ZICTA

ZAMBIA INFORMATION AND COMMUNICATIONS TECHNOLOGY AUTHORITY

Lusaka, Zambia; 13 January 2017

Regulation of RF Human Hazards

Presentation based also on Chapter 9 ‘Human Hazards’, Author’s Wiley book ‘Radio Spectrum Management: Policies, Regulations, Standards and Techniques’; published August 2016

You may look at:

EMC_Europe2016_Wroclaw_Sep 2016_Mazar_20April16_EMF.pdf

Human Hazards_Mazar_AsiaPacific_BKK_25April16.pdf

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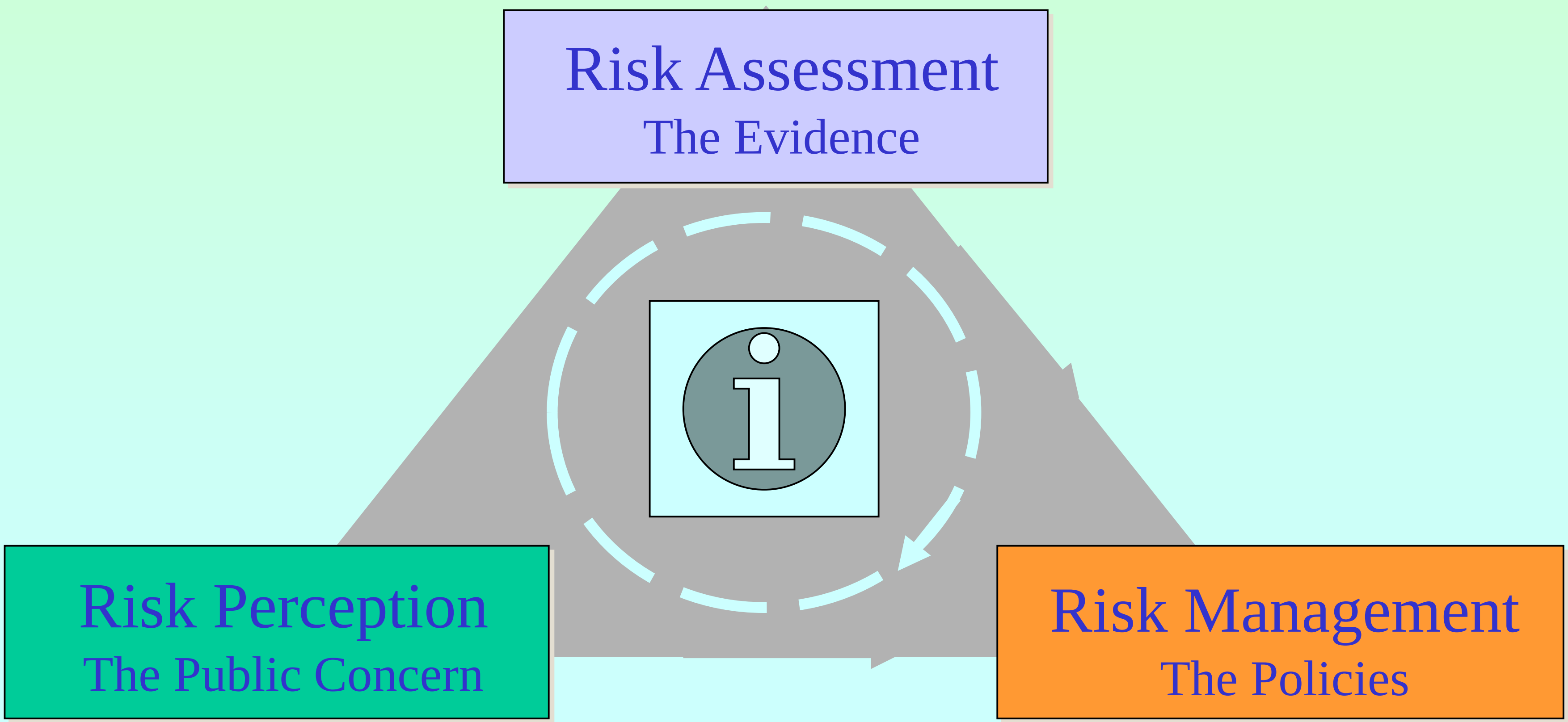
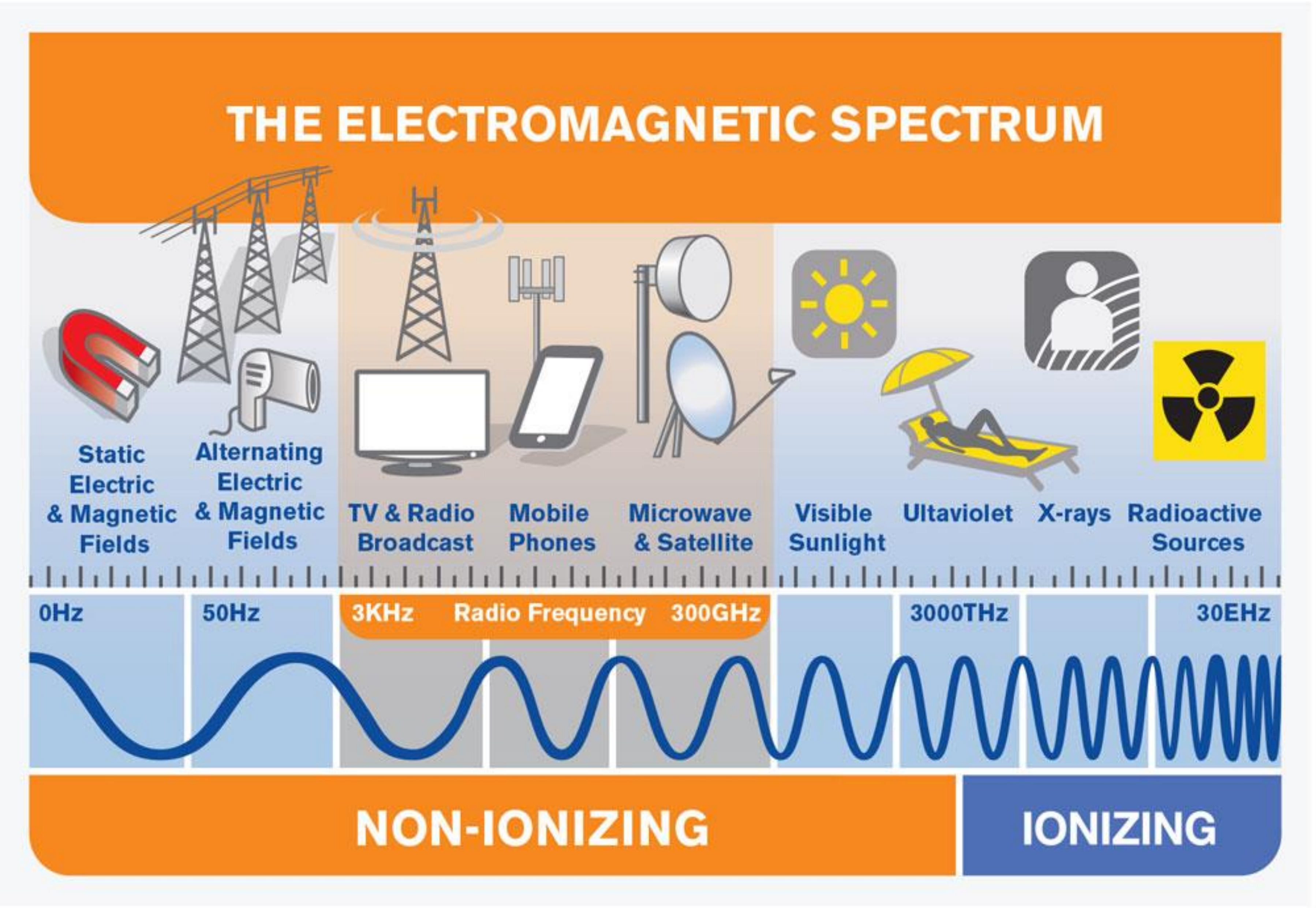
World Health Organization

Dr E. van Deventer; Department of Public Health and Environment Geneva, Switzerland;
ITU-D Q 7/2 22 Apr 16

Electromagnetic Radiofrequency Fields; National Management and Regulatory Approaches

- **Mobile phone use is ubiquitous with an estimated 4.6 billion subscriptions globally**
- **To date, no adverse health effects have been established from RF fields exposures**
- **Studies are on-going to assess potential long-term effects of wireless technologies**



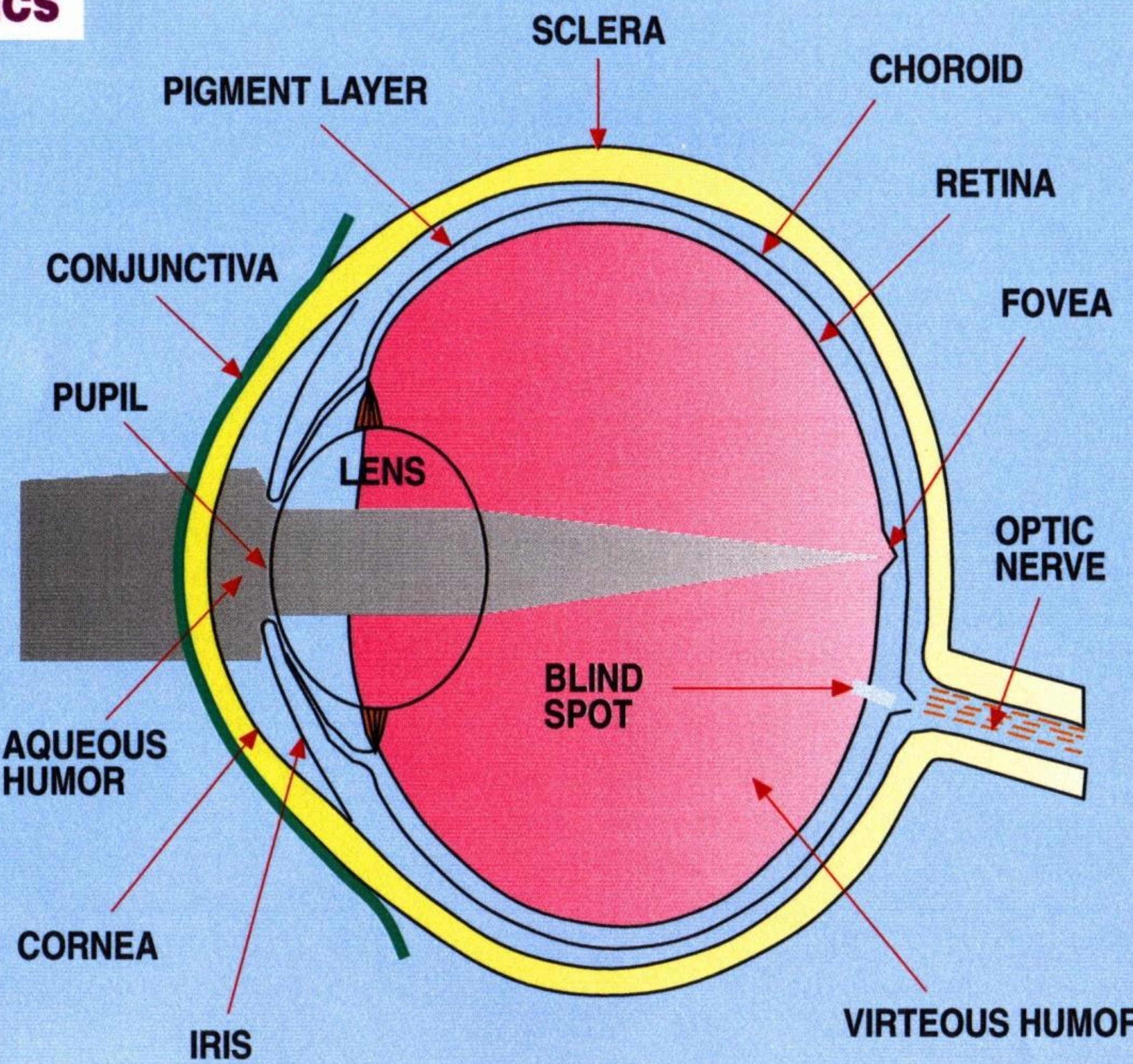


Source: ITU-T Report 2014 *EMF Considerations in* ***Smart Sustainable Cities***

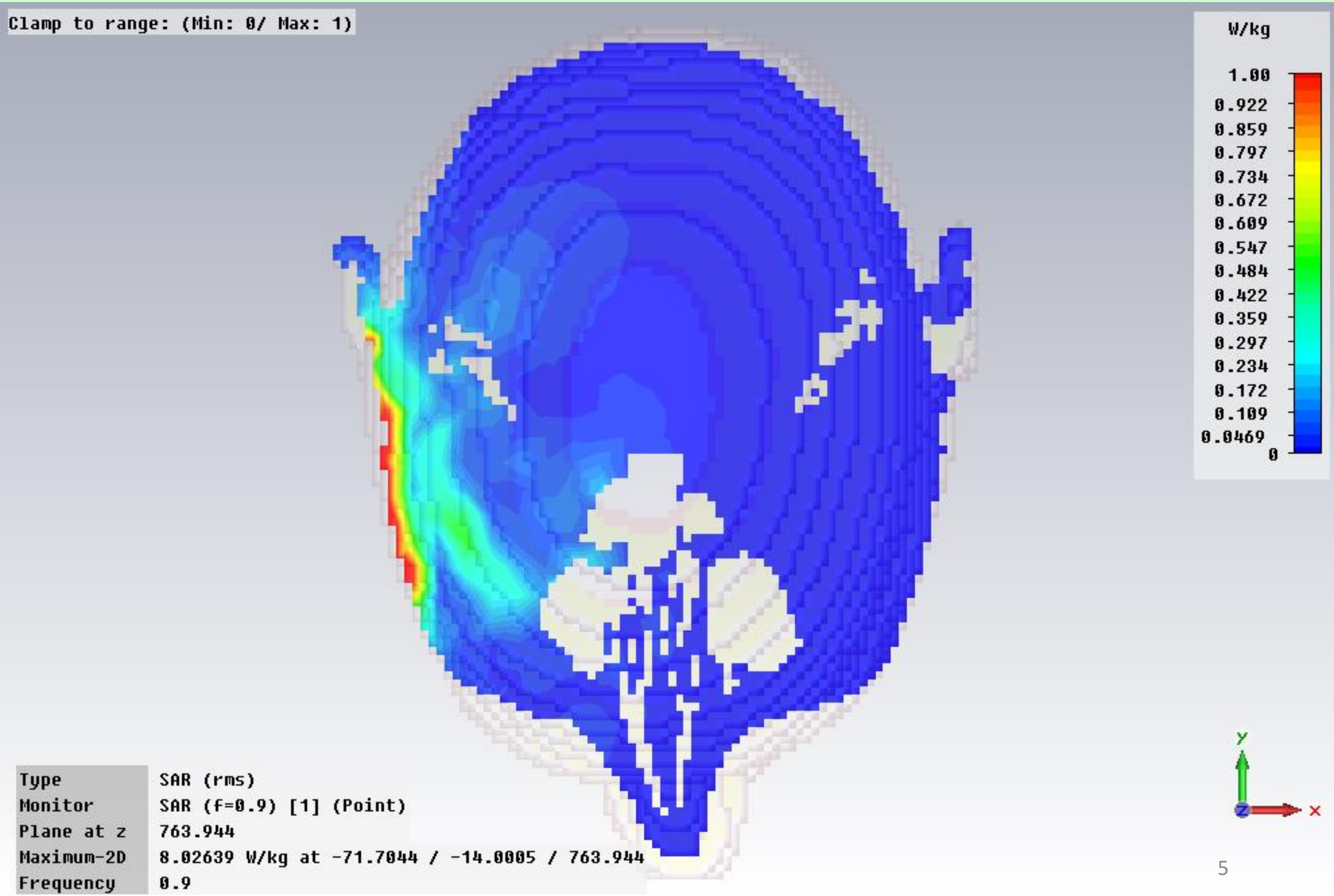
The Human Eye (Moshe Netzer)

SUSCEPTIBILITY CHRACTERISTICS

- **POOR BLOOD CIRCULATION**
- **LENSE OPACITY**
- **CORNEA DAMAGE**
- **RETINA RAPTURE**

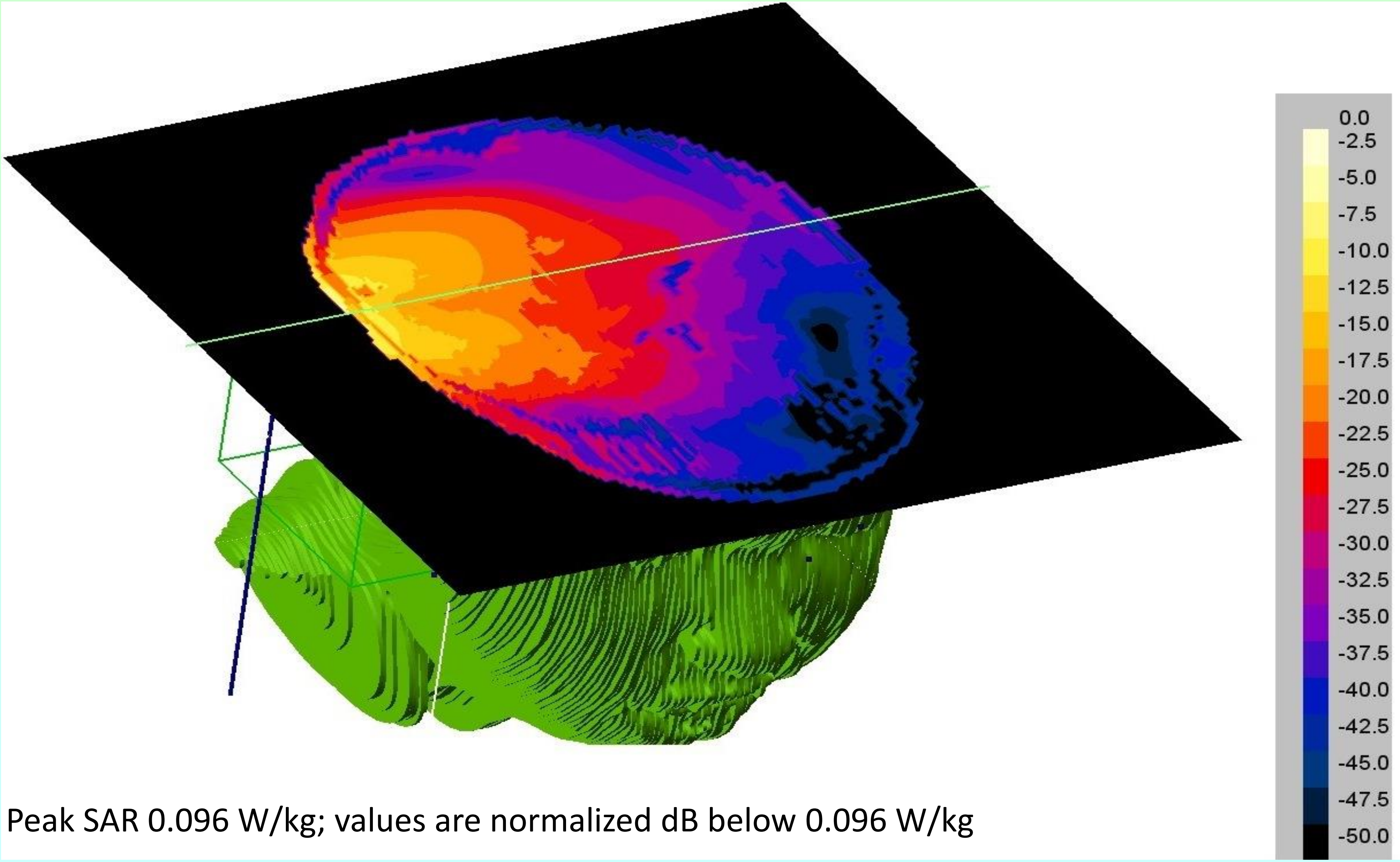


SAR phantom simulation (Stefan Chulski & Stav Revich from HIT)



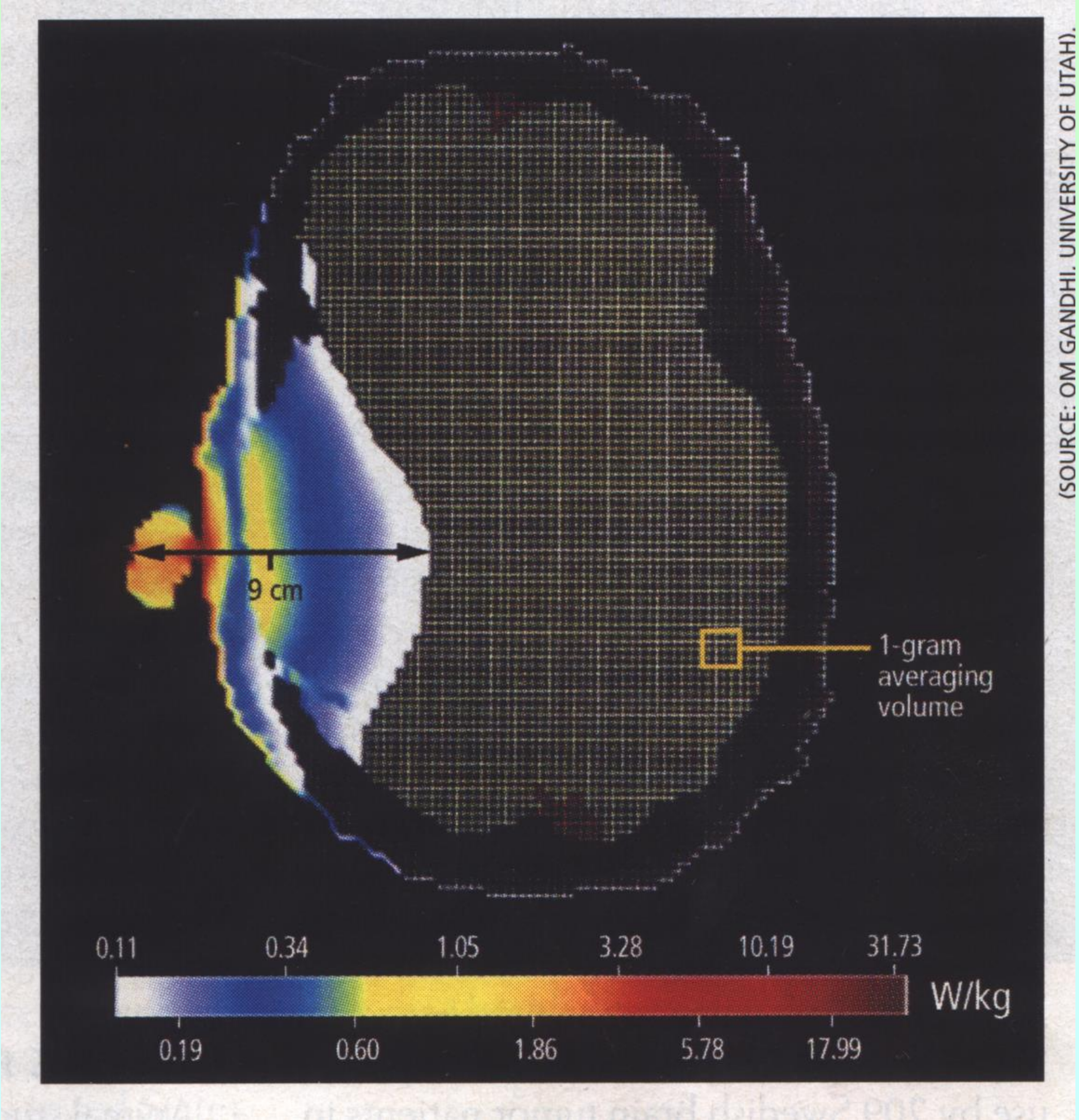
Numerical simulation of SAR; for a three years child

Source: Dr. Jafar Keshvari, Bio-electromagnetics
Aalto University, Helsinki-Finland

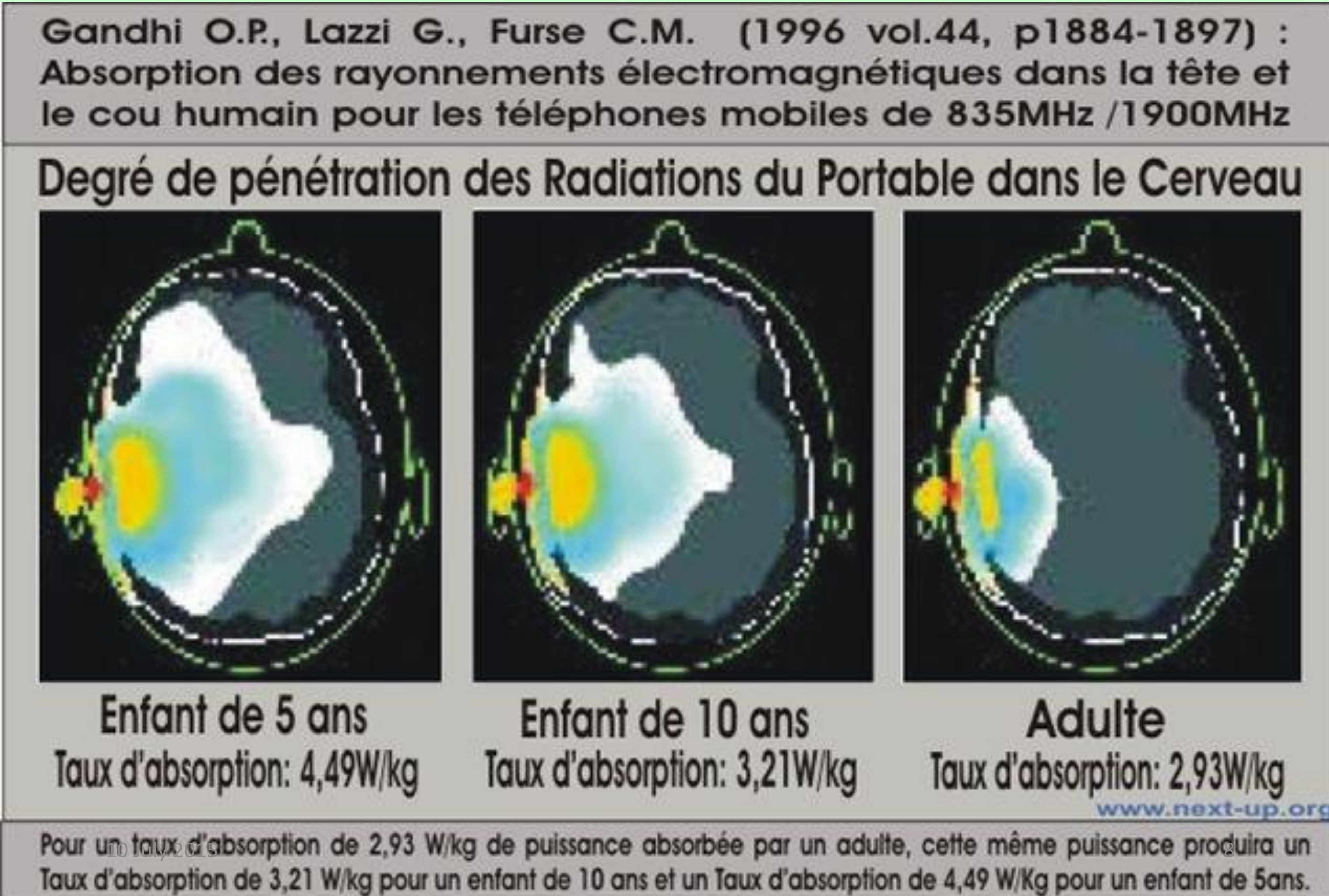


Peak SAR 0.096 W/kg; values are normalized dB below 0.096 W/kg

Typical SAR from a Cell Phone (Moshe Netzer)

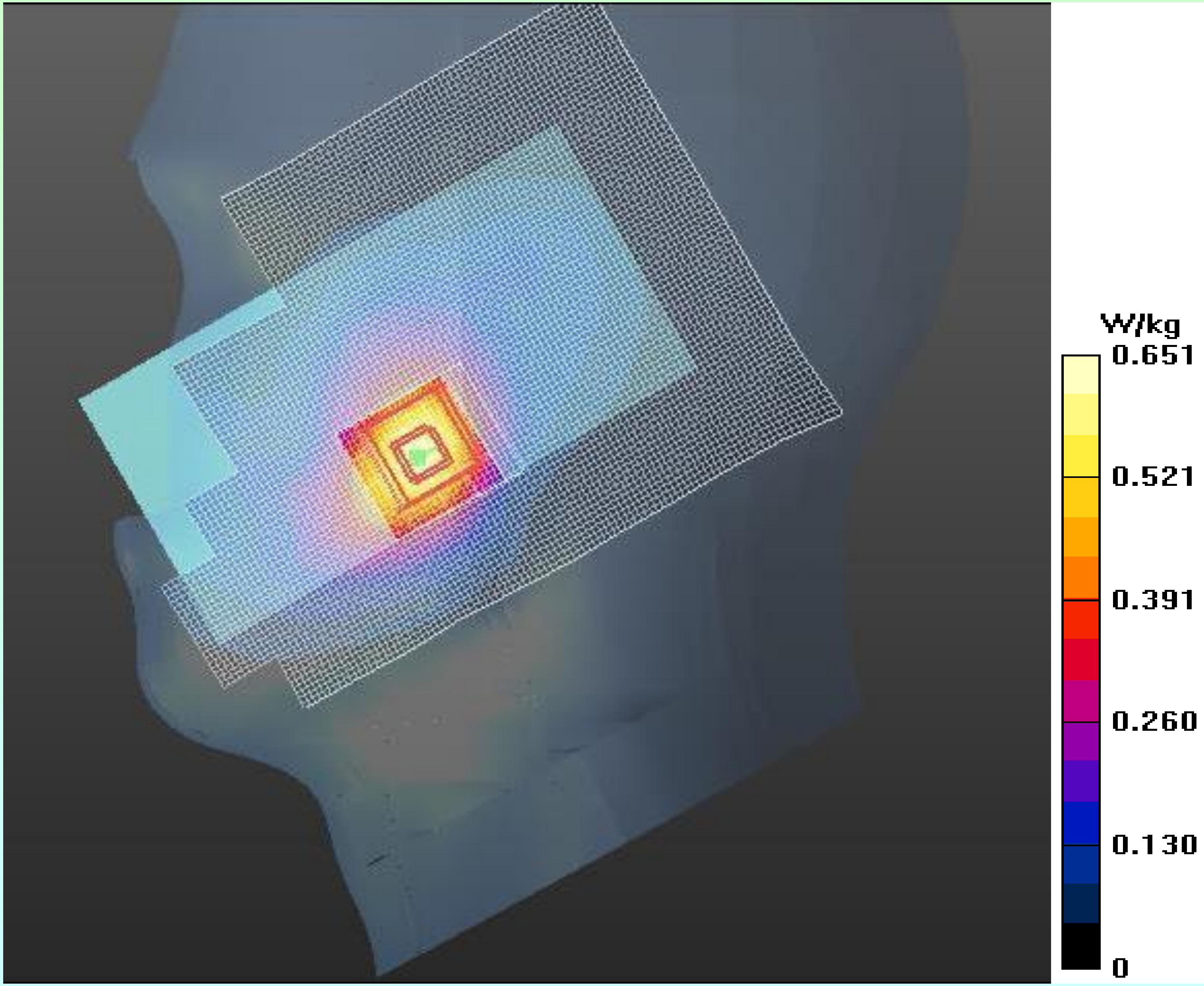


SAR overexposure in the brain

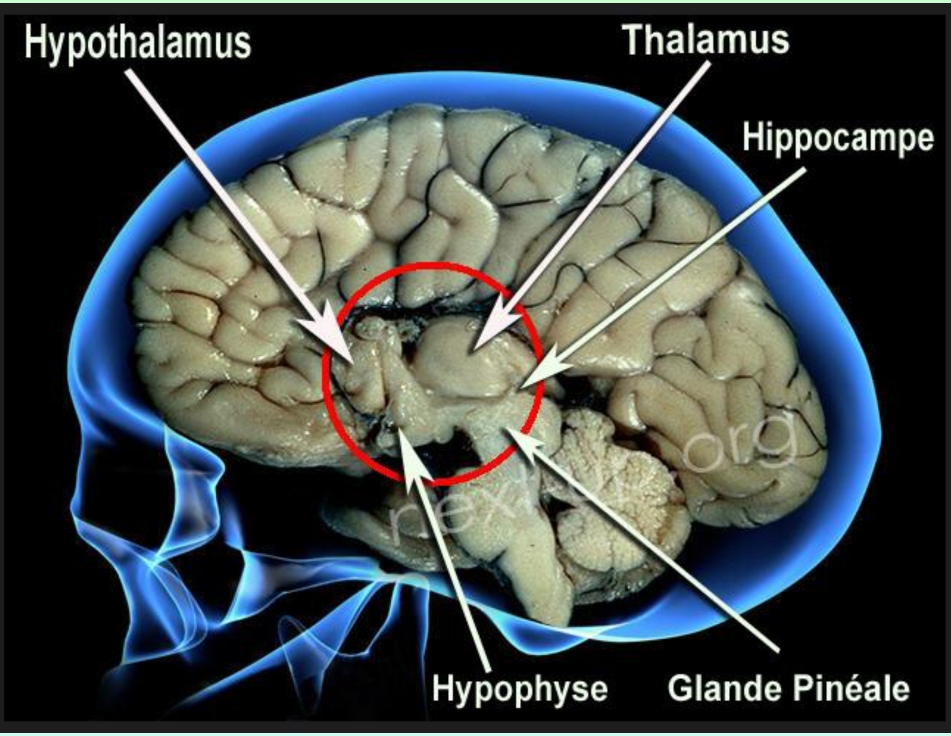


SAR real measurement for a commercial mobile phone

Source: Dr. Jafar Keshvari, Bio-electromagnetics Aalto University, Helsinki-Finland



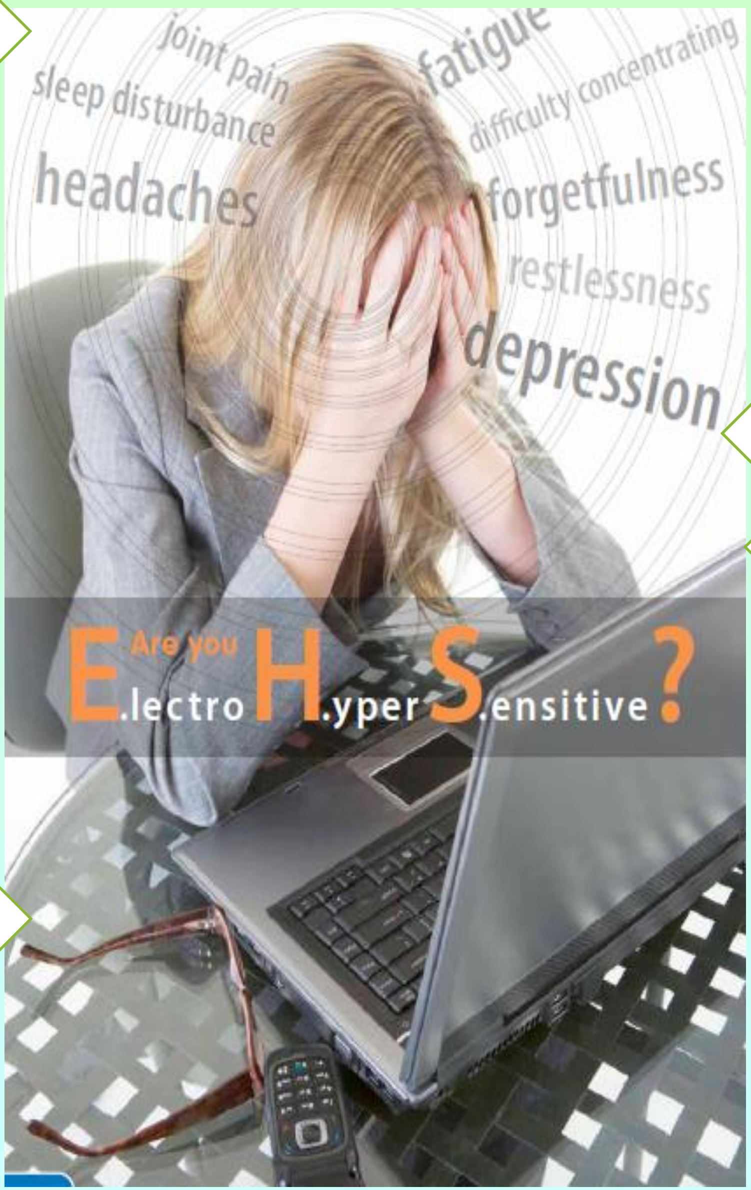
Brain is Exposed to Cellphone Radiation (Dr. Shalita)



Electromagnetic Hyper-Sensitivity; electro-phobia

Subjective phobia, phantom risk (?!)

Precautionary Principle: billions of cellular users phones and millions of base-stations worldwide



Type I error imposes regulatory restrictions on factors that turn out to be harmless.

Type II error : acceptance of a null hypothesis that turns out to be false

There is no evidence of causality between pains and RF exposure

Measurement of Radiation (partly Dr. Zamir Shalita, BS.1698)

Questions to be raised

Monitoring of human exposure around the world reveals that the levels are very low, relative to ICNIRP reference levels:

- 2001 to 2004 (WHO 2007:30), UK conducted radio surveys at 289 schools with base stations on or near them. The highest levels measured anywhere were **3.5×10^{-3}** (= 12.2×10^{-6} of the power density), with the 90% of the schools having a highest compliance factor below 2.9×10^{-4} (**8.4×10^{-8}** power density) – which are very low values indeed.
- See also IARC 2013:58, fig. 1.11 specifies a cumulative distribution of exposure quotients corresponding to 3321 spot measurements made by OFCOM at 499 sites where public concern had been expressed about nearby base stations; the quotient values are median 8.1×10^{-6} of ICNIRP power density, ranging from the **5th percentile 3.0×10^{-8} to 95th percentile 2.5×10^{-4}**.
- Two hundred randomly selected people in urban, sub-urban, and rural subgroups have measured on 2005–2006 in France (Viel et al. 2009; see also IARC 2013:114) for 24 hours a day, 184 daily measurements. At the GSM 900/1800 bands most of the time, the recorded field strength was below detection level (**0.05 V/m); 0.05 V/m is 3.63%** of the ICNIRP level at 900 MHz. 12.3% of measurements at the FM band indicate field strength above the detection threshold; the mean field strength was 0.17 V/m (Viel et al. 2009:552), the maximum field strength was always lower than 1.5 V/m. ANFR 2007 reveals that at 2004-2007, the average measurements are less than 2% of the field strength limit (less than 0.04 % of power density); more than 75% of the measurements were less than 2% of the field strength limit, regardless of the frequency band considered.

So: **Why do we need to make so many measurements?**

May be ICNIRP reference levels are too high?

What is the minimal Tx power (not from handset) to measure and approve RF hazards?

Hillel (ex) Radio Antenna: Closed due to hypersensitivity

Yehuda Halevi, TelAviv; Israel

Base Station Antenna Pattern: Azimuth and Elevation (Dr. Zamir Shalita)

ITU activities on Human Hazards

- ITU Plenipotentiary Resolution 176 (Rev. Busan, 2014) *Human exposure to and measurement of electromagnetic fields*
- ITU-D 2014 Report Question 23/1 *Strategies & Policies Concerning Human Exposure to EMF*
- ITU-R 2011 Handbook *Spectrum Monitoring, Edition of 2011*, Ch. 5- Specific monitoring systems & procedures
- ITU-R Recommendation BS.1698 *Evaluating Fields from Terrestrial Broadcasting Transmitting Systems Operating in any Frequency Band for Assessing Exposure to Non-Ionizing Radiation*
- **ITU-T Study Group (SG) 5 Recommendations:**

❖ K.52 *Guidance on complying with limits for human exposure to electromagnetic fields*

❖ K.61 *Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations*

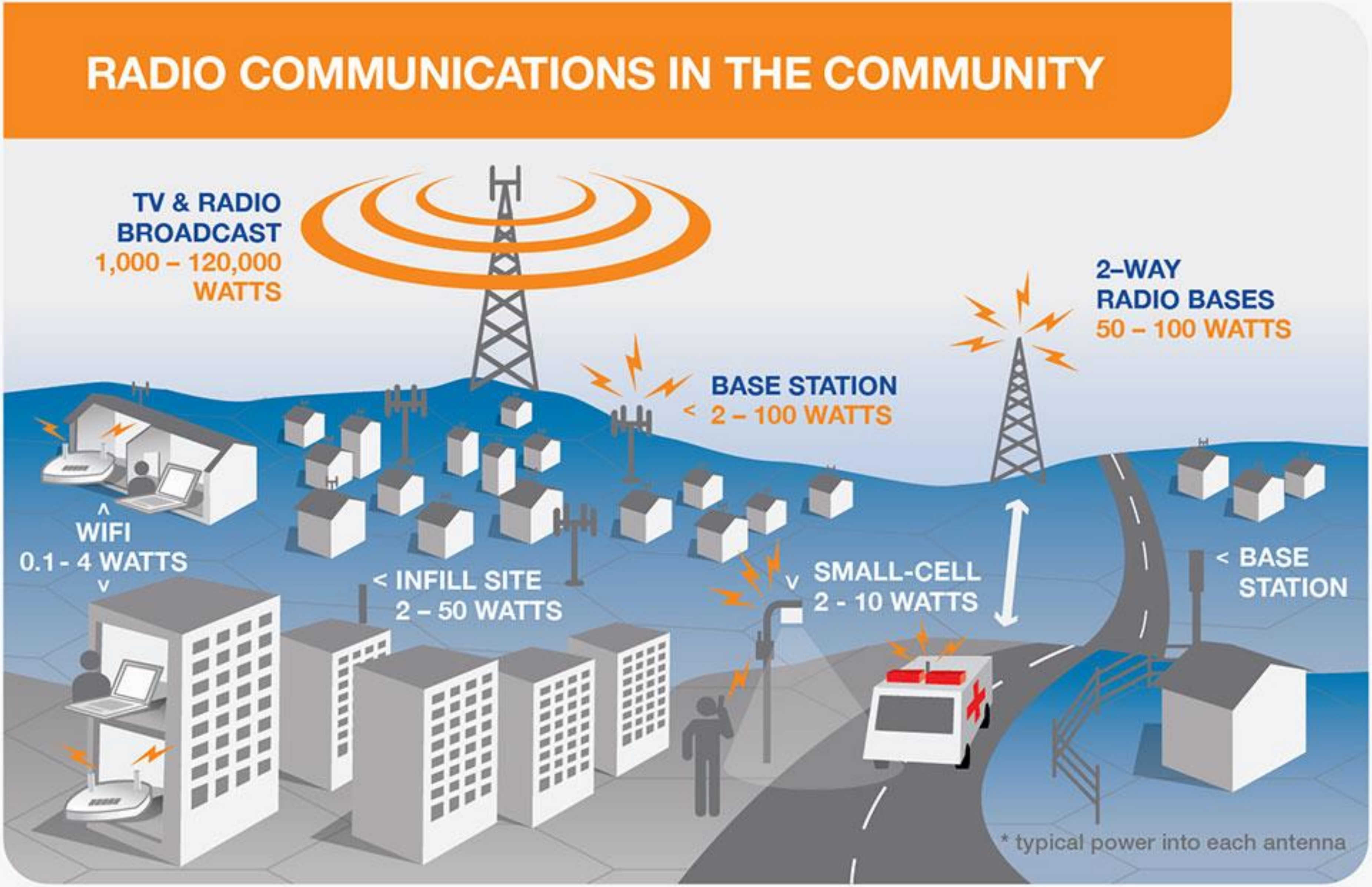
❖ K.70 *Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations*

❖ K.83 *Monitoring of electromagnetic field levels*

❖ K.91 *Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields*

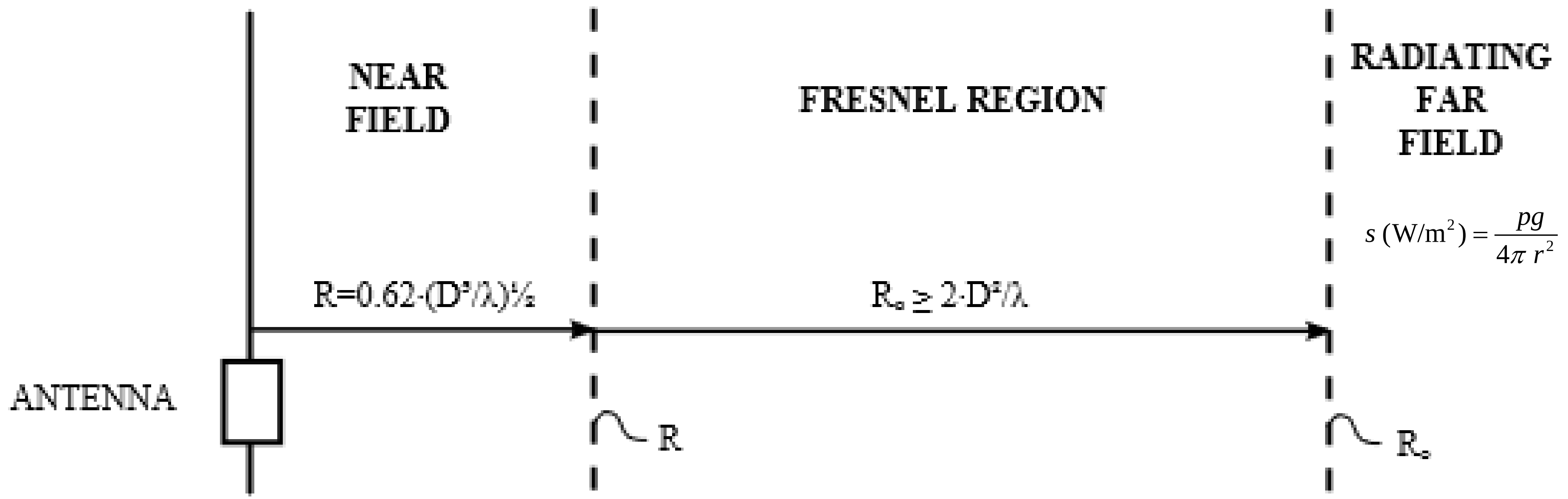
- *ITU-T Technical report on "Electromagnetic field (EMF) considerations in **smart sustainable cities**"*
- **ITU EMF Guide**
- Responses to WHO : Monograph; Fundamental Principles; Fact Sheet

Author is nominated to represent ITU-R Study Groups 1, 5 & 6 on RF human-hazards interesectoral activities
Except BS 1698; the authot is much involved in all these publications



Source: ITU-T Report 2014 *EMF Considerations in Smart Sustainable Cities*

Various radiation zones of Wikipedia



If X >= 2**D**^{2}/λ, **far-field** region

If 2**D**^{2}/λ >X> λ/2∏ **radiating** near-field region

If λ/2∏ >X **reactive** near-field region

ICNIRP- Established Effects of EMF (Paolo_Vecchia)

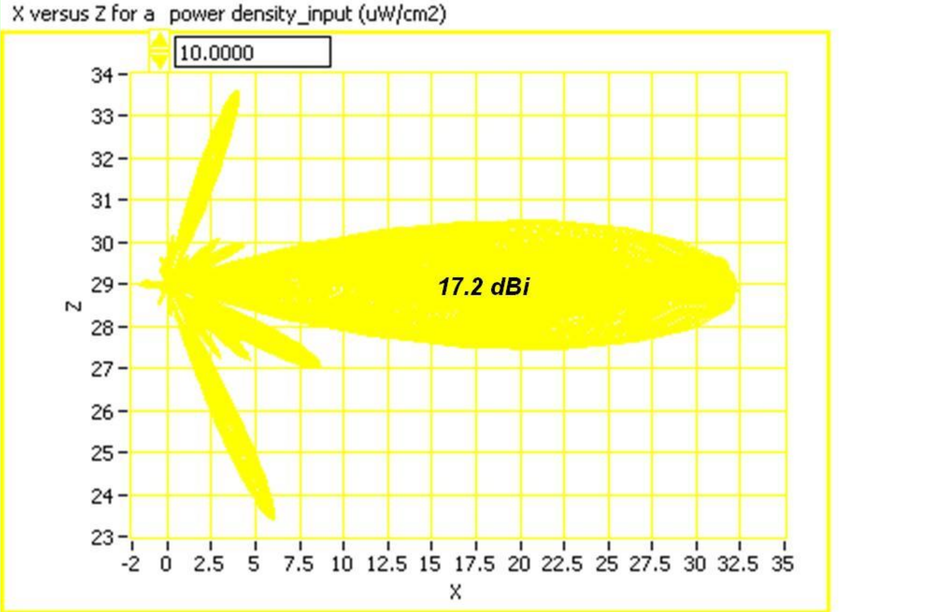
- All effects of EMF that have been established so far are acute in nature

- ELF
- Stimulation of electrically excitable tissues

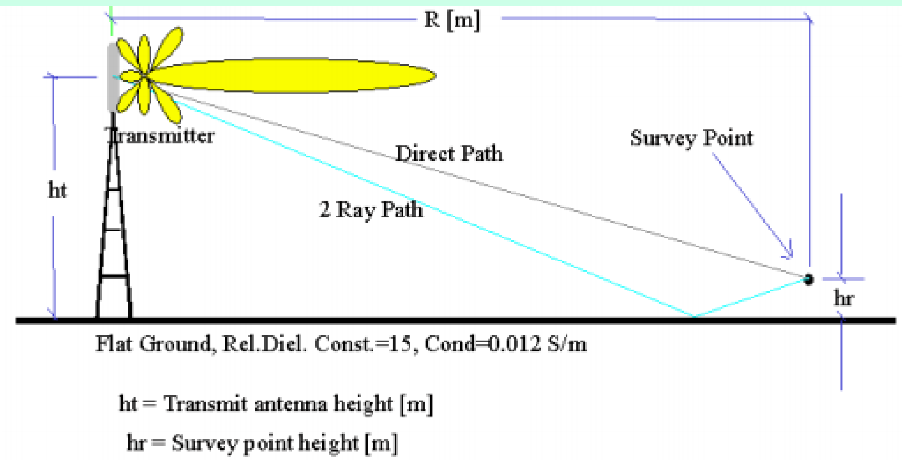
- RF
- Increase of body temperature (general or local)

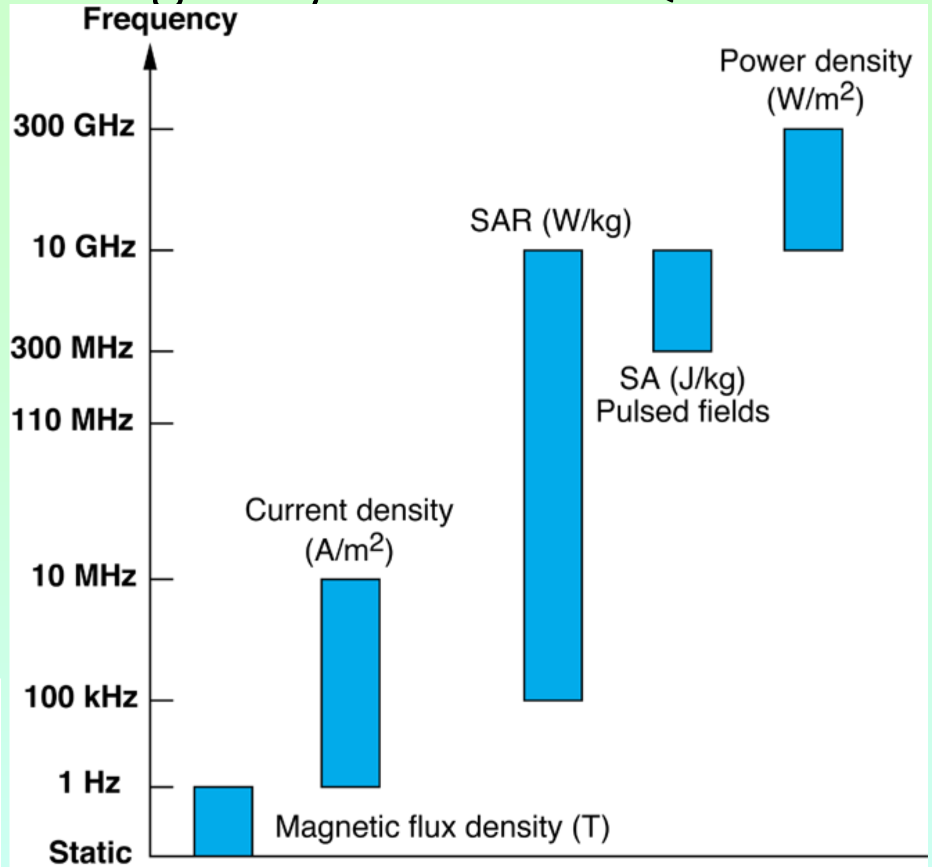
Such acute effects occur above given exposure thresholds

Biologically Effective Quantities



אנטנה מסוג 739686, עבור תדר 850 מגא-הרץ, בשימוש במתקנים רגילים





SA: Specific Absorption

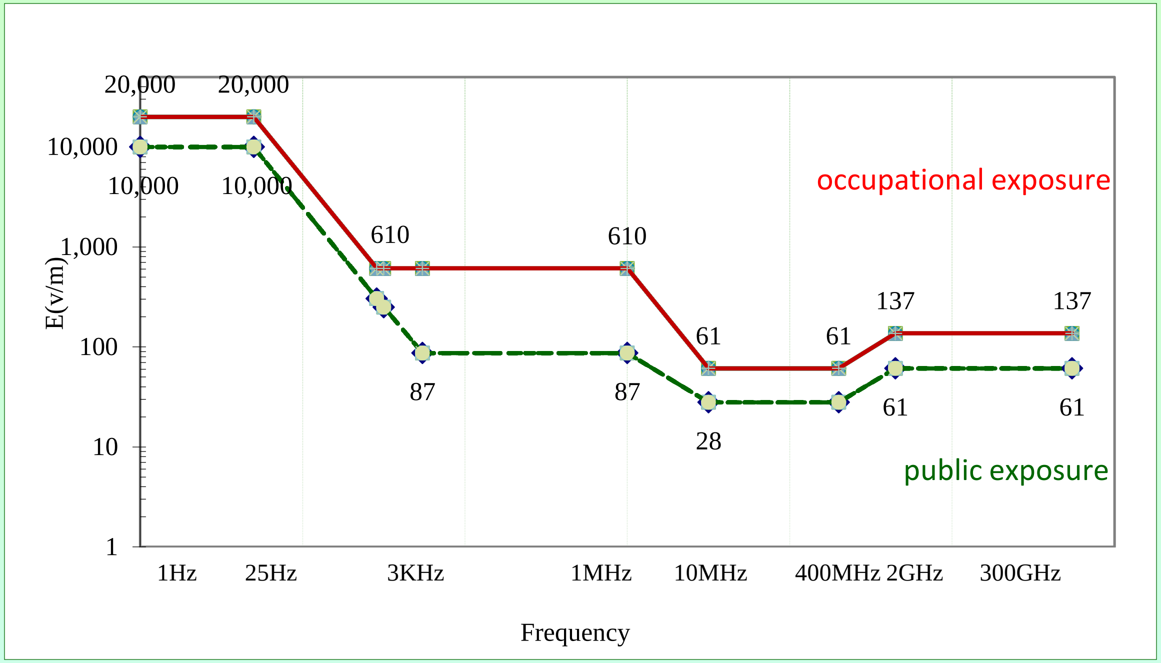
Physical Quantities and Units

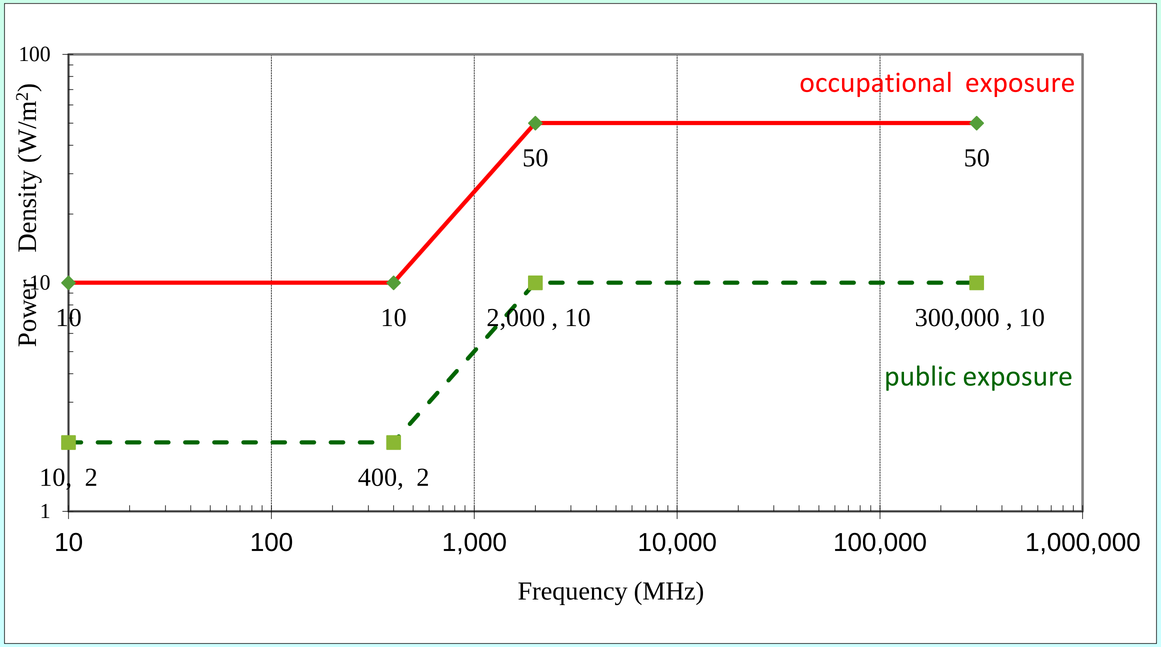
Quantity	Symbol	Unit	Symbol
Frequency	*f*	Hertz	Hz
Electric field strength	*e*	Volt per metre	V/m
Power	*p*	Watts	W
Power density or power flux density	*s*	Watt per square metre	W/m^2
		mWatt per square cm	mW/cm^2
Specific Absorption Rate	*SAR*	Watt per kilogram	W/kg
		mWatt per gram	mW/g

ICNIRP 1998 p.511 reference levels for occupational & general public exposure- table7

Frequency range	Electric field strength (V/m)		Equivalent plane wave power density $S_{eq}(W/m^2)$	
	general public	occupational	general public	occupational
1-25 Hz	10,000	20,000	-	
0.025- 0.82 KHz	250/f(KHz)	500/f(KHz)	-	
0.82 -3 KHz	250/f(KHz)	610	-	
3-1000 KHz	87	610	-	
1-10 MHz	$87/f^{1/2}$ (MHz)	610/f (MHz)	-	
10-400 MHz	28	61	2	**10**
400-2000 MHz	$1.375f^{1/2}$ (MHz)	$3f^{1/2}$ (MHz)	f/200	**f/40**
2-300 GHz	**61**	**137**	**10**	**50**

ICNIRP 1998 p.511 reference levels for occupational & general public exposure- graphs





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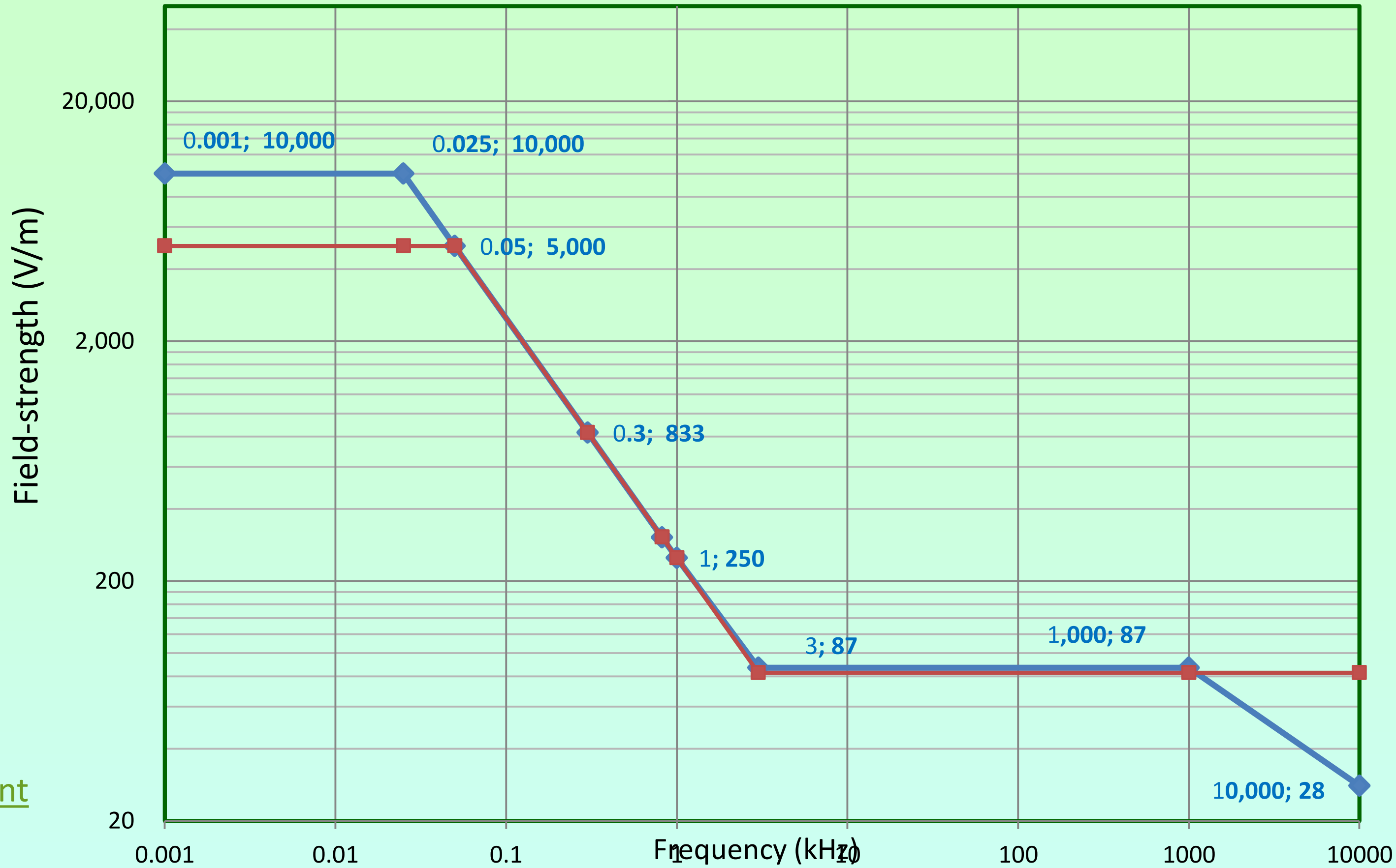
Reference levels: ICNIRP 2010 compared to ICNIRP 1998 till 10 MHz



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for non-thermal effects, ICNIRP 2010 is relevant for frequencies up to 10 MHz

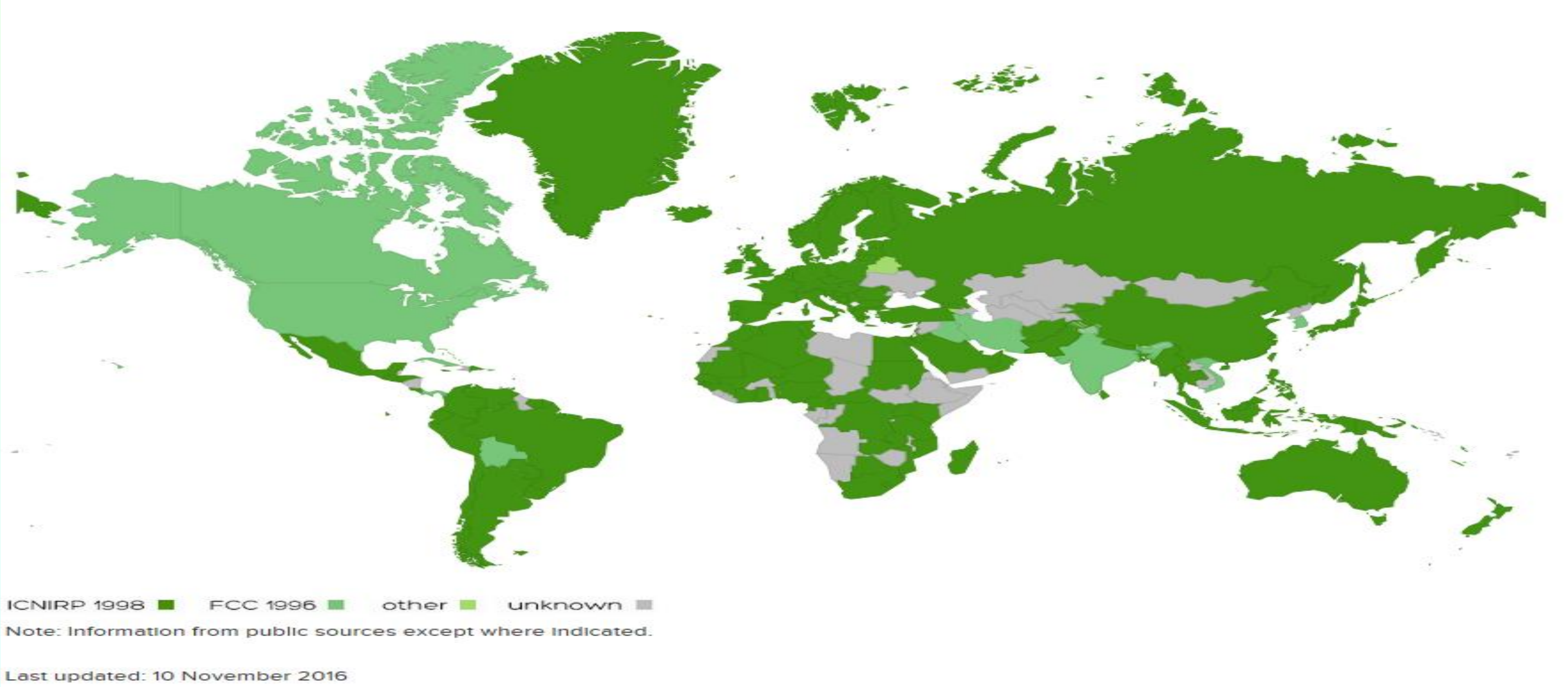
ICNIRP 1998; General Public Exposure (V/m) ICNIRP 2010; General Public Exposure (V/m)

1. ICNIRP reconfirmed its 1998 RF guidelines in 2009 and started revision of RF guidelines in 2012
2. WHO & ICNIRP collaborate to publish the Environment Health Criteria (EHC) monograph by 2016
3. Monograph may be the basis to revise the ICNIRP (1998) and ICNIRP 2010 RF exposure guidelines
4. ICNIRP states at http://www.icnirp.org/en/activities/work-plan/details/work-plan-hf.html "The Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz) published in 1998 are now being revised and replaced step by step, as explained in the Statement on EMF guidelines (2009). Revision of the LF and static parts are finalized. Currently, ICNIRP is revising the guidelines on limiting exposure to high and radiofrequency fields in the range (**100 kHz** - 300 GHz)."

Public RF limits – mobile devices

ICNIRP 1998 - 150
FCC 1996 - 19
Other - 2

GSMA

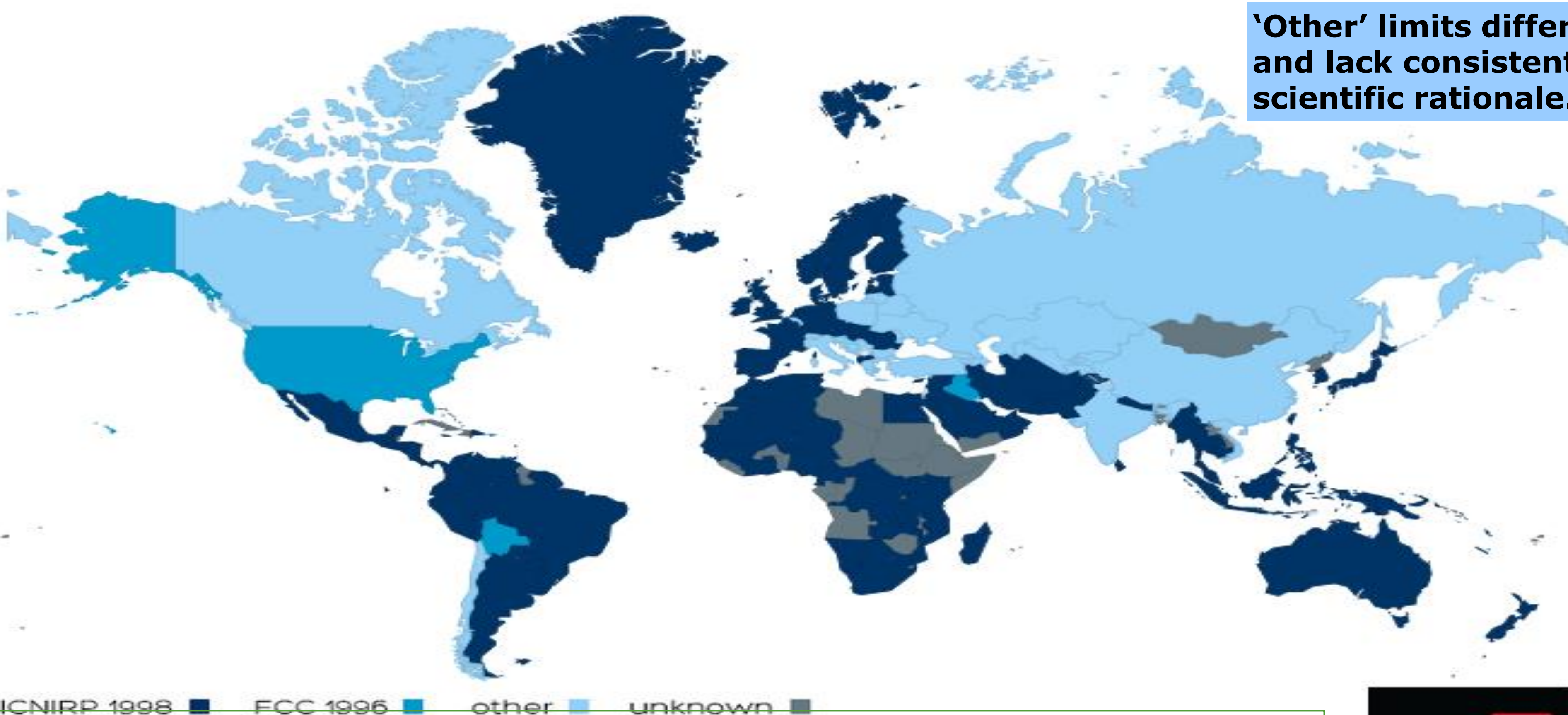


http://www.gsma.com/publicpolicy/consumer-affairs/emf-and-health/emf-policy

Public RF limits – mobile networks

ICNIRP 1998 - 125
FCC 1996 - 11
Other - 36

'Other' limits differ and lack consistent scientific rationale.



http://www.gsma.com/publicpolicy/consumer-affairs/emf-and-health/emf-policy

ote: Information from public sources except where indicated.

ast updated: 4 April 2016

Representative general population/uncontrolled exposure reference levels

<table>
<tr><th></th><th>PD 1,000 MHz (W/m^2)</th><th>SAR (W/kg)</th></tr>
<tr><td>USA</td><td rowspan="2">$f/150$
=6.67; 133/%</td><td>1.6, averaged over 1g tissue</td></tr>
<tr><td>Japan</td><td rowspan="2">2.0 , over 10 g</td></tr>
<tr><td>ICNIRP1998; IEEE 2006; AUS; NZL; EC Directive 004/40/EC</td><td rowspan="2">$f/200$
=5; 100%</td></tr>
<tr><td>Korea</td><td rowspan="2">1.6, averaged over 1g tissue</td></tr>
<tr><td>Canada</td><td>$0.02619f^{0.6834}$
=2.94; 59%</td></tr>
<tr><td>China</td><td>0.4; 8%</td><td>2.0 , over 10 g</td></tr>
</table>

Specific Absorption Rate (SAR) limits for portable wireless devices

- The SAR is determined from measurements of the E-field (e) in an anatomically-correct phantom model (liquid-filled dielectric shell) of the human head using a robotically-scanned miniature E-field probe

- The SAR (W/kg) is determined from the relationship between E and the tissue properties, i.e.,

$$\text{SAR} = \sigma|e^2|/\rho$$

where σ is the liquid conductivity and ρ is the density

SAR is "the time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given mass density (ρ_m)"
(ITU-T 2012 K.91:9) in W/kg

$$SAR = \frac{d}{dt}\left(\frac{dw}{dm}\right) = \frac{d}{dt}\left(\frac{dw}{\rho_m dv}\right)$$

SAR can be ascertained in three ways as indicated by the following equations:

E : value of the internal electric field strength in the body tissue (V/m)
σ : conductivity of body tissue (S/m) (siemens per meter, or mho per meter)

$$\mathrm{SAR} = \frac{\sigma e^2}{\rho} = C_i \frac{dT}{dt} = \frac{J^2}{\sigma\rho}$$

ρ : mass density of body tissue (kg/m^3)
C_i : heat capacity of body tissue (J/kg °C)
dT/dt : time derivative of temperature in body tissue (°C/s)
J : value of the induced current density in the body tissue (A/m^2).

Maximal power from handsets: Specific Absorption Rate, SAR (W/kg)

ICNIRP	European Community	USA and Canada
From 10 MHz to 10 GHz; Localized SAR (Head and Trunk)		Portable Devices; General Population/ Uncontrolled
2.0; averaged over 10 g tissue (also IEEE 2005 level)		1.6; averaged over 1g tissue

FCC 2016 Limits for Maximum Permissible Exposure (MPE)

Reassessment of RF Exposure Limits & Policies, and Proposed Changes in the Rules Regarding Human Exposure to RF Fields

Frequency range (MHz)	*electric field strength (V/m)*	*magnetic field strength (A/m)*	*power density (**mW/cm²**)*	*averaging time (minutes)*
(A) limits for occupational/controlled exposure				
0.3 – 3.0	614	1.63	100 *	6
3.0 – 30	1,842/*f*	4.89/*f*	900/f^2 *	6
30 – 300	61.4	0.163	1.0	6
300 – 1,500	–	–	*f*/300	6
1,500 – 100,000	–	–	5	6
(B) limits for general population/uncontrolled exposure				
0.3 – 1.34	614	1.63	100 *	30
1.34 – 30	824/*f*	2.19/*f*	180/f^2 *	30
30 – 300	**27.5**	0.073	0.2	30
300 – 1,500	–	–	***f*/1,500**	30
1,500 – 100,000	–	–	**1.0**	30

[1] FCC uses different units than ICNIRP 1998 for power density: mW/cm² and not W/m²; W/m² = 0.1 mW/cm²

ICNIRP vs. N. America and Japan reference levels

ICNIRP 1998, EC (1999/519) and IEEE reference levels for public exposure

Frequency range	electric field strength (V/m)	equivalent plane wave power density S_{eq} (W/m^2)
10–400 MHz	28	2
400-2000 MHz	$1.375f^{1/2}$	$f/200$
2-300 GHz	61	10

USA and Japan Maximum Permissible Exposure for general population/uncontrolled

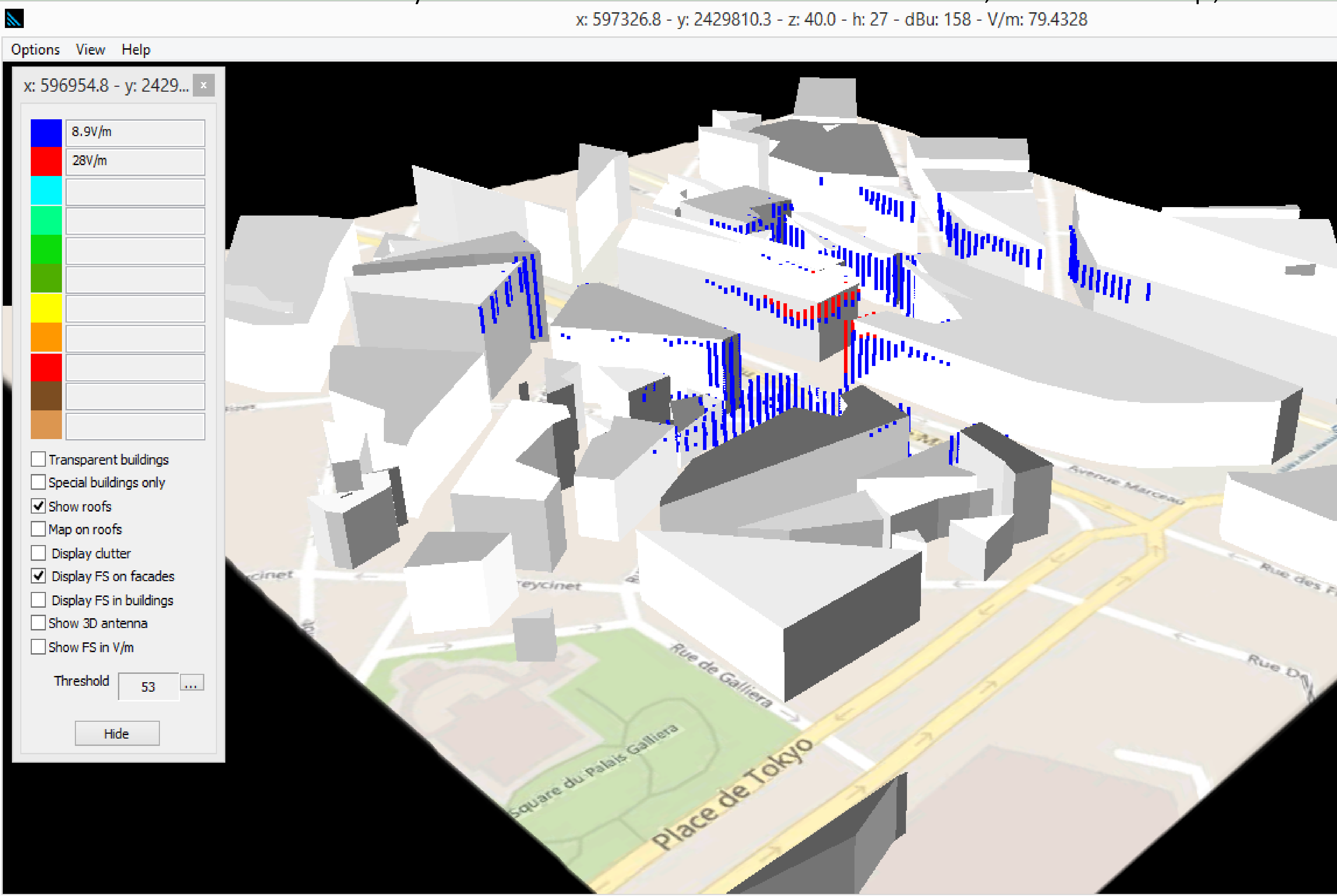
RF (MHz)	electric Field (*E*) (V/m)	power Density (*S*) (mW/cm^2)
30-300	27.5	0.2
300-1500	--	$f/1,500$
1,500-100,000	--	1

[1] FCC uses different units than ICNIRP for power density: mW/cm^2 and not W/m^2; $W/m^2 = 0.1\ mW/cm^2$

ICNIRP 1998, FCC §1.1310 & Canada Safety Code SC6 (W/m^2)

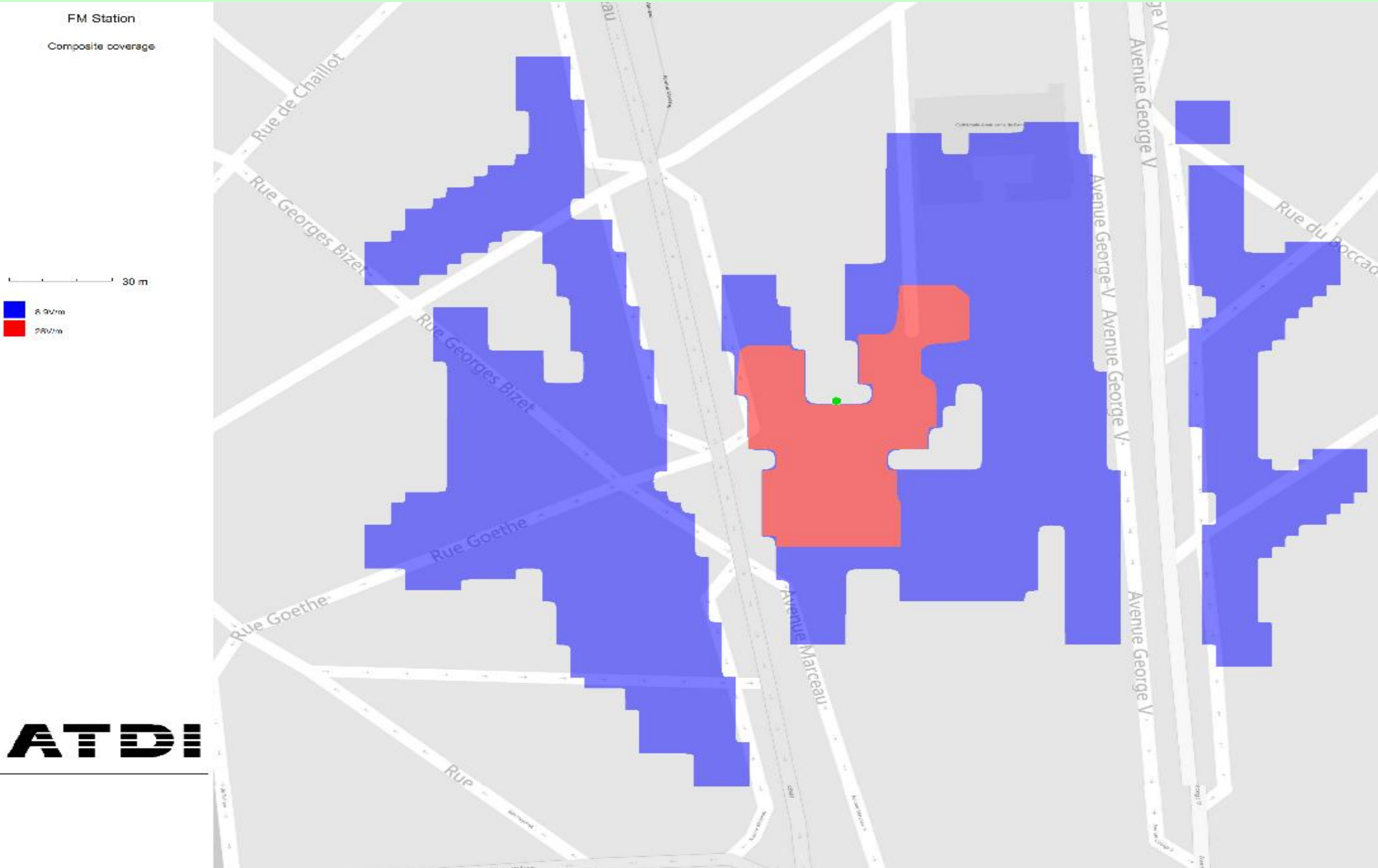
Frequency	ICNIRP 1998	FCC §1.1310	SC6
300 MHz	**2**	**2**	**1.291**
1,500 MHz	f/200=1500/200=**7.5**	**10**	$0.02619 \times f^{0.6834}$ =**3.88**
3,000 MHz	**10**		$0.02619 \times f^{0.6834}$ =**6.23**
6,000 MHz	**10**		

Three dimensions FM safety-distances: 100MHz transmitter of 60,000 Watts eirp, 60m



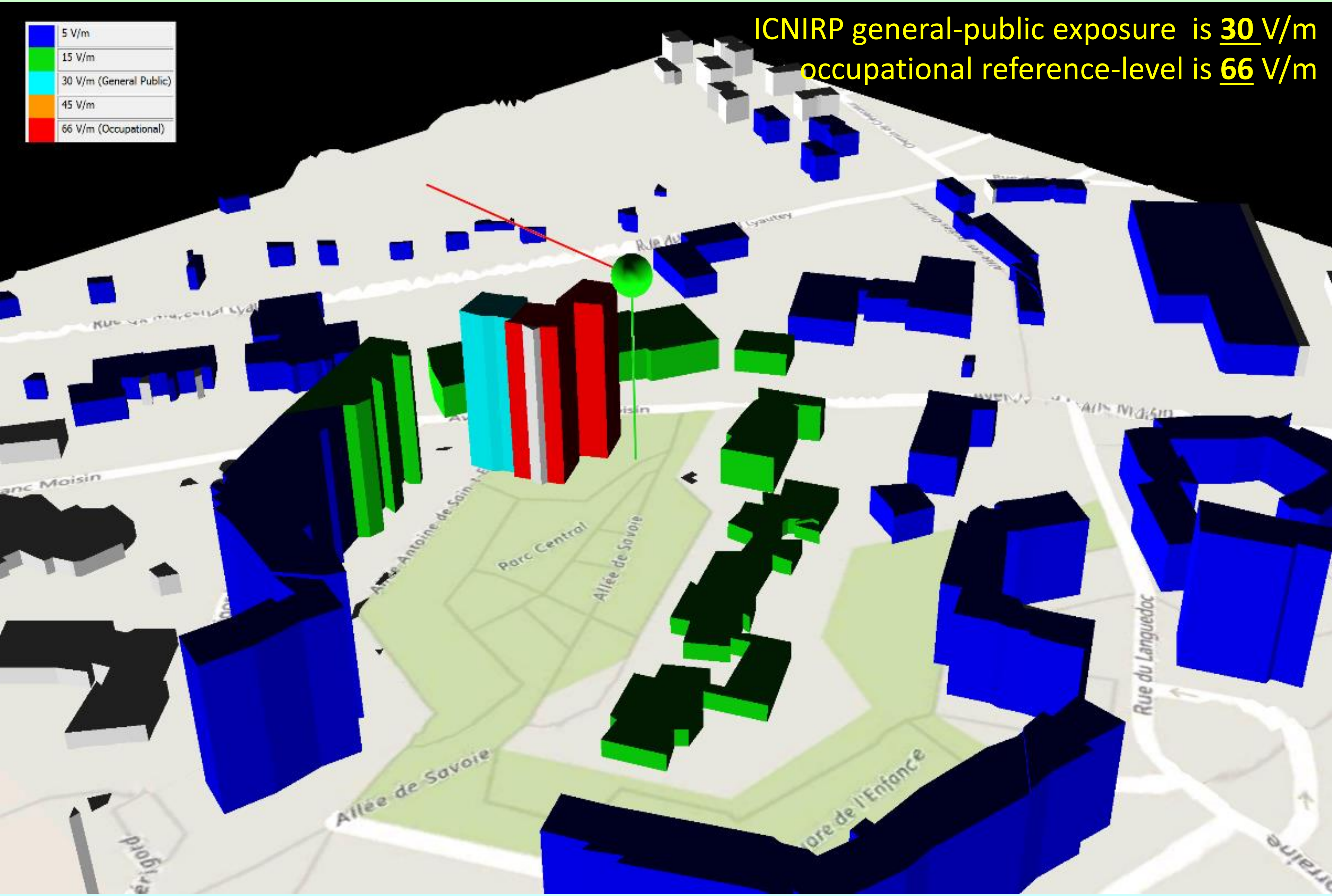
See ATDI's contribution: ITU-R Doc 6/395 6July15Fig2 and **SG2RGQ/246-E** 8 Jan17fig3

2D FM safety-distances: 100 MHz transmitter of 60,000 Watts eirp, 60m



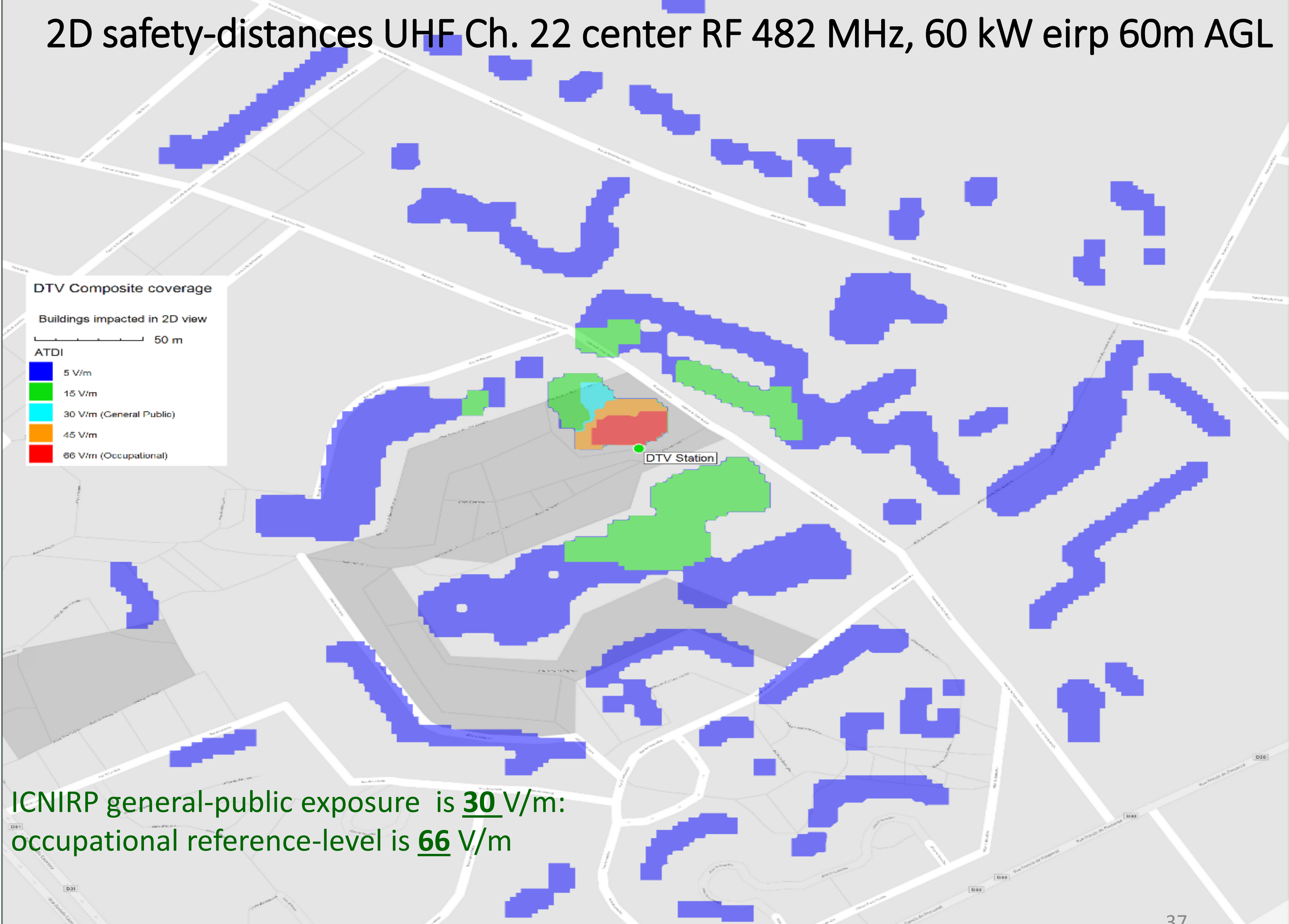
See ITU-RDoc 6/395 6July15Fig.3&**SG2RGQ/246-E** 8Jan17fig4

3D TV safety-distances UHF Ch. 22 (Reg1) center RF 482 MHz, 60,000 W eirp 60m AGL



ATDI's future contribution to ITU-R WP1C June 17

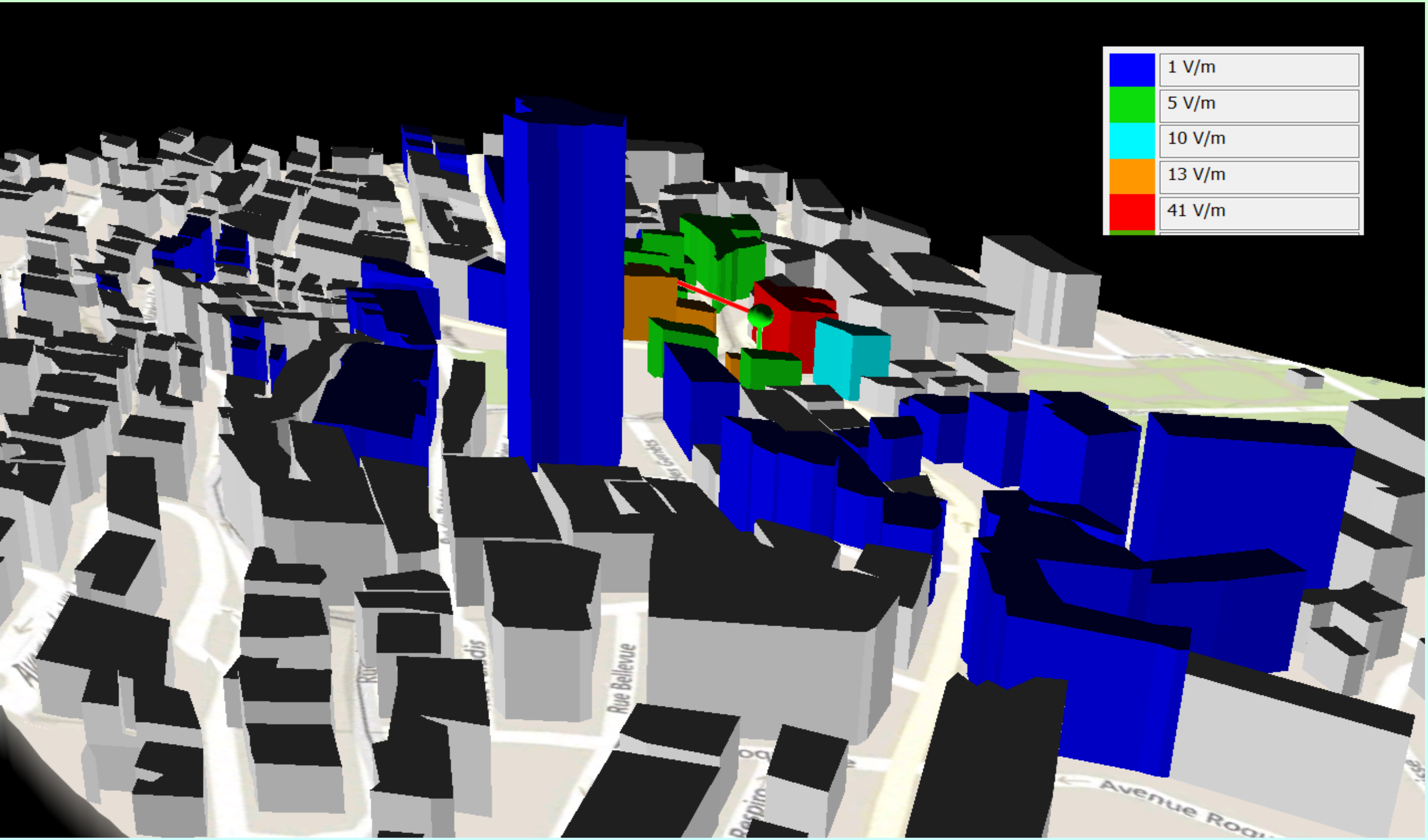
2D safety-distances UHF Ch. 22 center RF 482 MHz, 60 kW eirp 60m AGL



ICNIRP general-public exposure is **30** V/m:
occupational reference-level is **66** V/m

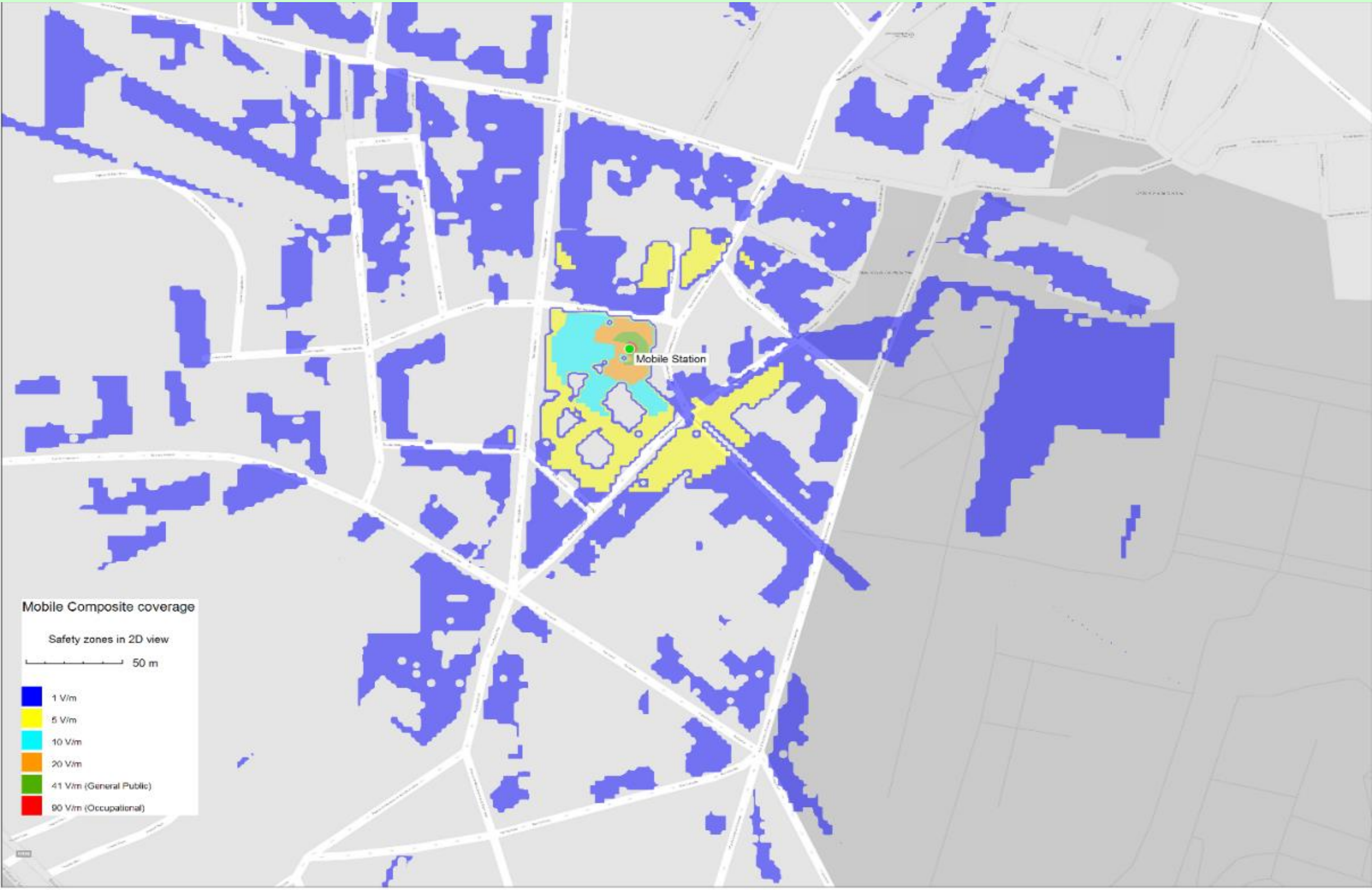
Three dimensions cellular safety-distances showing buildings impacted

For max. downlink power of 100 W, ant gain (including losses) 17 dBi, eirp is 5 kW; the free-space outdoor propagation loss safety-contours are 9.5 m for 41 V/m and 30 m for 13 V/M



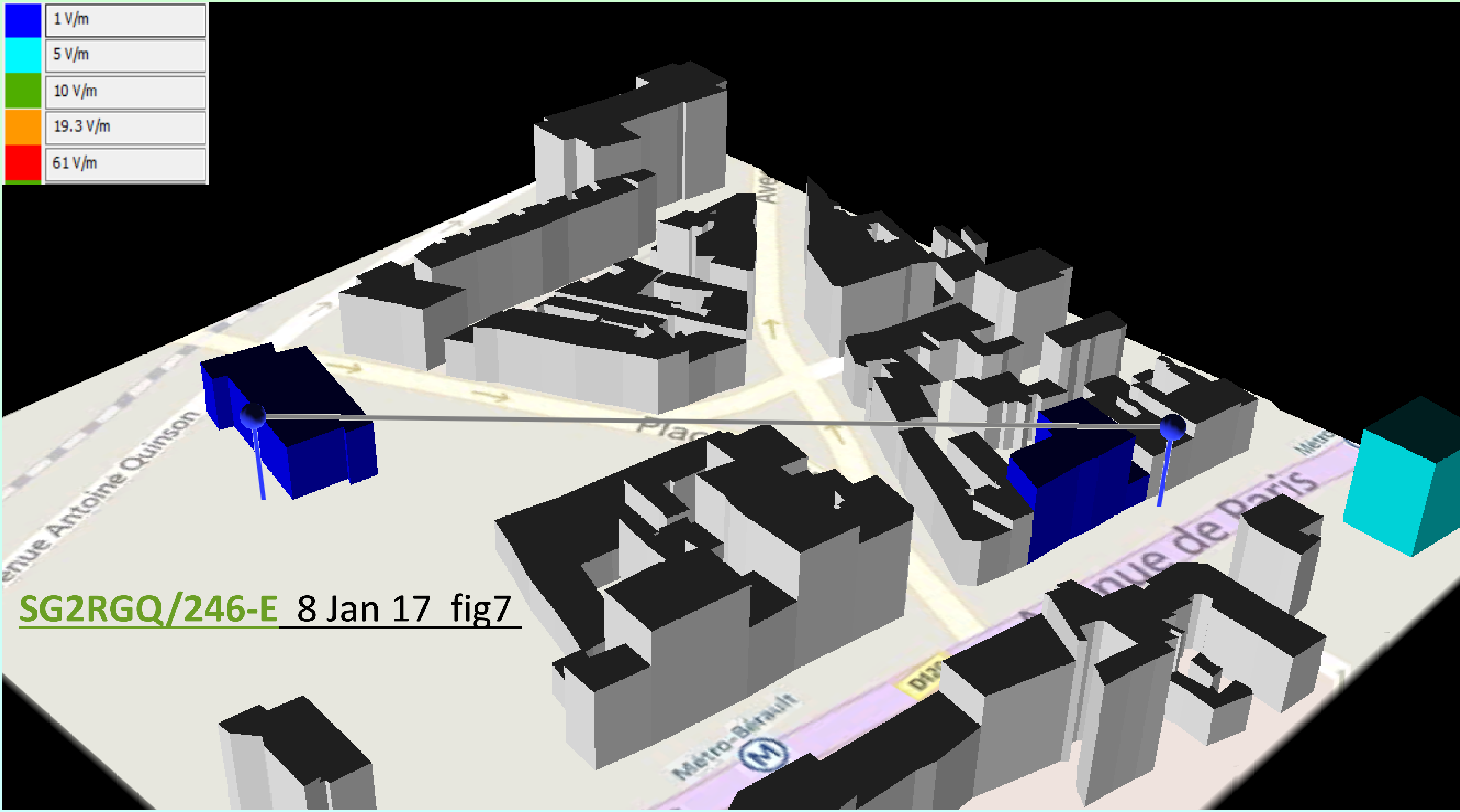
See contribution of ATDI: ITU-D SG2RGQ/246-E; **8 Jan17** fig5

Two dimensions cellular safety-distances



See ATDI contribution ITU-D Doc 5D/007 and 5A/008; p. 4; & **SG2RGQ/246-E** 8Jan17fig6

P2P 3 dimensions exposure, using ITU-R F.699 antenna patterns; 40 kW eirp



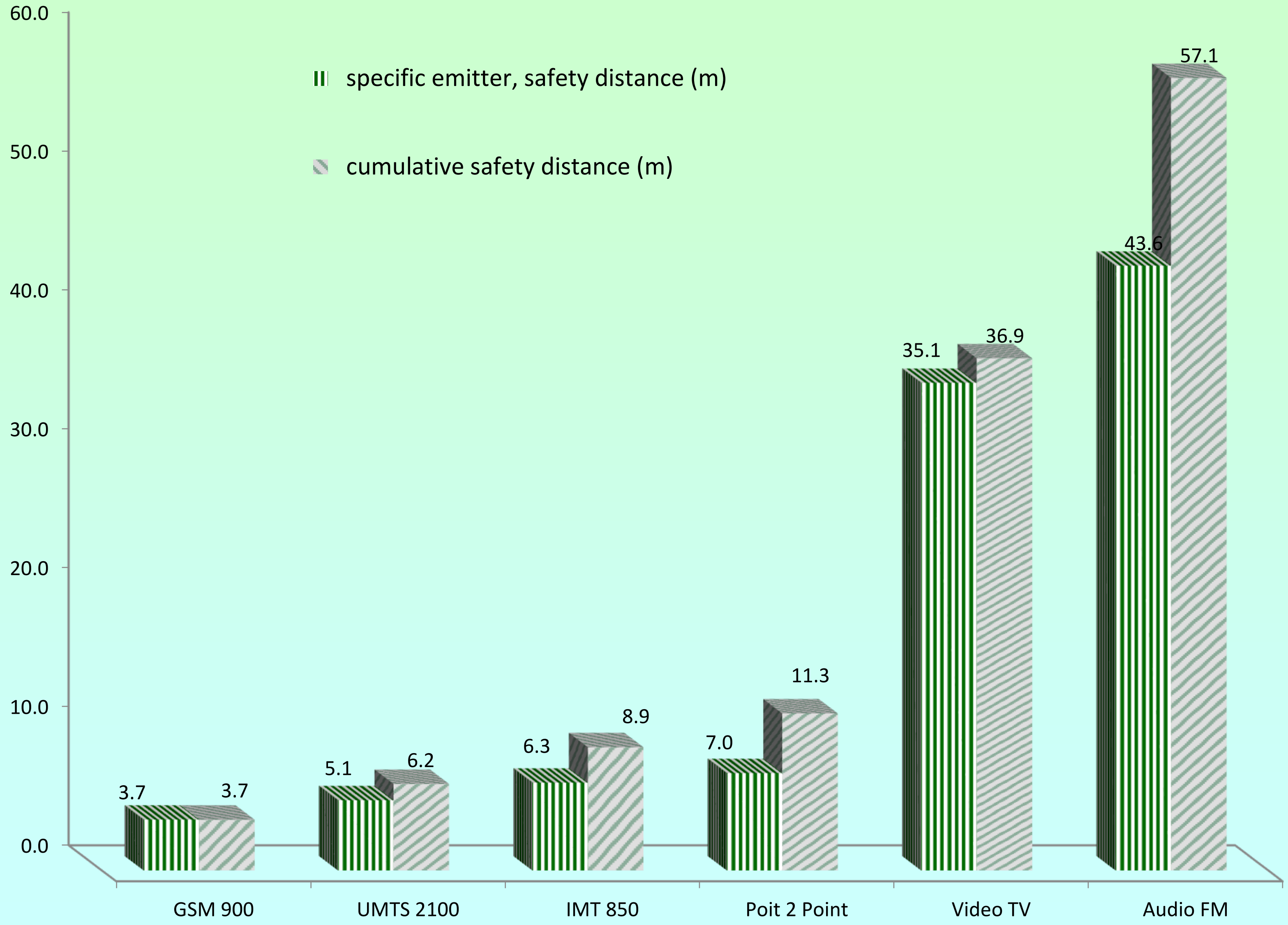
SG2RGQ/246-E 8 Jan 17 fig7

Worst-case horizontal safety-distances & cumulative exposure; co-located site

Transmission System	GSM 900	UMTS 2100	IMT 850	point-to-point	Video TV	Audio FM
Frequency (MHz)	891	2100	800	514	514	100
ICNIRP limit, power density (W/m^2)	4.75	10.00	4.00	2.57	2.57	2.00
Antenna Gain (dBi)	16	18	18	23	17	10
Antenna elevation model or real pattern	742 265	TBXLHA	80010302_08 24	ITU-R F.1336	ITU-R F.699	ITU-R F.699
Ant. Altitude above ground level (m)	32	45	15	25	60	60
Cable Loss (dB)	0	1	1	1	1	1
Power (Watt)	20	64	40	10	1,000	6,000
EIRP (Watt)	800	3,210	2,000	1,580	39,810	47,660
Specific safety distance (m)	3.7	5.1	6.3	7.0	35.1	43.6
Cumulative safety distance (m)	3.7	6.3	8.9	11.3	36.9	57.1
ICNIRP limit, field strength (V/m)	41.30	61.00	38.89	31.17	31.17	28.00
Specific field strength at 50m, ICNIRP ratio	0.08	0.10	0.13	0.14	0.70	0.85
Cumulative field strength ratio	0.08	0.13	0.18	0.23	0.74	1.13

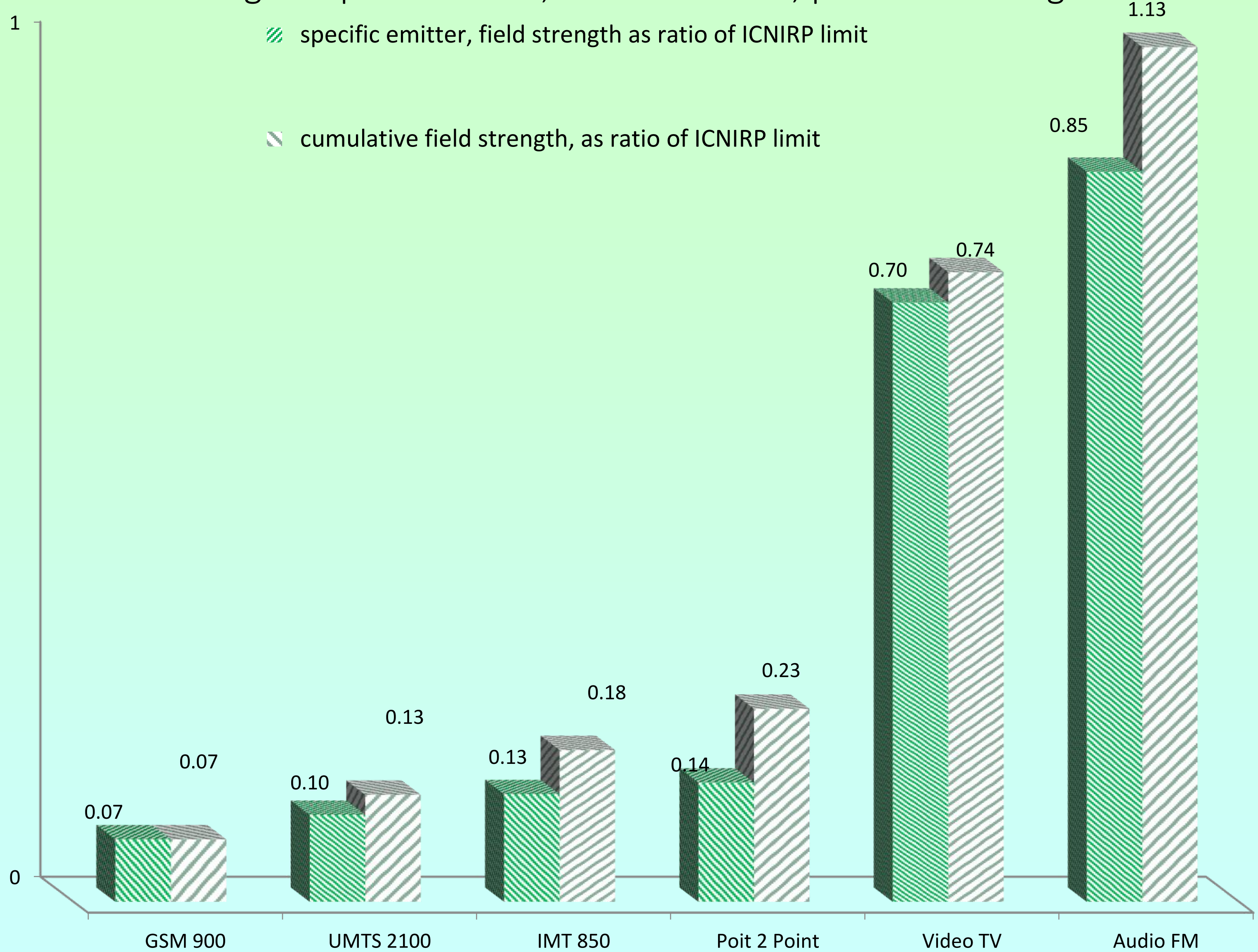
calculated by author

Cumulative horizontal safety-distance, co-located site; y axis (m)



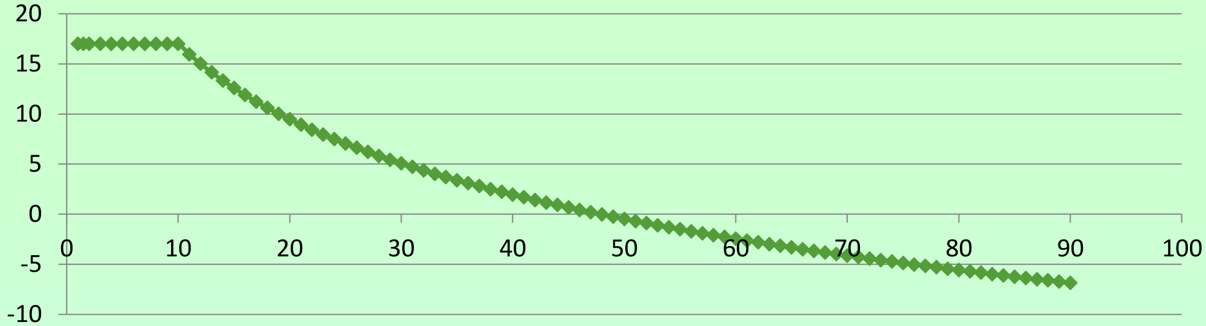
calculated by author, mazar@ties.itu.int

Cumulative field strength exposure ratio , co-located site; point of investigation at 50 meter

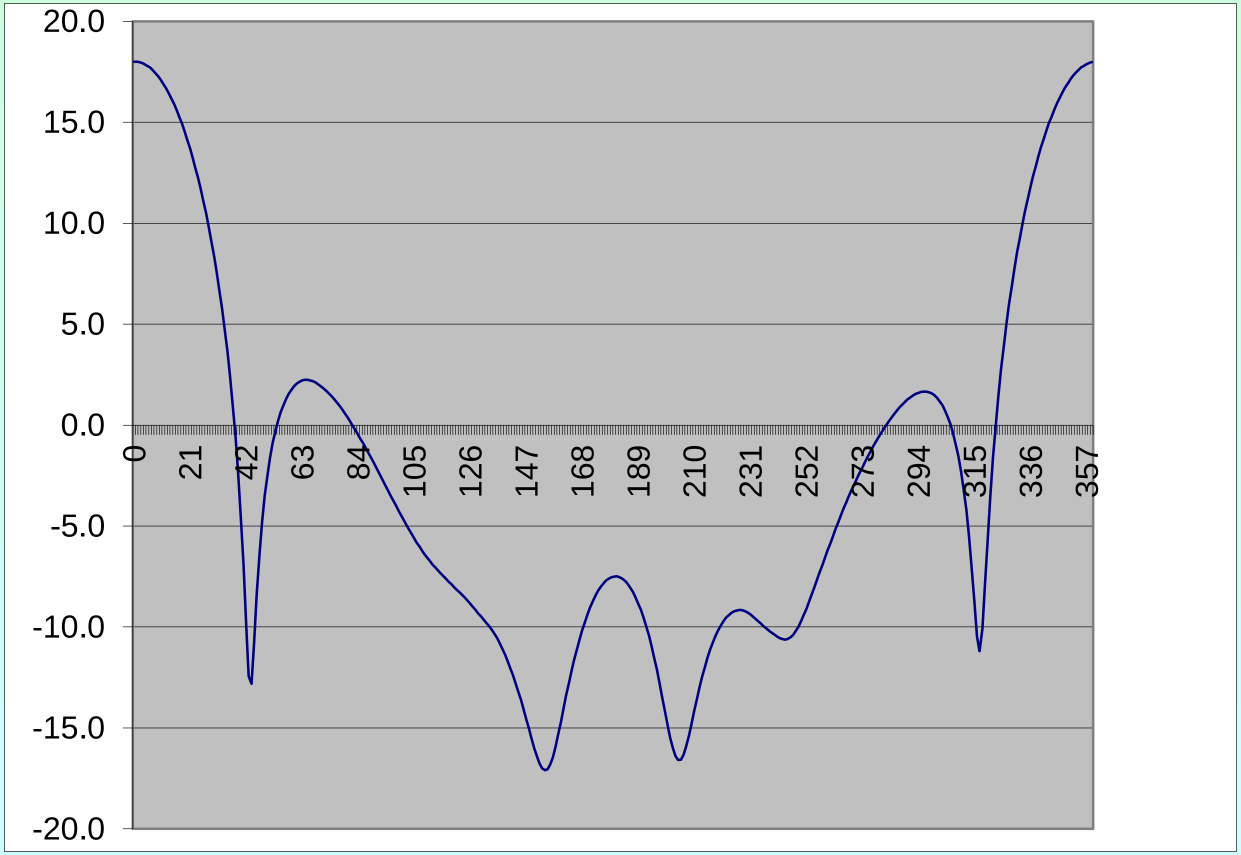


calculated by author

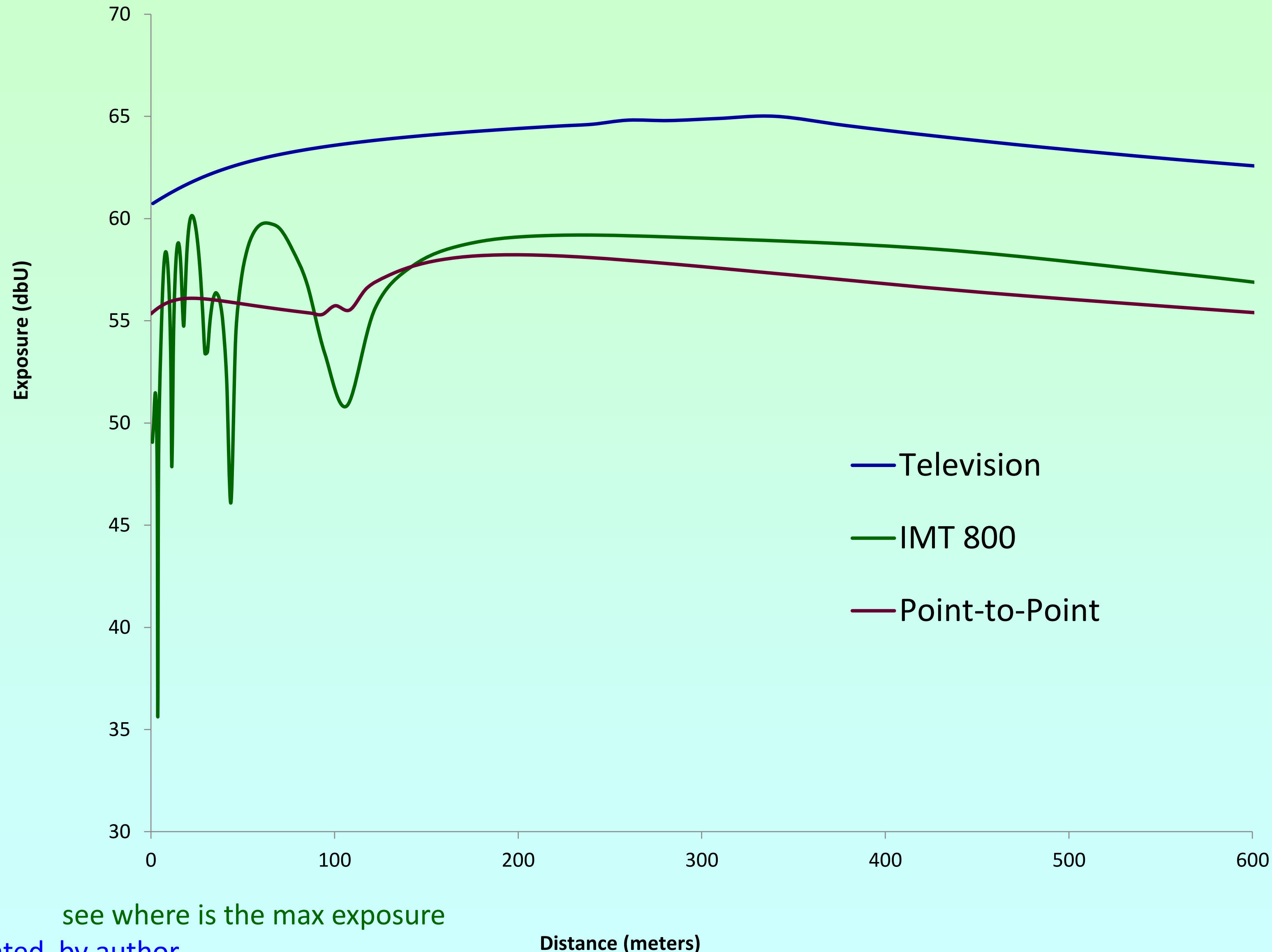
Vertical pattern of TV antenna 17 dBi calculated by ITU-R Rec. F.699



Vertical pattern of 80010302_0824_X_CO_M45_00T; Anatel



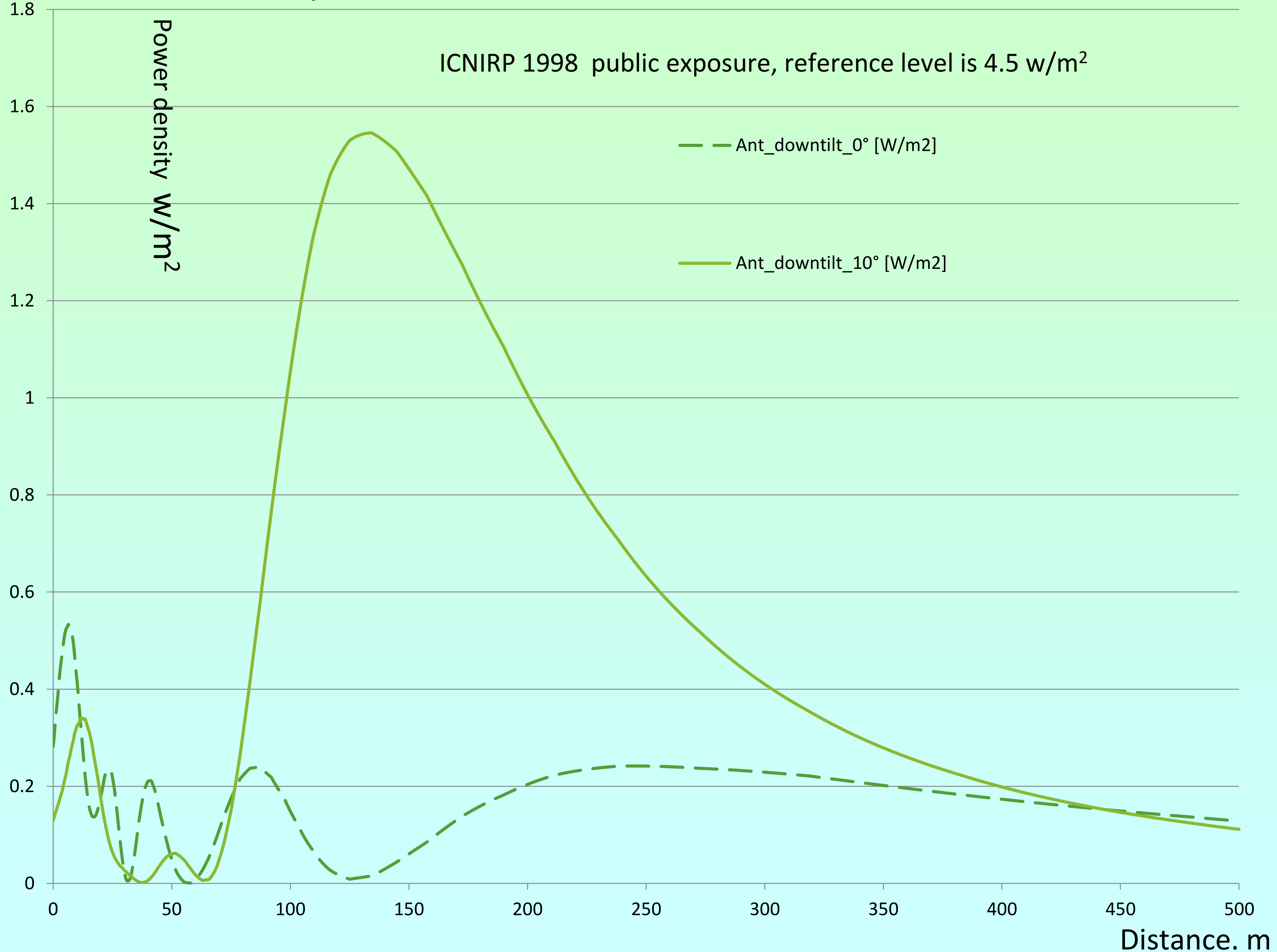
Field Strength (dBµV/m) vs. distance (m), co-located site TV, IMT 850 & Point 2 Point



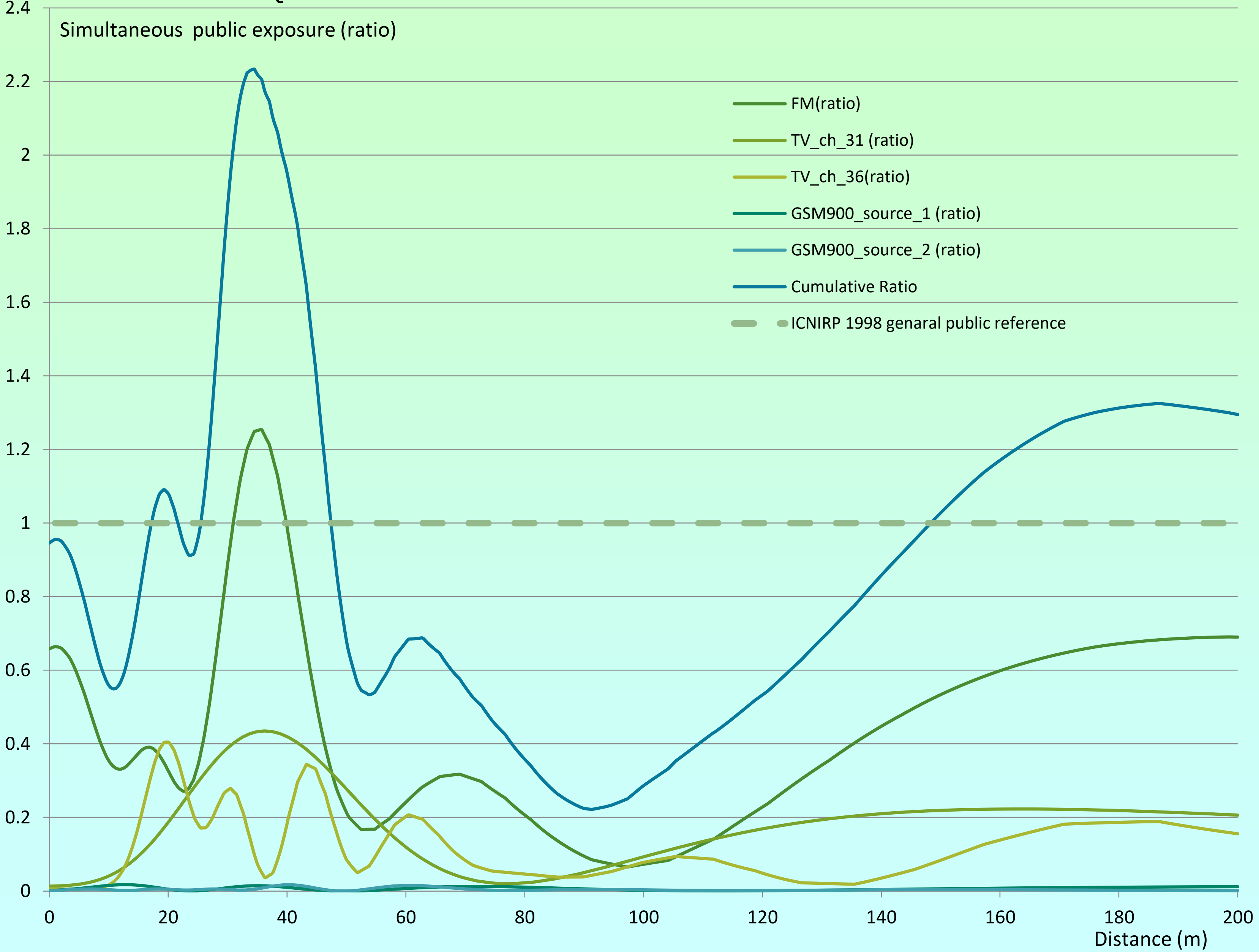
see where is the max exposure

calculated by author

Power density vs. horizontal distance, for 2 down-tilts

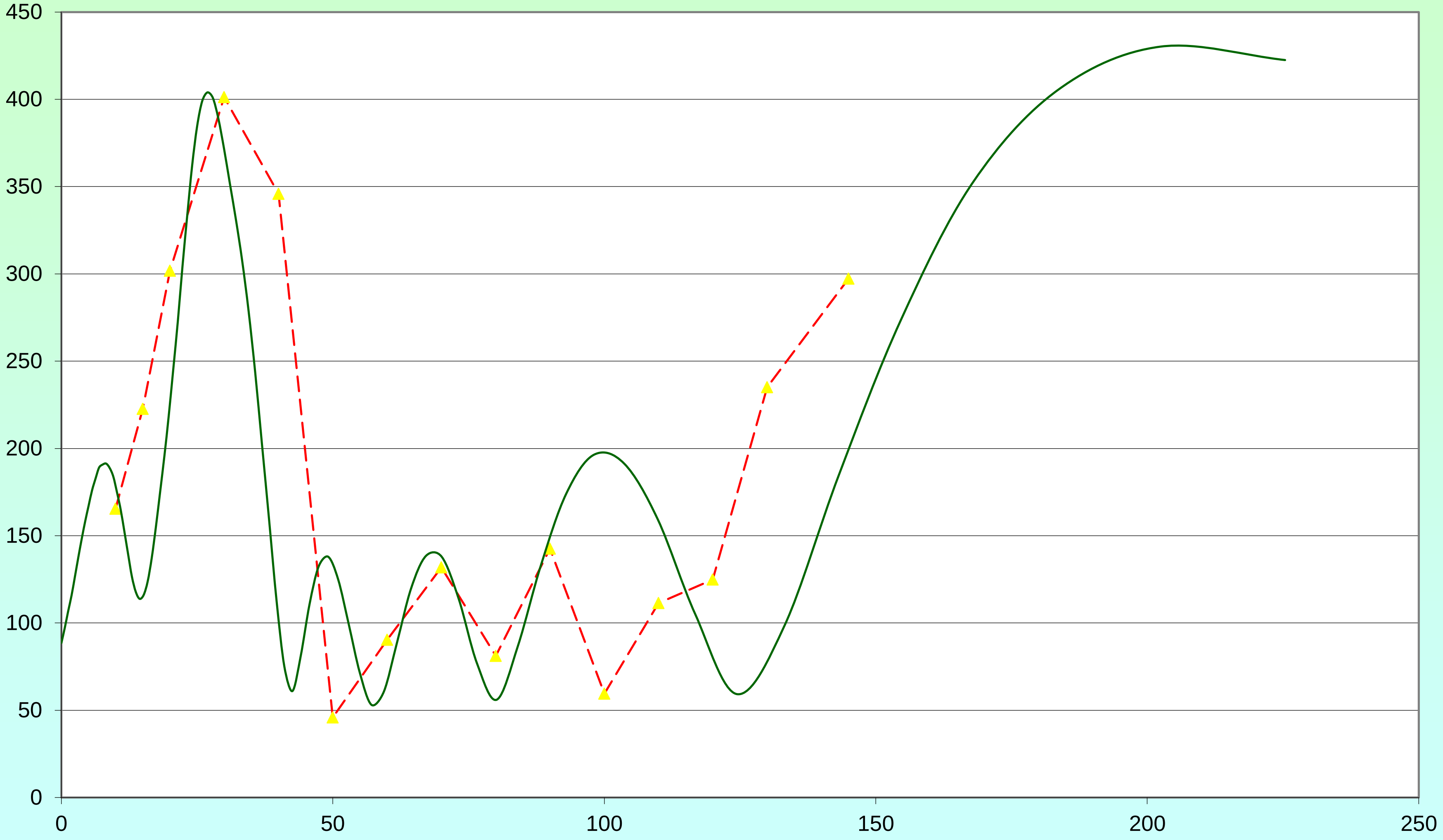


Coefficient W_t vs. distance, co-located site, FM, TV & GSM 900



Field Strength (mV/m) vs. distance (m)

RF = 1875.8 MHz; red- measured, green- calculated



Measured and calculated by ANATEL 2012, Eng . Agostinho Linhares de Souza Filho

RF Hazards limits & their impact on network planning

Excessive limits affect network planning

- Co-location and MIMO increase the safety distance and restrict mast construction near buildings
- Countries (e.g. Switzerland) reduce by 100 (and Salzburg by 9,000) the power density level and restrict the cellular BTS planning and location
- Lower RF exposure limits enforce to decrease the EIRP (in order to reduce the power density and field strength near the station) or to extend the distance of the mast from the public
- Handling low exposure thresholds by additional cellular antennas or RF Spectrum

Mitigation techniques to decrease the radiation level (1)

- Avoid wireless communications if the transmitter & receiver stations are fixed
  - Avoid WiFi routers based on cellular infrastructure
  - Use Satellite and Cable TV
- Maximize sharing, including active frequencies sharing among cellular operators
- Maximize the RF to operators in order to decrease sites

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, if possible, ant. 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)
- **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)
- **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 ant. (ITU-T 2007 K.70 p.22)

Low exposure thresholds by additional cellular antennas or RF Spectrum

Simplistic equations; see Mazar Wiley book, to be published April 2016

For a given network (technology, number of sites, RF spectrum, quality of service), better coverage is achieved by transmitting at higher effective power (for both downlink and uplink channels), installing base stations at higher altitude above ground level (less signal attenuation) and using lower radio frequency.

Max. channel capacity for each communications link in a given network is derived from Shannon Hartley monumental paper (**Shannon 1948 p.43, theorem 17**), relating capacity (bit/s), RF bandwidth (Hz) and the signal to noise (dimensionless) ratio

$$c = b \times log_2 (1 + s/n)$$

Moreover, in urban scenario *s/n* is small. LTE RSRQ (Reference Signal Received Quality) quantifies the capacity; UE measures this parameter as reference signal. Values higher than −9dB guarantee the best subscriber experience; the range between −9 and −12dB can be seen as neutral with a slight degradation of Quality of Service. So for *s/n* very small relative to 1, 5.1 aims to:

$$c = b \times log_2 (1 + s/n) \approx b \times \frac{s/n}{\ln 2} \approx 1.44 \times b \times s/n$$

Therefore, staying with the same *capacity* *c*- less sites (reduced *s*) can be compensated by more frequency *band* (*b*).

The capacity is limited by power *s* and noise density n_o.

Summary: cellular capacity is limited by power and noise; adding RF to base stations may decrease the number of base stations and the total EMF

Related author's presentations

- A Global Survey and Comparison of Different Regulatory Approaches to Non-Ionizing RADHAZ and Spurious Emissions, IEEE TelAviv, COMCAS, November 2009. Hyperlink to the slides presentation; 9 November 2009
- A Comparison Between European and North American Wireless Regulations, presentation at the 'Technical Symposium at ITU Telecom World 2011' www.itu.int/worl2011 on 27 October 2011; hyperlink to the slides presentation, 27 October 2011
- Technical limits of Human Exposure to RF from Cellular Base Stations and Handsets, Jerusalem, 11 April 2013. Professional presentation of the Ministry of Communications to the experts of Ministry of Environmental Protection, human-exposure monitoring laboratories and cellular operators
- Technical limits of Human Exposure to RF from Broadcasting Emitters, Cellular Base Stations and Handsets, at 'Holon institute of technology', 30 January 2014
- Smart_Cities_RF_Human_Exposure_Ministries_of_Comms_Energy.pdf; presentation at intra-ministerial commission, on 21 January 2015
- January 2016, presentations in Singapore, Beijing, Chengdu and Shenzhen
- January2016_Human_Hazards_Mazar_SRTC_in_Chinese.pdf

U may visit my web sites http://mazar.atwebpages.com/
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Any Questions ?