ITU Regional Forum for Europe 5G
Strategies, policies and implementation

EMF and other challenges
Setting the context

RF Human Hazards;
Implementing 5G for Good: Does EMF Matter?

23 October 2020

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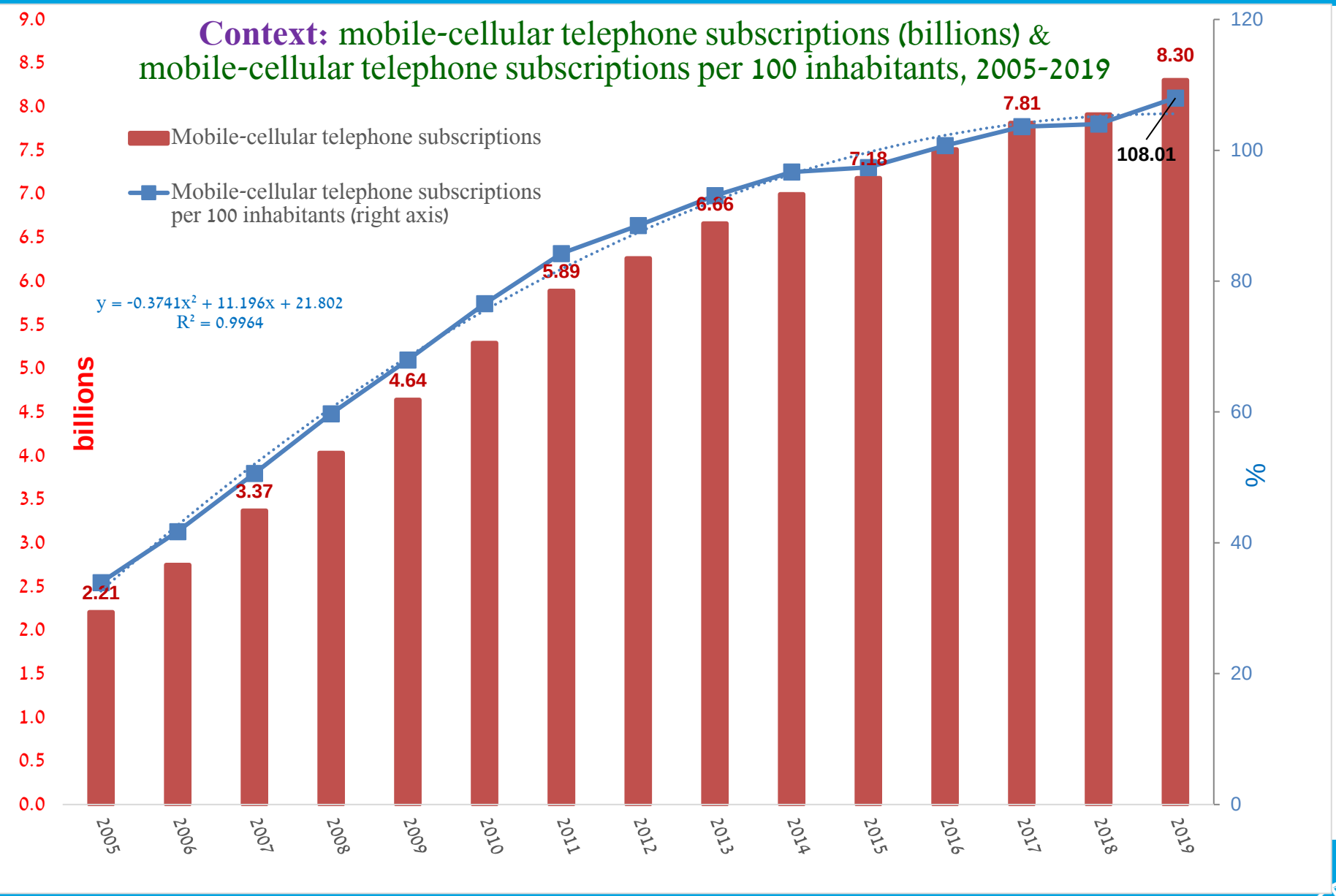


based on ITU indicators, 24th Edition/July 2020

Does EMF Matter? White background-paper: ITU provisions related to 5G and EMF

1. Review of ITU Recommendations, Reports, Conferences and events divided by sectors
2. ITU-R/D/T resources relating to EMF and 5G
3. Identification of IMT frequency bands in ITU Radio Regulations (2020 edition)
4. Report ITU-R SM.2452 on EMF measurements
5. ITU-T K.series Recommendations and Supplements ; ITU-T detailing the characteristics of 5G emissions: K Suppl. 9 and K Supp. 16
6. ITU Workshops and Initiatives on EMF
7. ITU, Human Capacity Building Opportunities

ITU-T Recommendations on EMF assessment

ITU-T SG5 (Environment, climate change and circular economy) has been particularly active in developing recommendations for the protection from and measurement/computation of RF fields. Enclosed the EMF ITU-T Recommendations (Standards). All of them include "related supplements":

1. K.52: Guidance on complying with limits for human exposure to electromagnetic fields
2. K.61: Guidance on measurement and numerical prediction of EMF for compliance with human exposure limits for telecommunication installations
3. K.70: Mitigation techniques to limit human exposure to EMFs in the vicinity of radio stations
4. K.83: Monitoring of electromagnetic field levels
5. K.90: Evaluation techniques and working procedures for compliance with exposure limits of network operator personnel to power-frequency EMF
6. K.91: Guidance for assessment, evaluation and monitoring of human exposure to RF-EMF
7. K.100: Measurement of RF-EMF to determine compliance with human exposure limits when a base station is put into service
8. K.113: Generation of RF-EMF level maps
9. K.121: Guidance on the environmental management for compliance with RF-EMF limits for radiocommunication base stations
10. K.122: Exposure levels in close proximity of radiocommunication antennas

New Supplements ITU-T K on EMF

1. Suppl. 9: 5G technology and human exposure to RF EMF
2. Suppl.10: Analysis of EMF compatibility aspects and definition of requirements for 5G mobile systems
3. K.Suppl.13: RF-EMF exposure levels from mobile and portable devices during different conditions of use
4. K.Suppl.14: Impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment
5. K. Suppl. 16: EMF compliance assessments for 5G wireless networks
6. K. Suppl. 19: EMF strength inside underground railway trains
7. K Suppl. 20: ITU-T K.91 – Supplement on radiofrequency exposure evaluation around underground base stations
8. K.70 Appendix I – Software: EMF-estimator

International Electrotechnical Commission (IEC)

5G IEC- **Standards**; Oct. 2020

1. IEC/IEEE 62209-1528 (2020): Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-worn wireless communication devices - Part 1528: Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 GHz)
2. IEC 62232 (2017): Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure
3. IEC TR62630 (2010): Guidance for evaluating exposure from multiple electromagnetic sources
4. IEC TR63170 (2018): Measurement procedure for the evaluation of power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 100 GHz
5. IEC/IEEE 62704-1 (2017): Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz - Part 1: General requirements for using the finite difference time-domain (FDTD) method for SAR calculations
6. IEC/IEEE 62704-2 (2017): Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz - Part 2: Specific requirements for finite difference time domain (FDTD) modelling of exposure from vehicle mounted antennas
7. IEC/IEEE 62704-3 (2017): Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz - Part 3: Specific requirements for using the finite difference time domain (FDTD) method for SAR calculations of mobile phones
8. IEC/IEEE 62704-4 (2020): Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communication devices, 30 MHz to 6 GHz - Part 4: General requirements for using the finite element method for SAR calculations

International Electrotechnical Commission (IEC)
5G IEC- Ongoing; Oct. 2020

1. IEC / IEEE 63195-1: Measurement procedure for the assessment of power density of human exposure to radio frequency fields from wireless devices operating in close proximity to the head and body – Frequency range of 6 GHz to 300 GHz, expected in Aug. 2021
2. IEC/ IEEE 63195-2: Determining the power density of the electromagnetic field associated with human exposure to wireless devices operating in close proximity to the head and body using computational techniques, 6 GHz to 300 GHz, expected in Aug. 2021

International organisations/ standardisation bodies related to 5G and EMF

1. WHO, ICNIRP and IEEE
2. Thorough analysis of Tables and Figures of ICNIRP (2020) Guidelines and IEEE 95.1 (2019) standard in force for the IMT frequencies 450 MHz–71 GHz
3. Exposure limits from base stations, cellulars and handsets applicable to 5G
4. Compare/Contrast ICNIRP (1998), IEEE 95-1 (2019) and ICNIRP (2020)

Open issues directly and indirectly related to 5G & EMF

1. Misinformation
2. Delays in installing base-stations
3. Economic cost for society
4. Environment, including EMF hazards to animals and plants

ITU Radio Regulations (2020 edition), 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

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

1. Ofcom published on February 2020 recent measurements of EMF emissions close to 16 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 1998 general public exposure in ICNIRP Guidelines (400–2,000 MHz) *f* (MHz)/200 (W/m^2), & 2–300 GHz 10 (W/m^2)
   2) the highest level recorded being approximately 1.5% of the **power-density** reference level
   3) In all locations, the largest contribution to the measured levels comes from **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; see ANFR Sept. 2018
Summarized results 2017: 90% of measured levels in 2017 in rural areas are below 0.95 V/m

	Mesurements nº	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**

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

Questions to be raised

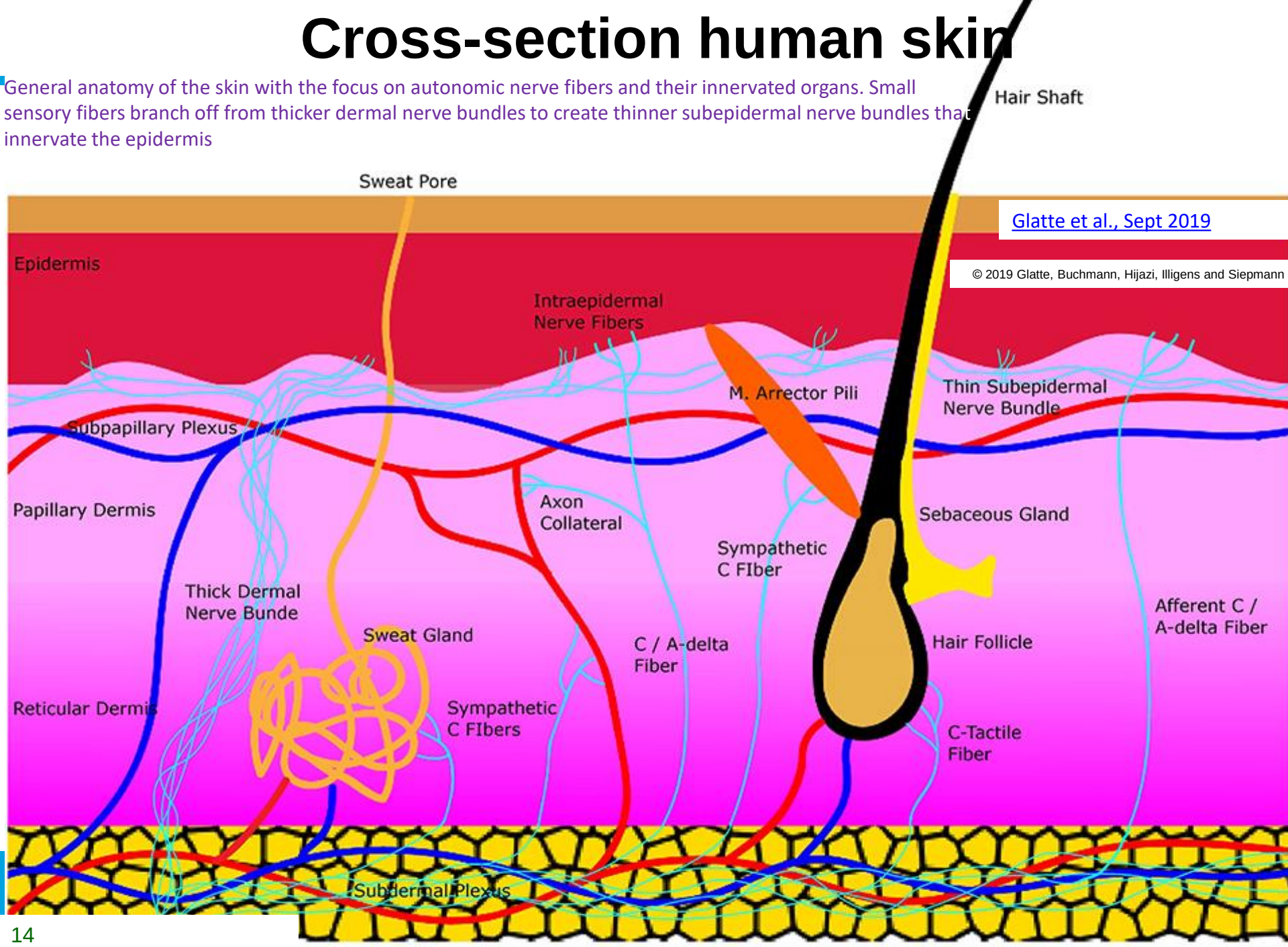
Compliance calculations and some periodic measurements are essential. However:

1. Do we need to make so many nation-wide measurements?

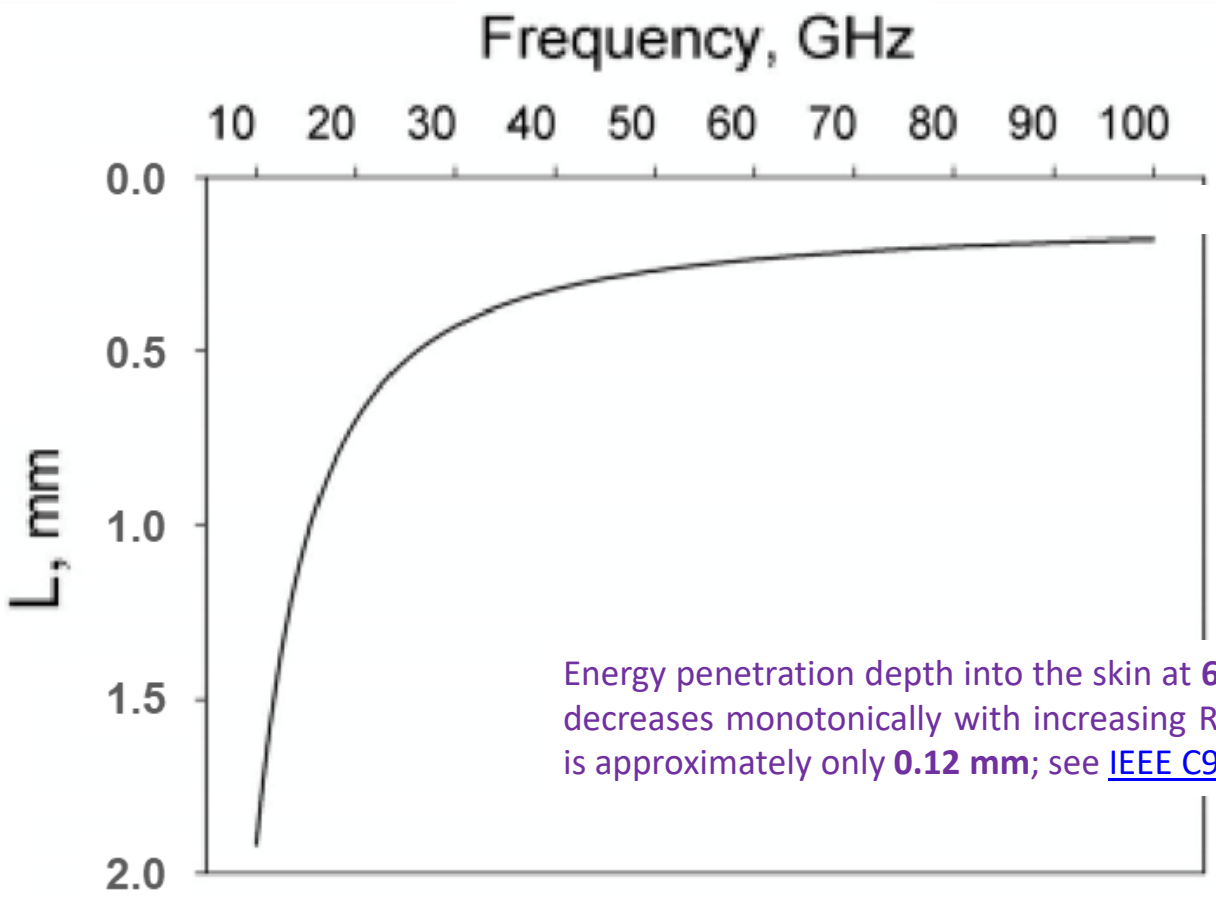
2. Maybe ICNIRP reference levels are too liberal?

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

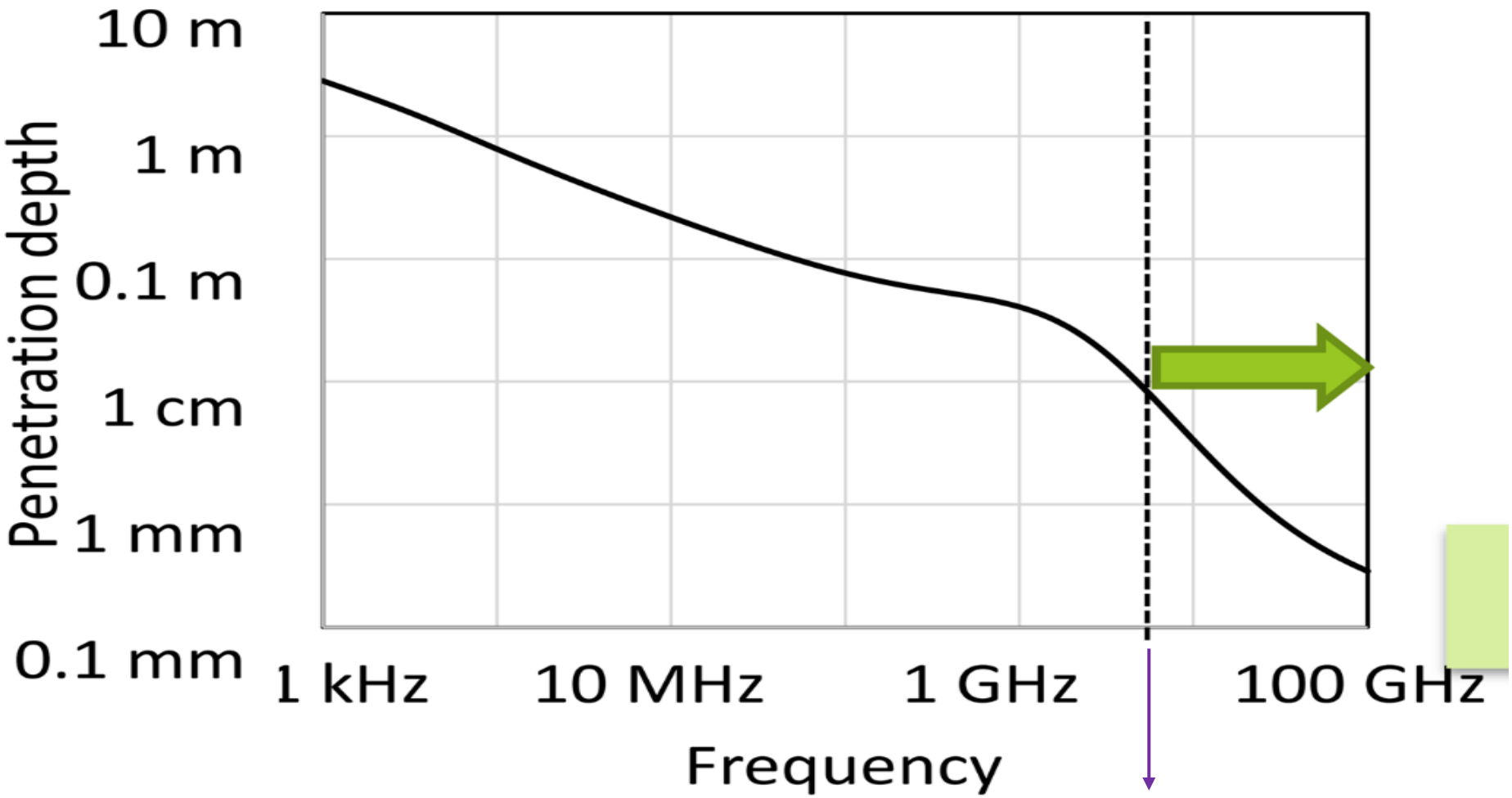


© 2019 Glatte, Buchmann, Hijazi, Illigens and Siepmann

Glatte et al., Sept 2019

Energy penetration depth into the skin at **6 GHz** is approximately **4 mm**; penetration decreases monotonically with increasing RF. At **300 GHz**, energy penetration depth is approximately only **0.12 mm**; see IEEE C95.1-2019 p. 69, A.2.5.4

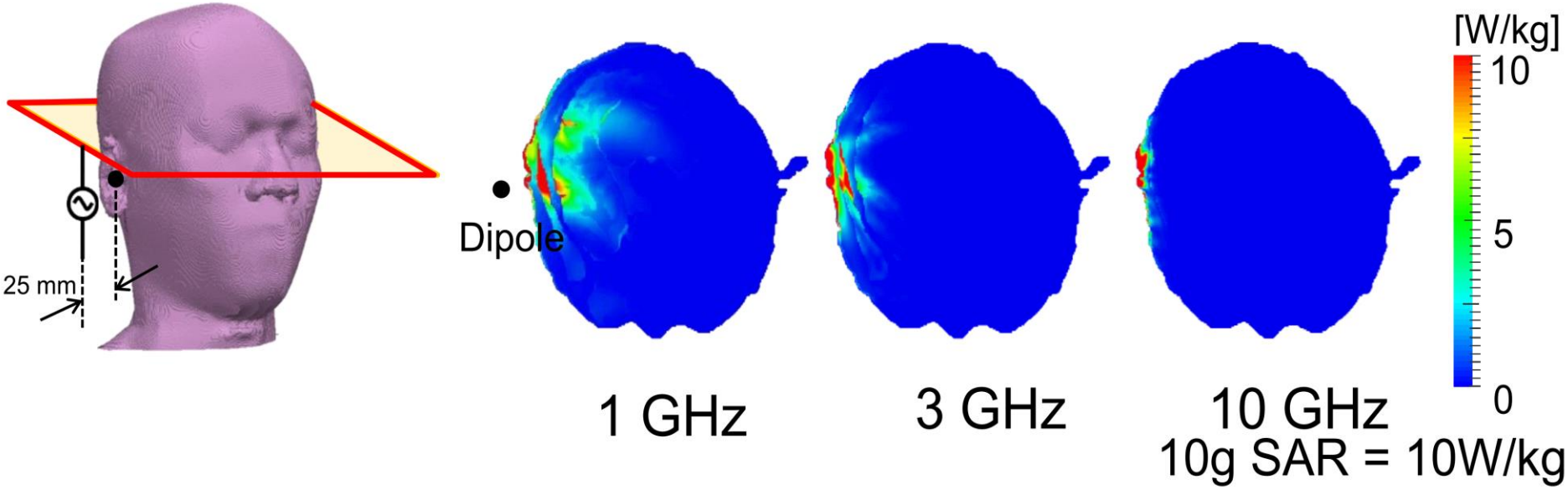
Penetration depth becomes shallower; source, Akimasa Hirata in 5G higher RF



Above 6 GHz, skin surface heating is dominant

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

- Purpose of the guidelines: to protect people exposed to RF electromagnetic fields 100 kHz–300 GHz
- Two types of restrictions (as in next slides see ICNIRP 2020 **Guidelines in brief**; https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html; not from the Guidelines
  - **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

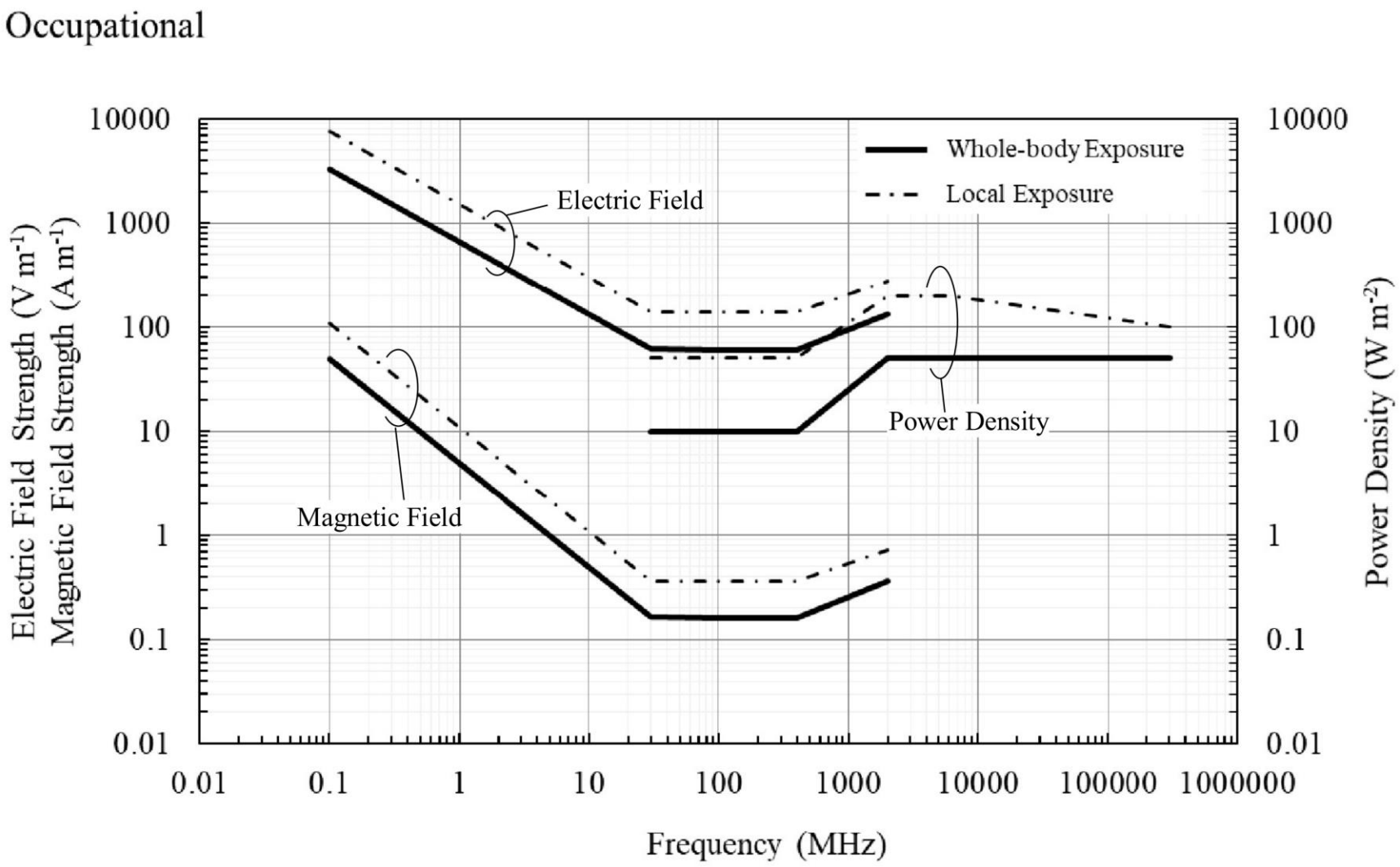
– cancer

– electro-hypersensitivity

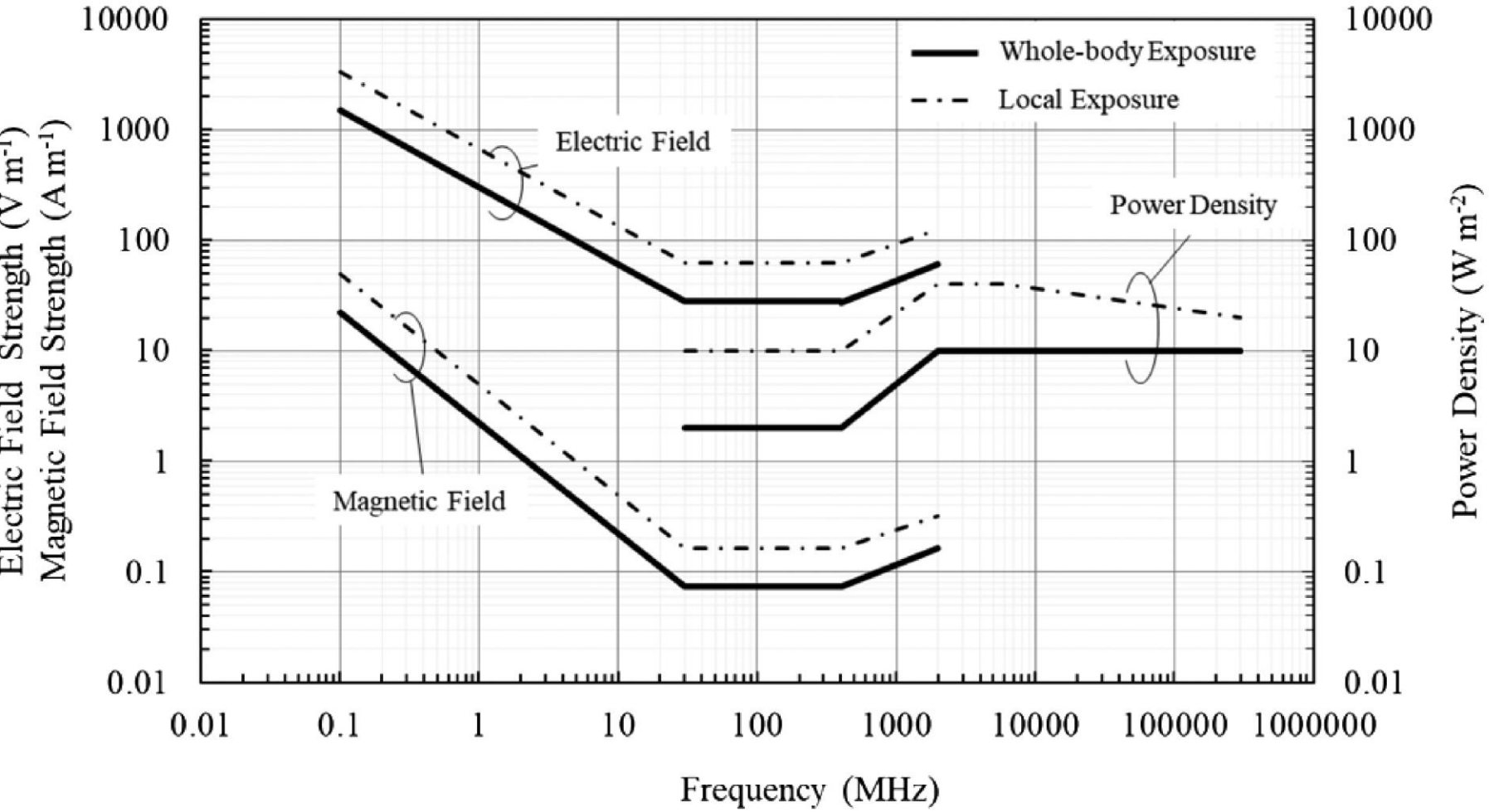
– infertility

– other health effects

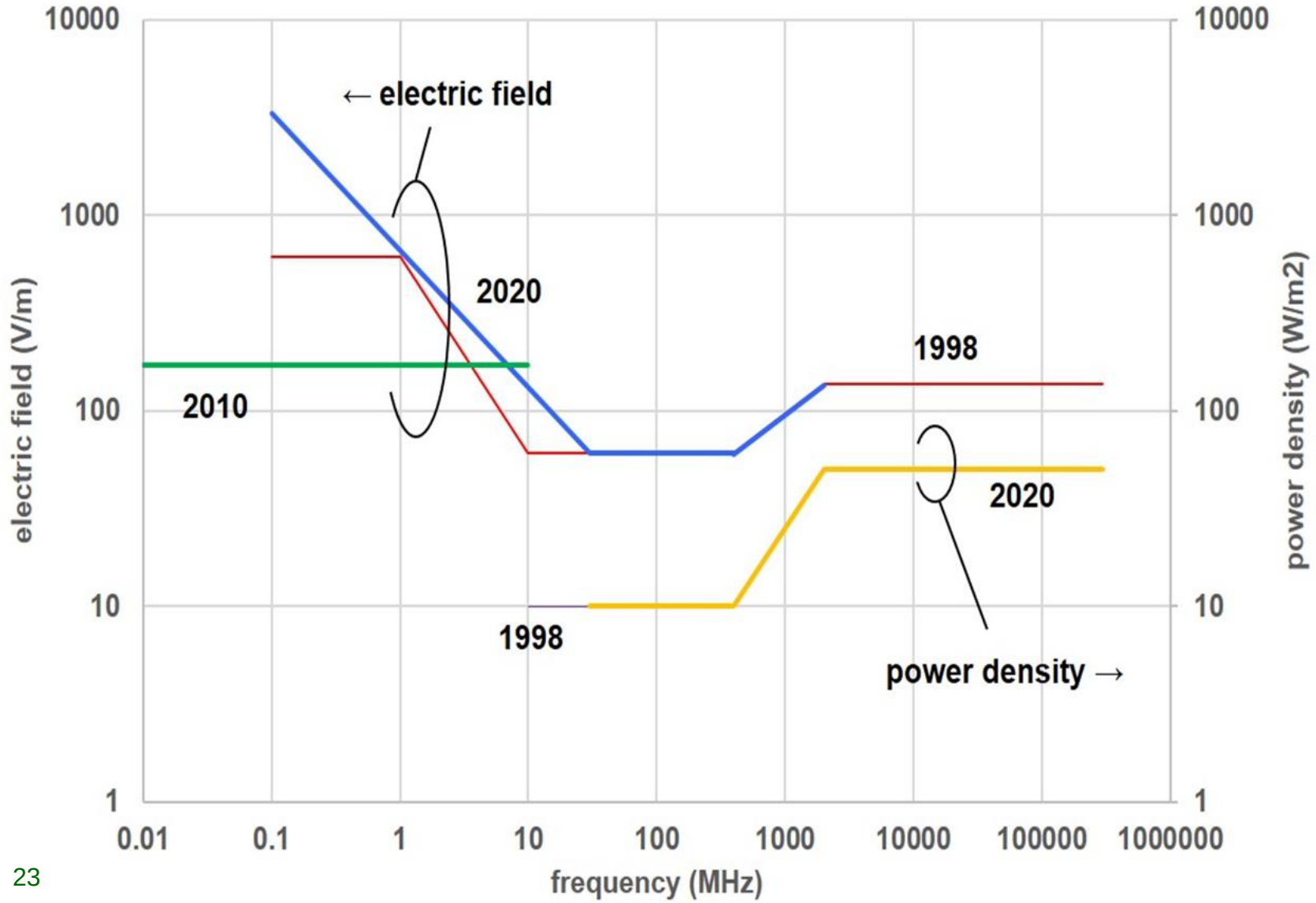
ICNIRP 2020 based on Tables 5 & 6, Fig.1 ***Occupational*** *exposures* **≥ *6 min***



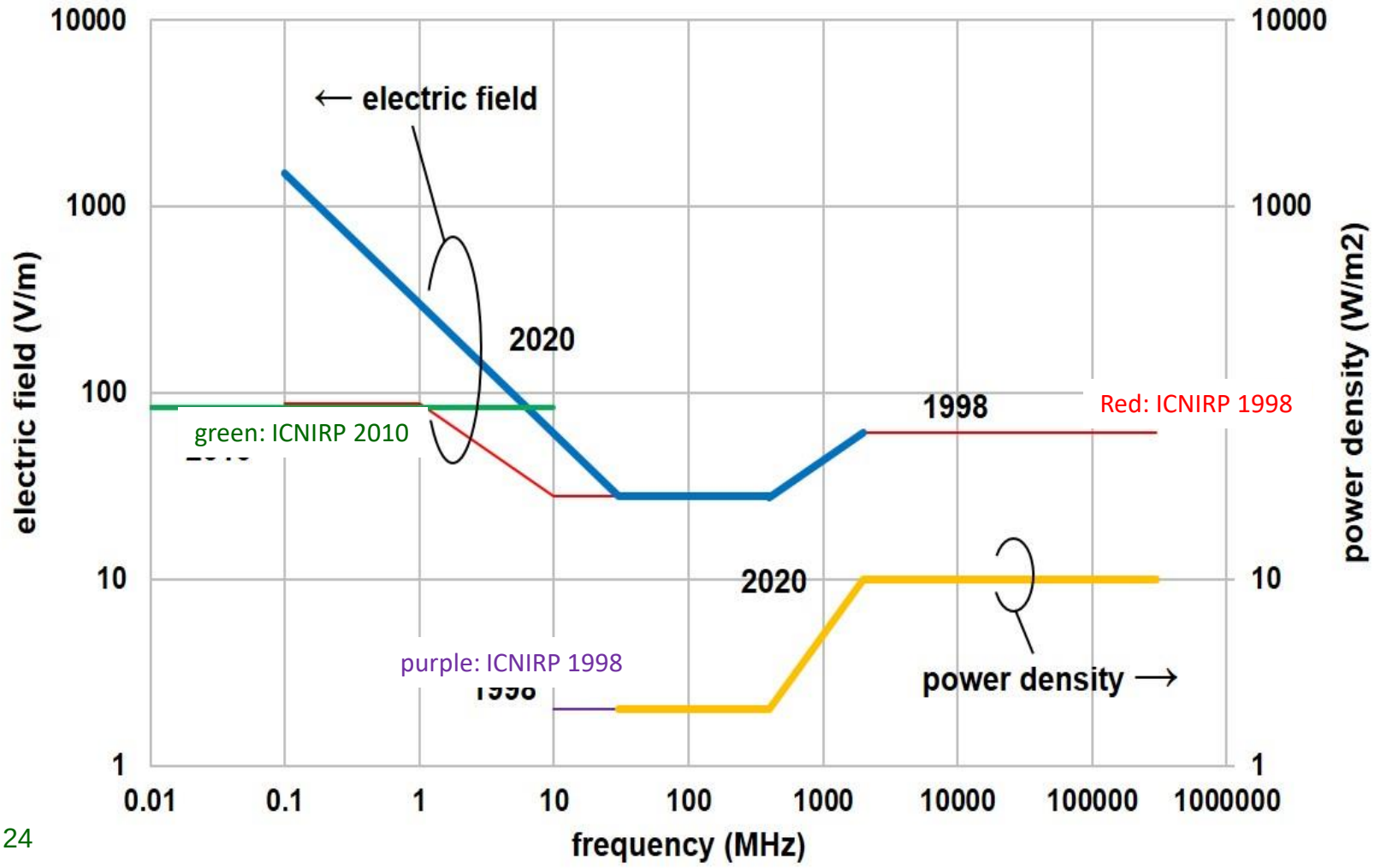
ICNIRP 2020 based on Tables 5 & 6, Fig.2, ***general public*** *exposures ≥6 min*



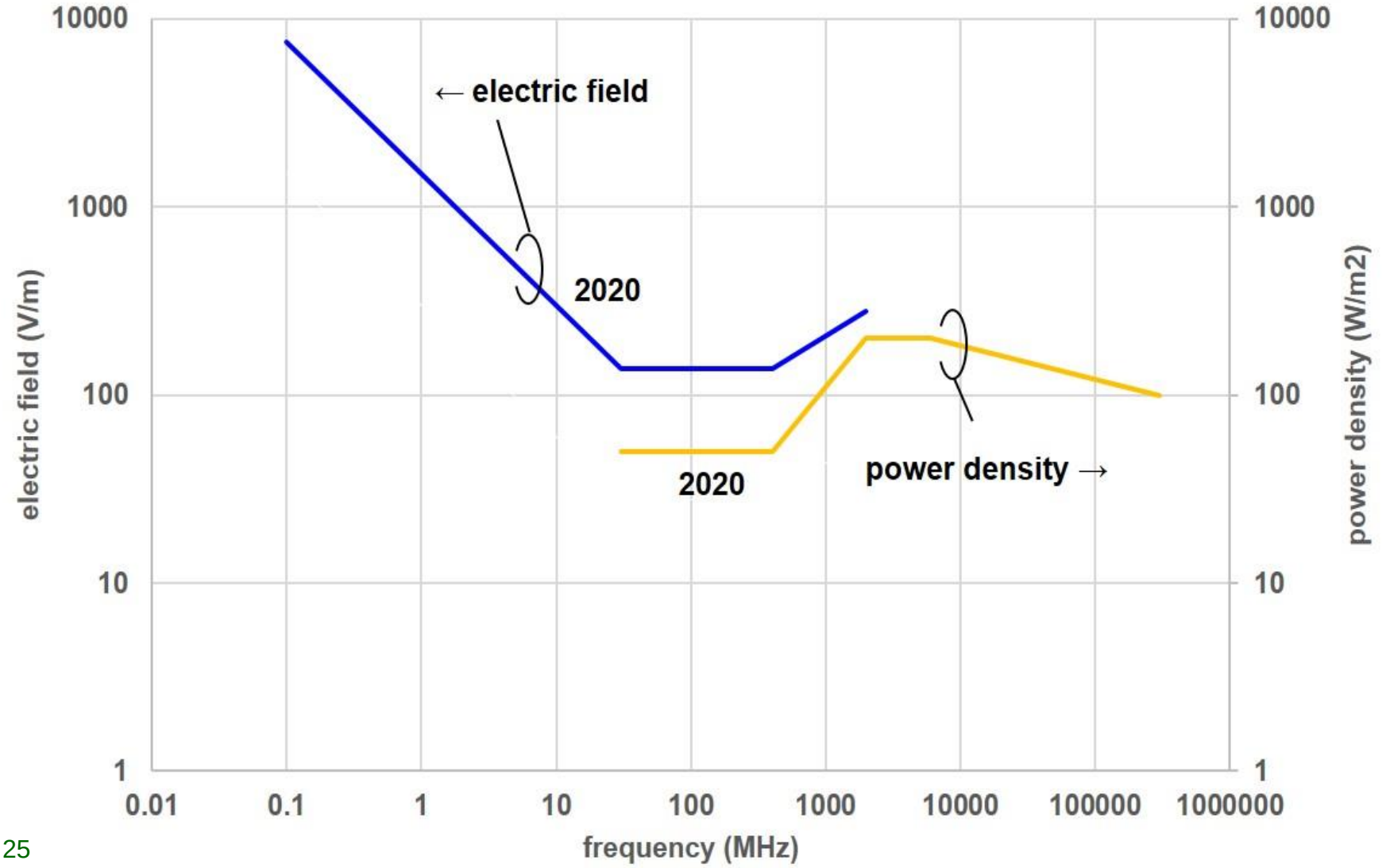
ICNIRP 2020 Web (not Guidelines) Fig.1, **whole-body, occupational, ICNIRP 1998, ICNIRP 2010 & ICNIRP 2020** see ICNIRP 2020 Tables 5 & 6 for full specifications



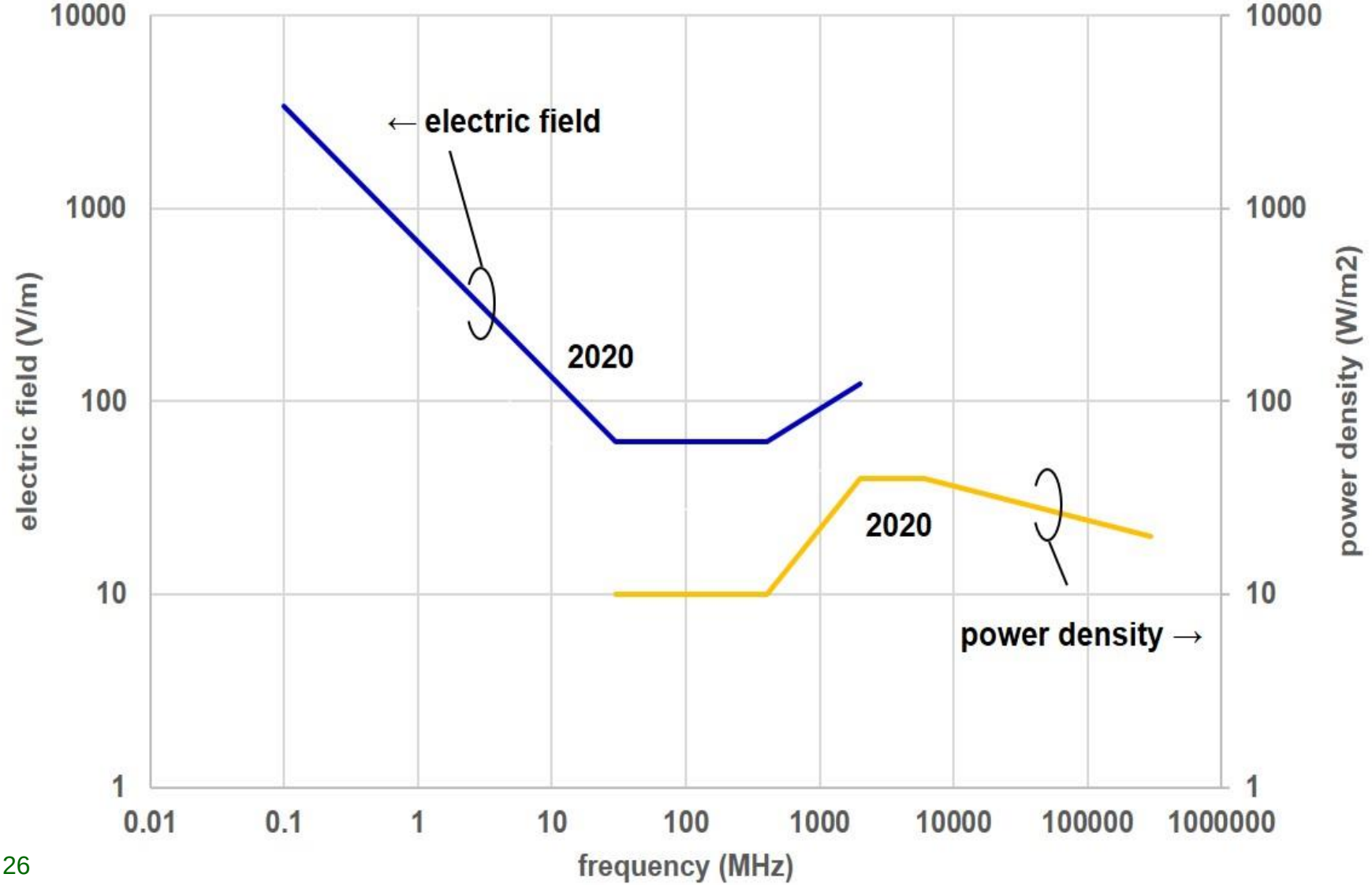
ICNIRP 2020 Web Fig. 2, based on Table 6 the **general public** applying to **whole-body exposures ≥6 min**, for the ICNIRP 2020 guidelines only



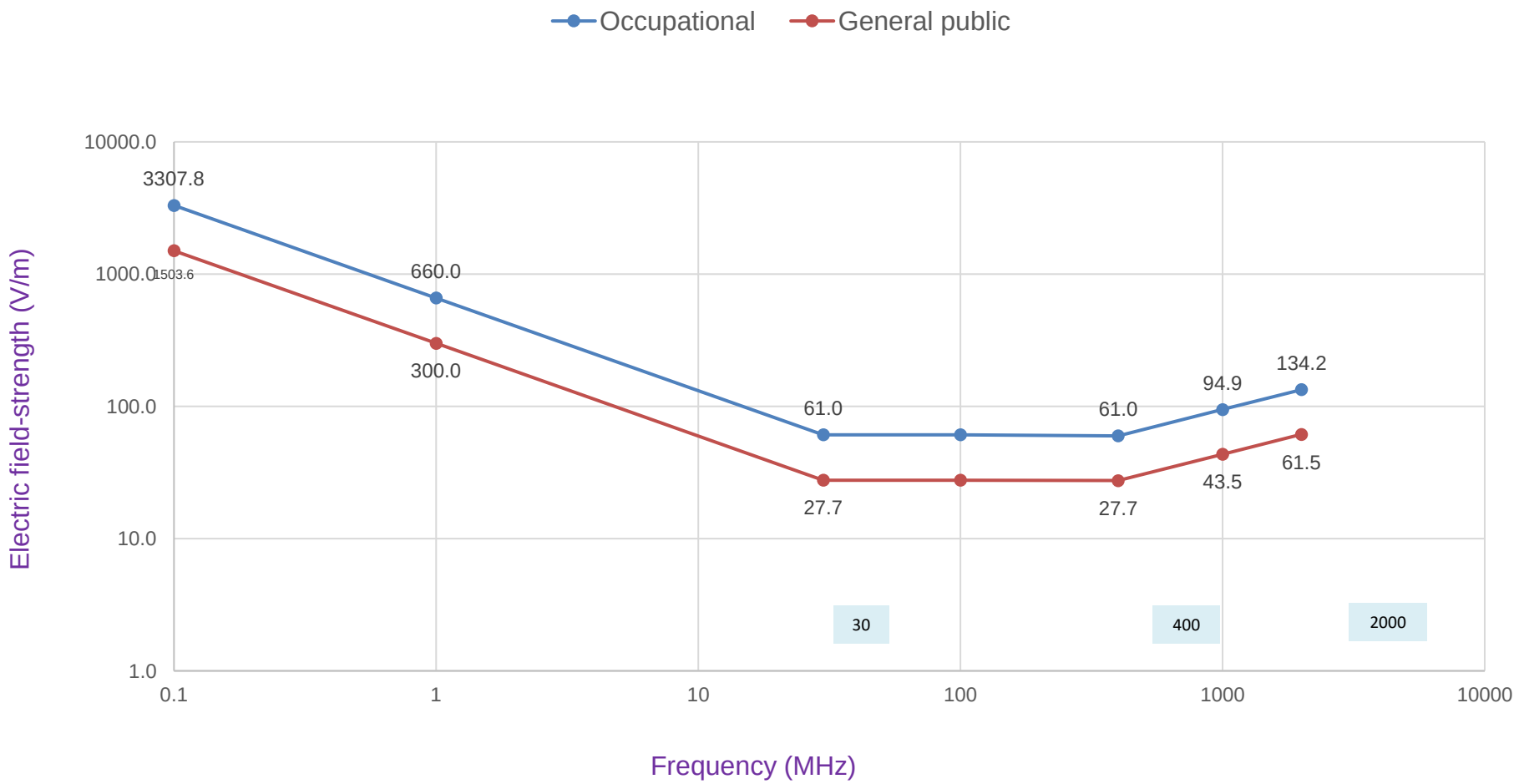
ICNIRP 2020 Web Fig. 3, **occupational, local exposures** of **≥6 minutes**, 100 kHz–300 GHz; see Tables 5 & 6 for full specifications



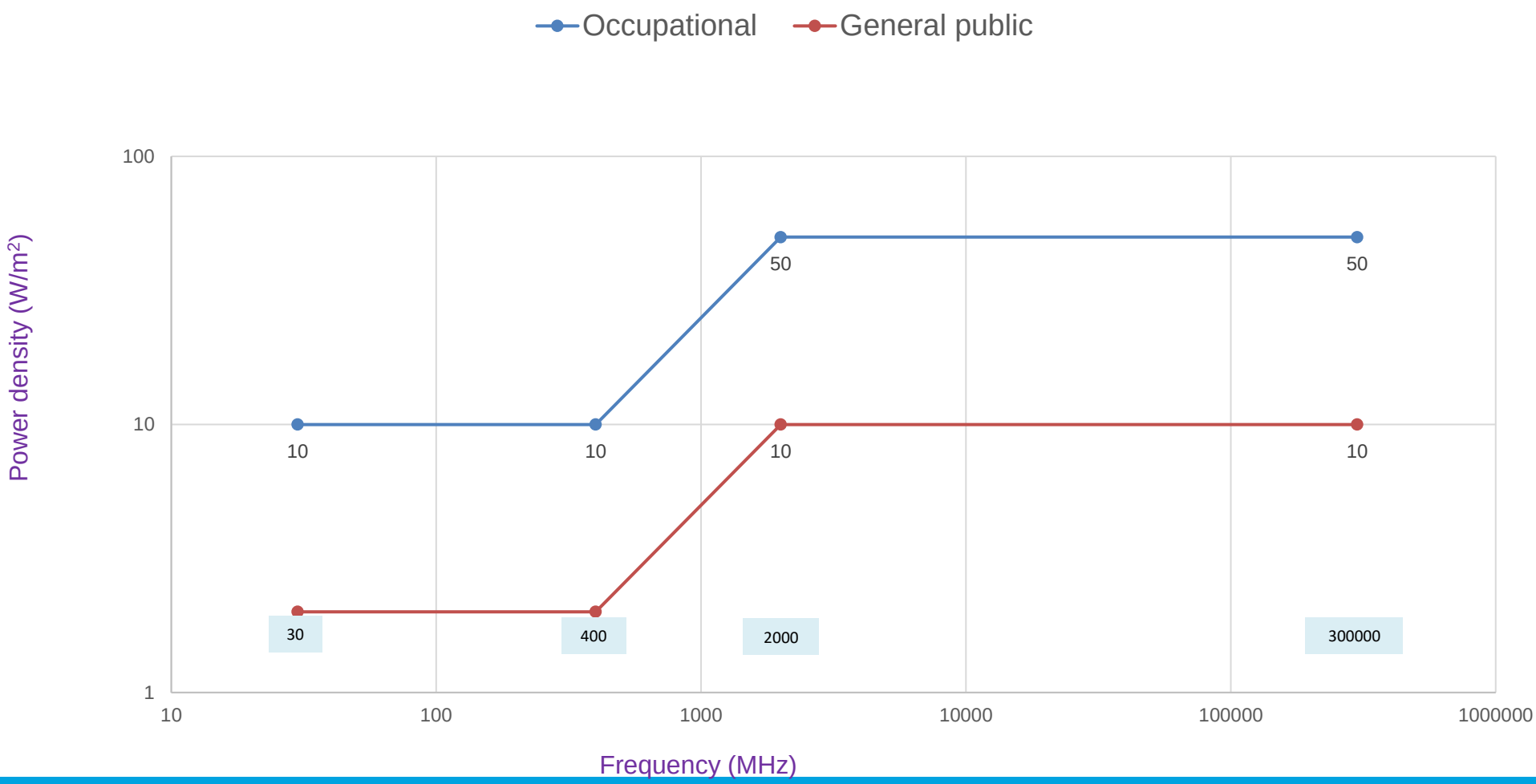
ICNIRP 2020 Web Fig. 4 **general public, local exposures ≥6 min** 100 kHz – 300 GHz



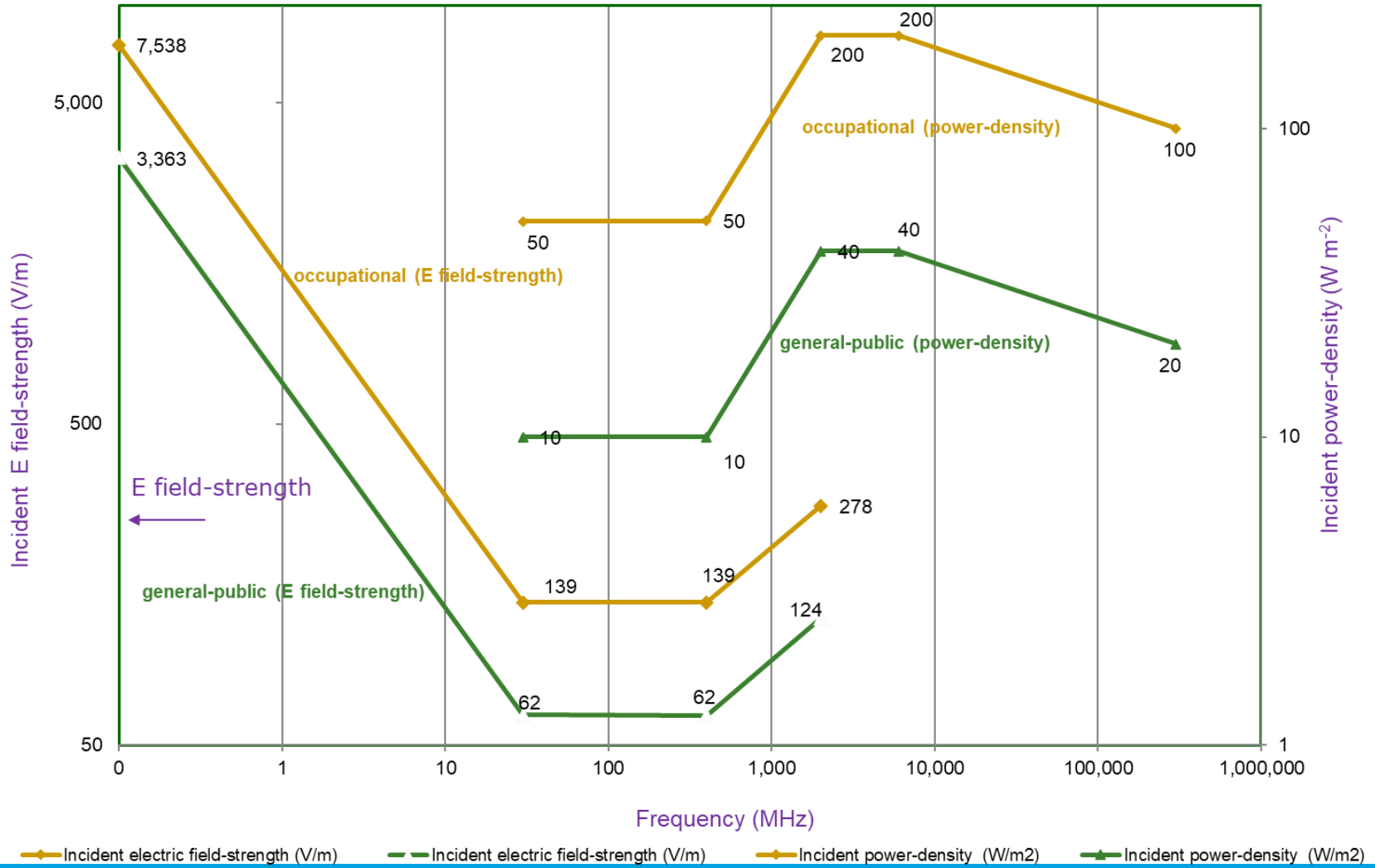
Comparing ICNIRP 2020 **field-strength** for occupational & general-public exposures, **0.1 MHz–2 000 MHz**, based on **Table 5**, p. 495: **averaged over 30 minutes & the whole body** (source, Mazar)



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)

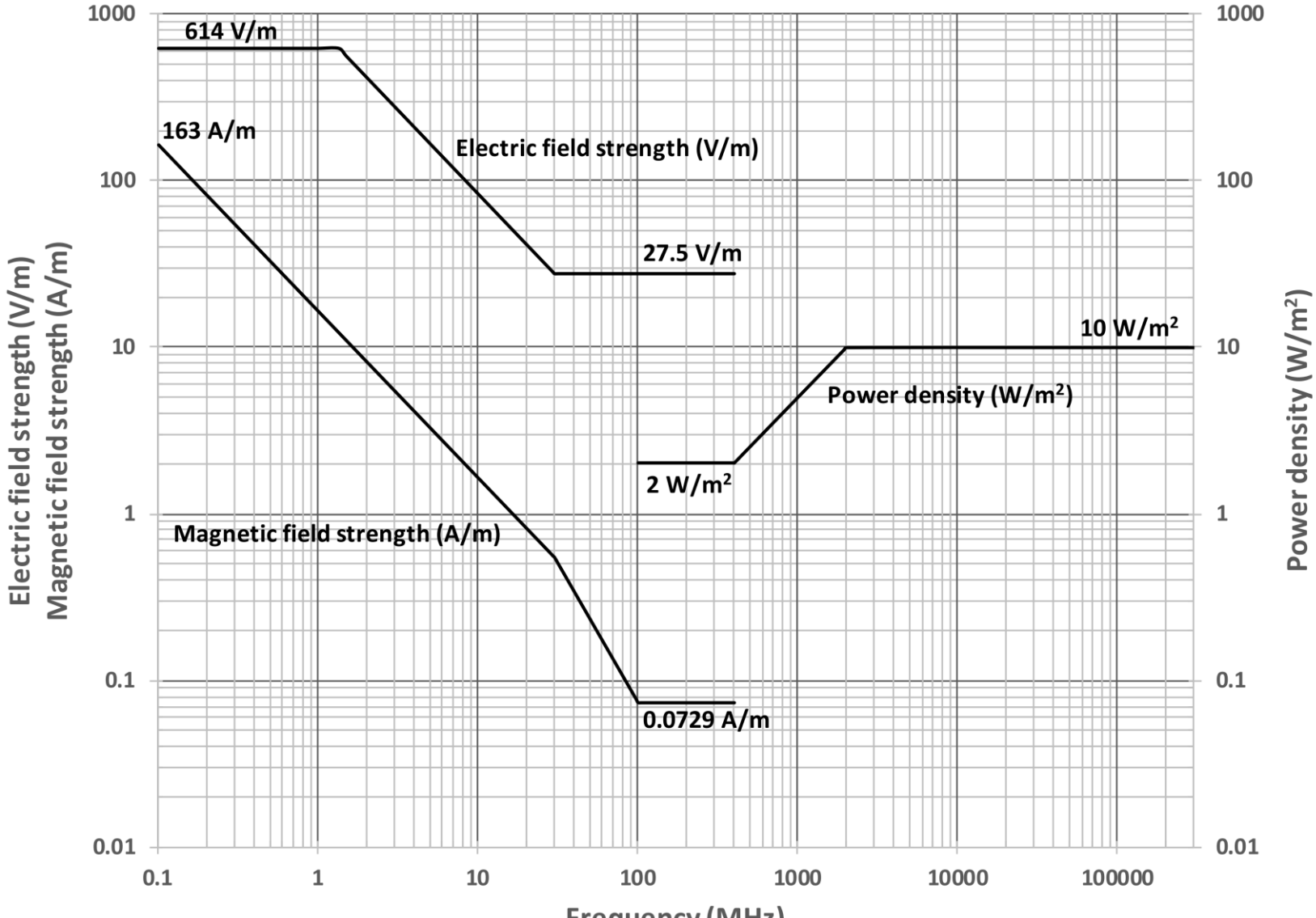


Comparing ICNIRP 2020 incident electric field-strength & power-density for occupational & general-public exposures, 100 kHz–300 GHz, see **Table 6**, p. 496: **local exposure, averaged over 6 minutes** (source, Mazar)

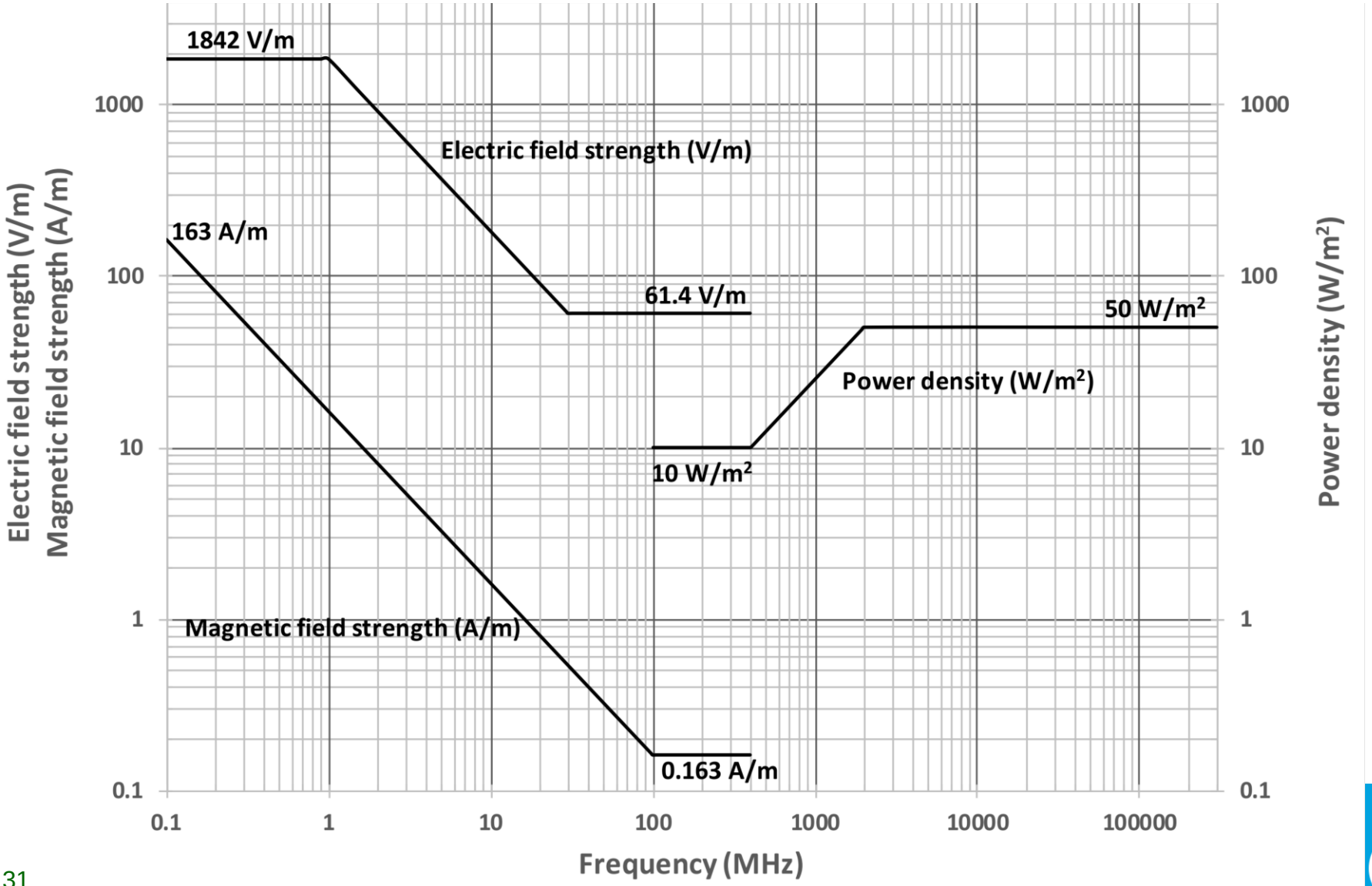


Note: the unit of the figure's left-side is electric field-strength V/m, & the right-side is W/m^2 power-density

IEEE C95.1-2019 Fig. 3: Graphical representations of the ERLs in Table 7 for electric & magnetic fields & plane-wave-equivalent power density—Persons in unrestricted environments

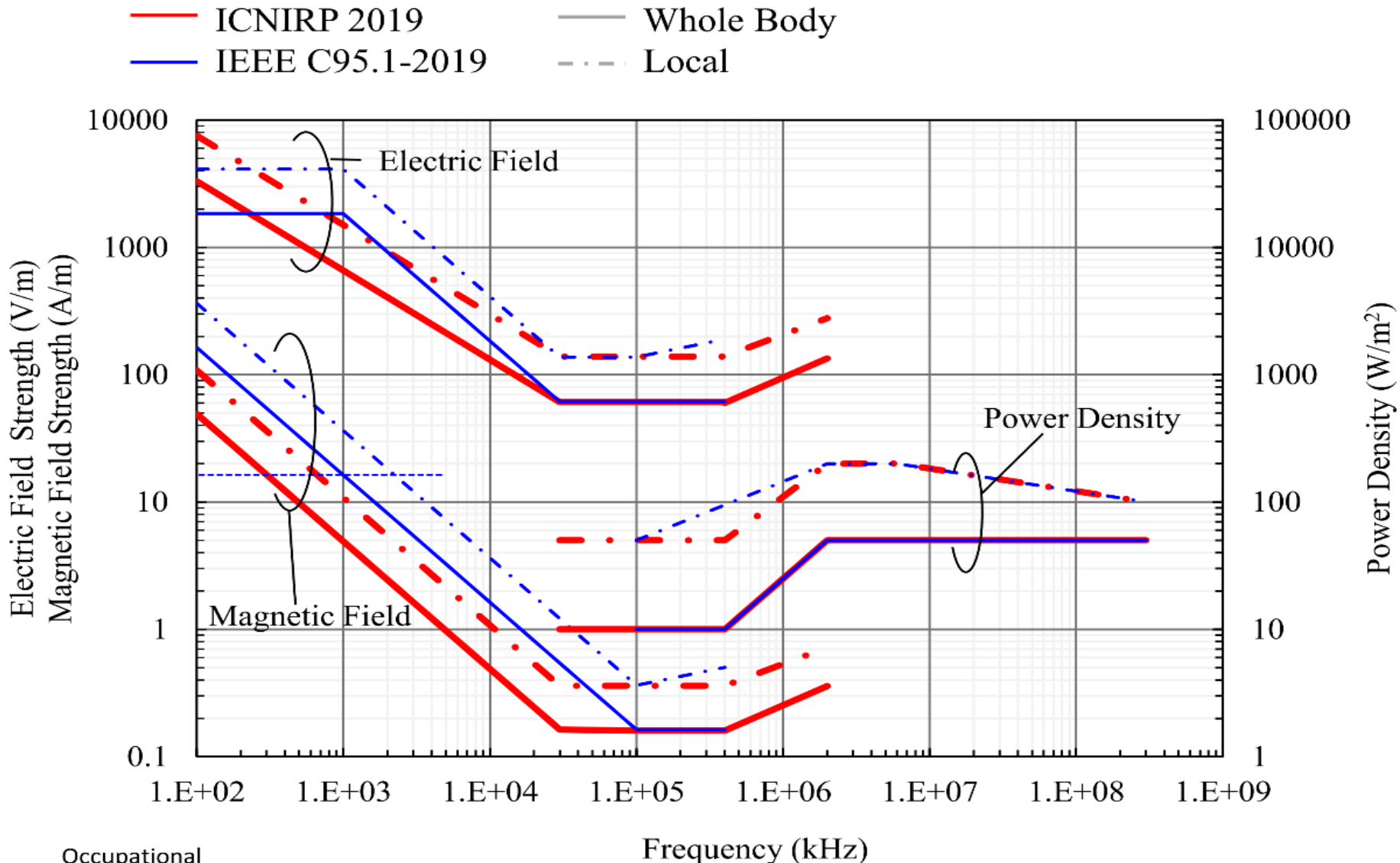


IEEE C95.1-2019 Fig. 4: Graphical representations of the ERLs in Table 8 for electric and magnetic fields and plane-wave-equivalent power density—Persons permitted in restricted environments



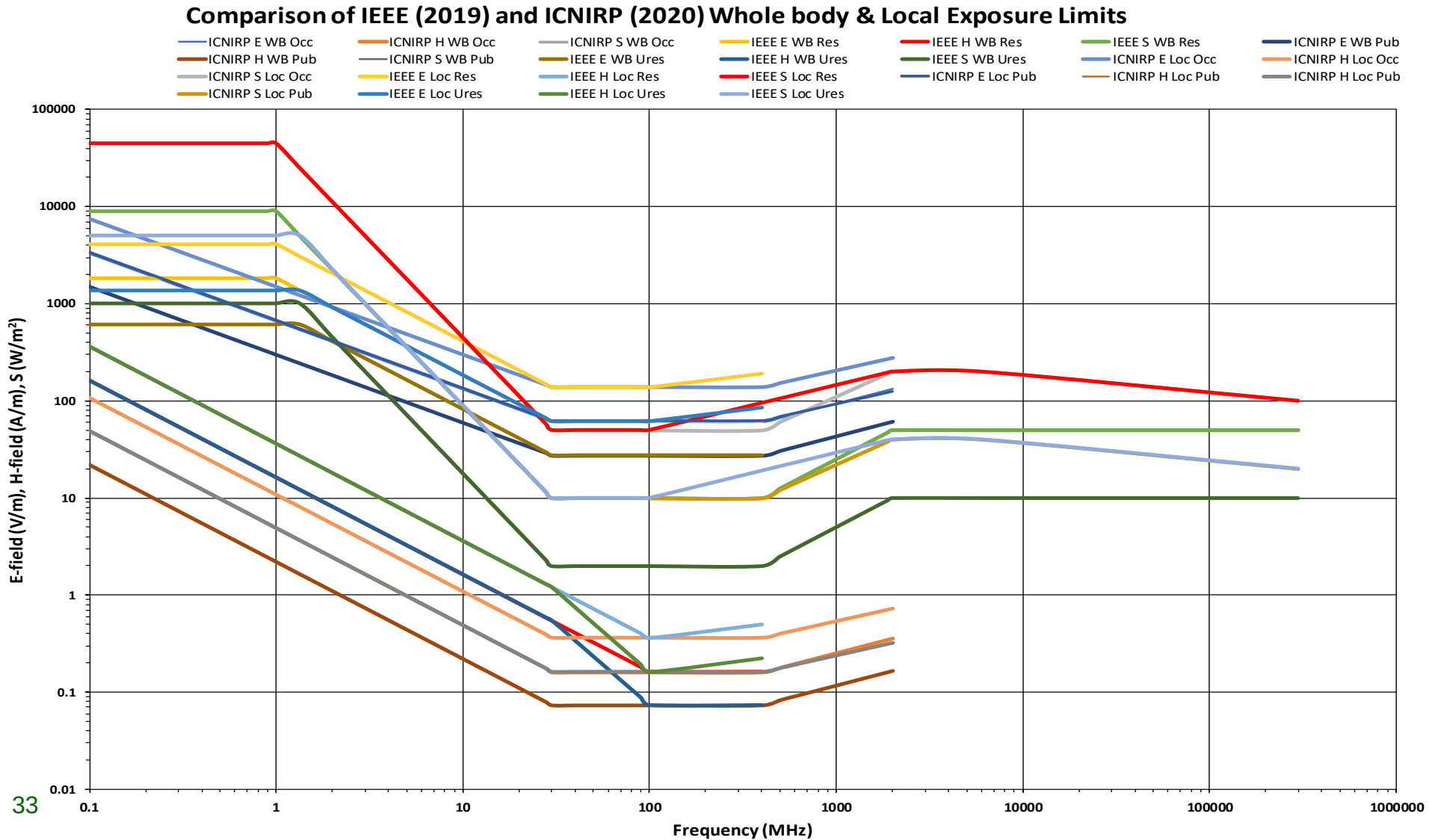
Akimasa **Hirata**, Keynote-speaker, EMC Europe 2020 open-session 23 Sept. 2020

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

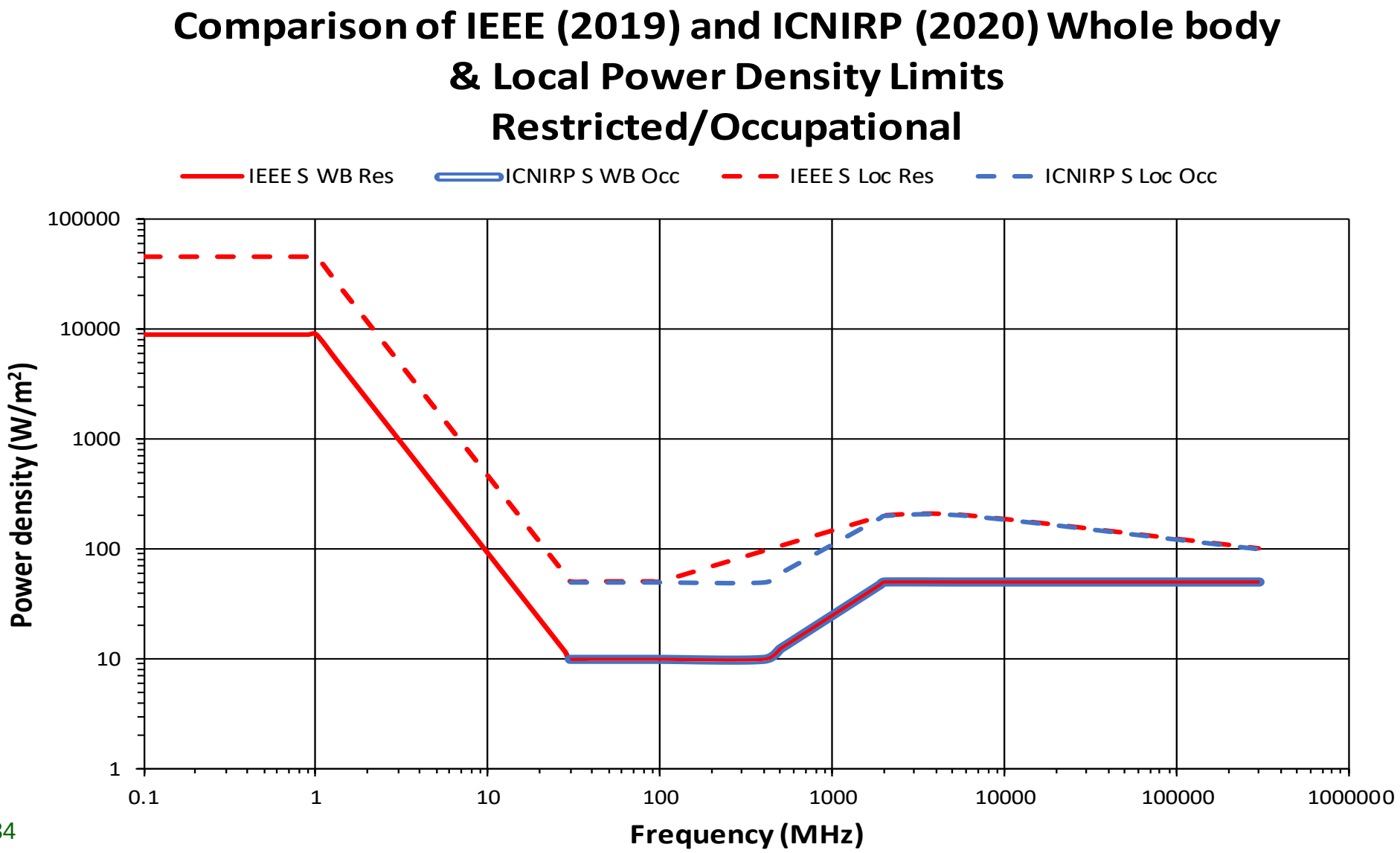


Occupational

source, IEEE/ICES Ric Tell, 4 June 2020)

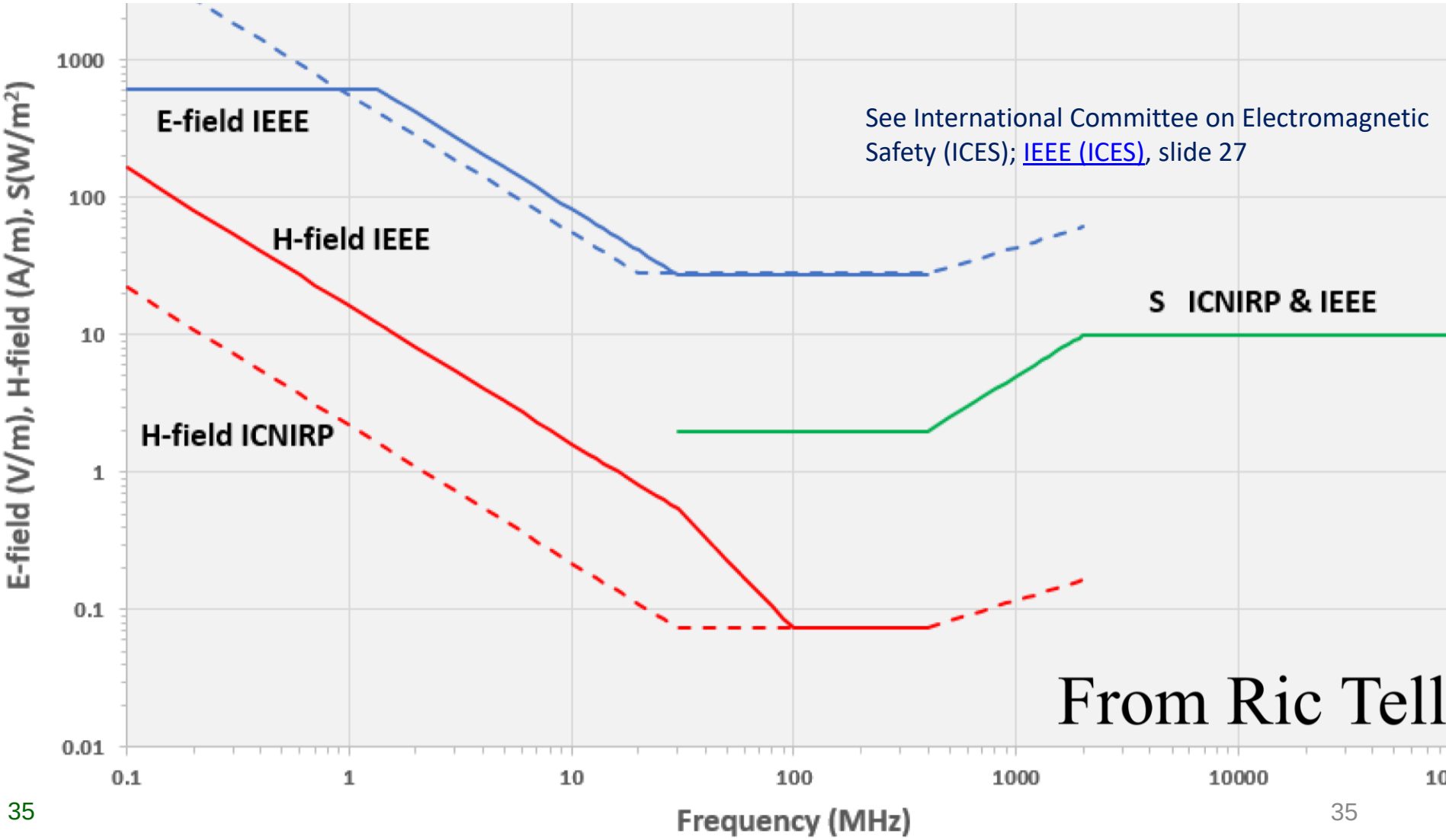


source, IEEE/ICES Ric Tell, 4 June 2020)



IEEE/ICNIRP differences in limits general public/ unrestricted environment

power-densities above 30 MHz are identical (also to ICNIRP 1998)

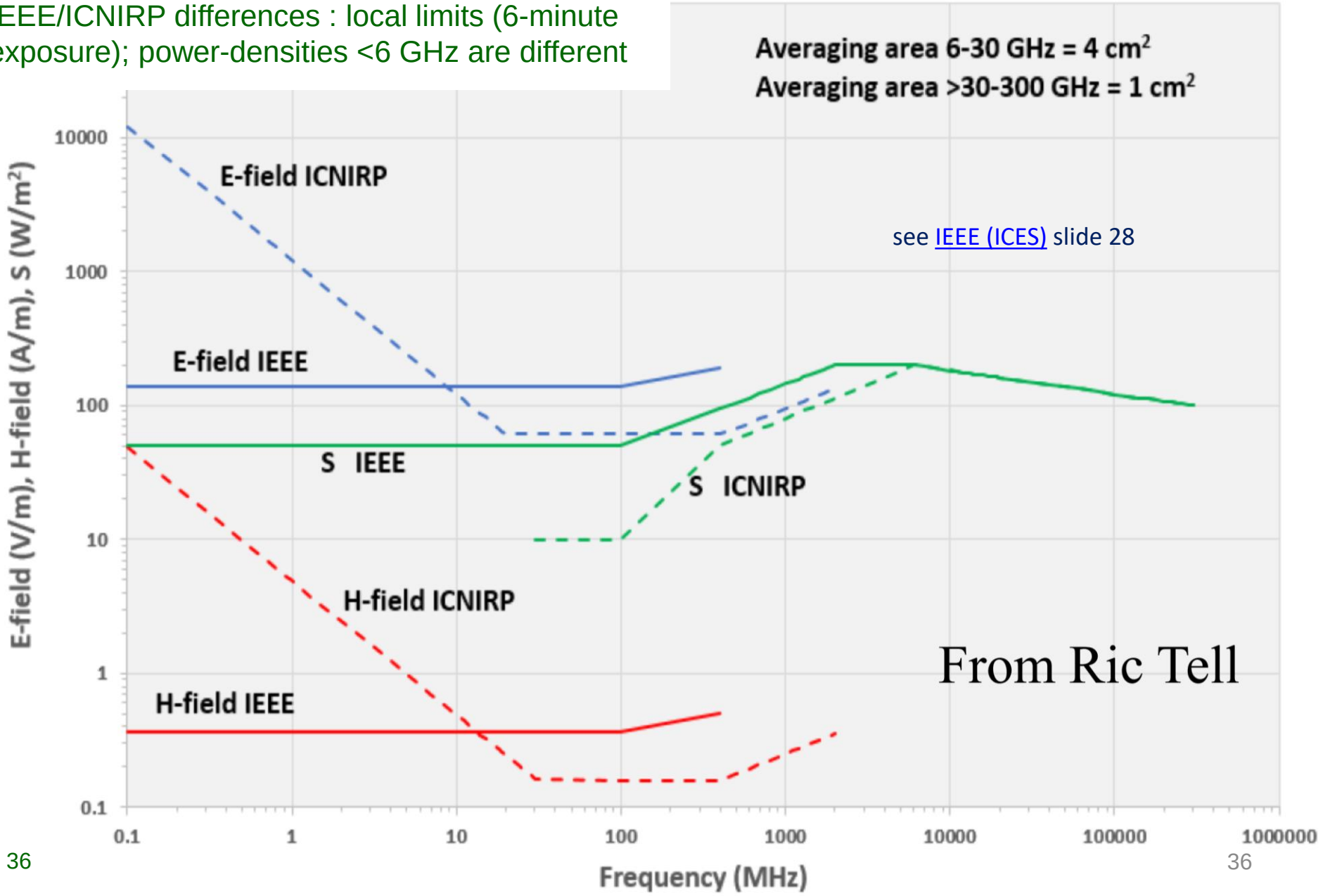


See International Committee on Electromagnetic Safety (ICES); IEEE (ICES), slide 27

From Ric Tell

35

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



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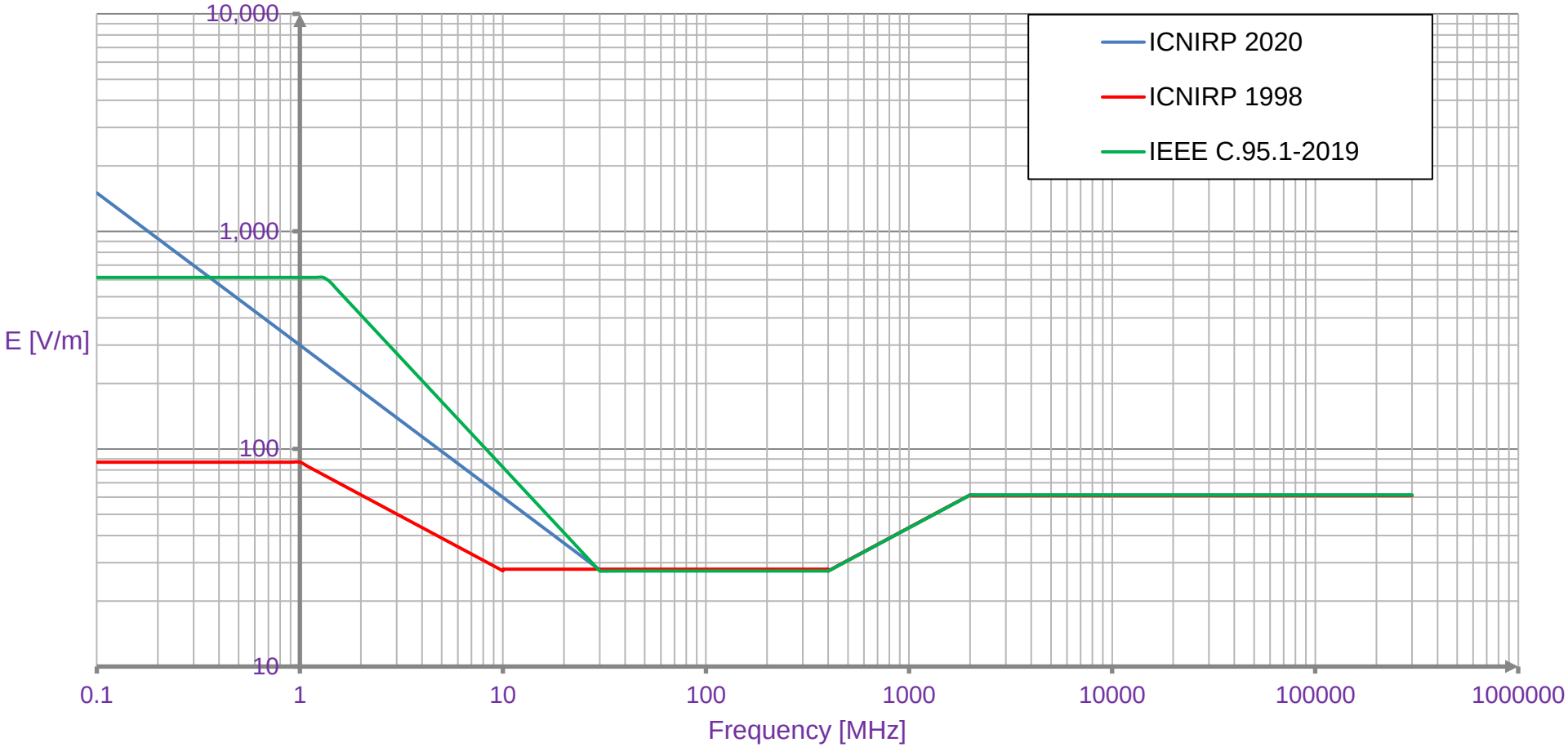
Reference exposure levels general-public (V/m, also above 400 MHz)



Source, Spectrum Management & Broadcasting 02 July 2020,
Dr. Lewicki Fryderyk, Electromagnetic Fields and 5G Implementation

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

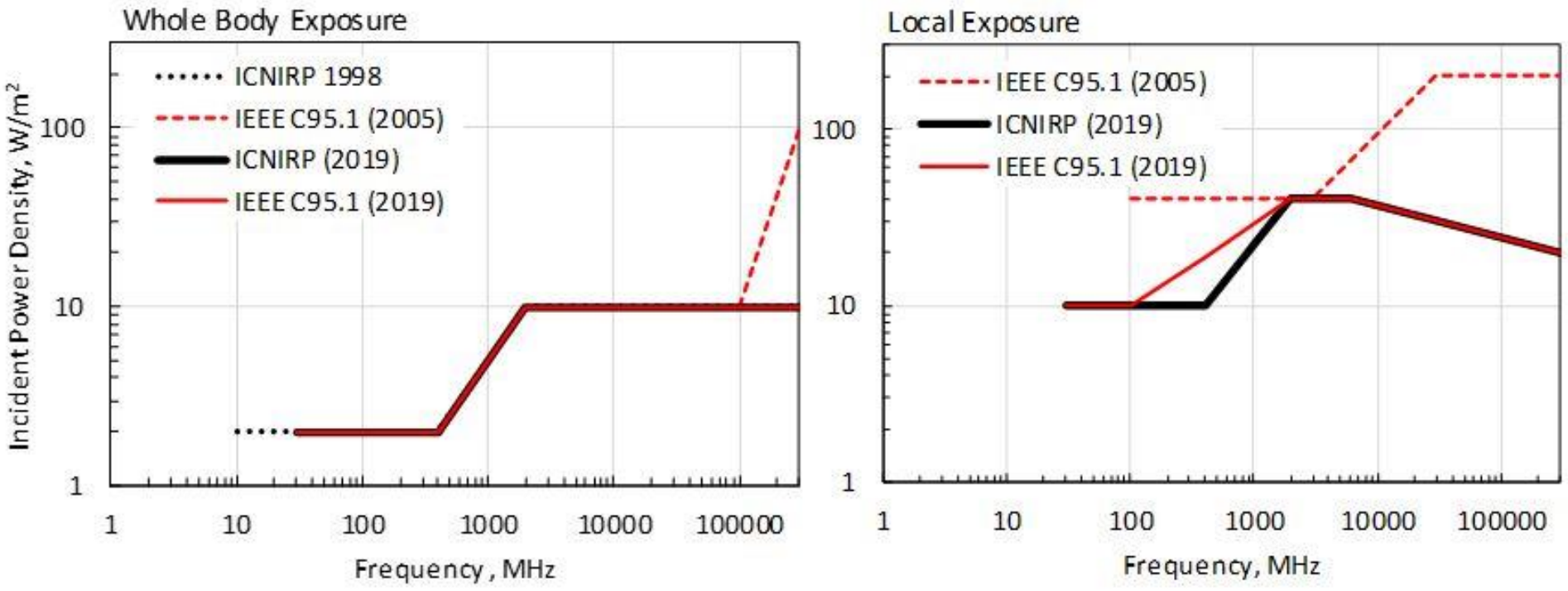
	Frequency range	Incident power density	Averaging area	Averaging time
ICNIRP (1998)	2-10 GHz	10 W/m²		6 min
	10-300 GHz	10 W/m² (200 W/m²)	20 cm² (1 cm²)	Decrease from 6 min to 10 s
IEEE (2005)	Whole Body Exposure			
	5-30 GHz	10 W/m²	100 λ^2 *	Decrease from 30 min to 5 min
	30-100 GHz	10 W/m²	100 cm²	Decrease from 5 min to 2.8 min
	100-300 GHz	Increase from 10 W/m² to 100 W/m²	100 cm²	Decrease from 2.8 min to 10 s
	Local Exposure			
	3-30 GHz	Increase from 40 W/m² to 200 W/m²	peak	Decrease from 30 min to 5 min
	30-300 GHz	200 W/m²		Decrease from 5 min to 10 s
ICNIRP (2019)	Whole Body Exposure			
	2-300 GHz	10 W/m²		30 min
	Local Exposure			
	6-300 GHz	Decrease from 40 W/m² to 20 W/m²	4 cm²	6 min
	30-300 GHz	Decrease from 60 W/m² to 40 W/m²	1 cm²	6 min
IEEE C95.1 (2019)	Whole Body Exposure			
	2-300 GHz	10 W/m²		30 min
	Local Exposure			
	6-300 GHz	Decrease from 40 W/m² to 20 W/m²	4 cm²	6 min
	30-300 GHz	Decrease from 60 W/m² to 40 W/m²	1 cm²	6 min

* λ means the free space wavelength

ICNIRP vs IEEE Limits for general public (lower tier)

Source 5G Comms Systems and RF Exposure Limits; IEEE Future Net. Tech Focus, Volume 3, Issue 2, Sept. 2019; Dr. Akimasa **Hirata** et al..

ICNIRP vs IEEE: exposure reference levels for general public



Source 5G Communications Systems and Radiofrequency Exposure Limits; IEEE Future Net. Tech Focus, Volume 3, Issue 2, September 2019; Dr. 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 30 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 W/m²** for general-public & **f_M/40 W/m²** for occupational
      - **2000 to 300 000 MHz 10 W/m²** for general-public & 50 W/m² for occupational

Mitigation techniques to decrease the 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 the radiation level (2)

- **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)
- **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)
- **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)
- **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

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?'

- **Other 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
9) 2020 IEEE Israel Conference on Electromagnetic Compatibility (EMC), 15 Oct. 2020; Updated Human Exposure Standards IEEE 2019 and ICNIRP 2020, towards 5G applications

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