# **RF Exposure Safety Limits** – **ICES position**

C-K. Chou, Ph.D. Chairman, Technical Committee 95 International Committee on Electromagnetic Safety Institute of Electrical and Electronics Engineers Piscataway, New Jersey USA

# Outline

- IEEE RF Safety Standard
- RF Safety Research Trend
- Ionizing vs Non-ionizing Radiation
- Biological Complexity
- Engineering Complexity
- Research Summary
- Conclusions



# **IEEE RF Safety Standard History**

1960: USASI C95 Radiation Hazards Project and Committee chartered 1966: USAS C95.1-1966  $> 10 \text{ mW/cm}^2$  (10 MHz to 100 GHz) based on simple thermal model **1974**: ANSI C95.1-1974 (limits for E<sup>2</sup> and H<sup>2</sup>) 1982: ANSI C95.1-1982 (incorporated dosimetry) **1991**: IEEE C95.1-1991 (two tiers – reaffirmed 1997) 2006: IEEE C95.1-2005 published on April 19, 2006 (comprehensive revision, 250 pages, 1143 ref.)



#### USAS C95.1-1966 standard (1+ page)

#### USA Standard Safety Level of Electromagnetic Radiation With Respect to Personnel

#### 1. Purpose

Recommendations are made to prevent possible harmful effects on mankind, resulting from exposure to electromagnetic radiation in the frequency range from 10 MHz (megahertz) to 100 GHz (gigahertz). They apply to all radiations originating from radio stations, radar equipment, and other possible sources of electromagnetic radiation such as used for communication, radio-navigation and industrial and scientific purposes. These recommendations are not intended to apply to the deliberate exposure of patients by or under the direction of practitioners of the healing arts.

#### 2. Definitions

2.1 Whole Body Irradiation. Pertains to the case in which the entire body is exposed to the incident electromagnetic energy or in which the cross section of the body is smaller than the cross section of the incident radiation beam.

2.2 Partial Body Irradiation. Pertains to the case in which part of the body is exposed to the incident electromagnetic energy.

2.3 Radiation Protection Guide. Radiation level which should not be exceeded without careful consideration of the reasons for doing so.<sup>1</sup>

#### 3. Recommendations

For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 MHz to 100 GHz, the radiation protection guide is 10 mW/cm<sup>2</sup> (milliwatt per square centimeter) as averaged over any

Johannesburg October 9, 2007 Slide 4 possible 0.1-hour period. This means the following:

- Power Density: 10 mW/cm<sup>2</sup> for periods of 0.1 hour or more
- Energy Density: 1 mWh/cm<sup>2</sup> (milliwatthour per square centimeter) during any 0.1-hour period

This guide applies whether the radiation is continuous or intermittent.

#### 4. Explanation

Exposure to electromagnetic radiation in the frequency range under consideration is but one of several sources of heat input into the body. Body temperature depends in part on sources of heat input such as electromagnetic radiation, physical labor and high ambient temperature and on heat dissipation capability as affected by clothing, humidity, etc. People who suffer from circulatory difficulties and certain other ailments are more vulnerable. It is also known that details of anatomy, the frequency of radiation, and its penetration affect the percentage of absorbed radiation. Hence, the nower levels established by the radiation protection guide numbers are related in a complicated way to power levels at which damage occurs. The guide numbers are appropriate for moderate environments. Under conditions of moderate to severe heat stress the guide number given should be appropriately reduced. Under conditions of intense cold, higher guide numbers may also be appropriate after careful consideration is given to the individual situation. These values are based on an evaluation of presently available knowledge, and with due consideration of tolerable rise in tissue temperature. They may be subject to revision as more knowledge is gained. Radiation characterized by a power level tenfold smaller will not result in any noticable effect on mankind. Radiation levels which are tenfold larger than recommended are certainly dangerous.

C95.1

#### 5. Whole Body Irradiation and Partial Body Irradiation

These formulated recommendations pertain to both whole body irradiation and partial body irradiation. Partial body irradiation must be included since it has been shown that some parts of the human body lc.g., eyes, testicles) may be harmed if exposed to incident radiation levels significantly in excess of the recommended levels.

#### USAS C95.1-1966

#### Safety Level of Electromagnetic Radiation With Respect to Personnel



<sup>&</sup>lt;sup>1</sup>Adapted from Background Material for the Development of Radiation Protection Standards, Report No. 1, Federal Radiation Council, Washington, D.C., May 13, 1960.

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



- SC-1: Measurements & Calculations SC-2: Warning Signs/Hazard Comm SC-3: 0-3 kHz SC-4: 3 kHz - 300 GHz SC-5: EEDs
- SC-1: Marine Radar
- **SC-2: Wireless Phones**
- SC-3: RF-Protective Clothing

#### International Committee on Electromagnetic Safety (ICES)

#### Scope

"Development of standards for the safe use of electromagnetic energy in the range of 0 Hz to 300 GHz relative to the potential hazards of exposure of humans, volatile materials, and explosive devices to such energy. Such standards will be based on established effects and will include safety levels for human exposure to electric, magnetic and electromagnetic fields, including induced currents from such fields, methods for the assessment of human exposure to such fields, standards for products that emit electromagnetic energy by design or as a byproduct of their operation, and environmental limits."



## International Committee on Electromagnetic Safety

#### **TC95 Subcommittee 4:**

132 members, 42% from outside the US representing the following 23 countries:

Australia	4	Italy	3
Bulgaria	2	Japan	3
Canada	4	Korea	2
China	3	Netherlands	2
Finland	3	New Zealand	1
France	1	Poland	2
Germany	1	Slovenia	1
Greece	3	South Africa	2
Hungary	1	Sweden	1
Ireland	3	Switzerland	3
Israel	2	Thailand	1
		United Kingdom	8



International Committee on Electromagnetic Safety

### **SC4 Membership Composition**

Academia	36	27%
Government	45	34%
Industry	22	17%
Consultant	27	20%
General Public	2	2%
Total	132	100%



### C95.1-1991 needs a complete revision

- ICES is committed to the development of a science-based RF safety standard that is protective of public health, unambiguous, and practical to implement
- The RF standard should be harmonized with other international standards to the extent where scientifically defensible



# **Extensive Database**

- The biological effects of RF exposure have been studied for more than 50 years.
- The WHO EMF Project website (<u>http://www.who.int/peh-emf/en/</u>) contains more than 2500 entries, of which more than 1400 are relevant to health effects of RF exposure.
- At the close of the evaluation by ICES, 1143 studies were listed in the references.



## Weight of evidence:

For purposes of this standard, the outcome of assessing the published information about the biological and health effects from exposure to RF energy. This process includes evaluation of the quality of test methods, the size and power of the study designs, the consistency of results across studies, and the biological plausibility of doseresponse relationships and statistical associations.



### **Definitions**

## **Biological effect:**

An established effect caused by, or in response to, exposure to a biological, chemical or physical agent, including electromagnetic energy. Biological effects are alterations of the structure, metabolism, or functions of a whole organism, its organs, tissues, and cells. Biological effects can occur without harming health and can be beneficial. Biological effects can also include sensation phenomena and adaptive responses.





### **Definitions**

#### **Adverse health effect:**

#### A biological effect characterized by a harmful change in health

NOTE 1—Adverse effects do not include biological effects without a harmful health effect, changes in subjective feelings of well-being that are a result of anxiety about RF effects or impacts of RF infrastructure that are not physically related to RF emissions, or indirect effects caused by electromagnetic interference with electronic devices.

NOTE 2—Sensations (perceptions by human sense organs) *per se* are not considered adverse effects. Thus a sensation of warmth at millimeter and other wavelengths and the microwave auditory effect under the underlying special conditions are not recognized as effects to be protected against by this standard. Painful or aversive electrostimulation resulting from exposure at frequencies below 0.1 MHz is treated as an adverse effect.



### **Definitions**

### **Established effect:**

An effect is considered *established* when consistent findings of that effect have been published in the peer-reviewed scientific literature, with evidence of the effect being demonstrated by independent laboratories, and where there is consensus in the scientific community that the effect occurs for the specified exposure conditions.





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

- Science-based recommendations are made to protect against all known adverse effects in human beings associated with RF exposure
- 3 kHz to 5 MHz, minimize effects associated with electrostimulation
- 100 kHz to 300 GHz, protect against effects associated with heating
- Approved by 91.3% of SC4 voting members
- Approved by 96% of ICES and IEEE Standards Association voting members
- Approved by Standards Board October 2005, in print April 19, 2006

IEEE ICES

# **C95.1 Standard's major revision**

- A notable revision to the new standard is the recommendation of peak spatial average SAR of 2 and 10 W/kg averaged over 10 g tissue for the lower and upper tier, respectively.
- This revision resolves a major harmonization issue with RF standards.





		Action level <sup>a</sup> SAR <sup>b</sup> (W/kg)	Persons in controlled environments SAR <sup>c</sup> (W/kg)
Whole-body exposure	Whole-Body Average (WBA)	0.08	0.4
Localized exposure	Localized (peak spatial-average)	2 <sup>c</sup>	10 <sup>c</sup>
Localized exposure	Extremities <sup>d</sup> and pinnae	4 <sup>c</sup>	20 <sup>c</sup>
<sup>a</sup> BR for the general public when an RF safety program is unavailable.			
<sup>b</sup> SAR is averaged over the appropriate averaging times as shown in Table 8 and Table 9.			
<sup>c</sup> Averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube). <sup>*</sup>			
<sup>d</sup> The extremities are the arms and legs distal from the elbows and knees, respectively.			

<sup>\*</sup>The volume of the cube is approximately 10 cm<sup>3</sup>.





#### **RF Source (years)**

- Radar (50-60's)
- Broadcasting (60-70's)
- Microwave Oven (70-80's)
- Police Radar (80's)
- Mobile Communication (90's ?)
  - Two-way radios (since 60's) Localized
  - Mobile phones
  - Base stations
  - Wi-Fi

Whole body Whole body Localized Localized

Localized

Whole body

Whole body

**Body Exposure** 



**RF Bioeffects Publications** 





# Ionizing vs. Non-Ionizing Energy

#### Ionizing

- Sufficient energy to alter chemical bonds and atomic structure
- 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
- No known chronic/cumulative effects



# **Biological Complexity**

- In vivo study
  - Species
  - Strain
  - Sex
  - Age
  - Extrapolation from animal to humans
- In vitro study
  - Monolayer
  - Cell suspension
  - Isolated tissue
  - Extrapolation to human beings



# Cataract study

# Ophthalmologist looking for cataract

Concernance of the local division of the loc

Microwave induced Cataract In a rabbit eye

# Facial burns but no cataract

Summer Lating

# **Engineering Complexity**

- Far Field Exposure
- Near Field Exposure
- RF Dosimetry
- Resonance
- Modulation
  - CW, Pulsed
  - AM, FM, TDMA, CDMA
- Experimental Artifacts
- Temperature Control



# Health policy must be Science based

- A single study can form the basis of an hypothesis, but does not provide the basis for hazard identification.
- Confirmation of the results of any study is needed through replication and/or supportive studies.
- The resulting body of evidence forms the basis for science-based judgments by defining exposure levels for
  - adverse health effects
  - no observable adverse effects



#### Biological and Health Effect Studies of RF Exposure in the WHO Database

Study Type	Ongoing studies	Reported but not published	Peer- reviewed papers
Epidemiology	45	7	250
Human	59	17	201
Animal	51	30	767
In Vitro	<u>62</u>	<u>34</u>	<u>443</u>
Totals	217	88	1661



### Mobile Telephony Related Studies

Study Type/Subtype	Ongoing	Completed w/o Publication	Published Papers
Epidemiology	36	6	78
Human / Provocation	59	16	114
In Vitro	52	26	133
Long Term Animal Studies			
Cell Line Injection Tumor Bioassay	0	0	2
<b>Chemical-Radiation-Genetically Initiated</b>	4	1	20
Rodent Bioassay	4	1	9
All Other Animal Studies	36	18	167
Grand Total	191	68	523

# **WHO Comment on Database**

- scientific knowledge in this area is now more extensive than for most chemicals.
- WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields.

#### http://www.who.int/pehemf/about/WhatisEMF/en/index1.html



# **New RF Research Programs**

WHO estimated **\$250 M** already spent on mobile telephony bioeffect research

Country	Time	Budget
	period	(M€)
Australia	2004-2009	1.5
Denmark	2004-2008	4.0
Finland	2004-2007	1.5
Germany	2002-2007	17.0
UK: MTHR 1	2002-2008	10.8
MTHR 2	2007-2012	est 11.25
France	2006-2010	4.8
Korea	2005-2010	10.8
Netherlands	2006-2014	16.6
Switzerland	2006-2010	3.2
USA/NTP	2005-2010	18.0
	Total	99.45 M€
		\$130M
+ Japan, China, etc.		

### **Annex B summary**

- The biological database established over 50 years shows no repeatable low level RF effect.
- Analysis of proposed mechanisms does not support nonthermal effects at RF frequencies.
- The established effect at lower frequencies is electrostimulation.
- The conclusions from reviews of the scientific database have been remarkably consistent over time confirming the safety and the basis of the IEEE standard.
- Published work following the ICES review has not altered the weight of evidence on health effects.



## **Animal Cancer Studies: Summary**

- All 29 studies since 1992 observed no significant change in tumor incidence except for Repacholi et al. (1997) and Anghileri et al. (2005).
- The few studies reporting effects have not been confirmed by more recent and well-designed studies with good exposure assessment.
- The weight of scientific evidence in 35 studies shows that RF exposure up to lifetime exposure (2 years) does not adversely affect carcinogenic processes (initiation, promotion or co-promotion) at whole-body SAR up to 4 W/kg.



# C.1.2 Risk profile for adverse effects

- 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



# **Low-level effects**

"Despite more than 50 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 and such effects are not useful for standard setting."





#### New 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)

IEEE

3 Park Avenue New York, NY 10016-5997, USA IEEE Std C95.1<sup>™</sup>-2005 (Revision of IEEE Std C95.1-1991)

19 April 2006

# Expert Scientific Reviews (1996-2007)

- Australian Committee on EM Energy Public Health Issues
- European Commission Expert Group
- European Committee on Toxicology, Eco-toxicology
- French Environmental Health and Safety Agency (AFSSE)
- Health Council of the Netherlands
- Hong Kong Office of the Telecommunications Authority
- International Commission on Non-Ionizing Radiation Protection (ICNIRP)
- International Radiation Protection Association (IRPA)
- Japanese Ministry of Post and Telecommunications
- New Zealand Ministry of Health and Ministry of Environment
- Nordic Authorities (Denmark, Finland, Iceland, Norway and Sweden)
- Royal Society of Canada Expert Panel and Health Canada
- Singapore Health Sciences Authority
- Swedish State Radiation Protection Authority
- U.K. Advisory Group of Non Ionizing Radiation
- U.K. Independent Expert Group on Mobile Phones (Stewart Report)
- U.K. National Radiological Protection Board
- U.S. Food and Drug Administration
- World Health Organization



## General Conclusion of Expert Scientific Reviews

- No credible evidence that RF exposures within internationally accepted limits cause any adverse health effects, but...
- More research is needed .....

#### Remarks

- One can never prove the null hypothesis and thus one can never prove that something is absolutely safe.
- There is no known mechanism for adverse health effects of RF exposure other than thermal.
- Due to the current extensive database, it is unlikely that results of ongoing studies will shift the weight of evidence on health effects.



# **Cellular Transmission Towers**



\*1 milliwatt (mW) = 1/1,000 watt

\*\*The ANSI/IEEE and NCRP safety standards for the general public in the environment depicted above are .550 milliwatts per square centimeter

## **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.



## **Promotes Harmonization of Standards**

- Supports WHO harmonization efforts
- Benefits of harmonization
  - <u>Consumers</u> gain the protection of an internationally recognized safety standard, and have equal access to products and services that are available to consumers elsewhere in the world
  - <u>Regulators</u> can have a consistent approach to regulation consistent with the recommendations of the WHO, the ITU and the WTO
  - Industry gains by developing and manufacturing products to a widely accepted international standard and, once tested for compliance, can make those products available around the world in a consistent and timely manner





- IEEE C95.1-2005 provides recommendations to protect against harmful effects in human beings exposed to electromagnetic fields in the frequency range from 3 kHz to 300 GHz.
- A notable revision to the new standard is the recommendation of peak spatial average SAR of 2 and 10 W/kg averaged over 10 g tissue for the lower and upper tier limits, respectively.
- This revision resolves a major harmonization issue with RF standards.
- Cooperative efforts should be continued to achieve internationally harmonized exposure limits.



## Science should converge to achieve ONE global standard



Thank you

# For more information: ck.chou@ieee.org

# One sun in the sky

