ITU-T Recommendations concerning Human Exposure to Electromagnetic Fields (EMFs)

1st Digital African Week
Forum on "Human Exposure to Electromagnetic Fields (EMFs) in Africa"
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Energy
& Environment

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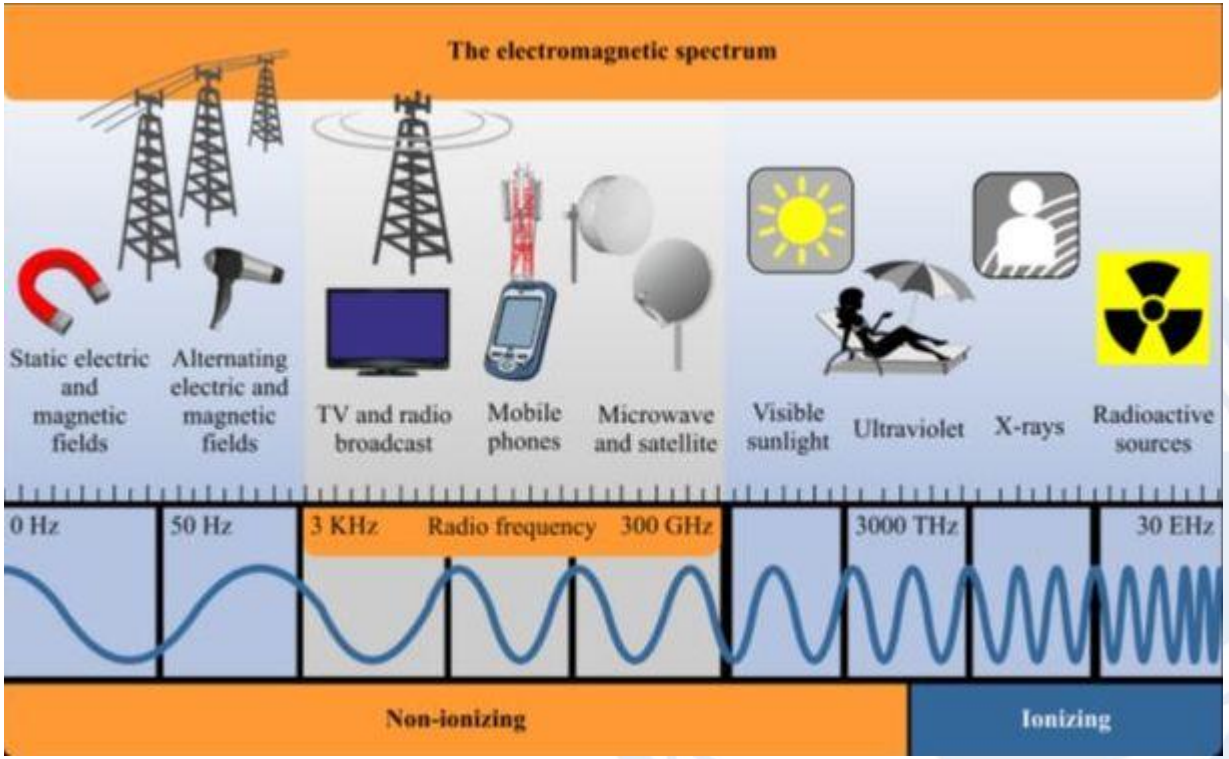
Introduction - Electromagnetic spectrum

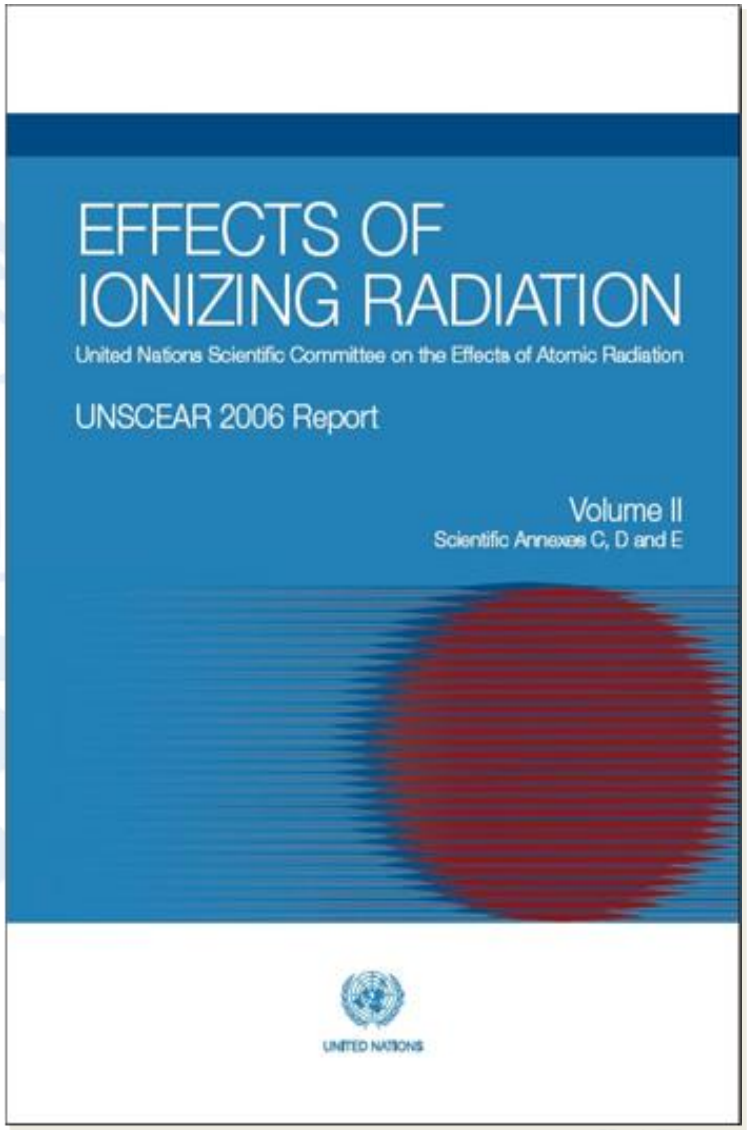


Type of radiation	**Energy $E = h\nu$**
Microwaves and radiowaves (up to 10^{12} Hz)	**$10^{-3} \div 10^{-12}$ eV**
Infrared (temperature 20°C)	**$3 \cdot 10^{-2}$ eV**
Visible light	**1,6 ÷ 3,1 eV**
Ultraviolet light	**$3{,}3 \cdot 10^{2}$ eV**
X – rays	**10^{4} eV**
γ - rays	**10^{6} eV**
Energy of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

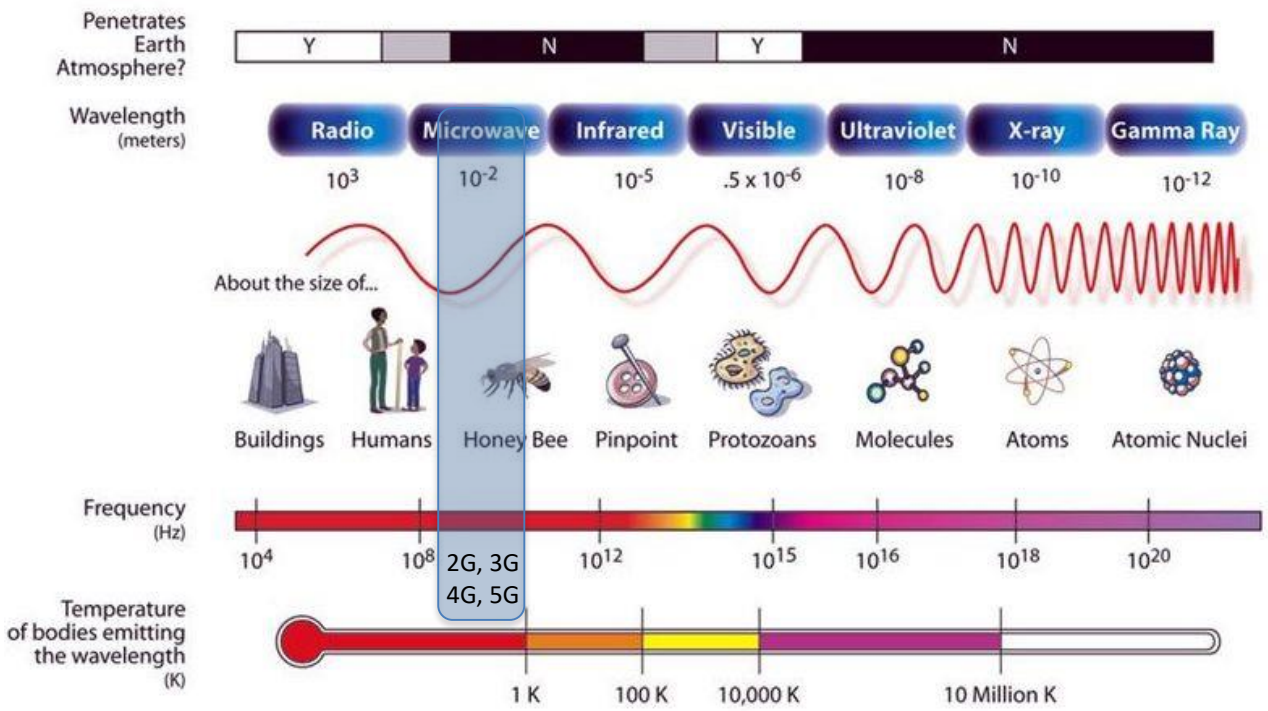
- The frequencies used in radio-communication are:
  - higher than those used by power supply systems,
  - lower than infrared radiation, visible light and ultraviolet, X and γ rays
- RF EMF energy is too small to break chemical molecules bonds

Ionizing radiation

- About 8 000 radioactive particles in our body are decayed in each second
- Each year we absorb 2.4 mSv dose of the natural ionizing radiation
- Dental x-rays: (0,02 mSv), chest x-rays (0,05 mSv) or head scanner (3 mSv) doses are acceptable because of the medical importance
- Acute radiation syndrome requires a dose of about 1000 mSv and a dose of 10000 mSv is acknowledged as a death dose
- So the exposure level is the most important factor



The resonance phenomena of the exposure

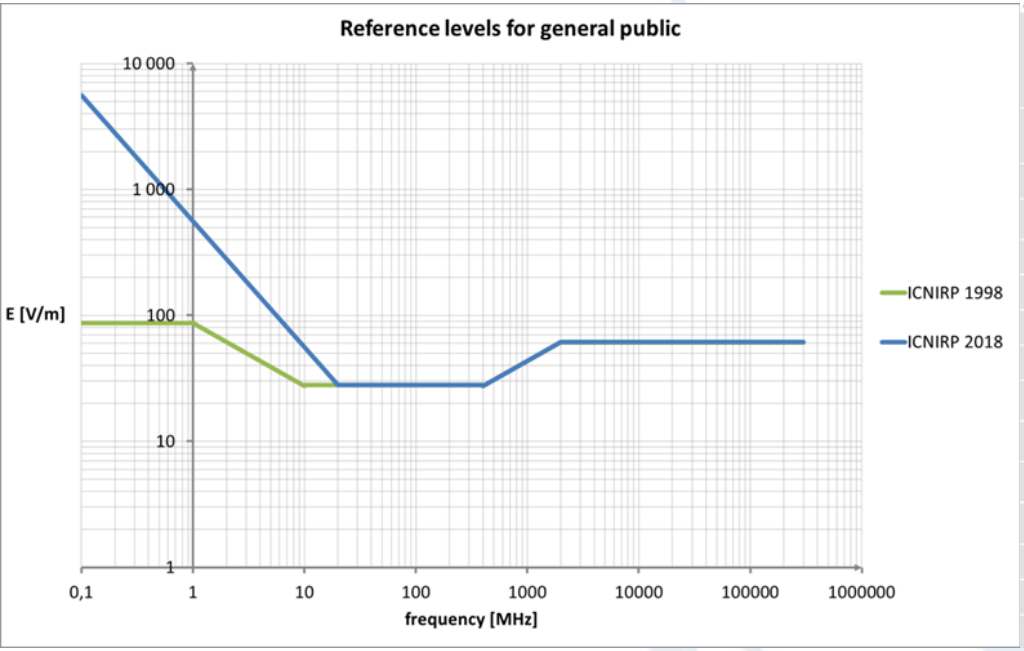


Source: htthttps://www.scienceinschool.org/2011/issue19/chemiluminescence

Frequency	Wavelength 0,4 λ
50 Hz	2 400 km
225 kHz	533 m
1 MHz	120 m
70 MHz	1,7 m
200 MHz	0,6 m
630 MHz	0,19 m
900 MHz	0,13 m
1800 MHz	0,067 m

- The maximum absorption of the human body (adult person) is for the radiation on the frequency: 35 MHz (grounded) to 70 MHz (ungrounded)
- For the lowest frequencies (for example 50 Hz or Long Waves) the human body is „transparent” for the electric field (very small absorption)

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...

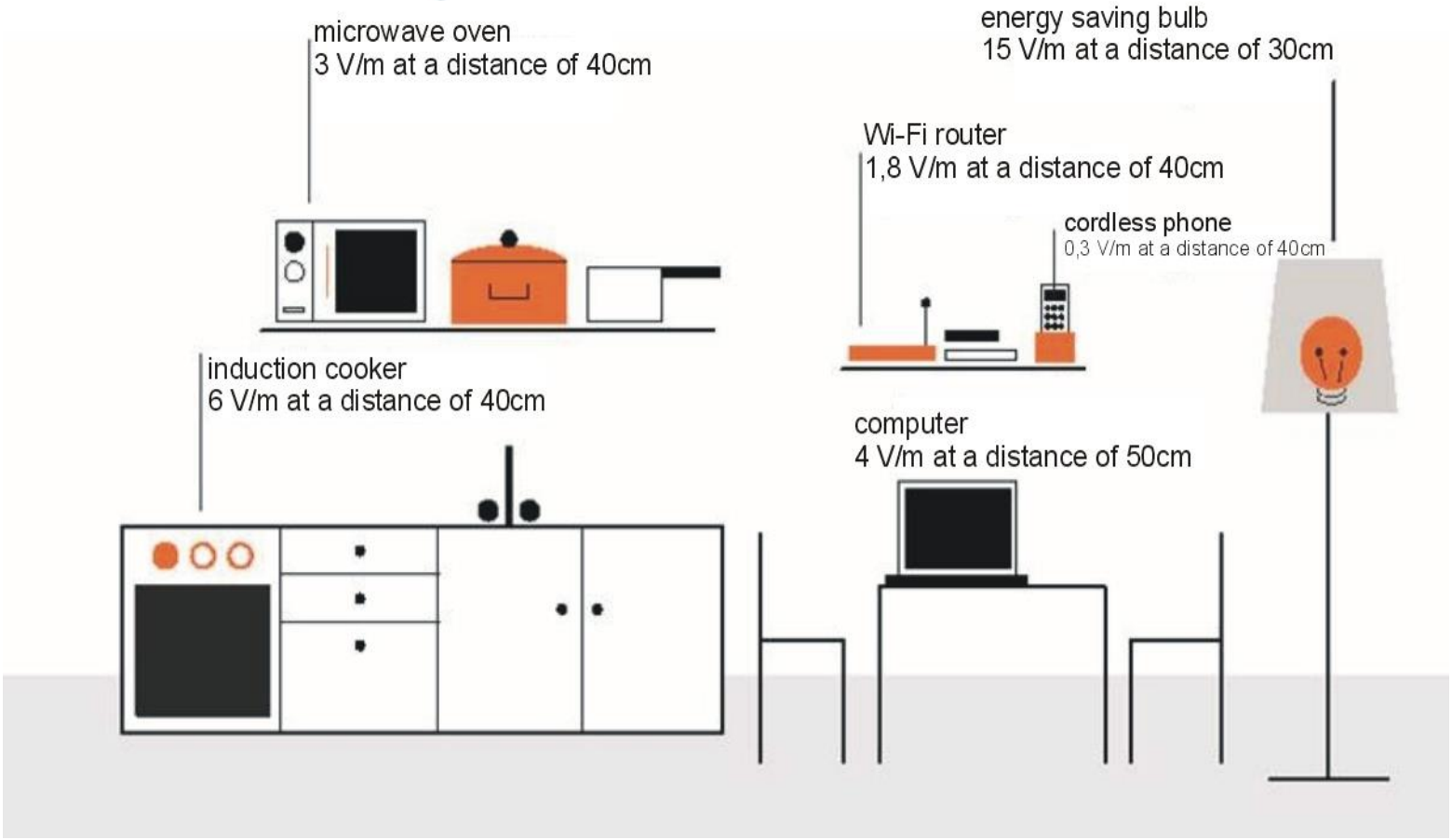
		Radiofrequency						
		Electric field (V/m)[i]		Power density (W/m^2)[i]		Specific absorption rate (SAR) (W/kg)[i]		
Country	Year	900 MHz	1800 MHz	900 MHz	1800 MHz	Whole body	Head and trunk	Limbs
Argentina	2017	41.25	58.36	4.5	9	0.08	2	4
Australia	2017	41.1[i]	58.1[i]	4.5[i]	9[i]	0.08	2	4
Austria	2017	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

- New draft of the ICNIRP guideline (under public consultation since 2018) gives almost no changes for frequencies used in radiocommunication

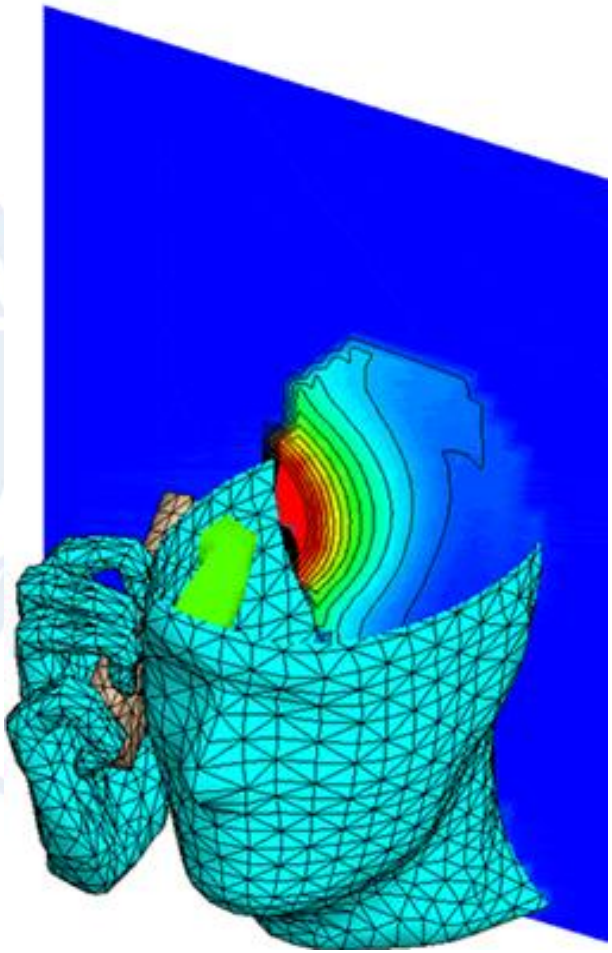
EMF exposure level in home environment



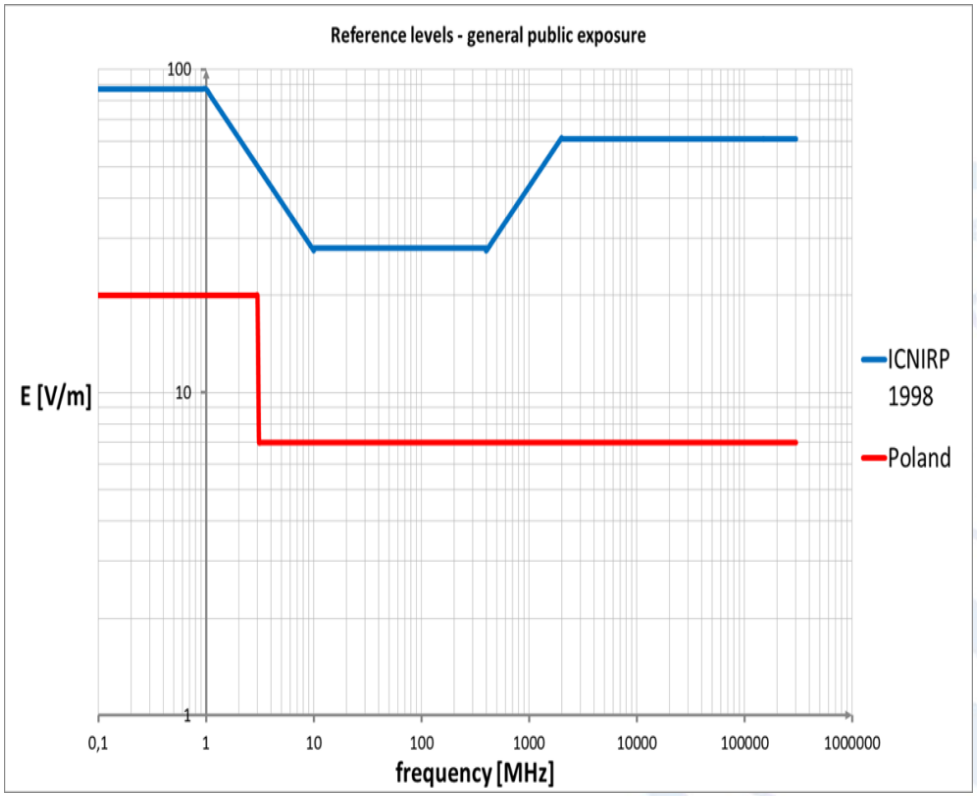
Exposure levels around typical electronic and electric equipment in home environment

Basic restrictions – Specific Absorption Rate (SAR)

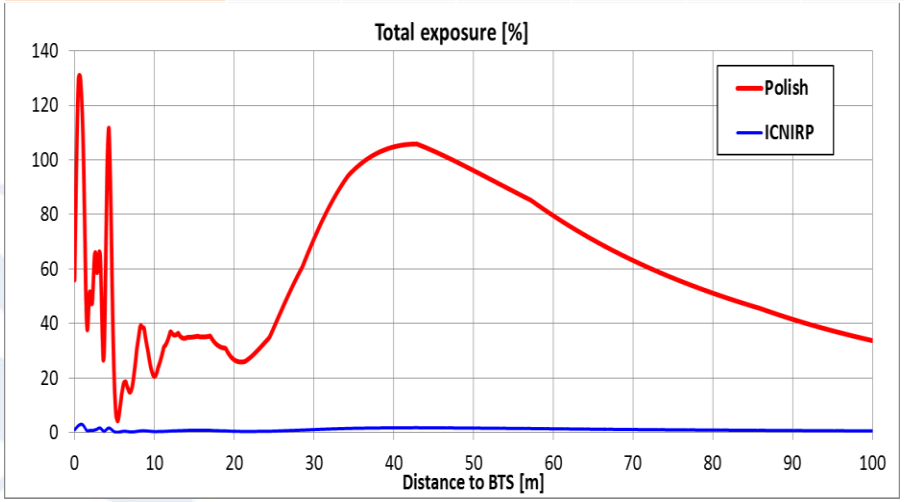
- The „basic restriction” (SAR) is related to radiofrequency-induced adverse health effects – but it is difficult to be measured
- However as concerning mobile handsets basic restrictions (SAR) are mainly used, because they are less restrictive than „reference levels” (such as electric field strength)
- 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)



RF EMF exposure limits: Very restrictive vs. ICNIRP



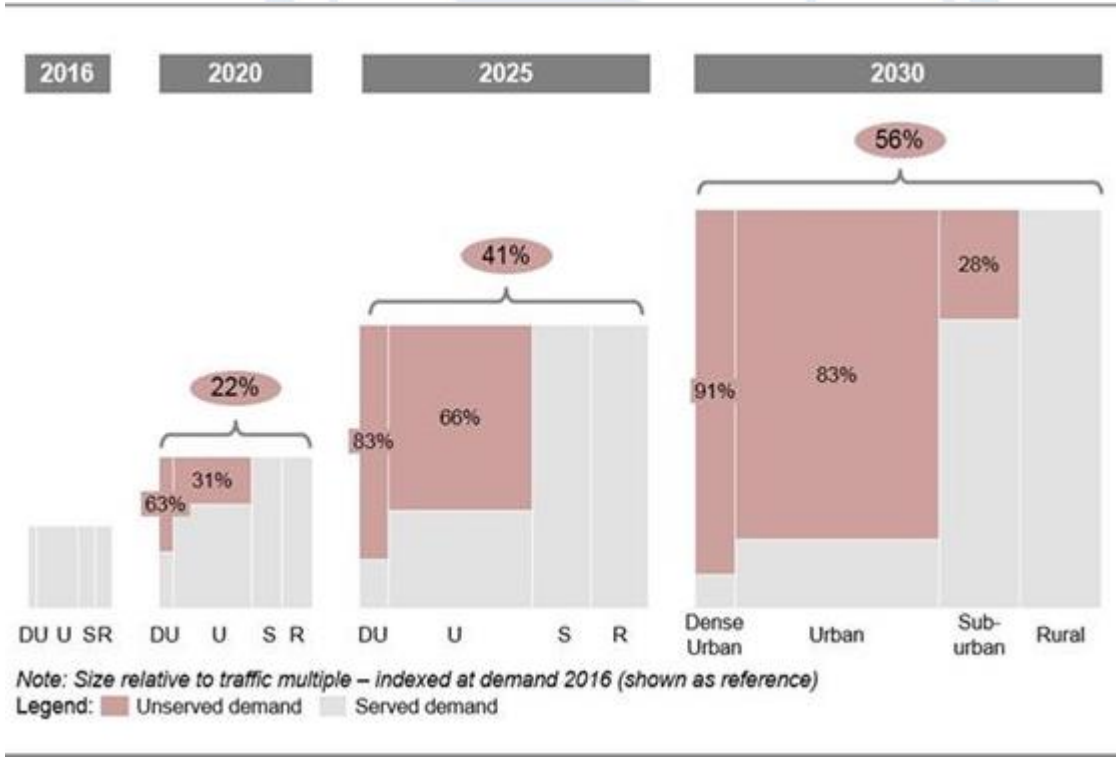
Results of measurements						
	Poland (average) V/m			France (median) V/m		
Year	2015	2016	2017	2015	2016	2017
Number of measurements	2161	2161	2161	3577	2993	2591
Rural	0.21	0.22	0.21	0.23	0.24	0.25
Urban	0.40	0.43	0.47	0.40	0.41	0.40



- The exposure level measured in country with very restrictive RF EMF exposure limits (Poland) and with ICNIRP exposure limits (France) are very similar
- Because of the more restrictive limits the „exclusion zones” (no access for people) in Poland is much bigger – no space for new emissions like 5G

Problem with very restrictive exposure limits

- Supplement 14 to ITU-T K-series of Recommendations:
- „The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment”
- Very restrictive RF EMF exposure limits may cause to have unserved demands

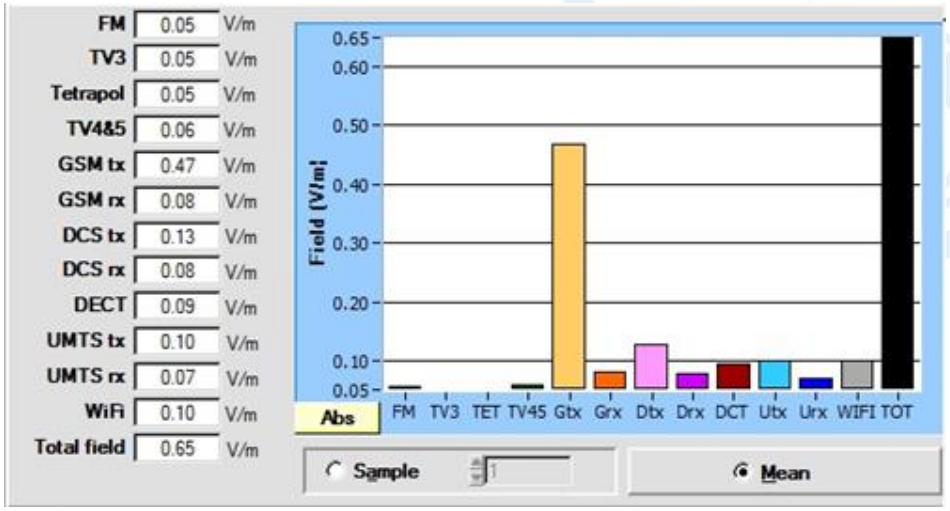


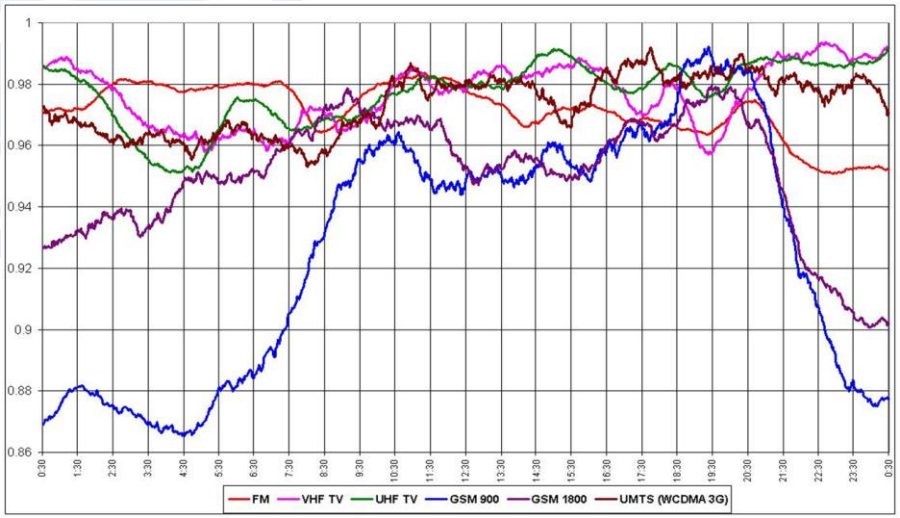
Measurement advantages

- It takes into account:
  - all radiating sources with real parameters
  - the real environment (reflections, antenna supporting hardware, obstacles)
  - Takes into account simultaneous exposure in the real way
- It can be done with little knowledge about radiating sources (an initial measurement of the occupied spectrum is required only)
- Good quality measurement equipment is accessible on the market
- A life demonstration of the measurement to the public is possible

Measurement disadvantages

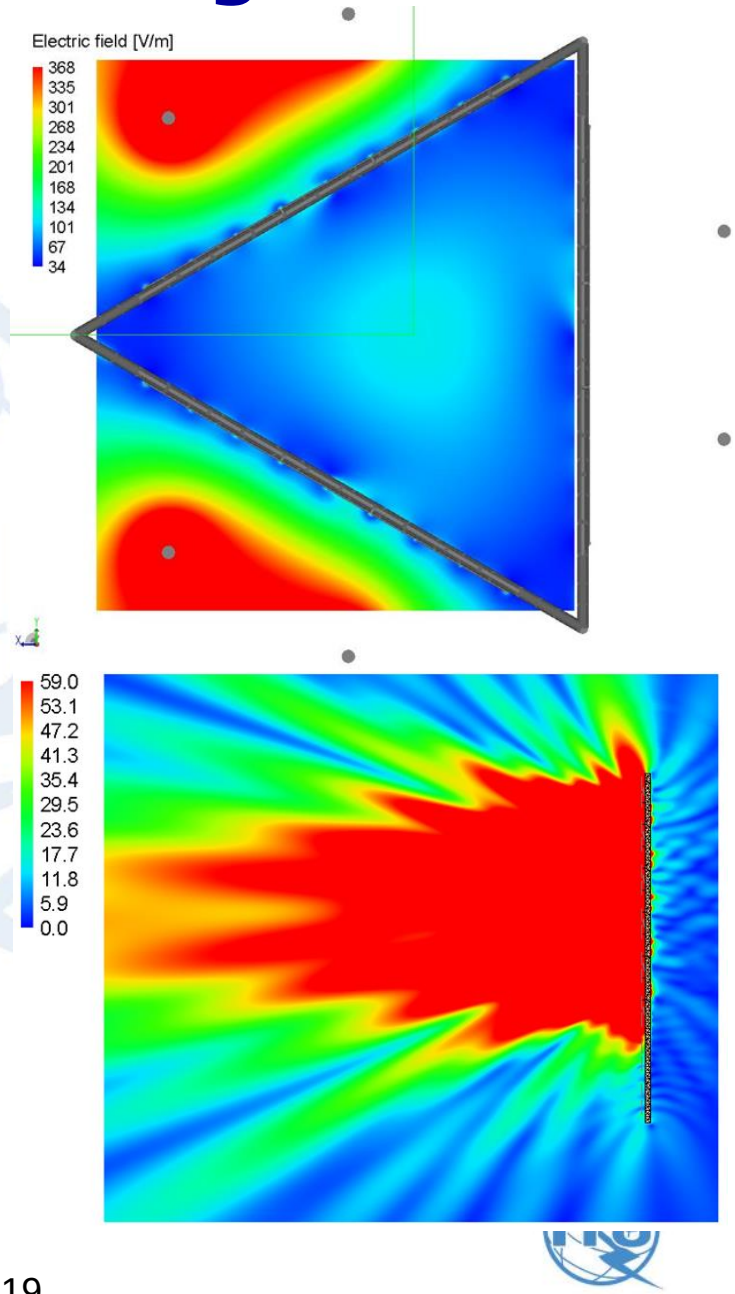
- Measurement is not possible for the radiating sources that do not exist yet
- It is difficult to take into account the time variation of the EMF (for example mobile communication)
- The effect of the presence of staff and equipment on the EMF distribution has to be avoided
- SAR measurements have to use phantoms that only approximate the human body





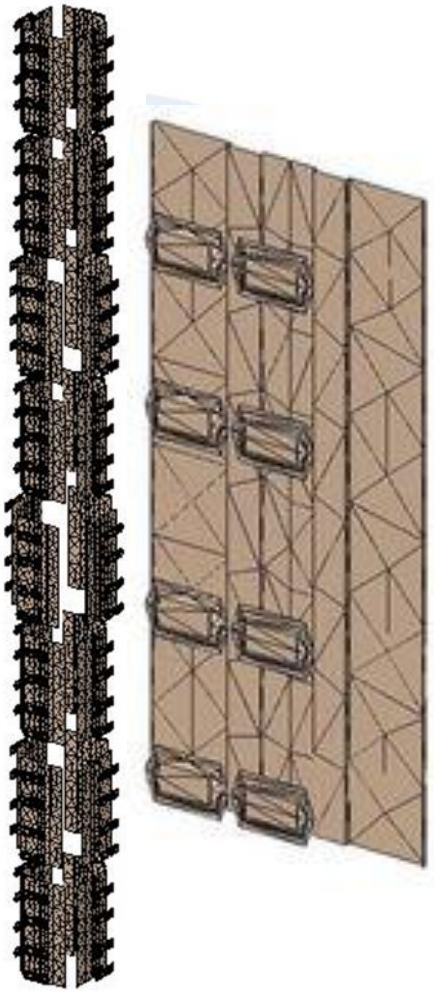
Calculations advantages

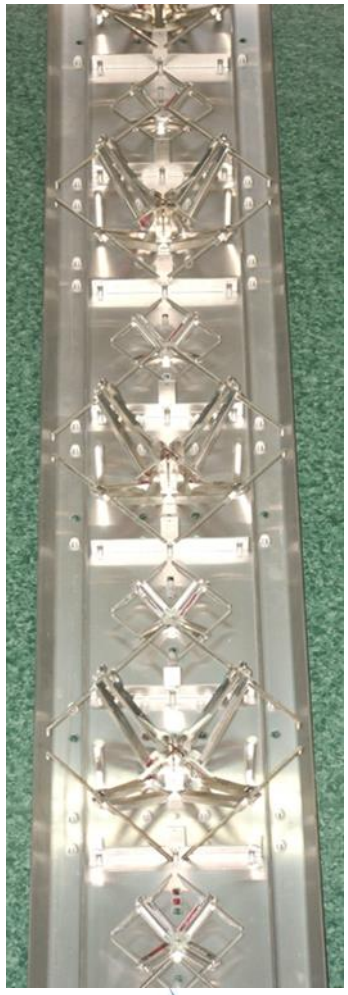
- Allows to consider the sources not operating yet
- Allows to apply the maximum possible radiation power (ERP's)
- Many calculation methods of different level of complexity and accuracy are available
- The calculation costs are lower then the costs of measurement
- Calculations may be done in areas with no access
- Possibility to obtain results on the dense grid
- Visualization of the results is easy



Calculations disadvantages

- Very accurate results require detailed description of the radiating antennas
- In most cases do not take into account the influence of reflections
- Require good knowledge of the software used
- Require at least basic knowledge concerning transmitting antennas

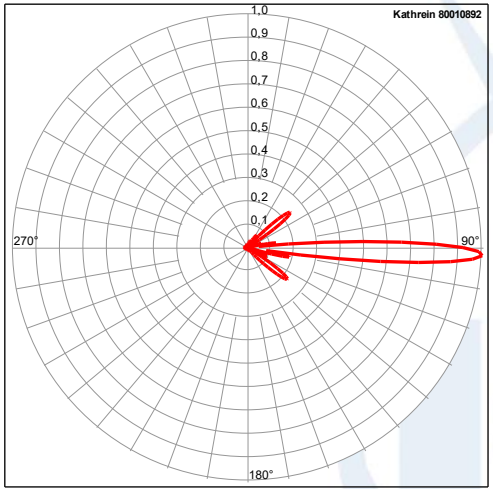


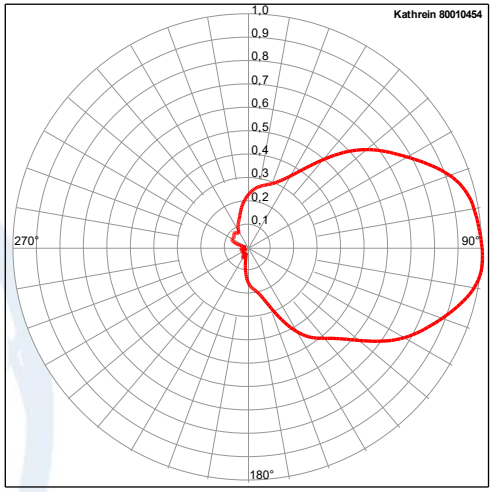


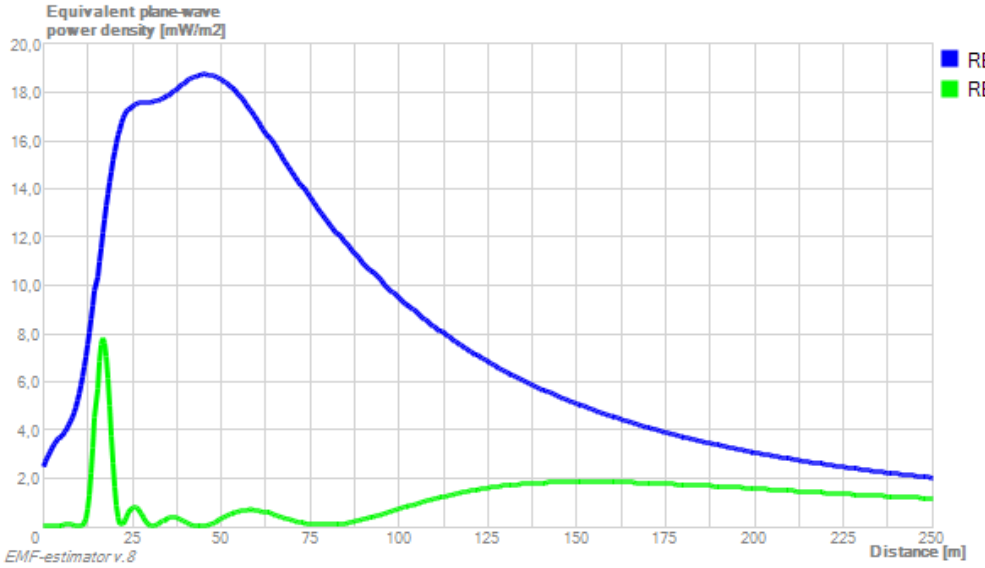
Influence of the antenna vertical radiation pattern

Tall RBS antenna (high gain)
Kathrein 80010892 - 2,691 m

Small RBS antenna (low gain)
Kathrein 80010454 - 0,270 m





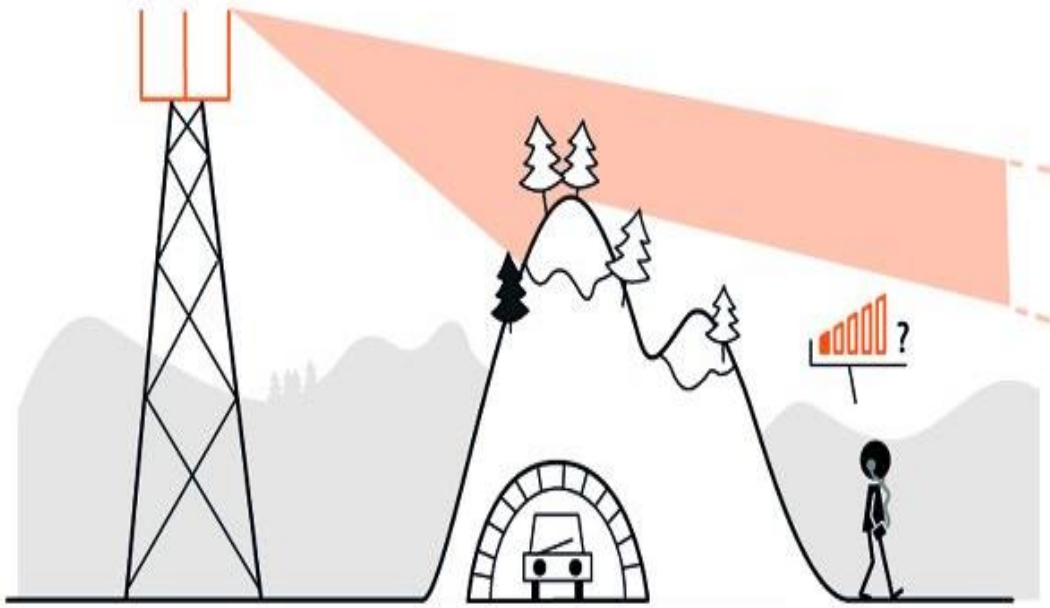


EIRP = 1000 W
Electric Field distribution
1,5 m above ground

High gain – green
Low gain - blue

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

International Telecommunication Union (ITU)

- ITU is UN Specialized Agency for ICT and Telecommunication
- It was founded in 1865 (earlier names CCIR & CCITT)

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)

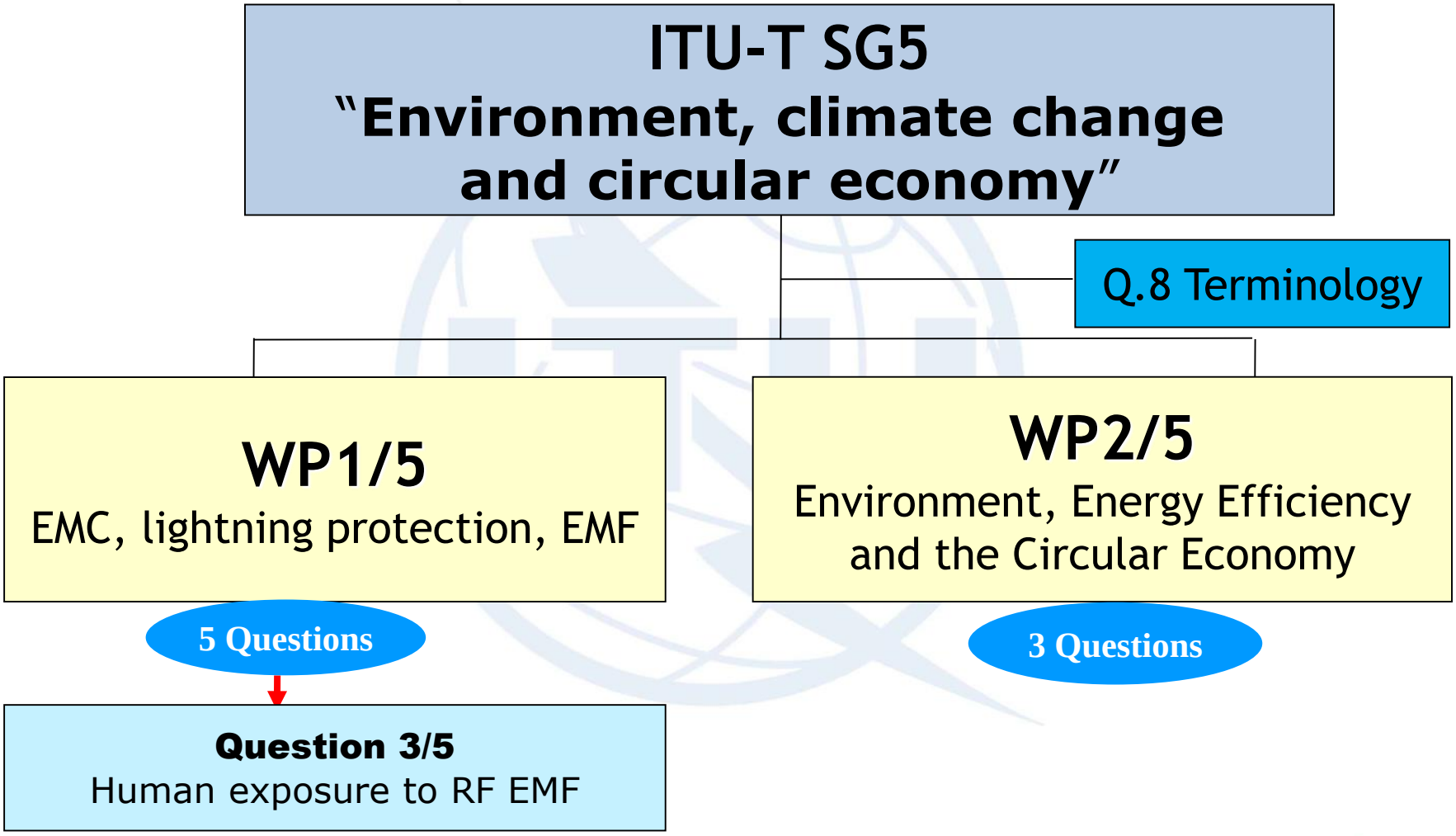
DEVELOPMENT

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

RADIOCOMMUNICATION

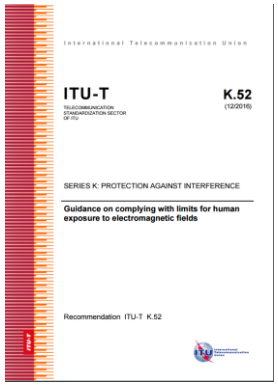
ITU-R Question 1/239 (Electromagnetic field measurements to assess human exposure).

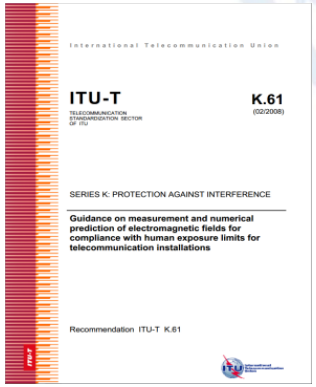
ITU-T Study Group 5 (SG5)

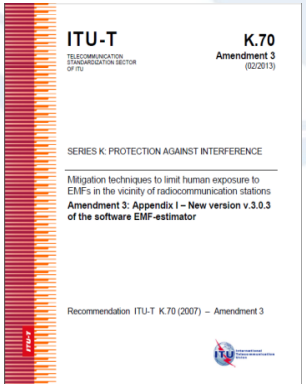


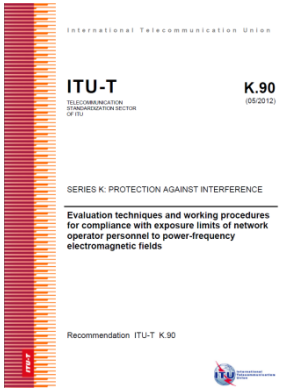
ITU-T Recommendations on EMF

- **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** (2011/2014) - 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**



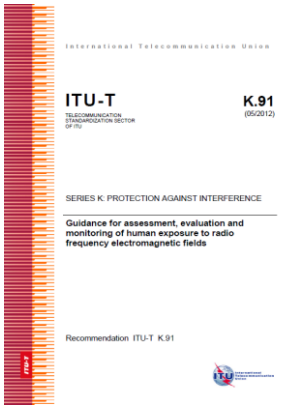


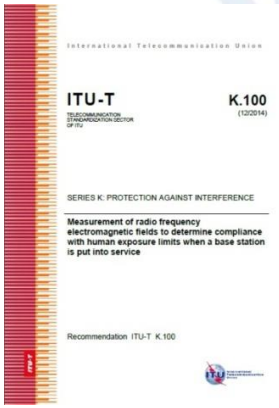


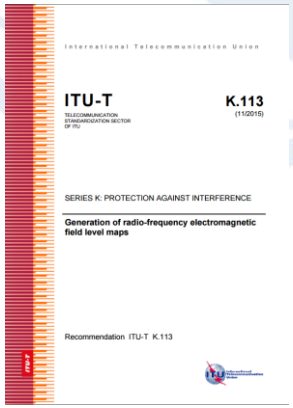


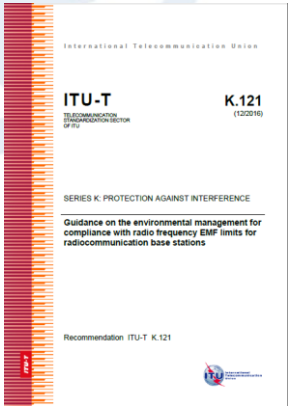
ITU-T Recommendations on EMF

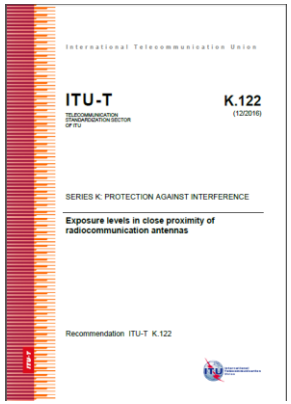
- **Recommendation ITU-T K.91** (2012/**2019**) - Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields – **includes "Uncertainty calculator" and "Watt_Guard" software, Supplement and mobile App "EMF-guide", mobile App „EMF Exposure"**
- **Recommendation 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







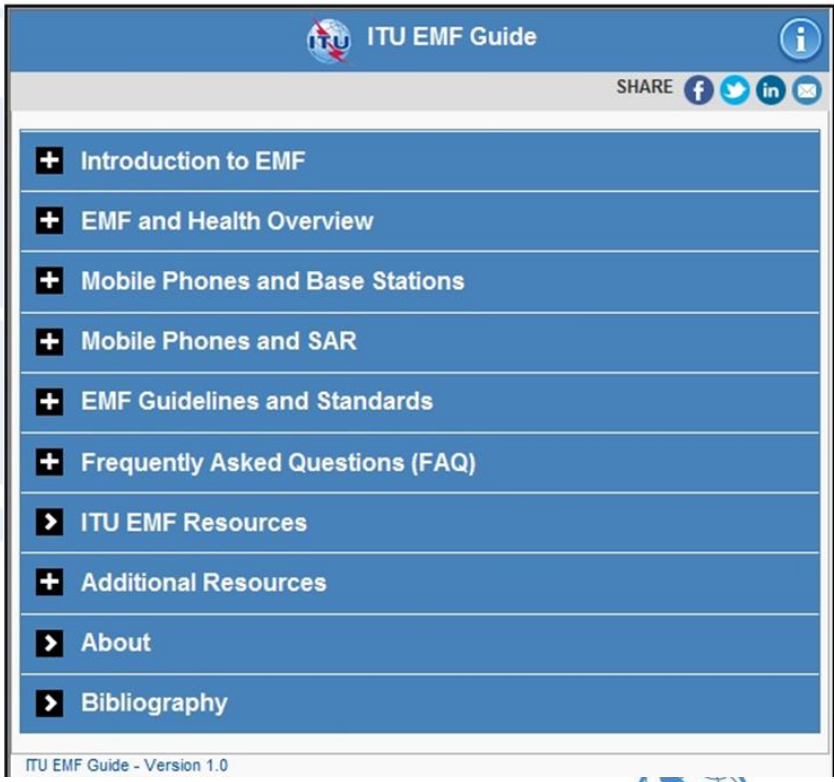




Recommendation ITU-T K.91

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



Recommendation ITU-T K.52

Guidance on complying with limits for human exposure to electromagnetic fields

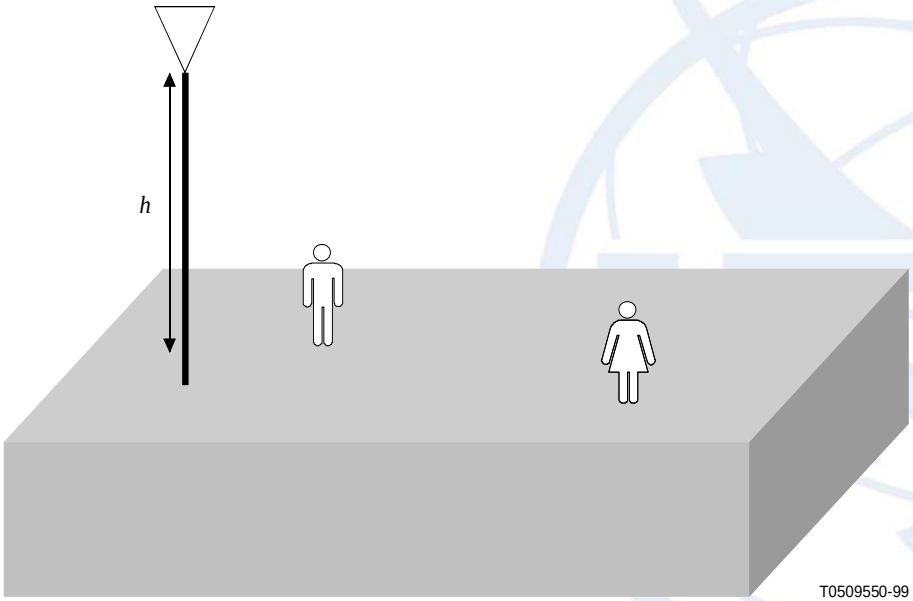


Figure B.1/K.52 – Illustration of the accessibility category 1

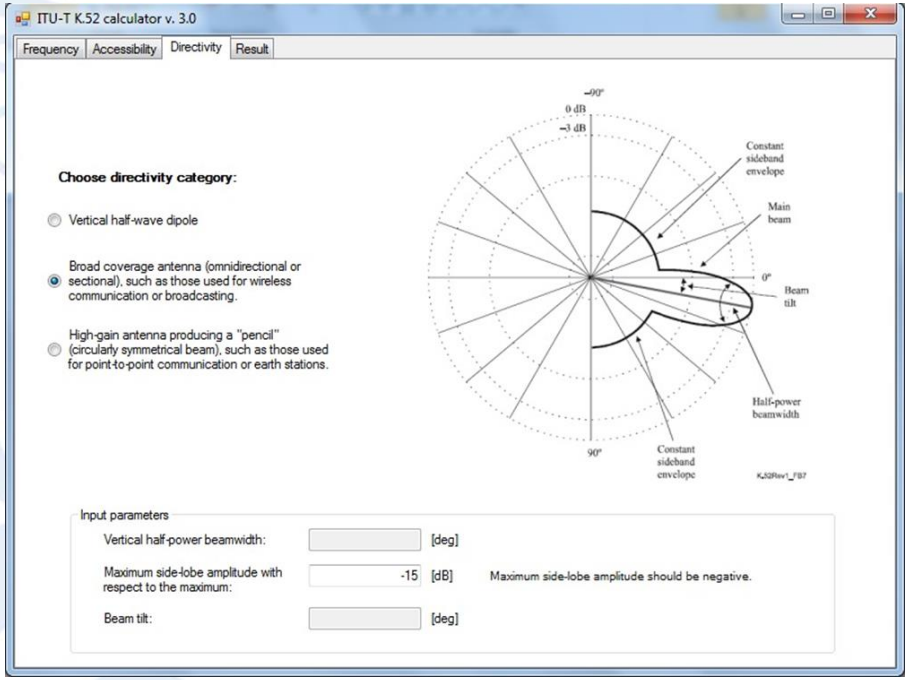
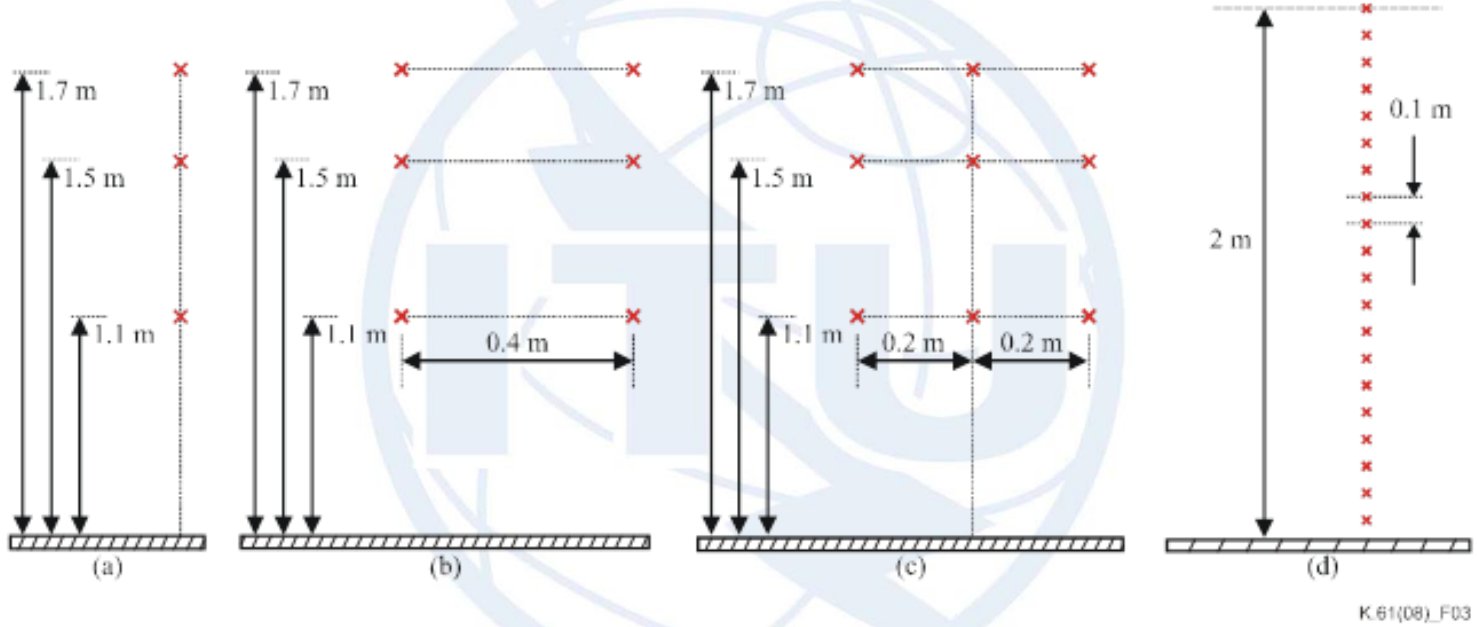


Figure B.7/K.52 – Illustration of terms relating to antenna patterns

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

Recommendation ITU-T K.61

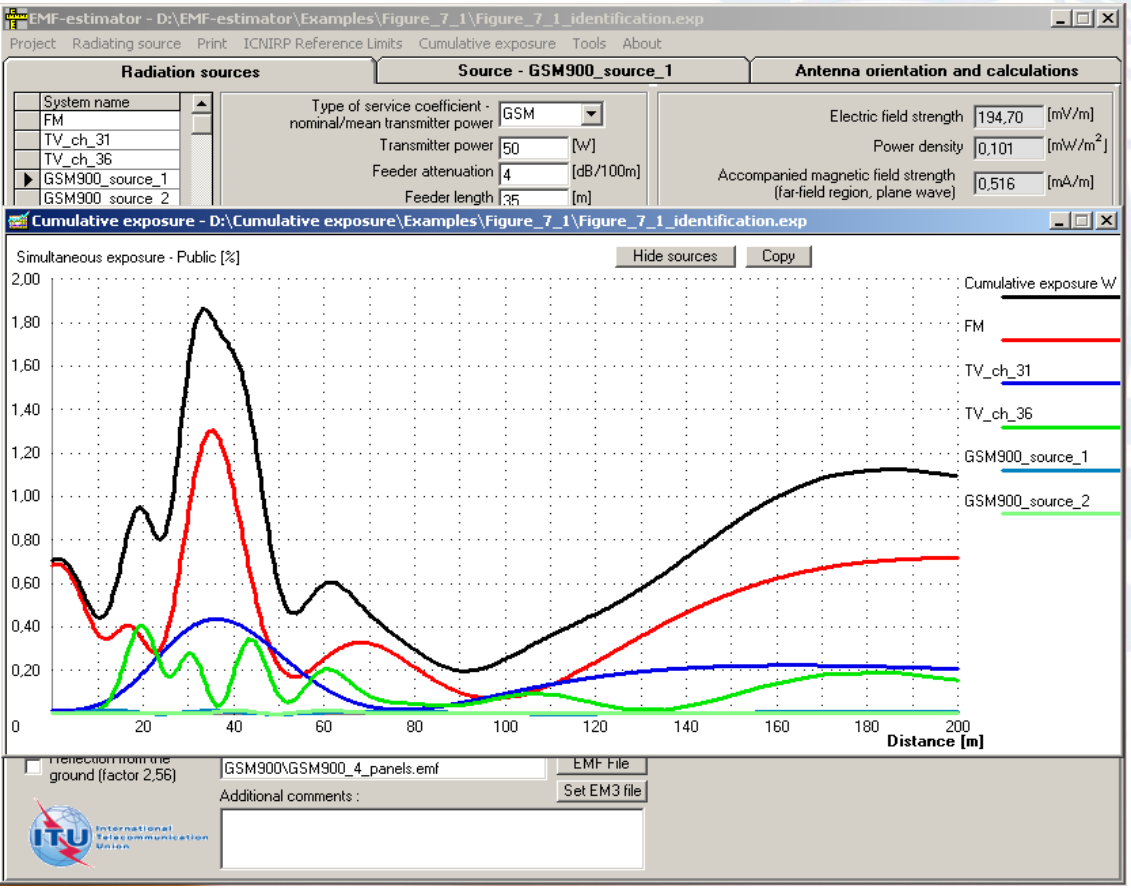
Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits, for telecommunication installations



- 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

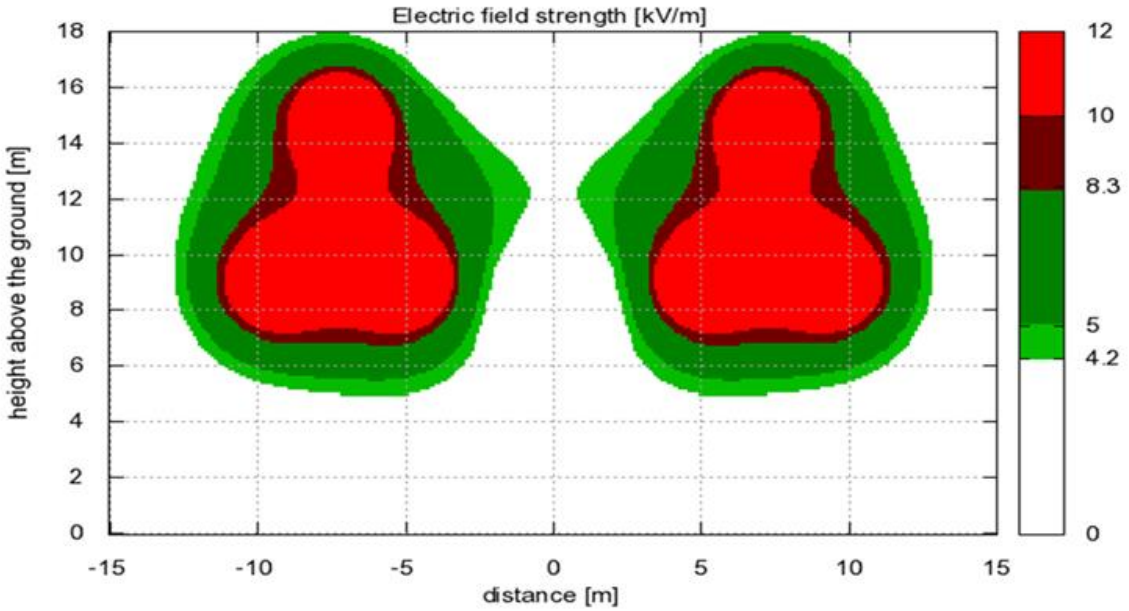
Recommendation ITU-T K.83

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

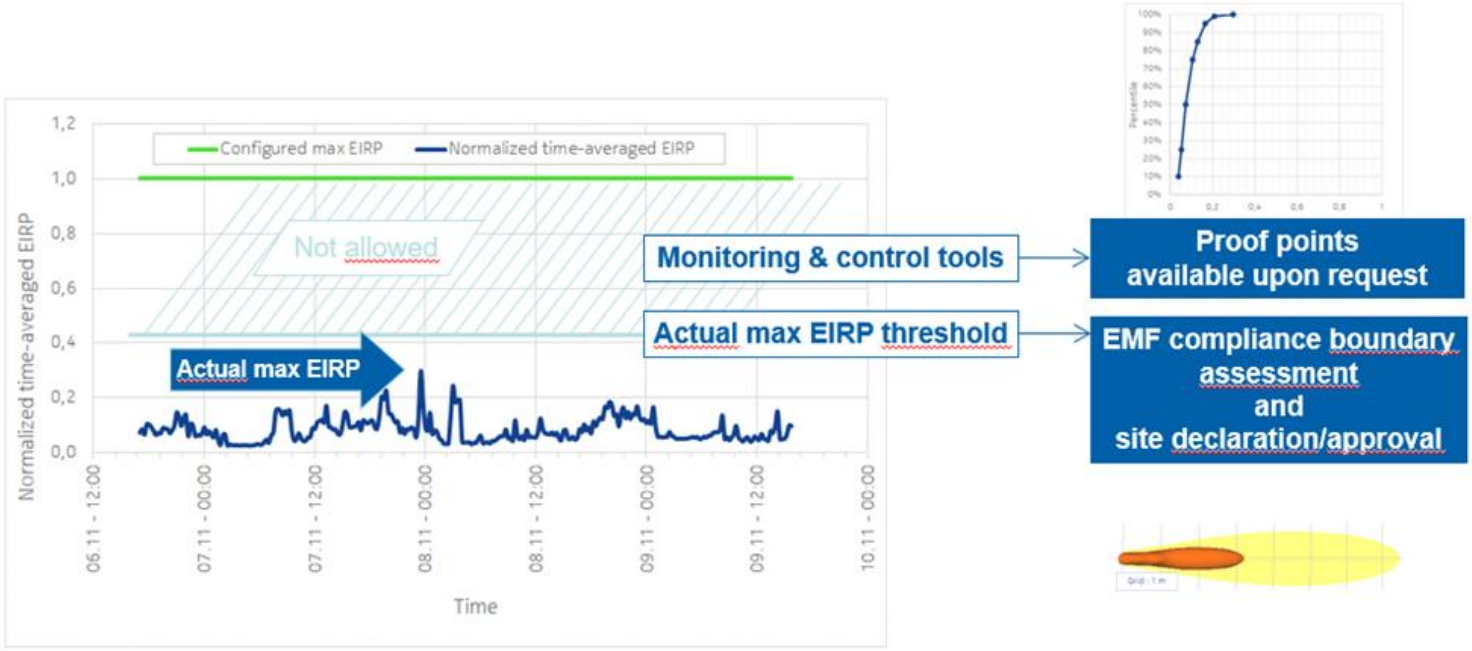
Evaluation techniques and working procedures for compliance with exposure limits of network operator personnel to power-frequency electromagnetic fields



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

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

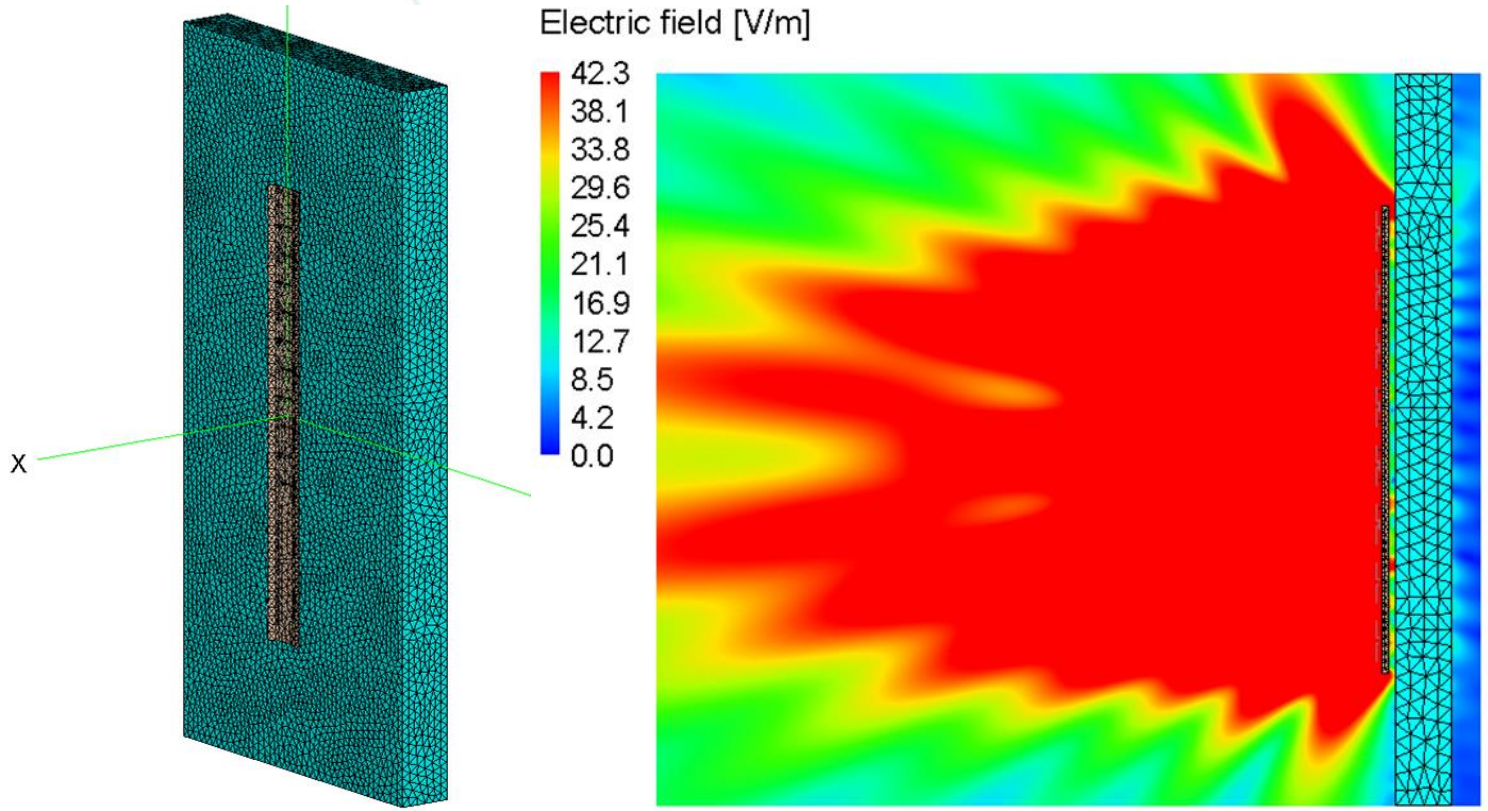
Recommendation ITU-T K.121

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

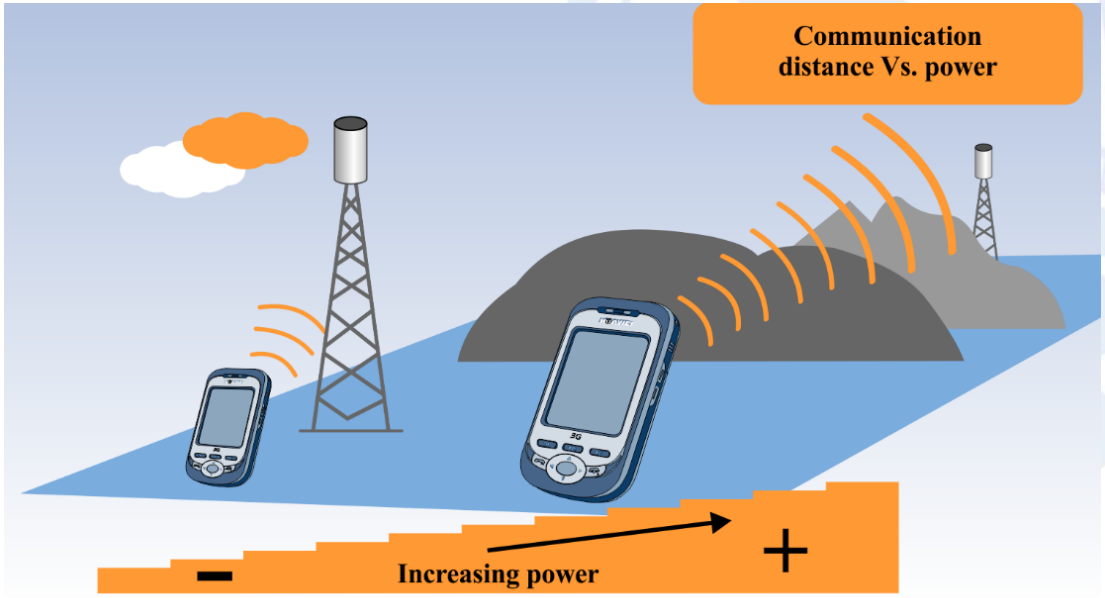
Exposure levels in the close proximity of the radiocommunication antennas



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

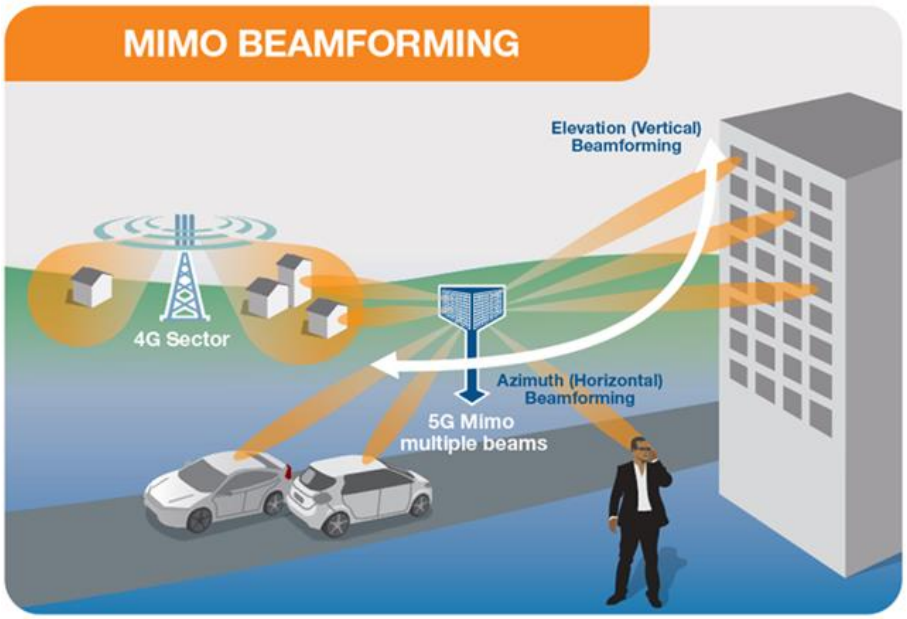
ITU-T Supplements on EMF

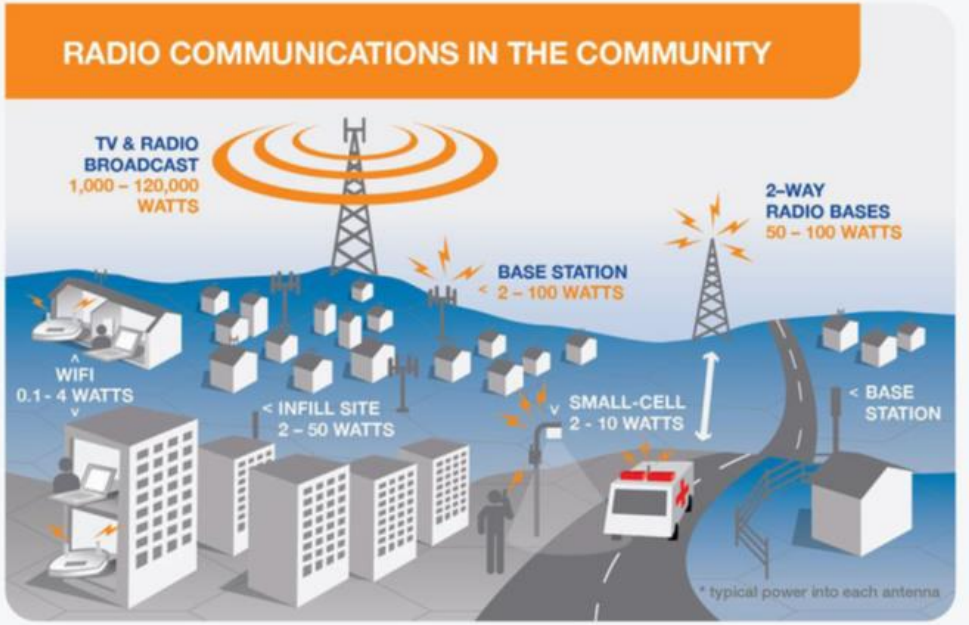
- ITU-T K Suppl. 1 (07/2014) ITU-T K.91 – Guide on electromagnetic fields and health
- ITU-T K Suppl. 4 (2015/2018) ITU-T K.91 - Electromagnetic field considerations in smart sustainable cities
- ITU-T K Suppl. 9 (11/2017) 5G technology and human exposure to RF EMF



ITU-T Supplements on 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 K.Suppl. 14 (05/2018) - 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 (2018/2019) - Electromagnetic field (EMF) compliance assessments for 5G wireless networks

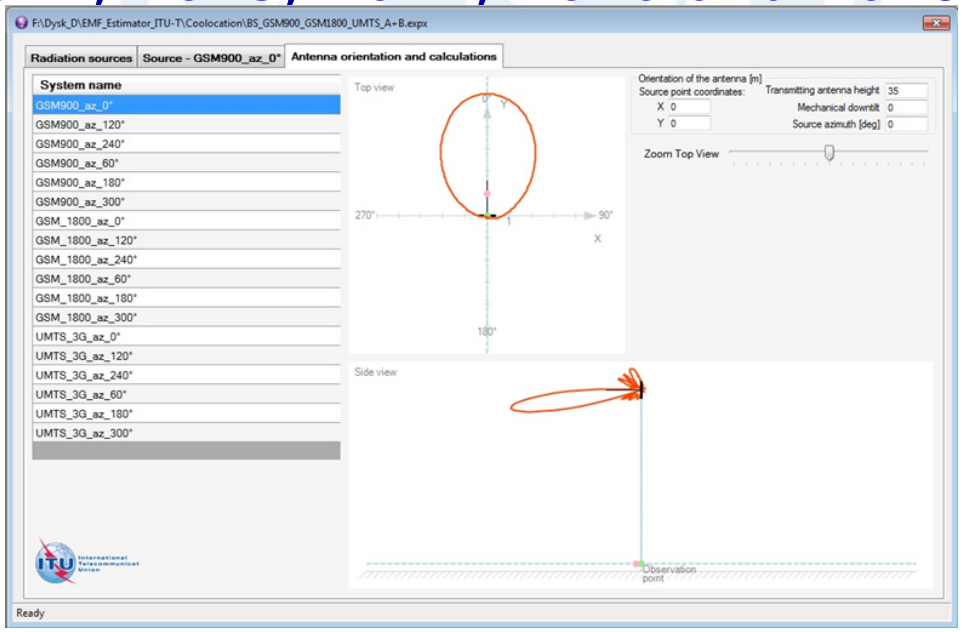




EMF-estimator

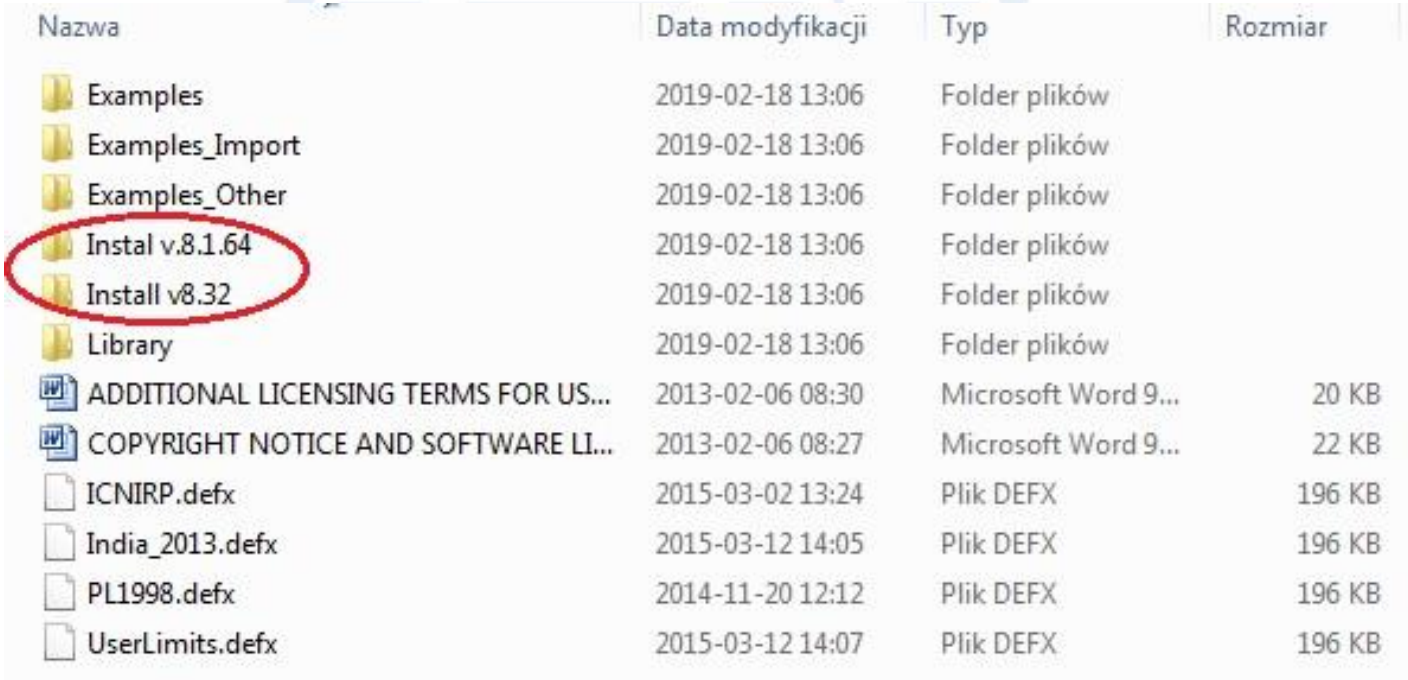
- Software tool that is Annex I to the ITU-T Recommendation K.70
- The last version of the software (v8.32 and v.1.64 – depending on the 32 or 64 bit Microsoft Access) may be loaded from the:

  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

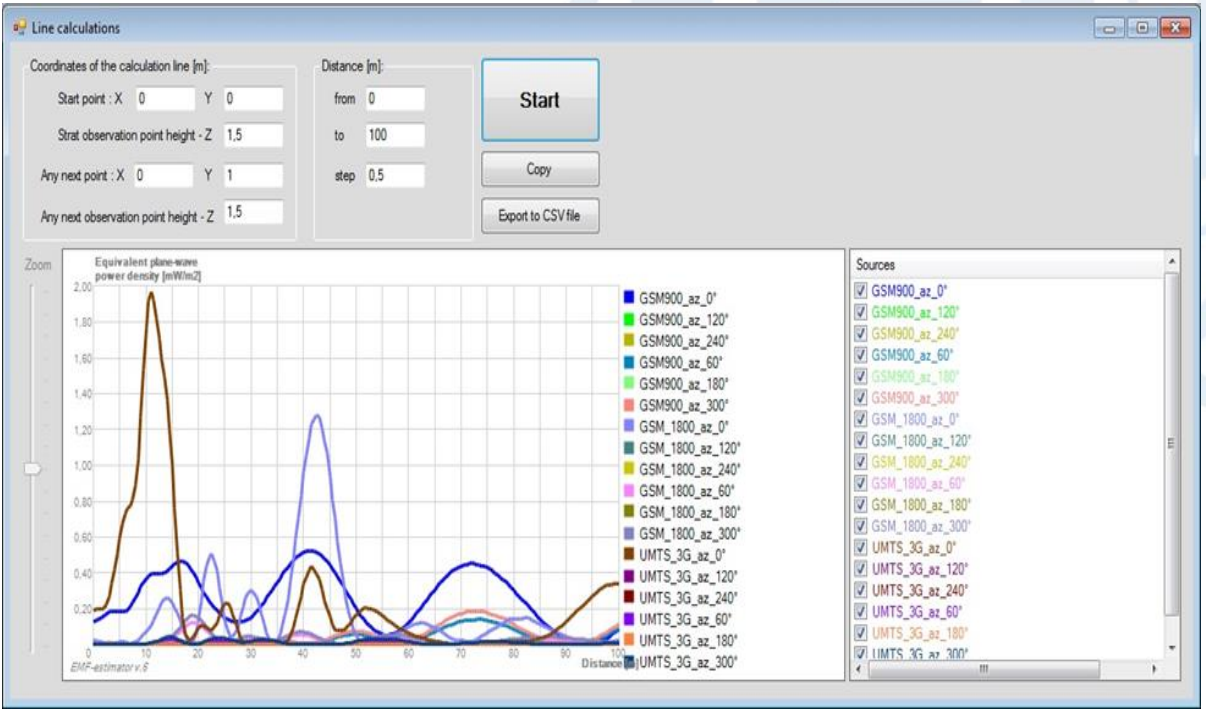
- It require the run Install procedure
- There are two versions because there are different version of the Microsoft Access software:
  - 32 bit version :Install v8.32
  - 64 bit version (with three variants): Install v.8.1.64
- If no Microsoft Access is installed than version v8.32 is recommended

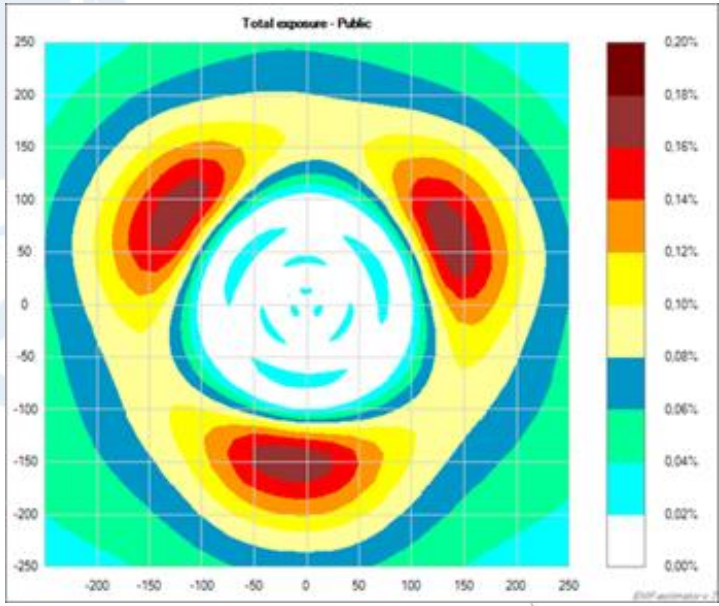


Nazwa	Data modyfikacji	Typ	Rozmiar
Examples	2019-02-18 13:06	Folder plików	
Examples_Import	2019-02-18 13:06	Folder plików	
Examples_Other	2019-02-18 13:06	Folder plików	
Instal v.8.1.64	2019-02-18 13:06	Folder plików	
Install v8.32	2019-02-18 13:06	Folder plików	
Library	2019-02-18 13:06	Folder plików	
ADDITIONAL LICENSING TERMS FOR US...	2013-02-06 08:30	Microsoft Word 9...	20 KB
COPYRIGHT NOTICE AND SOFTWARE LI...	2013-02-06 08:27	Microsoft Word 9...	22 KB
ICNIRP.defx	2015-03-02 13:24	Plik DEFX	196 KB
India_2013.defx	2015-03-12 14:05	Plik DEFX	196 KB
PL1998.defx	2014-11-20 12:12	Plik DEFX	196 KB
UserLimits.defx	2015-03-12 14:07	Plik DEFX	196 KB

EMF-estimator

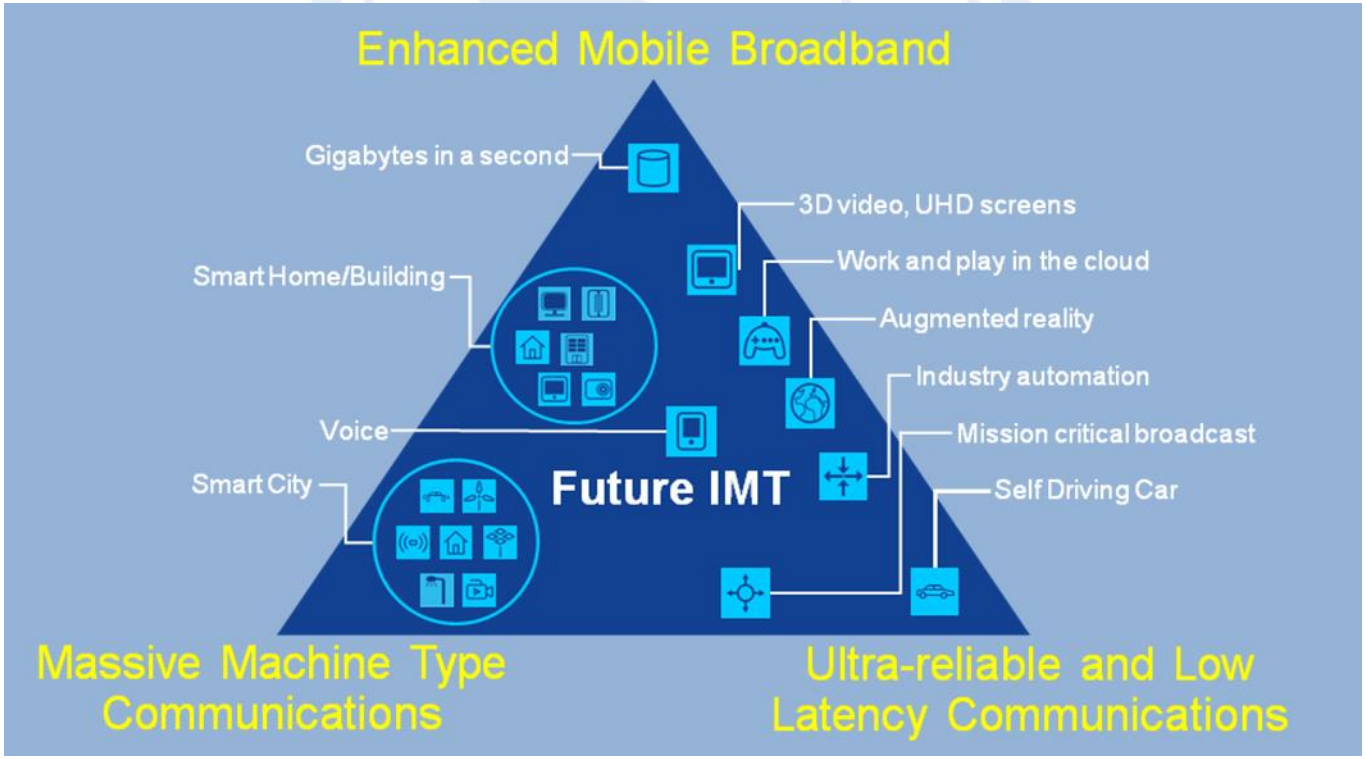
- EMF-estimator applies the point source and cylindrical models so it is valid starting from radiating near field region
- It may be used in the region of the radiating near-field but with lower accuracy
- It allows the evaluation of the exposure to the RF EMF and the comparison with the exposure limits





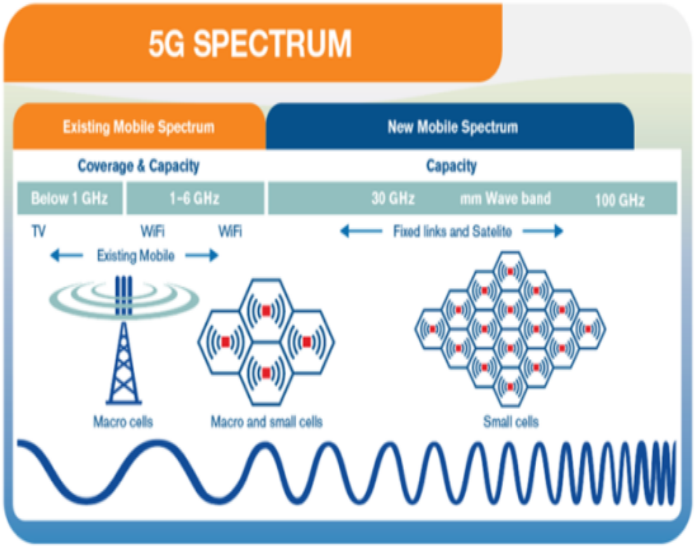
Introduction - 5G mobile systems (ITU-R M.2083)

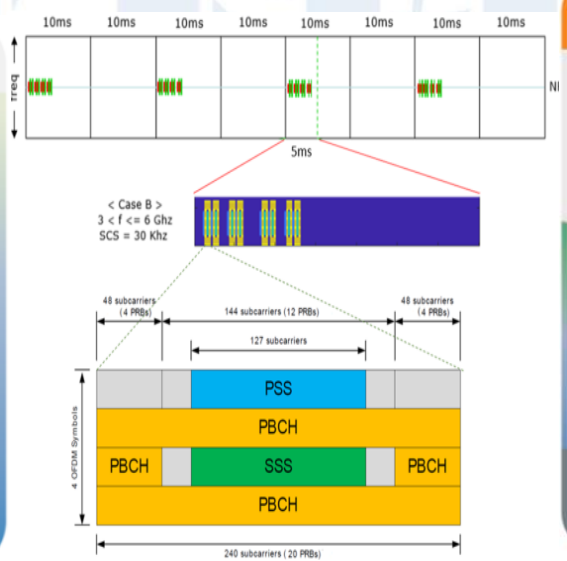
- The 5G system will cover three main different applications with different properties
  - Enhanced Mobile Broadband
  - Massive Machine Type Communications
  - Ultra-reliable and Law Latency Communications

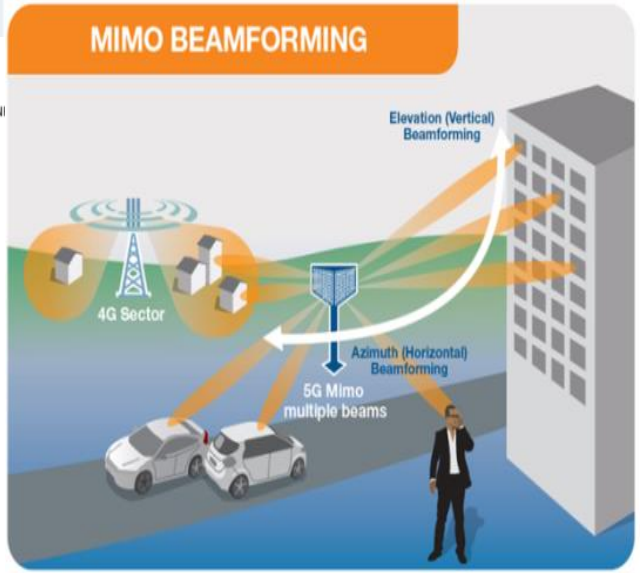


5G and PEM

- 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

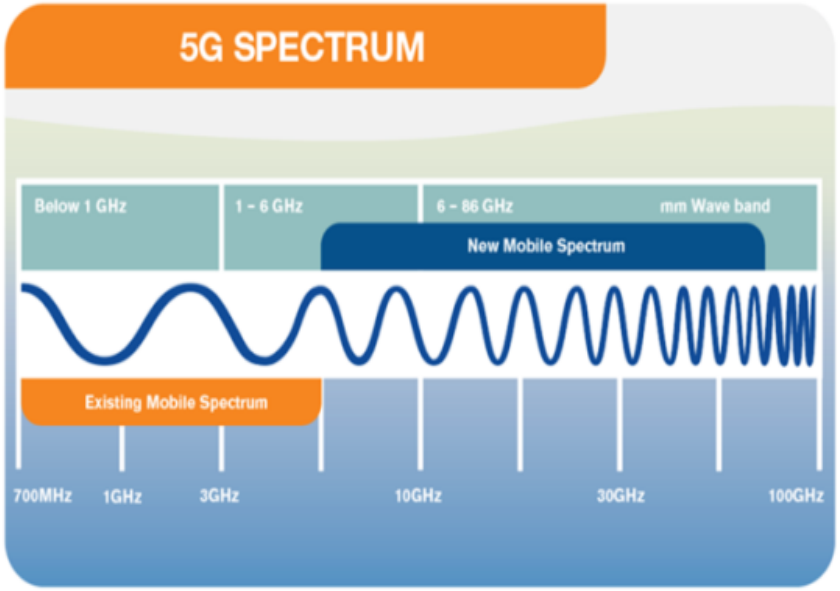






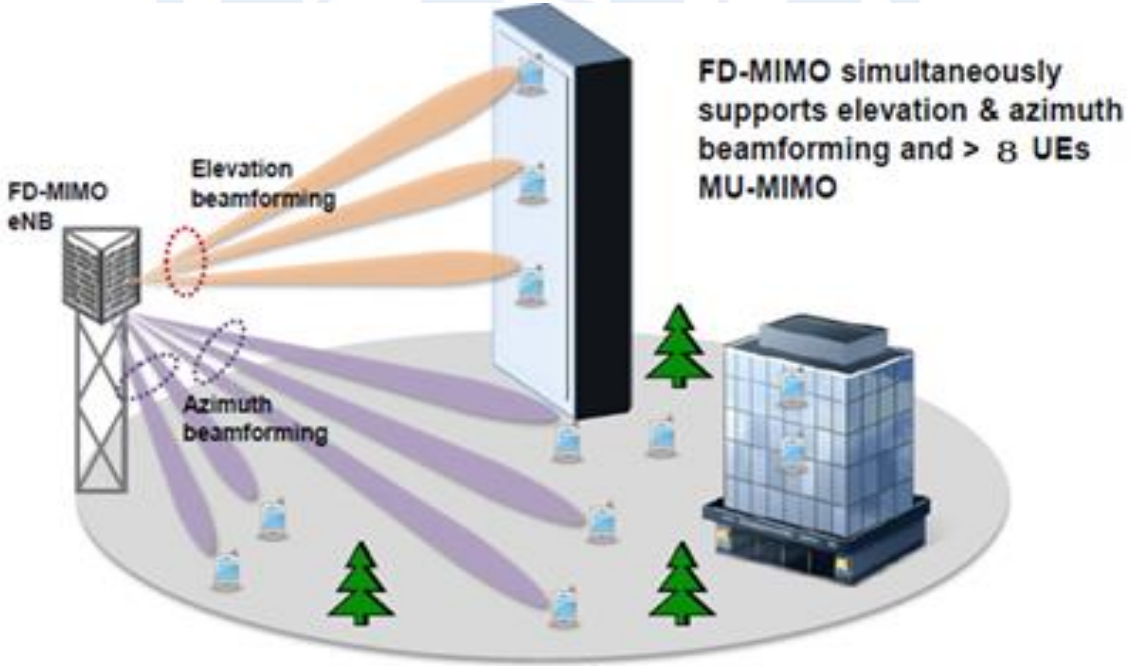
5G and PEM

- 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
- 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 substantially reduce the exposure in the environment



5G and small cells

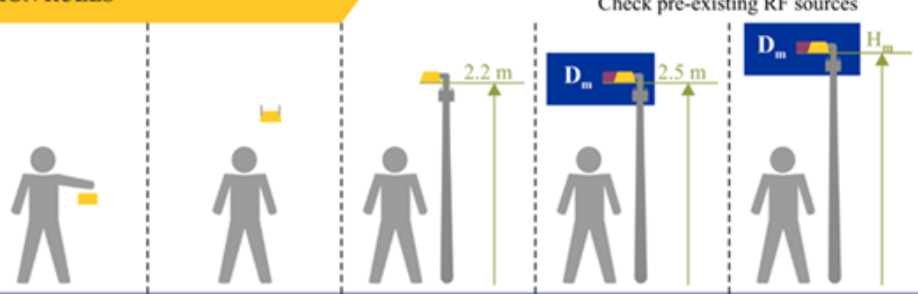
- Small cells will be much widely used especially for the high speed transmission that requires a very broadband transmission
- The use of the higher frequencies will result in lower coverages – small cells. Base stations will be located closer to the user, but the used power will be smaller too
- Current 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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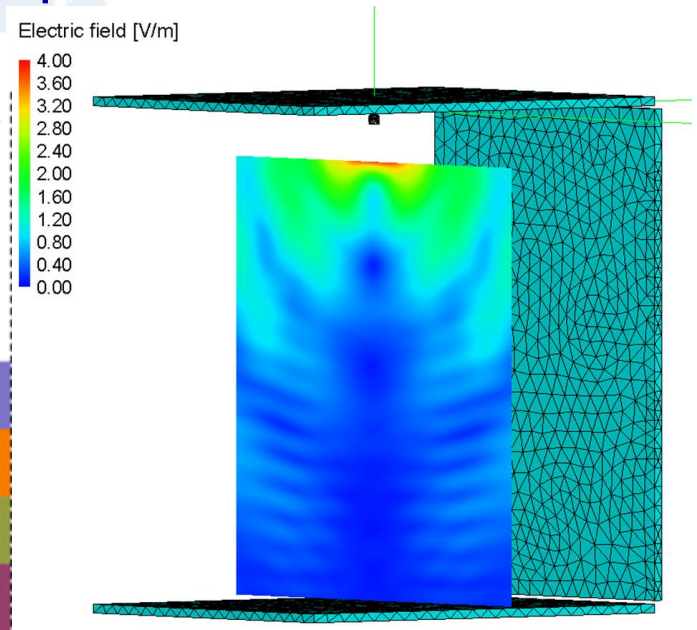
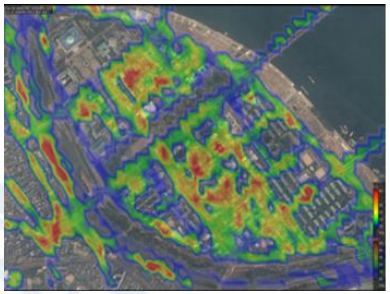


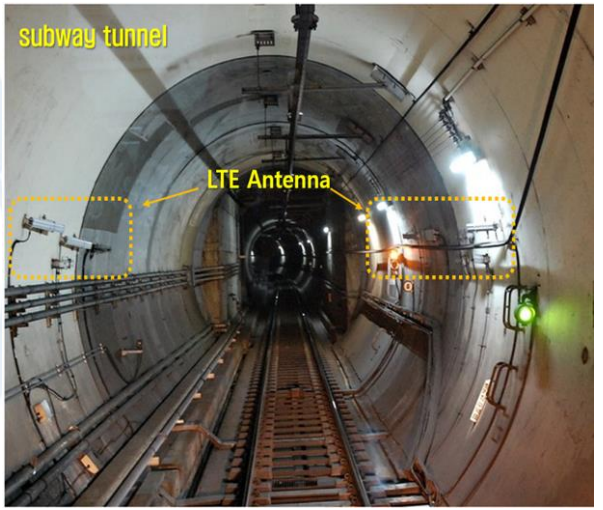
Internet of things (IoT), M2M

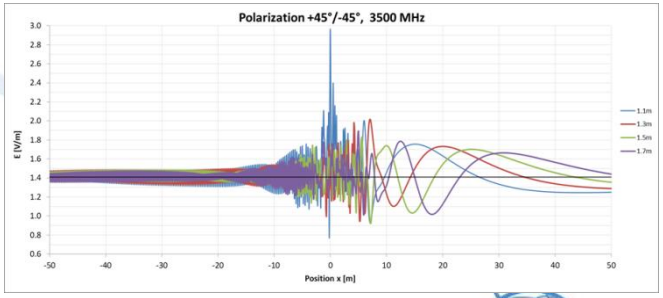
- It is expected that many devices will be connected to the internet using radiowaves. It will result in many possible improvements in our lives
- It means that the number of radiating sources will increase dramatically
- Almost all of them will be very low power and short range devices. They will communicate 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

Current studies in ITU-T SG5

- **ITU-T K.workers**: Assessment and management of compliance with RF EMF exposure limits for workers at radiocommunication sites
- **ITU-T K.peak**: Comparison between peak and real exposure in the long-term considerations
- **ITU-T K.reflection**: Impact of the metallic structures for the EMF exposure level
- **ITU-T K.Small**: Small base stations - impact on the overall exposure level
- **ITU-T K.Zones**: Guidance on Determining the Compliance Boundaries (the exclusion zone) of a Live Antenna
- **ITU-T KSTR.EMF_assess**: Case studies of RF-EMF assessments







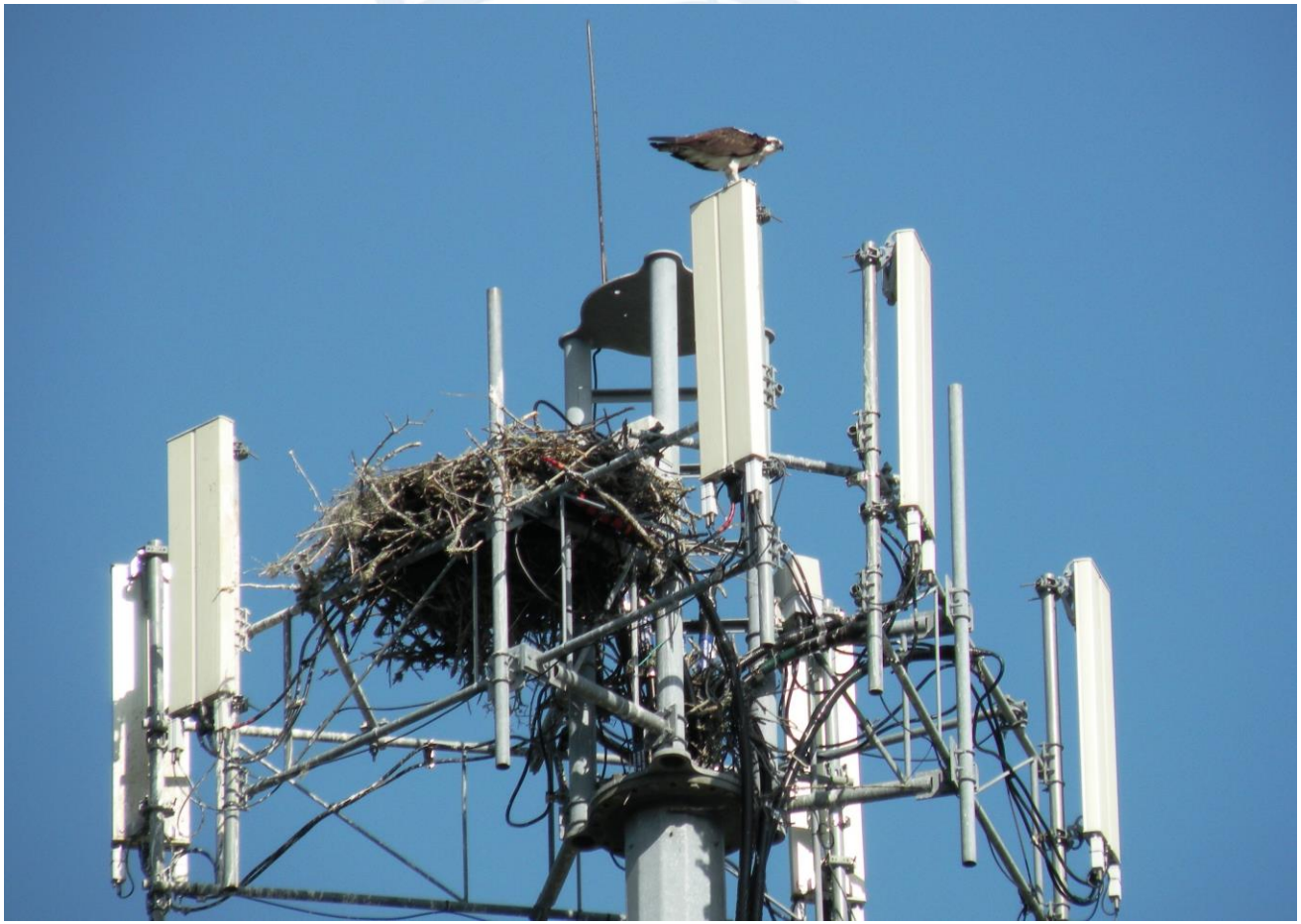
Conclusions

- 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

General Comments

- Some people are against RF EMF, but the same problem was earlier as concerning electricity or steam machines
- The exposure level to RF EMF is under control
  - Medical authorities (like WHO) are responsible for proper RF EMF exposure limits
  - Standardization organizations (like ITU) are responsible for the compliance assessment
- 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 this year

Thank you
Questions ?



RF EMF Exposure - mobile handset

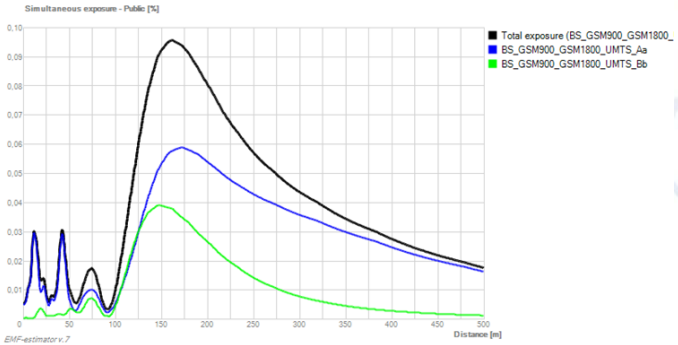
- Each mobile phone is equipped with Automatic Power Control system which adjusts the output power level to the minimum required value necessary to establish connection with a base station
- Power radiated by the mobile phone is lower if the user is close to a base station and higher if the distance 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

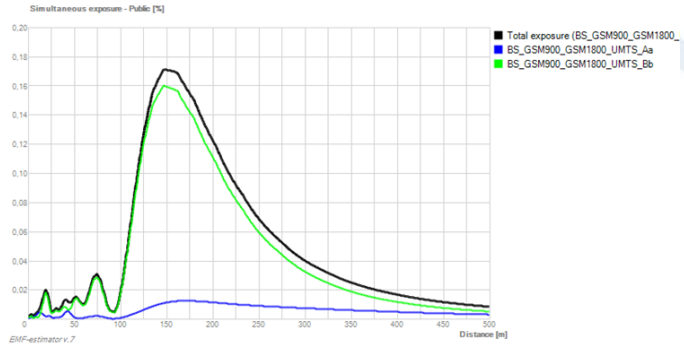
RF EMF Exposure - mobile handset

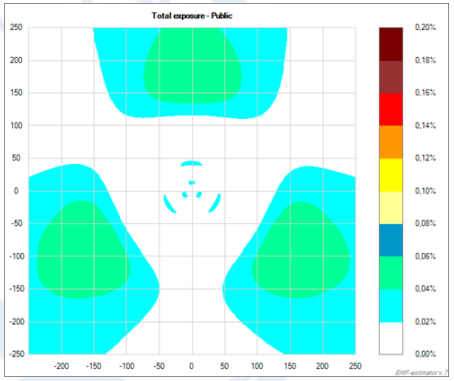
- Mobile phone is a semi-duplex device. It means that a mobile phone can not transmit and receive at the same time
- During the voice connection a mobile phone is switching from receiving to transmitting mode many times in the way which is not noticeable for the user, so the two-way communication is 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

Sharing infrastructure

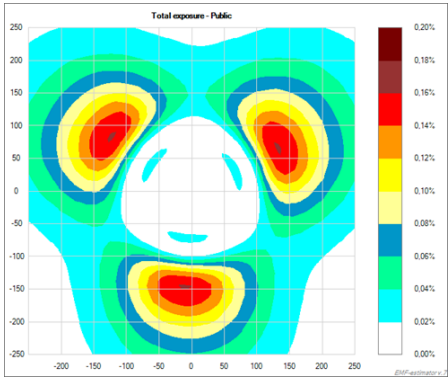
- It is predicted that operators applying 5G mobile systems will share physical infrastructure more frequently (shared sites)
- Below an example of exposure level around two co-located base stations is presented (colored lines) together with total exposure level (black line)
- The total exposure is lower than simple sum of that caused by each operator



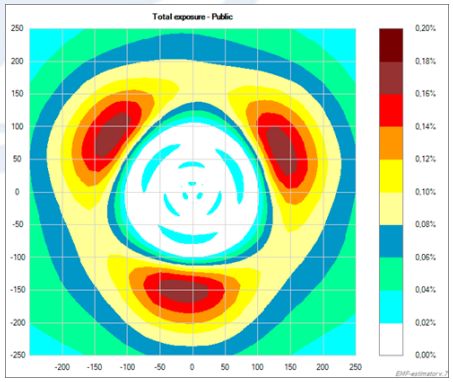




Base Station A



Base Station B



Base Stations A+B