

IEEE- Israel society of Electromagnetic Compatibility (EMC) Conference



Updated Human Exposure Standards IEEE 2019 and ICNIRP 2020, towards 5G applications

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Context: Mobile-cellular telephone subscriptions (billions) & Mobile-cellular telephone subscriptions per 100 inhabitants, 2005-2019

Mobile-cellular telephone subscriptions

Mobile-cellular telephone subscriptions per 100 inhabitants (right axis)

$$21.802x + 11.196 +^2 x 0.3741y = - \\ 0.9964 = ^2 R$$

billions

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

120

100

80

60

40

20

0

%

1. Presenting WHO, ICNIRP and IEEE
2. Compare/Contrast Tables and Figures of updated ICNIRP (2020) Guidelines and IEEE 95.1 (2019) standard in force for the IMT frequencies 450 MHz–71 GHz
3. Exposure from bases stations, cellular and handsets limits, applicable to 5G

Following ITU-R Final Acts of WRC-19, Footnotes identifying the band for IMT

Band	Footnotes identifying the band for IMT		
	Region 1	Region 2	Region 3
450-470 MHz		5.286AA	
470-698 MHz	-	5.295, 5.308A	5.296A
694/698-960 MHz	5.317A	5.317A	5.313A, 5.317A
1 427-1 518 MHz	5.341A, 5.346	5.341B	5.341C, 5.346A
1 710-2 025 MHz		5.384A, 5.388	
2 110-2 200 MHz		5.388	
2 300-2 400 MHz		5.384A	
2 500-2 690 MHz		5.384A	
3 300-3 400 MHz	5.429B	5.429D	5.429F
3 400-3 600 MHz	5.430A	5.431B	5.432A, 5.432B, 5.433A
3 600-3 700 MHz	-	5.434	-
4 800-4 990 MHz	5.441B	5.441A, 5.441B	5.441B
24.25-27.5 GHz *		5.532AB	
37-43.5 GHz*		5.550B	
45.5-47 GHz*	5.553A	5.553A	5.553A
47.2-48.2 GHz*	5.553B	5.553B	5.553B
66-71 GHz*		5.559AA	

* revised at WRC-19

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Global monitoring : levels are very low, relative to ICNIRP reference levels

- 1.Ofcom published on February 2020 the results of recent measurements of EMF emissions close to sixteen 5G-enabled mobile phone base stations showing EMF levels at a total of 22 5G sites in 10 UK cities:
- 2.In 10 cities across the UK; base stations support technologies in addition to 5G, including 2G, 3G and 4G:
 - 1) EMF emission levels from 5G-enabled base stations remain at small fractions of the reference levels for 1998 general public exposure in ICNIRP Guidelines (400–2,000 MHz) f (MHz)/200 (W/m²), & 2–300 GHz 10 (W/m²)
 - 2) the highest level recorded being approximately 1.5% of the **power-density** reference level
 - 3) In all locations, largest contribution to the measured levels comes from previous generations of mobile technology (2G, 3G, 4G);
 - 4) The highest level observed in the band used for 5G was just 0.039% of the reference level

French ANFR, RF-EMF 2018 annual survey of over 2,500 public exposure measurements See [ANFR Sept. 2018](#) abstract

Summarized results 2017: 90% of exposure levels measured in 2017 in rural areas are below 0.95 V/m.

* Values below the typical sensitivity threshold of the measuring devices, which equals 0.38 V/m

	Mesurements n°	50% (median values)	90 %	99 %	Max
Rural	425; 16 %	0,25* V/m	0,95 V/m	2,8 V/m	3,95 V/m
Urban	2166; 84 %	0,4 V/m	1,67 V/m	5,6 V/m	11,25 V/m
Indoor	1666; 64%	0,31* V/m	1,34 V/m	4,1 V/m	10,54 V/m
Outdoor	914: 36%	0,52 V/m	1,93 V/m	6,3 V/m	11,25 V/m
Total	2591	0,36* V/m	1,57 V/m	5,5 V/m	11,25 V/m

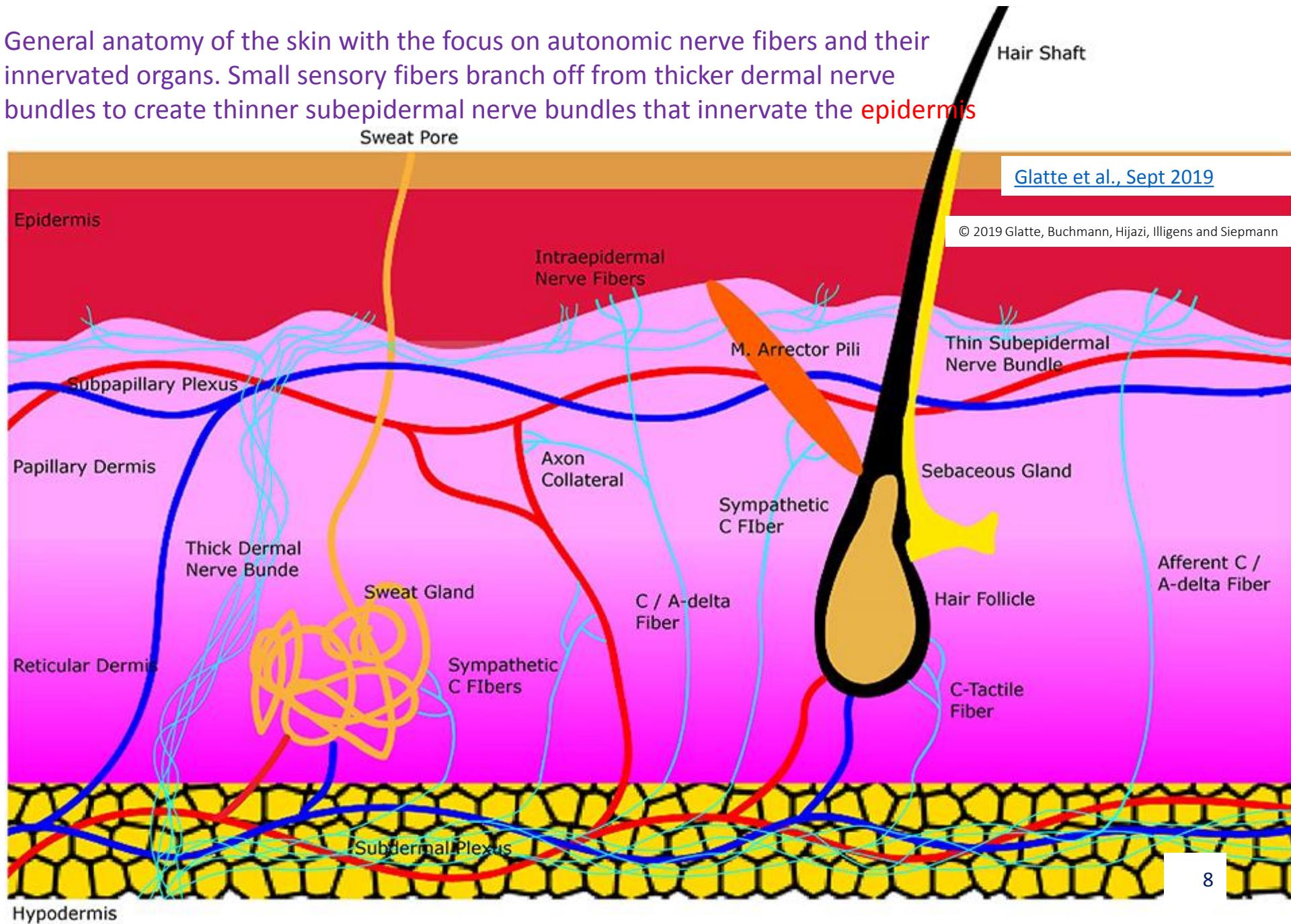
Questions to be raised

Compliance calculations and some periodic measurements are essential. However:

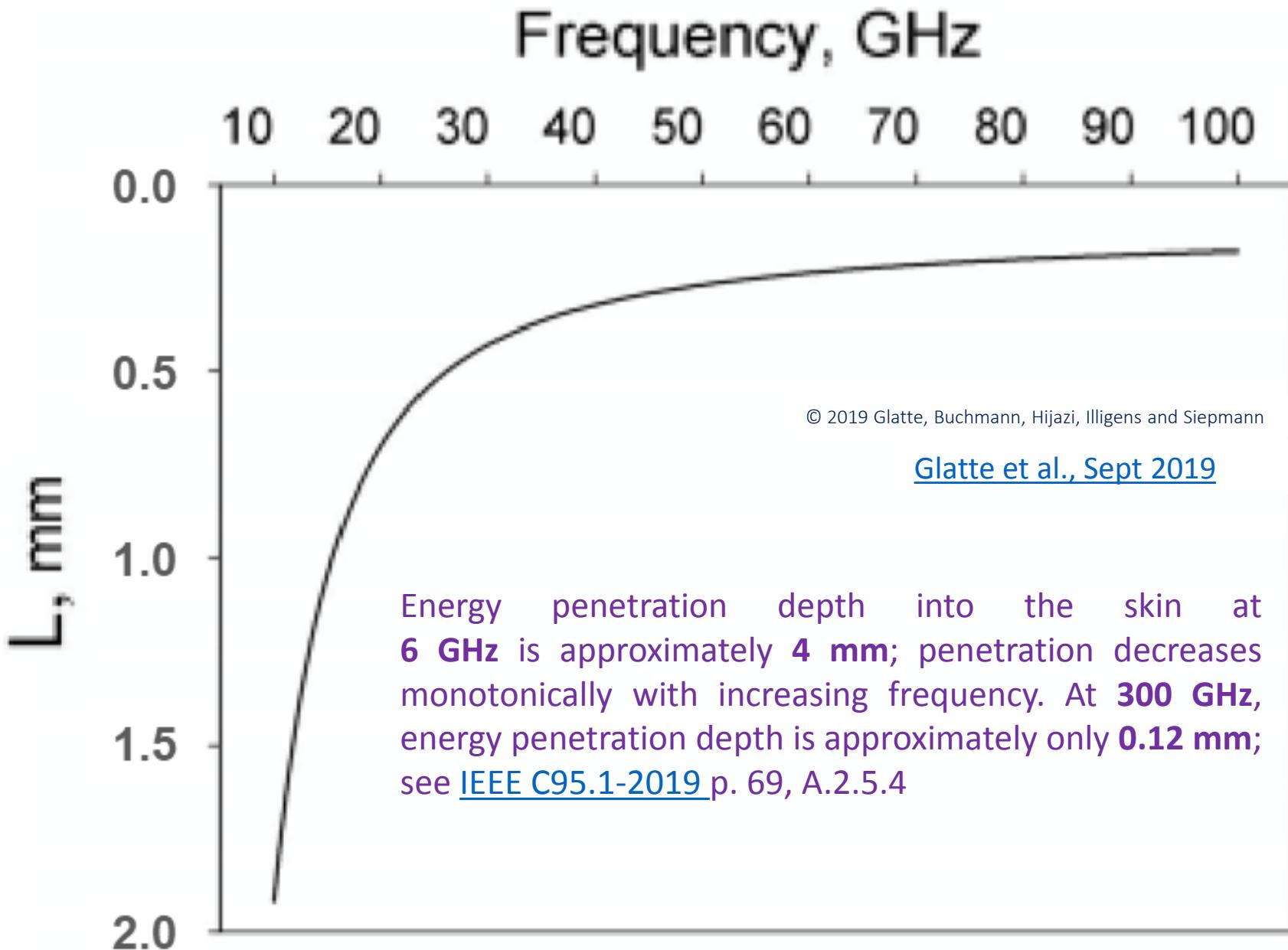
1. Do we need to make once a year measurements?
2. May be ICNIRP reference levels are too liberal?

Cross-section human skin

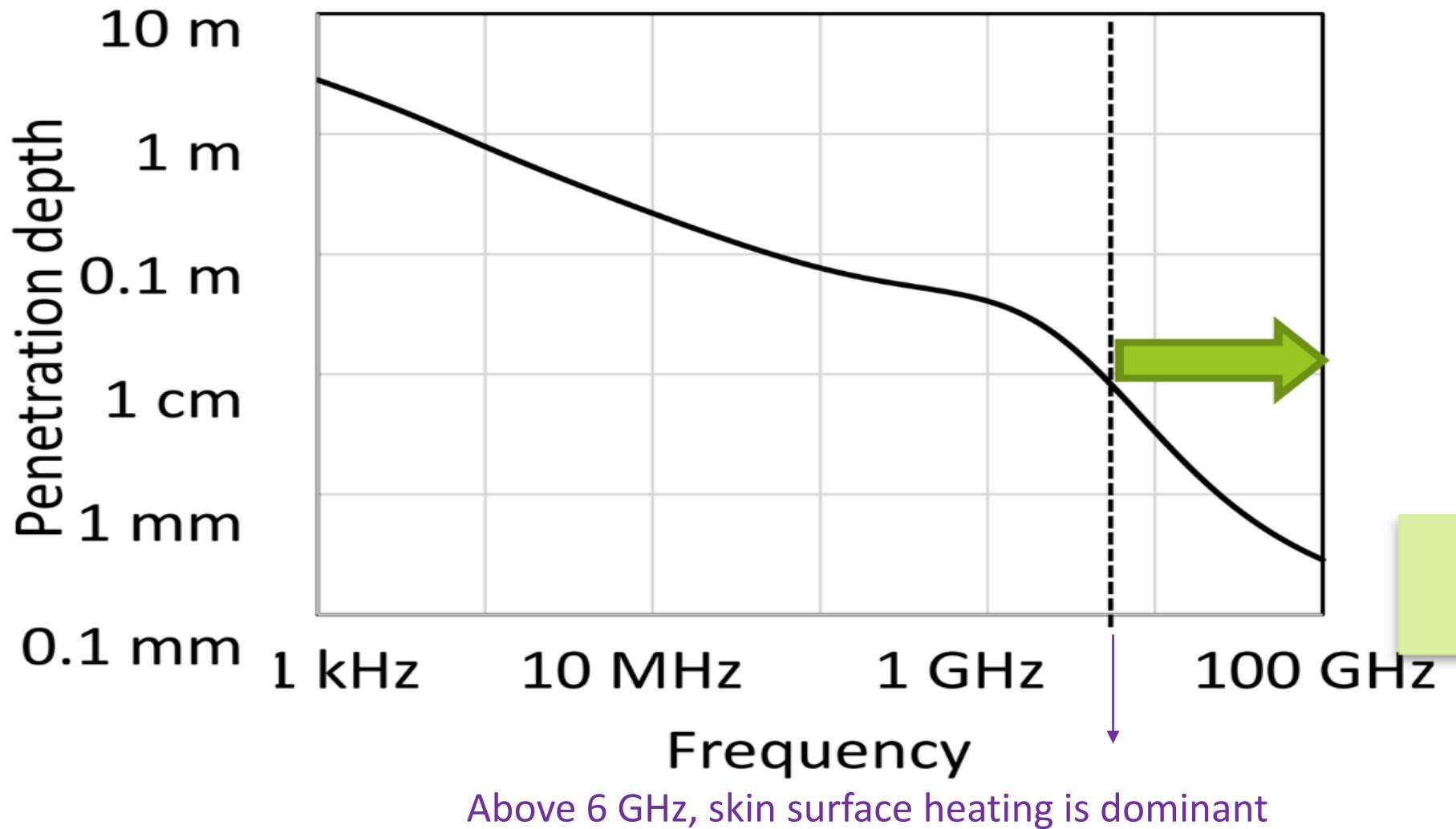
General anatomy of the skin with the focus on autonomic nerve fibers and their innervated organs. Small sensory fibers branch off from thicker dermal nerve bundles to create thinner subepidermal nerve bundles that innervate the **epidermis**



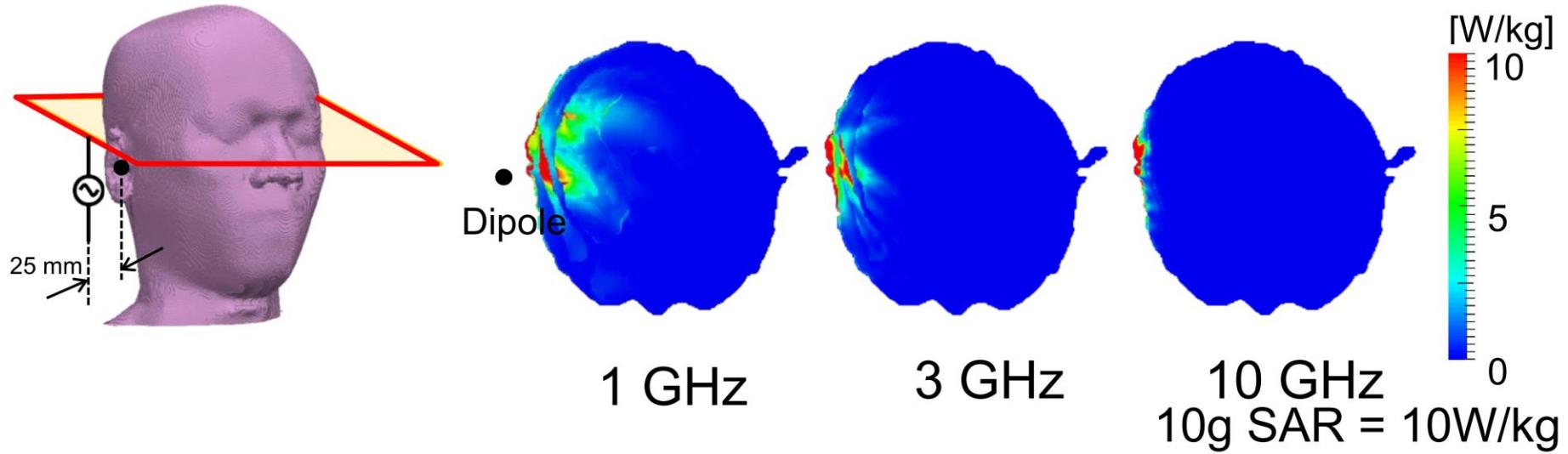
mmWaves mostly absorbed in outer skin layers



Penetration depth becomes shallower; source, Akimasa Hirata in 5G higher RF



Measured power absorption in biological tissues; source, [Akimasa Hirata in 5G higher RF](#)



ICNIRP 2020 Guidelines for limiting exposure to electromagnetic fields (100 KHz to 300 GHz)

Published in: Health Phys 118(5): 483–524; 2020;
[DOI: 10.1097/HP.0000000000001210](https://doi.org/10.1097/HP.0000000000001210)

- Purpose of the guidelines: to protect people exposed to RF electromagnetic fields 100 kHz–300 GHz
- Two types of restrictions (as next slides see [ICNIRP 2020 Guidelines in brief](#); not from the Guidelines <https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html>)
 - **Basic restrictions** refer to fields in people (cannot be measured easily)
 - **Reference levels** refer to fields in the environment (can be measured easily). Typically used to ensure safety.

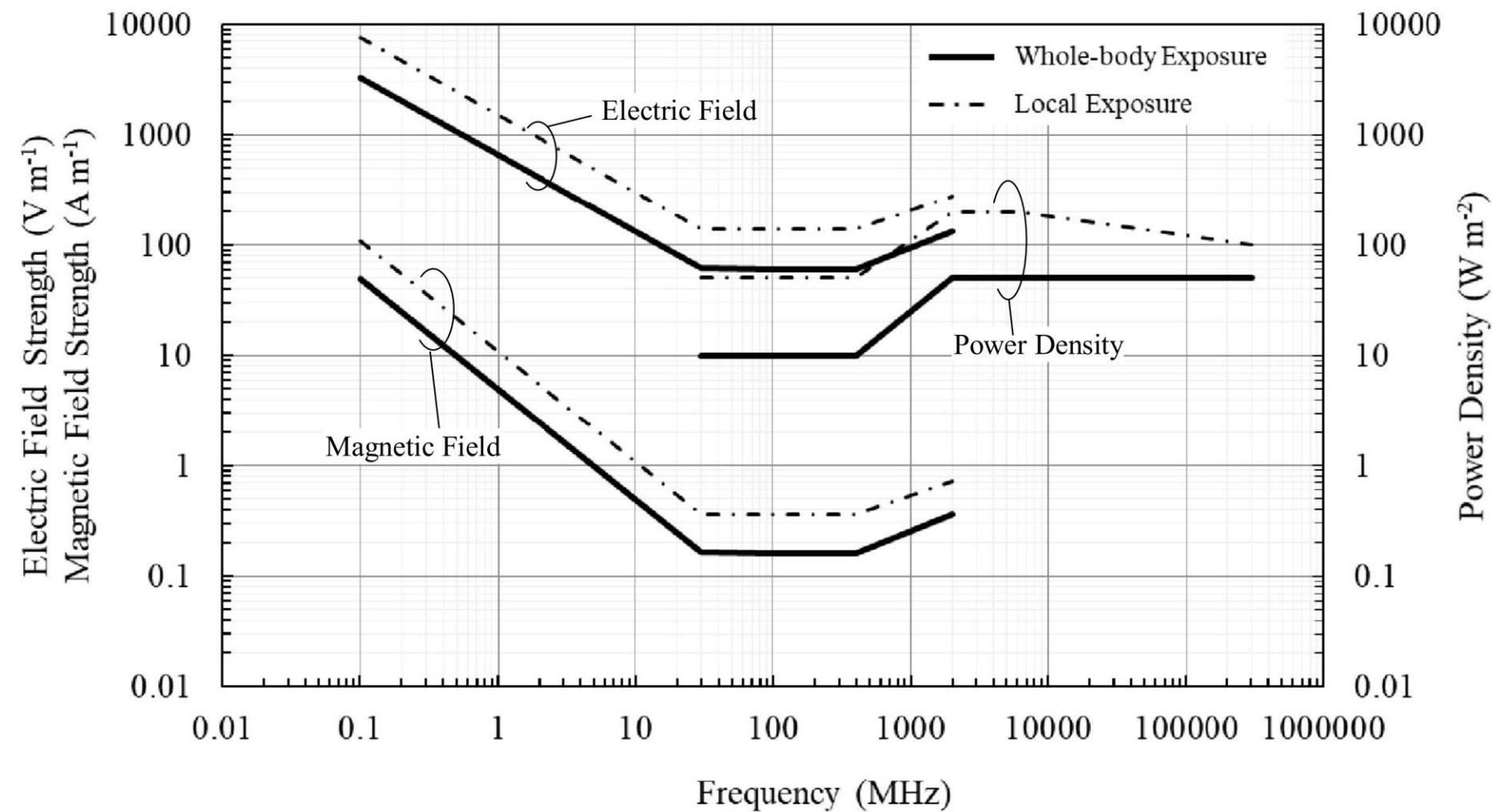
ICNIRP 2020 Guidelines- How is it done?

1. Identify scientific data on effects of exposure
2. Determine effects considered both
 - adverse to humans
 - scientifically substantiated
3. Identify minimum exposure level needed to produce harm
4. Apply reduction factors: larger for general public than for workers
5. This results in exposure restrictions with a large margin of safety

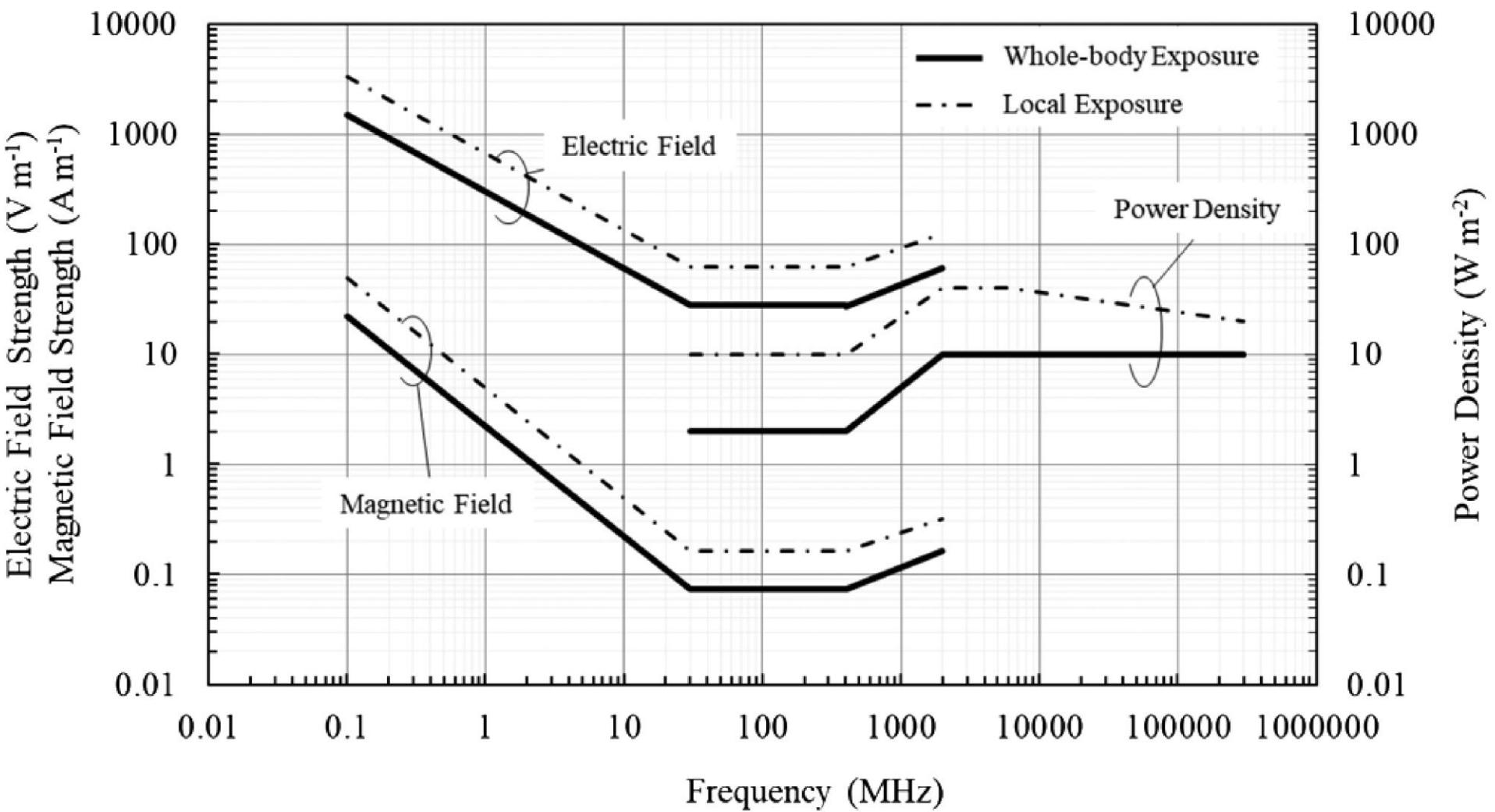
ICNIRP 2020 Guidelines- Scientific Basis

- Major reviews and original papers
- Only adverse health effects through:
 - nerve stimulation (up to ~10 MHz, limits from 2010 guidelines)
 - heating (from ~100 kHz)
- No evidence for
 - cancer
 - electrohypersensitivity
 - infertility
 - other health effects

Occupational

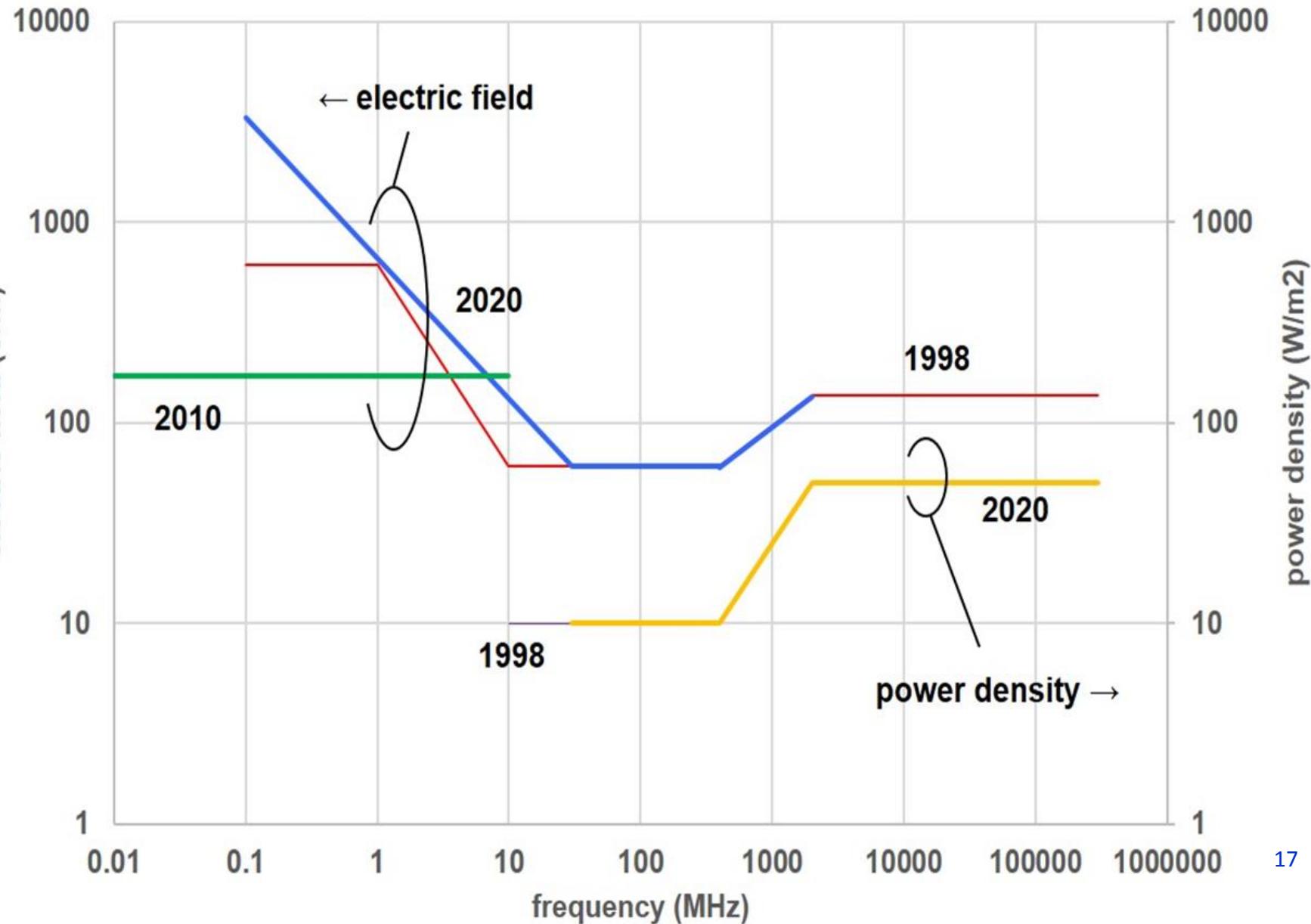


General Public

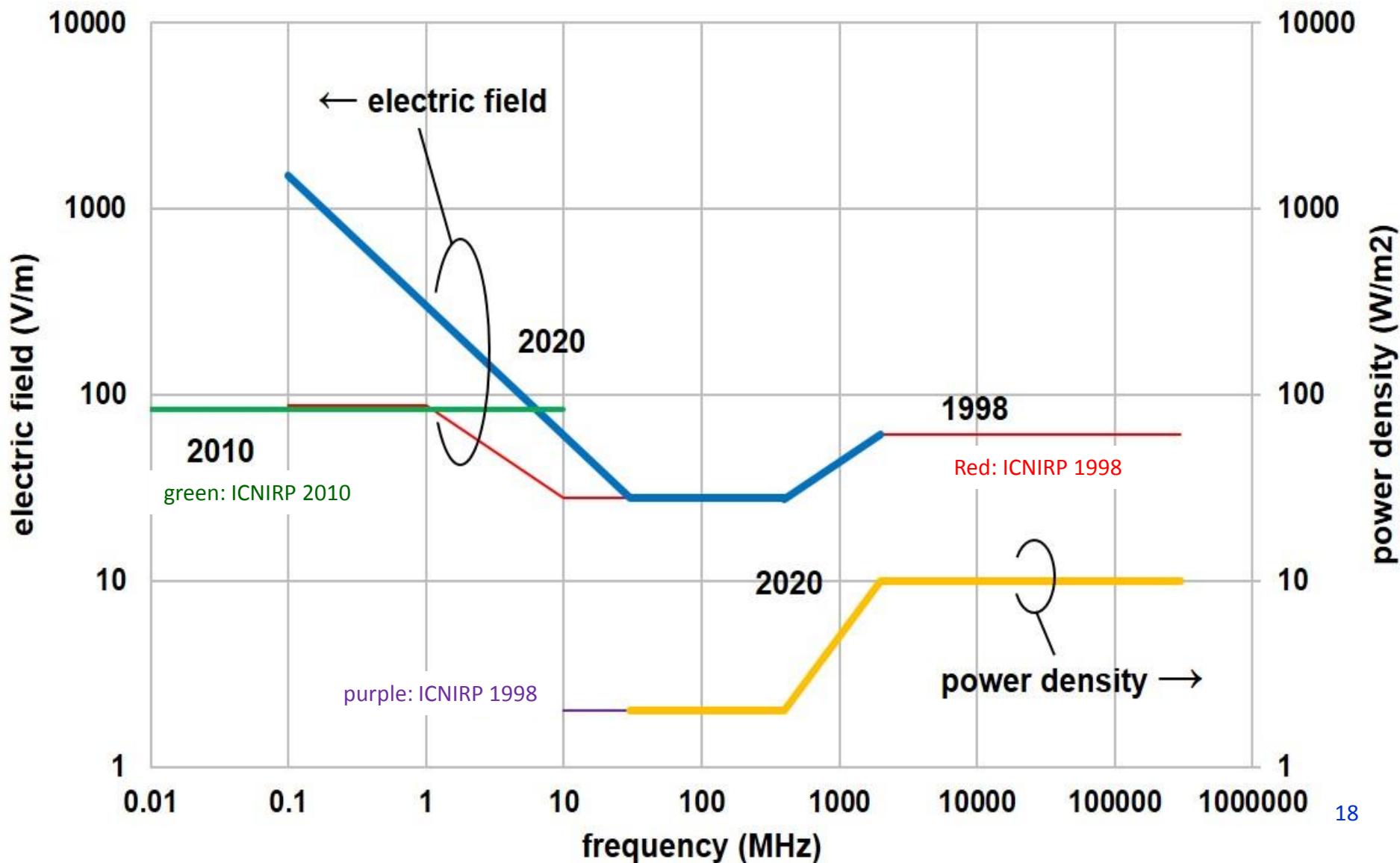


ICNIRP 2010 and ICNIRP 2020;

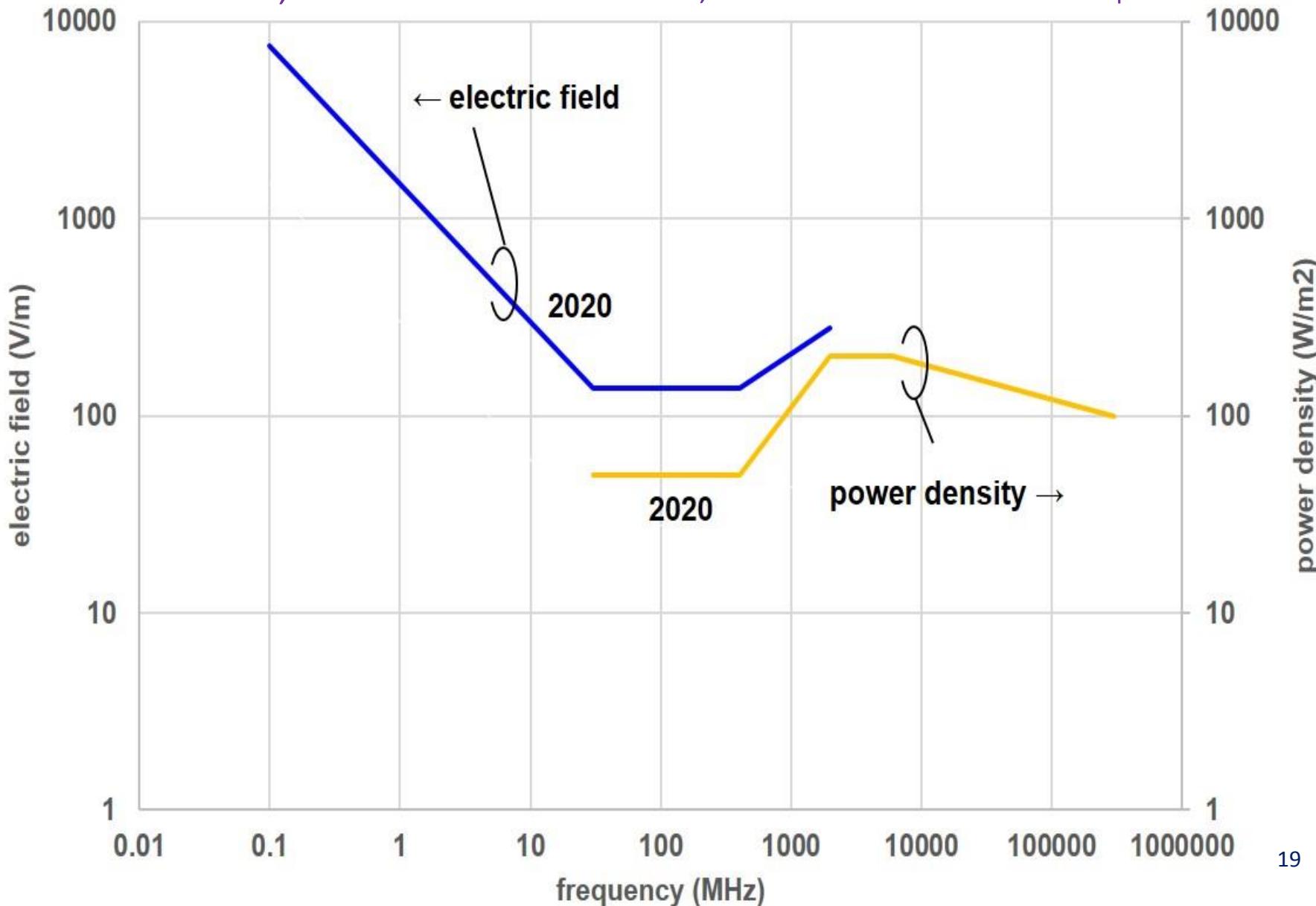
see ICNIRP 2020 Tables 5 & 6, for full specifications



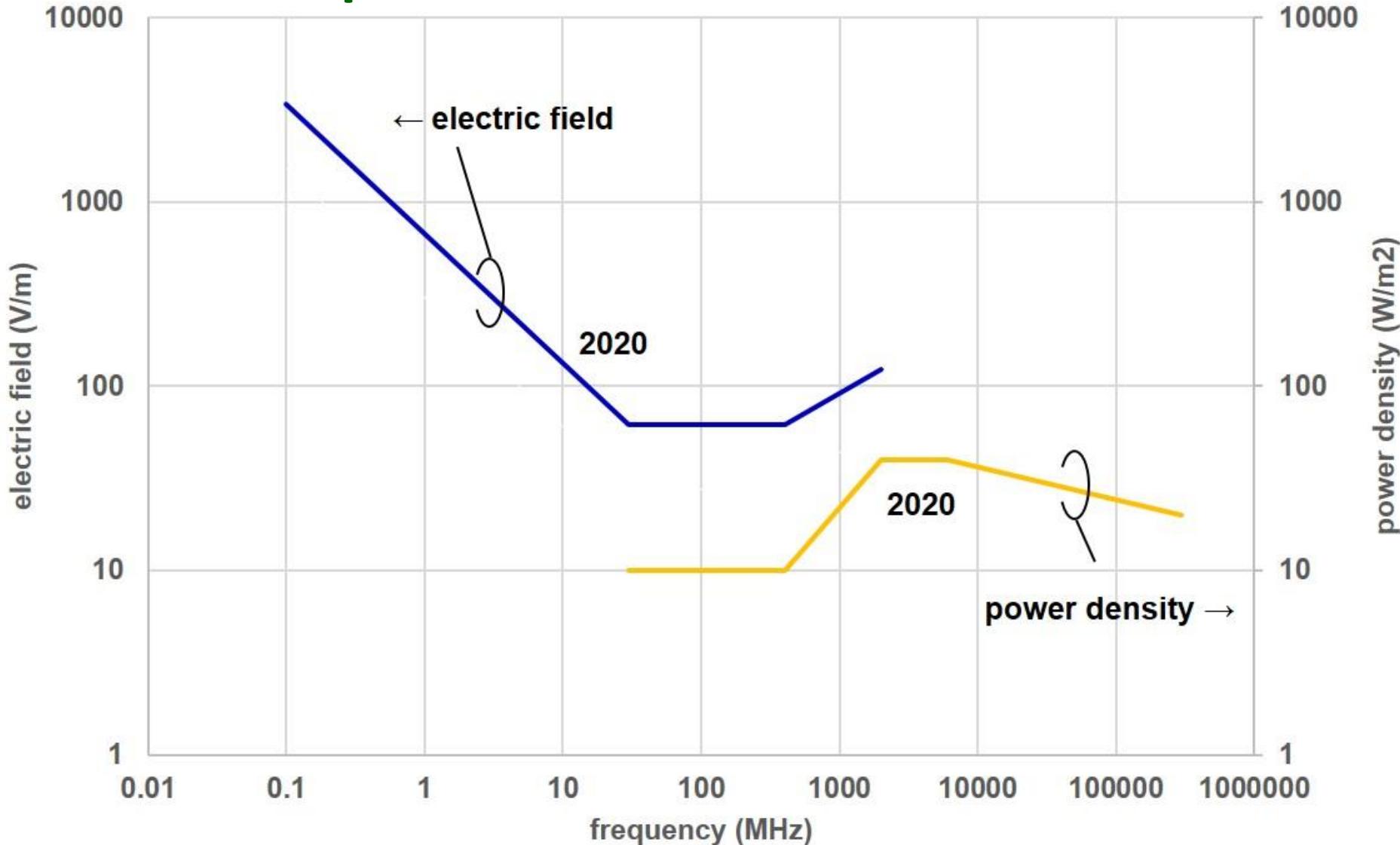
ICNIRP 2020 Web Fig. 2, based on Table 6 the **general public** applying to **whole-body exposures ≥ 6 min**, for the ICNIRP 2020 guidelines only



ICNIRP 2020 Web Fig. 3, occupational, local exposures of
≥6 minutes, 100 kHz–300 GHz; see Tables 5 & 6 for full specifications

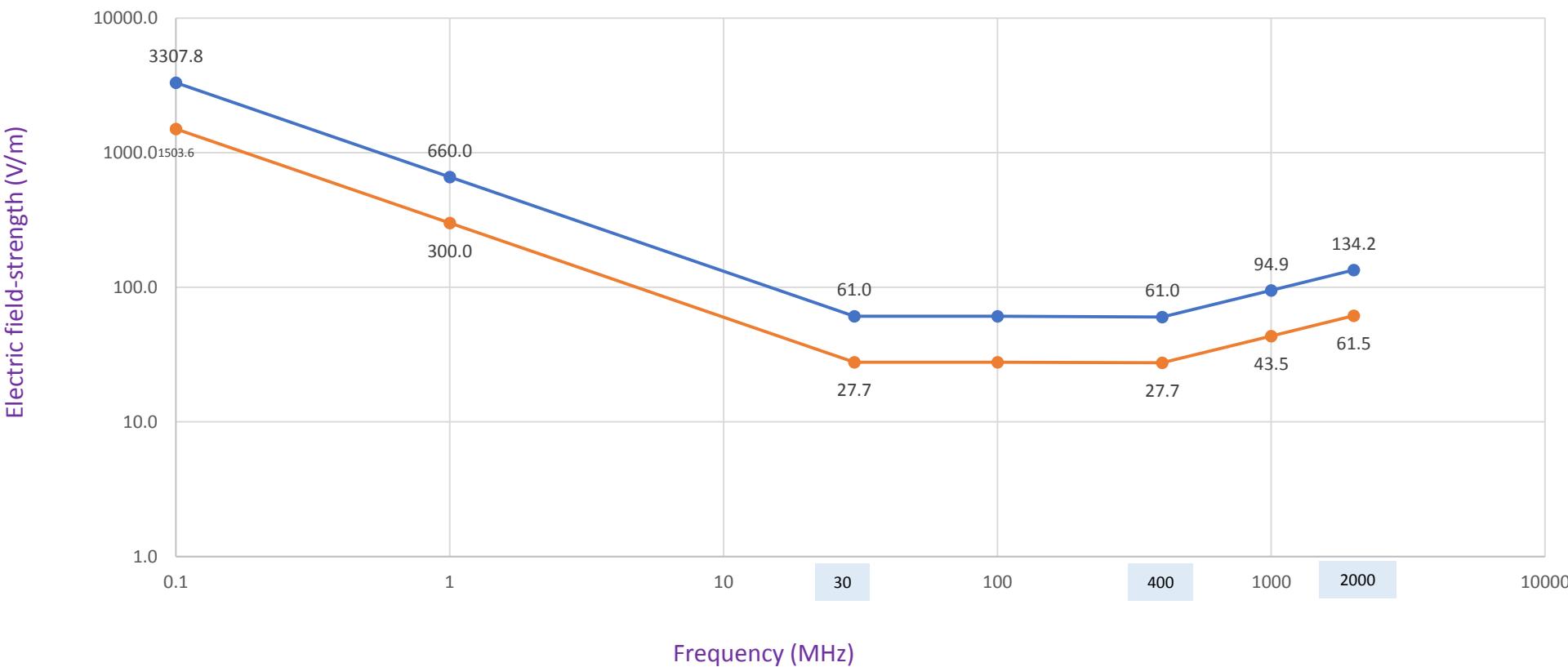


ICNIRP 2020 Web Fig. 4 general public, local exposures ≥ 6 min 100 kHz to 300 GHz



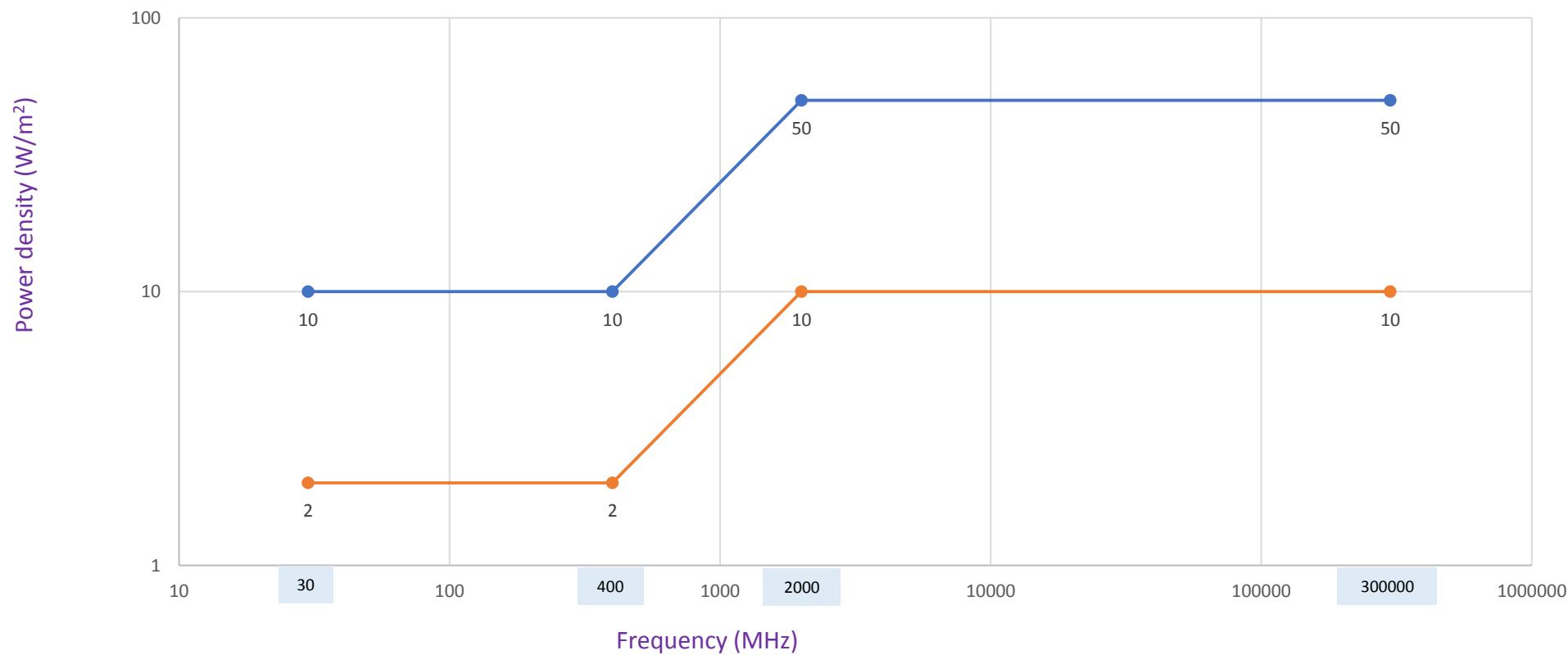
Comparing ICNIRP 2020 **field-strength** for occupational & general-public exposures, 0.1 MHz– 2 000 MHz, based on **Table 5**, p. 495: **averaged over 30 minutes & the whole body** (source, Mazar)

● Occupational ● General public

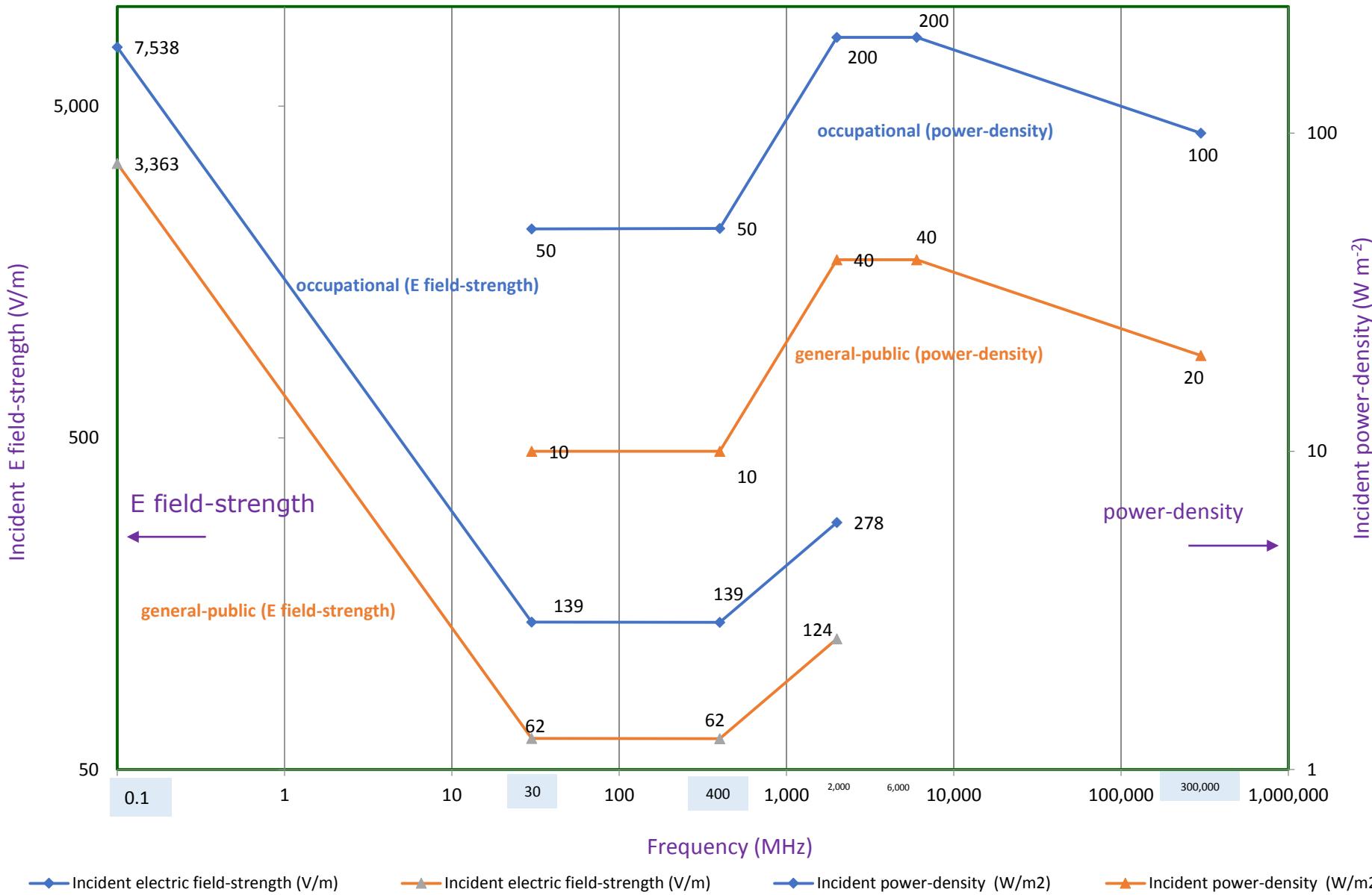


Comparing ICNIRP 2020 **power-density** for occupational & general-public exposures, 30 MHz– 300 GHz, based on **Table 5**, p. 495: **averaged over 30 minutes and the whole body (source, Mazar)**

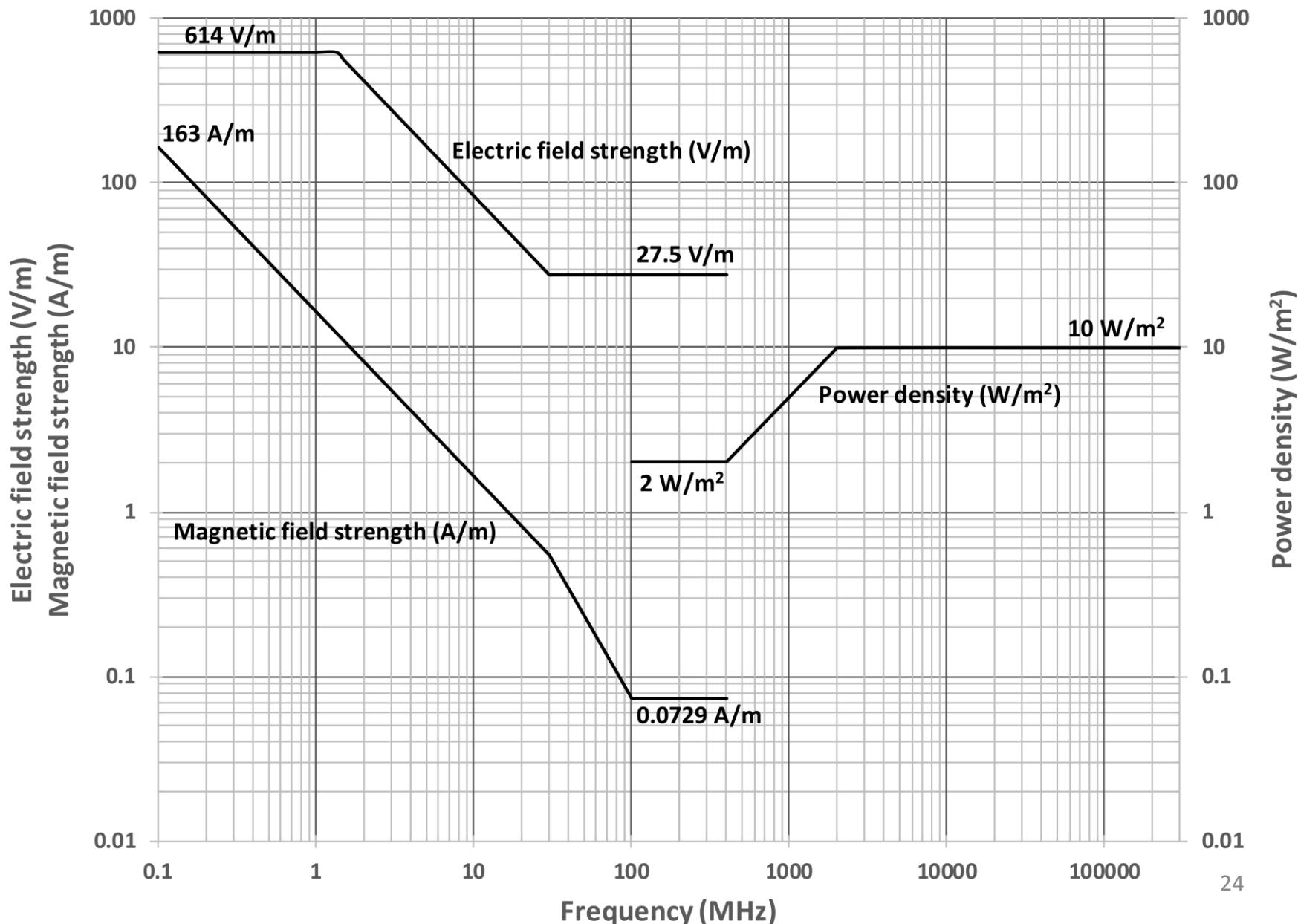
● Occupational ● General public



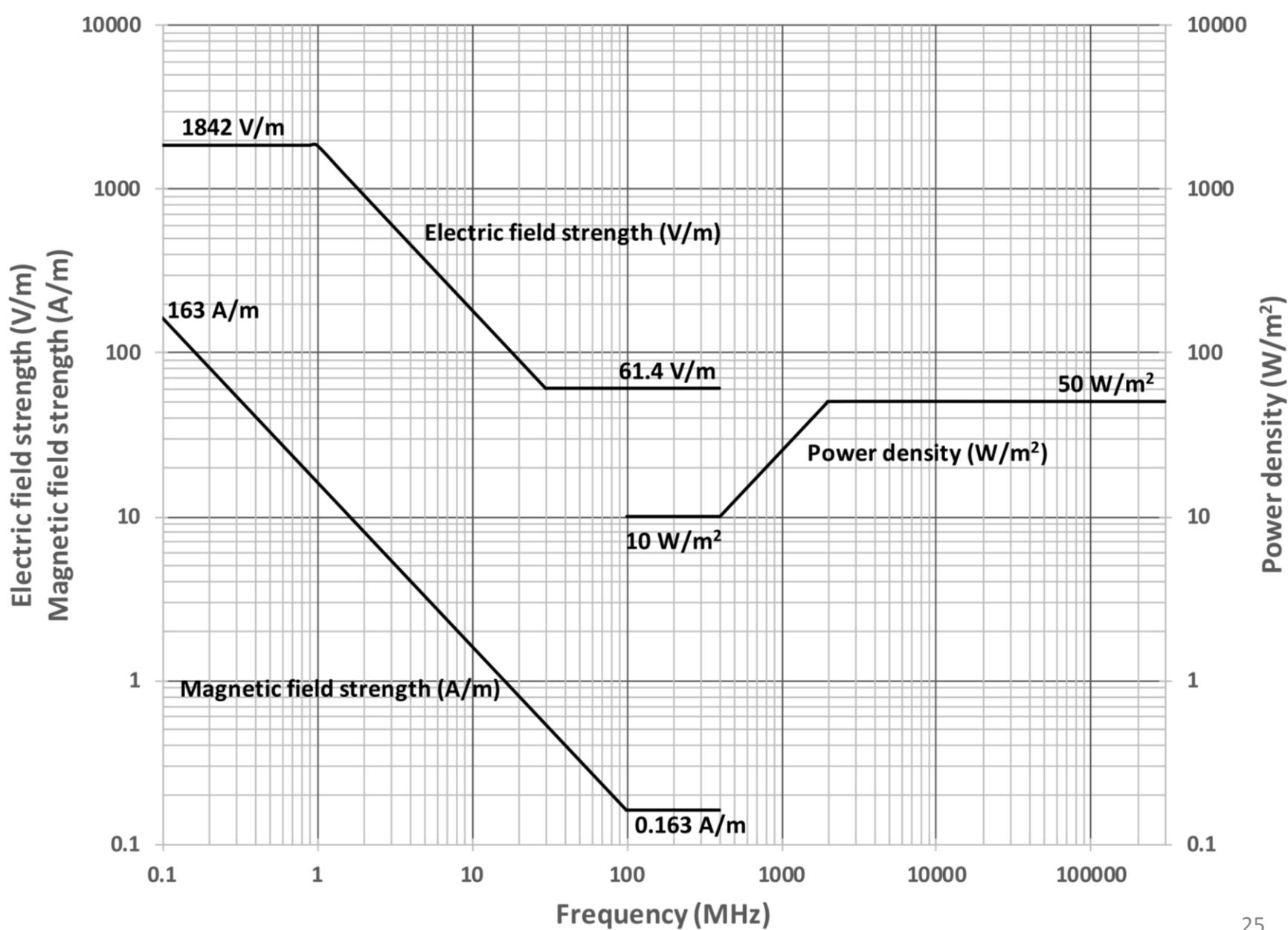
Comparing ICNIRP 2020 incident electric field-strength & power-density for occupational & general-public exposures, 100 kHz–300 GHz, see **Table 6**, p. 496: **local exposure, averaged over 6 minutes** (source, Mazar)



[IEEE C95.1-2019](#) Fig. 3: ERLs graphical representations in Table 7 for electric & magnetic fields & plane-wave-equivalent power density—Persons in unrestricted environments

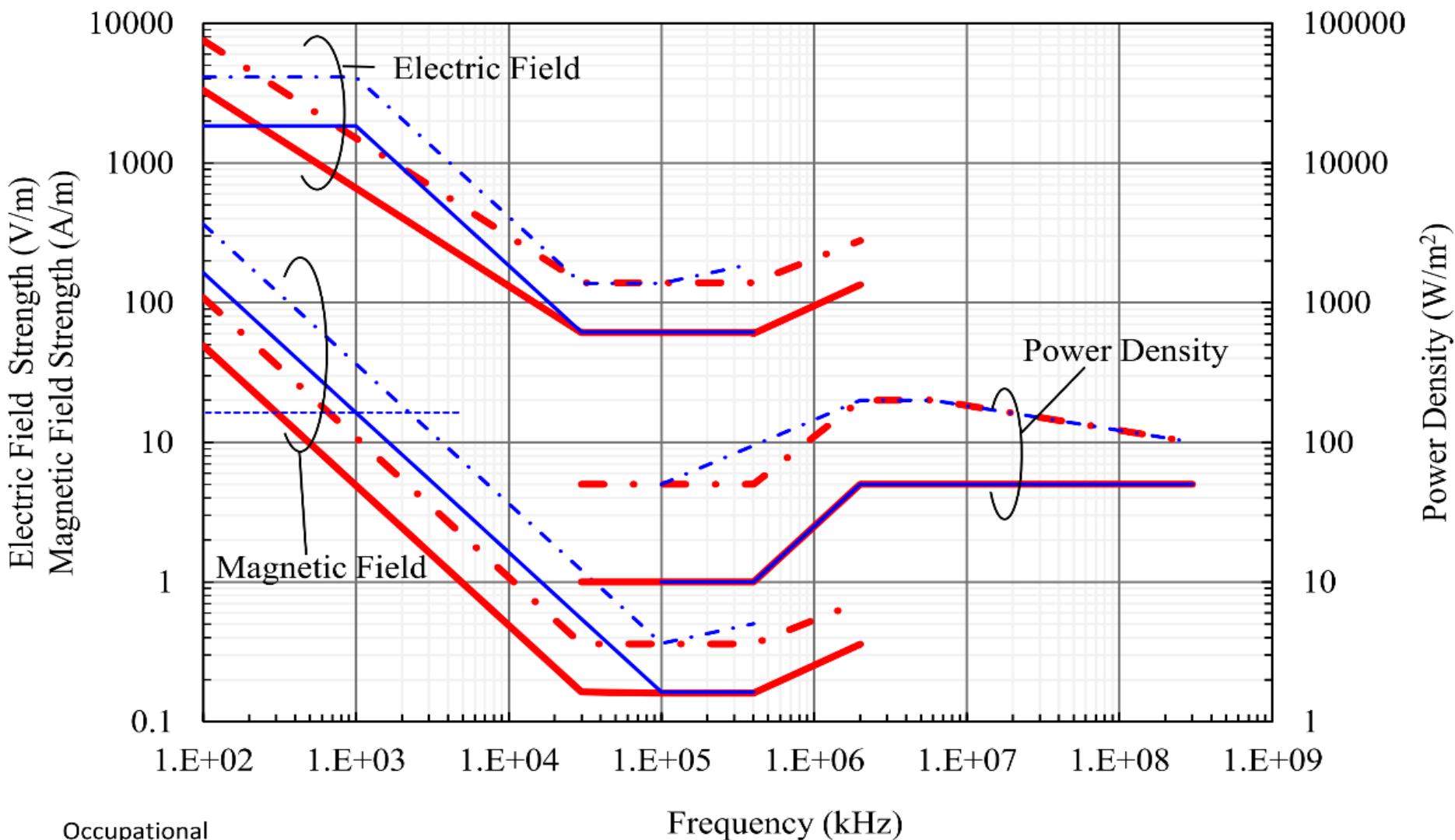


IEEE C95.1-2019 Fig. 4: ERLs' graphical representations in Table 8 for electric & magnetic fields & plane-wave-equivalent power density—Persons permitted in restricted environments



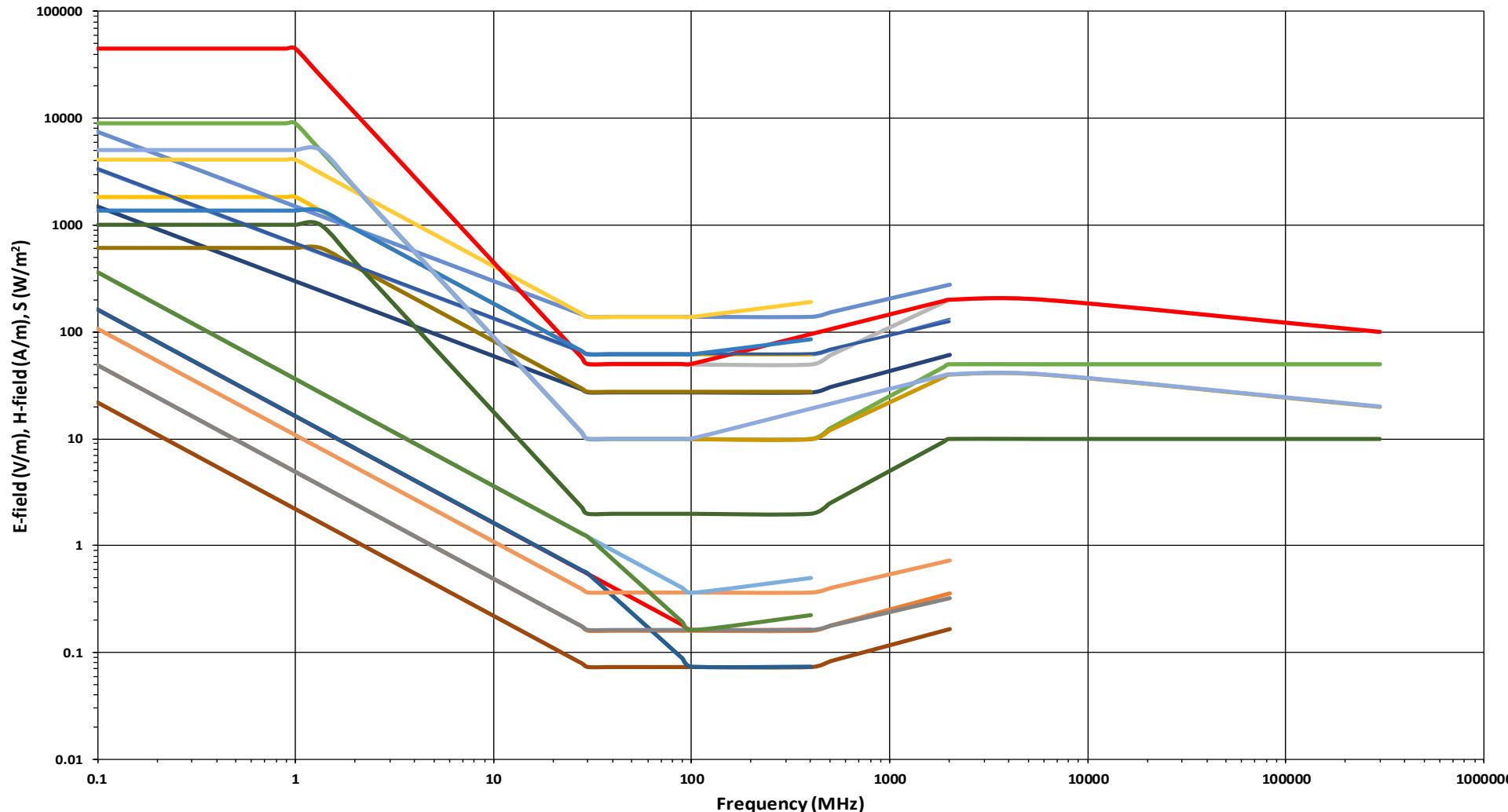
'Human Exposure Standards and Compliance Assessment– 5G and Beyond'

— ICNIRP 2019 — Whole Body
— IEEE C95.1-2019 - - - Local

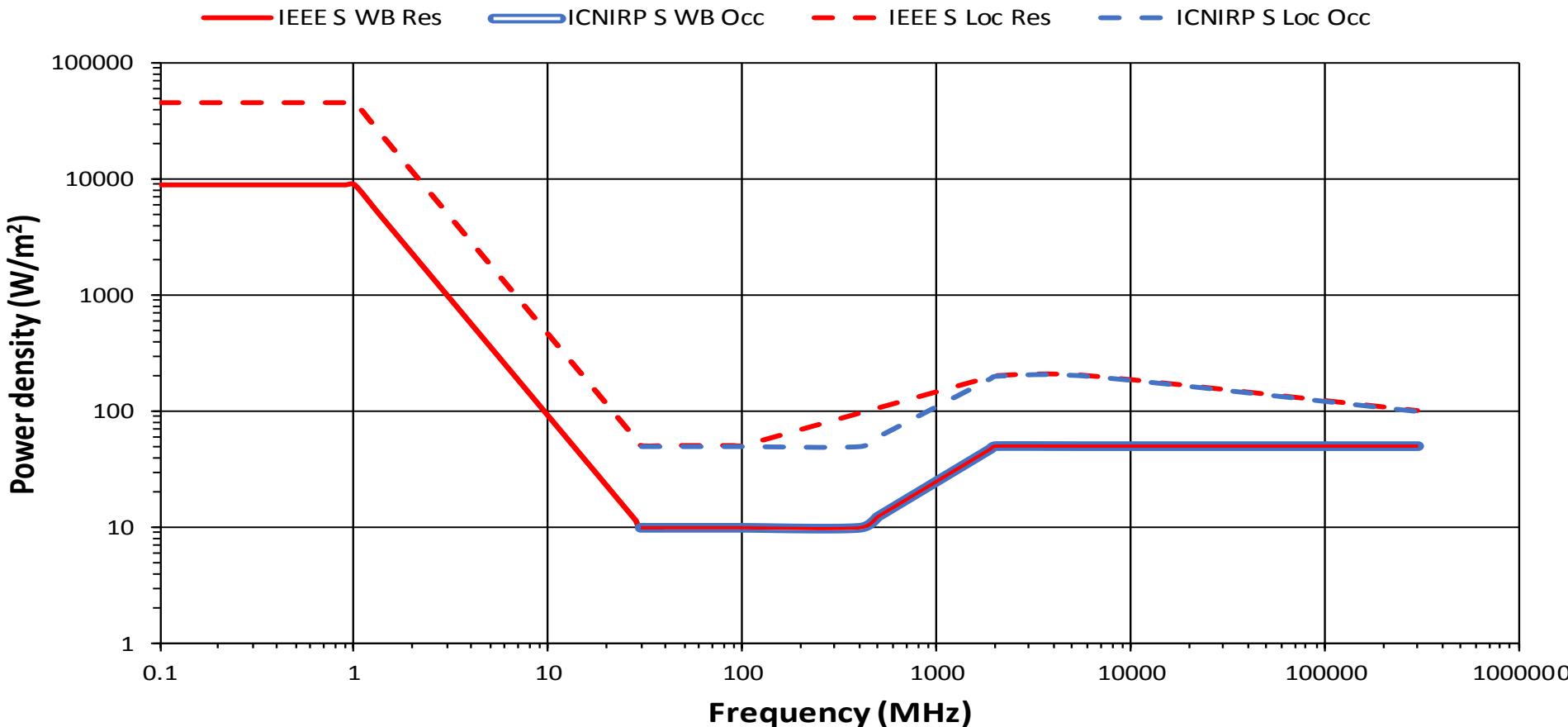


Comparison of IEEE (2019) and ICNIRP (2020) Whole body & Local Exposure Limits

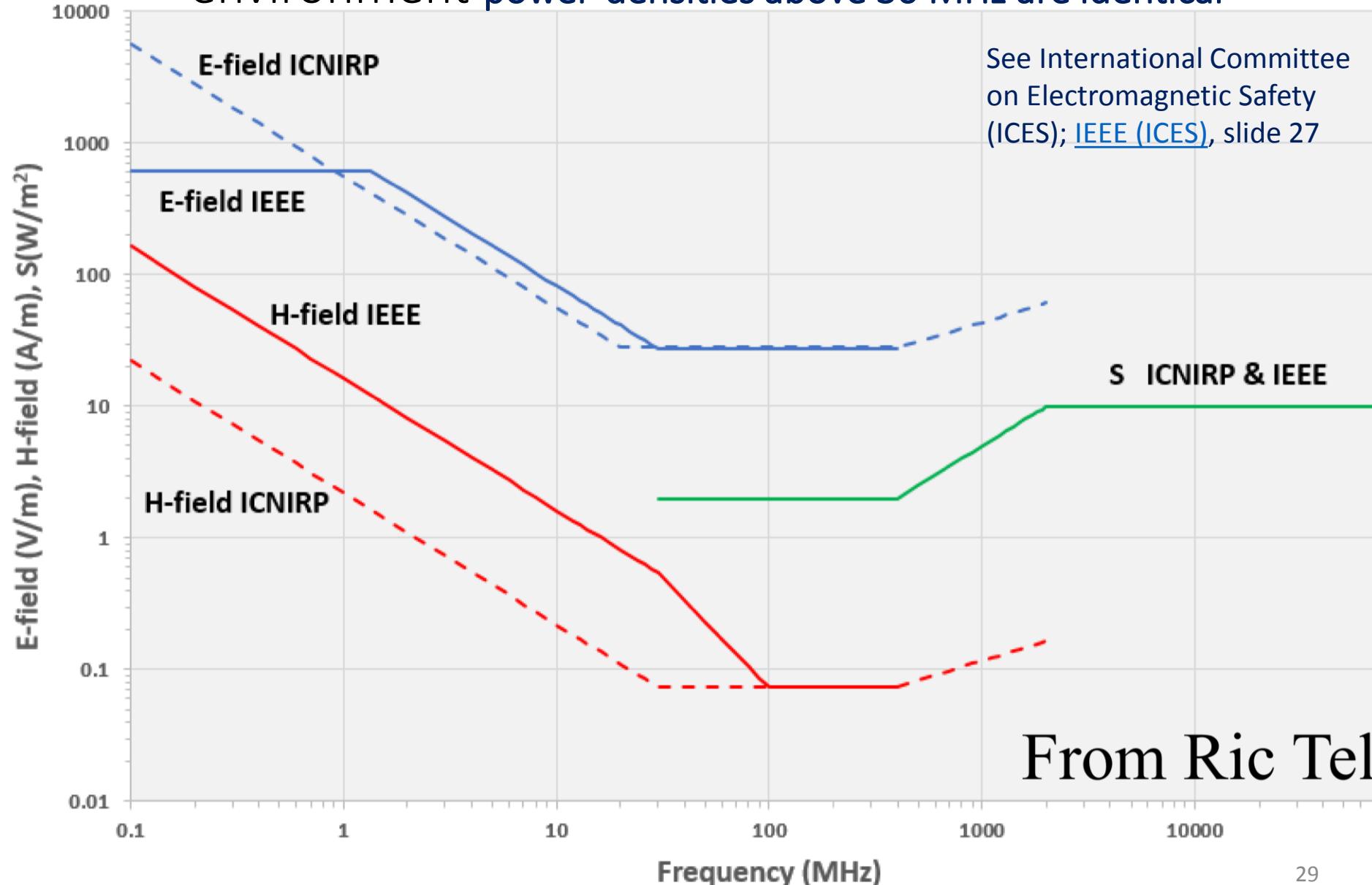
ICNIRP E WB Occ	ICNIRP H WB Occ	ICNIRP S WB Occ	IEEE E WB Res	IEEE H WB Res	IEEE S WB Res	ICNIRP E Loc Occ	ICNIRP H Loc Occ	ICNIRP H Loc Pub
ICNIRP H WB Pub	ICNIRP S WB Pub	ICNIRP S Loc Occ	IEEE E WB Ures	IEEE H WB Ures	IEEE S WB Ures	ICNIRP E Loc Pub	ICNIRP H Loc Pub	ICNIRP H Loc Pub
ICNIRP S Loc Occ	IEEE E Loc Res	IEEE E Loc Ures	IEEE H Loc Res	IEEE H Loc Ures	IEEE S Loc Res	IEEE S Loc Ures	ICNIRP H Loc Pub	ICNIRP H Loc Pub
ICNIRP S Loc Pub	IEEE E Loc Ures							



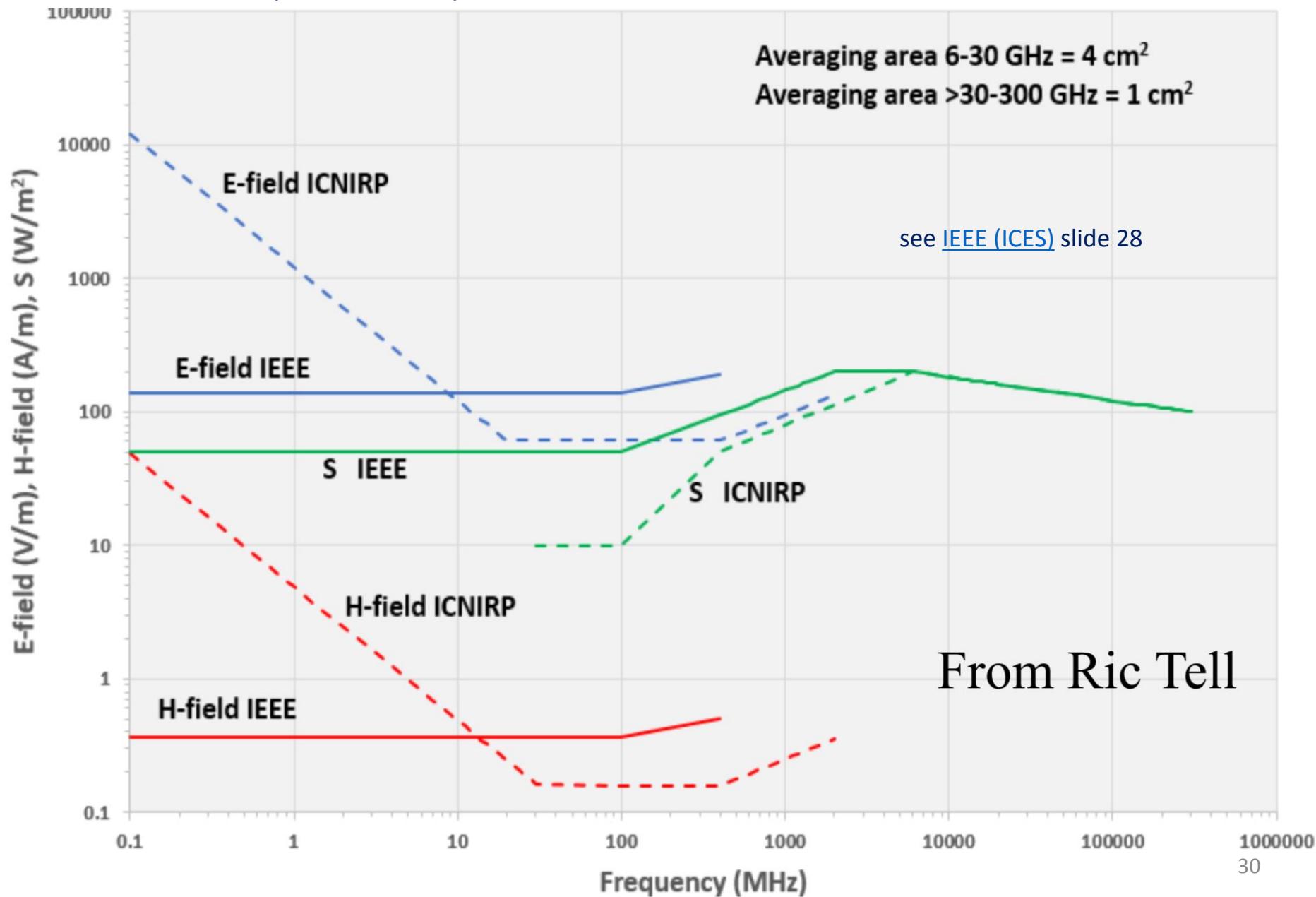
Comparison of IEEE (2019) and ICNIRP (2020) Whole body & Local Power Density Limits Restricted/Occupational



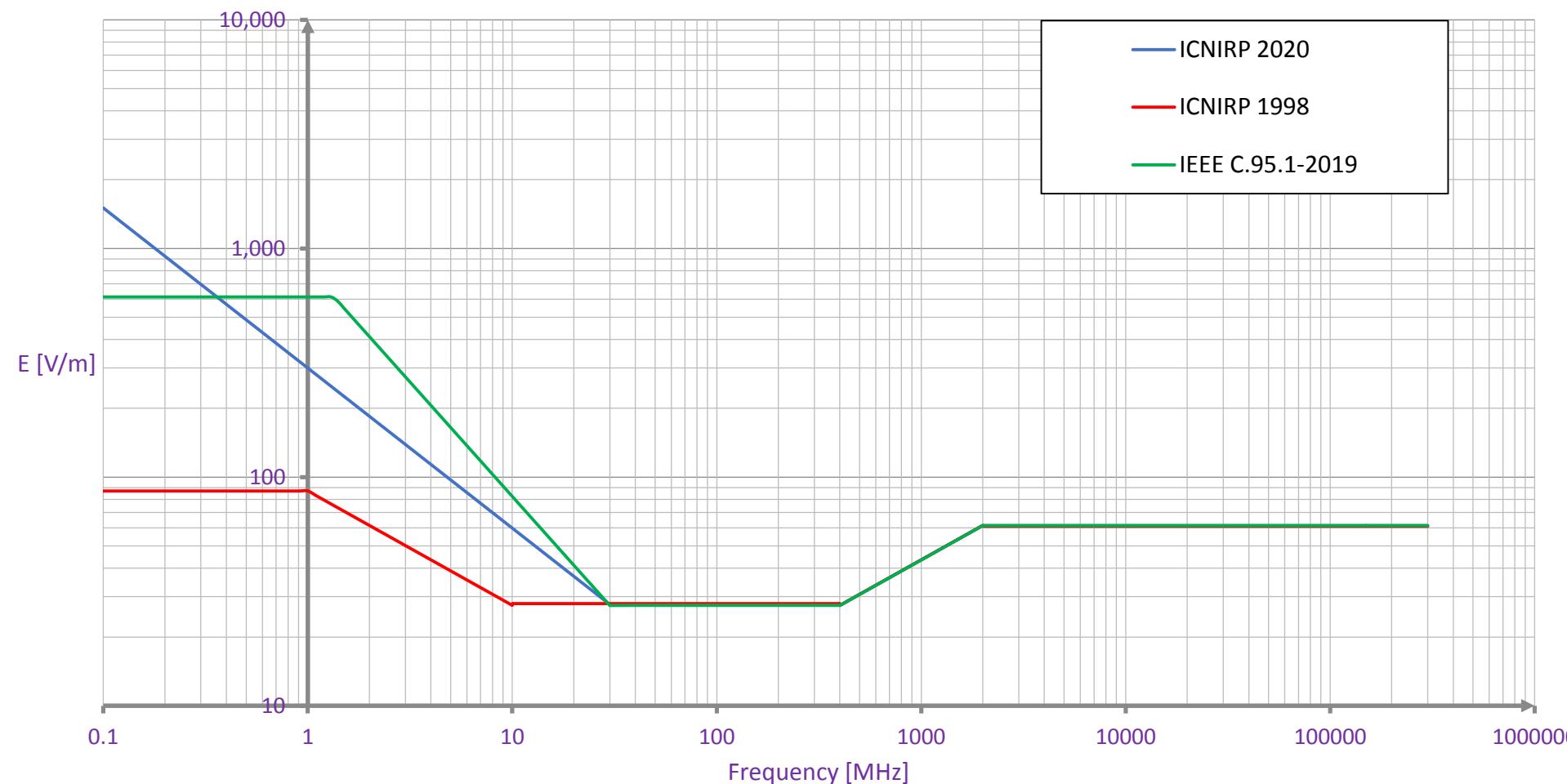
IEEE/ICNIRP differences in limits general public/ unrestricted environment power-densities above 30 MHz are identical



IEEE/ICNIRP differences in limits: local exposure limits (assuming 6-minute exposure); power-densities below 6 GHz are different



Reference exposure levels general-public (V/m, also above 400 MHz)



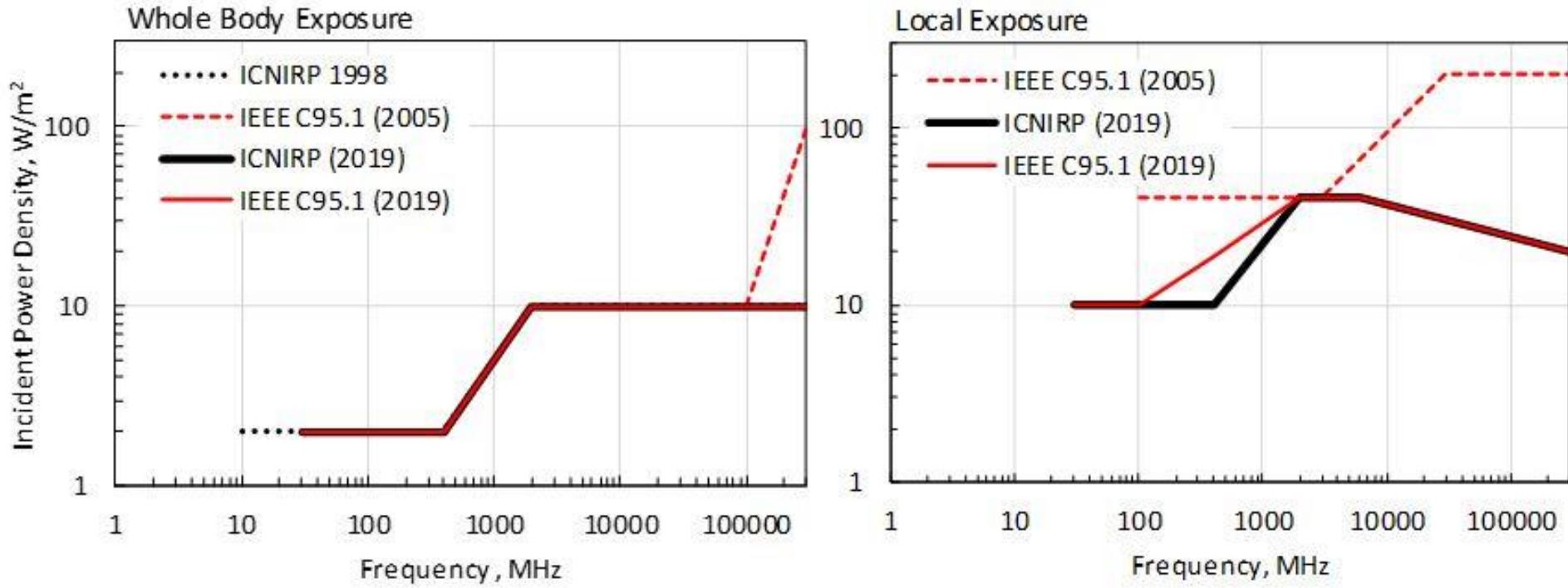
Source, [Spectrum Management and Broadcasting 02 July 2020, Dr. Lewicki Fryderyk, Electromagnetic Fields and 5G Implementation](#)

Table 1 Limits for general public (lower tier) in ICNIRP and IEEE

	Frequency range	Incident power density	Averaging area	Averaging time
ICNIRP (1998)	2-10 GHz	10 W/m ²	20 cm ² (1 cm ²)	6 min
	10-300 GHz	10 W/m ² (200 W/m ²)		Decrease from 6 min to 10 s
IEEE (2005)	Whole Body Exposure			
	5-30 GHz	10 W/m ²	100 λ ² *	Decrease from 30 min to 5 min
	30-100 GHz	10 W/m ²	100 cm ²	Decrease from 5 min to 2.8 min
	100-300 GHz	Increase from 10 W/m ² to 100 W/m ²	100 cm ²	Decrease from 2.8 min to 10 s
	Local Exposure			
	3-30 GHz	Increase from 40 W/m ² to 200 W/m ²	peak	Decrease from 30 min to 5 min
	30-300 GHz	200 W/m ²		Decrease from 5 min to 10 s
ICNIRP (2019)	Whole Body Exposure			
	2-300 GHz	10 W/m ²		30 min
	Local Exposure			
	6-300 GHz	Decrease from 40 W/m ² to 20 W/m ²	4 cm ²	6 min
	30-300 GHz	Decrease from 60 W/m ² to 40 W/m ²	1 cm ²	6 min
IEEE C95.1 (2019)	Whole Body Exposure			
	2-300 GHz	10 W/m ²		30 min
	Local Exposure			
	6-300 GHz	Decrease from 40 W/m ² to 20 W/m ²	4 cm ²	6 min
	30-300 GHz	Decrease from 60 W/m ² to 40 W/m ²	1 cm ²	6 min

* λ means the free space wavelength

Exposure reference levels for general public in ICNIRP and IEEE



Source [5G Communications Systems and Radiofrequency Exposure Limits; IEEE Future Networks Tech Focus, Volume 3, Issue 2, September 2019; Pr. Akimasa Hirata et al.](#)

IEEE C95.1 2019 & ICNIRP 2020 Guidelines are largely harmonized

1. ICNIRP Guidelines (1998, and 2020) & IEEE Standard (2019) separate between general-public and occupational
2. The exposure levels of ICNIRP 2020 & IEEE Standard whole-body levels above 400 MHz are identical!
 - 1) SAR equals **2 W/kg** for general-public and **10 W/kg** for occupational
 - 2) Exposure reference-levels equals at:
 - **400 to 2000 MHz $f_M/200 \text{ W/m}^2$** for general-public & **$f_M/40 \text{ W/m}^2$** for occupational
 - **2000 to 300 000 MHz 10 W/m²** for general-public & **50 W/m²** for occupational

Mitigation techniques to decrease radiation level (1)

1. Maximize RF to operators in order to decrease number of sites
2. Maximize sharing, including active frequencies sharing among cellular operators
3. Close the WI-FI access point when not in use

Mitigation techniques to decrease radiation level (2)

1. **Restrict access** to areas where the exposure limits are exceeded. Physical barriers, lockout procedures and adequate signs are essential; workers can use protective clothing (ITU-T 2004 [K.52](#) p.19)
2. **Increase the antenna height.** The distances to all points of investigation are increased and the radiation level is reduced. Moreover, additional attenuation to the radiation is achieved due to the increase of elevation angle and decrease of transmitting antenna sidelobe (ITU-T 2007 [K.70](#) p.22)
3. **Increase the antenna gain** (mainly by reducing the elevation beam width), and consequently decrease the radiation in the direction accessible to people. The vertical beam width may be used to reduce the radiation level in close proximity to the antenna. Moreover, the same value of the EIRP can be achieved by a low power transmitter feeding high gain antenna or by high power transmitter feeding low gain antenna. As far as the protection against radiation is concerned, a much better choice is to use the low power transmitter feeding the high gain antenna. (ITU-T 2007 [K.70](#) p.22)
4. **Minimize exposure to the min. needed** to maintain the quality of the service, as quality criterion. Decrease the Tx power & consequently decrease linearly the power density in all the observation points. As it reduces the coverage area, it is used only if other methods cannot be applied (2007 [K.70](#) p.22)

Summary Q 7/2 EMF Oct. 2020

Administrations are encouraged to follow the ICNIRP Guidelines or IEEE Standard, or limits set by their own experts.

The best practice for Administrations that choose to use international RF-EMF exposure limits is to limit the exposure levels to the thresholds specified in ICNIRP (2020) Guidelines.

Additional publications of the Author on EMF

- ITU Conferences and workshops on EMF

- 1) [A Comparison Between European and North American Wireless Regulations](#), presentation at the ‘Technical Symposium at ITU Telecom World 2011’ www.itu.int/worl2011; the [slides presentation](#), 27 October 2011
 - 2) [2016 ITU R-D-T ‘Intersectoral activities on human exposure to EMF’; Bangkok, 26 April 2016](#)
 - 3) [2017 ITU Workshop ‘5G, EMF & Health’; Warsaw, Poland, 5 December 2017](#)
 - 4) [2018 ITU workshop ‘modern policies, guidelines, regulations and assessments of human exposure to RF-EMF’; Geneva, Switzerland, 10 October 2018 ; see \[slide\]\(#\)](#)
 - 5) PRIDA Track 1 (T1) [On-line English workshop](#) 20thApril–1stMay2020. [First week slides v2](#); see pp. 237–296, EMF presentation 24 April 2020
 - 6) PRIDA Track 1 (T1) [Atelier de renforcement des capacités sur la gestion moderne du spectre 11-22 mai 2020.](#) [First week slides v2](#); see pp. 224–278, EMF présentation 15 mai 2020
 - 7) ITU Regional Forum for Europe [on 5G Strategies, policies and implementation](#); 22-23 Oct 2020; ‘RF Human Hazards; EMFs Implementing 5G for Good: Does EMF Matter?’
 - Papers and Presentations
- 1) Updated [Chapter 9](#) on EMF exposure of my Wiley book on [Spectrum Management](#)
 - 2) [Human RF Exposure Limits: Reference Levels in Europe, USA, Canada, China, Japan and Korea](#) EMC Europe 2016; Wroclaw, Poland, 9 Sept. 2016
 - 3) [Regulation of RF Human Hazards](#) Lusaka, Zambia; 13 January 2017
 - 4) [EMF Concerns and Perceptions](#) Modiin, Israel; 25 March 2019
 - 5) [EMF, New ICNIRP Guidelines and IEEE C95.1-2019 Standard: Differences and Similarities](#); Warsaw, Poland; 3 Dec 2019
 - 6) Module on EMF to the ITU Spectrum Training; April 2020
 - 7) [EMF_HumanHazardsPresentation_MaccabimMazar9June2020.pdf](#)
 - 8) [Academic Course Advanced Wireless Communications Mazar3 Regulation EMC HumanHazards 2020.pdf](#)

ITU workshop on modern policies, guidelines, regulations and assessments of human exposure to RF-EMF

ITU, Geneva 10 Oct. 18

Any Questions?

See workshop presentations at

<https://www.itu.int/en/ITU-D/Study-Groups/2018-2021/Pages/meetings/session-Q7-2-oct18.aspx>

