Ministerstwo Cyfryzacji

Ministerstwo Zdrowia
Patronat Honorowy Ministra Zdrowia

MINISTERSTWO KLIMATU

National Institute of Telecommunications

IV International Conference

Electromagnetic field
and the future of telecommunication

Research. Monitoring. National and international experience.

EMF, New ICNIRP Guidelines and IEEE C95.1-2019 Standard: Differences and Similarities

International Conference: EMF and the Future of Telecommunications

3-4 December, 2019

ATDI ADVANCED SPECTRUM SOFTWARE 30 YEARS OF EXPERIENCE

Dr. Haim Mazar (Madjar); h.mazar@atdi-group.com re-elected vice-chair ITU-Radio Study Group 5 (terrestrial services)
ITU, inter-sector officer on EMF

ITU International Telecommunication Union

Background: Main Existing ICNIRP Guidelines and IEEE Standards

International Commission on Non-ionizing Radiation Protection (ICNIRP); Institute of Electrical and Electronics Engineers (IEEE)

1. C95.6- 2002 IEEE Std 'Safety Levels, exposure to EMF, 0 – 3 kHz'
2. C95.1-2005 IEEE 'Safety Levels, exposure to RF-EMF, 3 kHz – 300 GHz'
3. C95.1-2019 IEEE 'Safety Levels, exposure to EMF, 0 Hz – 300 GHz'
4. ICNIRP 1998 Guidelines for limiting exposure to EMF up to 300 GHZ
5. ICNIRP 2010 Guidelines for limiting exposure to EMF 1 Hz –100 kHz

The EMF limits at ICNIRP 1998 and C95.1-2005 are similar

15 Oct 2019 C95.1-2019 Std revises & combines Stds IC95.1-2005 & C95.6-2002 into a single standard; changes on exposure above 6 GHz/10 GHz

ICNIRP will soon publish its Guidelines. Among other 32 comments, ITU proposed to ICNIRP to combine ICNIRP 1998 and ICNIRP 2010

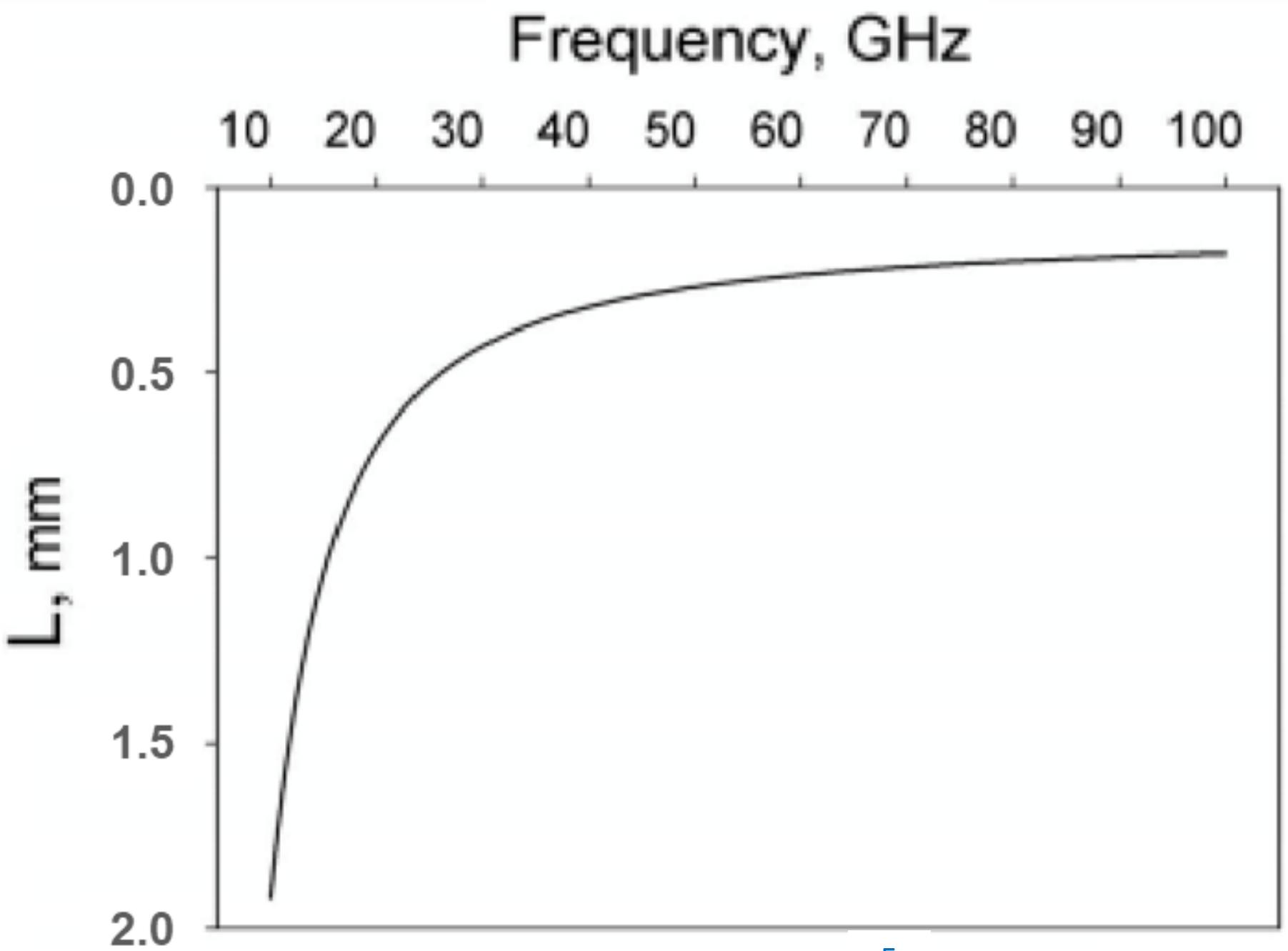
C95.1-2019 Purpose

Purpose : to provide science-based exposure criteria to protect against established adverse health effects in humans associated with exposure to EMF; induced and contact currents; and contact voltages, over the frequency range of 0 Hz to 300 GHz

C95.1-2019 Introduction

IEEE does not waive any rights in copyright to the documents

1. For exposures above 6 GHz, the energy is absorbed close to the body surface
2. The energy penetration depth into the skin at 6 GHz is ~ 4 mm, and the penetration decreases monotonically with increasing frequency. At 300 GHz, the energy penetration depth is ~ only 0.12 mm; (see next slide)
3. Due to different biological effects of exposure to particular frequencies, the standard addresses three bands: 0 Hz-100 kHz, 100 kHz - 6 GHz, and 6 - 300 GHz
4. C95.1-2005 was based primarily on research published before 2003; and RF biological effects databases was necessary for this revision
5. IEEE and ICNIRP agree that thermal effects continue to be the appropriate basis for protection against RF exposure at frequencies above 100 kHz



mmWaves mostly absorbed in outer skin layers

Glatte et al., Sept 2019

Updated IEEE C95.1-2019 reference levels: Safety factors applying 100 kHz- 6 GHz Thermal Effects

1. Whole body averaged (WBA)
   Behavioral effects in animals over many frequencies, threshold at 4 W/kg
   10x - 0.4 W/kg for upper tier (controlled environment)
   50x - 0.08 W/kg for lower tier (general public)

2. Localized exposure (averaged in 10 g)
   Cataract observed in rabbits, threshold at 100 W/kg
   10x - 10 W/kg for upper tier
   50x - 2 W/kg for lower tier

3. SAR is averaged over 30 min for WBA exposure and 6 min for local exposure

4. Epithelial power density through body surface is averaged over 6 min

IEEE C95.1-2019 Table 5—DRLs (100 kHz to 6 GHz)

Thermal Effects

Conditions	Persons in **unrestricted** environments SAR (W/kg)	Persons permitted in **restricted** environments SAR (W/kg)
Whole-body exposure	0.08	0.4
Local exposure (head and torso)	2	10
Local exposure (limbs and pinnae)	4	20

DRL: Dosimetric Reference Limits

IEEE C95.1-2019 Table 6—DRLs (6 GHz to 300 GHz) Thermal Effects

Conditions	Epithelial power density (W/m^2)	
	Persons in **unrestricted** Environments	Persons permitted in **restricted** environments
Body surface	20	100

DRL: Dosimetric Reference Limits

IEEE C95.1-2019 Table 7—ERLs for whole-body exposure of persons in unrestricted environments (100 kHz to 300 GHz)

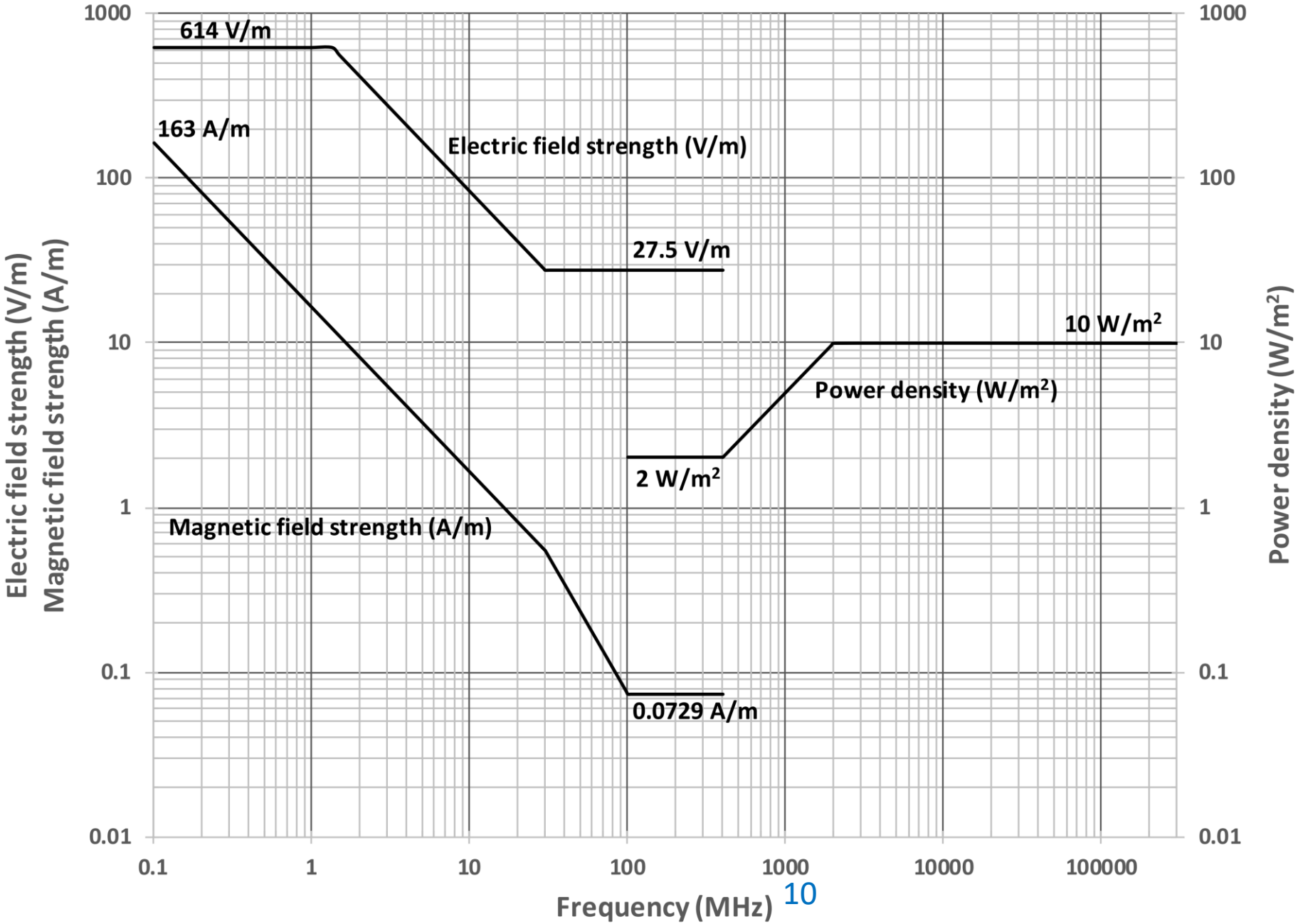
Thermal Effects

Frequency range (MHz)	Electric field Strength (E)[a,b,c] (V/m)	Magnetic field strength (H)[a,b,c] (A/m)	Power density (S)[a,b,c] (W/m²)		Averaging time (min)
			S_E	S_H	
0.1 to 1.34	614	$16.3/f_M$	1000	$100\,000\ f_M^2$	30
1.34 to 30	$823.8/f_M$	$16.3/f_M$	$1800 / f_M^2$	$100\,000 / f_M^2$	
30 to 100	27.5	$158.3/f_M^{1.668}$	2	$9\,400\,000 / f_M^{3.336}$	
100 to 400		0.0729	2		
400 to 2000			$f_M/200$		
2000 to 300 000			10		

exposure reference levels (ERLs)

At low frequencies (e.g., 1 MHz) the wavelength is high (300 m.),
so only part of the signal's energy heats our body

IEEE C95.1-2019 Fig. 3: Graphics of ERLs in Table 7, EMF & plane-wave-equivalent power density, unrestricted environments



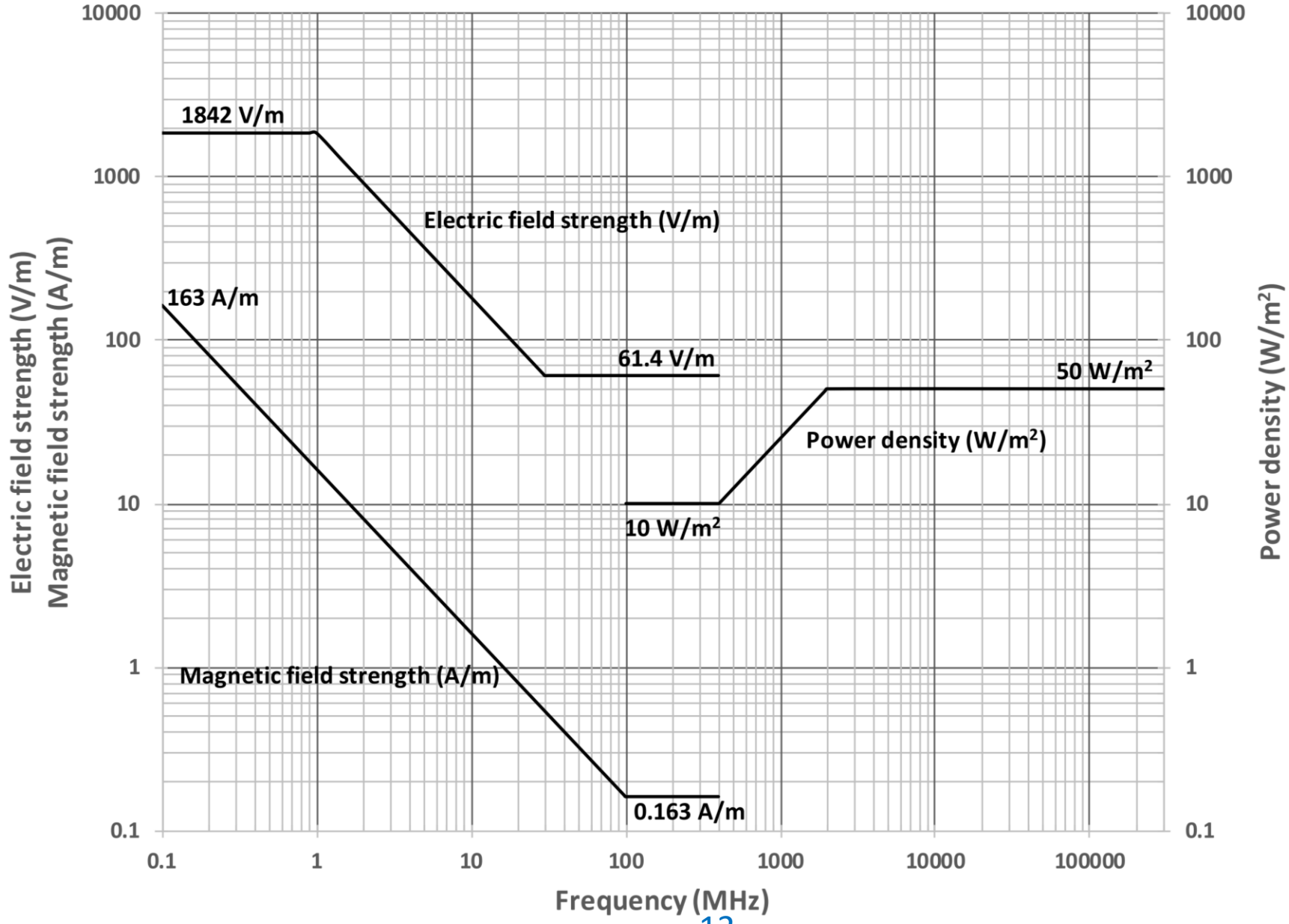
Thermal Effects

International Telecommunication Union

IEEE C95.1-2019 Table 8—ERLs for whole-body exposure, restricted environments (100 kHz—300 GHz)

Frequency range (MHz)	Electric field Strength (E)[a,b,c] (V/m)	Magnetic field strength (H)[a,b,c] (A/m)	Power density (S)[a,b,c] (W/m^2)		Averaging time (min)
			S_E	S_H	
0.1 to 1.0	1842	$16.3/f_M$	9000	$100\,000\,f_M^2$	30
1.0 to 30	$1842/f_M$		$9000/f_M^2$		
30 to 100	61.4		10		
100 to 400		0.163	10		
400 to 2000			$f_M/40$		
2000 to 300 000			50		

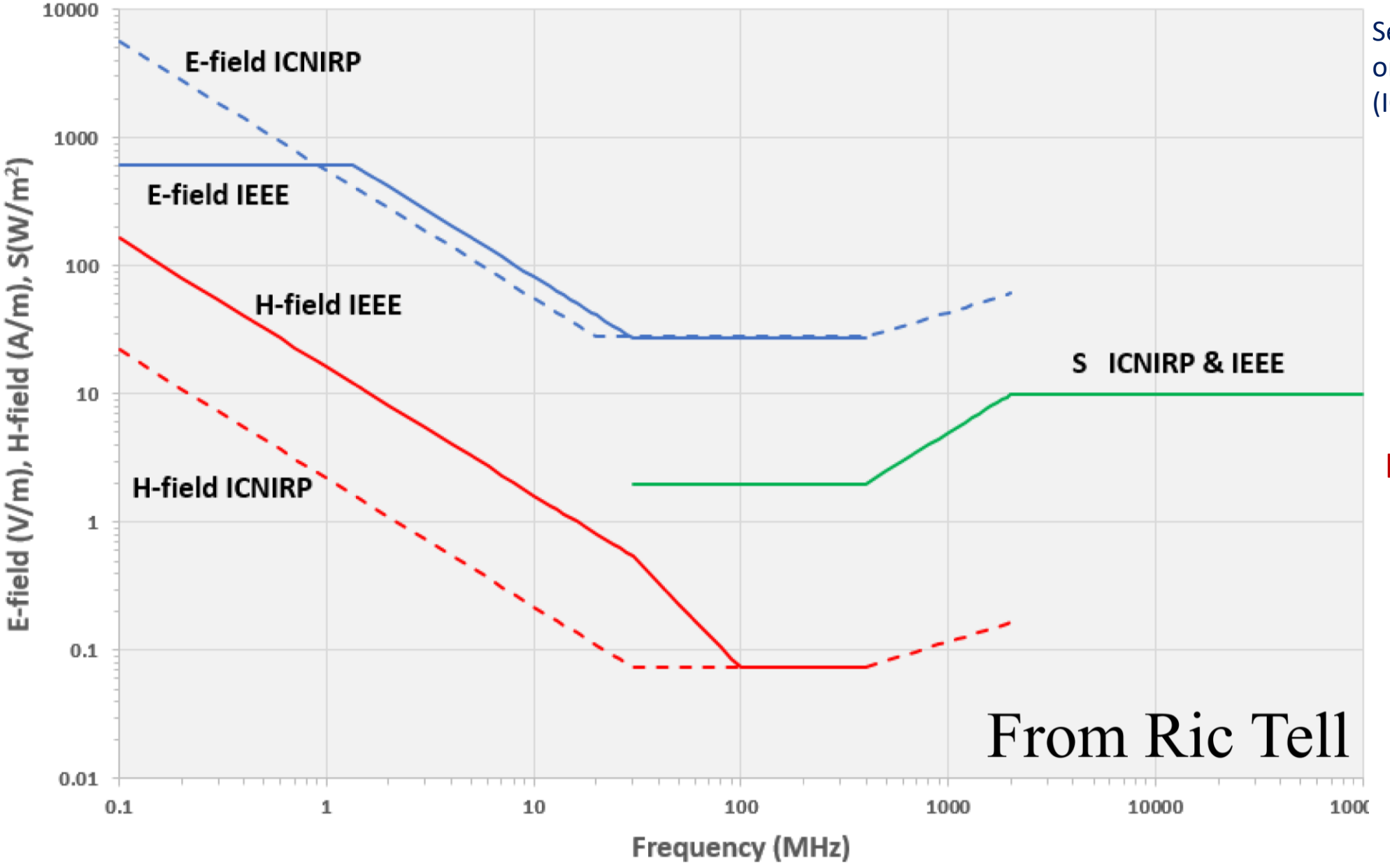
IEEE C95.1-2019 Fig. 4: Graphics of ERLs in Table 8 for EMF & plane-wave-equivalent power density—restricted environments



Thermal Effects

International Telecommunication Union

2019 IEEE/ICNIRP differences in limits, general public/unrestricted environment

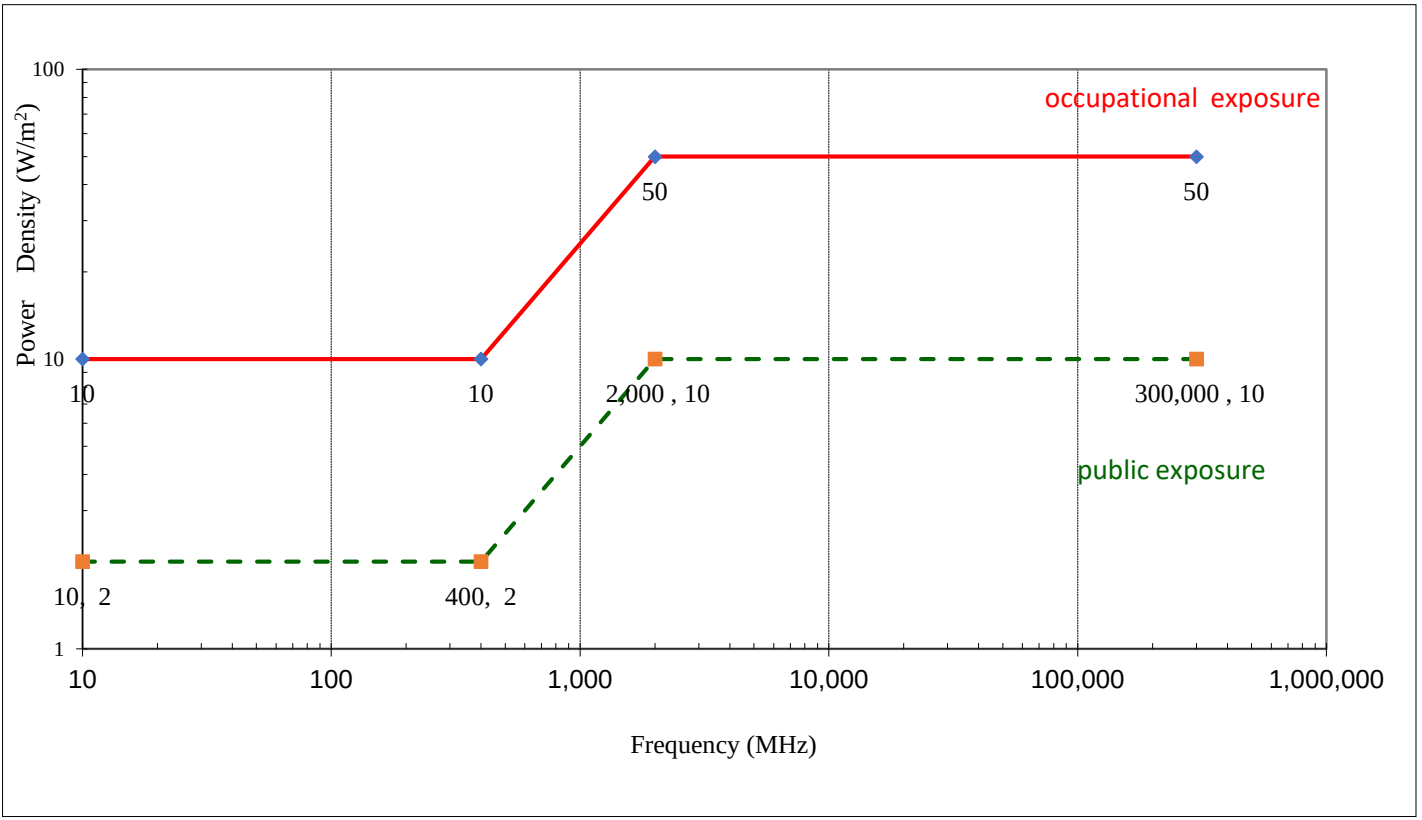


See International Committee on Electromagnetic Safety (ICES); IEEE (ICES), slide 27

power-densities above 30 MHz are identical

International Telecommunication Union

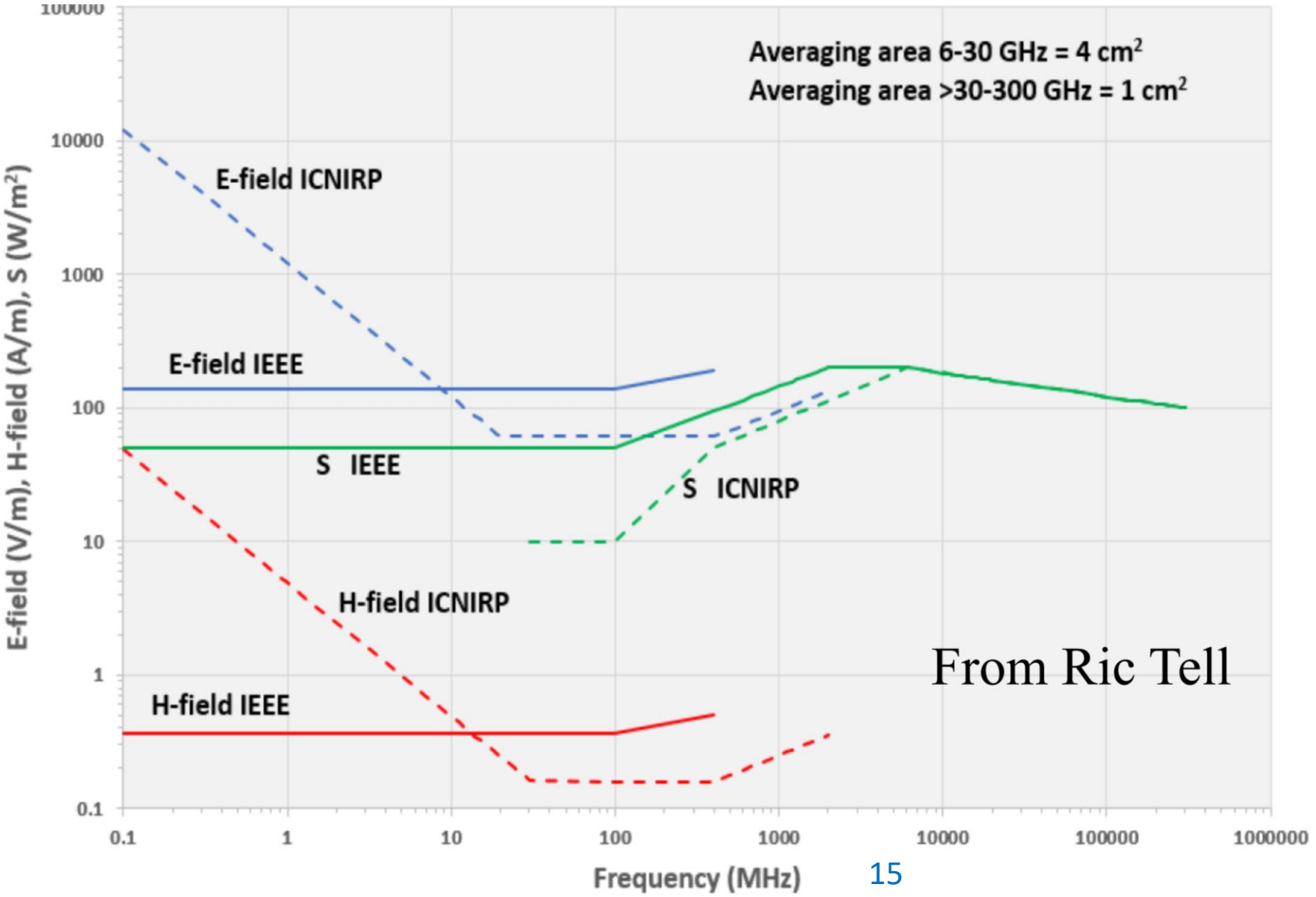
ICNIRP 1998 Table 7, power-density reference levels above 10MHz for occupational & general public



1. Poland operates cellular in the European bands: 800, 900, 1800, 2100 & 2600 MHz
2. For Poland 5G- 3500 & 700 MHz are the most relevant
3. Example: ICNIRP 1998 public exposure at 3500 MHz & higher RF equals 10 W/m^2
4. IEEE 2019 WBA and new ICNIRP limits are also 10 W/m^2

See Mazar H. 2016 Fig 9.2

IEEE/ICNIRP differences in limits local exposure limits (assuming 6-minute exposure)



see IEEE (ICES) slide 28

power-densities below 6 GHz are different

Similarities to previous IEEE standards in the revised IEEE C95.1-2019 (see B.1.2.1 p. 73 of 95.1)

1. Scientific basis of the adverse effect levels, i.e., electrostimulation for low frequencies and heating for high frequencies

2. Exposure limits for electrostimulation effects are kept the same as in IEEE Stds C95.6-2002 and C95.1-2005

3. Exposure limits, on whole body average and peak spatial average SARs, remain the same to prevent heating effects from exposure over much of the RF spectrum

4. Exposure reference levels for the general-public remain the same as in IEEE C95.1-2005

5. Controlled environment (upper tier) levels are protective

6. The risk of harm from general-public EMF exposure below the IEEE levels has not been confirmed by scientific evidence

Main differences in IEEE C95.1-2019

1. Upper RF boundary for whole body average (WBA) SAR has been **changed** from 3 GHz to 6 GHz because of improved measurement capabilities and to harmonize with the anticipated revised ICNIRP guidelines

2. Term 'extremities' is changed to 'limbs' involving the whole arms and legs, instead of portions distal to the elbows and knees. This change is to harmonize with C95.6-2002 and the ICNIRP guidelines

3. Local exposure ERL is now frequency dependent, instead of being a fixed factor of 20 times the whole-body ERL, regardless of frequency

4. Averaging time is 30 minutes for whole body RF exposure and 6 minutes for local exposure

Changes in IEEE C95.1-2019 (Cont. 1)

1. Local exposure limits between 6 GHz and 300 GHz have changed: the dosimetric reference limit (DRL) is the epithelial power density inside the body surface, and exposure reference levels (ERLs) is the incident power density outside the body. For smaller areas, relaxed limits are allowed

2. Averaging power density area is defined as a 4 cm^2 square

3. Small exposed areas above 30 GHz: the epithelial power density is allowed to exceed the DRL or ERL by a factor of 2, with an averaging area of 1 cm^2

4. Peak DRL and ERL limits for local exposures to pulsed RF fields are defined, and new fluence limits for single RF-modulated pulses above 30 GHz are introduced. The averaging area for single pulse fluence is 1 cm^2 square

Main differences in IEEE C95.1-2019 : (Cont. 2)

1. The upper tier (controlled environment) whole-body exposure ERLs above 300 MHz are different from those in C95.1-2005 to maintain a consistent 5x factor between tiers and to harmonize with ICNIRP guidelines

2. The former induced current limit for both feet is an unrealistic condition and is removed. The induced current limits for a single foot are retained

3. rms induced and contact current limits for continuous sinusoidal waveforms (100 kHz to 110 MHz) are changed from those in Table 7 of C95.1-2005 to frequency dependent values

RF-EMF Regulatory framework in Europe and Poland

1. Poland is moving towards harmonization of regulations, even at a global level
2. Official government proposal to use EU exposure limits since 01.01.2020
3. EU published:
   1. Directive 2004/40/EC 'exposure of workers to the risks arising from EMF';
   2. EU Council Recommendation 1999/519/EC, 'exposure of the general public to EMF 0 Hz to 300 GHz'
4. Both publications refer intensely to ICNIRP 1998
5. Europe in general follows ICNIRP 1998 levels from base stations and handsets
6. Despite the non-mandatory Recommendation, some EU countries adopt more restrictive thresholds
7. Some interesting Questions:
   1. Will EU refer to the new ICNIRP limits?
   2. To change the official Polish proposal to ICNIRP 2019?

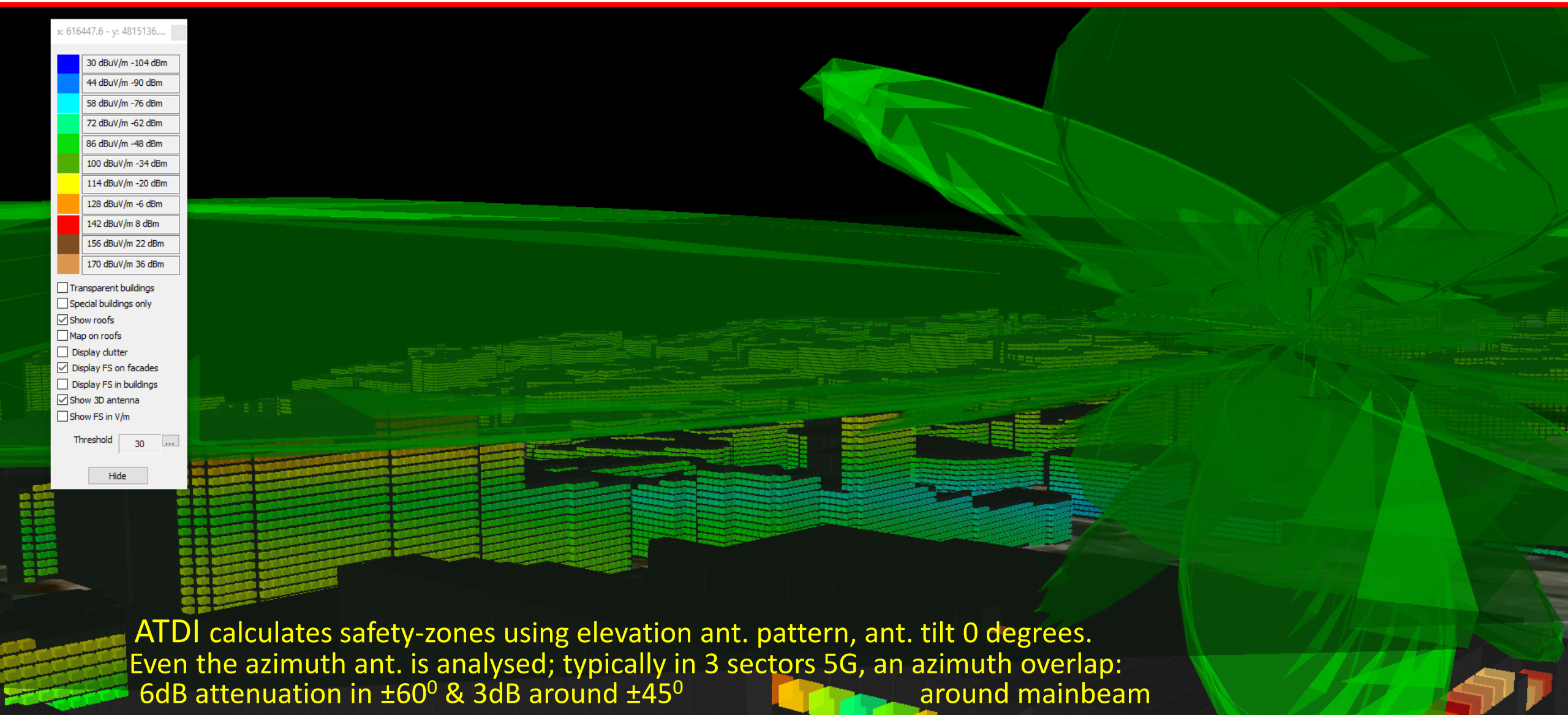
Summary

1. Compliance with human exposure limits for EMF is a significant health and safety issue to regulators, service providers and wireless equipment suppliers

2. There is no scientific reason to use different exposure limits in different countries

3. Countries should follow the updated ICNIRP (and IEEE limits)

4. Poland may follow EU Recommendation 1999/519/EC on EMF (ICNIRP levels)



ATDI calculates safety-zones using elevation ant. pattern, ant. tilt 0 degrees.
Even the azimuth ant. is analysed; typically in 3 sectors 5G, an azimuth overlap:
6dB attenuation in $\pm 60^0$ & 3dB around $\pm 45^0$ around mainbeam

Recent EMF material from Author

1. ITU Conferences on EMF

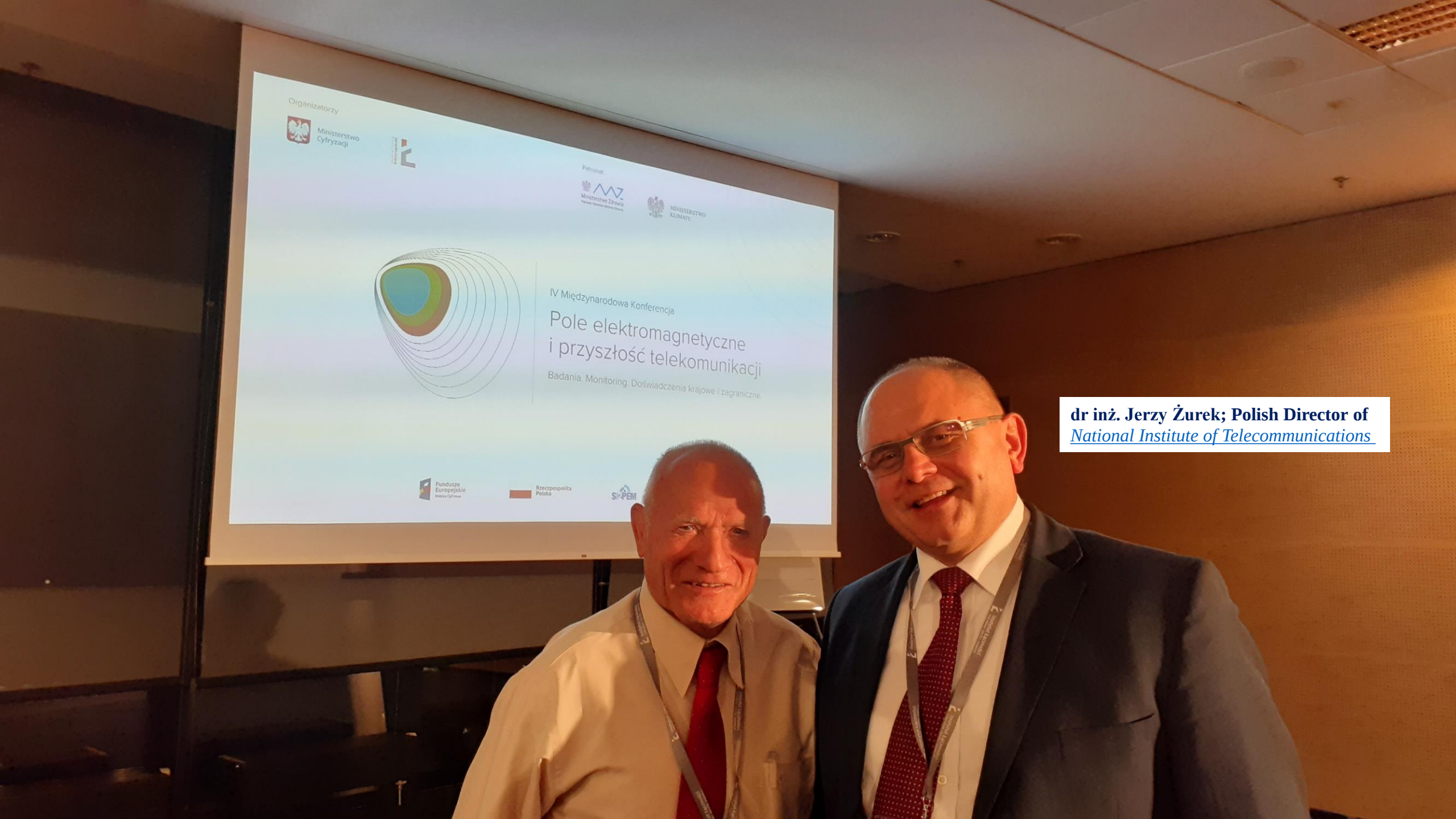
1) A Comparison Between European and North American Wireless Regulations, presentation at the 'Technical Symposium at ITU Telecom World 2011' www.itu.int/worl2011; the slides presentation, 27 October 2011
2) 2016 ITU R-D-T 'Intersectoral activities on human exposure to EMF'; Bangkok, 26 April 2016
3) 2017 ITU Workshop '5G, EMF & Health'; Warsaw, Poland, 5 December 017
4) 2018 ITU workshop 'modern policies, guidelines, regulations and assessments of human exposure to RF-EMF'; Geneva, Switzerland, 10 October 2018

2. 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 (this presentation); Warsaw, Poland; 3 Dec 2019

Haim Mazar
ITU

Marek Zagórski
Polish Minister of Digital Affairs



dr inż. Jerzy Żurek; Polish Director of *National Institute of Telecommunications*


ITU
International
Telecommunication
Union


Ministerstwo Cyfryzacji
National Institute of Telecommunications
Electromagnetic field and the future of telecommunication
EMF, New ICNIRP Guidelines and IEEE C95.1-2019 Standard: Differences and Similarities
International Conference: EMF and the Future of Telecommunications
3-4 December, 2019
ATDI
Dr. Haim Mazar (Madjar), re-elected vice-chair ITU-Radio Study Group 5 (terrestrial services)
Instytut Łączności
5
12
250
1
100
36
Instytut Łączności
5
12
250
1
100
ITU
International Telecommunication Union


Background: Main Existing ICNIRP Guidelines and IEEE Standards
1. C95.6- 2002 IEEE Std 'Safety Levels, exposure to EMF 0-3 kHz'
2. C95.1-2005 IEEE 'Safety Levels, exposure to RF-EMF, 3 kHz- 300 GHz'
3. C95.1-2019 IEEE 'Safety Levels, exposure to EMF, 0 Hz to 300 GHz'
4. ICNIRP 1998 Guidelines for limiting exposure to EMF up to 300 GHZ
5. ICNIRP 2010 Guidelines for limiting exposure to EMF 1Hz–100 kHz
The EMF limits at ICNIRP 1998 and C95.1-2005 are similar
15 Oct 2019 C95.1-2019 Std revises & combines Stds IC95.1-2005 & C95.6-2002 into a single standard; changes on exposure above 6 GHz/10 GHz
Instytut Łączności
PAŃSTWOWY INSTYTUT BADAWCZY
www.it-pib.pl
12


After the presentation, TV interviews
the Author on RF-EMF national policies