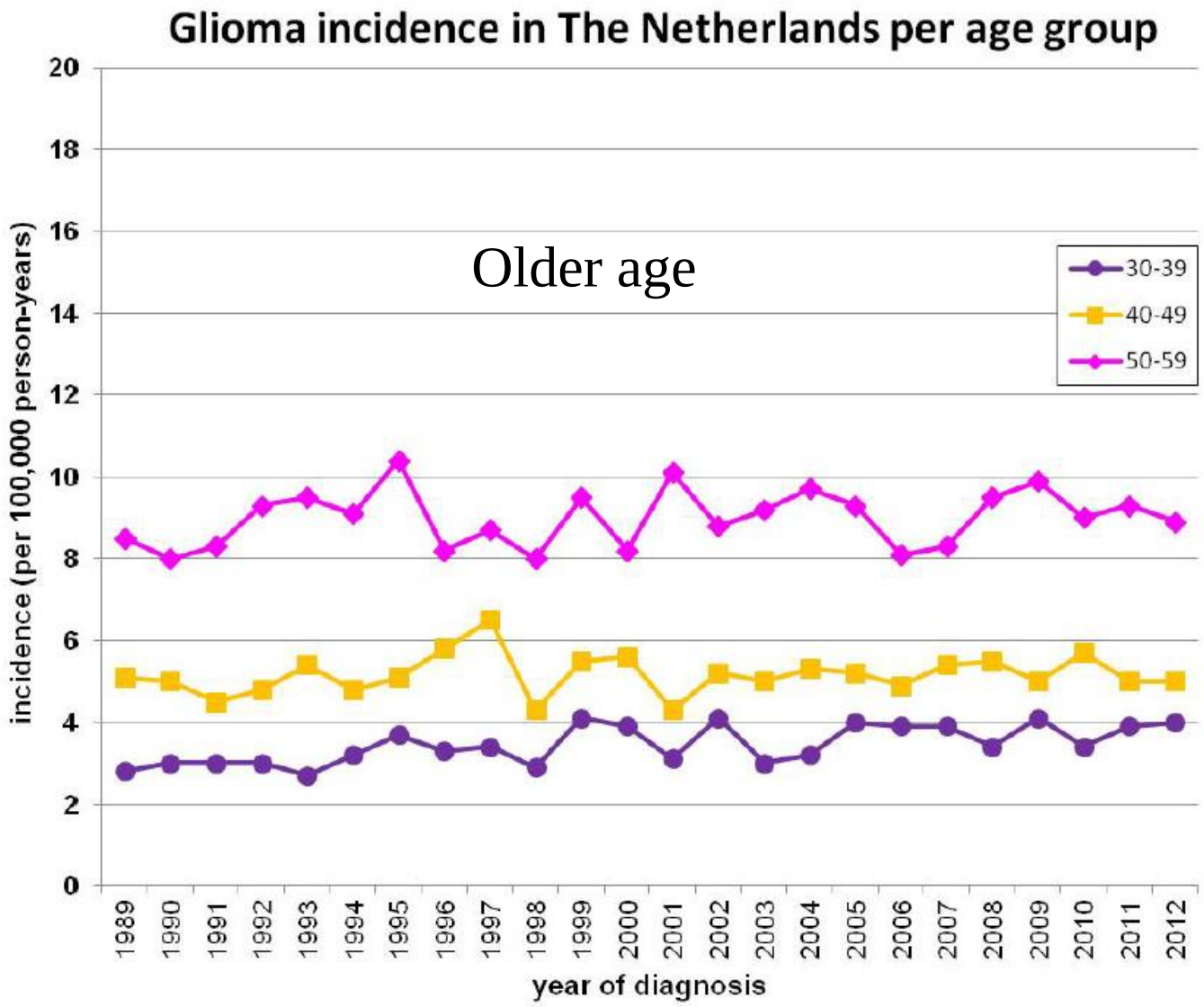
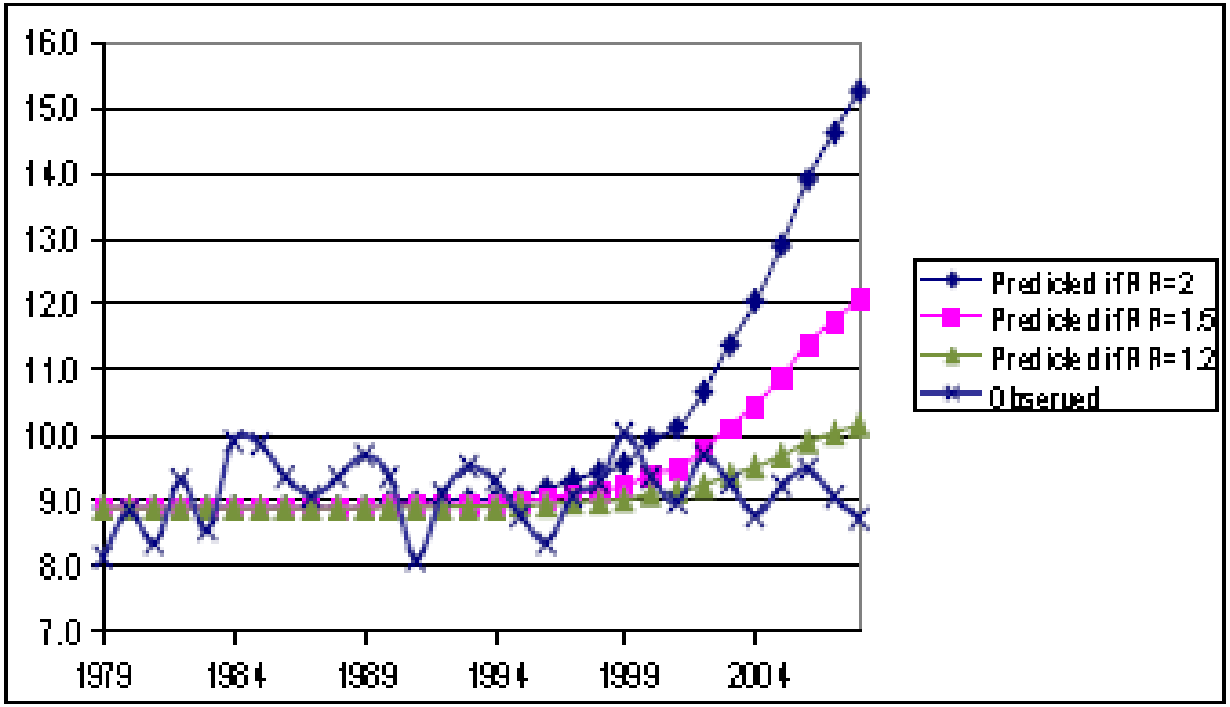


Figure 2c Glioma incidence in the Netherlands from 1989-2012 for the age groups 30-39, 40-49 and 50-59 years. Source: Netherlands Cancer Registry managed by CCCNL.

Increase in brain tumour rates?

All users at increased risk after 10 years



Glioma

International Agency for Research on Cancer

World Health Organization

Deltour et al., Epidemiology, 2012

Little et al., BMJ, 2012

Electrohypersensitivity EHS

- EMF Refugee Zone in France

- "Wi-Fi refugees" 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.

Example: Swedish Radiation Safety Authority (2015*)

Brain cancer: "… not convincing in linking mobile phone use to the occurrence of glioma or other tumours of the head region among adults. Recent studies described in this report do not change this conclusion although these have covered longer exposure periods." "It is also too early to draw firm conclusions regarding risk of brain tumours in children and adolescents, but the available literature to date does not indicate an increased risk."

EHS: "While the symptoms experienced by patients with EHS are real and some individuals suffer severely, studies so far have not provided evidence that exposure to electromagnetic fields is a causal factor. Several studies have indicated a nocebo effect, i.e. an adverse effect caused by an expectation that something is harmful."

Transmitters: "In line with previous studies, new studies on adult and childhood cancer with improved exposure assessment do not indicate any health risks for the general public related to exposure from radiofrequency electromagnetic fields from far-field sources, such as base stations and radio and TV transmitters. There is no new evidence indicating a causal link to exposure from far-field sources such as mobile phone base stations or wireless local data networks in schools or at home."

*2016 report reaffirms the 2015 results.

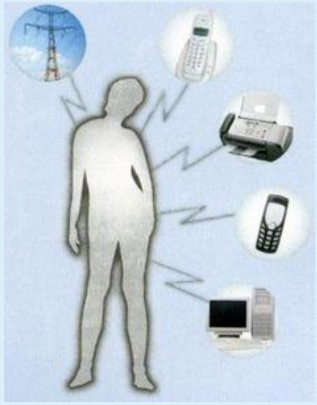
Expert Reviews (2010-2016)

Statements from Governments and Expert Panels Concerning Health Effects and Safe Exposure Levels of Radiofrequency Energy (67 citations)

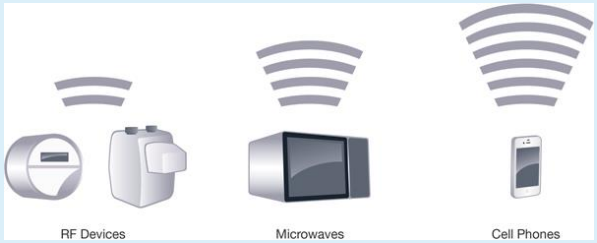
http://www.ices-emfsafety.org/expert-reviews/

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

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 26 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.

ICNIRP Guidelines on RF Exposures

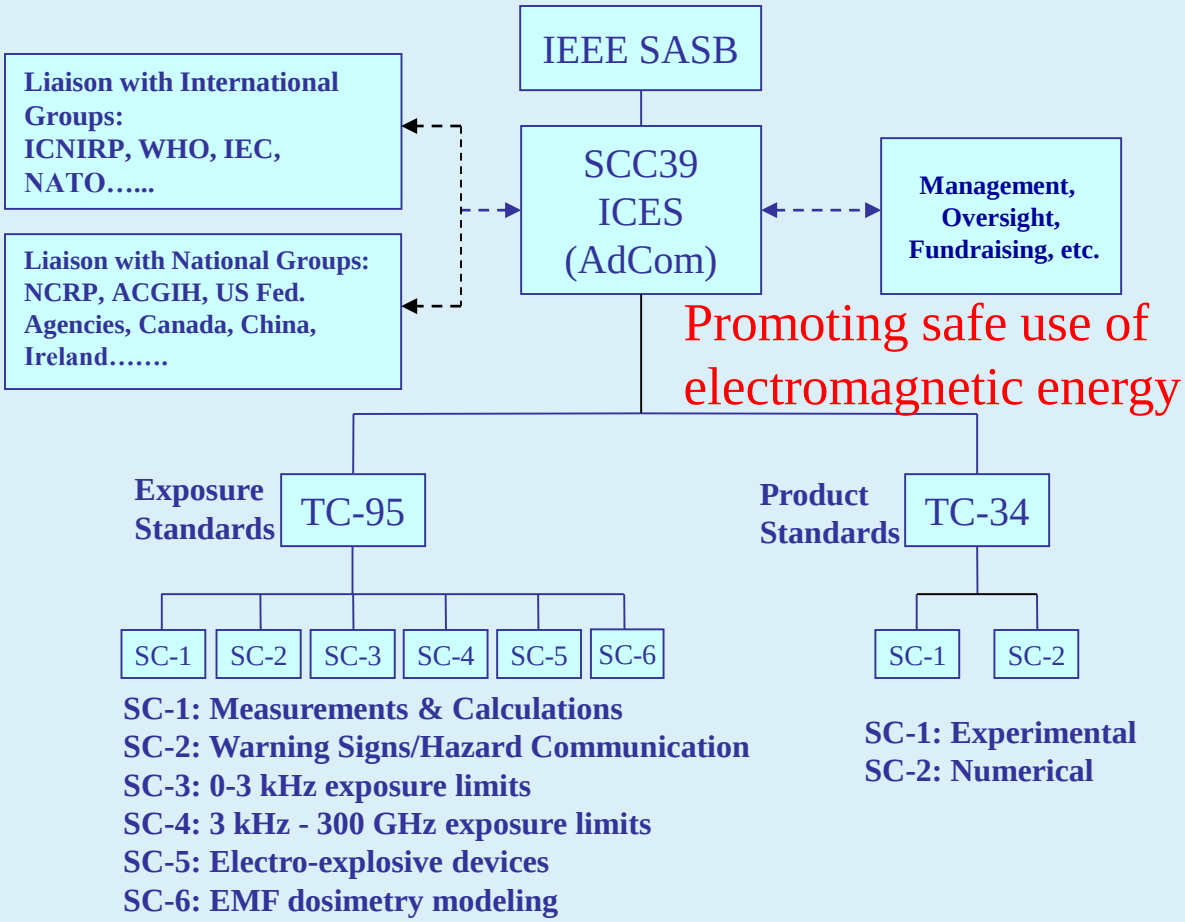
- For limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)

  Health Physics 74(4):494-522; 1998

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

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

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



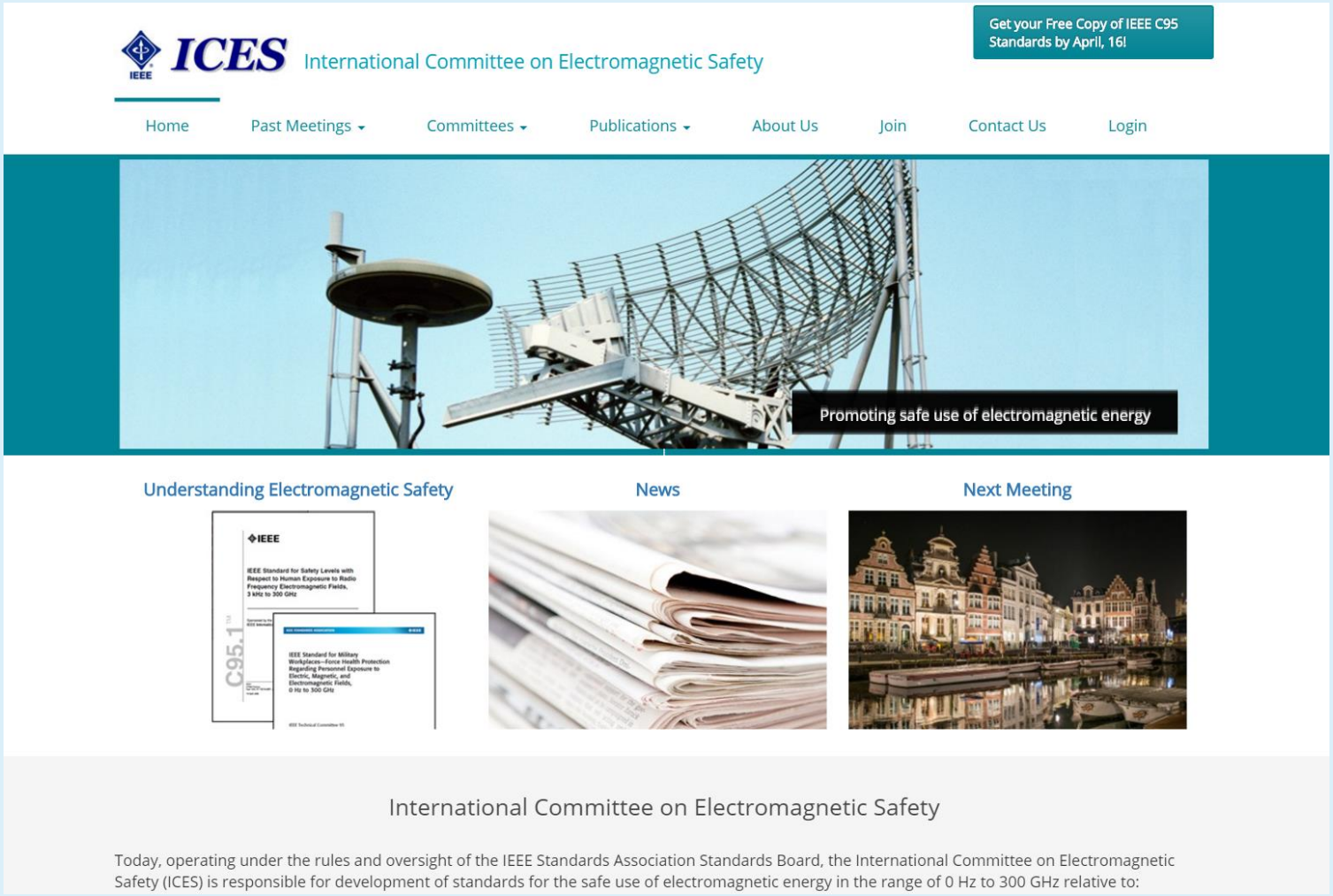
IEEE-SA Standards Process

- **Open Process**
  - Allows for challenging and testing of all viewpoints
- **Consensus process**
  - Balloting at Subcommittee and Sponsor level
  - 75% of ballots must be returned with at least a 75% approval to reach consensus
  - All negative comments and their resolutions must be recirculated

Examples:

- C95.6 (2002): 90% approval
- C95.1 (2005): 96% approval
- C95.1-2345 (2014): 98% approval

ICES Website
http://www.ices-emfsafety.org/



ICES Website
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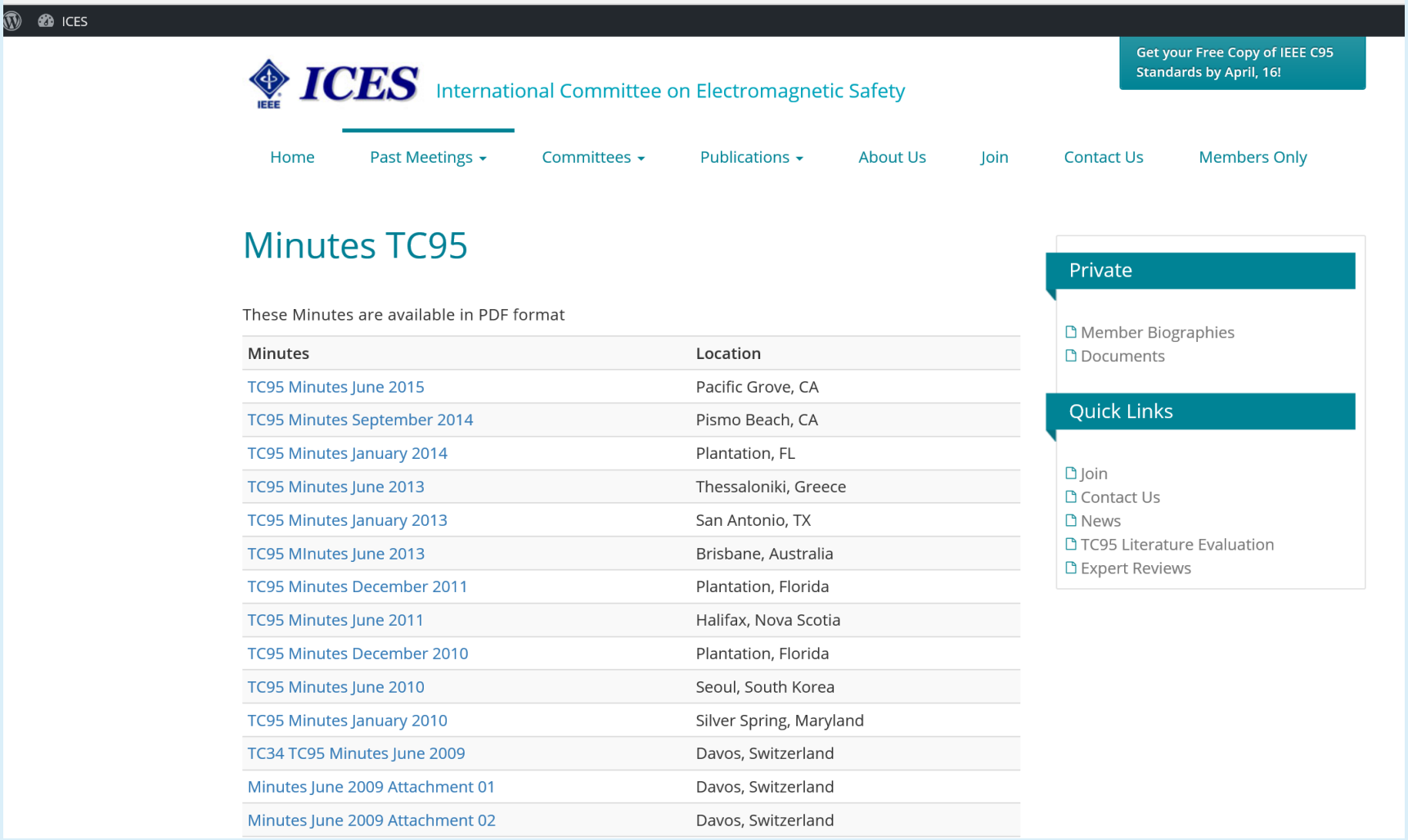

Reports

ICES Annual Report for 2015
ICES Annual Report for 2014
ICES Annual Report for 2013
ICES Annual Report for 2012
ICES Annual Report for 2011
ICES Annual Report for 2010
ICES Annual Report for 2009
ICES Annual Report for 2008
ICES Annual Report for 2007
ICES Annual Report for 2006
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ICES Annual Report for 2004
ICES Annual Report for 2003
ICES Annual Report for 2002
ICES Annual Report for 2001
ICES Annual Report for 2000
ICES Brochure

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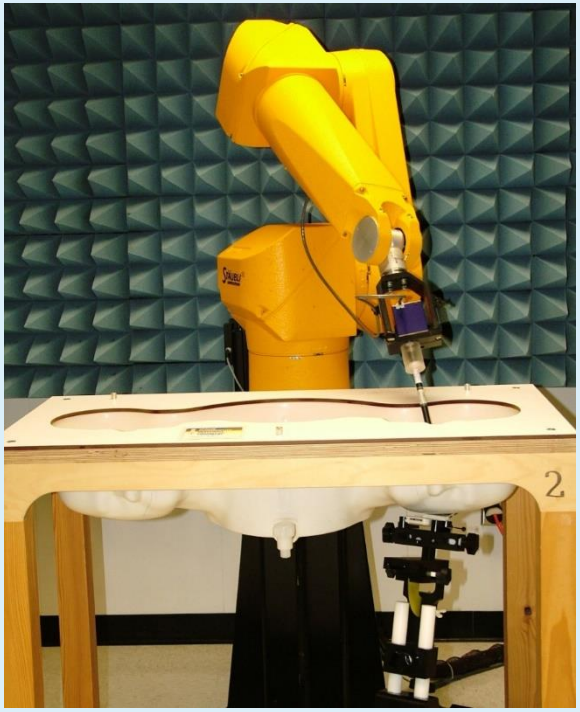
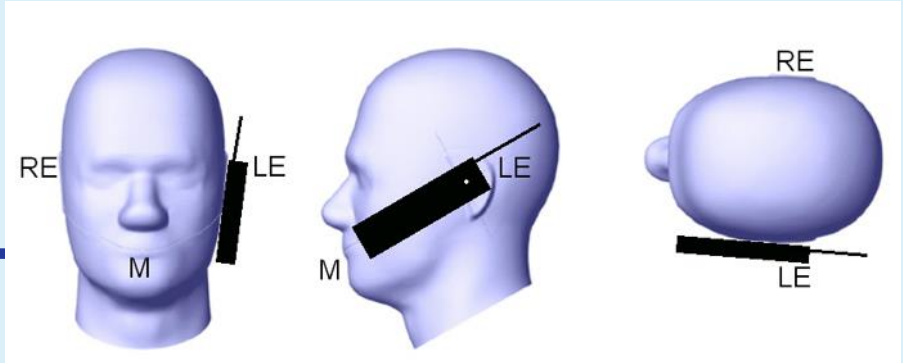
IEEE/ICES TC 34 update



IEEE/ICES product SAR assessment measurement standards

- Measurement standard IEEE 1528 was published in 2013
- The present activities regarding product SAR assessment measurement standards continues as joint activities with IEC TC106, mainly with IEC MT1, IEC PT62209-3 project teams.
- The objective is to publish all SAR assessment related product standards as dual logo standards with IEC.
- The expected time for publishing dual logo SAR assessment measurement standards is late 2017 or early 2018.



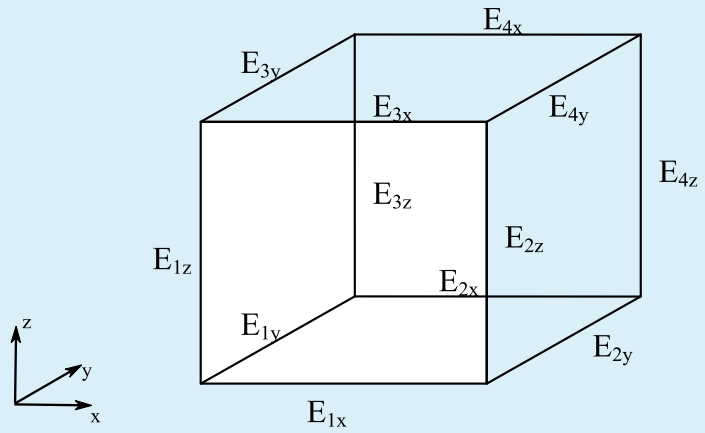
IEEE ICES

IEEE/ICE product SAR assessment numerical dual logo standards

- Project Reference – IEC/IEEE 62704-1:

  "Specific Absorption Rate (SAR) in the Human Body from Wireless Communications Devices: General Requirements for using the Finite Difference Time Domain (FDTD) Method for SAR Calculation"

- Forecast Publication Date – January 2017



IEEE ICES

IEEE/ICE product SAR assessment numerical dual logo standards

- Project Reference – IEC/IEEE 62704-2:

  "Specific Absorption Rate (SAR) in the Human Body from Wireless Communications Devices: Specific Requirements for Finite Difference Time Domain (FDTD) Modelling of Exposure from Vehicle Mounted Antennas"

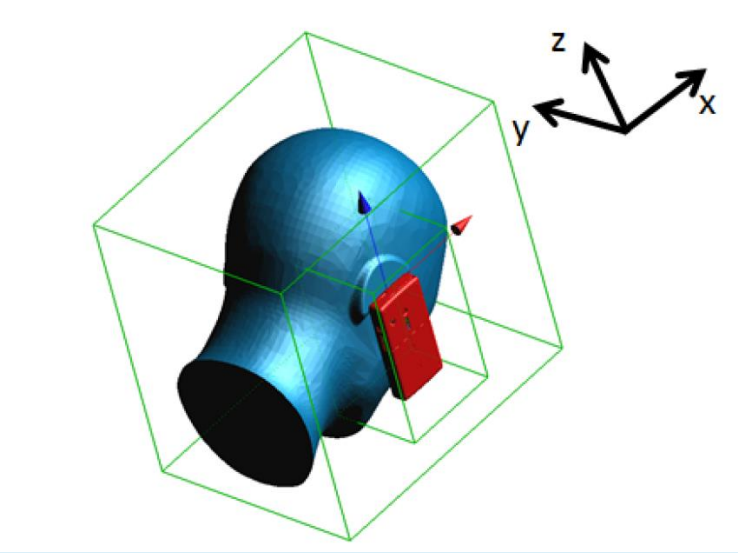
- Forecast Publication Date – January 2017

IEEE/ICE product SAR assessment numerical dual logo standards

- Project Reference – IEC/IEEE 62704-3:

  "Specific Absorption Rate (SAR) in the Human Body from Wireless Communications Devices: Specific Requirements for Finite Difference Time Domain (FDTD) Modelling of Exposure from mobile wireless communication devices"

- Forecast Publication Date – Late 2017



IEEE/ICE product SAR assessment numerical dual logo standards

- Project Reference – IEC/IEEE 62704-4:

  "Specific Absorption Rate (SAR) in the Human Body from Wireless Communications Devices: General Requirements for using the Finite Element Method (FEM) Method for SAR Calculation"

- Status:
  - The progress was slow but good progress during 2016
  - Planed committe draft for early 2017

Other related IEC standards

- **IEC 62232:2011**

Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure

- **IEC 62479 Ed. 1.0 b:2010**

Assessment of the compliance of low-power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)

IEEE Exposure Standards History

1960: USASI C95 Radiation Hazards Project and Committee chartered
1966: USAS C95.1-1966
10 mW/cm^2 (10 MHz to 100 GHz)
based on simple thermal model
1974: ANSI C95.1-1974 (limits for E^2 and H^2)
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

TC95 Standards

SC-1 (Techniques, Procedures, Instrumentation and Computation)

- C95.3-2002: Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz to 300 GHz (Reaffirmed 2008)*

- C95.3.1-2010: Recommended Practice for Measurements and Computation of Electric, Magnetic and Electromagnetic Fields With Respect to Human Exposure to Such Fields, 0 Hz – 100 kHz.

TC95 Standards

SC-1 (Continued)

- 1460-1996: IEEE Guide for the Measurement of Quasi-Static Magnetic and Electric Fields (Reaffirmed 2002, 2008, incorporated into C95.3.1-2010)
- **PC95.3-201X:** Draft Recommended Practice for Measurements and Computations of Electric, Magnetic and Electro-magnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 300 GHz (Revision of C95.3-2002—will incorporate C95.3.1-2010)
  - Discussing spatial averaging

TC95 Standards

SC-2 (Terminology, Units of Measurement and Hazard Communication)

- C95.2-1999: IEEE Standard for Radio Frequency Energy and Current Flow Symbols (Reaffirmed 2005)
- C95.7-2005: IEEE Recommended Practice for Radiofrequency Safety Programs
- C95.7-2014: IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz (Revision of C95.7-2005)

TC95 Standards

SC-3 (Safety Levels with Respect to Human Exposure, 0-3 kHz)

- C95.6-2002: IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz (Reaffirmed 2007)

SC-4 (Safety Levels with Respect to Human Exposure, 3 kHz-300 GHz)

- C95.1-2005: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency electromagnetic Fields, 3 kHz to 300 GHz

TC95 Standards

SC-3/SC-4

- C95.1-2345* -2014: IEEE Standard for Military Workplaces—Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz (Sponsor ballot 98% approval) NATO Accepted this standard on November 26, 2015 as STANAG 2345 (Edition 4).

- **PC95.1-201X:** Draft Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz (Revision—incorporates C95.1-2005 and C95.6-2002)

* NATO adopted Under an agreement between IEEE and the NATO Standardization Agency

TC95 Standards

SC-5 (Safety Levels with Respect to Electro-Explosive Devices)

- C95.4-2002: IEEE Recommended Practice for Determining Safe Distances From Radio Frequency Transmitting Antennas When Using Electric Blasting Caps During Explosive Operations (Reaffirmed 2008)
- Reactivate SC5 activities, will harmonize with other international standards

TC95 Exposure Standards

SC-6 (EMF Dosimetry Modeling)

- Newly formed in September 2014, working on LF range first involving detailed dosimetry and neurological models
- Invited members with expertise in electrical engineering, computer modeling, neurology, physiology, and electrical safety
- Special section: Recent progress in low-frequency dosimetry modeling: from induction to electrostimulation *Physics in Medicine and Biology* Volume 61 Number 12, 21 June 2016
  http://iopscience.iop.org/issue/0031-9155/61/12
- Developed low frequency research agenda

IEEE ICES Subcommittee 3
C95.6-2002 (0-3 kHz)

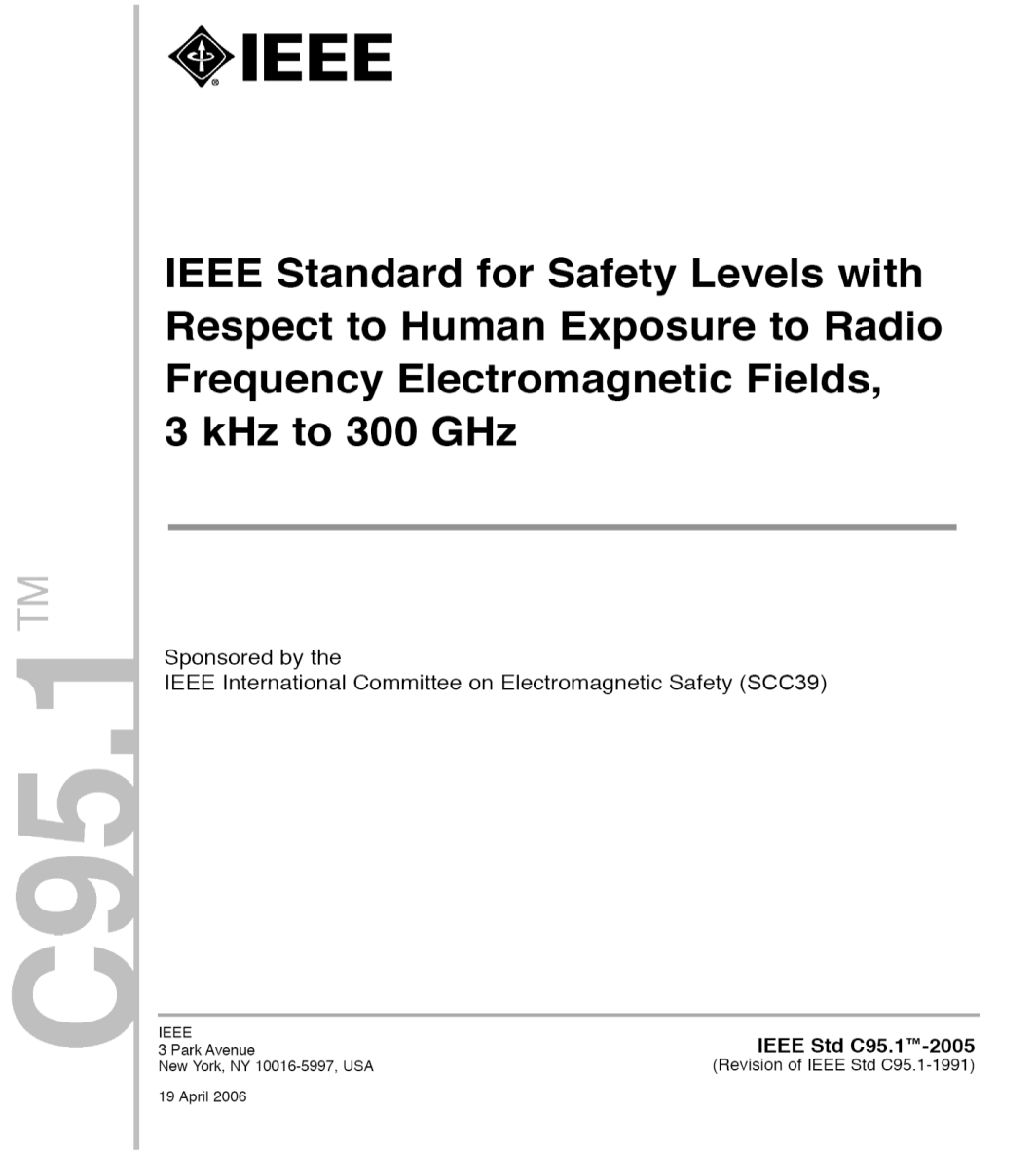
- Organized in 1991
- About 75 members from 11 different countries
- Broad expertise: biology, biophysics, engineering, epidemiology, medicine, etc.
- Members associated with Universities, Industry, Military, Government Agencies, Public, Consultants, Labor Unions, etc.

SC4 Membership Composition C95.1-2005 (3 kHz -300 GHz)

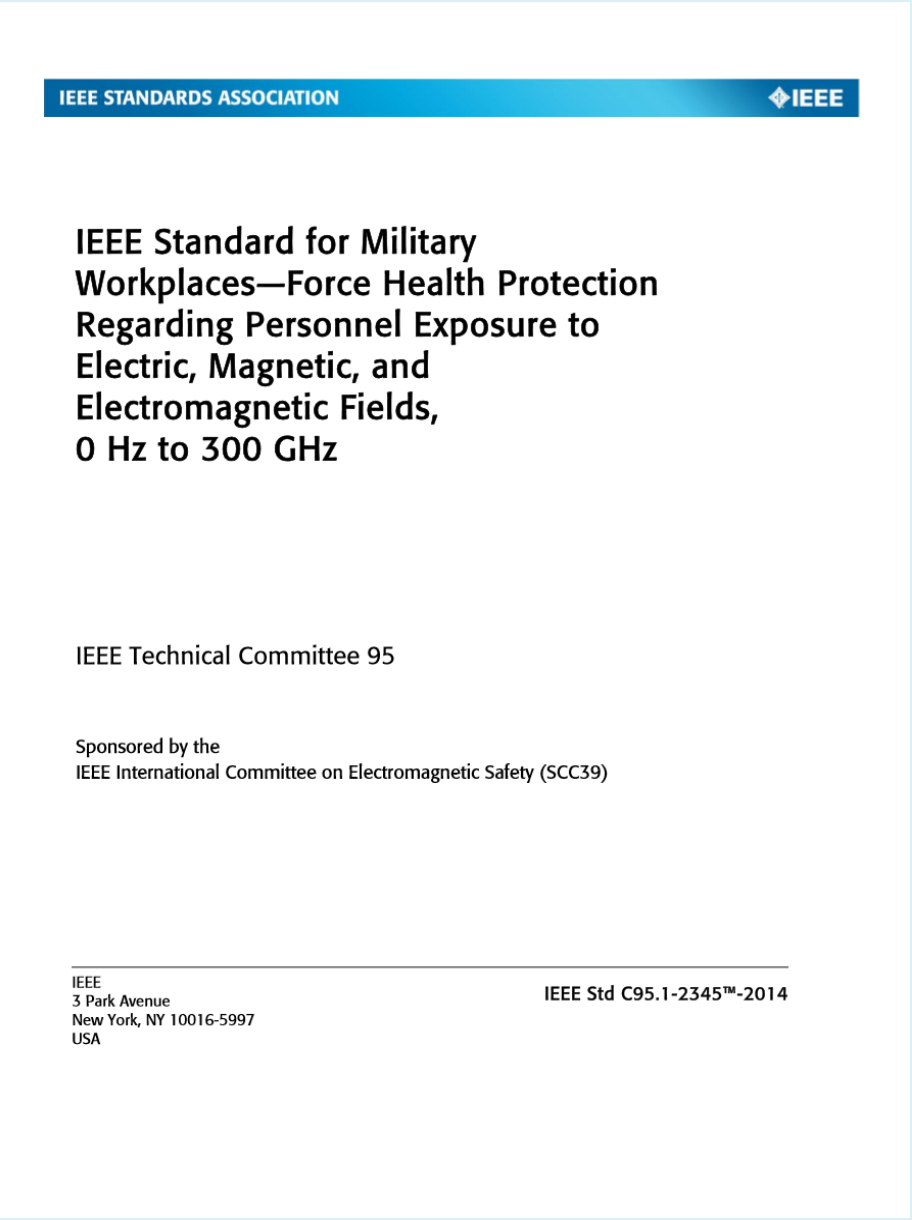
Biol Sci/Biophy	50	38%
Eng/Phys	52	39%
Psychology	5	4%
Medicine	6	5%
Env Health/Risk	11	8%
Others	8	6%
Total*	132	100%

From 24 countries

IEEE Std. C95.1-2005
pp 1-250



IEEE Std. C95.1-2345-2014
pp 1-57


IEEE STANDARDS ASSOCIATION IEEE

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

Weight of evidence

Subcommittee 4 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)**

Percentage evaluation

- Count percent of published positive reports on a subject
- vs. percent of negative reports
- Assuming some of the positive reports are correct
- Apply precautionary principle
- More research is needed

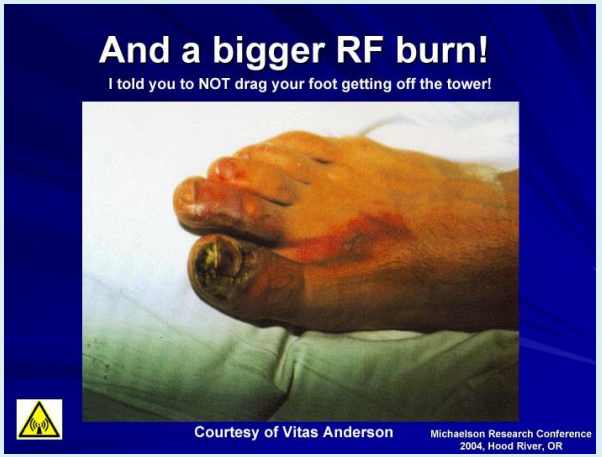
Positive effects evaluation

- Collect and emphasize positive effects
- Apply precautionary principle
- Demand a much lower exposure limit (0.3 nW/cm^2)

"Picking Cherries in Science: The Bio-Initiative Report"
by Kenneth R. Foster & Lorne Trottier, February 15, 2013 in *Science-Based Medicine*
https://www.sciencebasedmedicine.org/picking-cherries-in-science-the-bio-initiative-report/

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 ?

- No adverse effects have been established from low-level exposures despite 50 years of research
- No known interaction mechanisms
- No meaningful dose-response relationship
- Speculative
- Inappropriate for standard setting

*The committee is unaware of any more recent studies that would change the conclusions reached in the 2005 version of the standard. (2011 June meeting conclusion)

Basis of C95.1-2005

The development of this standard is based on protection against the following established adverse health effects:

- aversive or painful electrostimulation due to excessive RF internal electric fields (3 kHz – 5 MHz)
- RF shocks or burns due to contact with excessively high RF currents (3 kHz – 110 MHz)
- heating pain or tissue burns due to excessive localized RF exposure (> 100 kHz)
- behavioral disruption, heat exhaustion or heat stroke due to excessive whole body RF exposures (> 100 kHz)

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

Basic restrictions for frequencies between 100 kHz and 3 GHz

		Action level[a] SAR[b] (W/kg)	Persons in controlled environments SAR[c] (W/kg)
Whole-body exposure	Whole-Body Average (WBA)	0.08	0.4
Localized exposure	Localized (peak spatial-average)	2[c]	10[c]
Localized exposure	Extremities[d] and pinnae	4[c]	20[c]

[a]BR for the general public when an RF safety program is unavailable.

[b]SAR is averaged over the appropriate averaging times as shown in Table 8 and Table 9.

[c]Averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube).*

[d]The extremities are the arms and legs distal from the elbows and knees, respectively.

*The volume of the cube is approximately 10 cm^3.

IEEE C95.1-2005
Maximum Permissible Exposure (MPE)

Table 8—MPE for the upper tier (people in controlled environments)
(see Figure 3 for graphical representation)

Frequency range (MHz)	RMS electric field strength (E)[a] (V/m)	RMS magnetic field strength (H)[a] (A/m)	RMS power density (S) E-field, H-field (W/m^2)	Averaging time $\|E\|^2$, $\|H\|^2$ or S (min)
0.1–1.0	1842	$16.3/f_M$	$(9000, 100\,000/f_M^2)$[b]	6
1.0–30	$1842/f_M$	$16.3/f_M$	$(9000/f_M^2, 100\,000/f_M^2)$	6
30–100	61.4	$16.3/f_M$	$(10, 100\,000/f_M^2)$	6
100–300	61.4	0.163	10	6
300–3000	–	–	$f_M/30$	6
3000–30 000	–	–	100	$19.63/f_G^{1.079}$
30 000–300 000	–	–	100	$2.524/f_G^{0.476}$

NOTE—f_M is the frequency in MHz, f_G is the frequency in GHz.

IEEE C95.1-2005

Maximum Permissible Exposure (MPE)

Table 9—Action level (MPE for the general public when an RF safety program is unavailable) (see Figure 4 for graphical representation)

Frequency range (MHz)	RMS electric field strength (E)[a] (V/m)	RMS magnetic field strength (H)[a] (A/m)	RMS power density (S) E-field, H-field (W/m^2)	Averaging time[b] $\|E\|^2$, $\|H\|^2$ or S (min)	
0.1–1.34	614	$16.3/f_M$	$(1000, 100\,000/f_M^2)$[c]	6	6
1.34–3	$823.8/f_M$	$16.3/f_M$	$(1800/f_M^2, 100\,000/f_M^2)$	$f_M^2/0.3$	6
3–30	$823.8/f_M$	$16.3/f_M$	$(1800/f_M^2, 100\,000/f_M^2)$	30	6
30–100	27.5	$158.3/f_M^{1.668}$	$(2, 9\,400\,000/f_M^{3.336})$	30	$0.0636\,f_M^{1.337}$
100–400	27.5	0.0729	2	30	30
400–2000	–	–	$f_M/200$	30	
2000–5000	–	–	10	30	
5000–30 000	–	–	10	$150/f_G$	
30 000–100 000	–	–	10	$25.24/f_G^{0.476}$	
100 000–300 000	–	–	$(90f_G–7000)/200$	$5048/[(9f_G–700)f_G^{0.476}]$	

NOTE—f_M is the frequency in MHz, f_G is the frequency in GHz.

NATO adopted

- On November 26, 2015, this standard became NATO STANAG 2345 Edition 4.

NATO
OTAN

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Measure field intensity with a broadband survey meter

Densitometry

Measure power density in mW/cm^2 or $\mu W/cm^2$ with a survey meter

Compare with Reference Limits or MPE

Monitoring field intensity

TEST EQUIPMENT 50 FEET FROM PROBE

Operator interaction with the field can lead to significant differences in compliance measurements at antenna sites.

Fence and signs to control exposures

Example of a misused sign

RF is not radioactive!

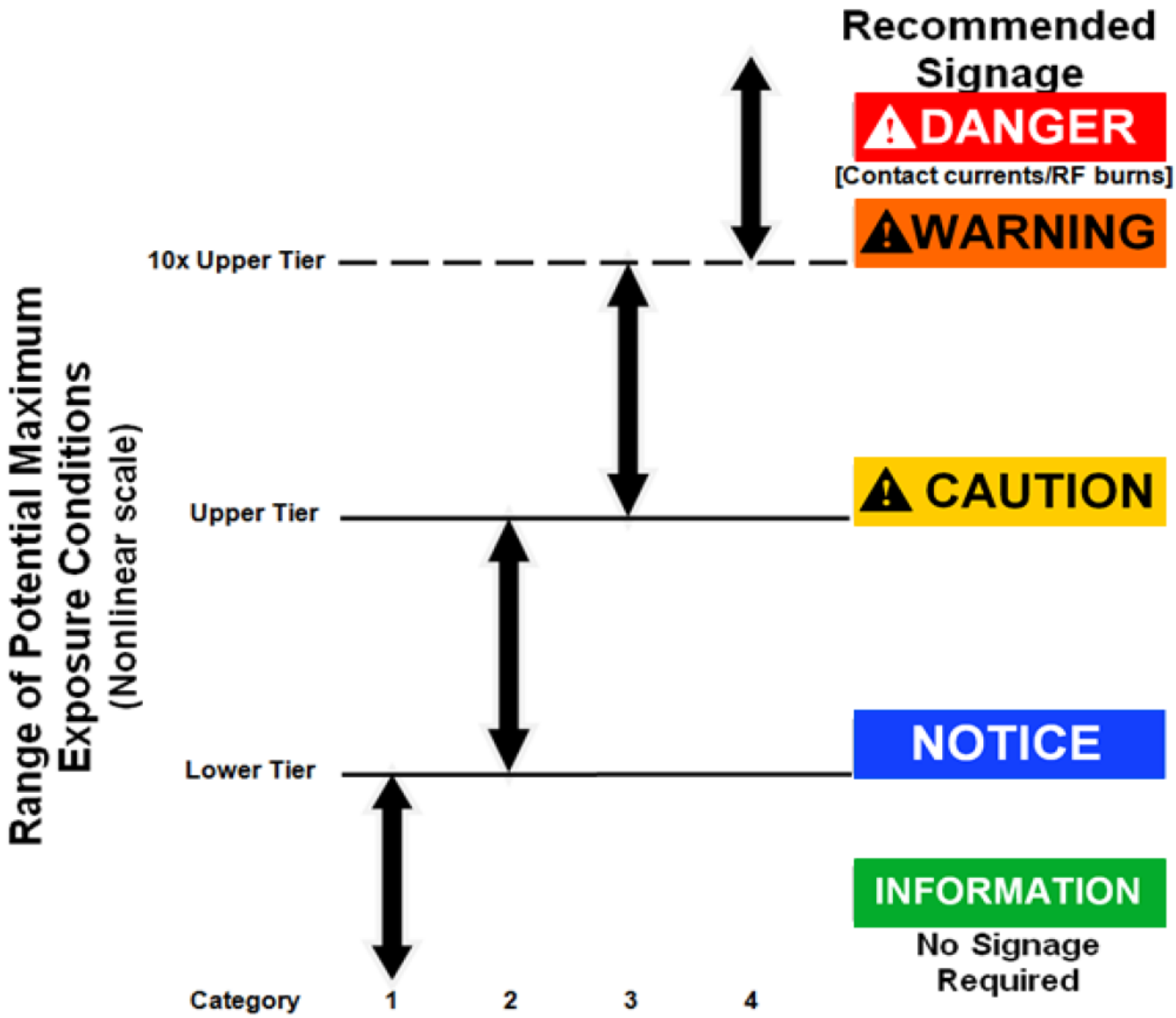
Over usage of signs

C95.7-2014: IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz

- Four categories based on the potential hazard, as defined by exposure limits, and specifying appropriate controls for each category.

- Such controls include engineering and administrative controls as well as the use of personal protective equipment, placement of appropriate RF safety signage, designation of restricted access areas, the use of personal RF monitors, and RF safety awareness training.

RF Safety Program Exposure Categorization



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Annexes in C95.7-2014

- Annex A: Topics for inclusion in RF safety awareness training
- Annex B: Examples of key aspects of RFSPs for selected exposure scenarios
- Annex C: Identifying RF sources and categorization of potential exposure conditions
- Annex D: RF fields—general measurement issues
- Annex E: Estimating RF exposure potential
- Annex F: Example reference materials
- Annex G: Example over-exposure incident report form format (use for designing organization-specific form)
- Annex H: Glossary

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 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 C95.3™-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 C95.6™-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.

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Regulations

Two approaches of protection

- Established Adverse Health Effects
- Possible Biological Effects

International RF Safety Standards

- **IEEE ICES C95.1-2005:** "*The purpose of this standard is to provide exposure limits to protect against established adverse effects to human health induced by exposure to RF electric, magnetic and electromagnetic fields over the frequency range of 3 kHz to 300 GHz*."
  *C95.1-2345 (2014) for NATO application

- **ICNIRP (1998):** "*this publication is to establish guidelines for limiting EMF exposure that will provide protection against known adverse health effects*".
  *ICNIRP reconfirmed its RF guidelines in 2009.

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/cm^2 as a precautionary action level)

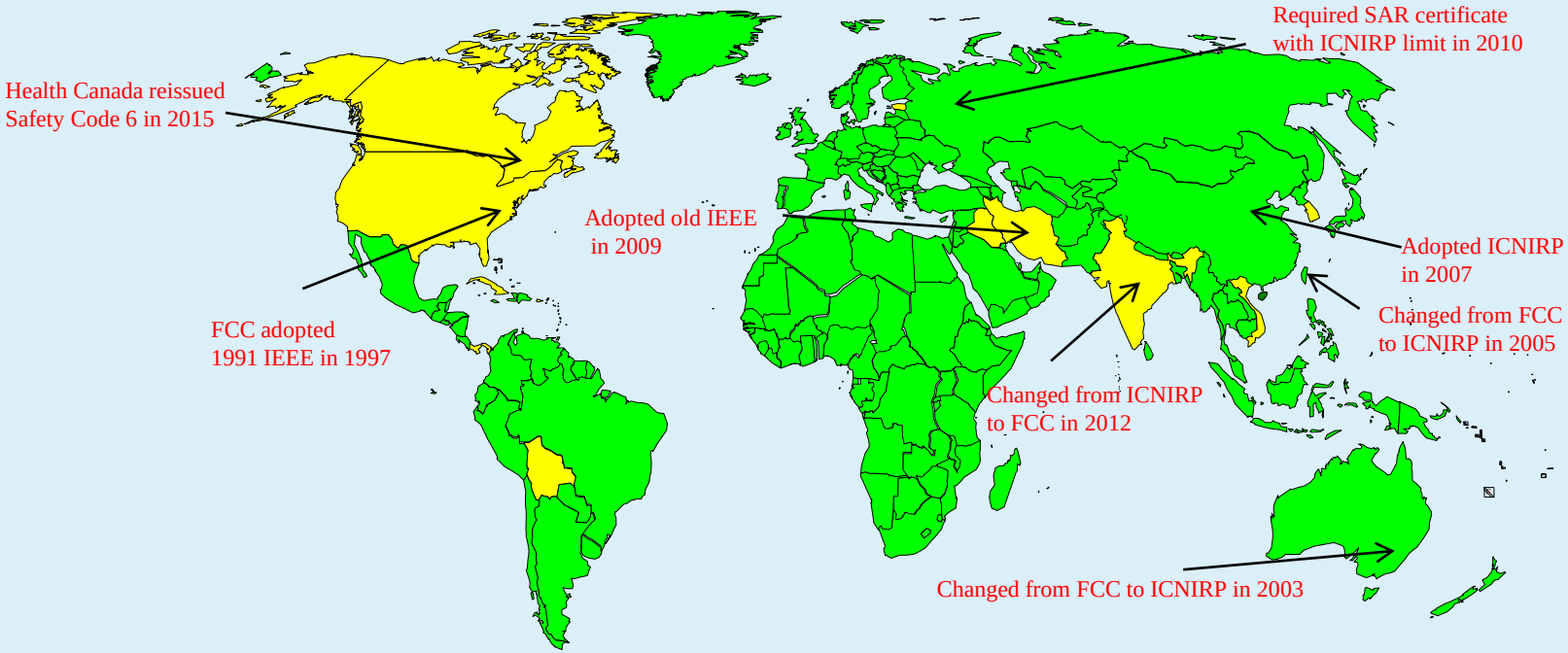
Example of the two different approaches

- "*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 finish*ed."

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.

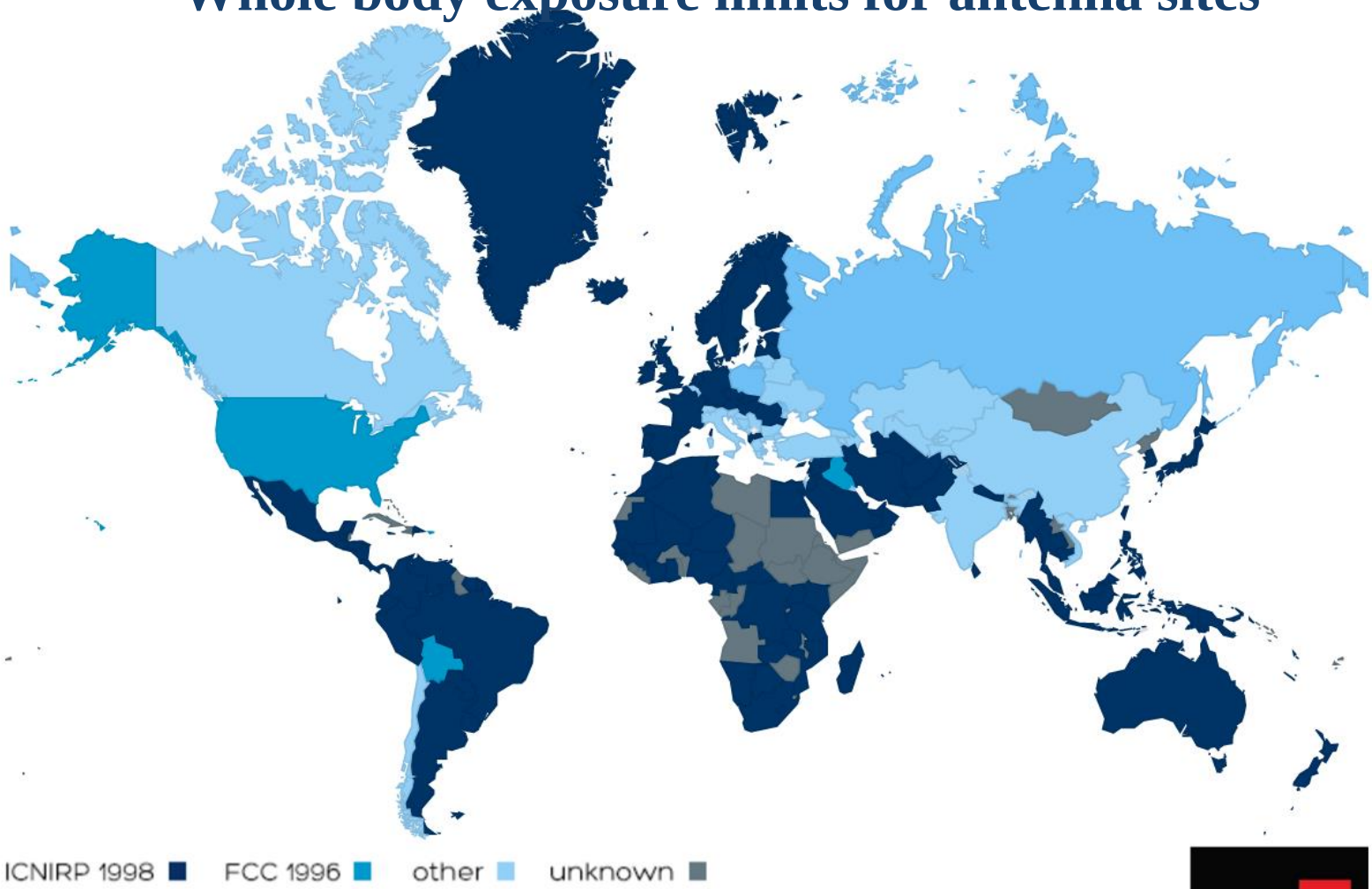
- This is an important difference from the approach used by the IEEE and ICNIRP.

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



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

Note: Information from public sources except where indicated.

Last updated: 24 April 2016

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.

Risk Communication

Risk and risk perception factors

- Wireless communication technology is complex
- Inability of science to “prove safety” for anything
- Risk communications aim to:
  - Establish the communicator as a trusted source of information
  - Convey information

Risk and risk perception factors

- Risk perception
- Perception => Reality
- Precautionary recommendations can increase concerns.
- WHO supports the levels set by ICNIRP as they are based on up-to-date scientific information.
- WHO recommends against arbitrary precautionary levels.

Differences between Science and Media

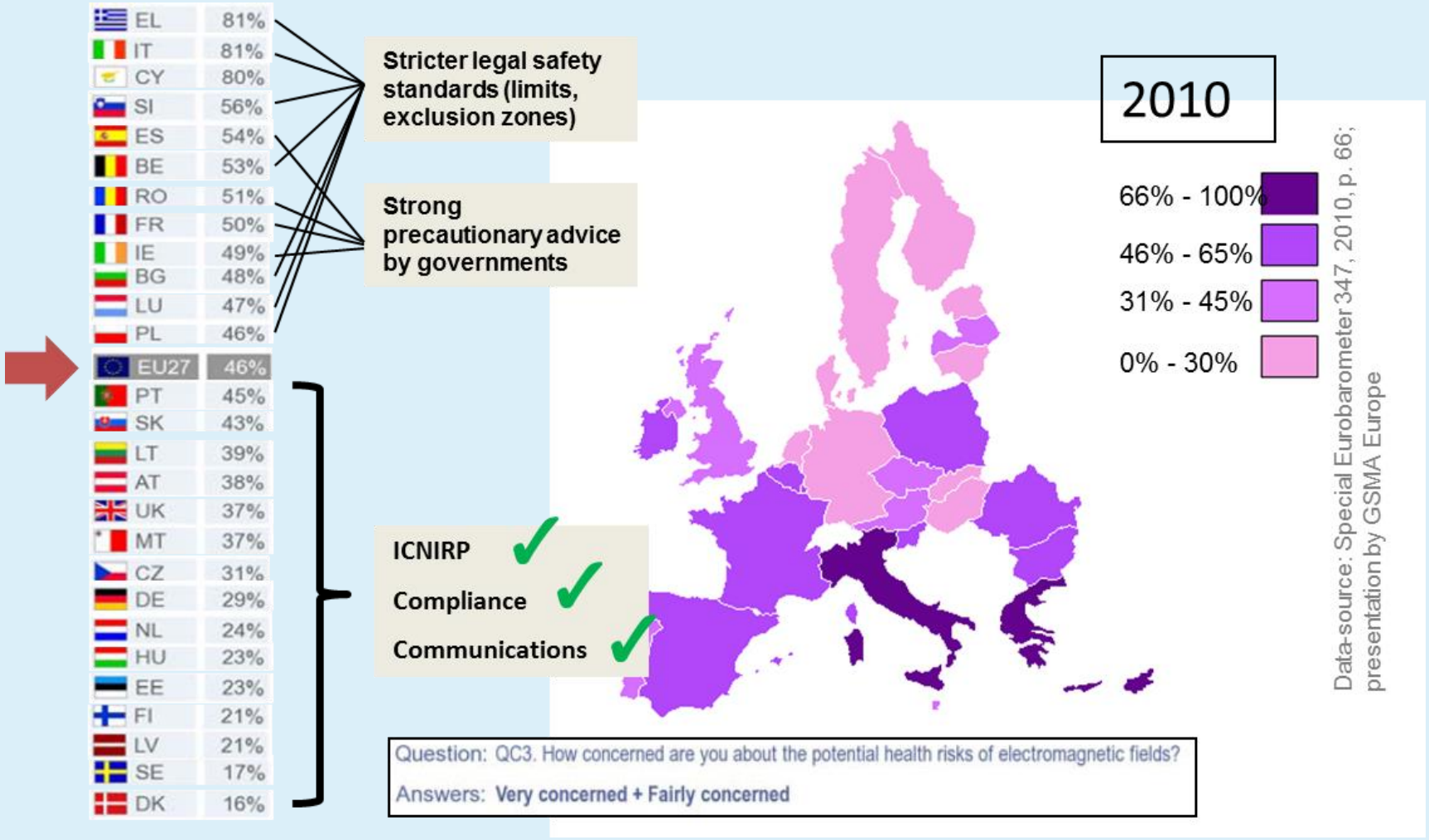
Science	Media
Consensus	Conflicts
Truth	“News“
General Laws	Stories
to be continued	

Problems in Media Communication

- Media reports on EME issues often are not verified and reviewed
- Statements from so called “Experts”
- “Spot light” reporting, not “weight of evidence”
- Sensationalism, need to have a “hook” in each story
- 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.

Relationship between Policies and Public Concern



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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

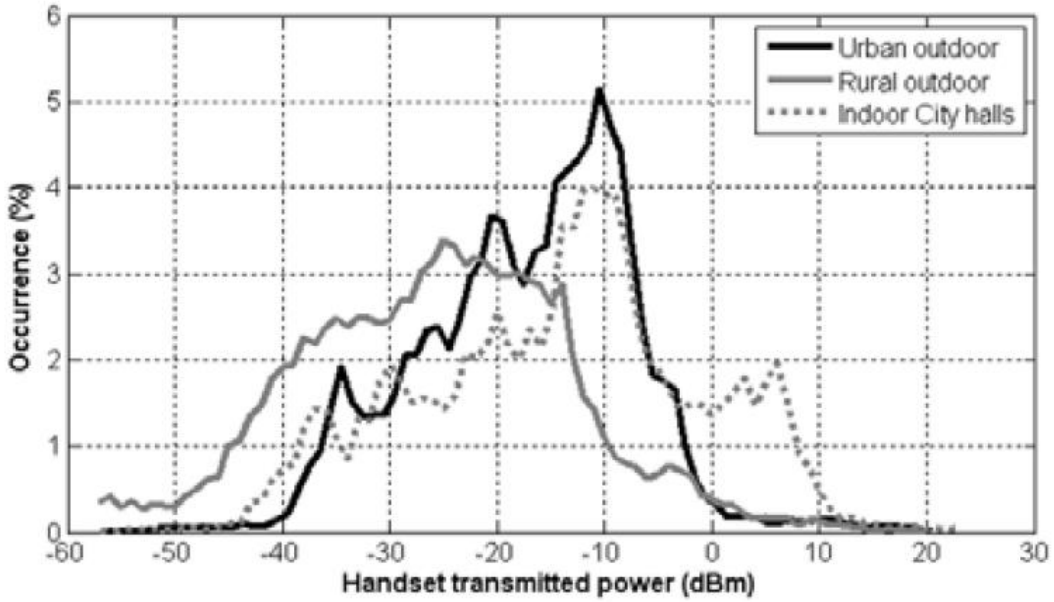
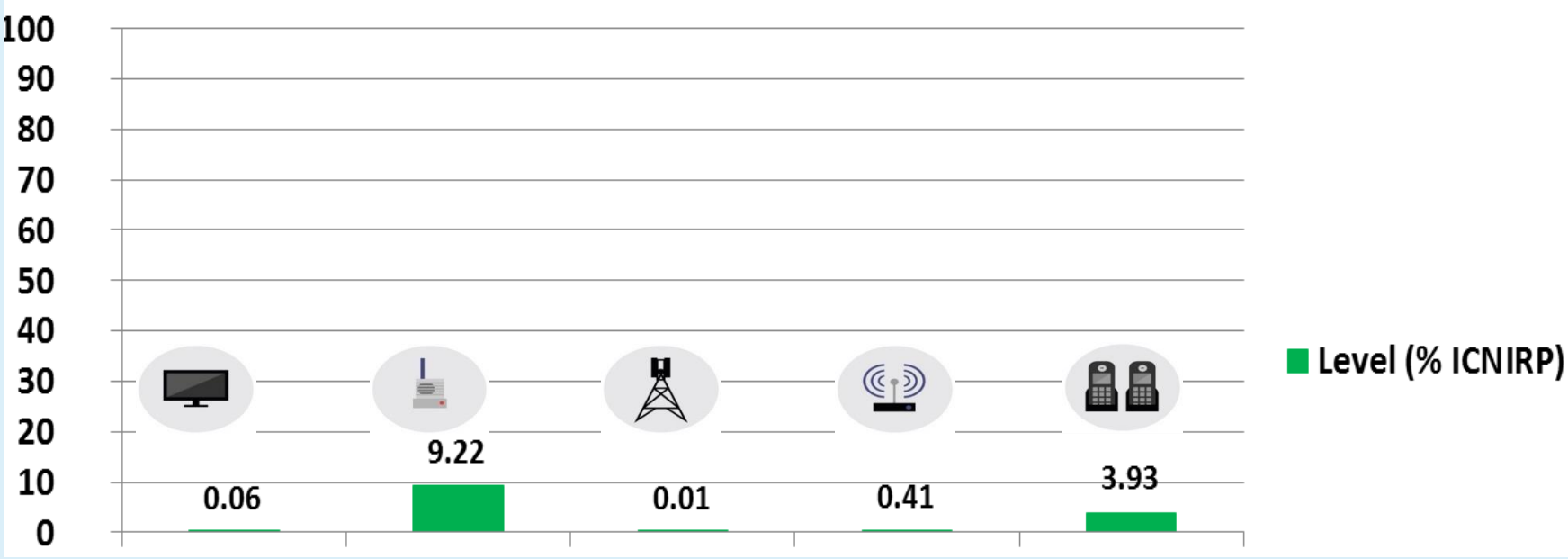


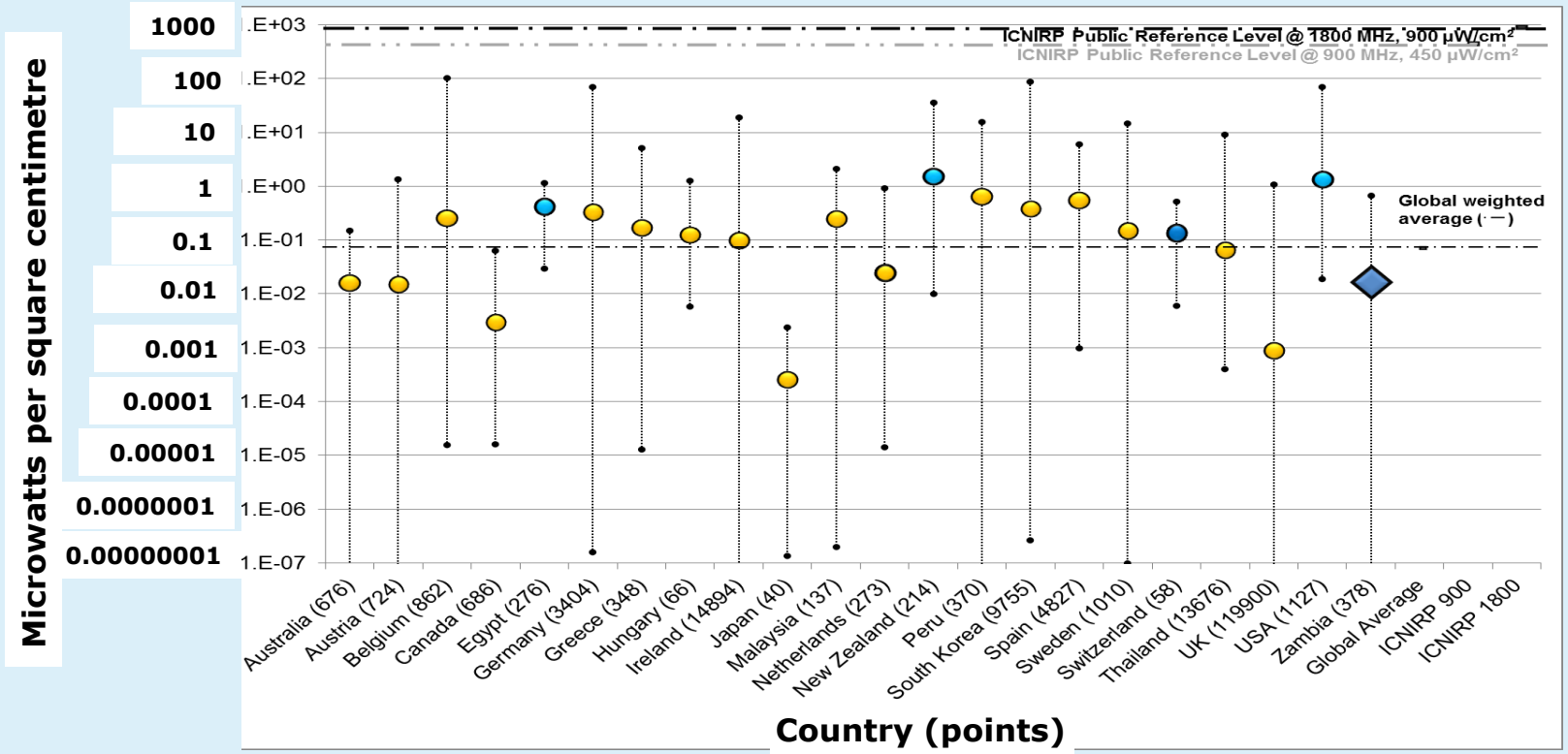
Fig. 3. Distribution of mobile phone transmitted power in different areas.

Mobile levels similar to other radio sources



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

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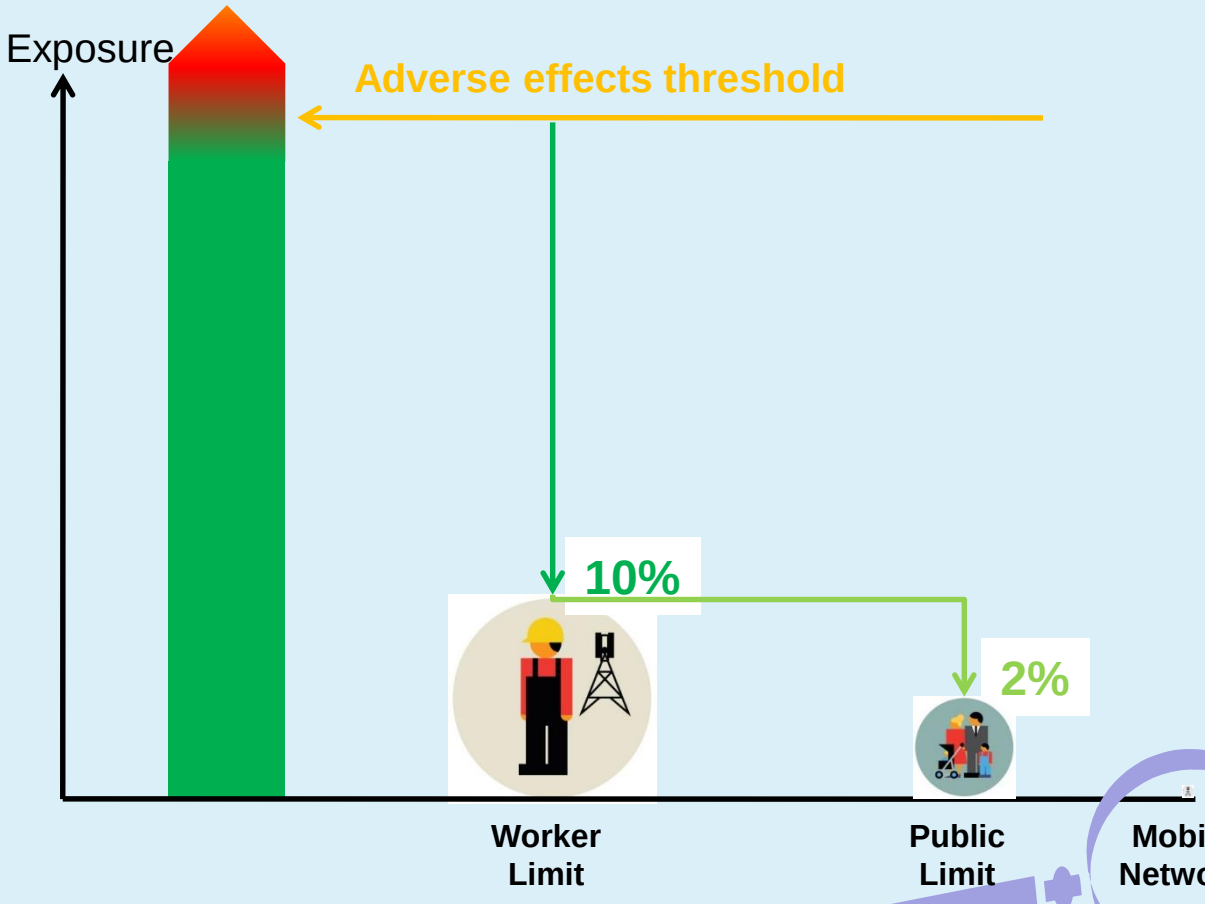
Rooftop Antennas

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.

RF exposure limits include substantial safety factors



www.icnirp.org

www.who.int/emf

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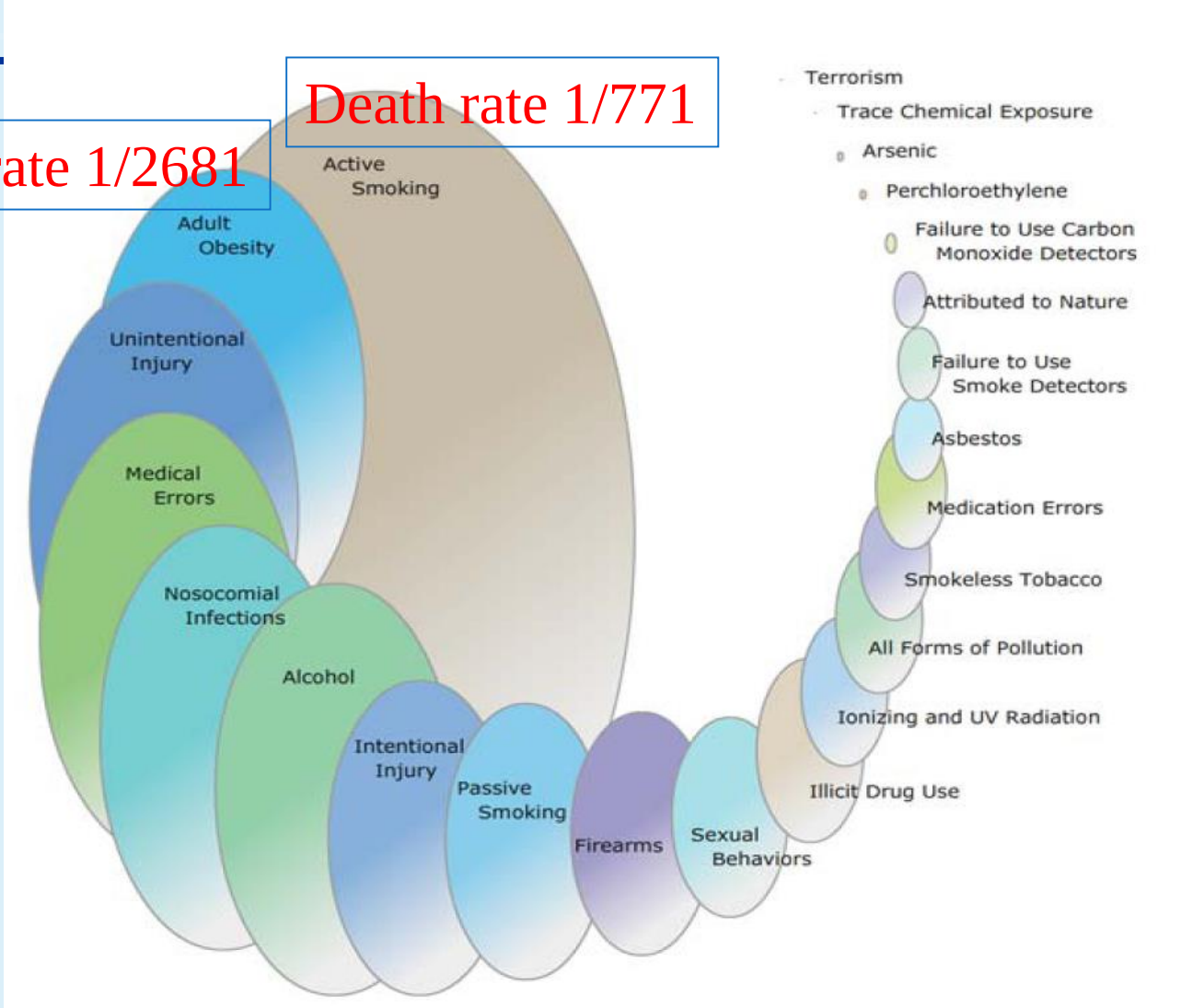
WHO – Mobile Networks (2013)

'Studies to date provide no indication that environmental exposure to RF fields, such as from base stations, increases the risk of cancer or any other disease.'

American Council on Science and Health – Risk Rings of Exposures



TIAN CHENG

Deadly risk

Established Scientific Understanding (in green)

- Microwave radiation is dangerous
- ✓ Only when at high intensity
- We don't have enough understanding of its effects
- ✓ More than 60 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.
- More than 60 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).

(Possible Effects)

Built on Solid Rocks (Established Effects)

Thank You

Contact:
ck.chou@ieee.org