Electromagnetic Fields and 5G Implementation

ITU Regional Symposium for Europe and CIS
on
Spectrum Management and Broadcasting
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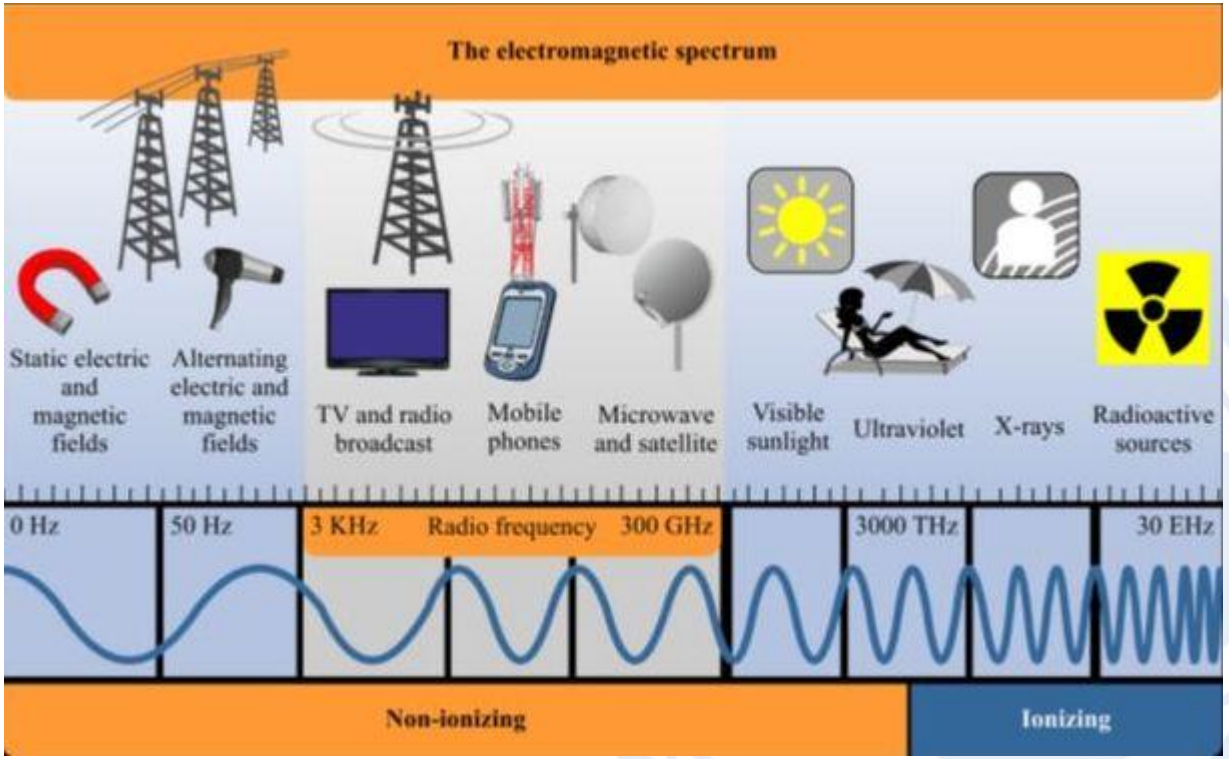
Energy
& Environment

ITU

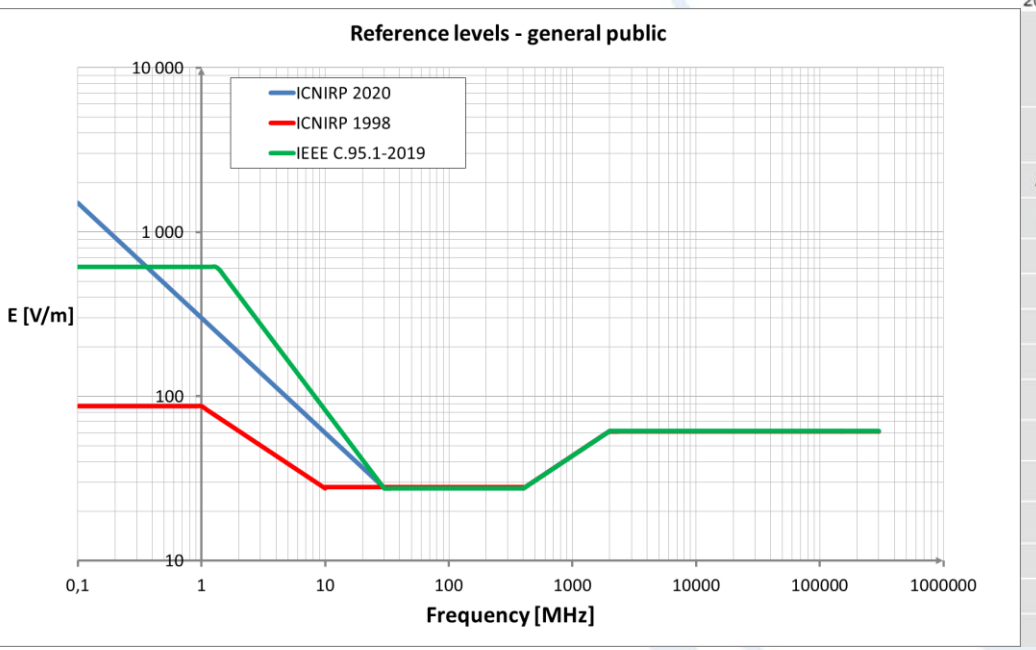
Introduction - Electromagnetic spectrum



Type of radiation	Energy $E = h\nu$
Microwaves and radiowaves (up to 10^{12} Hz)	$10^{-3} \div 10^{-12}$ eV
Infrared (temperature 20°C)	$3 \cdot 10^{-2}$ eV
Visible light	1,6 ÷ 3,1 eV
Ultraviolet light	$3{,}3 \cdot 10^{2}$ eV
X – rays	10^{4} eV
γ - rays	10^{6} eV
Energy of the nucleus bonds	1 ÷ 15 eV

- The frequencies used in radio-communication are:
  - higher than those used by power supply systems,
  - lower than infrared radiation, visible light and ultraviolet, X and γ rays
- RF EMF energy is too small to break chemical molecules bonds

WHO recommend the use of the ICNIRP exposure limits



set table
2017-05-31

Download filtered data as: CSV table | XML (simple) | JSON (simple)
Download **complete** data set as: CSV table | Excel | CSV list | more...

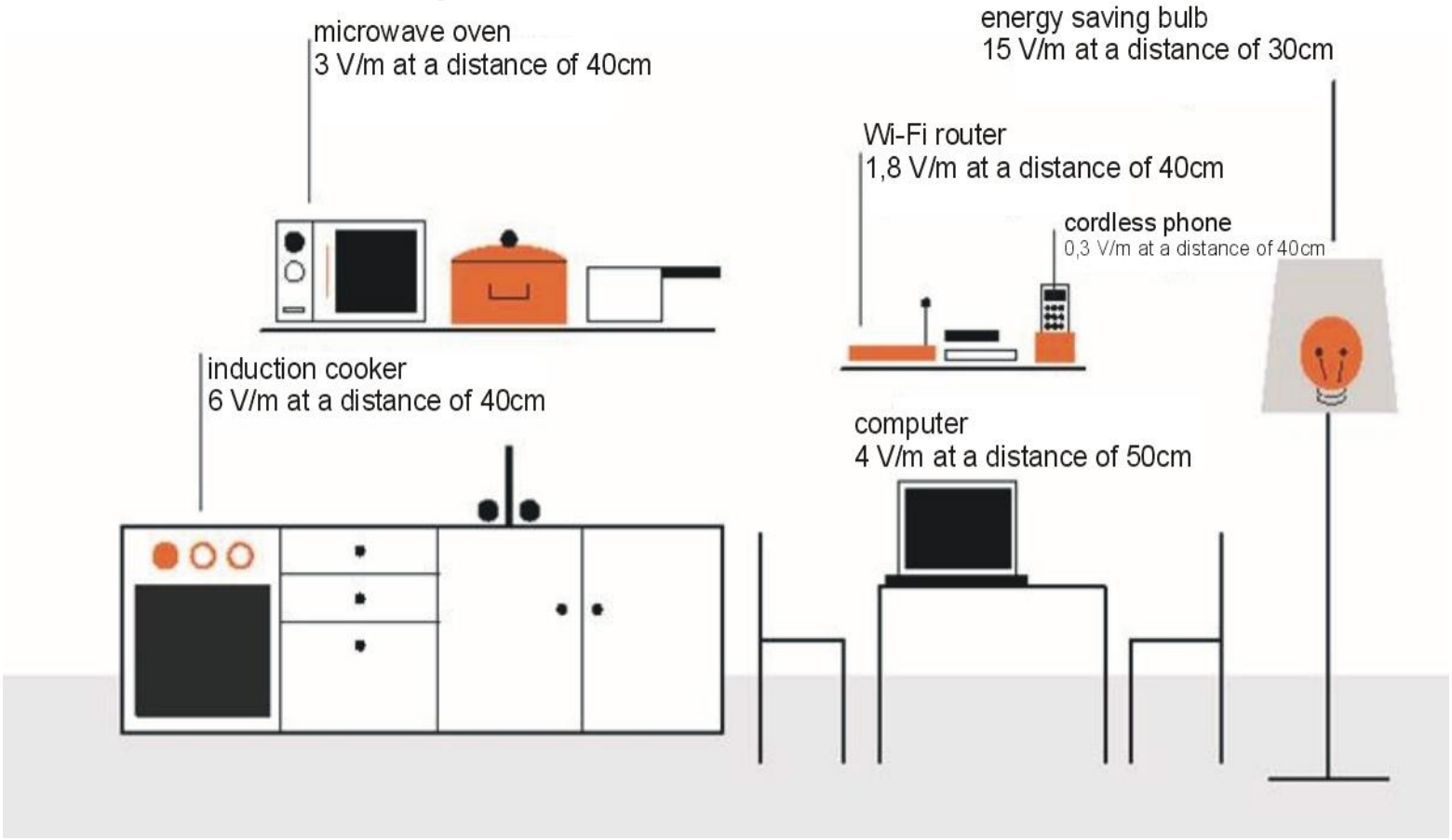
		Radiofrequency						
		Electric field (V/m)[i]		Power density (W/m^2)[i]		Specific absorption rate (SAR) (W/kg)[i]		
Country	Year	900 MHz	1800 MHz	900 MHz	1800 MHz	Whole body	Head and trunk	Limbs
Argentina	2017	41.25	58.36	4.5	9	0.08	2	4
Australia	2017	41.1[i]	58.1[i]	4.5[i]	9[i]	0.08	2	4
Austria	2017	41.25	58.34	4.5	9	0.08	2	4
Bahrain	2017	41	58	4.5	9	0.08	2	4
Belgium	2017	[i]	[i]	[i]	[i]			
Brazil	2017	41.25	58.34	4.5	9	0.08	2	4
Bulgaria	2017	6.14[i]	6.14	0.1[i]	0.1			
Canada	2017	32.1[i]	40.07[i]	2.74[i]	4.4[i]	0.08	1.6[i]	4
Chile	2017			0.1/1.0[i]	0.1/1.0[i]	1.6/2[i]	1.6/2[i]	1.6/2[i]
Cuba	2017						0.8/1.6[i]	
Cyprus	2017	41	58	4.5	9	[0.08]	[2]	[4]
Finland	2017	41.4	58.55	4.5	9	0.08	2	4
France	2017	41	58	4.5	9	0.08	2	4

- WHO website with RF EMF exposure limits

http://apps.who.int/gho/data/node.main.EMFLIMITSPUBLICRADIOFREQUENCY?lang=e

- ICNIRP guidelines (1998 & 2020) and IEEE exposure limits (2019) are almost identical (for frequencies used in radiocommunication)

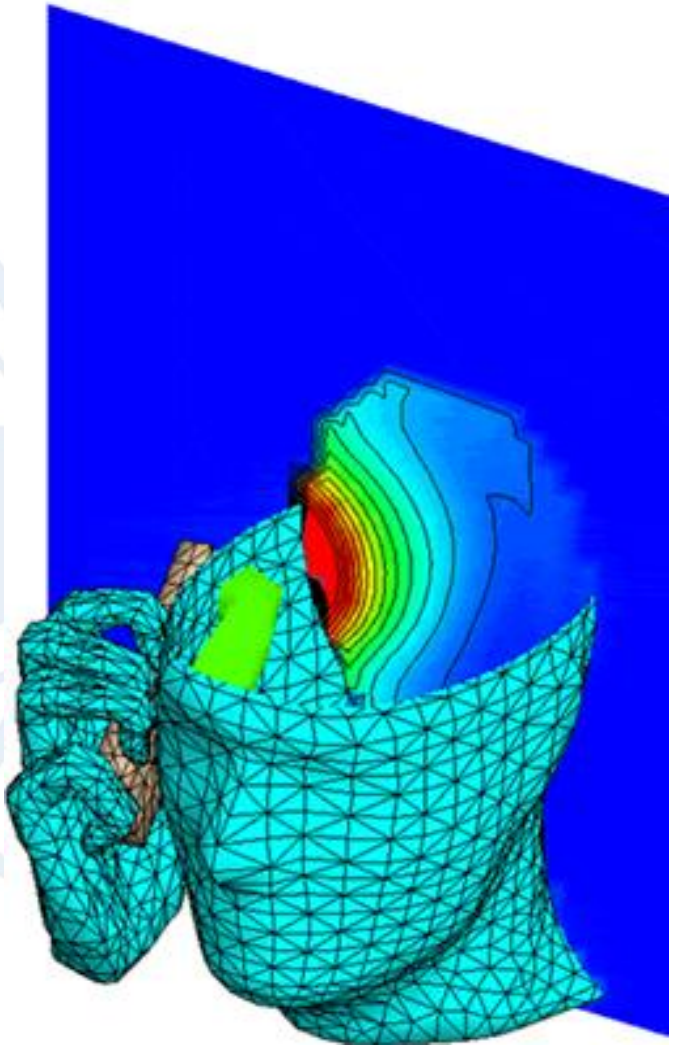
EMF exposure level in home environment



Exposure levels around typical electronic and electric equipment in home environment

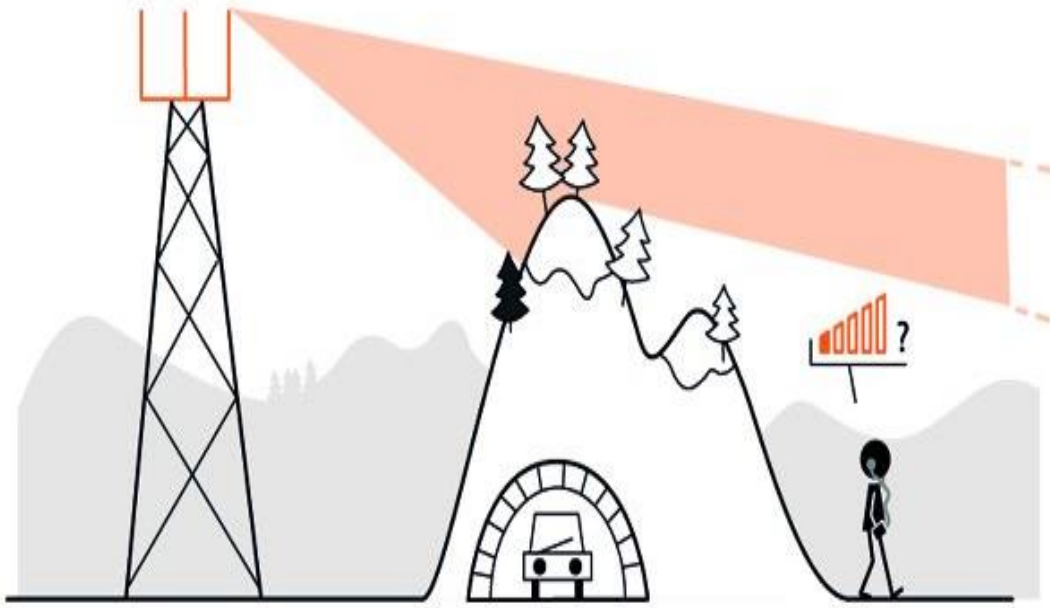
Exposure limits for devices

- The exposure limits for devices are accepted around the world
- The „basic restriction” in form of Specific Absorption rate (SAR) is valid
- For the general public the local SAR = 20 W/kg is considered by WHO/ICNIRP as adverse health effect threshold. If the protection ratio 10 is applied the exposure limit is SAR = 2W/kg
- For a comparison a human adult generates (for the whole body) a total of approximately:
  - 1 W/kg at rest (Weyand et al., 2009)
  - 2 W/kg – in standing position
  - 12 W/kg – in running (Teunissen et al., 2007)



Location of antennas

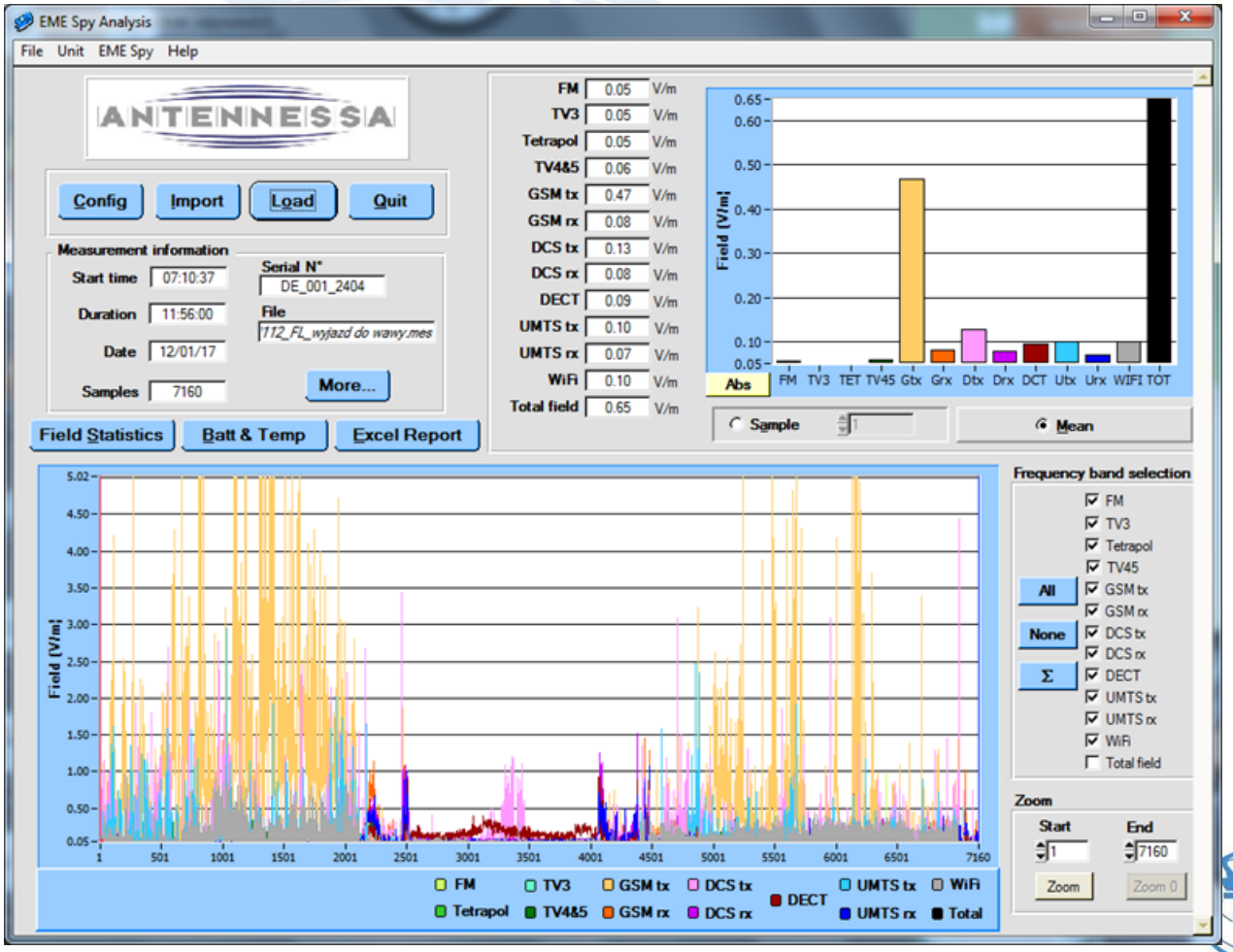
- Coverage of the wireless service depends strongly on antenna height – coverage radius increases with the antenna height
- Macro BS are usually located on the highest buildings or towers
- Any obstacles (for example buildings, walls, hills etc.) between transmitter and receiver reduce the coverage
- Cell coverage can not be too big – it may interfere with neighboring cells
- In result, the power delivered to the antenna, antenna location and height have to be properly adjusted



Source: Orange

Example of the results of measurements

- Measurements during trip from Wroclaw to Warsaw (and back)
- The biggest exposure level inside train an in 900 MHz band was noticed



ITU's Mandate on EMF

ITU PP Resolution 176 - "Measurement and assessment concerns related to human exposure to electromagnetic fields" (Dubai, 2018)

3 SECTORS

STANDARDIZATION

WTSA Resolution 72 - "Measurement concerns related to human exposure to electromagnetic fields" (Rev. Hammamet, 2016)

ITU-T SG5, Question 3/5
Human exposure to RF EMF

DEVELOPMENT

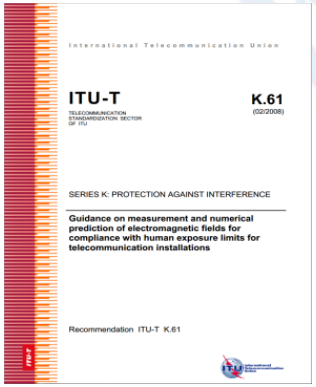
WTDC Resolution 62 - "Assessment and measurement of human exposure to electromagnetic fields" (Rev. Buenos Aires, 2017)

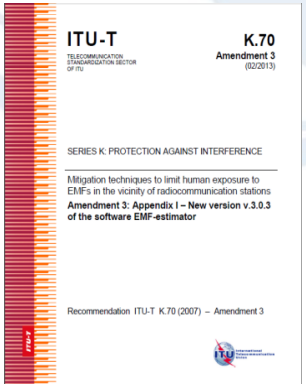
RADIOCOMMUNICATION

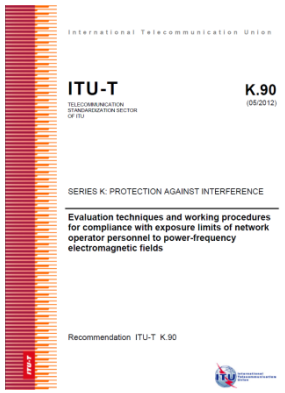
ITU-R Question 1/239 (Electromagnetic field measurements to assess human exposure).

ITU-T Recommendations on EMF

- **Recommendation ITU-T K.52** (2000/**2018**) - Guidance on complying with limits for human exposure to electromagnetic fields – **includes „K.52calculator" software**
- **Recommendation ITU-T K.61** (2003/**2018**) - Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations
- **Recommendation ITU-T K.70** (2007/**2019**) **-** Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations – **includes „EMF Estimator" software**
- **Recommendation ITU-T K.83** (2011/**2020**) - Monitoring of electromagnetic field levels
- **Recommendation ITU-T K.90** (2012/**2019**) - Evaluation techniques and working procedures for compliance with exposure limits of network operator personnel to power-frequency electromagnetic fields– **includes „EMFACDC" software**





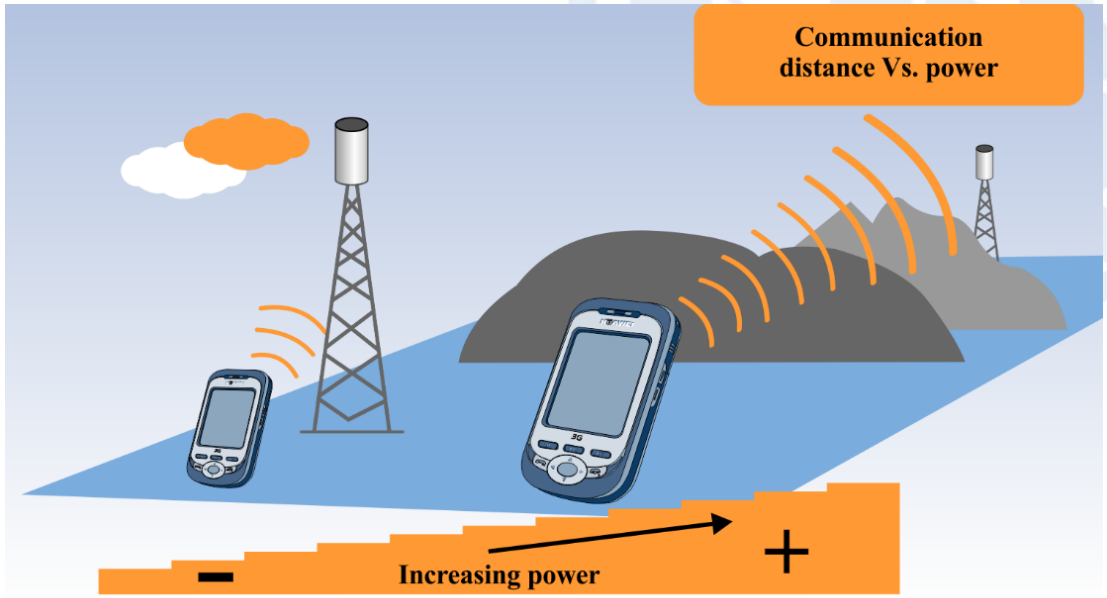


ITU-T Recommendations on EMF

- **Recommendation ITU-T K.91** (2012/**2020**) - Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields – **includes "Uncertainty calculator" and "Watt_Guard" software, Supplement and mobile App "EMF-guide", mobile App „EMF Exposure"**
- **Recommendation ITU-T K.100** (2014/**2019**) - Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service
- **Recommendation ITU-T K.113** (**2015**) - Generation of radiofrequency electromagnetic field level maps
- **Recommendation ITU-T K.121** (2016) - Guidance on the Environmental Management for Electromagnetic Radiation from Radiocommunication Base Stations
- **Recommendation ITU-T K.122** (**2016**) - Exposure levels in the close proximity of the radiocommunication antennas
- **Recommendation ITU-T K.145** (**2019**) - Assessment and management of compliance with RF EMF exposure limits for workers at radiocommunication sites and facilities

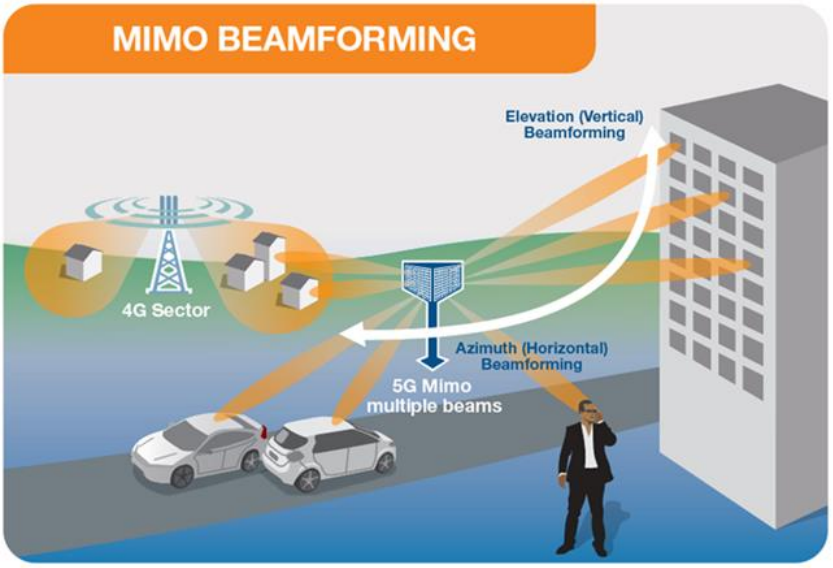
ITU-T Supplements on EMF

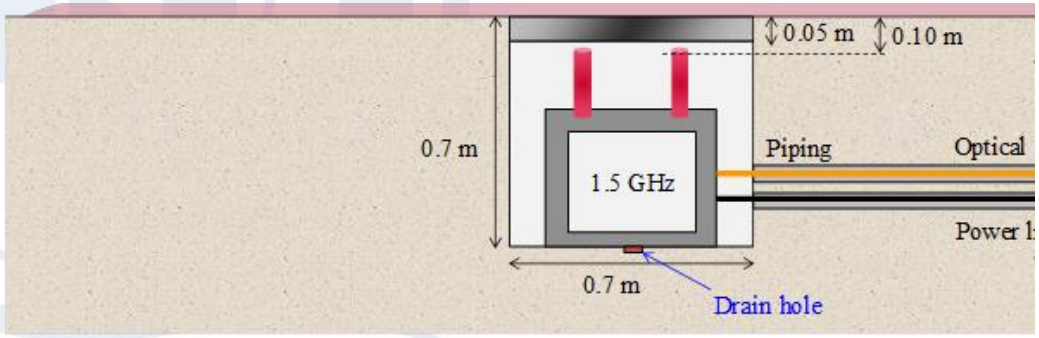
- **ITU-T K Suppl. 1** (05/2020) ITU-T K.91 – Guide on electromagnetic fields and health
- **ITU-T K Suppl. 4** (09/2018) ITU-T K.91 - Electromagnetic field considerations in smart sustainable cities
- **ITU-T K Suppl. 9** (05/2019) 5G technology and human exposure to RF EMF
- **ITU-T K.Suppl. 13** (05/2018) - Radiofrequency electromagnetic field (RF-EMF) exposure levels from mobile and portable devices during different conditions of use



ITU-T Supplements on EMF

- **ITU-T K.Suppl. 14** (09/2019) - The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment
- **ITU-T K.Suppl. 16** (05/2019) - Electromagnetic field (EMF) compliance assessments for 5G wireless networks
- **ITU-T K.Suppl. 19** (09/2019) - EMF strength inside subway train
- **ITU-T K.Suppl. 20** (05/2020) - RF Exposure evaluation around base station installed underground

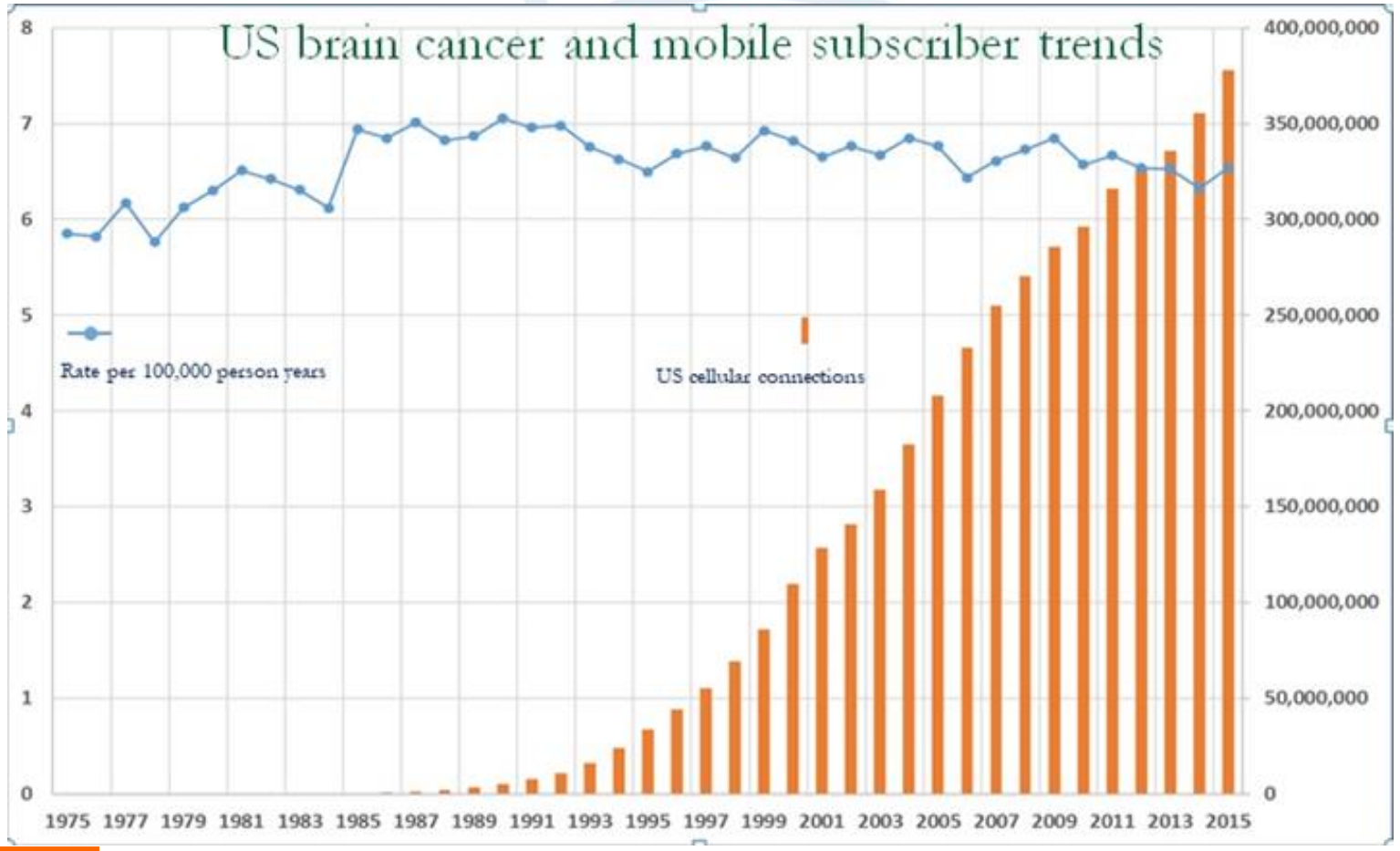




(b) Structure and service area

Mobile systems & cancer

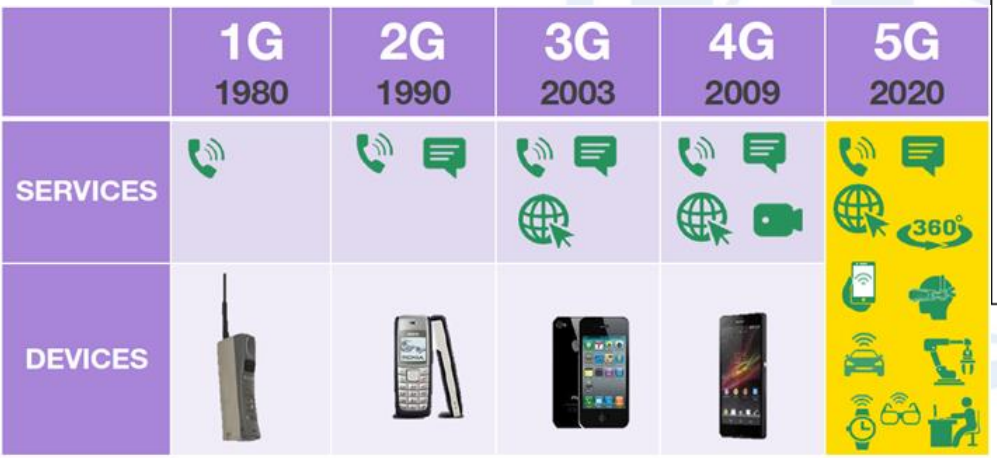
Overall, incidence data of the Surveillance, Epidemiology and End Results (SEER) do not support the view that cellular phone use causes brain cancer

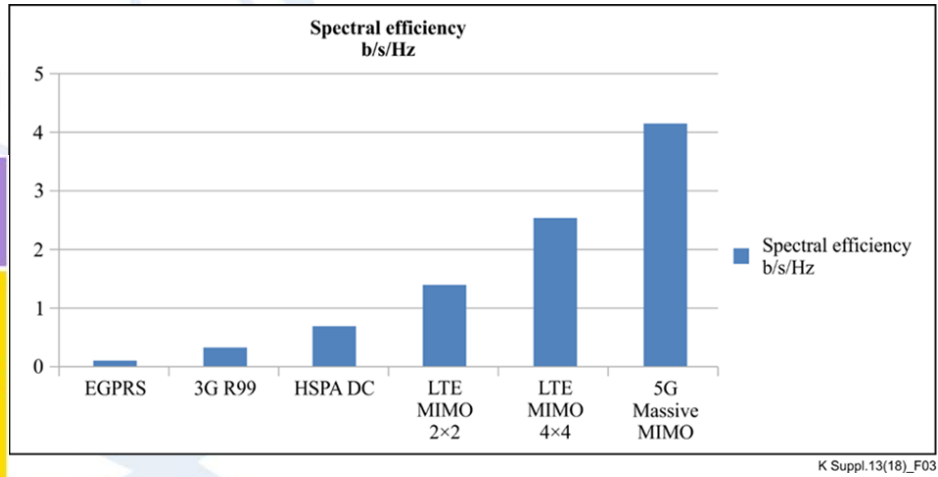


Based on CTIA and SEER data, and Inskip et al., 2010

Development of the mobile systems

- Some people are against RF EMF, but the same problem was earlier as concerning electricity or steam machines
- 5G will replace 2G, 3G and 4G as it is much more efficient - require less energy and produce less RF EMF exposure send the same amount of information
- 5G will be replaced by 6G – ITU is working on it since 2019

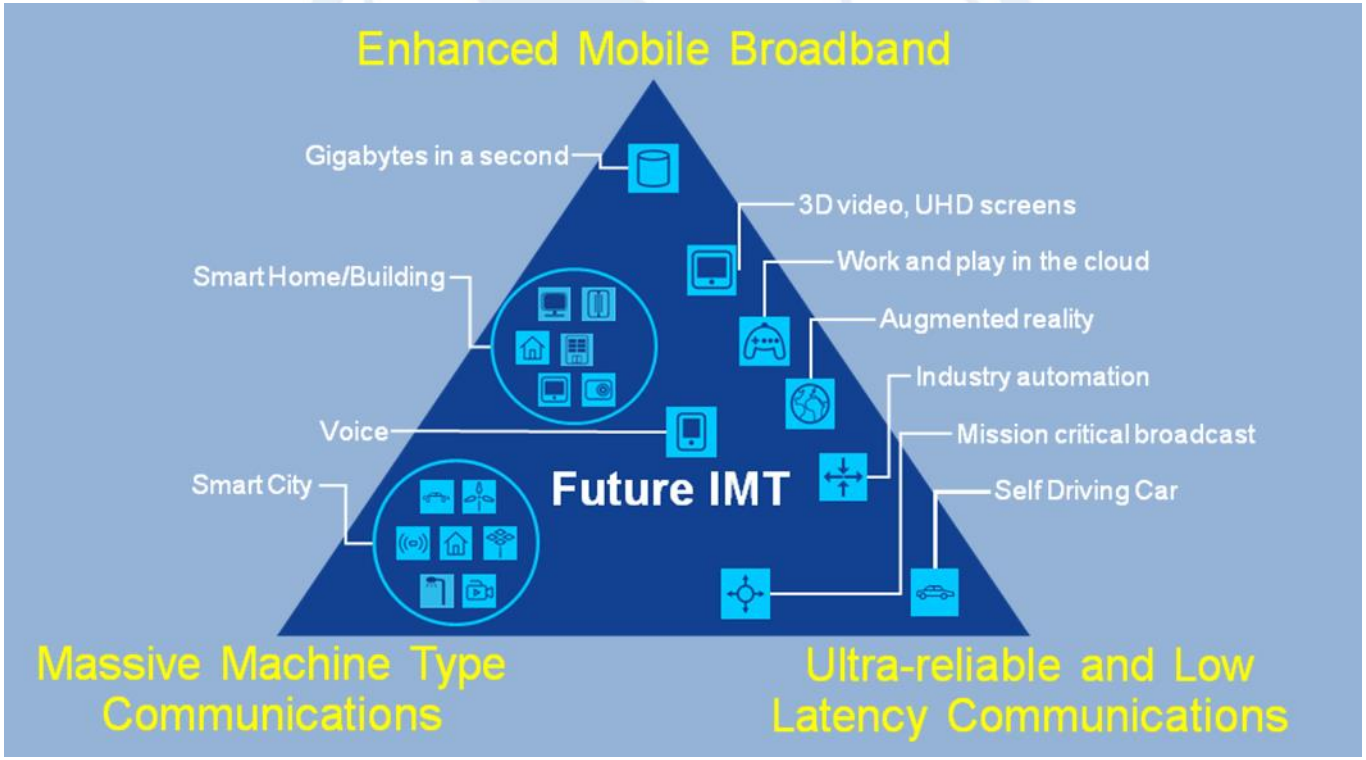




Evolution of the mobile systems (source: Orange)

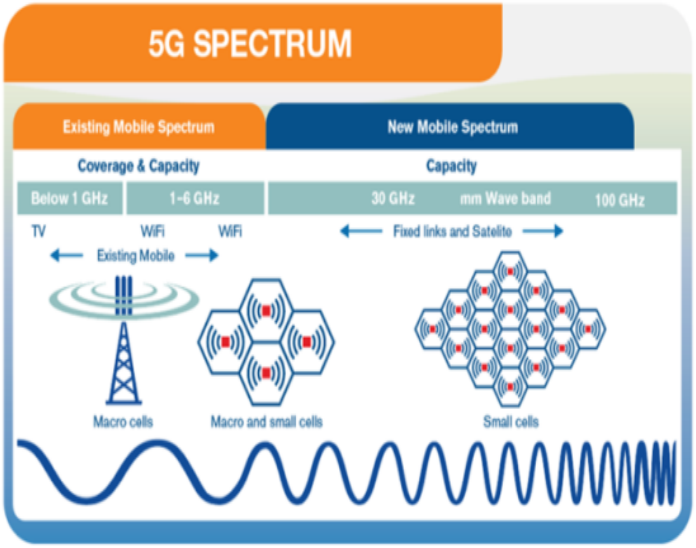
5G mobile systems (ITU-R M.2083)

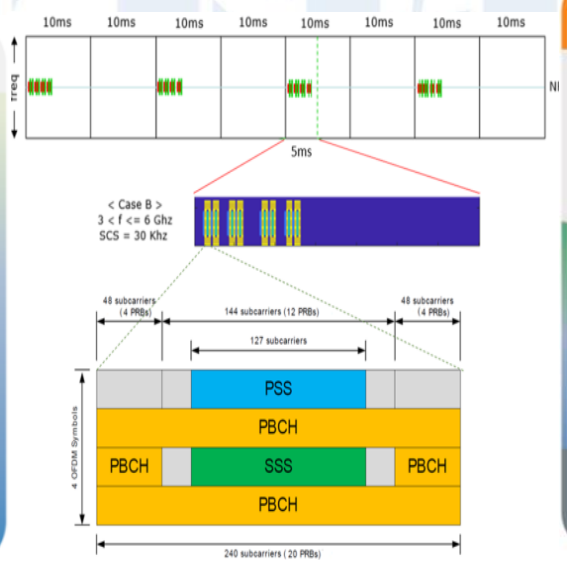
- The 5G system will cover three main different applications with different properties
  - Enhanced Mobile Broadband
  - Massive Machine Type Communications
  - Ultra-reliable and Law Latency Communications

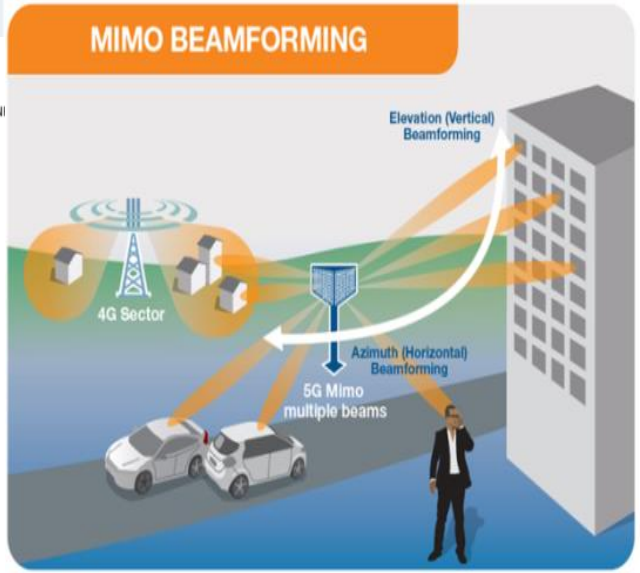


5G and PEM

- Substantial increase in the number of small cells
- Big variation of the exposure level in space (AAS antennas - beamforming)
- Big variation of the exposure level in time (Time Division Duplex)
- Substantial increase in the number of simultaneously emitting sources

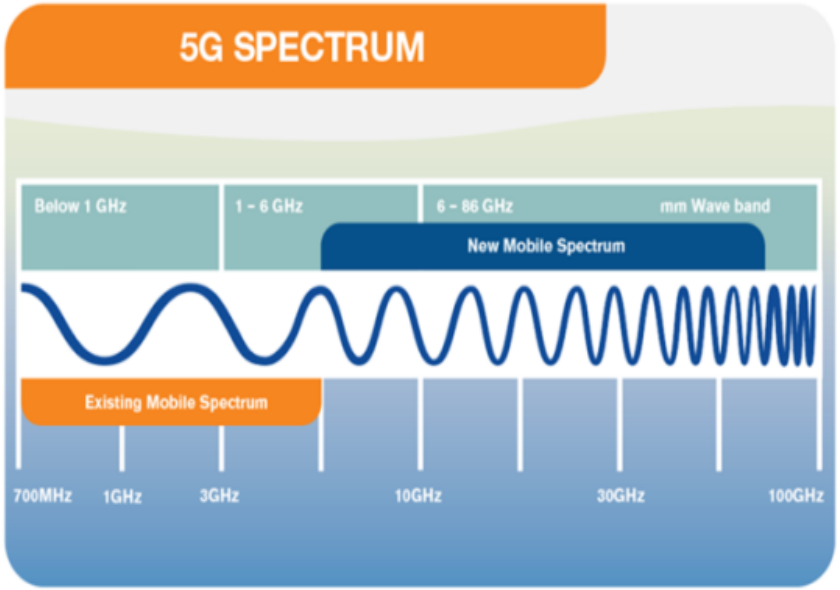






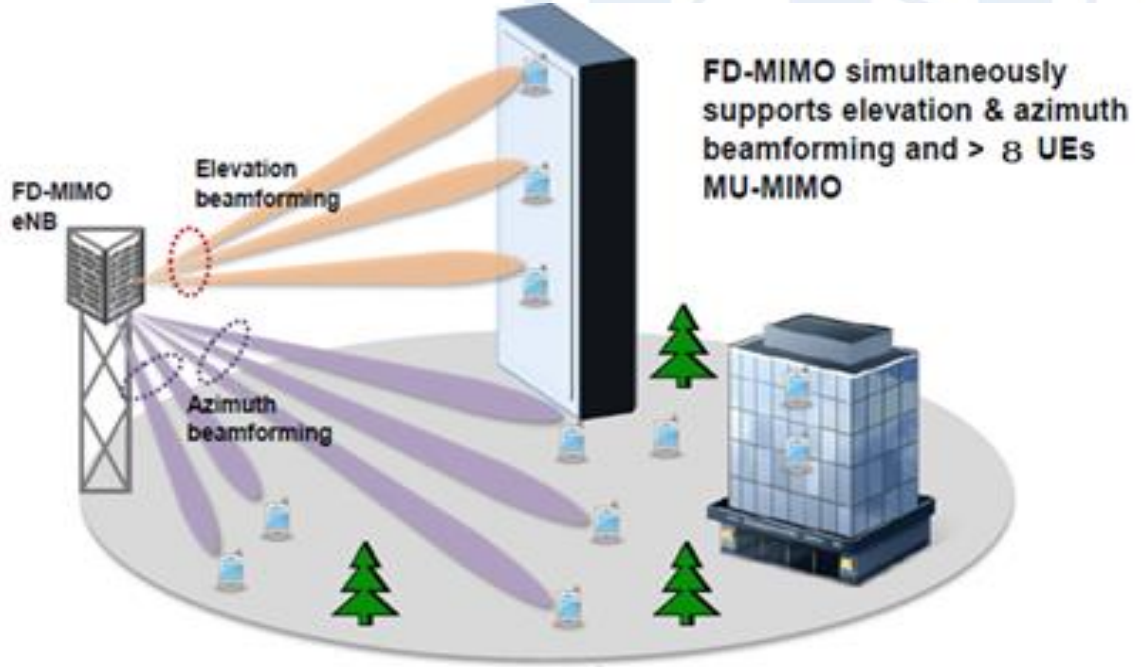
5G and PEM

- Frequency aggregation as a rule
- The use of frequencies above 6 GHz
- Parallel use of the different systems and modulations
- Internet of Things (IoT)
- Requirement of new assessment methods



Smart antennas

- Current mobile systems: 2G, 3G and 4G apply base stations that are covering the whole intended area, usually 120° sectors
- Smart antennas, that are planned for use in 5G will have narrow antenna beam (or beams) directed directly to the user (or users)
- This will allow to reduce the exposure in the environment



5G and small cells

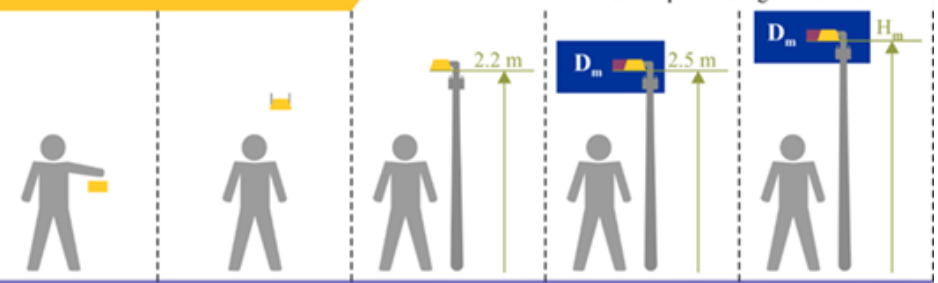
- Small cells will be much widely used especially for the high speed transmission that requires a very broadband transmission (big propagation losses)
- The use of the higher frequencies will result in lower coverages. Base stations will be located closer to the user, and the power used will be smaller too
- Current experience shows that the use of the small cells (indoor and outdoor) reduces overall exposure level

SIMPLIFIED INSTALLATION RULES

From IEC 62232 Ed. 2.0

Installation must be done according to instructions from the manufacturer or entity putting into service

Check pre-existing RF sources



Installation class	E0	E2	E10	E100	E+
Total EIRP	N/A	≤ 2 W	≤ 10 W	≤ 100 W	No limit
Minimum height above walkway	None	None	2.2 m	2.5 m	H_m (calculation)
Exclusion zone	None, touch compliant	Provided in manufacturer's instructions small D_m not shown on the picture		Provided in manufacturer's instructions D_m in main lobe direction	
Check pre-existing RF sources	N/A	N/A	N/A	5 D_m in main lobe direction D_m in other directions	

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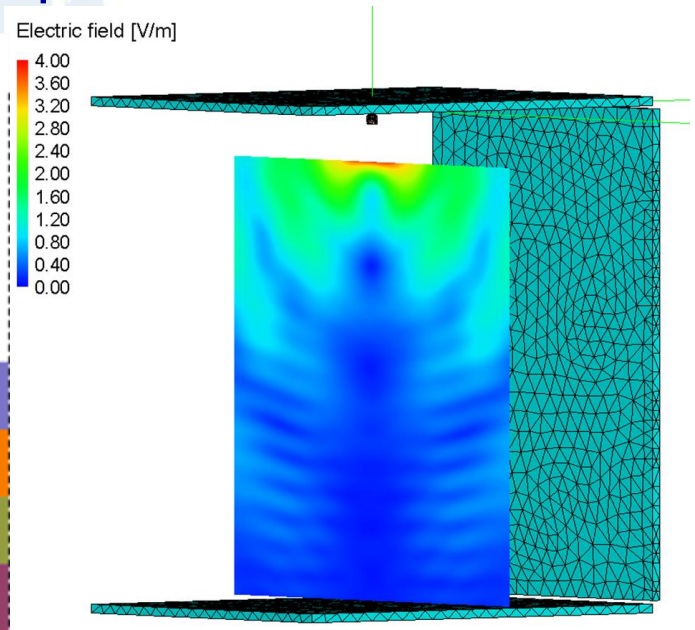


Internet of things (IoT), M2M

- It is expected that many devices will be connected to the internet using radiowaves. It will result in many possible improvements in our lives
- It means that the number of radiating sources will increase dramatically
- Almost all of them will be very low power and short range devices. They will communicate on the event-based, periodic and automatic communication modes
- It means that the exposure level from such devices will be very low and in most cases may be neglected

Conclusions

- ITU is very active in sharing knowledge and tools concerning assessment of human exposure to RF EMF
- Good communication with public is a very important task
- Efficient deployment of wireless infrastructure reduces the RF EMF exposure from networks and devices
- in the development of the 5G system the possibility of the reduction of the human exposure to RF EMF is one of the key issues taken into account

Thank you
Questions ?

Orange Expert
Energy
& Environment

Appendix

Recommendation ITU-T K.52

Guidance on complying with limits for human exposure to electromagnetic fields

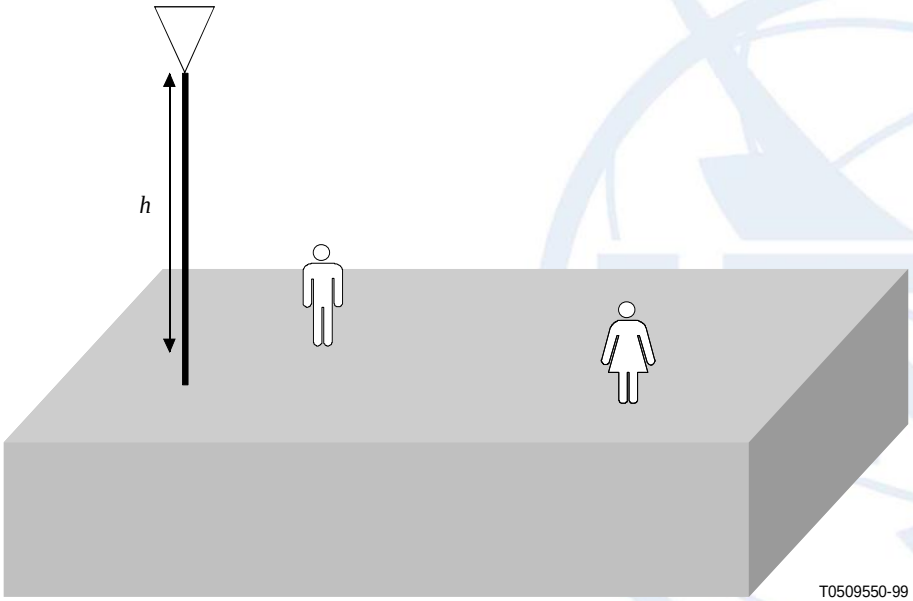


Figure B.1/K.52 – Illustration of the accessibility category 1

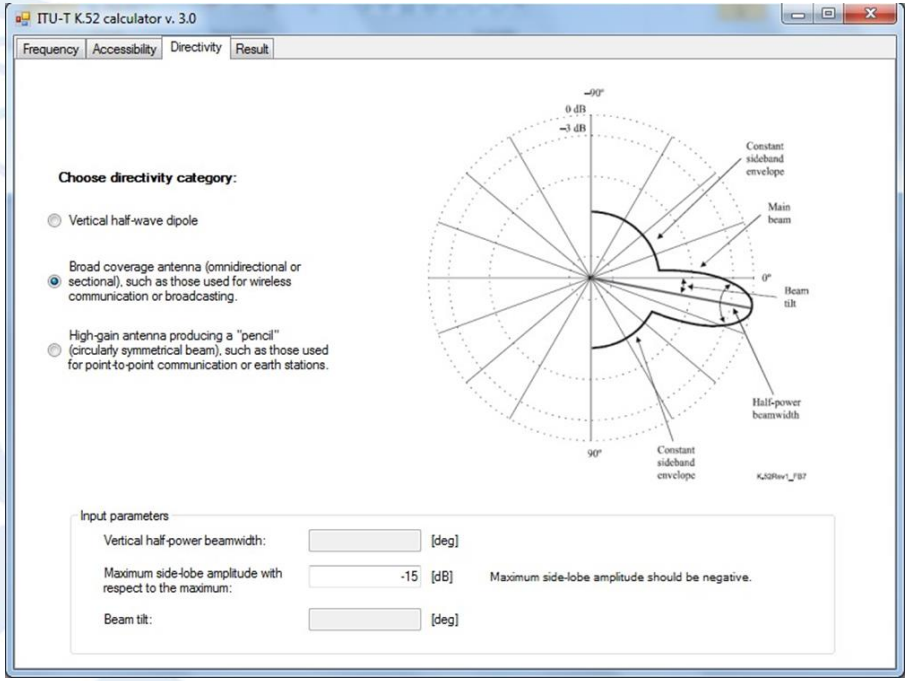
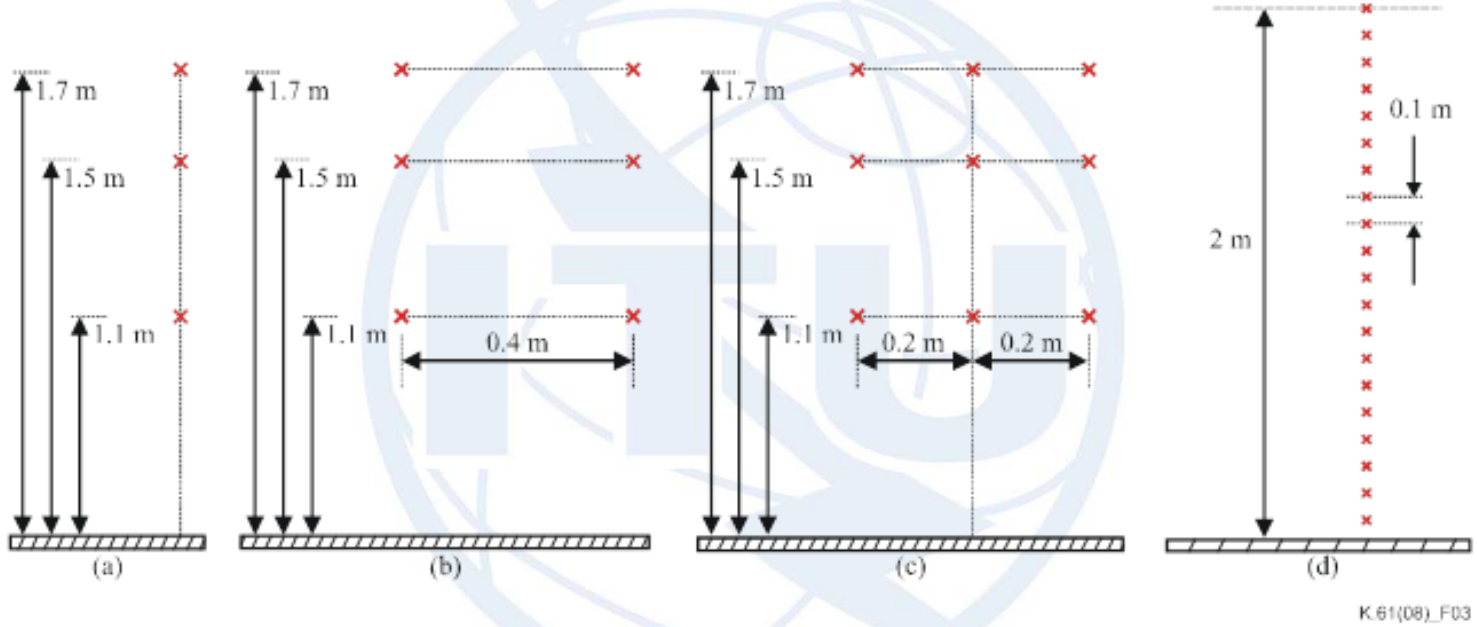


Figure B.7/K.52 – Illustration of terms relating to antenna patterns

Compliance testing in an easy way:
Accessibility category + directivity category
= maximum EIRP Compliance with ICNIRP limits

Recommendation ITU-T K.61

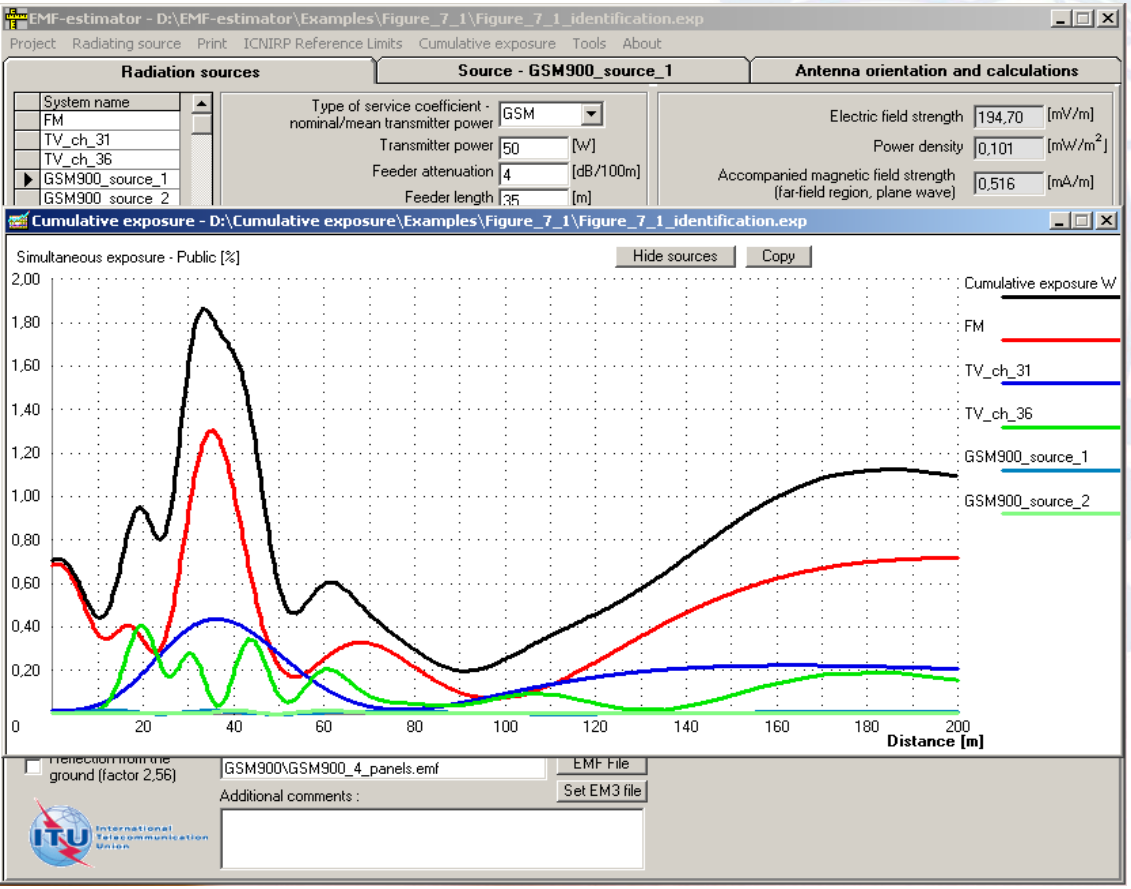
Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits, for telecommunication installations



- Measurement instrumentation, measurement uncertainties, Probe selection, Procedures, Safety precautions, Field regions, Multiple sources, Time and spatial variability
- List and short description of numerical methods

Recommendation ITU-T K.70

Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations



- Modeling of the transmitting antennas
- Importance of the Vertical Radiation Pattern (VRP)
- Identification of the main source of radiation
- Mitigation techniques employed to reduce radiation level – if required
- EMF-estimator – software including the library of examples of transmitting antennas

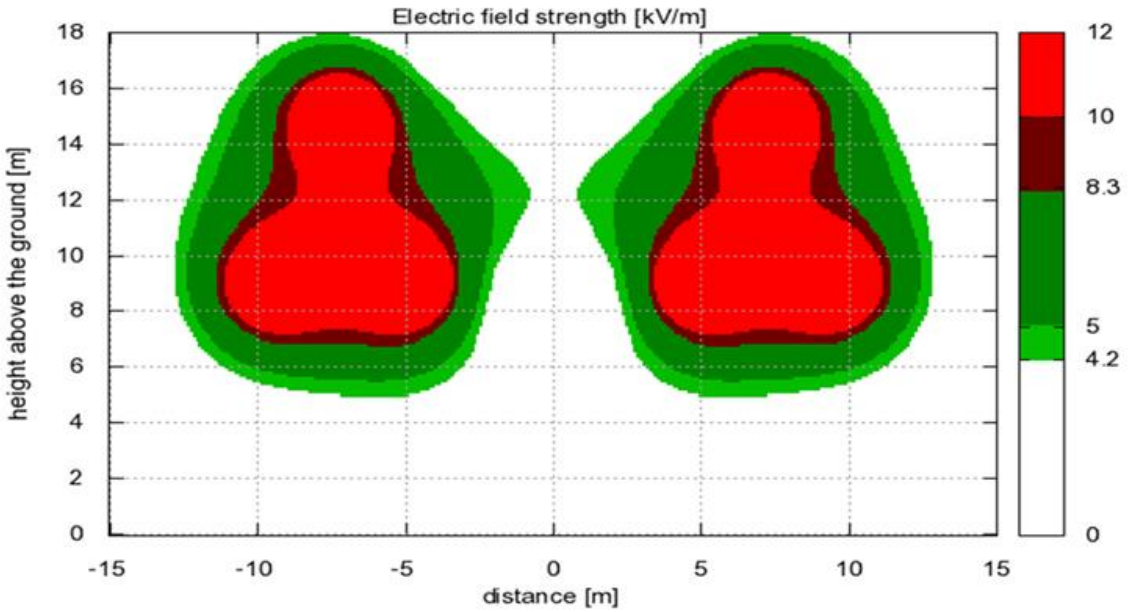
Recommendation ITU-T K.83

Monitoring of EMF levels

- EMF fields are unknown to the general public
- The confidence may be achieved thanks to the control of the EMF by taking continuous measurements and having a proper communication (for example websites)
- The balance between costs and accuracy is very important (broadband and frequency selective measurement)

Recommendation ITU-T K.90

Evaluation techniques and working procedures for compliance with exposure limits of network operator personnel to power-frequency electromagnetic fields

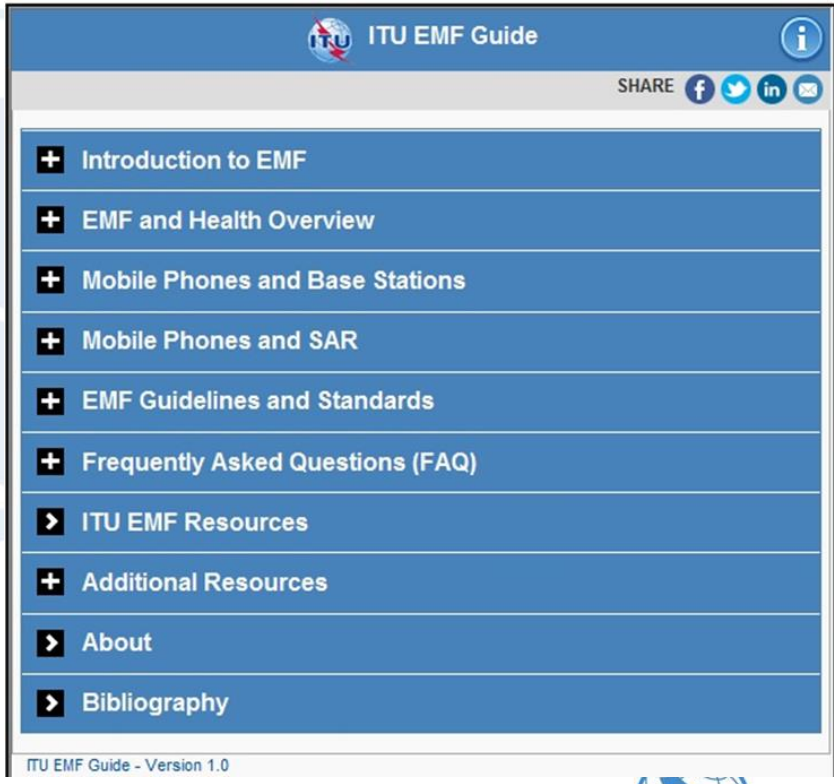


- EMF in the vicinity of medium-voltage (MV) and high-voltage (HV) power lines at power frequencies (DC, 50 Hz, and 60 Hz); Software: freq EMFACDC

Recommendation ITU-T K.91

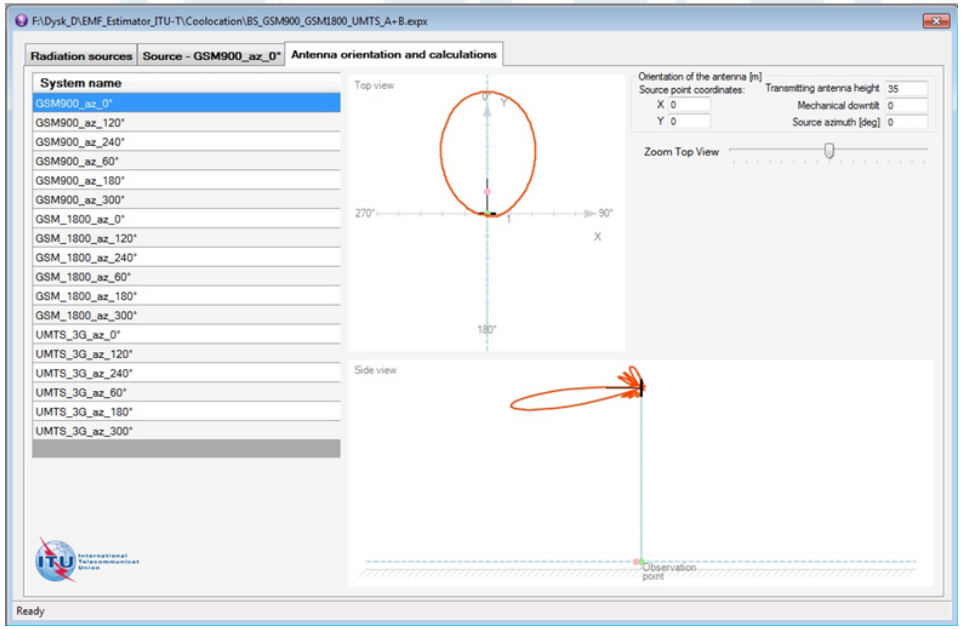
Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields

- There are plenty of standards concerning human exposure assessment
- Most of the standards are very general or product oriented
- In real environment there are many sources of radiation operating simultaneously
- Guidance on the assessment of human exposure is required



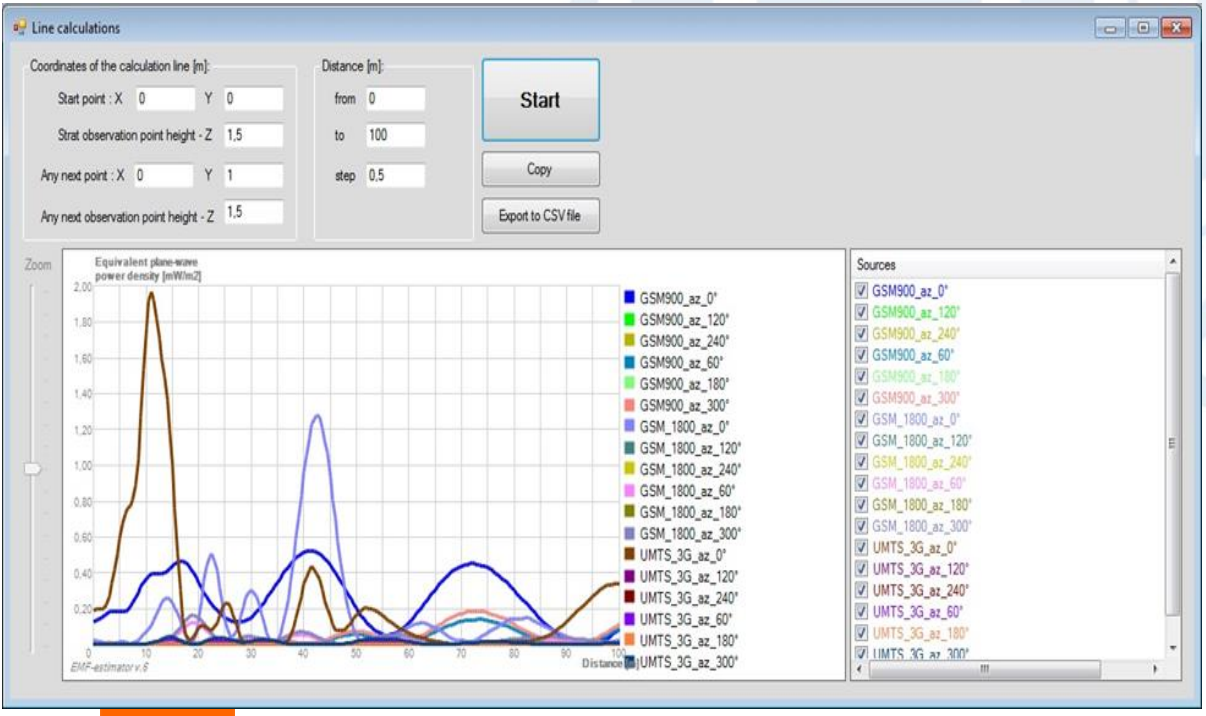
EMF-estimator

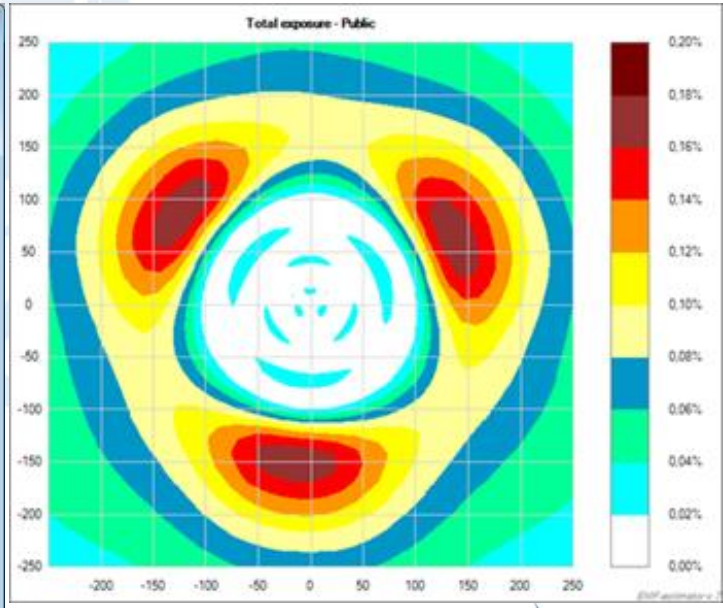
- Software tool that is Annex I to the ITU-T Recommendation K.70
- The last version (v8.32 and v.1.64 – depending on the 32 or 64 bit Microsoft Access) may be loaded from the:
  https://www.itu.int/rec/T-REC-K.70-201801-P
  https://www.itu.int/rec/T-REC-K.70-201809-I!Amd2
- EMF-estimator is offered by ITU-T since 06.2007
- It is periodically updated / expanded according to the needs (in 2009, 2011, 2013, 2014, 2016 and 2018)



EMF-estimator

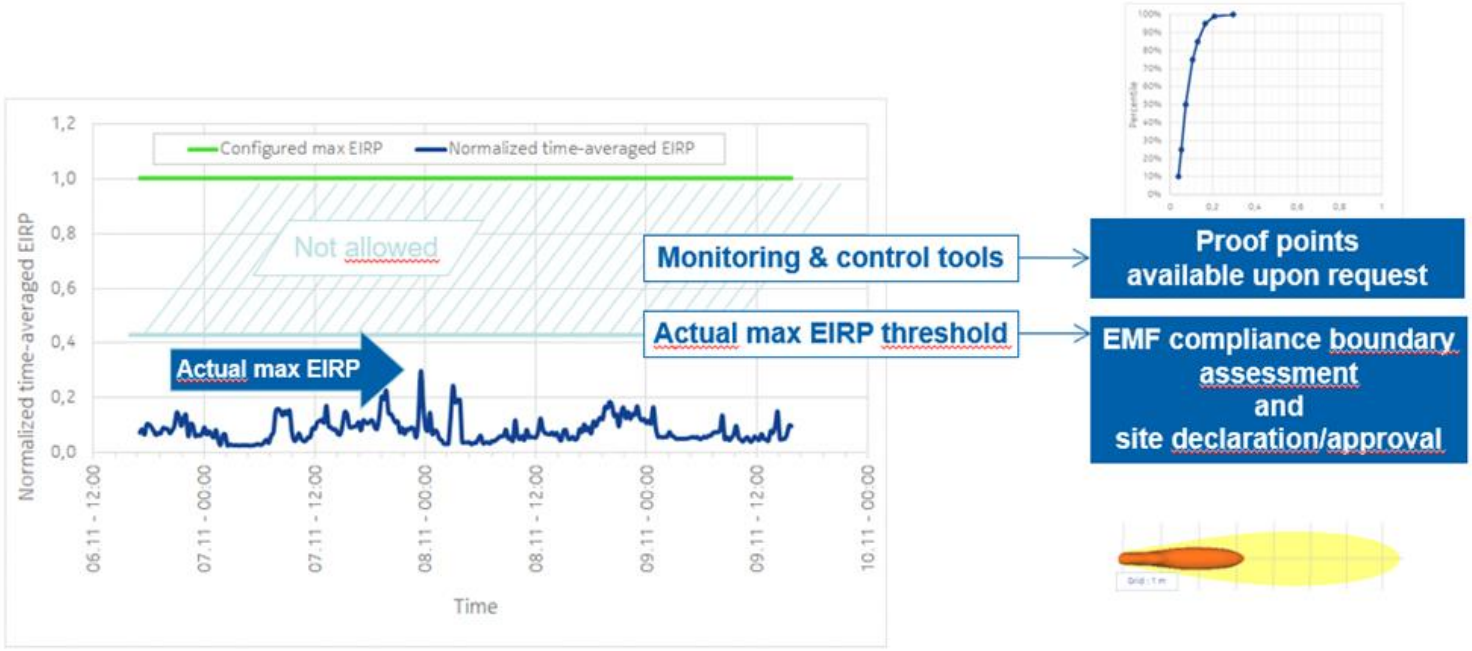
- EMF-estimator applies the point source and cylindrical models so it is valid starting from radiating near field region
- It allows the evaluation of the exposure to the RF EMF and the comparison with the exposure limits





Recommendation ITU-T K.100

Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service



- The measurement procedure to assess compliance with general public EMF exposure limits
- Simplified assessment procedures to identify those installations which are inherently compliant

Recommendation ITU-T K.113

Generation of radiofrequency electromagnetic fields (RF-EMF) level maps

Colour										
Name	Maya blue	Dodger blue	Cerulen blue	Light green	Lime green	Green	Golden Yellow	Orange	Orange red	Red
Hexadecimal colour code	#73c2fb	#1e90ff	#2a52be	#90ee90	#32cd32	#008000	#ffdf00	#ffa500	#ff4500	#ff0000
Percentage (*P*) in relation to the E-field limit %	$P \leq 1$	$1 < P \leq 2$	$2 < P \leq 4$	$4 < P \leq 8$	$8 < P \leq 15$	$15 < P \leq 20$	$20 < P \leq 35$	$35 < P \leq 50$	$50 < P \leq 100$	$P > 100$

This Recommendation describes methods and characteristics of the systems used for generating radio-frequency electromagnetic field (RF-EMF) maps

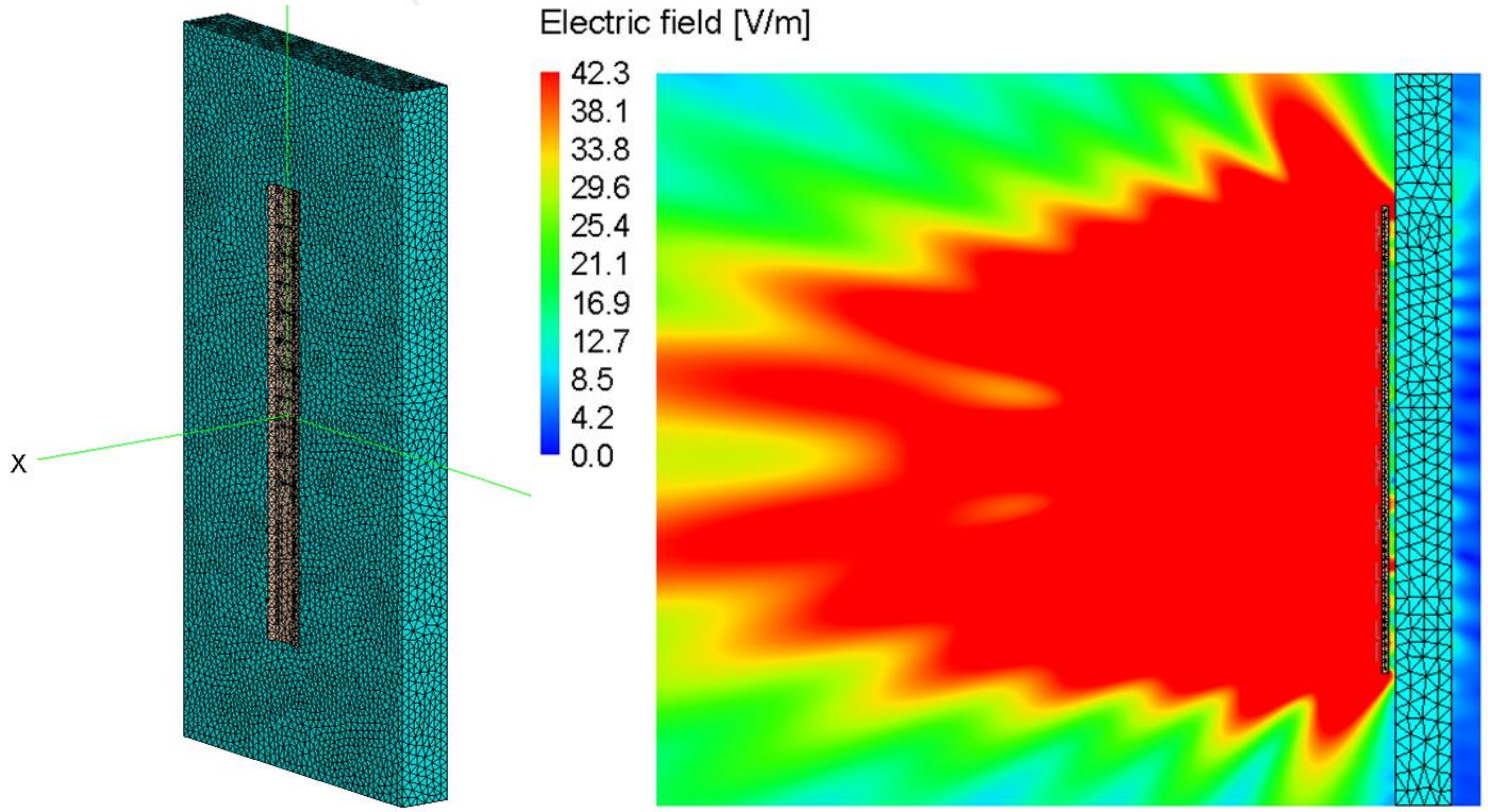
Recommendation ITU-T K.121

Guidance on the Environmental Management for Electromagnetic Radiation from Radiocommunication Base Stations

- The purpose of this Recommendation is:
- to provide guidance on the environmental management of compliance with RF-EMF human exposure standards
- to promote the harmonization of environmental management for RF-EMF emissions for telecommunications operators, and give advice on its effective management
- to proactively identify the RF-EMF environment in areas surrounding radiocommunication base stations, and also promote the sustainable development of wireless communication technology

Recommendation ITU-T K.122

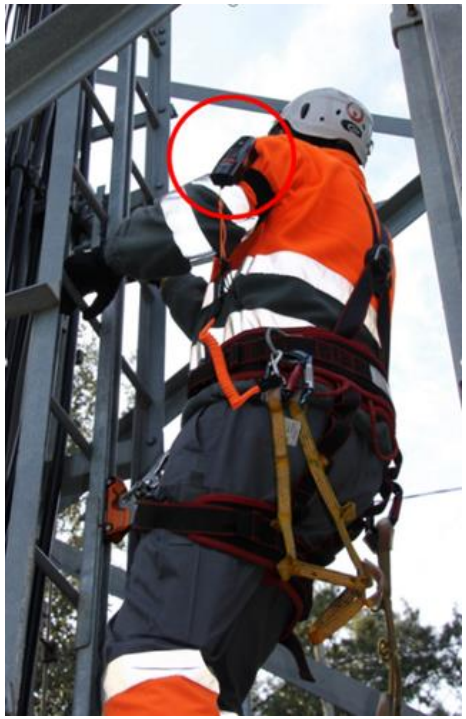
Exposure levels in the close proximity of the radiocommunication antennas

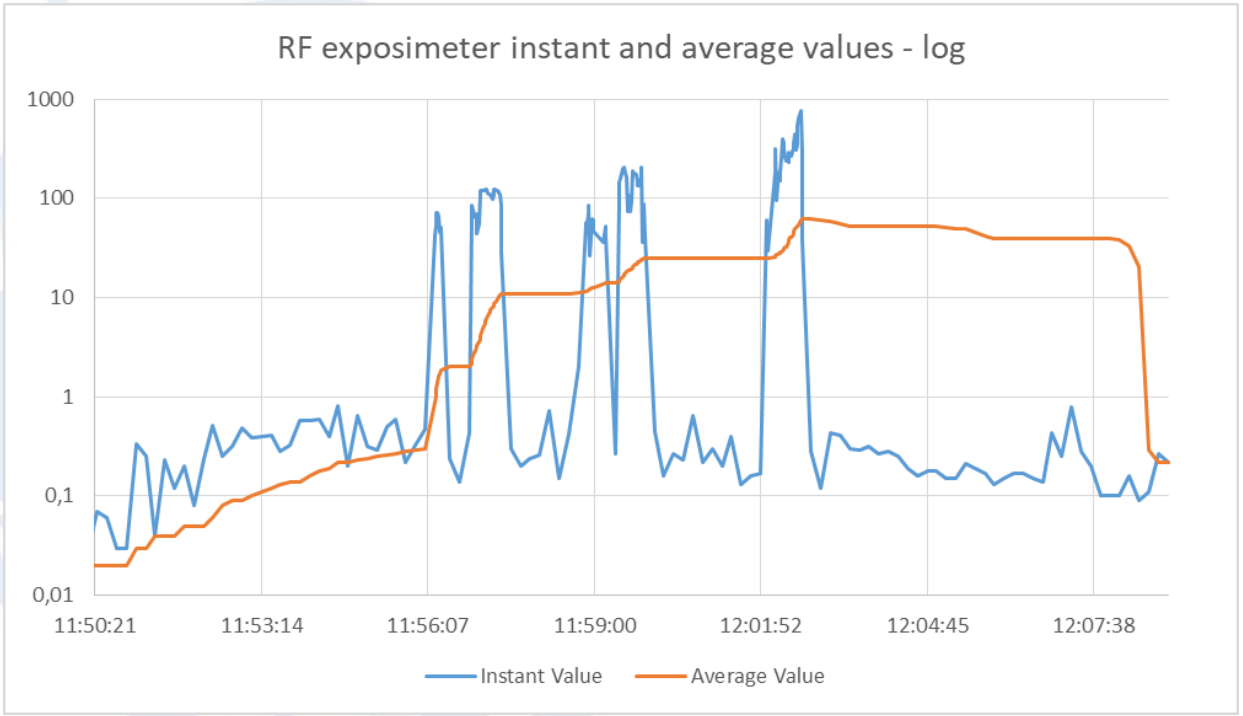


The guidance concerning the exposure levels in close proximity to transmitting antennas is important for safety of the radiocommunication staff operating in such areas.

Recommendation ITU-T K.145

Assessment and management of compliance with radio frequency electromagnetic field exposure limits for workers at radiocommunication sites and facilities





The guidance on the protection of workers against radio frequency electromagnetic fields (RF-EMFs) exposure in their working environments

RF EMF Exposure - mobile handset

- Each mobile phone is equipped with Automatic Power Control system which adjusts the output power level to the minimum required value necessary to establish connection with a base station
- Power radiated by the mobile phone is lower if the user is close to a base station and higher if the distance to a base station is longer. The power is also increased if a user is inside a building or car, because of an attenuation of the signal by the building walls or a car body

RF EMF Exposure - mobile handset

- Mobile phone is a semi-duplex device. It means that a mobile phone can not transmit and receive at the same time
- During the voice connection a mobile phone is switching from receiving to transmitting mode many times in the way which is not noticeable for the user, so the two-way communication is possible
- If during the voice call the user is listening then the mobile phone is not radiating
- The efficient way to decrease the exposure level during the voice call is to limit the time in which the user is speaking