

**Conference on  
“Occupational Exposure to Electromagnetic Fields:  
paving the way for a future EU initiative”**



# **IEEE EMF Exposure Standards**

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**International Committee on Electromagnetic Safety**

**Institute of Electrical and Electronics Engineers**

**Piscataway, New Jersey**

**USA**



# Outline

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- ❖ History
- ❖ ICES Organization & Operation
- ❖ C95.6-2002
- ❖ C95.1-2005
- ❖ Conclusions



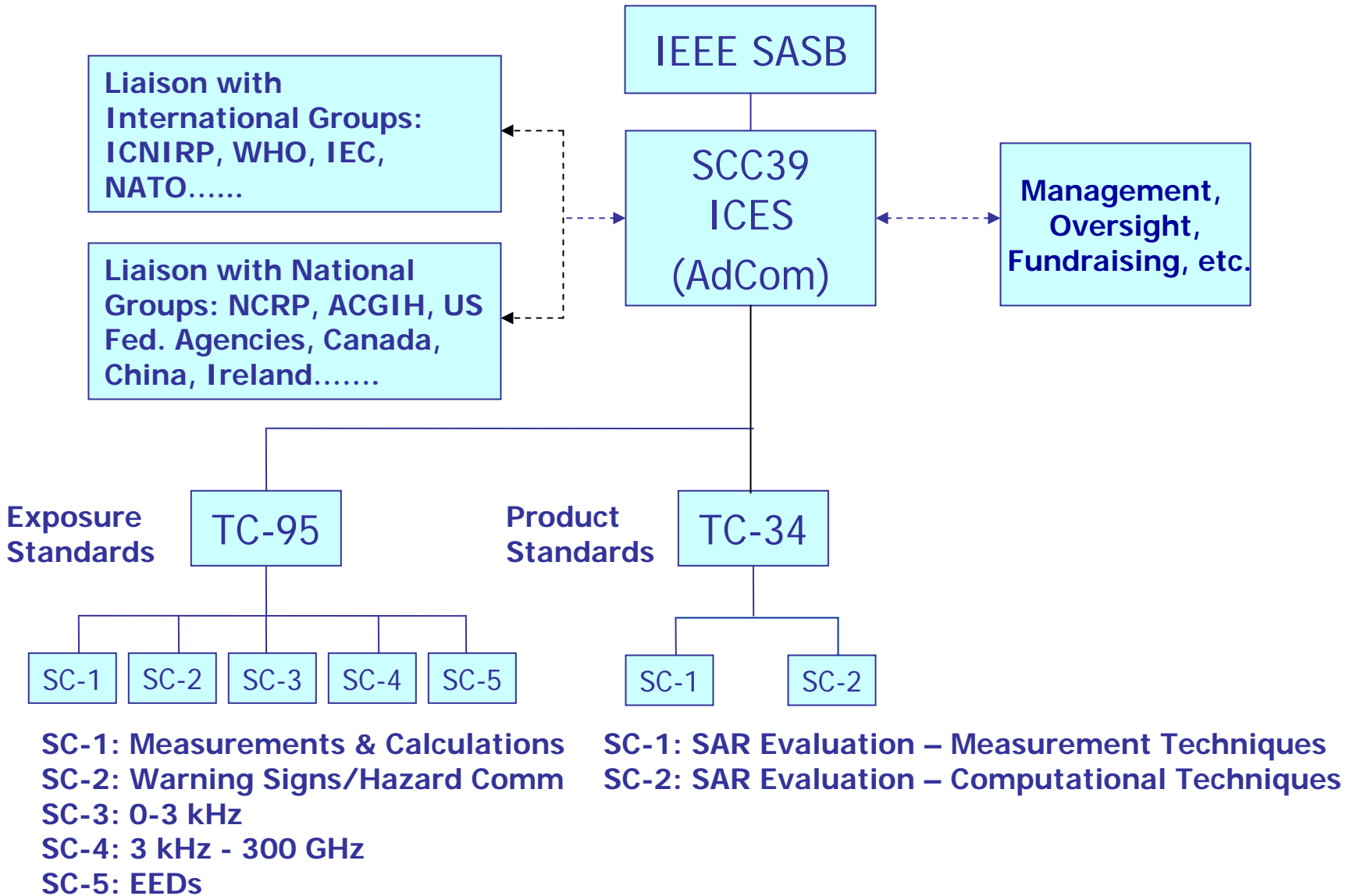
# IEEE Safety Standards History

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- 1960: USASI C95 Radiation Hazards Project and Committee chartered
- 1966: USAS C95.1-1966
  - 10 mW/cm<sup>2</sup> (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 (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.)



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



## Scope

- ❖ Develop standards for the **safe use** of electromagnetic energy
- ❖ Based on **established effects** and include safety levels for human exposure to electric, magnetic and electromagnetic fields, including induced currents from such fields
- ❖ Develop methods for the assessment of human exposure to such fields, and standards for products

# IEEE ICES Subcommittee 3

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





# Subcommittee 3

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## ❖ Members associated with

- ICNIRP
- International Agency for Research on Cancer's (IARC) expert EMF scientific work group
- United Kingdom Department of Health
- Health Council of the Netherlands
- Health Canada
- US Government: National Institutes of Health, Food and Drug Administration, National Institute of Occupational Health and Safety, Department of Transportation, etc.
- Industry (Medtronic, e.g., pacemakers and defibrillators)



# SC4 Membership Composition

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**132 members, 42% from outside the US representing 23 countries.**

**The distribution of affiliations of the membership is as follows:**

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

With balanced expertise in biological and physical sciences



# IEEE Standards Process

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- ❖ Open Process
- ❖ Consensus process
  - Allows for challenging and testing of all viewpoints
  - Balloting at Subcommittee and Sponsor level
  - 75% of ballots must be returned with at least a 75% approval to reach consensus
- ❖ All negative comments must be addressed and recirculated
- ❖ C95.6-2002: 90% approval
- ❖ C95.1-2005: 96% approval

# SC3 Primary Challenge - How to Treat Potential Long-Term Effects

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- ❖ The Subcommittee debated a rationale for a number of years
- ❖ The appropriate rationale became clearer toward the end of the 1990s as better scientific reviews were reported, e.g.,
  - Advisory Group on Non-Ionizing Radiation of UK NRPB
  - Health Council of the Netherlands
  - US EMF RAPID Program
  - ICNIRP
  - IARC
- ❖ Both long-term and short-term effects were considered

# Consensus of IEEE ICES TC95/SC3 on Potential Long-Term Effects

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- ❖ Lack of clear evidence- no sufficient, reliable evidence to conclude that long-term exposures to electric and magnetic fields are adverse to human health or cause a disease, including cancer.
- ❖ No confirmed mechanisms- would provide a firm basis to predict adverse effects from low-level, long-term exposure.



# IEEE C95.6 -2002 Standard is Based on Established Mechanisms

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- ❖ **A bioelectric mechanism with the following characteristics:**
  - can be used to predict a biological effect in humans
  - an explicit model can be made using equations of parametric relationships
  - has been verified in humans, or animal data can be confidently extrapolated to humans
  - is supported by strong evidence
  - is widely accepted among experts in the scientific community

# Established Mechanisms

## ❖ **Electrostimulation**

- Nerve excitation
- Muscle excitation
- Cardiac excitation
- Synaptic activity alteration
  - Phosphenes
  - Visually evoked potentials

## ❖ **Magnetohydrodynamic mechanisms**

- Forces on charges due to rapid body motion in strong static and quasi-static fields.
- Generally associated with blood flow
- Changes in cardiac cycle, vertigo, difficulty with balance, nausea, headaches, numbness and tingling, phosphenes and unusual taste sensations.

## ❖ **Thermal - generally not an issue below 100 kHz**

# Adverse effects

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**Limits are designed to avoid the following short-term adverse reactions**

- **Aversive or painful stimulation of sensory neurons**
- **Muscle excitation that may lead to injuries while performing potentially hazardous activities**
- **Excitation of neurons or direct alteration of synaptic activity within the brain**
- **Cardiac excitation**
- **Adverse effects associated with induced potentials or forces on moving charges within the body, such as blood flow.**



## IEEE Std C95.6-2002

This standard was  
reaffirmed in 2007

The next revision of  
C95.1 will incorporate  
C95.6

IEEE Standards

## C95.6™

IEEE Standard for Safety Levels with  
Respect to Human Exposure to  
Electromagnetic Fields, 0–3 kHz

IEEE Standards Coordinating Committee 28

IEEE International Committee on  
Electromagnetic Safety on Non-Ionizing Radiation



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# SC4 Task for Revision

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- ❖ C95.1-1991 needed 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**





# C95.1-2005: Definitions

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## Weight of evidence includes evaluation of:

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




# IEEE/ICES TC95/SC4

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## 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 **established 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**



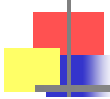


# C95.1-2005: Features

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- ❖ A notable feature of the 2005 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 resolves a major harmonization issue with other contemporary RF standards and guidelines.

# Basic restrictions for frequencies between 100 kHz and 3 GHz



**Table 6—BRs for frequencies between 100 kHz and 3 GHz**

		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>d</sup>The extremities are the arms and legs distal from the elbows and knees, respectively.



# Annex B summary

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- ❖ The biological database established over 50 years shows no repeatable low level RF effect.
- ❖ Analysis of proposed mechanisms does not support non-thermal 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.



## C.1.2 Risk profile for adverse effects

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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

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- ❖ 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 heating.
- ❖ Moreover, the relevance of **reported low-level effects to health remains speculative** and such effects are not useful for standard setting.”



# 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)

C95.1<sup>TM</sup>

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

19 April 2006

**IEEE Std C95.1<sup>TM</sup>-2005**  
(Revision of IEEE Std C95.1-1991)

# Harmonization of

## ICNIRP and IEEE C95.1-2005 RF Basic Restrictions

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- adverse health effect threshold (whole-body exposure)
  - ❑ 4 W/kg
- safety factors
  - ❑ 10 for occupational exposure
  - ❑ 50 for public exposure
- whole-body basic restrictions
  - ❑ 0.4 W/kg for occupational exposure
  - ❑ 0.08 W/kg for public exposure
- partial body basic restrictions
  - ❑ 10 W/kg for occupational exposure
  - ❑ 2 W/kg for public exposure (e.g., mobile phone use)



# SAR Basic Restrictions Comparisons

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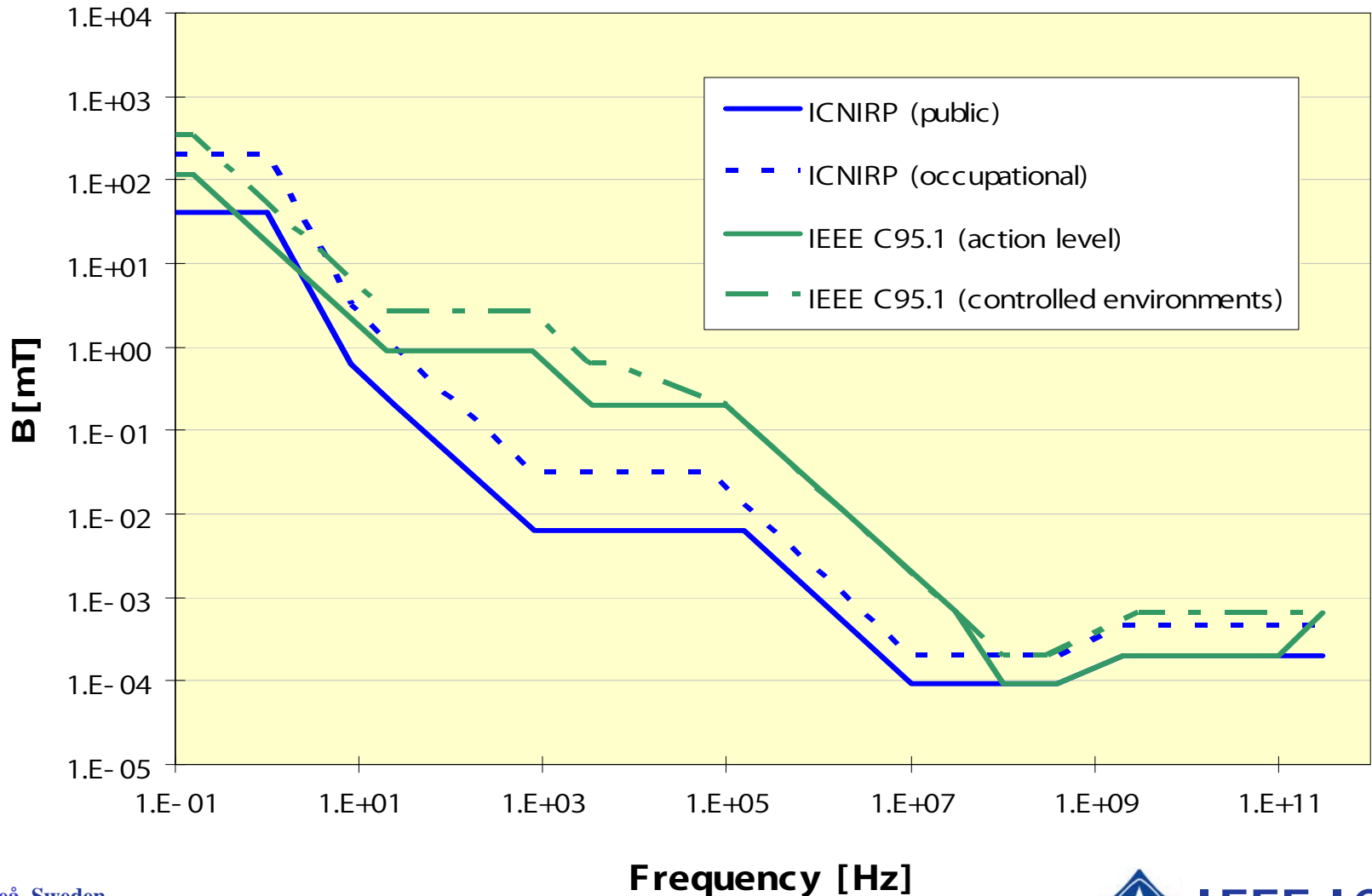
## IEEE C95.1- 2005 (2006)

- ❖ SAR applies between 100 kHz – 3 GHz
- ❖ Averaged over 10 g tissue in a cube
- ❖ Averaged over up to 30 min for general public and up to 6 min for controlled environment
- ❖ Pinnae have similar limit as extremities
- ❖ Upper arms and upper legs have same limits as body

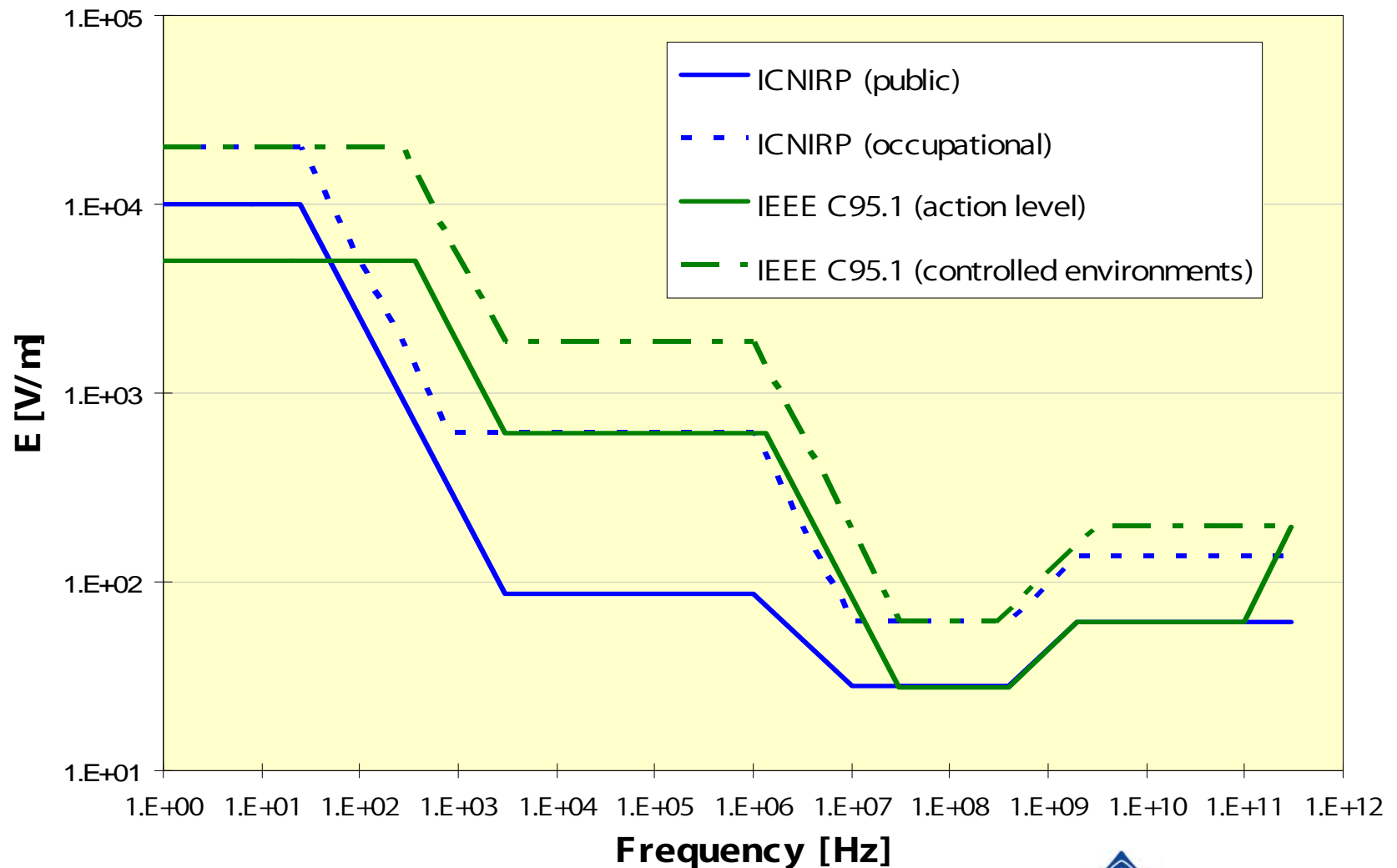
## ICNIRP (1998)

- ❖ SAR applies between 100 kHz -10 GHz
- ❖ Averaged over 10 g contiguous tissue
- ❖ Averaged over 6 min
- ❖ Pinnae limit is the same as body
- ❖ Upper arms and thighs are part of limbs and have different limits from body

# Comparison of ICNIRP/ICES B-field limits



# Comparison of ICNIRP/ICES E-field limits



# Conclusions

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- ❖ C95.6-2002 and C95.1-2005 standards are developed to protect against established adverse effects.
- ❖ At low frequencies below 100 kHz, minimizes effects associated with electrostimulation.
- ❖ 100 kHz to 300 GHz, protects against effects associated with heating.
- ❖ A notable change from C95.1-1991 is the recommended peak spatial average SAR values 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 other contemporary RF standards and guidelines.
- ❖ Cooperative efforts to achieve internationally harmonized exposure limits continue.



A photograph of a sunset over the ocean. The sun is a bright yellow orb on the horizon, with a shimmering reflection on the dark blue water. The sky is filled with soft, golden clouds, transitioning from a pale blue at the top to a deep orange near the horizon.

One harmonized standard

*Thank You*