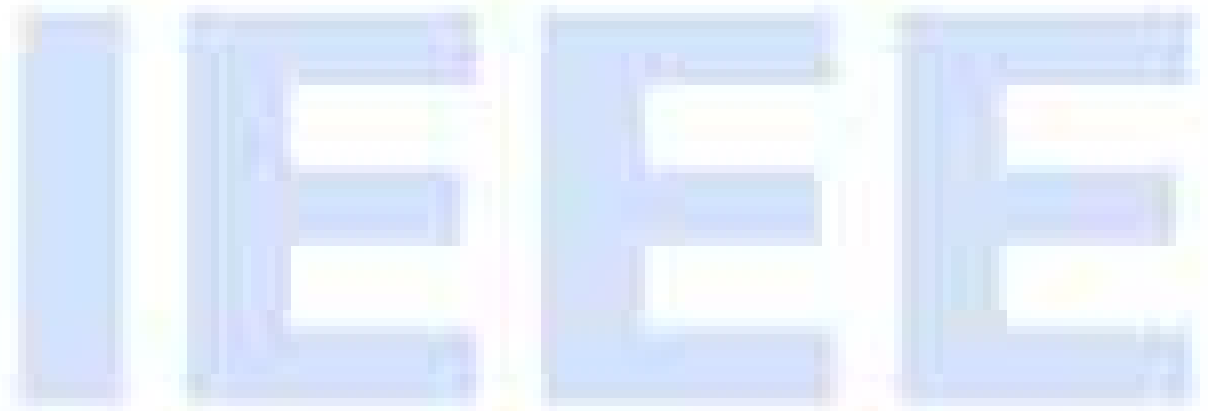


NEW IEEE C95.1-2005 RF SAFETY STANDARD



C-K. Chou, Ph.D.

IEEE International Committee on Electromagnetic Safety
Technical Committee 95, Subcommittee 4
New York, New York, USA.



IEEE RF Safety Standard History

1960: USASI C95 Radiation Hazards Project and Committee chartered

1966: ANSI C95.1-1966

- 10 mW/cm² (10 MHz to 100 GHz)
- based on simple thermal model

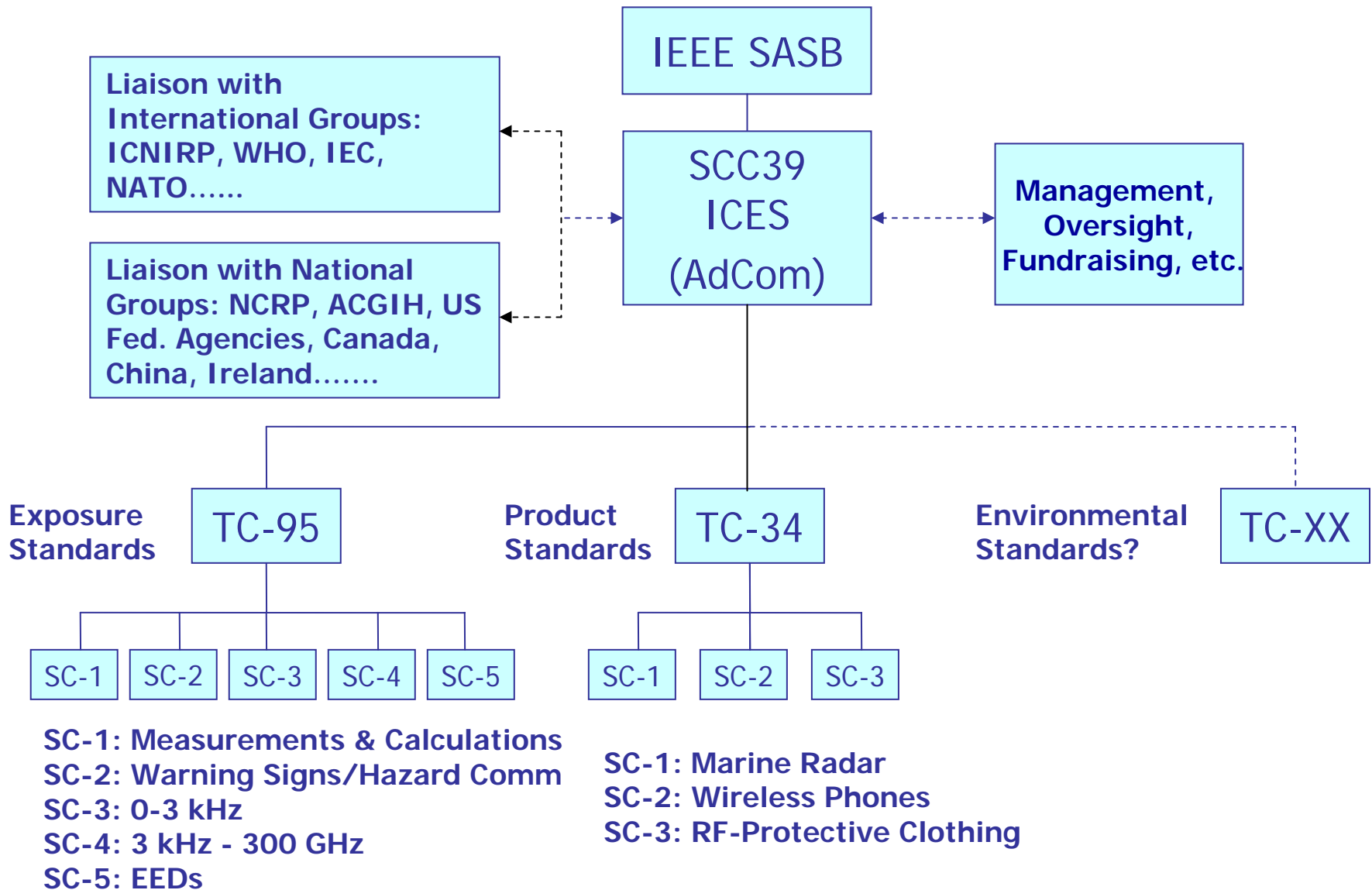
1974: ANSI C95.1-1974 (limits for E² and H²)

1982: ANSI C95.1-1982 (incorporated dosimetry)

1991: IEEE C95.1-1991 (two tiers)

2006: IEEE C95.1-2005 published on April 19, 2006
(comprehensive revision, 258 pages, 1143 ref.)

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



International Committee on Electromagnetic Safety

TC95 Subcommittee 4:

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

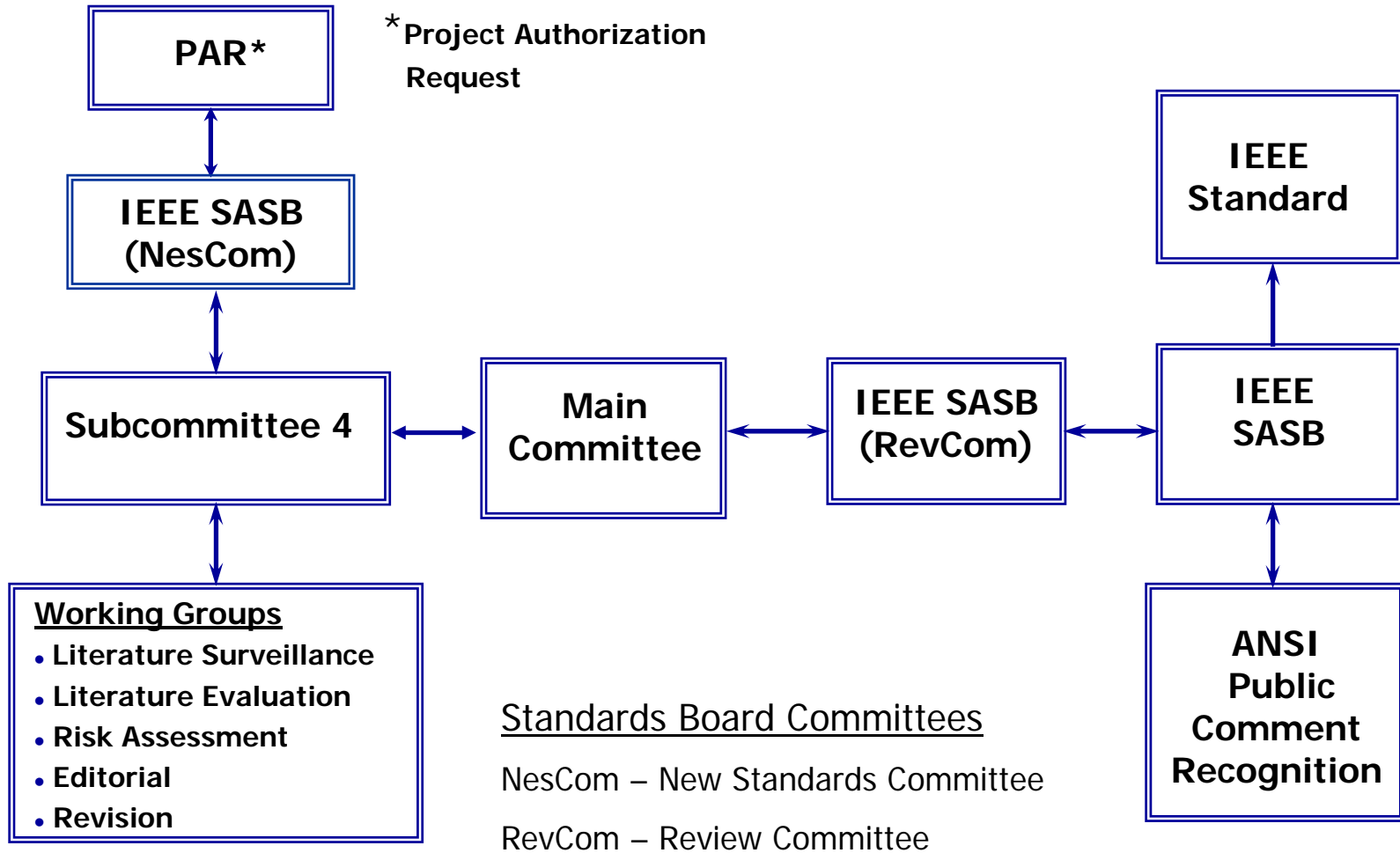
Australia	4	Italy	3
Bulgaria	2	Japan	3
Canada	4	Korea	2
China	3	Netherlands	2
Finland	3	New Zealand	1
France	1	Poland	2
Germany	1	Slovenia	1
Greece	3	South Africa	2
Hungary	1	Sweden	1
Ireland	3	Switzerland	3
Israel	2	Thailand	1
		United Kingdom	8



SC4 Membership Composition

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

Standards Development: Process







SC4 Task for Revision

- 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**

IEEE/ICES TC95/SC4


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



Outline of C95.1-2005 (Normative Section)

1. Overview
 - 1.1 Scope
 - 1.2 Purpose
 - 1.3 Introduction
2. References
3. Definitions
4. Recommendations
 - 4.1 Basic restrictions (BRs) and maximum permissible exposures (MPEs) for 3 kHz - 5 MHz
 - 4.2 BRs and MPEs for frequencies between 100 kHz and 3 GHz
 - 4.3 BRs for frequencies between 3 GHz and 300 GHz
 - 4.4 MPEs for frequencies between 100 kHz and 300 GHz
 - 4.5 Suggested limit for contact voltage to protect against RF burns
 - 4.6 Relaxation of the power density MPEs for localized exposures
 - 4.7 Assessing compliance with this standard
 - 4.8 RF safety programs



Outline of C95.1-2005 (Informative Section)

Annex A

Approach to revision of IEEE Std C95.1-1991 (1999 ed.)

A.1 ICES revision process

A.2 Basic concepts for developing the MPE values

Annex B

Identification of levels of RF exposure responsible for adverse effects: summary of the literature

B.1 Introduction

B.2 Executive Summary

B.3 Role of Mechanisms in Determination of Levels for Adverse Effects

B.4 Improvements in Dosimetry

B.5 Established Effects Forming the Basis of the Standard

B.6 Non Cancer Related Studies

B.7 Cancer Related Studies



Extensive Database

- The biological effects of RF exposure have been studied for more than **50 years**.
- The WHO website (<http://www.who.int/peh-emf/en/>) 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.

Annex B summary

- 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.



Annex C

Rationale

C.1 Introduction

C.2 Basic Restrictions (BR) and Maximum Permissible Exposure (MPE)

C.3 Adverse Effect Levels

C.4 Stimulatory Effects at Frequencies from 3 kHz to 5 MHz

C.5 Averaging Time

C.6 Safety Factors and Uncertainty Factors

C.7 Special Considerations



Rationale for Changing Peak Spatial Average SAR

(C.2.2.2.1)

- In previous standard, peak SAR based on dosimetry showing 20:1 ratio between peak and whole-body average SAR
- More recent data show >100:1 ratio (Bernardi et al. 2003) but relaxing peak SARs to levels >40 W/kg not acceptable to ICES SC4
- Adopted upper tier limit of 10 W/kg (same as in ICNIRP) based on biological rationale
- Limit is 10X less than SAR threshold for cataracts (permanent adverse tissue damage)
- An RF-induced cataract is a thermal effect with a threshold at 41 °C
- Peak SAR limit considered conservative because cataract thresholds determined in animals with compromised blood flow due to use of anesthetics



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.



Annex D to G

Annex D

Practical Applications - Examples

D.1 Introduction

D.2 Multi-frequency Exposures (Exposures To Multiple Sources)

D.3 Induced and Contact Current

D.4. Measurement Requirements

Annex E

Glossary

Annex F

Literature Database

Annex G

Bibliography



C95.1-2005: Definitions

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 **dose-response** 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.



Recommendations include:

- Basic restrictions (tissue electric field strength, SAR, and power density)
- Maximum permissible exposure (MPE) limits (external electric and magnetic field strengths, power density, currents) that are intended to ensure compliance with the basic restrictions.

Note: If basic restriction is not exceeded, MPE can be exceeded.



MPE Limits Above 300 MHz

- For controlled environment, no change in MPE.
- For general public/action level, due to new dosimetry data on children, the MPE above 300 MHz was discussed extensively.
- Harmonization with ICNIRP from 300 MHz to 100 GHz, and FCC from 2 to 100 GHz.
- Ramp up from 100 GHz to 300 GHz to match IEEE laser standard.

Localized SAR Limits for General Public/Action level

- Now based on **2 W/kg averaged over 10 grams of tissue** except for hands, wrist, **forearms**, ankles, **lower legs** and the **pinnae** where SAR must not exceed **4 W/kg over any 10 grams.**





Localized SAR Limits for Persons in Controlled Environments

- Now based on **10 W/kg averaged over 10 grams** of tissue except for hands, wrist, **forearms**, ankles, **lower legs** and the **pinnae** where SAR must not exceed **20 W/kg over any 10 grams**.
- The 10 W/kg local SAR limit is now harmonized with the value recommended by ICNIRP. However, limits for pinnae, upper arms and thighs are different from that specified by ICNIRP. Frequency range is 100 kHz to **3 GHz**.



Table 6—BRs 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

^aBR for the general public when an RF safety program is unavailable.

^bSAR is averaged over the appropriate averaging times as shown in Table 8 and Table 9.

^cAveraged over any 10 g of tissue (defined as a tissue volume in the shape of a cube).*

^dThe extremities are the arms and legs distal from the elbows and knees, respectively.

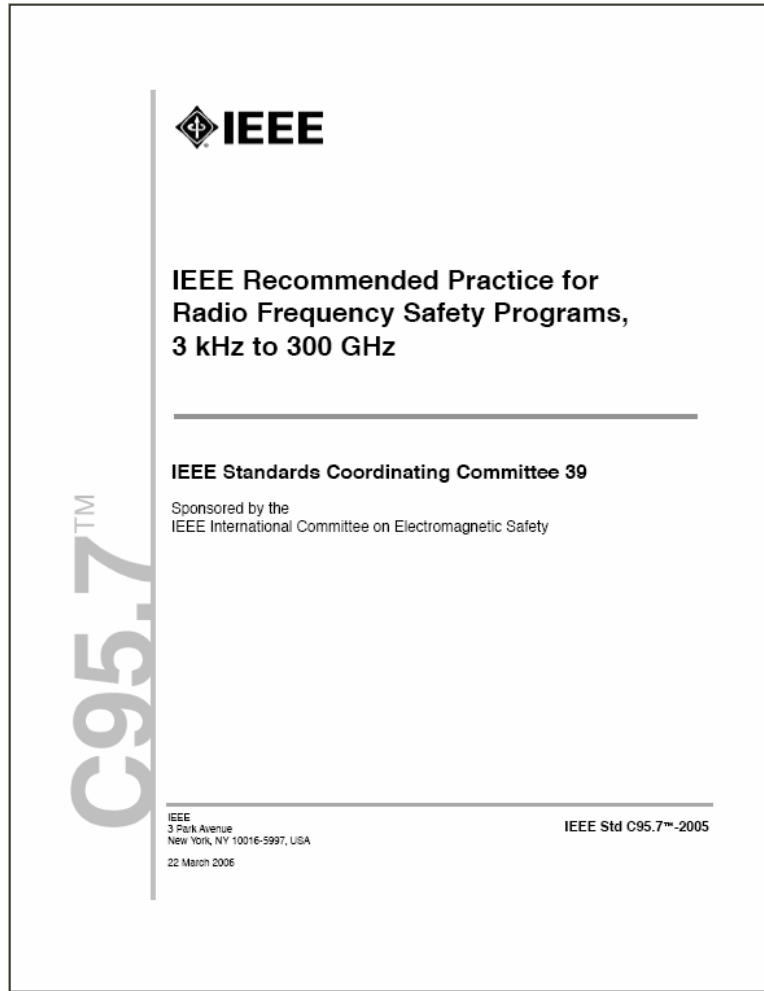
*The volume of the cube is approximately 10 cm³.



4.7 *Assessing compliance with standard*

- In practice, assessing compliance with standard consists of determining whether electric and magnetic fields, power densities, contact and induced currents, and contact voltages, exceed any of the corresponding MPEs.
- SAR evaluation may be necessary for some exposure conditions especially for evaluating exposure when the body is extremely close to an RF field source (within the reactive near-field region) and for highly localized exposures (e.g., mobile phone).

4.8 RF Safety Program



Where there may be access to RF fields, currents, and/or voltages that exceed the recommendations of the lower tier (Action Level), an RF safety program such as detailed in IEEE Std C95.7-2005 shall be implemented to ensure that exposures do not exceed the MPEs or BRs for exposures in a controlled environment.



SAR Basic Restrictions Comparisons with ICNIRP

ICES

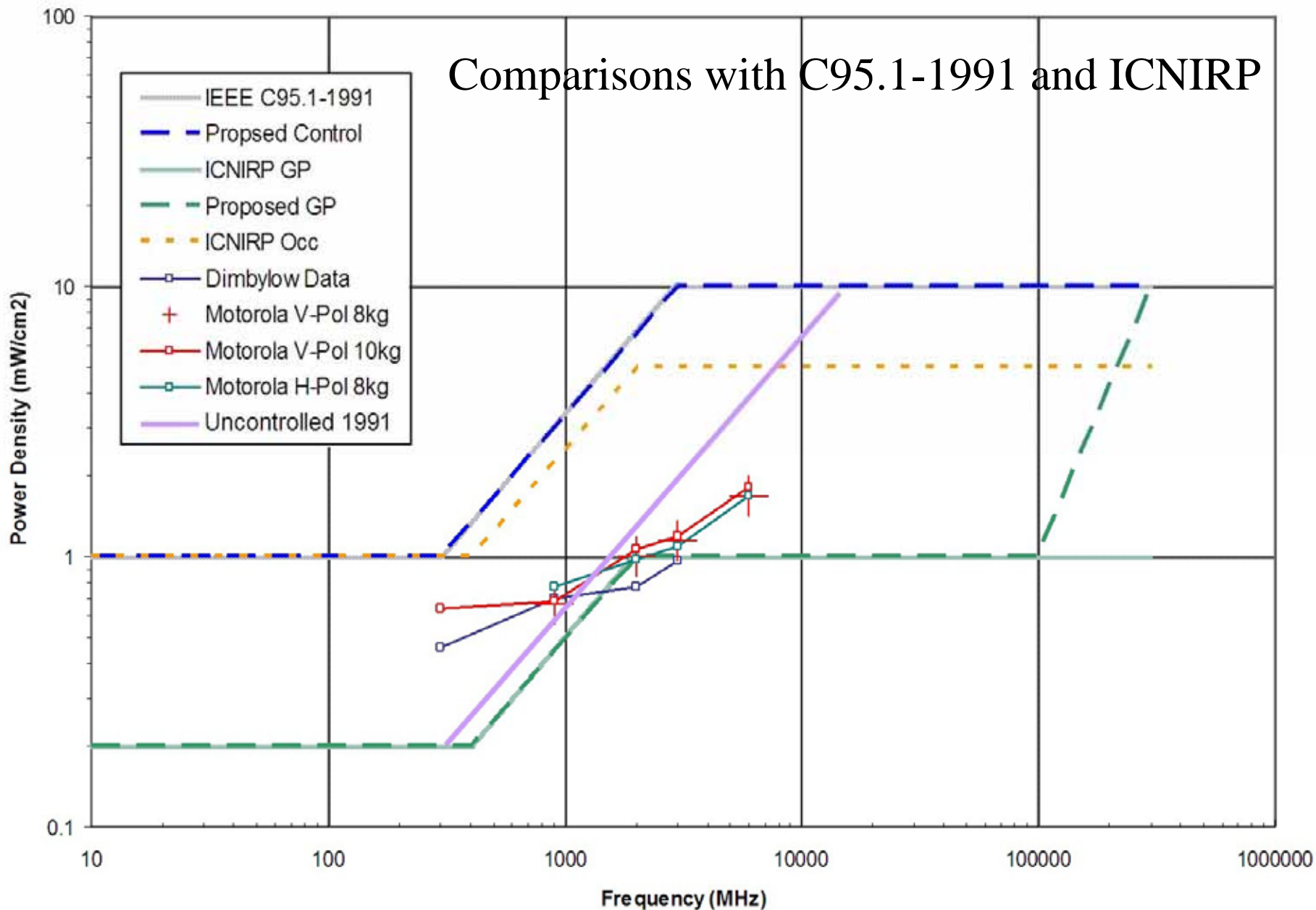
- “to protect against established adverse health effects”
- SAR applies between 100 kHz – 3 GHz
- Averaged over 10 g tissue in a cube
- Averaged over up to 30 min for general public and up to 6 min for controlled environment
- Pinnae have similar limit as extremities
- Upper arms and upper legs same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

ICNIRP

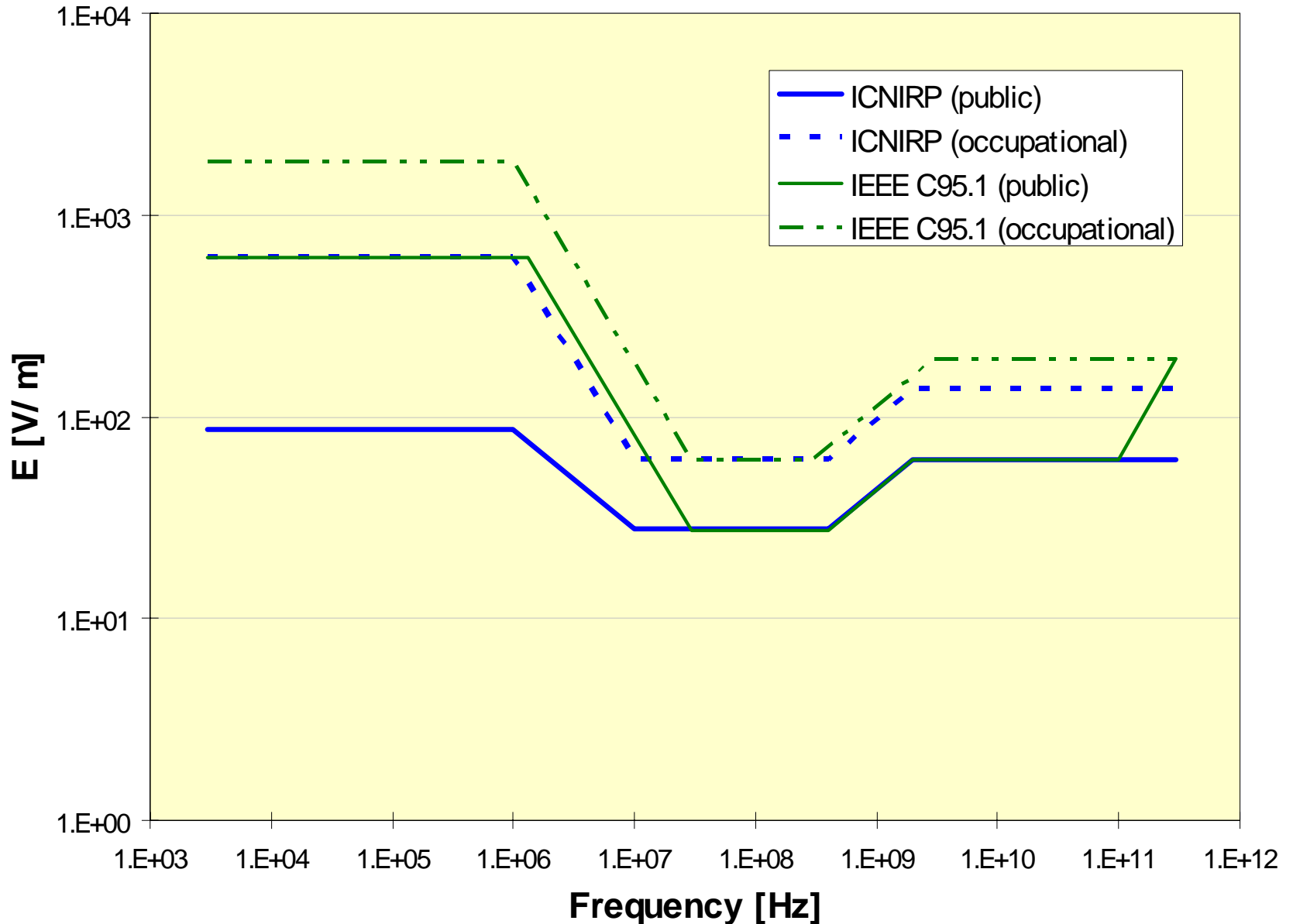
- “protection against known adverse health effects”
- SAR applies between 100 kHz -10 GHz
- Averaged over 10 g contiguous tissue
- Averaged over 6 min
- Pinnae limit is the same as body
- Upper arms and upper thighs are part of limbs and have different limits from body



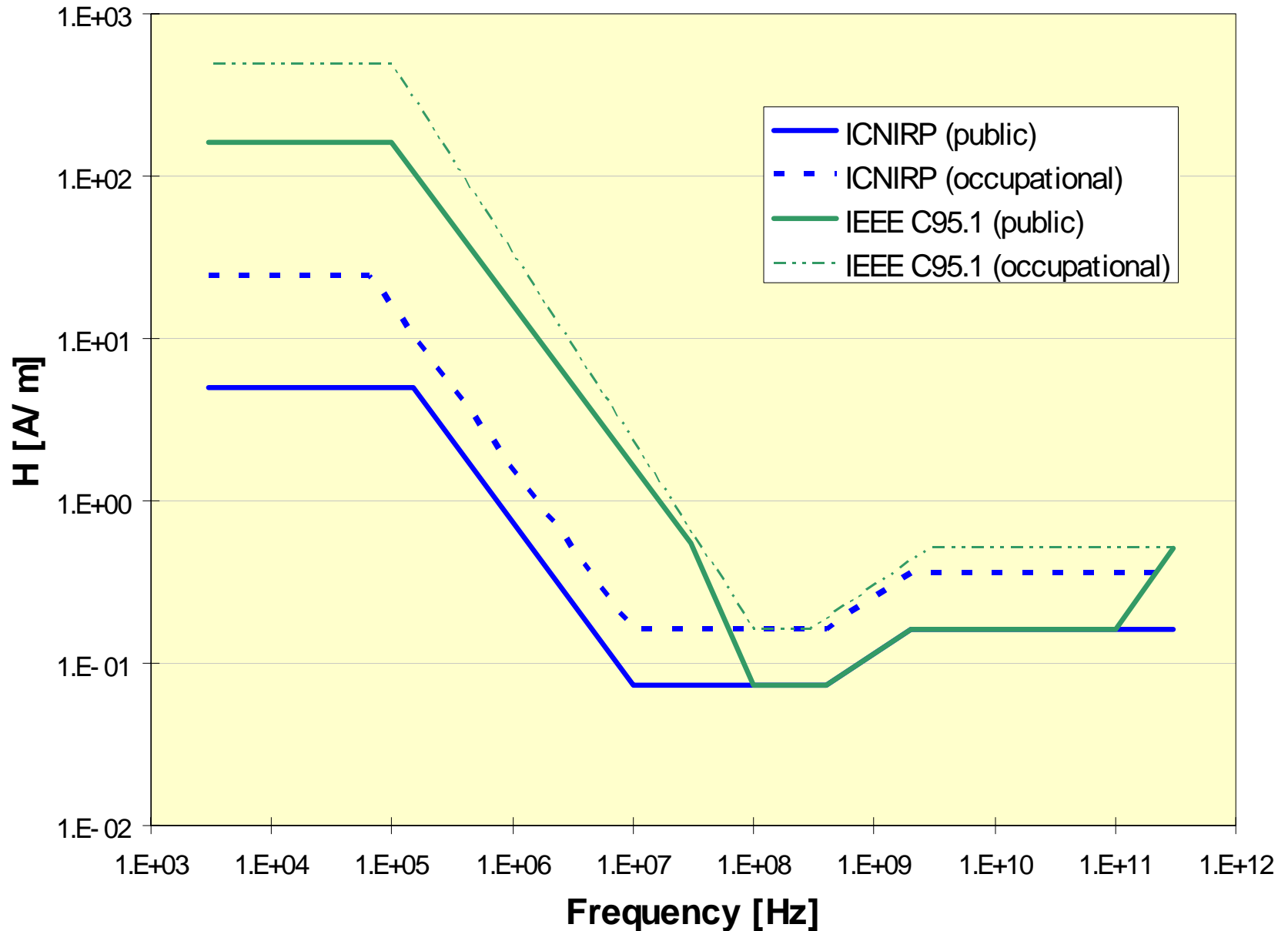
Comparisons with C95.1-1991 and ICNIRP



Comparison of ICNIRP/ICES E-field limits



Comparison of ICNIRP/ICES H-field limits





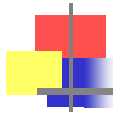
Promotes Harmonization of Standards

- Supports WHO harmonization efforts
- Benefits of harmonization
 - *Consumers* 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
 - *Regulators* 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

Conclusions

- 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

