ICNIRP Radiofrequency Guidelines
Public Consultation version

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Please Note

The following slides and narrative should be taken as an attempt to communicate the most salient features of the Public Consultation version of the updated ICNIRP RF Guidelines. Precision is sometimes omitted in order to aid in the understanding of more-general features of the guidelines.

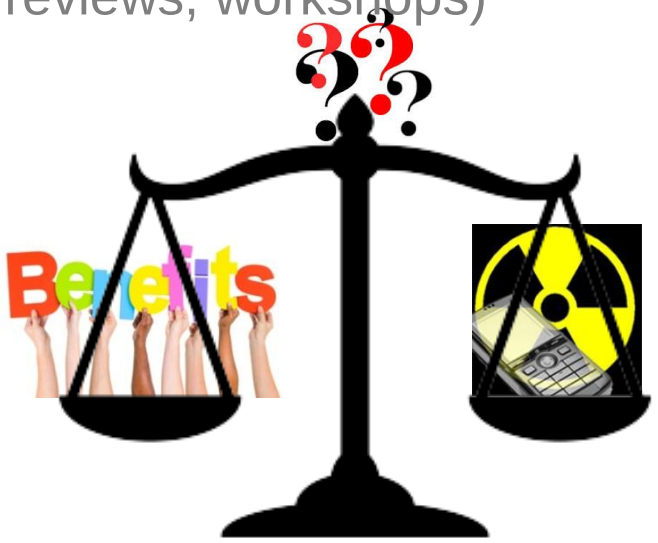
For the detail required to critique the proposed guidelines, it will be necessary to consider the public consultation document itself.

Competing perspectives on RF technology

The Independent, UK:
Mobile phones "more dangerous than smoking"

ICNIRP's role in the discussion

- International Radiation Protection Association (IRPA; founded 1966)
  - Represents national radiation protection societies
- IRPA founded ICNIRP in 1992
  - Parallel to International Commission on Radiological Protection (ICRP)
  - NFP NGO in official relations with World Health Organisation
  - To develop and disseminate science-based advice on limiting exposure to NIR (Guidelines, statements, reviews, workshops)
- ICNIRP
  - Independent organisation
  - Similar CoI policies to WHO
  - Guidelines are main activity



State of play

- ICNIRP 1998 (< 300 GHz)

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

ICNIRP GUIDELINES
FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC AND MAGNETIC FIELDS (1 Hz – 100 kHz)

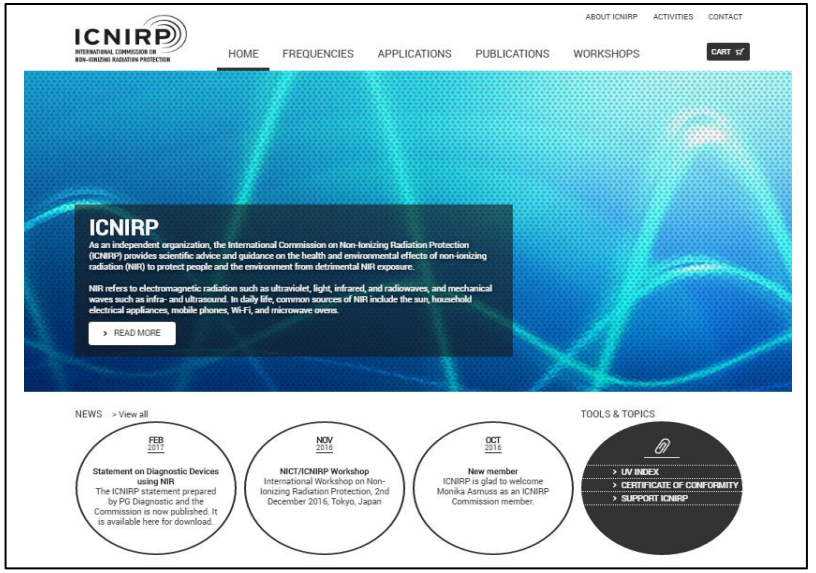
  - ICNIRP 2010 (< 10 MHz)

  - ICNIRP RF Public Consultation Document (100 kHz – 300 GHz)

ICNIRP
INTERNATIONAL COMMISSION ON
NON-IONIZING RADIATION PROTECTION

State of play

- ICNIRP RF Public Consultation Document (PCD)
  - Protection scheme, methods and limits; same as in the PCD
  - Slides available following presentation
  - Minor work remaining on formatting text etc
  - PCD available for comment from www.icnirp.org on July 10th, 2018



Key principle - *transparency*

- Make the derivation of limits as clear as possible
  - Easier to identify missing data
  - Easier to identify logical flaws
  - Easier to obtain useful feedback from scientific community
  - Easier to see what research is needed to improve guidelines in the future

Scope

- To limit exposure to radiofrequency EMFs (100 kHz – 300 GHz)
- To provide protection against adverse health effects to humans under realistic exposure conditions

- <u>Not included</u>
  - exposure for medical purposes (patients, carers and comforters)
  - compliance issues (e.g. measurement protocols)
  - electromagnetic compatibility

Main tools for protection

a) RF EMF Limits (basic restrictions & reference levels)
   - To be compliant with guidelines, these must be met

b) Guidance
   - New category
   - Where limits are not appropriate
   - Relevant detail to enable responsible EMF health & safety person to manage occupational exposure

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’

General Public versus Occupational Exposure

- In occupational exposure environments, can select suitable workers and provide training to mitigate risk
  - How to reduce exposure
  - What signs of potential RF effects to look for
  - What to do if such signs are detected
  - Capacity to detect and respond to such signs

- Not the case for the general public
  - So need larger reduction factors to ensure that knowledge of the exposure situation is not needed to provide safety
  - The fetus is treated as a member of the general public

Identification of health effect thresholds

a) Identify scientific literature regarding effects of exposure on biological systems (regardless of mechanism)
   - WHO Environmental Health Criterion, EHC (PCD; 2014)
   - SCENHIR (2015)
   - Subsequent research (informal evaluation process)

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)

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

Derivation of Basic Restrictions (BR)

a) Apply reduction factors to health effect thresholds
   - account for scientific uncertainty, relative importance of the health effect, variation across baseline conditions and the population
   - reduction factors may differ based on these parameters
   - consistency across limit types is sought unless there is a *substantive* reason for variation

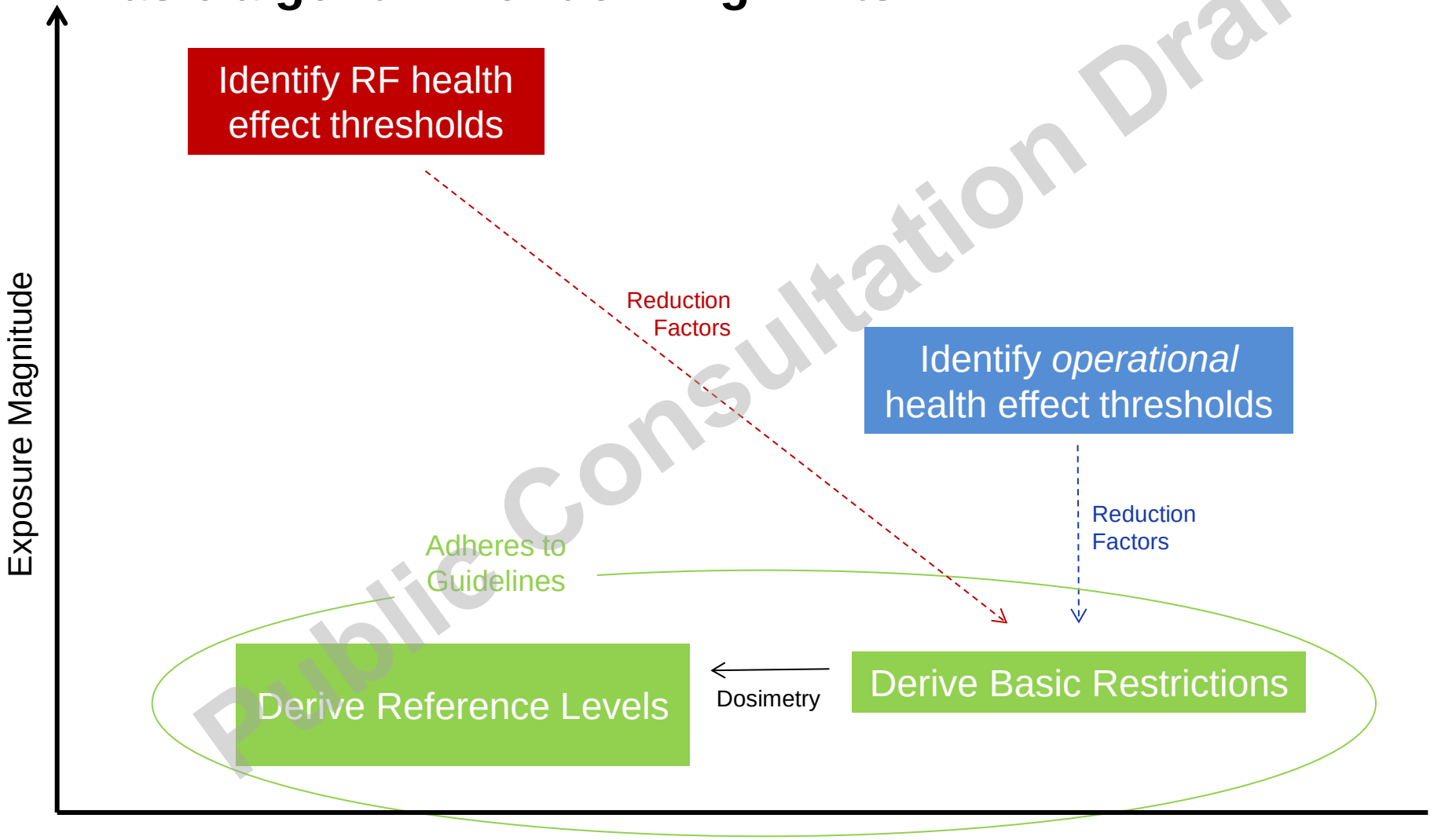
b) General Public reduction factors are higher than for Occupational
   - due to the assumption that the general public may not be aware of exposure and will not have any RF training to mitigate harm
   - accounts for potentially poorer health in general public than workers

Derivation of Reference Levels (RL)

a) Derive field strength values from BRs, to provide a more-practical method for ensuring safety

- RLs are derived so as to be conservative for realistic exposure conditions, but not all ***possible*** exposure conditions
- RLs may result in exposures that exceed basic restrictions, providing that
  - The violation is small (relative to the dosimetry uncertainty)
  - The violation does not impact on health

Basic algorithm for deriving limits

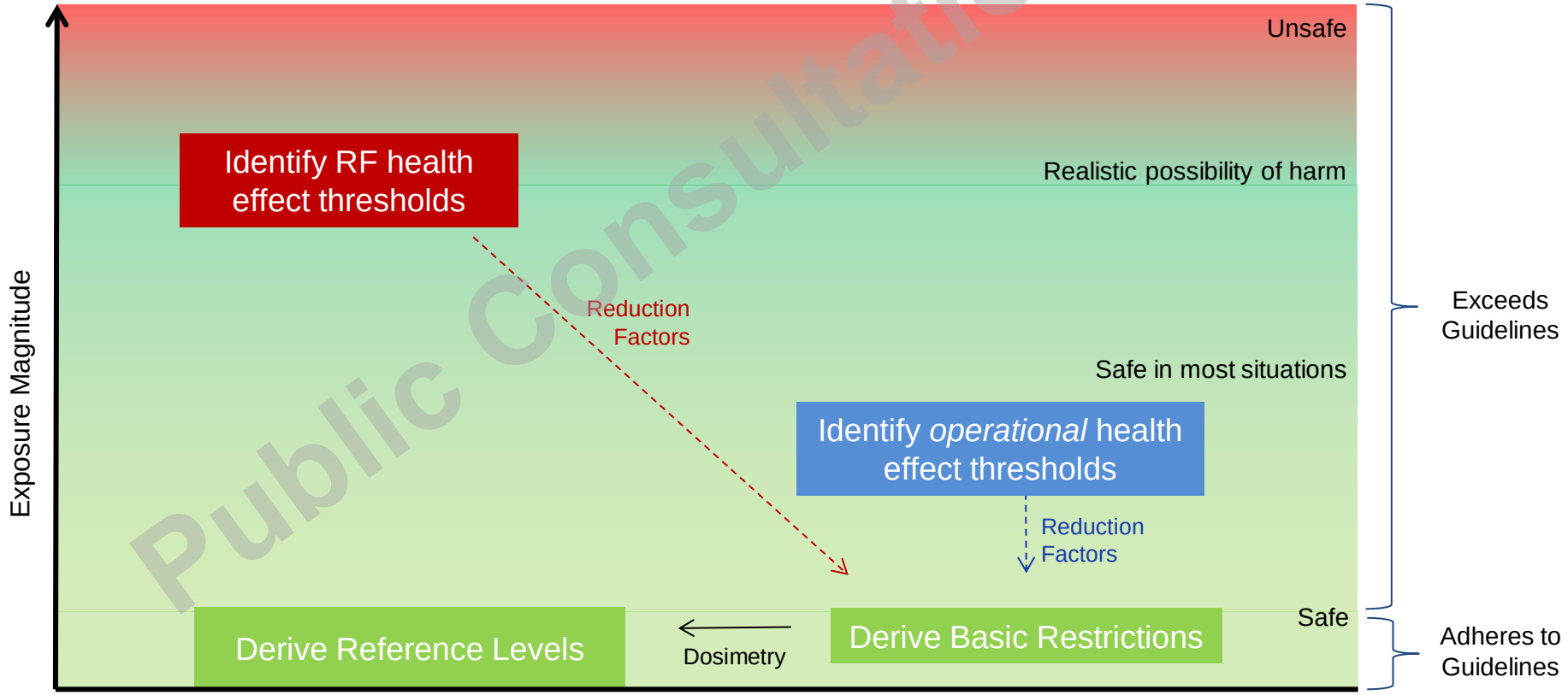


Conservative nature of guidelines

- Many conservative steps added to guideline setting process
  - Incorporating predictions of ***potential*** harm based on mechanisms, even where radiofrequency EMF has not been shown to cause harm
  - Basing limits on ***potential*** health effects, which do not normally cause harm (e.g. small temperature elevations can be uneventful or even beneficial)
  - Where only limited research is available, ***reducing the degree of certainty required*** to demonstrate radiofrequency-induced harm (i.e. accept best estimate)
  - The application of ***reduction factors*** to provide a buffer to harm
  - Applying reduction factors ***consistently***, even where, individually, less stringent reduction factors may appear justified
  - The ***conservative derivation*** of Reference Levels for most cases (e.g. plane wave exposure)

Conservative nature of guidelines

- Indeed, limits have been derived such that…
  - *All restrictions are considered highly conservative estimates that will remain protective unless they are **exceeded by a substantial margin***



Scientific basis - Health

- Draft WHO RF EHC (2014), SCENHIR (2015), & original papers not included
  - there is an extensive body of relevant literature, ranging from cellular research to cancer epidemiology

Scientific basis - Health

- No evidence that RF-EMF causes such diseases as cancer
  - available results of NTP study do not change this view
- No evidence that RF-EMF impairs health beyond effects that are due to established mechanisms of interaction
  - If other reported effects were substantiated, they would be included, regardless of mechanism

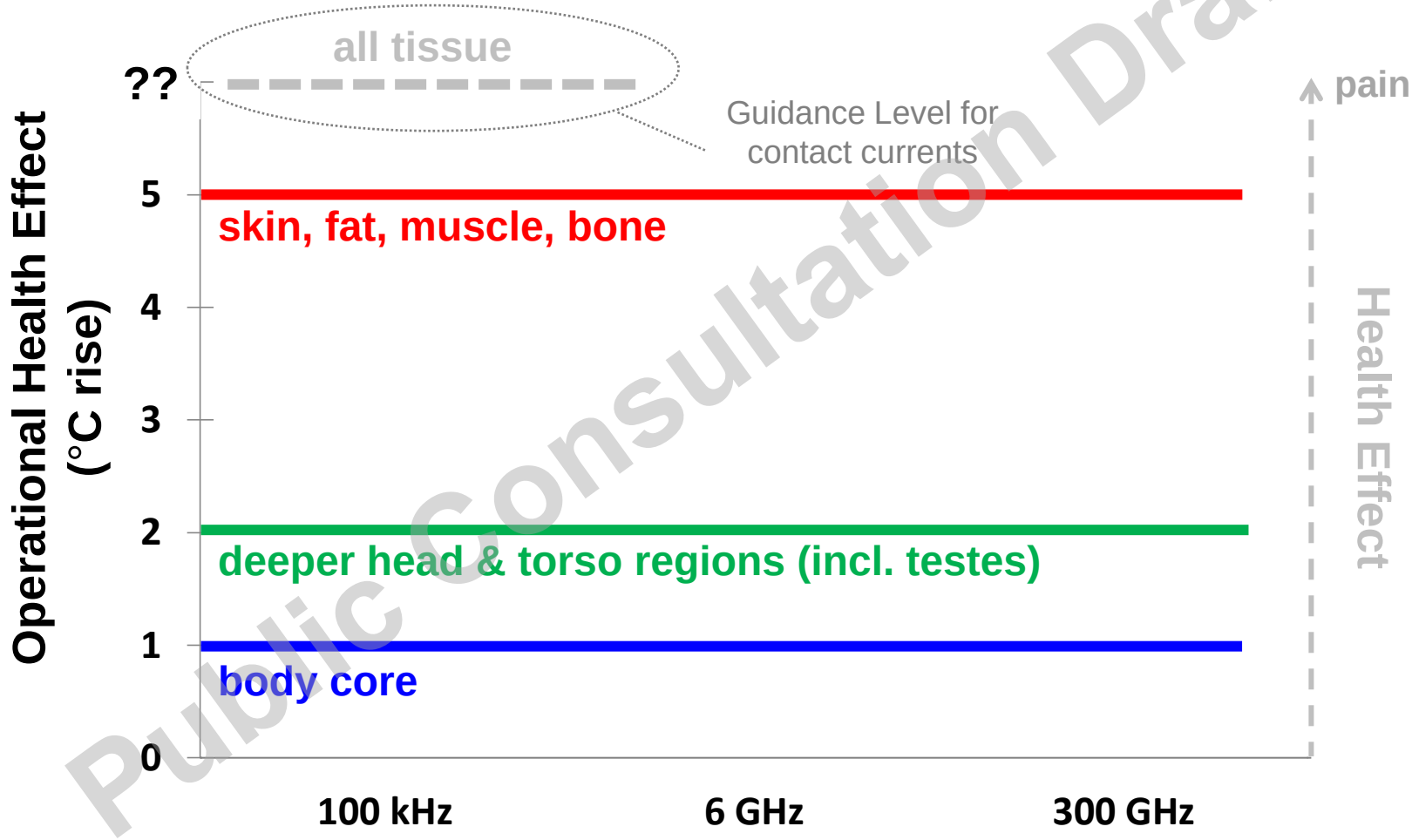
Primary effects of RF on the body

- Nerve stimulation
  - effects described in ICNIRP LF Guidelines (2010); not considered here
- (Electro)poration
  - reversible or permanent dielectric breakdown of cell membranes due to
    - intense electric field pulses of short duration (RF component of LF pulse)
    - 18 GHz CW
  - no limits formulated
    - no evidence that they relate to health in realistic exposure scenarios
    - LF guidelines account for pulses
    - traditional thermal effects have lower thresholds than CW-poration effects

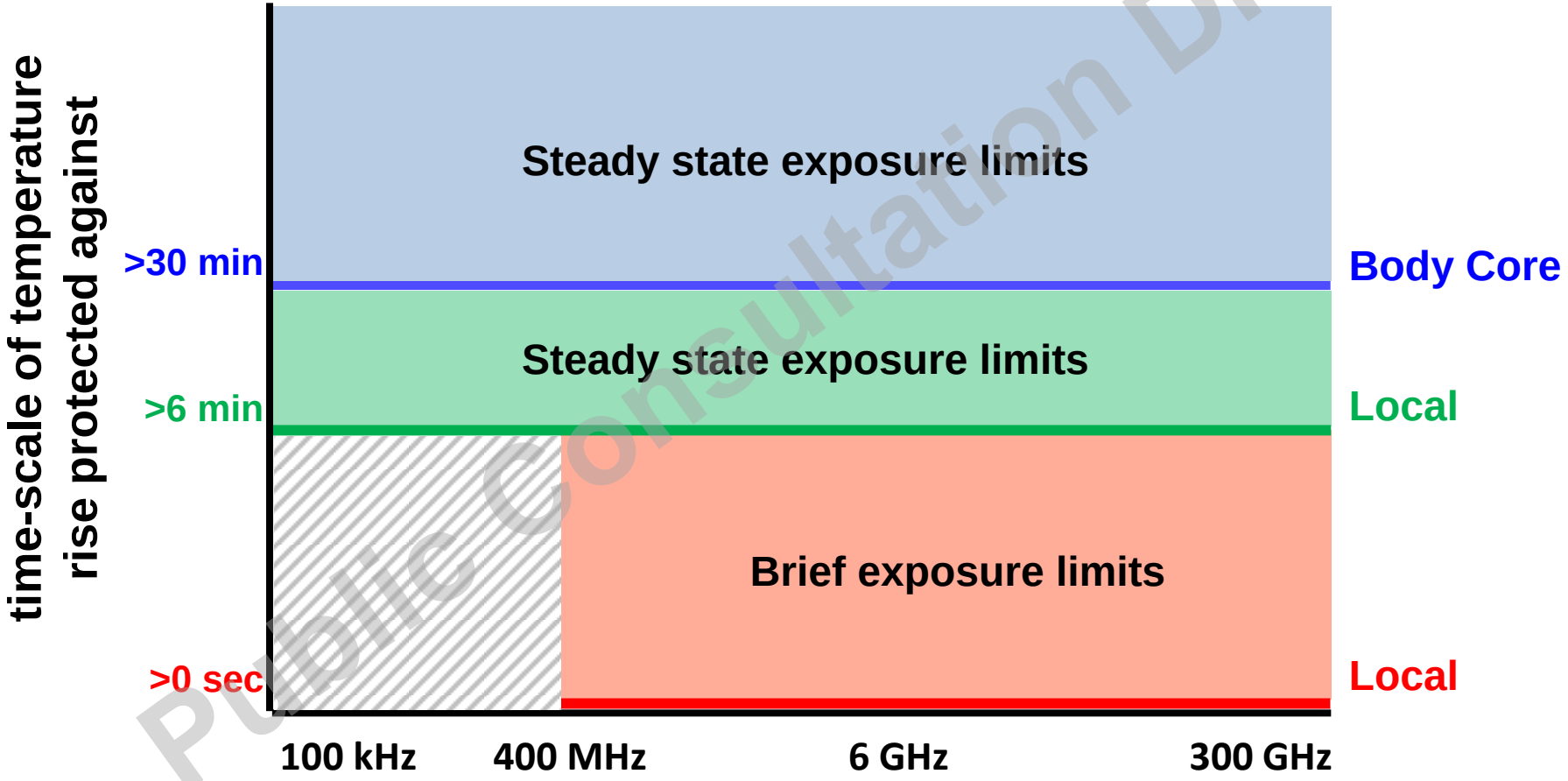
Primary effects of RF on the body

- Thermal (microwave hearing effect)
  - can occur from brief RF pulses (300 MHz-10 GHz); not considered harmful
  - no limits formulated
- Thermal (local and core temperature)
  - health effects primarily related to absolute body core or local temperature
  - body core and local temperature are dependent on many factors that are independent of RF (e.g. environmental temperature, work rate)
  - so, temperature 'increase' taken to represent health effects
  - restrictions set to avoid these

Operational Health Effect Thresholds v's Frequency

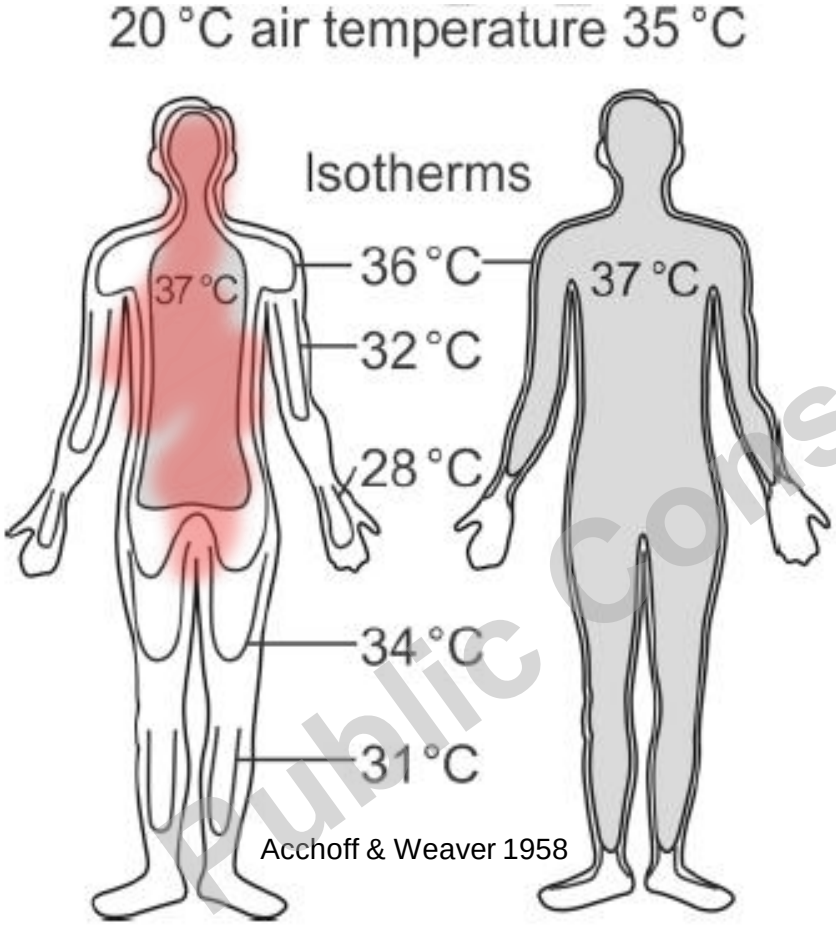


Basic Restriction averaging time v's Frequency



Basic Restrictions: 30-minute average

Protection against WB exposure (100 kHz - 300 GHz)



Threshold: Body core temperature rise 1°C

Operational v's Health Effect

Exposure: 4-6 W kg^{-1}

SAR_{WBA}; *30-minute*

	Occup.	*Gen. Pub.*	
Reduction Factors	10	50	*Variation: biology, baseline & environment; Uncertainty: science*
Basic Restrictions	0.4	0.08	*Total heat load; signs of heat stress*

Basic Restrictions: 6-minute average

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

Type 1 tissue
- all tissues in the upper arm, forearm, hand, thigh, leg, foot and auricle, and epidermal, dermal, fat, muscle and bone tissue
- lower baseline temperature (+5 °C to get to 41 °C)

Type 2 tissue
- all tissues in the head, eye, abdomen, back thorax and pelvis (excluding those defined as type 1 tissue)
- higher baseline temperature (+2 °C to get to 41 °C)

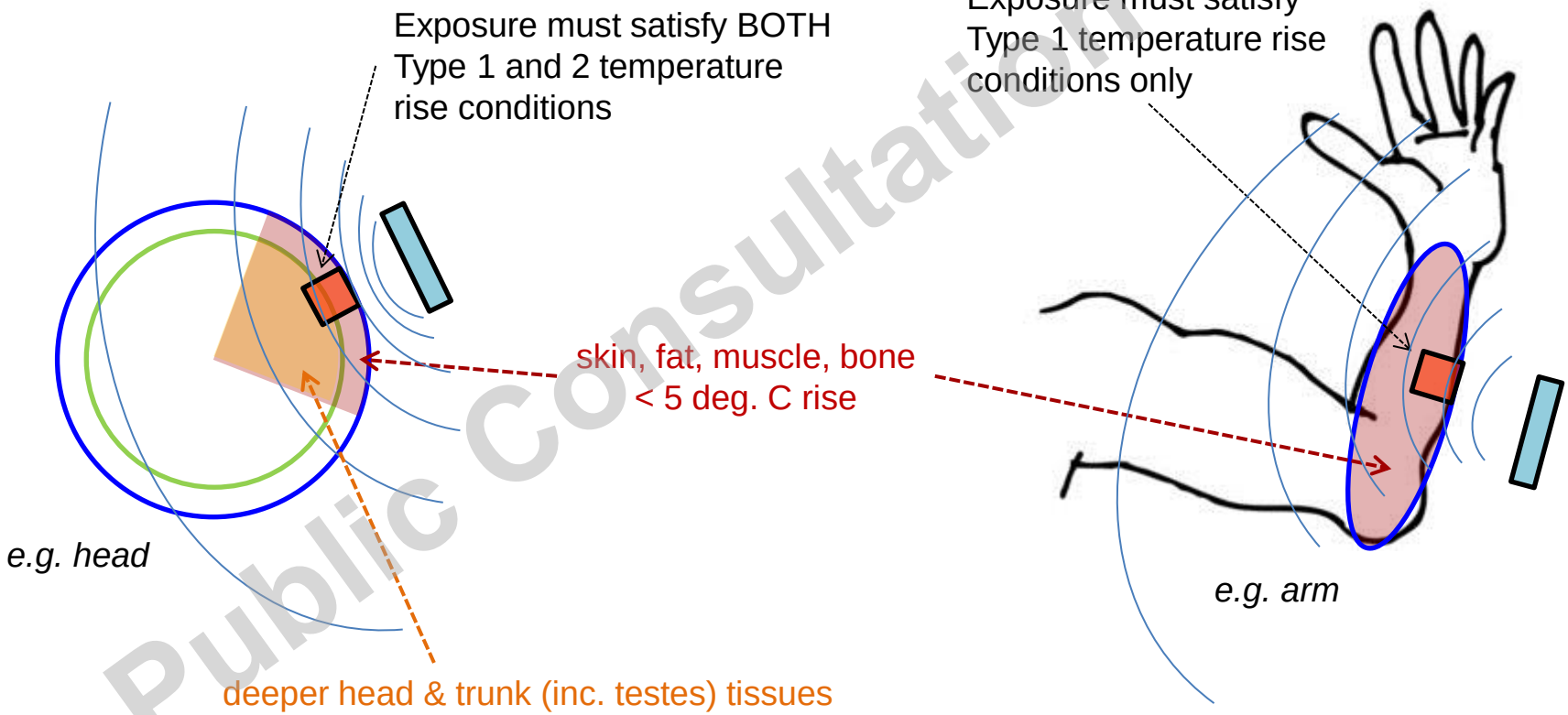
How we conceptualise 'Head & Torso' versus 'Limbs' exposure

'Head & Torso'
(head/neck/torso/testes)

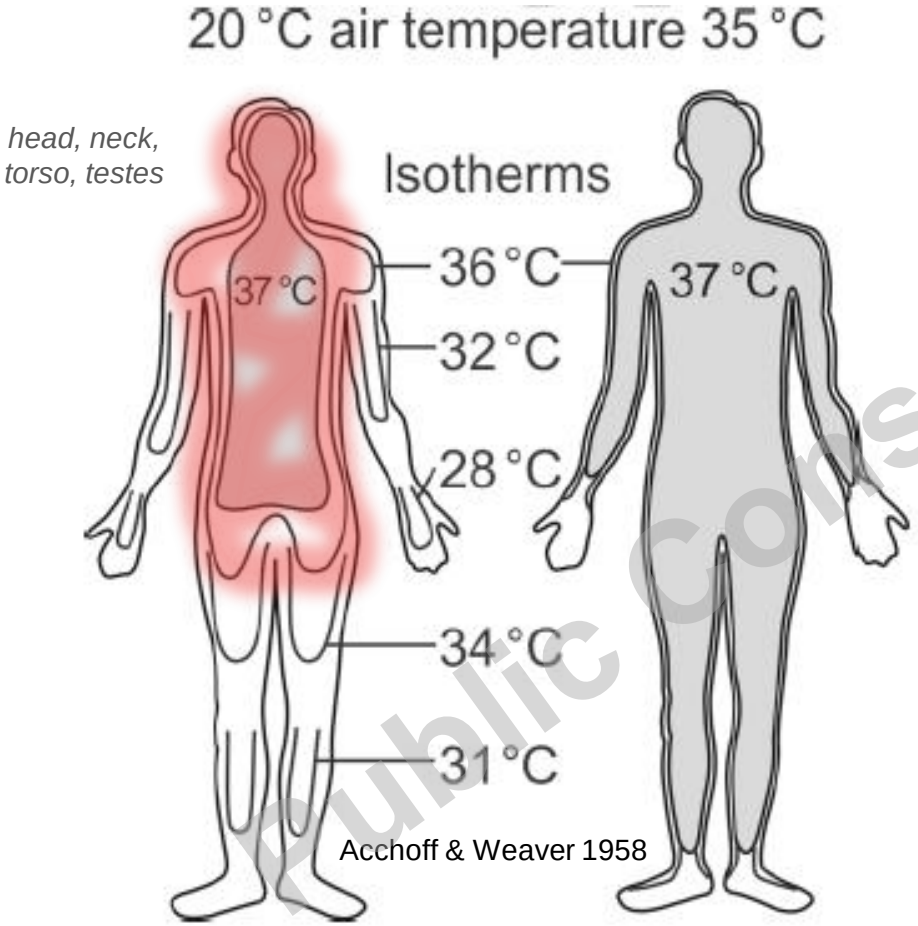
Exposure must satisfy BOTH Type 1 and 2 temperature rise conditions

'Limbs'

Exposure must satisfy Type 1 temperature rise conditions only



Protection against local exposure (6-min) ≤ 6 GHz: 'Head & Torso'

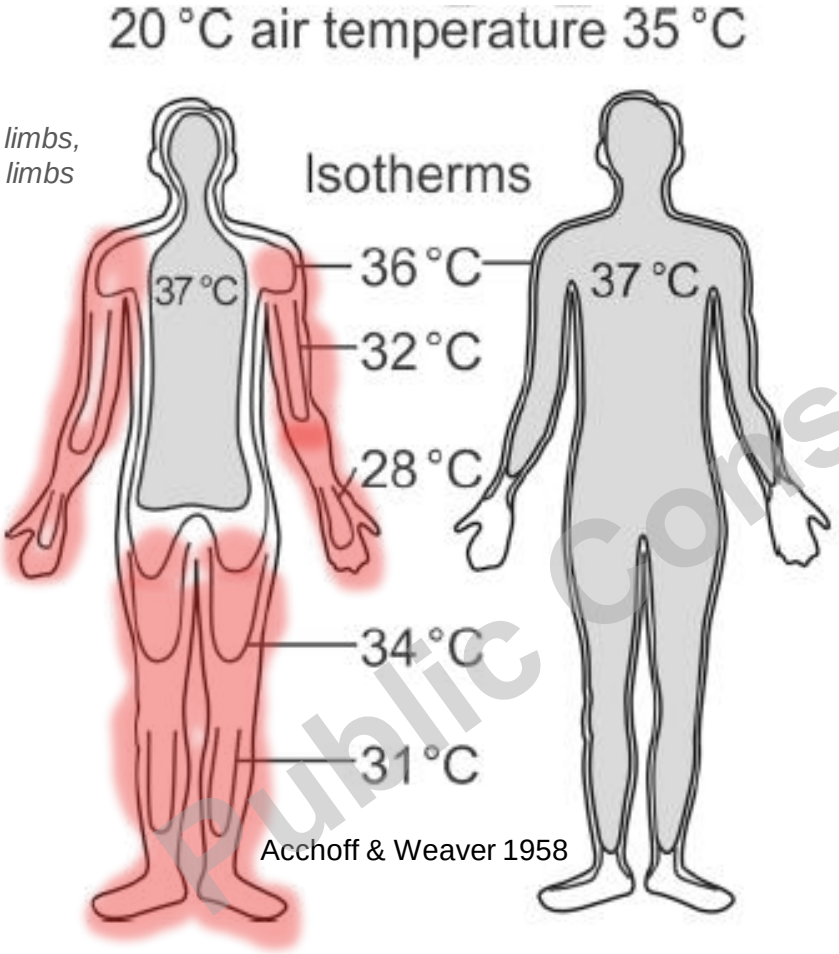


Threshold: Local temp. rise: 2°C deep head, trunk, testes; 5°C remaining tissue — *Operational v's Health Effect*

Exposure: 20 W kg^{-1} — SAR_{10g} (all tissues, cube); 6-minute;

	Occup.	*Gen. Pub.*	
Reduction Factors	2	10	*Variation: biology, baseline & environment; Uncertainty: science*
Basic Restrictions	10	2	*Signs of harm (e.g. pain)*

Protection against local exposure (6-min) ≤ 6 GHz: 'Limbs'



Threshold: Local temp. rise: 5°C (all limb tissue) — *Operational v's Health Effect*

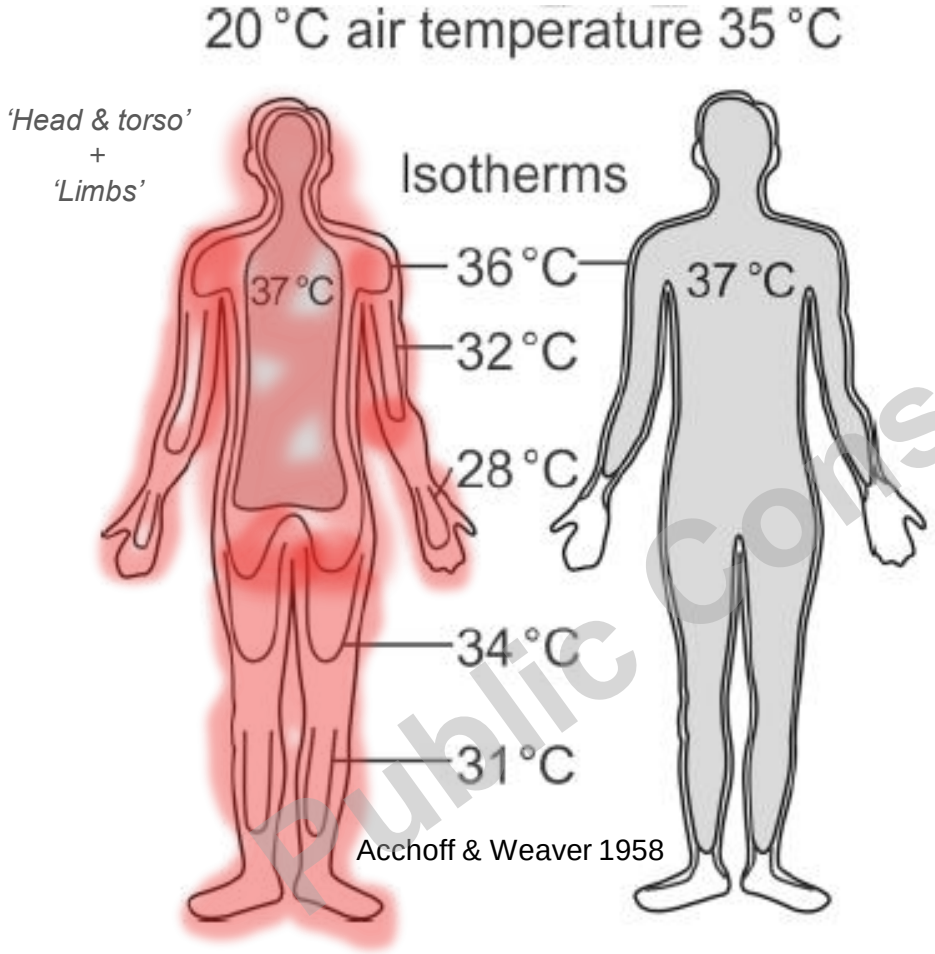
Exposure: 40 W kg^{-1} — SAR_{10g} (all tissues, cube); 6-minute

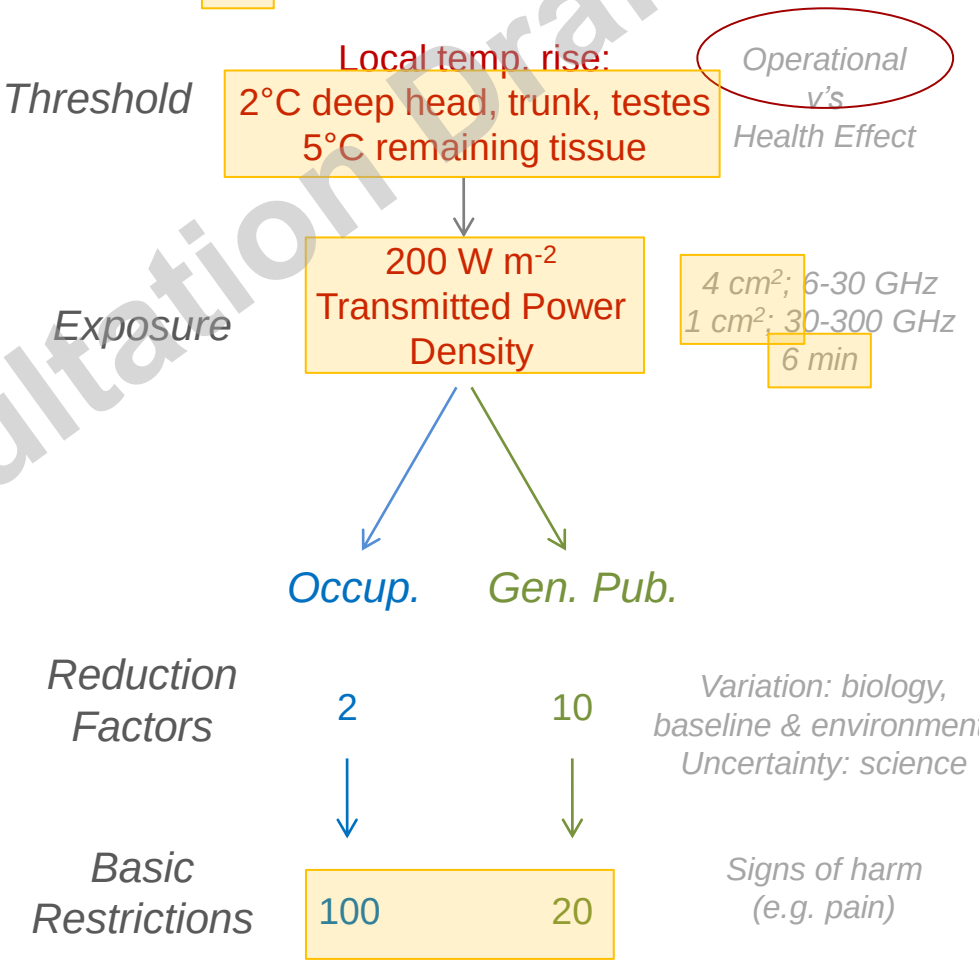
	Occup.	*Gen. Pub.*
Reduction Factors	2	10
Basic Restrictions	20	4

Variation: biology, baseline & environment; Uncertainty: science

Signs of harm (e.g. pain)

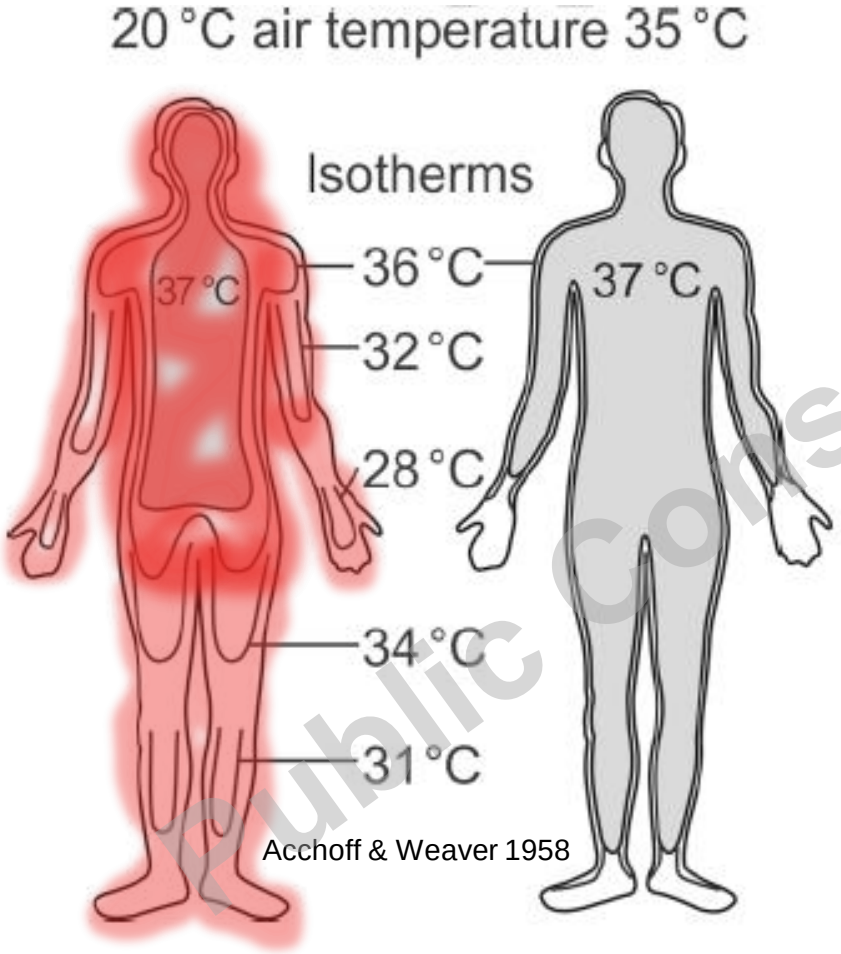
Protection against local exposure > 6 GHz





Basic Restrictions: <6-minute average

Protection against brief local exposure > 6 GHz: 'All Tissue'



Threshold: Local temp. rise: 2°C deep head, trunk, testes; 5°C remaining tissue — *Operational v's Health Effect*

Exposure: $5+3.54(t-1)^{0.5}$ kJ m^{-2} — H_{tr} (4-cm^2; < 30 GHz) (1-cm^2; ≥ 30 GHz)

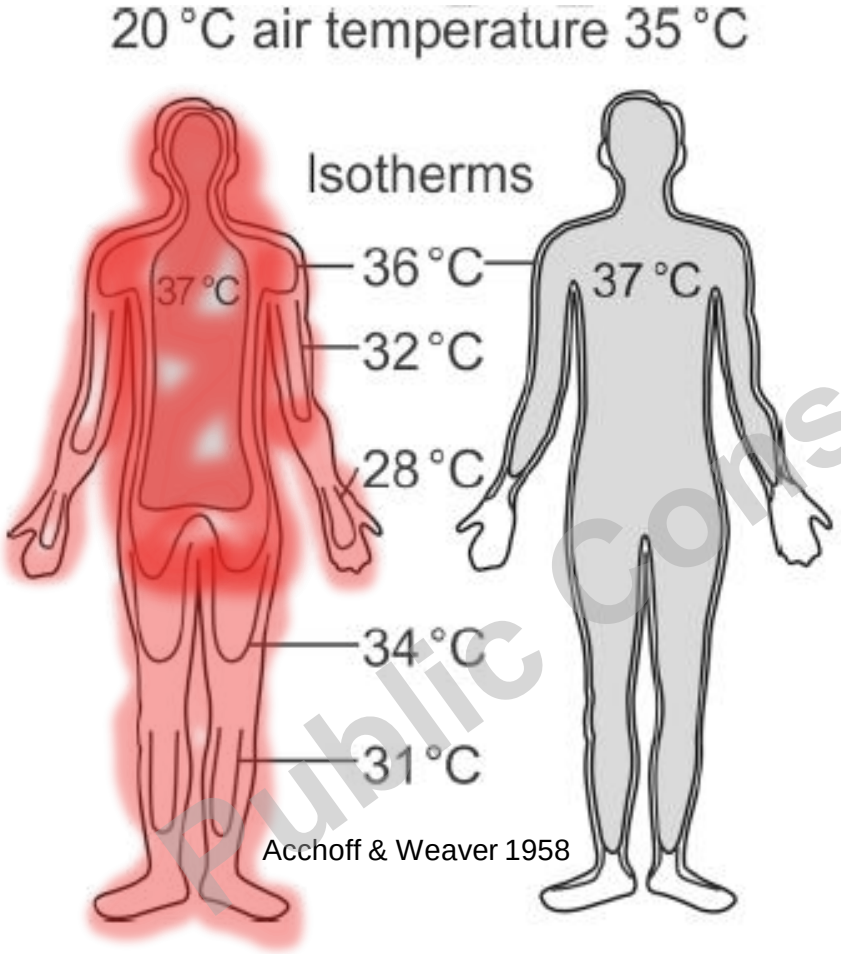
where 't' is time in sec; for t<1, t=1 is used

Occup. *Gen. Pub.*

Reduction Factors: 2 (Occup.), 10 (Gen. Pub.) — *Variation: biology, baseline & environment; Uncertainty: science*

Basic Restrictions: $2.5+1.77(t-1)^{0.5}$ (Occup.); $0.5+0.354(t-1)^{0.5}$ (Gen. Pub.) — *Signs of harm (e.g. pain)*

Protection against brief local exposure 0.4 - 6 GHz: 'All Tissue'



Threshold — Local temp. rise: 2°C deep head, trunk, testes; 5°C remaining tissue — *Operational v's Health Effect*

Exposure — $500+354(t-1)^{0.5}$ J kg^{-1} — SA_{10g} *(all tissues, cube)*

where 't' is time in sec; for t<1, t=1 is used

Occup. *Gen. Pub.*

Reduction Factors — 2 — 10 — *Variation: biology, baseline & environment; Uncertainty: science*

Basic Restrictions — $250+177(t-1)^{0.5}$ — $50+35.4(t-1)^{0.5}$ — *Signs of harm (e.g. pain)*

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 $\mathbf{S}_{tr}$ exposures are to be averaged over 6-minutes.
3. Local SAR is to be averaged over a 10-g cubic mass.
4. Local $\mathbf{S}_{tr}$ is to be averaged over 4 cm^2 (>6-30 GHz), or 1 cm^2 (>30 GHz).

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. $\mathbf{H}_{tr}$ 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)

Reference Levels

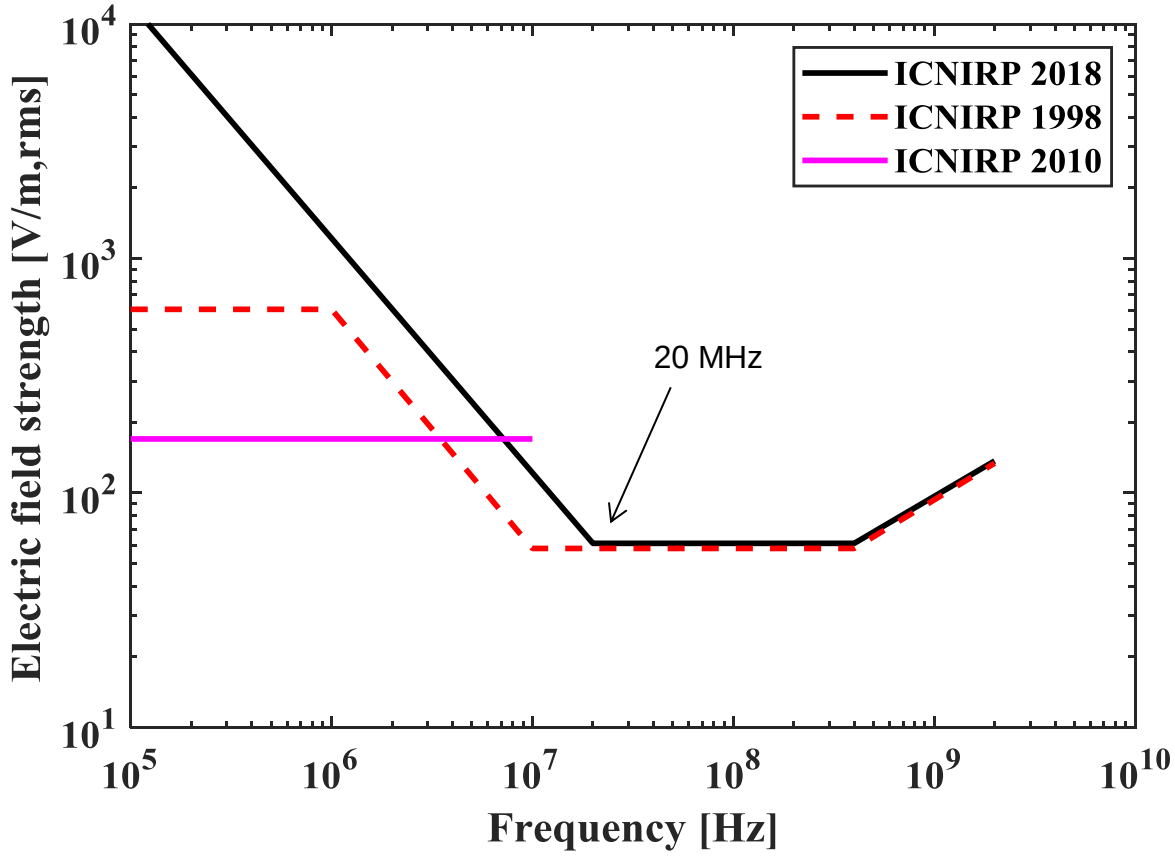
- Compliant with guidelines if either
  - Basic restrictions are met, or
  - Reference levels are met
- Separate Occupational and General Public RLs for
  - 30 minute average WBA (to match whole body average BRs)
  - 6-minute average, local (to match local steady-state BRs)
  - <6-minute, local (to match local brief BRs)
- IF RLs not met (or not available), BRs must be met

Table 4. Reference levels for whole body exposure to time-varying far-field electric, magnetic and electromagnetic fields, from 100 kHz to 300 GHz (unperturbed rms values).[a]

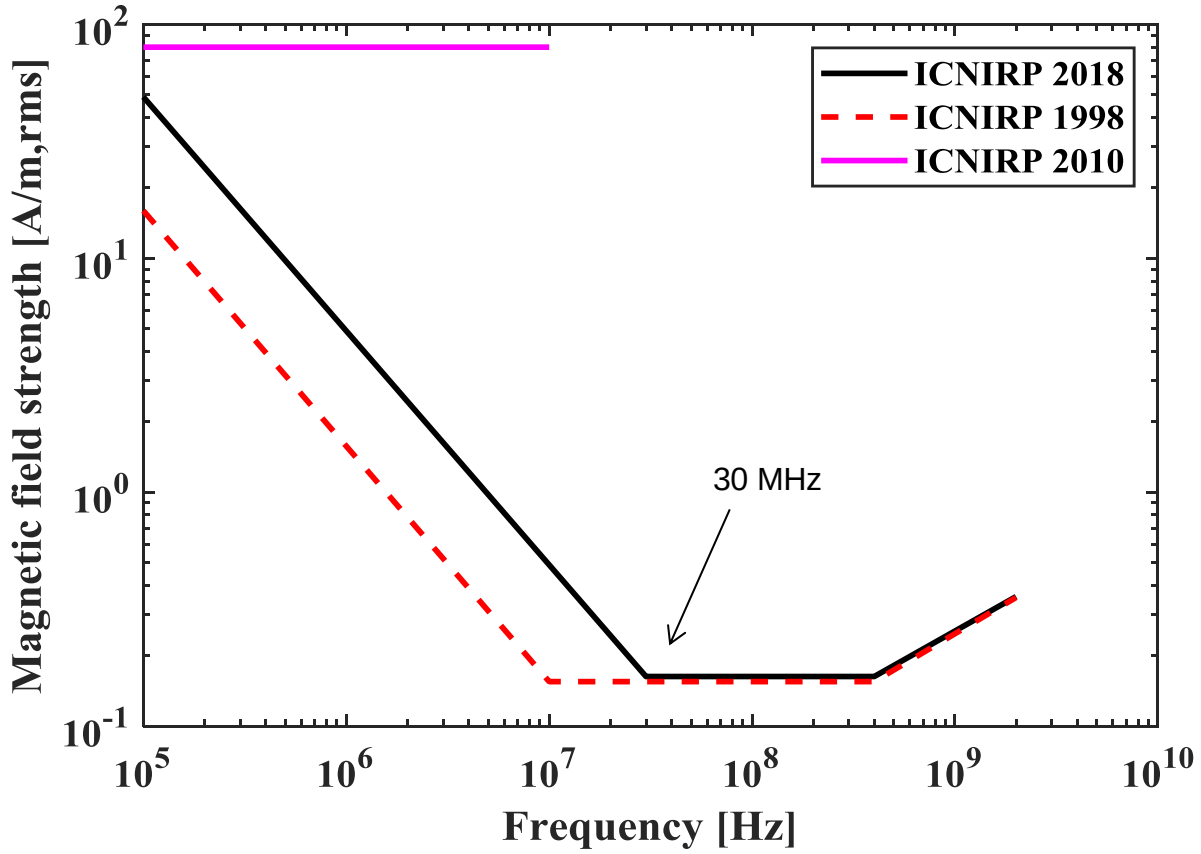
Exposure Scenario	Frequency Range	E-field strength ($V\ m^{-1}$)	H-field strength ($A\ m^{-1}$)	Incident plane wave power density (S_{inc}) ($W\ m^{-2}$)
Occupational	0.1-20 MHz#	1220/f	4.9/f	----
	>20-30 MHz#	61	4.9/f	----
	>30-400 MHz#	61	0.16	10
	>400-2,000 MHz*	$3f^{0.5}$	$0.008f^{0.5}$	f/40
	>2-300 GHz*	----	----	50
General Public	0.1-20 MHz#	560/f	2.2/f	----
	>20-30 MHz#	28	2.2/f	----
	>30-400 MHz#	28	0.073	2
	>400-2,000 MHz*	$1.375f^{0.5}$	$0.0037f^{0.5}$	f/200
	>2-300 GHz*	----	----	10

[a] Note:
1. *f* is frequency in MHz.
2. $\mathbf{S}_{inc}$, $\mathbf{E}^2$ and $\mathbf{H}^2$ are to be averaged over 30 minutes, over the whole body space. **E**- and **H**-field values are to be derived from these averaged values.
3. For frequencies up to 2 GHz, compliance for far-field exposure conditions is demonstrated if either the **E**-field, **H**-field of $\mathbf{S}_{inc}$ value is within the reference levels; only one is required.
#. For frequencies up to 400 MHz, for reactive and radiative near-field exposure conditions, exposure is compliant with the reference levels if 'both' **E**- and **H**-field levels are within the relevant far-field reference levels.
*. For frequencies above 400 MHz, far-field reference levels are also applicable to radiative near-field exposure conditions; no reference level is provided for reactive near-field exposure conditions within this frequency range.

WBA far-field E-field occupational reference levels - 30 mins (reduce by factor of √5 for General Public)



WBA far-field H-field occupational reference levels - 30 mins (reduce by factor of √5 for General Public)



WBA far-field S_{inc} occupational reference levels - 30 mins (reduce by a factor of 5 for General Public)

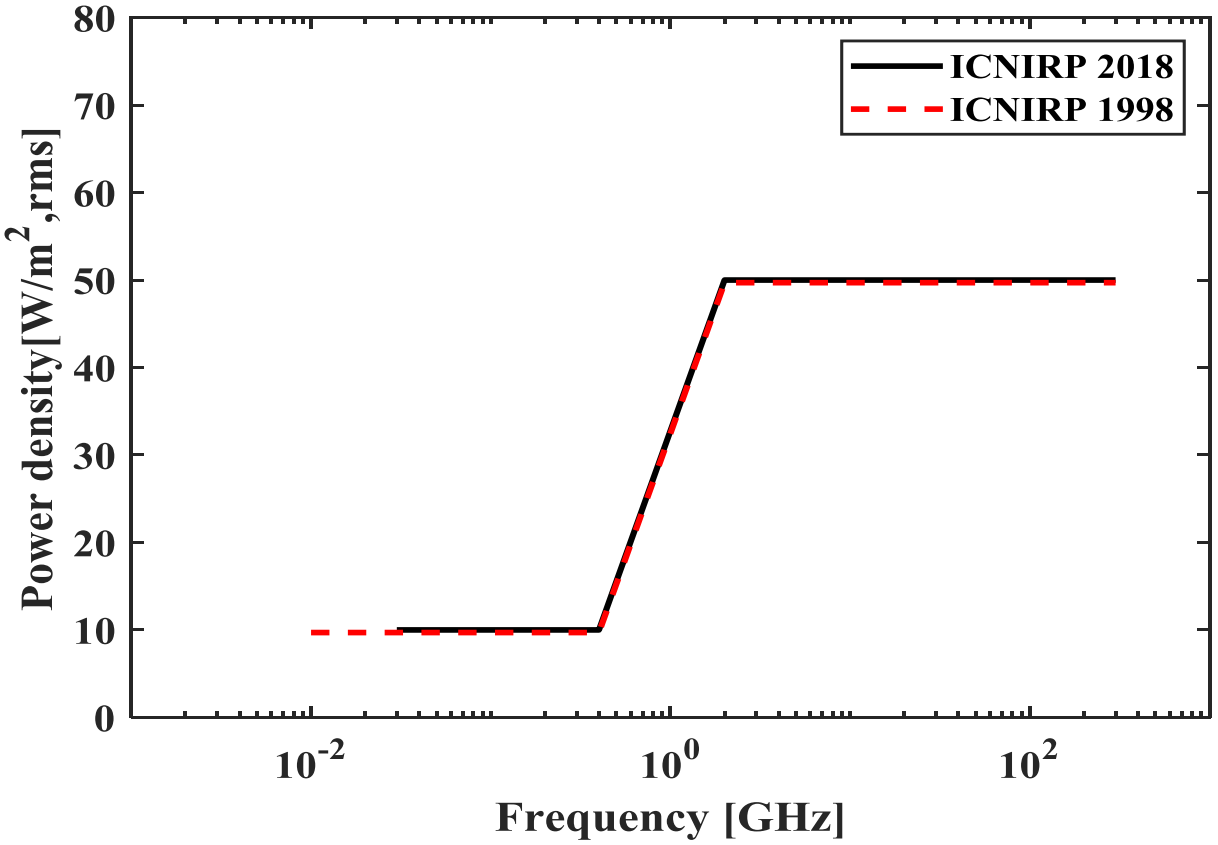


Table 5. Reference levels for local exposure to time varying far-field electric, magnetic and electromagnetic fields, from 100 kHz to 300 GHz, for time intervals of 6-minutes (unperturbed rms values).[a]

Exposure Scenario	Frequency Range	Incident plane wave power density (S_{inc}) ($W\ m^{-2}$)
Occupational	100 kHz – 6 GHz	See note 3
	>6-300 GHz#	$275f^{-0.177}$
	300 GHz#	100
General Public	100 kHz – 6 GHz	See note 3
	>6-300 GHz#	$55f^{-0.177}$
	300 GHz#	20

[a] Note:
1. *f* is frequency in GHz.
2. $\mathbf{S}_{inc}$ is to be averaged over 6-minutes, over a 4-cm^2 (6-30 GHz) or 1-cm^2 (>30-300 GHz) square region in space, representative of body surface area.
3. For far-field, radiative near-field and reactive near-field exposure conditions for frequencies up to 6 GHz, exposure is compliant if the spatial peak value, averaged over 6-minutes, is less than the whole body average far-field reference levels (from Table 4). Where relevant, equivalent plane wave power density can be used in place of incident plane wave power density (see Appendix A).
#. For frequencies above 6 GHz, far-field reference levels are also applicable to radiative near-field exposure conditions; no reference level is provided for reactive near-field exposure conditions within this frequency range.

Table 6. Reference levels for local exposure to time varying far-field electric, magnetic and electromagnetic fields, from 100 kHz to 300 GHz, for time intervals less than 6-minutes (unperturbed rms values).[a]

Exposure Scenario	Frequency Range	Incident plane wave energy density (H_{inc}) (kJ m^{-2})
Occupational	<400 MHz	See note 3
	400 MHz – 6 GHz#	$0.8f^{0.51}[2.5+1.77(t-1)^{0.5}]$
	> 6 – 300 GHz*	$2.75f^{-0.177}[2.5+1.77(t-1)^{0.5}]$
General Public	<400 MHz	See note 3
	400 MHz – 6 GHz#	$0.8f^{0.51}[0.5+0.354(t-1)^{0.5}]$
	> 6 – 300 GHz*	$2.75f^{-0.177}[0.5+0.354(t-1)^{0.5}]$

[a] Note:
1. *f* is frequency in GHz; *t* is time interval in seconds.
2. Peak $\mathbf{H}_{inc}$ is to be used for frequencies 400 MHz-6 GHz; $\mathbf{H}_{inc}$ is to be averaged over a 4-cm^2 (400 MHz-30 GHz) or 1-cm^2 (>30-300 GHz) square region in space, representative of body surface area.
3. For frequencies below 400 MHz, no additional constraint is imposed for brief intervals (the 6-minute average reference level described in Table 5 is to be used).
#. For reactive and radiative near-field exposure conditions for frequencies 400 MHz to 6 GHz, exposure is compliant with the reference levels if both the spatial peaks of the equivalent plane wave energy density, based on E- and H-field, is less than the corresponding $\mathbf{H}_{inc}$ reference level.
*. For frequencies above 6 GHz, far-field reference levels are also applicable to radiative near-field exposure conditions; no reference level is provided for reactive near-field exposure conditions within this frequency range.

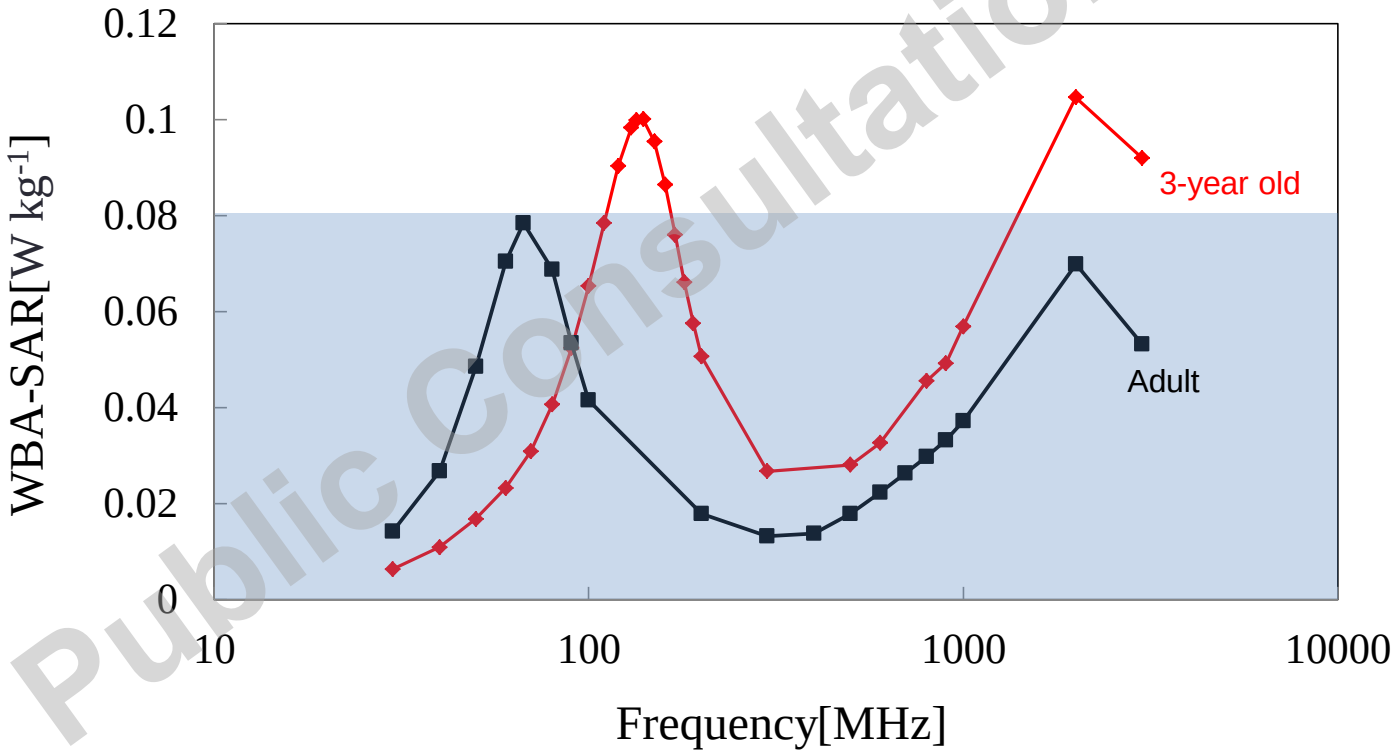
Table 7. Reference levels for current induced in any limb at frequencies between 100 kHz and 110 MHz.[a]

Exposure Scenario	Frequency Range	Current I_L (mA)
Occupational	100 kHz-110 MHz	100
General Public	100 kHz-110 MHz	45

[a] Note:
1. I_L^2 values are averaged over 6-minutes. Current values are to be derived from these averaged values.
2. Limb current reference levels are not provided for any other frequency range.

Reference Level issues (child)

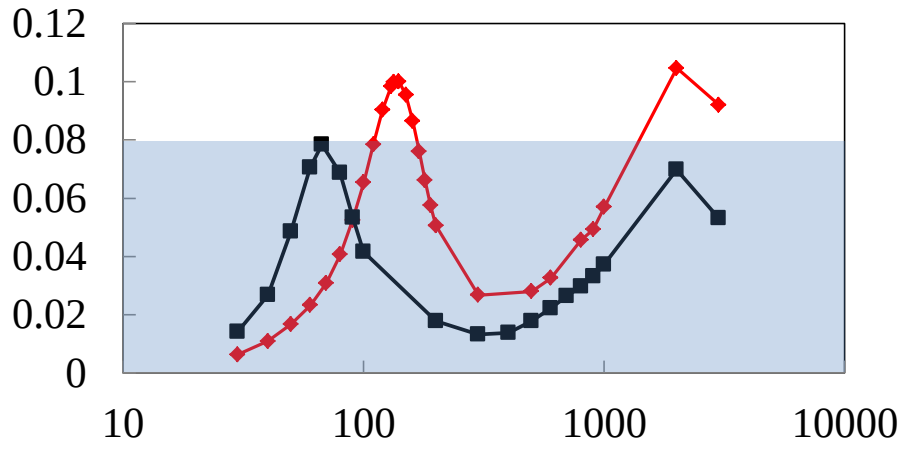
- RLs based on WBA SAR limits exceed BRs for small stature people



Hirata 2015 (Thermal damage workshop, Istanbul 2015)

Reference Level Issues (child)

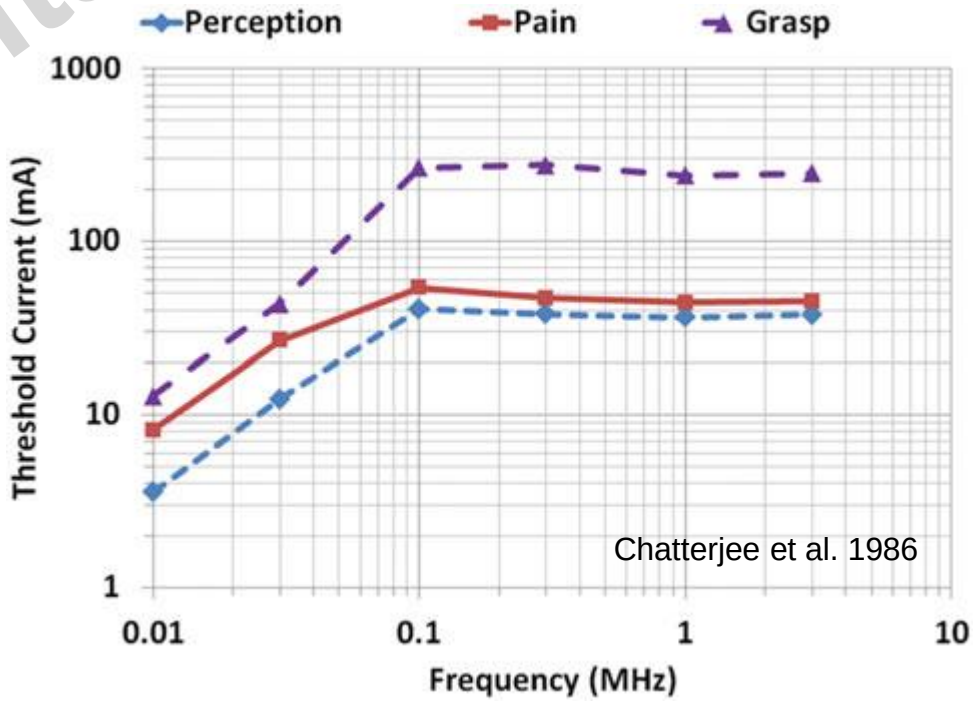
- Is this more than a theoretical issue?
  - Small violation only (within dosimetric uncertainty)
  - Does not affect the *health effect being protected against*
    - i.e. at reference level, body core temperature increase in small stature people will be less than for taller people (even though WBA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



Guidance (neither BRs or RLs)

Contact Currents (100 kHz – 110 MHz)

- When a person touches a charged conductive object, this can channel the power into a small region (where they touch the object)
- This can result in high current densities, pain and tissue damage



Contact Currents (100 kHz – 110 MHz)

- Dependent on many factors, for example
  - Dimensions of conducting object and person
  - Relative grounding
  - Heterogeneity of current density
    - Contact area
    - Tissue conductivity, density and heat capacity
    - Resistance between person and object
- Although Basic Restrictions will provide protection against this, the scenario is too complex for Reference Levels to account for

Contact Currents (100 kHz – 110 MHz)

- 'Guidance' is provided to assist those responsible for high power emitters to evaluate potential risks
- Guidance (what the available data suggest)
  - Thresholds for reversible pain are ~ 20 mA for adults, 10 mA for children
  - We don't know thresholds for tissue damage
  - We don't know upper frequency (likely 30-50 MHz)
  - Where exposure is required, risks can be minimised by
    - Connecting large metallic objects to ground
    - Training workers to make contact with RF insulating materials
    - Training workers to be aware of possible pain, burns and 'surprise'

Public Consultation Document (PCD)

- Available at www.icnirp.org on 10th July, 2018
  - Open for 3 months
  - ICNIRP will then work on addressing your comments
- Contributions from scientific community have already made a huge contribution to the development (including major reworking of logic)
- If you can find the time, *we would greatly appreciate your contributions to the guidelines*
- These can be either editorial or scientific

Public Consultation Document (PCD)

- For the science, these would ideally be
  - Brief clear statements
  - Brief justification for your statements (e.g. references)
  - Acknowledgement of competing views (to place your view into perspective)

www.icnirp.org

ICNIRP Radiofrequency Guidelines
Public Consultation version

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