

The draft ICNIRP radiofrequency guidelines

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Scope

- Limit exposure to radiofrequency EMFs (100 kHz – 300 GHz)
- Provide protection against adverse health effects to humans under *realistic* conditions
- Consider occupational and general public exposure
- Consider direct and indirect exposure (but only contact with charged objects)
- Not included:
 - Electromagnetic interference
 - Exposure for medical purposes
 - Compliance issues (e.g. measurements)

Current status

- Draft guidelines (exposure limits & rationale)
- Technical appendix (dosimetry issues, background reference levels)
- Biological appendix (overview health effects)
- Public consultation finished 9 October 2018
 - ~120 contributions, >1000 individual comments
- Almost finished! Publication hopefully August / September 2019

Identification of adverse health effect thresholds

- Identification of scientific data on effects of exposure on biological systems
- Determination of effects considered both
 - adverse to humans and
 - scientifically substantiated (independent replication, sufficient quality, scientifically explicable generally)
- Identification of adverse health effect threshold
 - minimum RF EMF exposure level shown to produce harm, or
 - where insufficient RF/biology research, minimum exposure predicted to cause harm from non-RF literature (i.e. *operational* adverse health effect threshold)

Derivation of Basic restrictions (=exposure limits)

- Application of reduction factors to health effect thresholds
 - account for scientific uncertainty, relative importance of the health effect, variation across the population
 - reduction factors may differ based on these parameters
 - consistency of reduction factors across limit types is sought, unless there is *substantive* reason for variation
- Reduction factors for general public are higher than for occupational
 - general public may not be aware of exposure and will not have any training to mitigate harm
 - variation in tolerance (e.g. for heating) may be larger in general public

Reference levels

- Field strength values derived from basic restrictions, to provide a practical method for determining compliance with basic restrictions
 - Reference levels are derived so as to be conservative for all *realistic* exposure conditions, but not all *possible* exposure conditions

Scientific basis

- Draft WHO RF EHC, SCENHIR, SSM reports + original papers not included
- Extensive body of relevant literature, ranging from cellular research to cancer epidemiology
- Research has only found evidence of potentially harmful effects from:
 - temperature elevation above thresholds
 - microwave hearing (thermal effect; not considered harmful, no limits)
 - nerve stimulation (described in ICNIRP 2010 ELF Guidelines; not considered separately here)
 - electroporation (no problem in practice; no limits formulated)

Scientific basis (cont.)

- No evidence that RF EMF causes such diseases as cancer
 - Results of NTP, Falcioni studies (animals, lifetime exposure) not convincing (statement on ICNIRP website)
- No evidence that RF EMF impairs health beyond effects that are due to established mechanisms of interaction
- Thermal biology literature also considered

Interaction mechanisms (temperature elevation)

- Temperature increases taken to represent health effects, and restrictions set to avoid these
- Health effects primarily related to absolute body core or local temperature
- Body core and local temperature depend on many factors that are independent of EMF, such as environmental temperature and physical activity
- Therefore: temperature increase used that is indicative of adverse health effects *assuming thermonormal baseline state*
- Distinction between steady-state and brief exposures (no dissipation of heat)

Body core temperature

- Mean body core temperature (approximately 37 °C) typically varies over the day by 0.5 °C
 - thermoregulatory functions (e.g. vasodilation, sweating) to keep body core temperature in thermonormal range
 - most health effects induced by hyperthermia (>38 °C) resolve readily with no lasting effects, but risk of accident and heat stroke increases (>40 °C)
- Increase >1 °C in body core temperature is defined as potentially harmful (=operational standard)
 - for comparison: ACGIH heat stress at work standard aims at protecting against >1 °C core body temperature increase

SAR and body core temperature

- RF modelling predicts:
 - ~6 W/kg WBA SAR, 1 h, ambient temperature of 28 °C: core body temperature increase ~1 °C (consistent with the limited human measurement research)
 - WBA SAR higher in children (more efficient heat dissipation)
- **ICNIRP suggests as adverse health effect threshold a WBA SAR of 4 W/kg averaged over 30 min (=time to ~ reach steady state)**
- Very conservative !
- Generation energy in human adult: ~1 W/kg at rest, ~2 W/kg standing, ~12 W/kg running

SAR and frequency

- Previous:
 - SAR up to 10 GHz, power density at higher frequencies
- Now:
 - *whole-body* SAR up to 300 GHz
 - *local* SAR up to 6 GHz
 - 6-300 GHz: *absorbed* (=incident - reflected) power density

Local exposure: tissues

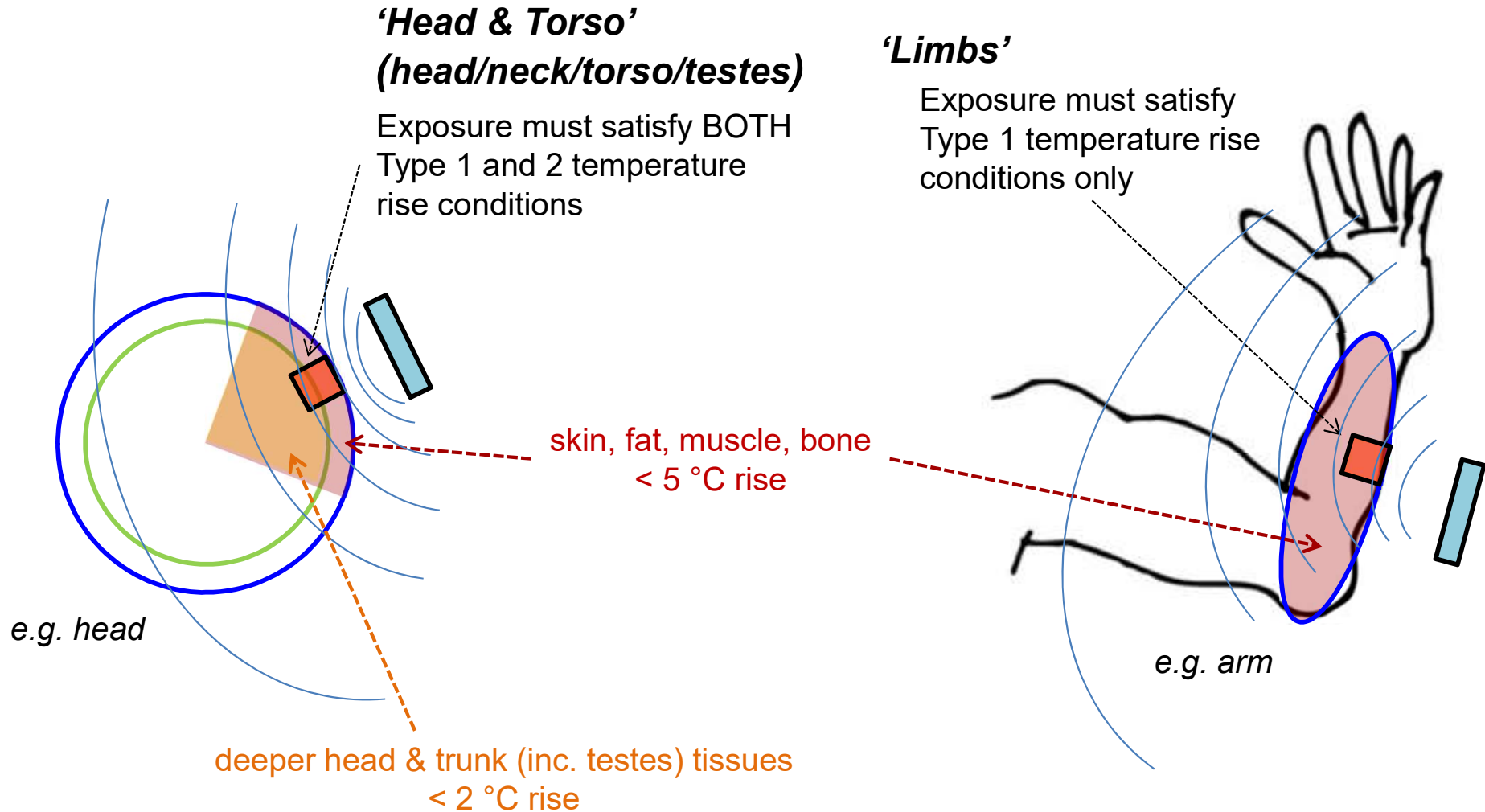
- Excessive localized heat can cause pain and damage cells. Tissue damage can occur at local temperatures $>41-43$ °C (time-dependent)
- Operational adverse health effect threshold:
- **Local temperature >41 °C potentially harmful**
- **Type-1 tissues** (normal temperature $< 33-36$ °C): **5 °C**
 - upper arm, forearm, hand, thigh, leg, foot, pinna, cornea, anterior chamber and iris of the eye, epidermal, dermal, fat, muscle and bone tissue
- **Type-2 tissues** (normal temperature < 38.5 °C): **2 °C**
 - all tissues in the head, eye, abdomen, back, thorax and pelvis, excluding those defined as Type-1 tissue

Local exposure: regions

- Difficult to use tissue types for exposure limits
- Definition of *regions*:
 - **Head & Torso** (head, eye, abdomen, back, thorax and pelvis)
 - **Limbs** (upper arm, forearm, hand, thigh, leg and foot)

		Tissue	
		Type 1	Type 2
Region	Head & Torso	Yes	Yes
	Limbs	Yes	No

Conceptualisation of exposure relative to tissue-type



Averaging mass

- SAR:
 - 10 g
 - shape:
 - was: contiguous tissue
 - now: cube (provides a better match with temperature increase than contiguous tissue)

Local exposure: adverse health effect levels

- Modelling/extrapolation suggests:
 - ≤ 6 GHz: SAR_{10g} of 20 W/kg: temperature increase max. 2 °C (4 °C with 40 W/kg)
 - >6 GHz: absorbed power density (S_{ab}) of 200 W/m²: temperature increase max. ~5 °C in superficial, less in deeper tissue
- **ICNIRP suggests as health effect levels:**
 - **100 kHz - 6 GHz:**
 - **Head & Torso: local SAR_{10g} 20 W/kg (av. over 6 min)**
 - **Limbs: local SAR_{10g} 40 W/kg (av. over 6 min)**
 - **>6 -300 GHz: S_{ab} 200 W/m² (av. over 6 min, 4 cm²)**
 - **Focal beam exposure: >30 -300 GHz: S_{ab} 400 W/m² (av. over 6 min, 1 cm²)**
- Also (complex) limits for short (pulsed) exposures

Contact current

- Effect = pain
- Threshold:
 - Adults: 20 mA
 - Child: 10 mA

Basic restrictions and differences with 1998 values

Parameter	Freq. range	ΔT	Spatial	Aver. time	Health effect level	RF	Occup.	RF	General public
Core ΔT	100 kHz-300 GHz	1°C	WBA	30 min 6 min	4 W/kg	10	0.4 W/kg	50	0.08 W/kg
Local ΔT (Head & Torso)	100 kHz-6 GHz	2°C	10 g	6 min	20 W/kg	2	10 W/kg	10	2 W/kg
Local ΔT (Limbs)	100 kHz-6 GHz	5°C	10 g	6 min	40 W/kg	2	20 W/kg	10	4 W/kg
Local ΔT (Head, Torso, Limbs)	>6-300 GHz 30-300 GHz 10-300 GHz	5°C	4 cm ² 1 cm ² 20 cm ²	6 min 6 min 68/f ^{1.05}	200 W/m ²	2	100 W/m ² 200 W/m ² 50 W/m ²	10	20 W/m ² 40 W/m ² 10 W/m ²
Pain (contact current)	100 kHz-110 MHz <i>(guidance level reference level)</i>	--	--	10 sec	20/10 mA (adult/child)	1	20 mA 40 mA	1	20/10 mA (ad./child) 20 mA

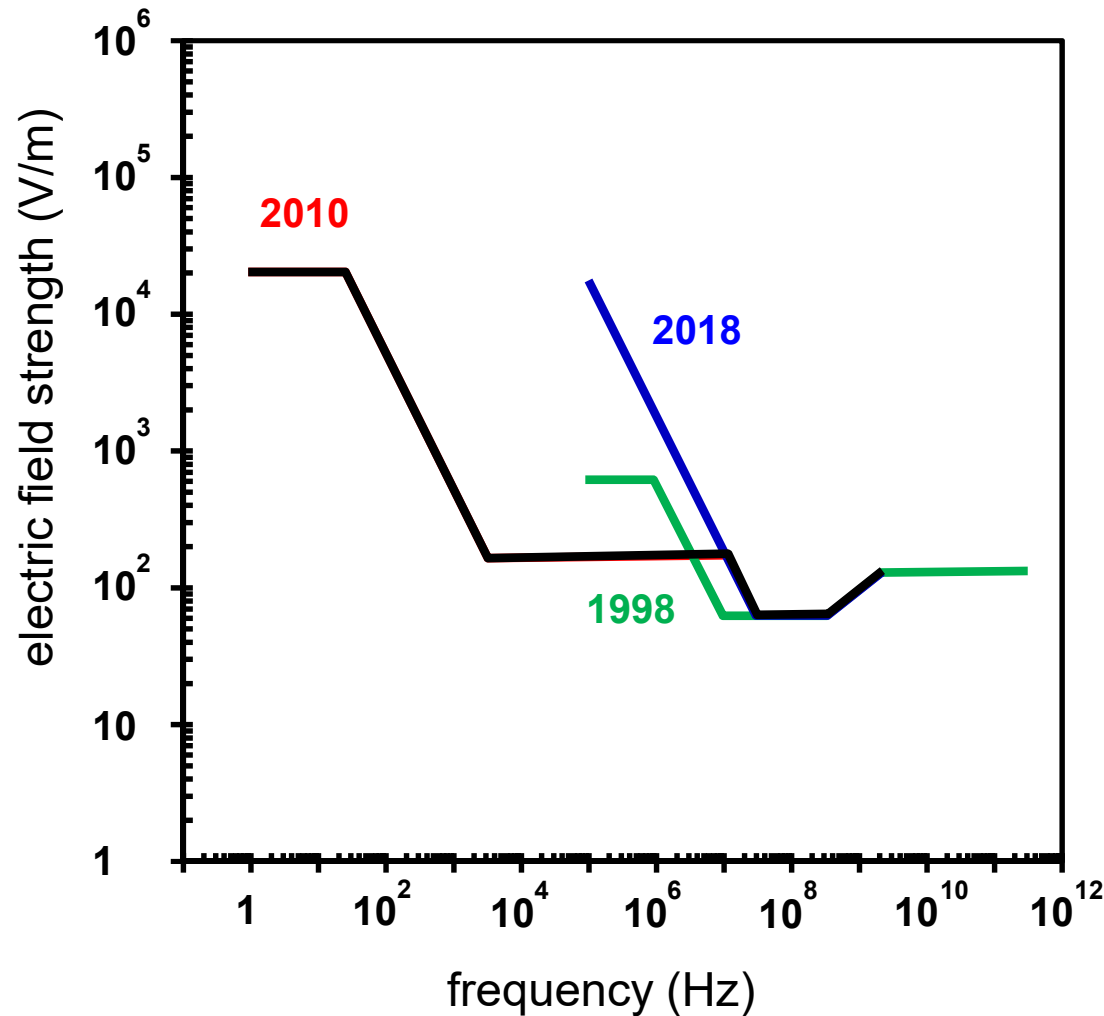
Reference levels

- Dependent on:
 - Workers / general public
 - Far field / radiative near field / reactive near field
 - Whole-body / local
- All reference levels for a given exposure frequency need to be satisfied simultaneously

Reference levels

- 100 kHz – 300 GHz:
 - Whole-body
 - Local, exposure ≥ 6 minutes
 - Local, exposure < 6 minutes
- 100 kHz – 10 MHz
 - Whole-body, peak field (from 2010 ELF guidelines)
 - E field: occupational 170 V/m, general public 83 V/m
 - H field: occupational 80 A/m, general public 21 A/m
- 10 MHz – 110 MHz:
 - Limb current (occupational 100 mA, general public 45 mA)

Reference levels (whole body, far field, occupational)



Basic restrictions for 5G frequencies (general public)

	Parameter	Averaging time	700 MHz	3.5 GHz	26 GHz
Long exposures (≥ 6 min)					
S_{ab} = absorbed power density					
Whole-body	SAR	30 min	0.08 W/kg	0.08 W/kg	0.08 W/kg
Local (Head & Torso)	SAR_{10g}	6 min	2 W/kg	2 W/kg	
Local (Limbs)	SAR_{10g}	6 min	4 W/kg	4 W/kg	
Local (all)	S_{ab}	6 min 4 cm ²			20 W/m ²

Reference levels for 5G frequencies (far field, general public)

	Parameter	Time	700 MHz	3.5 GHz	26 GHz
Long exposures (≥ 6 min)					
S_{inc} = incident power density (W/m^2)					
Whole-body	E field	Av. time 30 min	36.4 V/m	--	--
	S_{inc}	Av. time 30 min	--	10 W/m^2	10 W/m^2
Whole-body (spatial peak)	E field	Av. time 6 min	78.9 V/m	--	--
Local (4 cm^2)	S_{inc}	Av. time 6 min	--	40 W/m^2	30.9 W/m^2

Basic restrictions for 5G frequencies (general public)

	Parameter	Averaging time	700 MHz	3.5 GHz	26 GHz
Short exposures (< 6 min) (examples for 1 and 300 s exposures)					
SA = specific absorption					
U_{ab} = absorbed plane wave energy density (kJ/m²)					
Local (Head & Torso)	SA	Exposure 1 s	0.07 kJ/kg	0.07 kJ/kg	
		Exposure 300 s	0.66 kJ/kg	0.66 kJ/kg	
Local (Limbs)	SA	Exposure 1 s	0.11 kJ/kg	0.11 kJ/kg	
		Exposure 300 s	1.32 kJ/kg	1.32 kJ/kg	
Local (all)	U_{ab}	Exposure 1 s			0.72 kJ/m ²
		Exposure 300 s			6.60 kJ/m ²

Reference levels for 5G frequencies (far field, general public)

	Parameter	Time	700 MHz	3.5 GHz	26 GHz
Short exposures (< 6 min) (examples for 1 and 300 s exposures)					
U_{inc} = incident plane wave energy density (kJ/m²)					
Whole-body	U_{inc}	Exposure 1 s	0.6 kJ/m ²	1,4 kJ/m ²	--
Local (4 cm ²)	U_{inc}	Exposure 1 s	--	--	1.1 kJ/m ²
Whole-body	U_{inc}	Exposure 300 s	5.4 kJ/m ²	13.2 kJ/m ²	--
Local (4 cm ²)	U_{inc}	Exposure 300 s	--	--	10.2 kJ/m ²

Thanks for your attention