

International guidelines and opinions about human exposure to non-ionizing radiation

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The International EMF Project

Electromagnetic fields



Electromagnetic fields of all frequencies represent one of the most common and fastest growing environmental influences, about which anxiety and speculation are spreading. All populations are now exposed to varying degrees of EMF, and the levels will continue to increase as technology advances.

The International EMF Project

www.who.int/peh-emf/project/en/

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The International EMF Project

↓ **EMF Project Promotional Brochure**
pdf, 3.06Mb

The International EMF Project has been established to assess health and environmental effects of exposure to static and time varying electric and magnetic fields in the frequency range 0-300 GHz.

What is the International EMF Project

Organization structure of the project

Contact

For more information on the EMF Project, please send an email to emfproject@who.int.

Quick links

- Publications
- Contact us

Participating countries & entities in EMF Project

WHAT'S NEW!

Database on EMF exposure legislation



EMF exposure legislation

WHO | World Health Organization

gamapserver.who.int/gho/interactive_charts/phe/emf_standards/tablet/atlas.html

Search



Electromagnetic fields (EMF): Existence of national standards, 2014

Radio frequency: Public

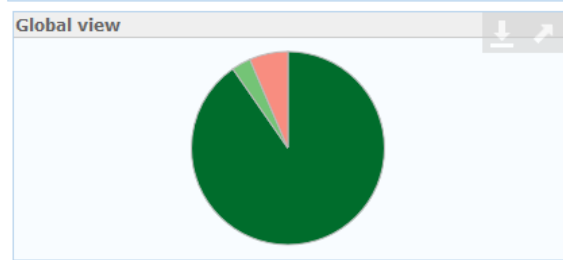
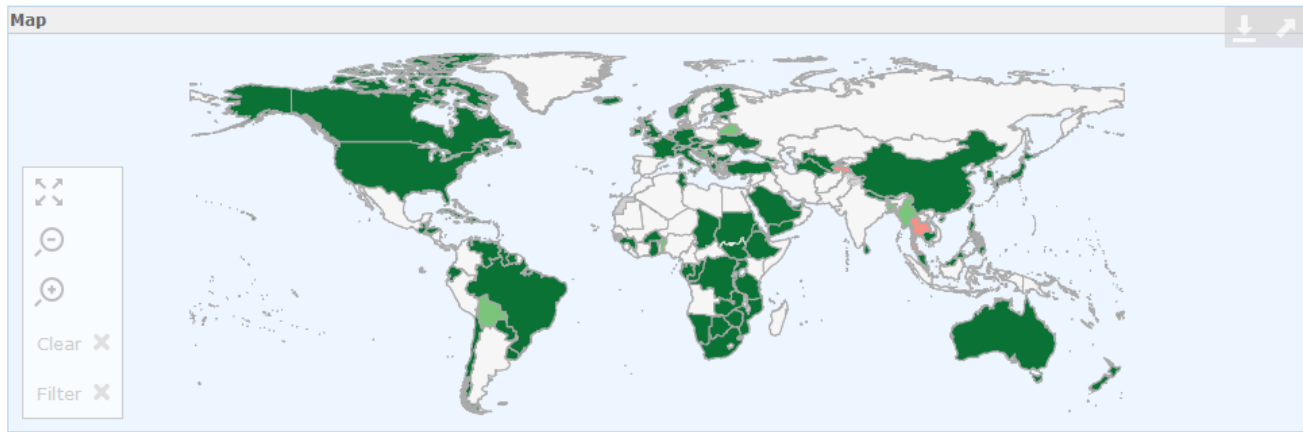
View by frequency range and population exposed

Filter by WHO region

Help

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Country	Existence of national standards
Afghanistan	Data not available
Albania	Data not available
Algeria	Data not available
Andorra	Data not available
Angola	Data not available
Antigua and Barbuda	Data not available
Argentina	Data not available
Armenia	Data not available
Australia	Yes
Austria	Yes
Azerbaijan	Data not available
Bahamas	Data not available
Bahrain	Yes



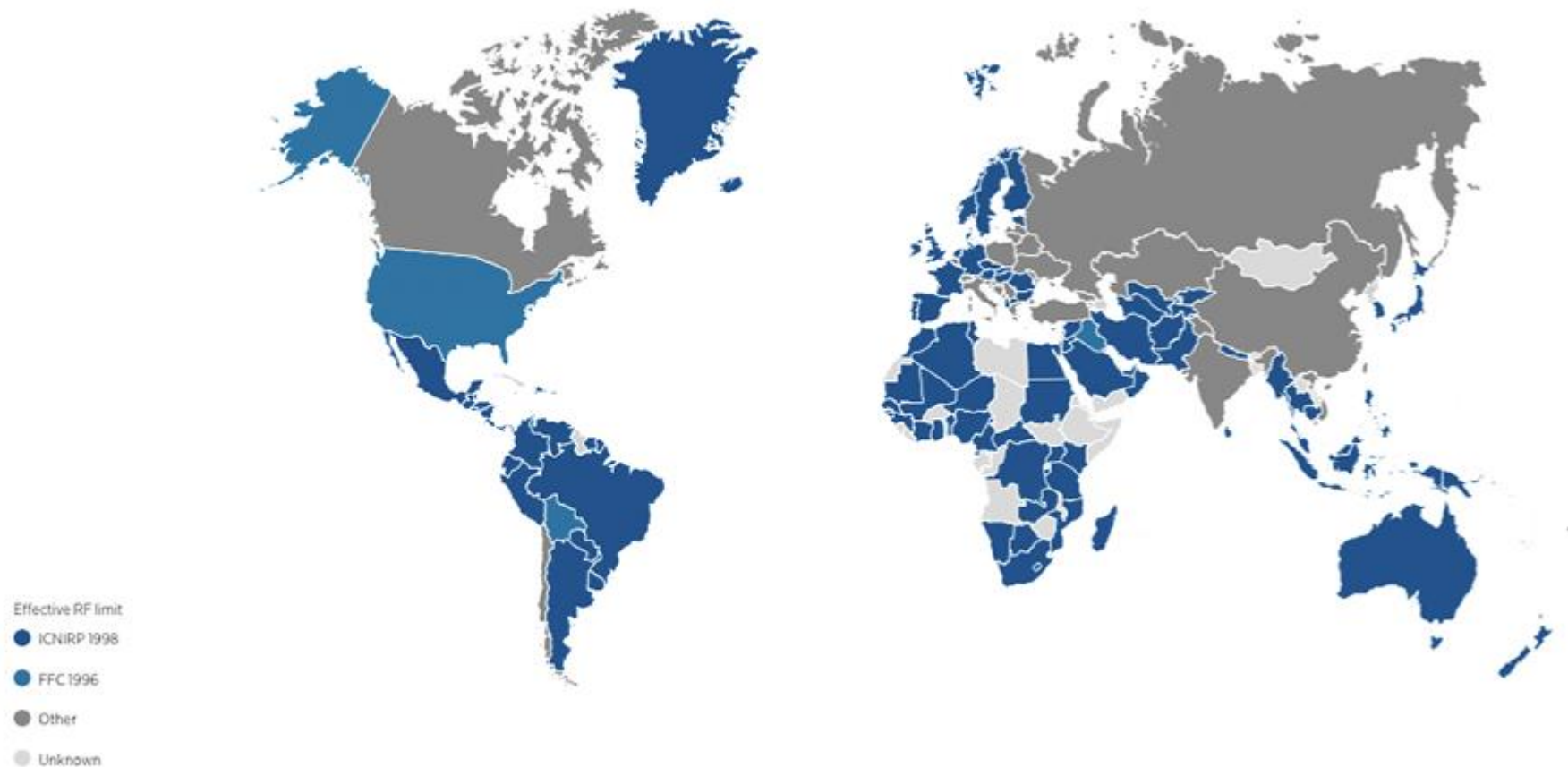
Legend

- Yes
- In preparation
- No
- Data not available
- Not applicable

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EMF exposure legislation



Guidelines for limiting exposure

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION



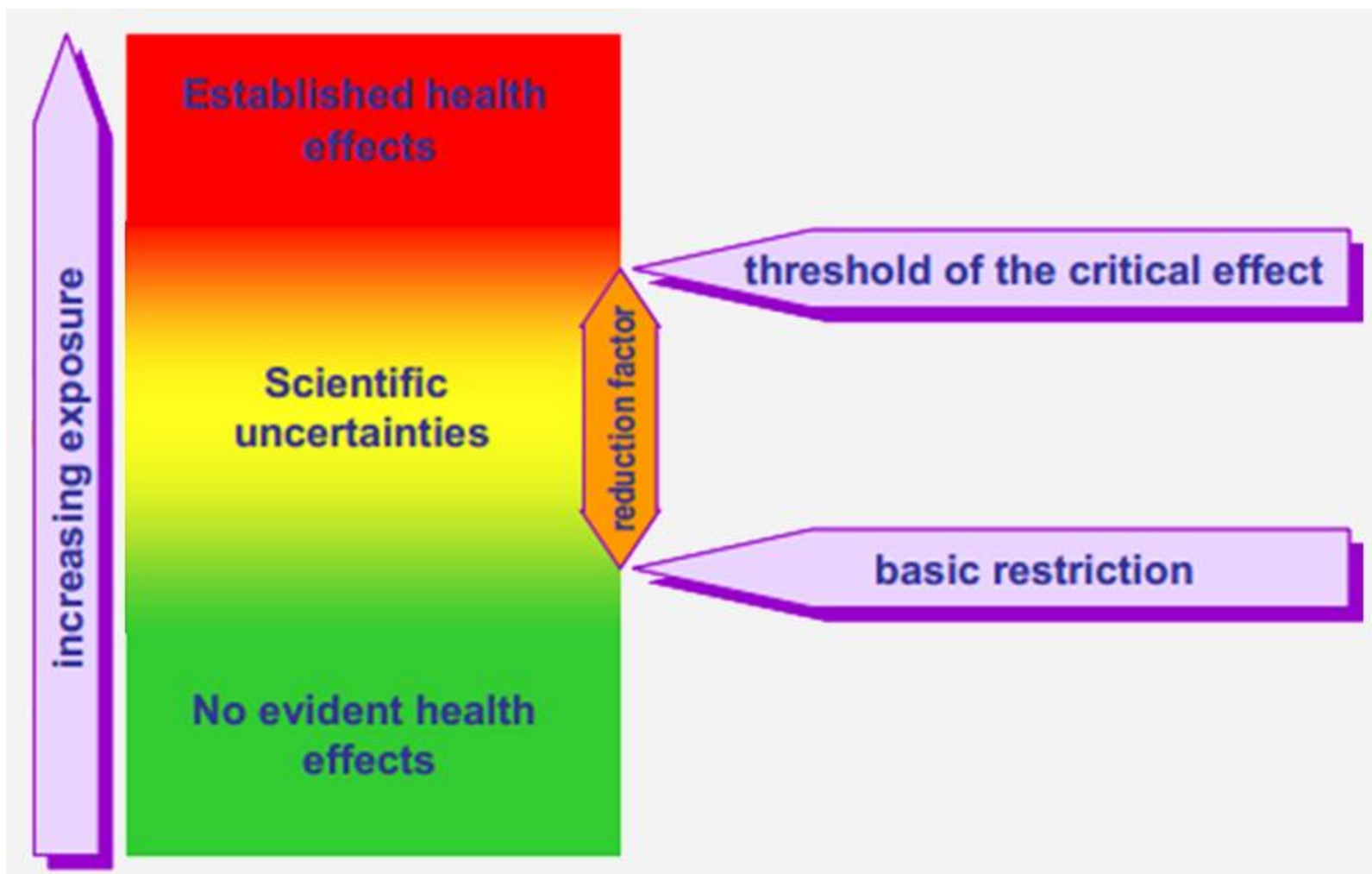
ICNIRP GUIDELINES

FOR LIMITING EXPOSURE TO TIME-VARYING
ELECTRIC, MAGNETIC AND ELECTROMAGNETIC
FIELDS (UP TO 300 GHz)

PUBLISHED IN: HEALTH PHYSICS 74 (4):494-522; 1998



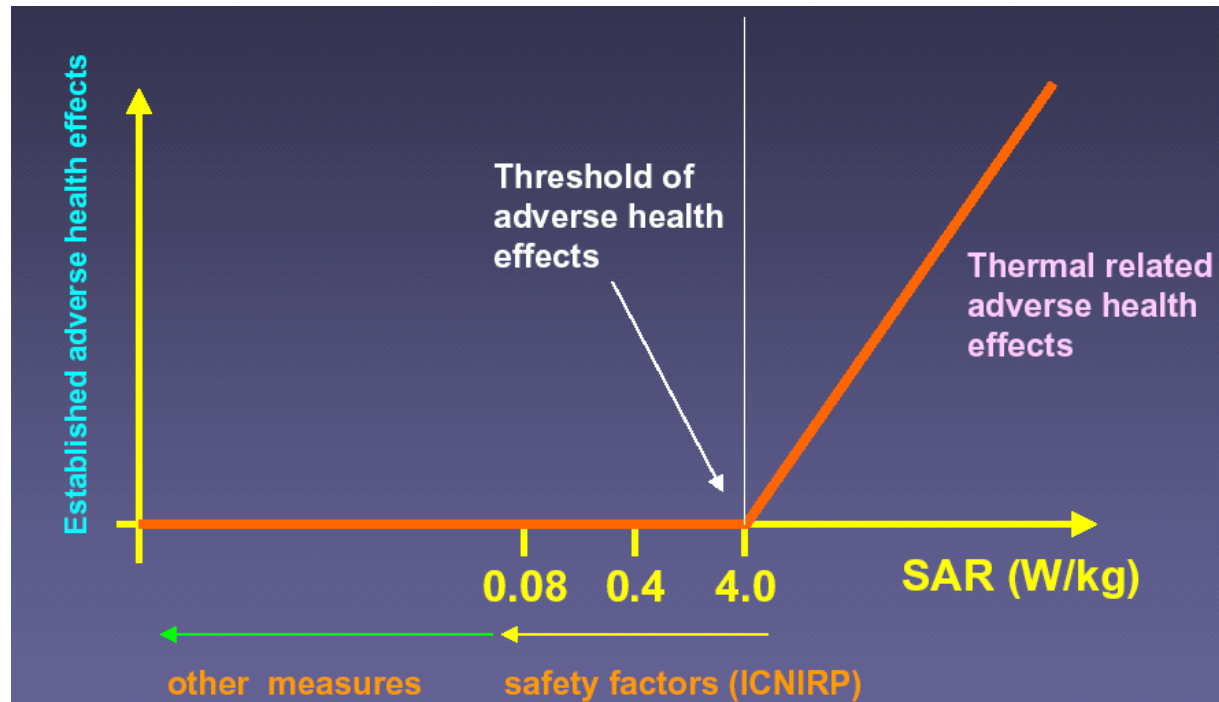
Derivation of limiting values



Terminology

Basic restrictions

- directly related to biological/health adverse effects
- most quantities cannot be readily measured



Terminology

Reference levels

- derived levels from basic restrictions
- quantities can be readily measured

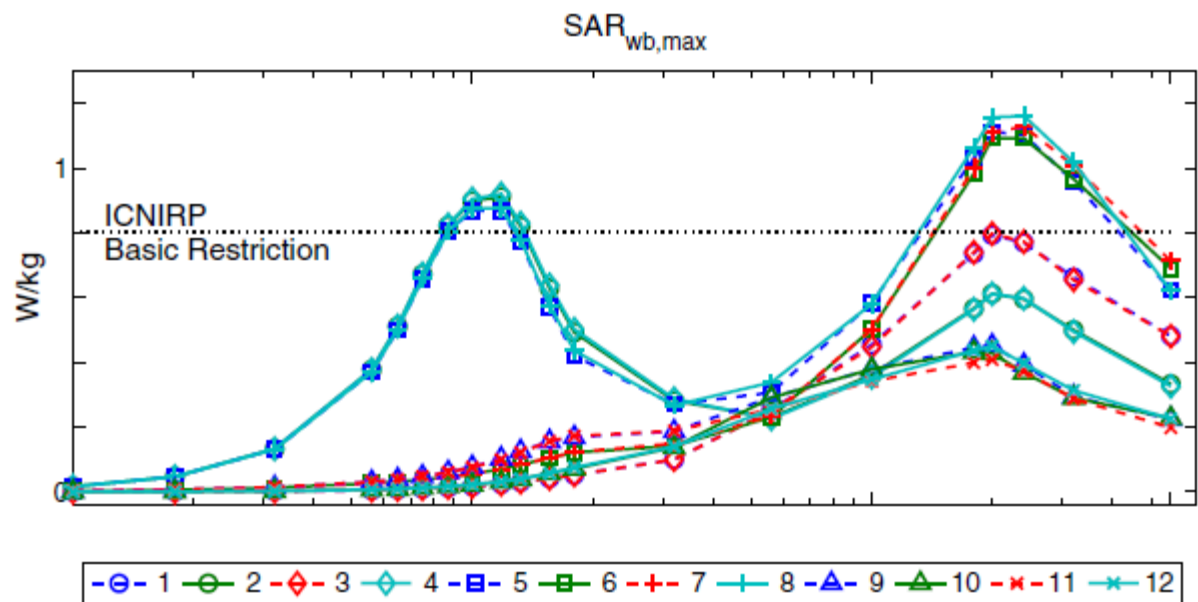
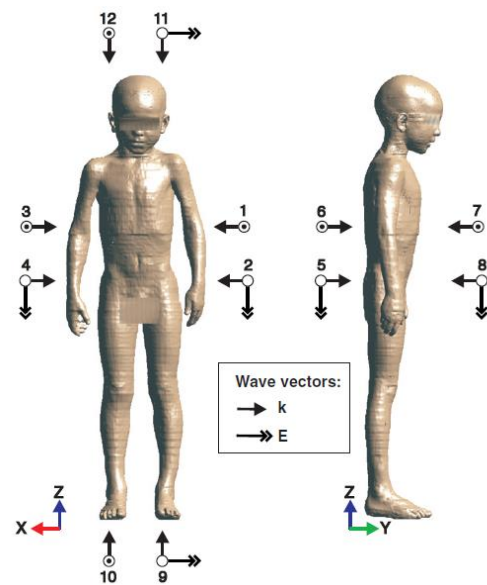


Figure 3. SAR_{wb} (top) and SAR_{10g} (bottom) for exposure at the ICNIRP reference level in the Thelionious model for 12 plane wave configurations.

source: Bakker et al., Phys Med Biol, 55:3115–3130, 2010

Reference levels

Some published studies ... showed that in the frequency ranges of body resonance (~100 MHz) and from 1 to 4 GHz for bodies shorter than 1.3 m in height (corresponding approximately to children aged 8 y or younger) at the recommended reference level the induced SARs could be up to 40% higher than the current basic restriction under worst-case conditions. However, this is negligible compared with the large reduction factor of 50 (5,000%) for the general public.

source: ICNIRP Statement, Health Physics 97(3):257-258, 2009

Basic restrictions

Table 4. Basic restrictions for time varying electric and magnetic fields for frequencies up to 10 GHz.^a

Exposure characteristics	Frequency range	Current density for head and trunk (mA m ⁻²) (rms)	Whole-body average SAR (W kg ⁻¹)	Localized SAR (head and trunk) (W kg ⁻¹)	Localized SAR (limbs) (W kg ⁻¹)
Occupational exposure	up to 1 Hz	40	—	—	—
	1–4 Hz	40/ <i>f</i>	—	—	—
	4 Hz–1 kHz	10	—	—	—
	1–100 kHz	<i>f</i> /100	—	—	—
	100 kHz–10 MHz	<i>f</i> /100	0.4	10	20
	10 MHz–10 GHz	—	0.4	10	20
General public exposure	up to 1 Hz	8	—	—	—
	1–4 Hz	8/ <i>f</i>	—	—	—
	4 Hz–1 kHz	2	—	—	—
	1–100 kHz	<i>f</i> /500	—	—	—
	100 kHz–10 MHz	<i>f</i> /500	0.08	2	4
	10 MHz–10 GHz	—	0.08	2	4

Reference levels

Table 6. Reference levels for occupational exposure to time-varying electric and magnetic fields (unperturbed rms values).^a

Frequency range	E-field strength (V m ⁻¹)	H-field strength (A m ⁻¹)	B-field (μT)	Equivalent plane wave power density S_{eq} (W m ⁻²)
up to 1 Hz	—	1.63×10^5	2×10^5	—
1–8 Hz	20,000	$1.63 \times 10^5/f^2$	$2 \times 10^5/f^2$	—
8–25 Hz	20,000	$2 \times 10^4/f$	$2.5 \times 10^4/f$	—
0.025–0.82 kHz	$500/f$	$20/f$	$25/f$	—
0.82–65 kHz	610	24.4	30.7	—
0.065–1 MHz	610	$1.6/f$	$2.0/f$	—
1–10 MHz	$610/f$	$1.6/f$	$2.0/f$	—
10–400 MHz	61	0.16	0.2	10
400–2,000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	$0.01f^{1/2}$	$f/40$
2–300 GHz	137	0.36	0.45	50

Multiple sources

Basic restriction:

$$\sum_{i=100 \text{ kHz}}^{10 \text{ GHz}} \frac{SAR_i}{SAR_L} + \sum_{i>10 \text{ GHz}}^{300 \text{ GHz}} \frac{S_i}{S_L} \leq 1$$

Reference levels:

$$\sum_{i=1 \text{ Hz}}^{1 \text{ MHz}} \frac{E_i}{E_{L,i}} + \sum_{i>1 \text{ MHz}}^{10 \text{ MHz}} \frac{E_i}{a} \leq 1$$

$$\sum_{j=1 \text{ Hz}}^{65 \text{ kHz}} \frac{H_j}{H_{L,j}} + \sum_{j>65 \text{ kHz}}^{10 \text{ MHz}} \frac{H_j}{b} \leq 1$$

Safety standard



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

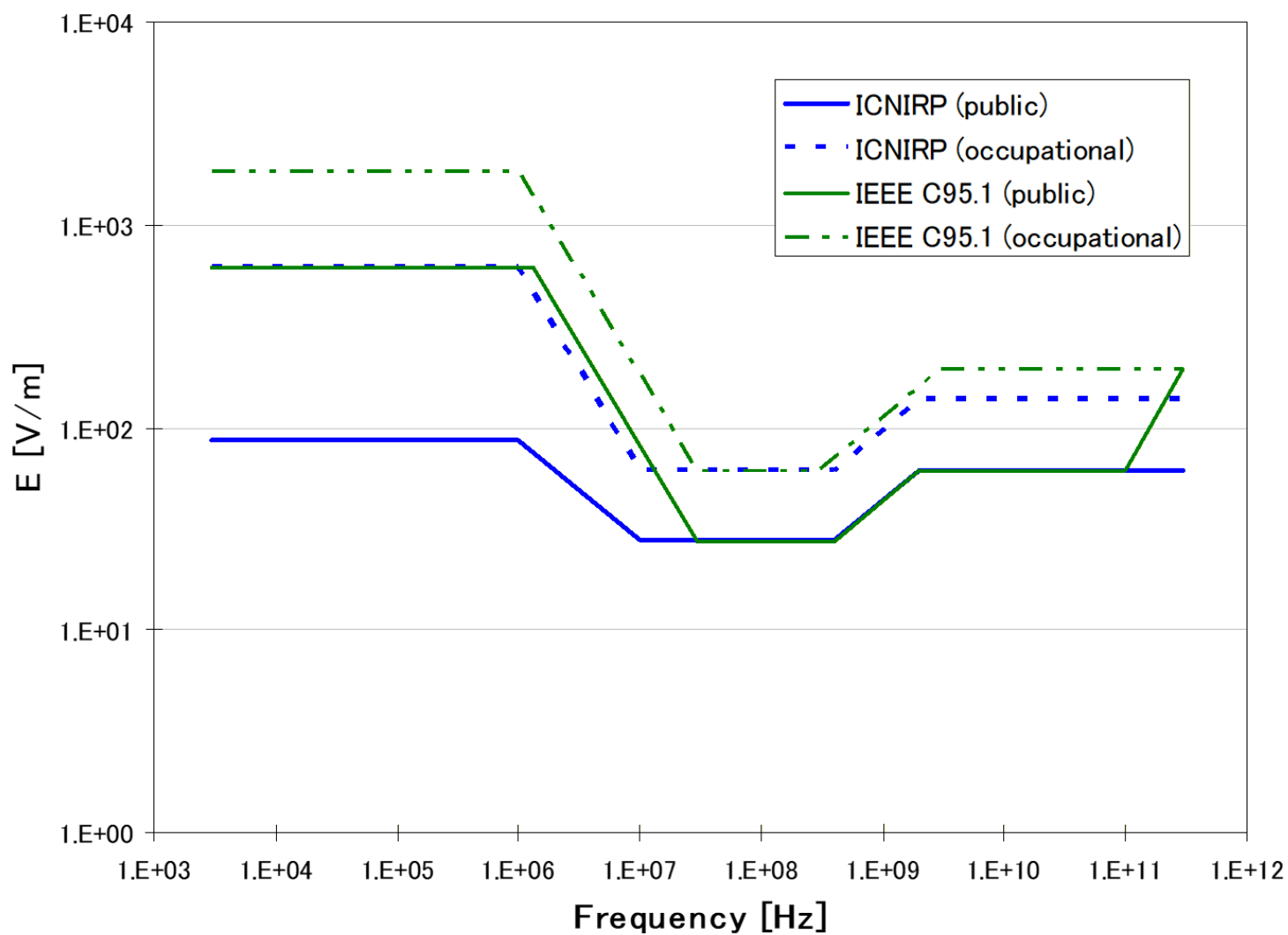
Sponsored by the
IEEE International Committee on Electromagnetic Safety (SCC39)

Comparison with ICNIRP

- Maximum permissible exposure (MPE) limits similar to reference levels
- Harmonization with ICNIRP from 300 MHz to 100 GHz and FCC from 2 to 100 GHz
- Basic restriction local SAR of 2 W/kg averaged over 10 gr of tissue except for hands, wrist, forearms, ankles, lower legs and the **pinnae** where SAR must not exceed 4 W/kg over any 10 gr
- Similar management of multiple exposure:

$$\sum_{i=1}^n \frac{S_{E_i}(\text{duty factor})}{MPE_{E_i}} < 1 \quad \sum_{i=1}^n \frac{S_{H_i}(\text{duty factor})}{MPE_{H_i}} < 1$$

Comparison with ICNIRP



Classification of mobile phones radiation

International Agency for Research on Cancer



PRESS RELEASE
N° 208

31 May 2011

IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS

Lyon, France, May 31, 2011 -- The WHO/International Agency for Research on Cancer (IARC) has classified radiofrequency electromagnetic fields as [possibly carcinogenic to humans \(Group 2B\)](#), based on an increased risk for [glioma](#), a malignant type of brain cancer¹, associated with wireless phone use.



Classification of mobile phones radiation

- The human evidence for an association was found to be limited, i.e., some but not all epidemiological studies showed an indication of an increased risk of glioma or acoustic neuroma, but bias and confounding could not be ruled out with reasonable confidence to assume a causal interpretation.
- As a classification of 2B is a mandate for further research using improved methodology, the IARC Section of Environment and Radiation will continue efforts to contribute to this open question using the most promising tools for scientific research available at the time.

Electromagnetic fields and public health: mobile phones

- To date, no adverse health effects have been established as being caused by mobile phone use.
- To date, research does not suggest any consistent evidence of adverse health effects from exposure to radiofrequency fields at levels below those that cause tissue heating. Further, research has not been able to provide support for a causal relationship between exposure to electromagnetic fields and self-reported symptoms, or “electromagnetic hypersensitivity”.
- Results of animal studies consistently show no increased cancer risk for long-term exposure to radiofrequency fields.

Reaction of ICNIRP to latest animal carcinogenicity studies



NOTE

ICNIRP NOTE ON RECENT ANIMAL CARCINOGENESIS STUDIES

Munich, Germany, 04.09.2018

Two recent animal studies investigating the carcinogenic potential of long-term exposure to radiofrequency electromagnetic fields (EMFs) associated with mobile phones have been released: one by the U.S. National Toxicology Program (NTP 2018a, b) and the other from the Ramazzini Institute (Falcioni et al. 2018). These studies, among others, have been taken into account during revision of the ICNIRP radiofrequency exposure guidelines. However, both studies have inconsistencies and limitations that affect the usefulness of their results for setting exposure guidelines, and both need to be considered within the context of other animal and human carcinogenicity research. Overall, based on the considerations outlined below, ICNIRP concludes that these studies do not provide a reliable basis for revising the existing radiofrequency exposure guidelines.

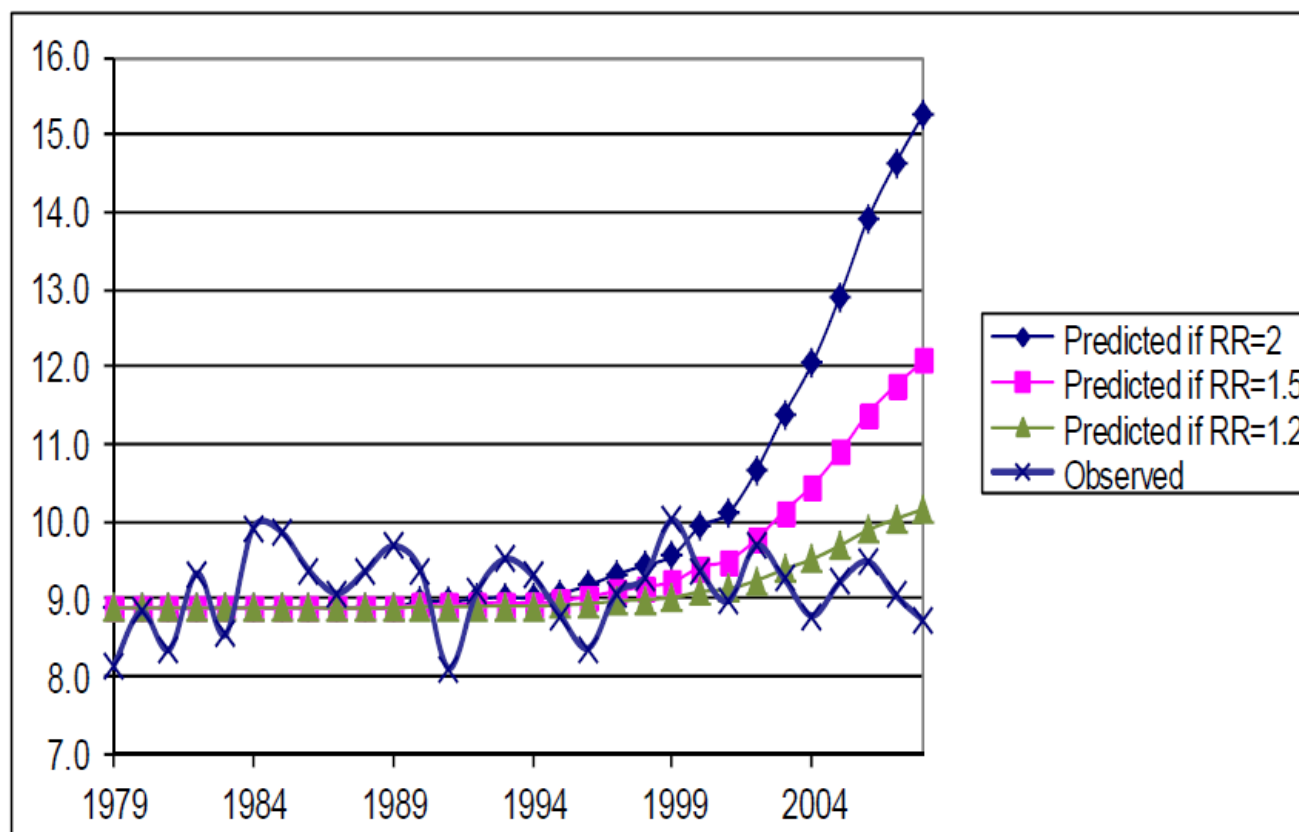


Potential health effects of exposure to electromagnetic fields

- Overall, the epidemiological studies on mobile phone RF EMF exposure do not show an increased risk of brain tumours. Furthermore, they do not indicate an increased risk for other cancers of the head and neck region. Some studies raised questions regarding an increased risk of glioma and acoustic neuroma in heavy users of mobile phones. The results of cohort and incidence time trend studies do not support an increased risk for glioma while the possibility of an association with acoustic neuroma remains open. Epidemiological studies do not indicate increased risk for other malignant diseases, including childhood cancer.

Potential health effects of exposure to electromagnetic fields

Figure 5. Observed glioma incidence rate in the Nordic countries and expected rates assuming mobile phone (regular mobile phone use of 10 years or more) related relative risk increases of 1.2, 1.5 and 2, respectively [Based on data from Deltour et al. 2012]



Potential health effects of exposure to electromagnetic fields

- There is a lack of evidence that mobile phone RF EMF affects cognitive functions in humans.
- For symptoms triggered by short-term exposure to RF fields (measured in minutes to hours), the consistent results from multiple double-blind experiments give a strong overall weight of evidence that such effects are not caused by RF exposure.
- The previous SCENIHR Opinion concluded that there were no adverse effects on reproduction and development from RF fields at non-thermal exposure levels. The inclusion of more recent human and animal data does not change this assessment.



Guidelines for limiting exposure



ICNIRP Radiofrequency Guidelines
Public Consultation Version
June 26th, 2018

ICNIRP Radiofrequency Guidelines *Public Consultation version*

Rodney Croft

Chair, ICNIRP RF Guidelines Project Group
University of Wollongong, Australia



Guidelines for limiting exposure



ICNIRP Radiofrequency Guidelines
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June 26th, 2018

Basic algorithm for deriving limits

- a) Identify health effect thresholds
 - as a function of exposure type and frequency
- b) Derive 'Basic Restrictions' (Occupational/General Public)
 - via application of reduction factors
- c) Derive 'Reference Levels' (Occupational/General Public)
 - more easily applied means of providing protection
- Where appropriate, provide 'guidance'



Guidelines for limiting exposure



ICNIRP Radiofrequency Guidelines
Public Consultation Version
June 26th, 2018

Identification of health effect thresholds

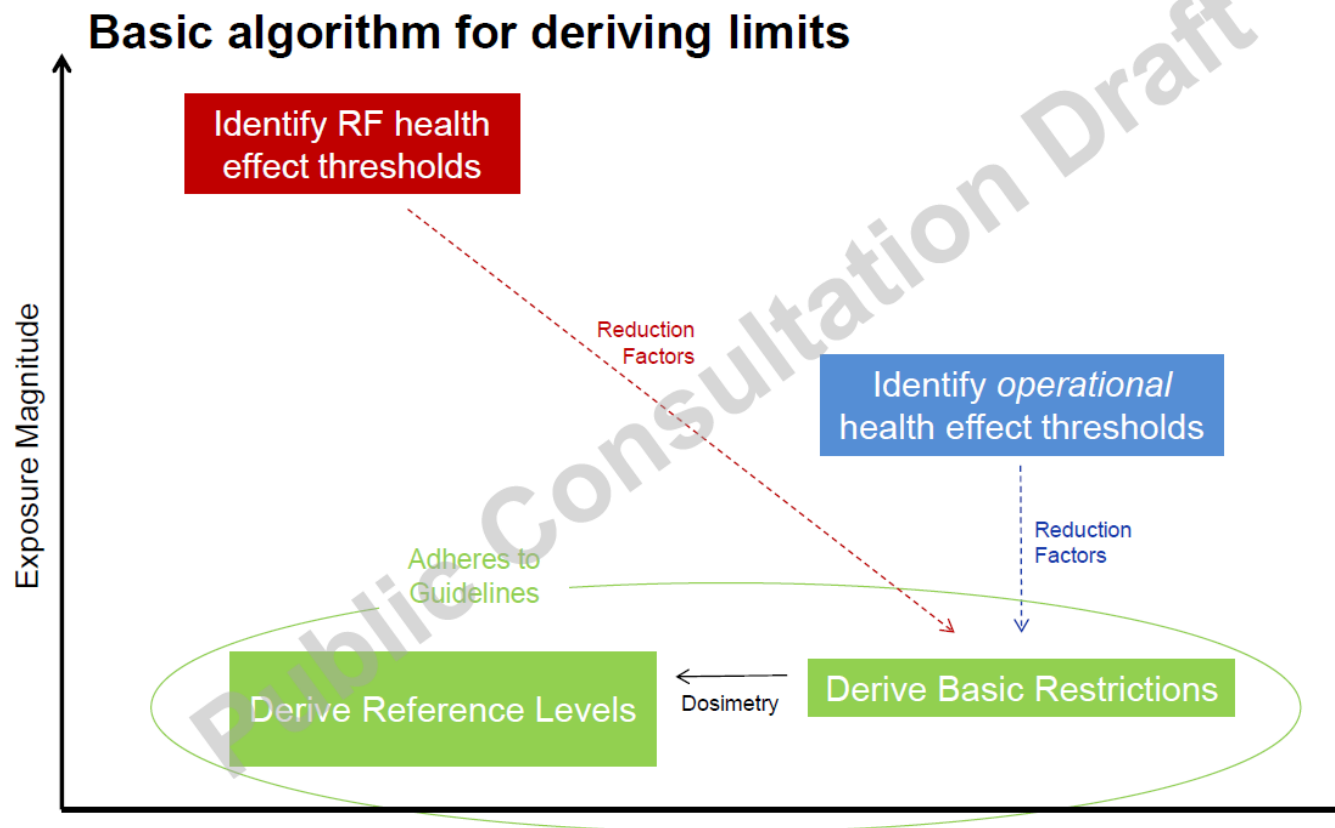
- a) Identify scientific literature regarding (non-thermal & thermal) effects of exposure on biological systems
- b) Determine radiofrequency EMF effects considered both
 - adverse to humans, and
 - scientifically substantiated (e.g. independent replication, sufficient quality, scientifically explicable more generally)
- c) Identify health effect threshold
 - minimum RF exposure shown to produce harm, or
 - where insufficient RF/biology research, minimum exposure **predicted** to cause harm from non-RF literature (i.e. **operational** health effect threshold)
 - e.g. 1 degree C body core temperature elevation



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Basic Restrictions Summary

Table 2. Basic restrictions for electric, magnetic and electromagnetic field exposure (≥ 6 -minutes).^a

Exposure Scenario	Frequency Range	Whole body average SAR (W kg ⁻¹)	Local head/torso SAR (W kg ⁻¹)	Local limb SAR (W kg ⁻¹)	Local S _{tr} (W m ⁻²)
Occupational	100 kHz – 6 GHz	0.4	10	20	---
	>6 GHz – 300 GHz	0.4	---	---	100
General Public	100 kHz – 6 GHz	0.08	2	4	---
	>6 GHz – 300 GHz	0.08	---	---	20

^a Note:

1. Whole body average SAR is to be averaged over 30-minutes.
2. Local SAR and S_{tr} exposures are to be averaged over 6-minutes.
3. Local SAR is to be averaged over a 10-g cubic mass.
4. Local S_{tr} is to be averaged over 4 cm² (>6-30 GHz), or 1 cm² (>30 GHz).

Guidelines for limiting exposure



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Basic Restrictions Summary

Table 3. Basic restrictions for electric, magnetic and electromagnetic field exposure (< 6-minutes).^a

Exposure Scenario	Frequency Range	Local SA (J kg^{-1})	Local H_{tr} (kJ m^{-2})
Occupational	400 MHz – 6 GHz	$250+177(t-1)^{0.5}$	---
	>6 GHz – 300 GHz	---	$2.5+1.770(t-1)^{0.5}$
General Public	400 MHz – 6 GHz	$50+35.4(t-1)^{0.5}$	---
	>6 GHz – 300 GHz	---	$0.5+0.354(t-1)^{0.5}$

^a Note:

1. SA is to be averaged over a 10-g cubical mass.
2. H_{tr} is to be averaged over 4 cm^2 (>6-30 GHz), or 1 cm^2 (>30 GHz).
3. 't' is any time interval, in seconds; for $t < 1$, 't = 1' must be used.

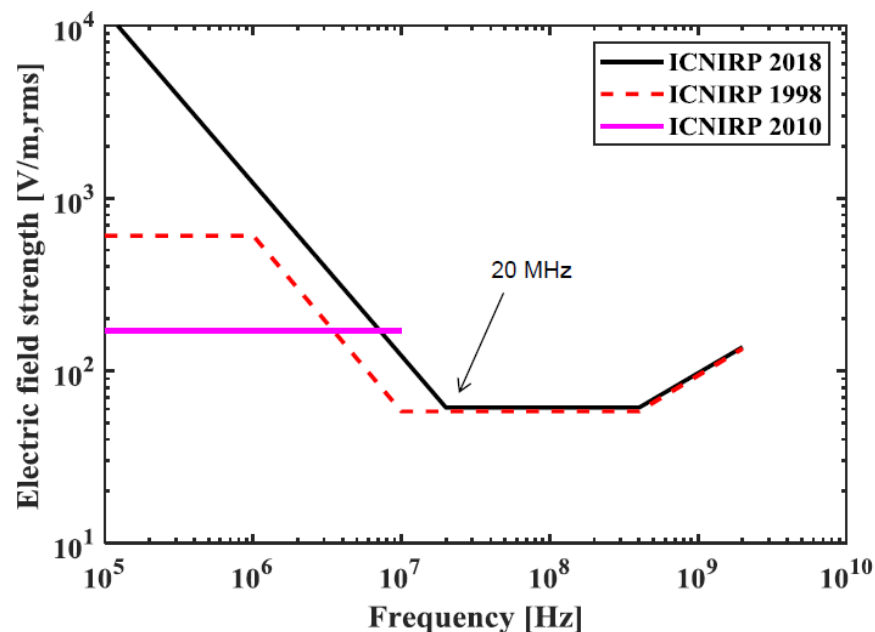
must satisfy all time intervals
(not based on pulse sequence)

Guidelines for limiting exposure



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WBA far-field E-field occupational reference levels - 30 mins (reduce by factor of $\sqrt{5}$ for General Public)



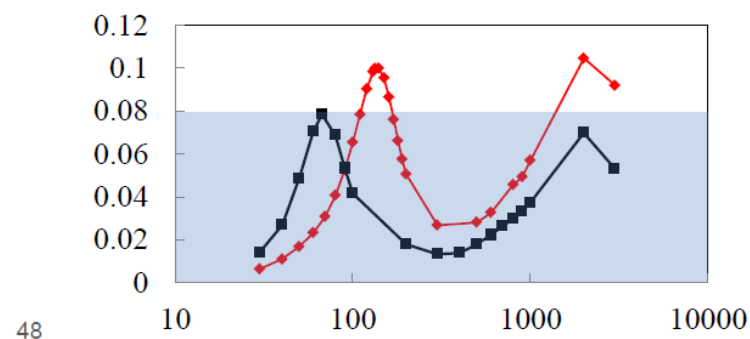
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Reference Level Issues (child)

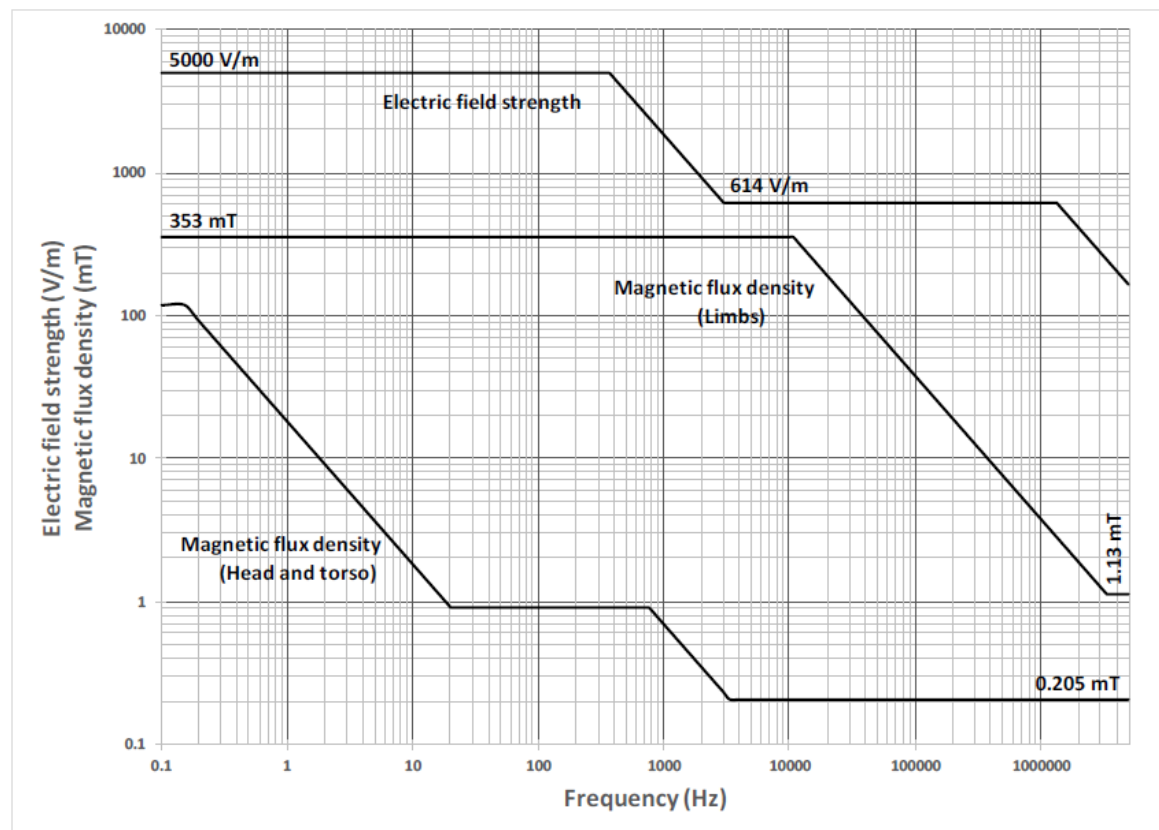
- Is this more than a theoretical issue?
 - Small violation only (within dosimetric uncertainty)
 - Does not affect the *health effect being protected against*
 - i.e. at reference level, body core temperature increase in small stature people will be less than for taller people (even though WBA SAR is higher for the child)
- Therefore, reference levels have not been adjusted



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Safety standard



(a) Persons in unrestricted environments

Ευχαριστώ για την προσοχή σας.