ADDRESSING EMF ISSUES TO ACHIEVE SMART SUSTAINABLE CITIES

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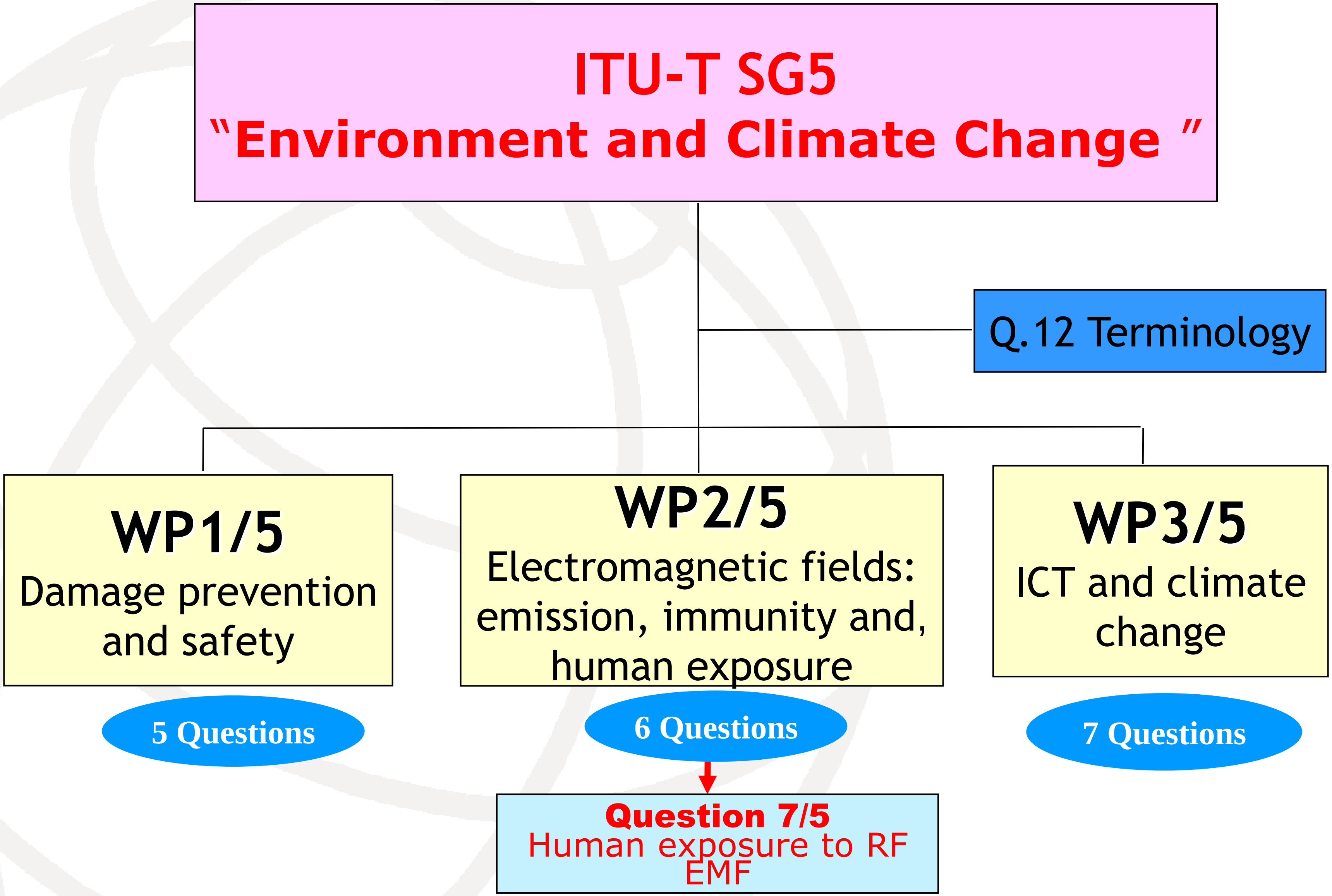
Outline

- Introduction
- ITU-T activity in EMF
- EMF overview
- Exposure limits
- ITU-T Recommendations
- EMF-estimator
- Exposure assessment
  - Measurements
  - Calculations
- Multisource environment
- Conclusions

Introduction



ITU-T SG5, WP2/5, Q7/5
Human exposure to electromagnetic fields (EMFs) due to radio systems and mobile equipment

- Best practice and mitigation techniques in the protection against non-ionizing radiation
- Implementation and guidance on radiocommunication installations
- Consideration of the areas near transmitting and base stations with many radiating sources representing various radiocommunication and broadcasting systems
- Support to developing countries – ITU-T Resolution 72 (WTSA-12, Dubai, 20-29 November 2012)
- http://www.itu.int/en/ITU-T/studygroups/2013-2016/05/Pages/default.aspx

ITU-T SG5
Focus Group on Smart Sustainable Cities (FG–SSC)

- FG-SSC includes „**EMF Considerations in Smart Sustainable Cities**„
- The design and deployment of wireless networks must ensure electromagnetic field (EMF) compliance and minimize human exposure to radio frequency (RF) radiation
- EMF considerations in Smart Sustainable Cities have to ensure the networks and connected devices operate safely and most efficiently
- http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx

Introduction

- There is significant community opposition to the deployment of mobile network antenna sites and other wireless infrastructure
- Fears about possible health risks from exposure to EMF, concerns about aesthetics or impacts on property values
- EMF fields are imperceptible and unknown for the general public
- Fears about EMF can result in social conflicts and lead to delays in the deployment wireless networks

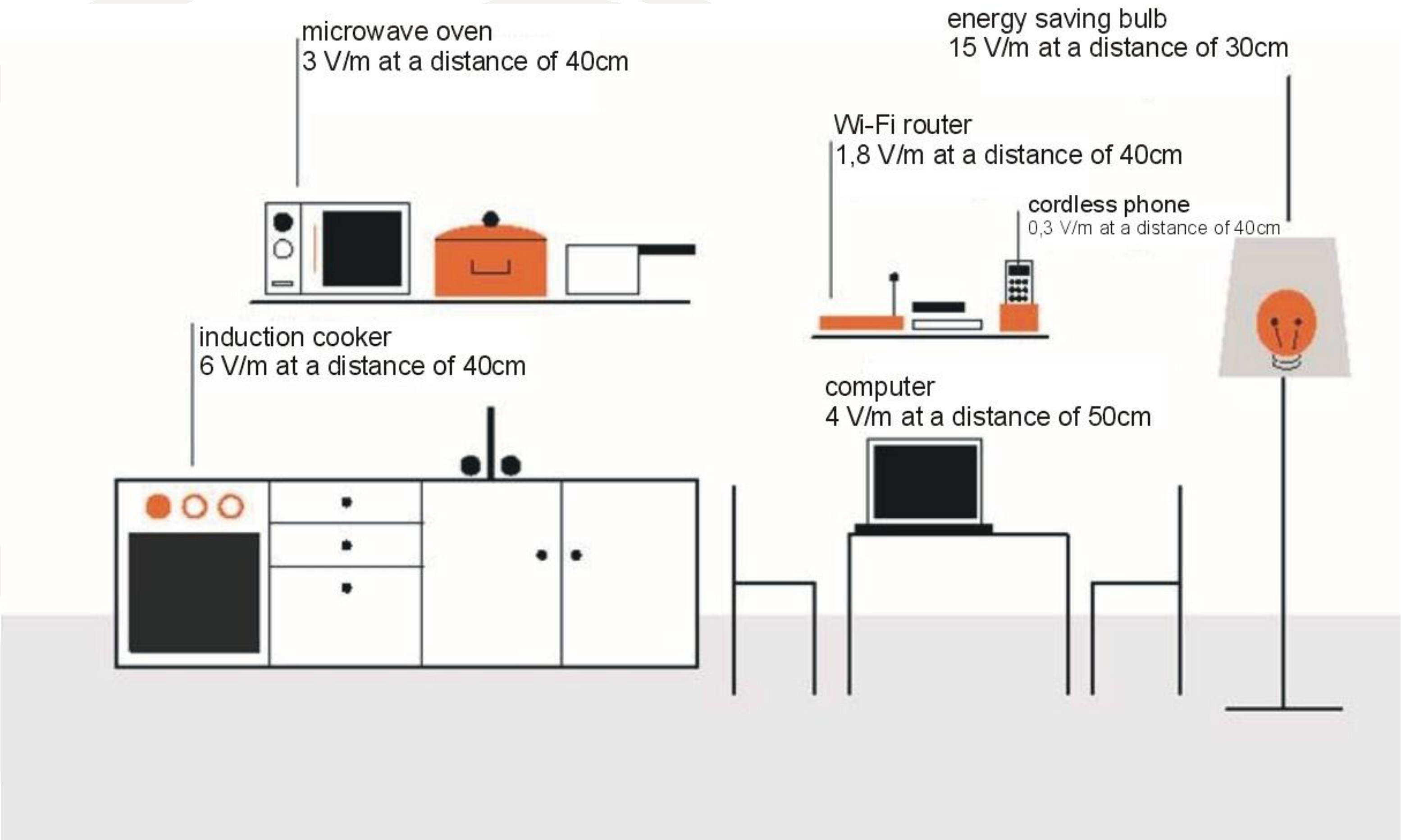
Introduction

- Constant development of the radio communication systems and networks
- 6,3 billions of mobile phones were in use around the world (2013)
- Constant growth of the number of base stations
- In general there is a bigger concern related to base stations then to mobile phones

Introduction

- The range of devices that are connected to the internet is rapidly growing
- In the most cases the connection is wireless – it means that the devices have to radiate electromagnetic fields (EMF)

EMF in home environment



Exposure levels around typical electronic and electric equipment in home environment

The electromagnetic spectrum

- This is unique resource with limited capacity
- The property of the electromagnetic fields strongly depends on the frequency

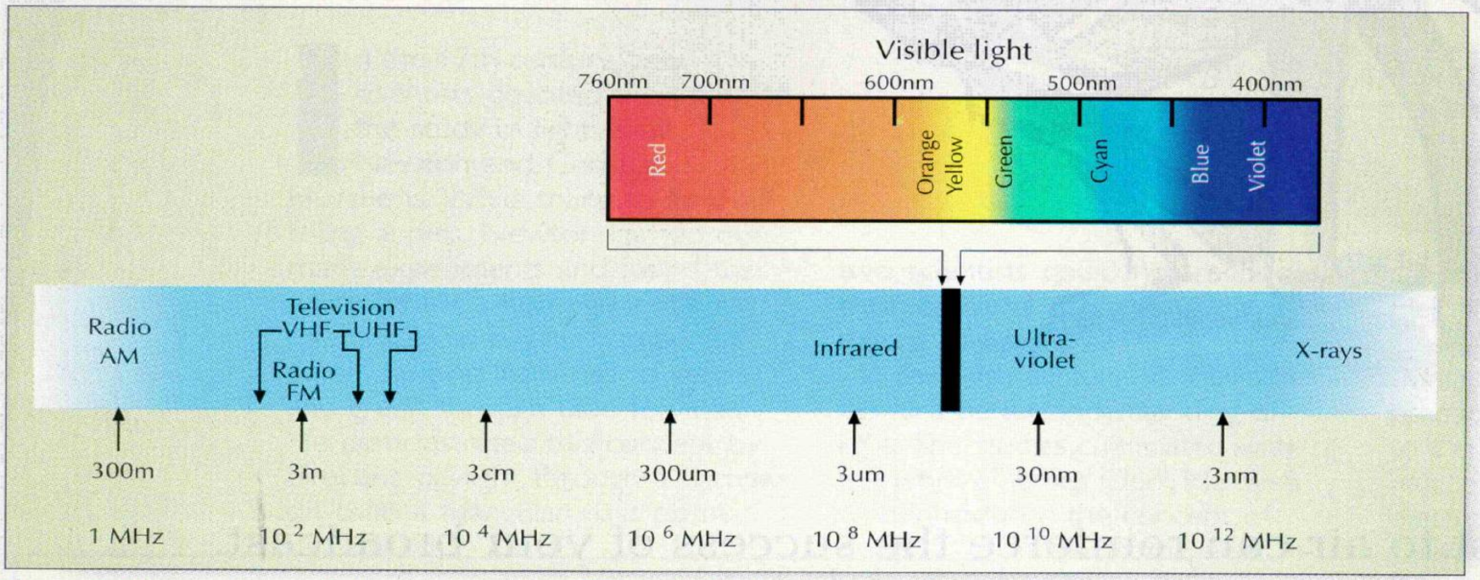


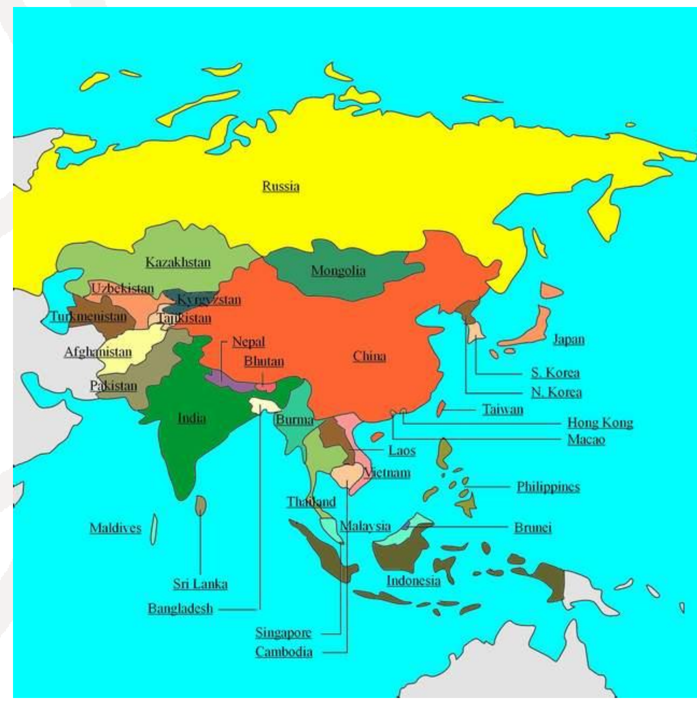
Figure 3. The spectrum of electromagnetic radiation includes the AM and FM radio bands, VHF and UHF television frequencies, and visible light.

Source: World Broadcast Engineering 10/2000

- RF EMF – frequencies lower then visible light
- Ionising radiation – frequencies higher then visible light

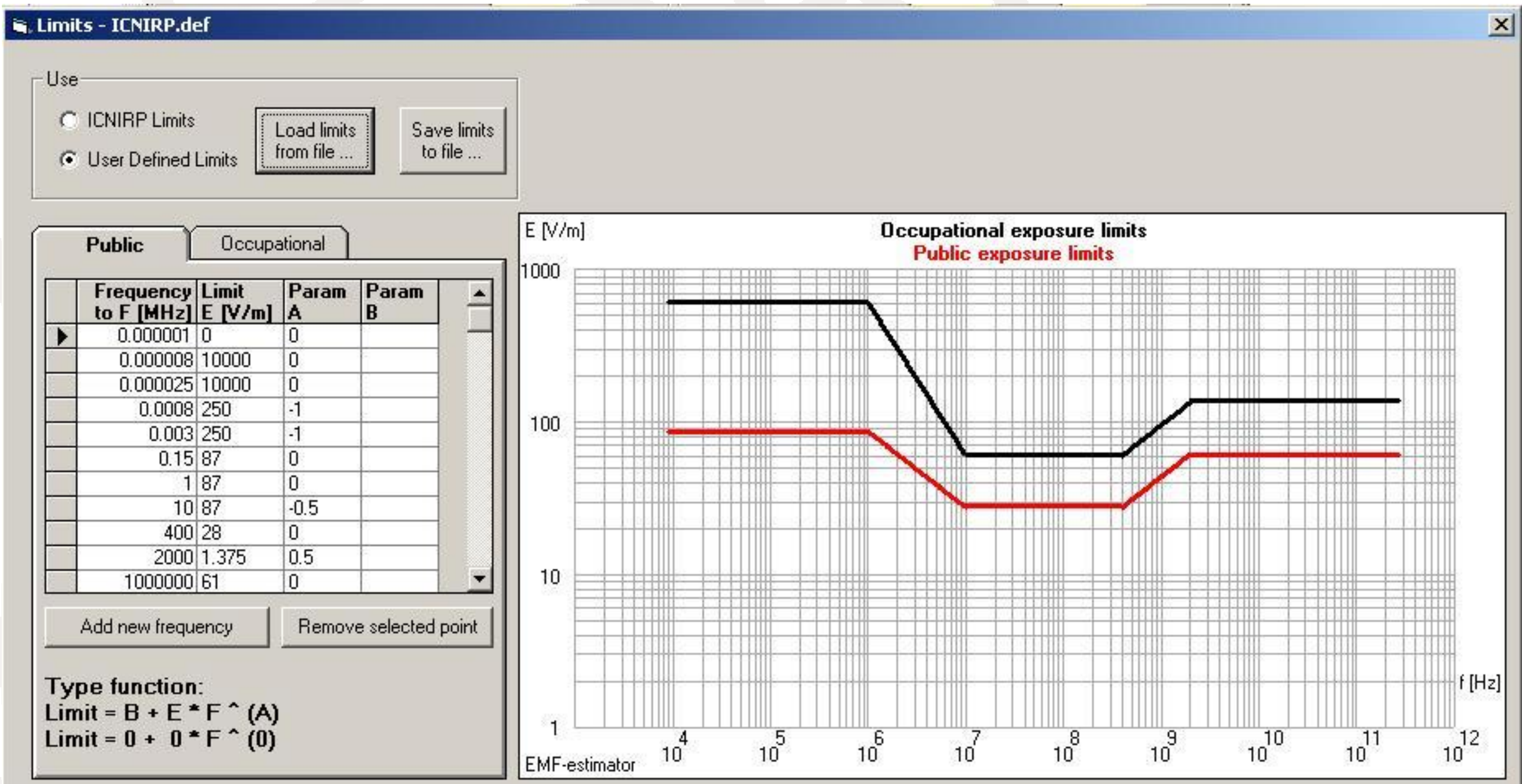
The exposure limits

- Data concerning exposure limits in different countries can be found on the WHO website: http://www.who.int/docstore/peh-emf/EMFStandards/who-0102/Worldmap5.htm
- There is no data in WHO with Thailand limits
- WHO and ITU recommends the use of the ICNIRP exposure limits



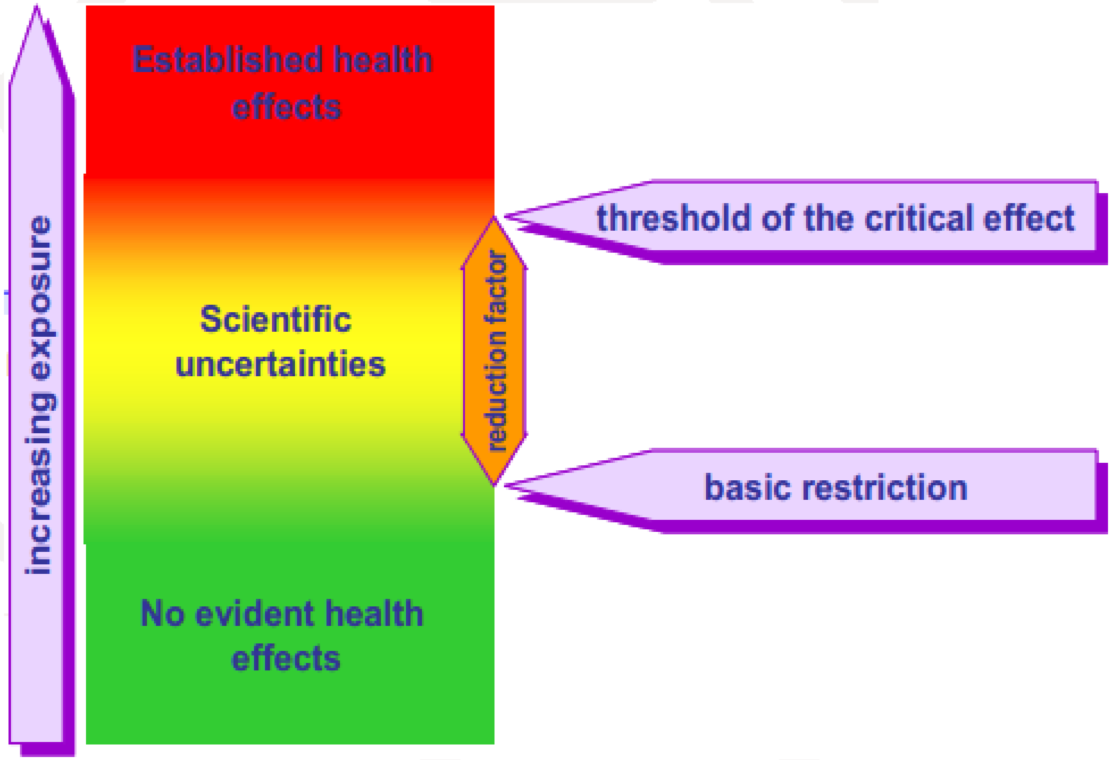
The ICNIRP exposure limits

- It is visible that the limits are also frequency dependent (chart from EMF-estimator)
- General public and occupational exposure



Exposure limits and reduction factor

A reduction factor is applied to establish a safe exposure level for occupational exposure (workers, factor of 10) and the general public (factor of 50)



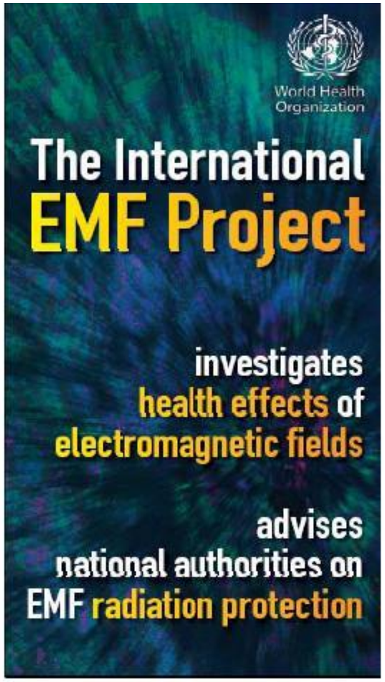
Source: ICNIRP presentation: EMF Safety Guidelines

Classification - International Agency for Research on Cancer (IARC)

Agents Classified by IARC (950)

IARC Classification	Examples of Agents
Carcinogenic to humans (107) (usually based on strong evidence of carcinogenicity in humans)	Asbestos Alcoholic beverages Benzene Mustard gas Radon gas Solar radiation Tobacco (smoked and smokeless) X-rays and Gamma
Probably carcinogenic to humans (59) (usually based on strong evidence of carcinogenicity in animals)	Creosotes Diesel engine exhaust Formaldehyde Polychlorinated biphenyls (PCBs)
Possibly carcinogenic to humans (267) (usually based on evidence in humans which is considered credible, but for which other explanations could not be ruled out)	RF fields Coffee Gasoline engine exhaust Pickled vegetables ELF magnetic fields Styrene

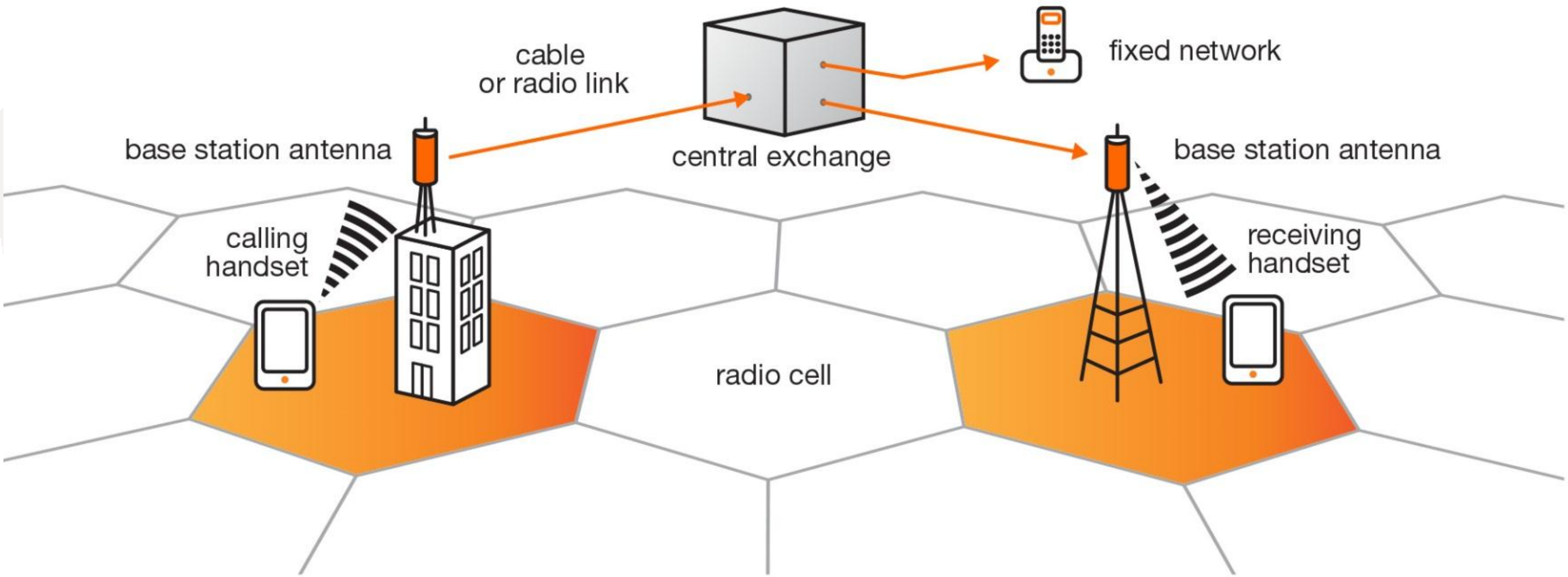
17 |



World Health Organization

Source: WHO presentation during ITU-D Q23/1 meeting, April 2012

How mobile system works

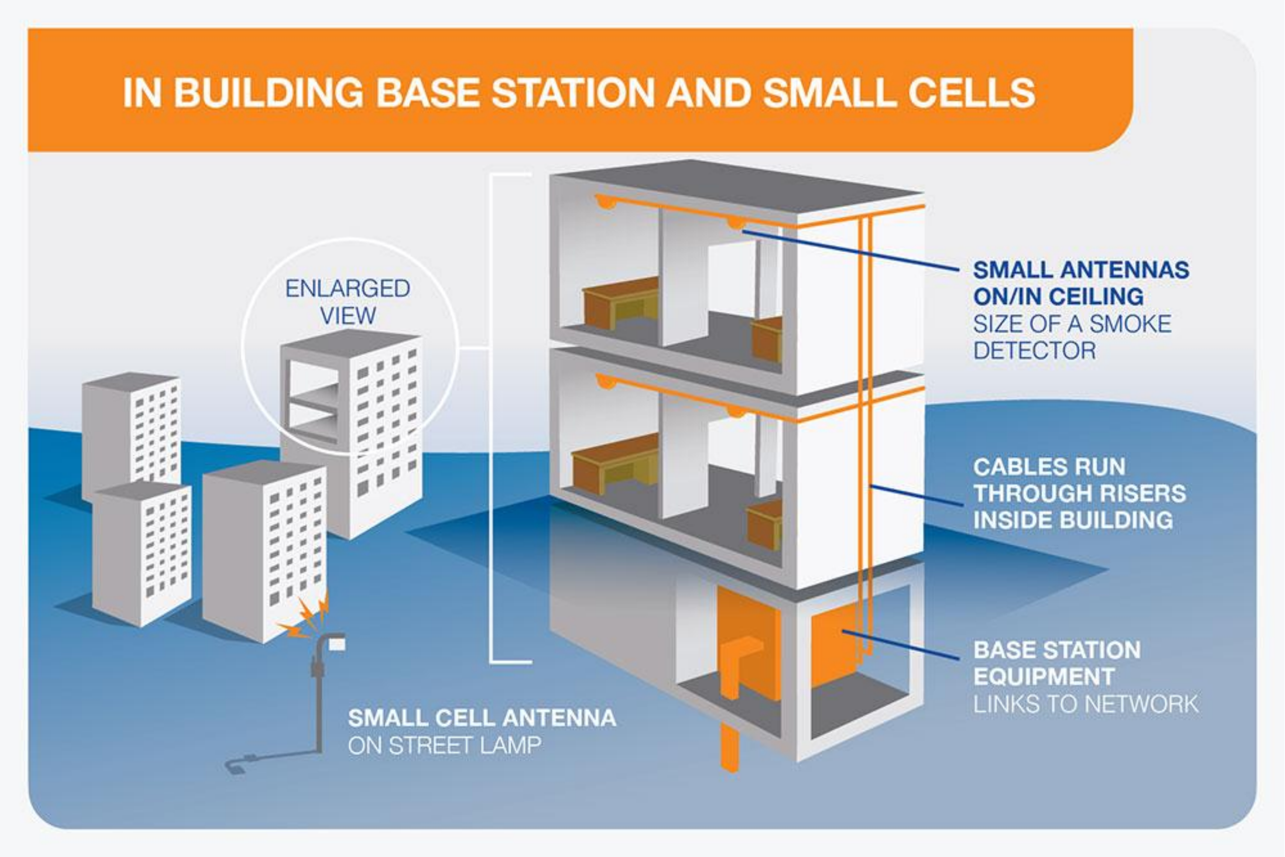


- Cellular system is establishing a connection via base station
- It is so even if mobile phones are very close one to another
- Increasing the capacity of the mobile network is realized by higher density of base stations networks

Exposure around mobile phone

- Each mobile phone is equipped in 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 is longer. The power is also increased if a user is inside a building or car, because of attenuation of the signal by the building walls or car body.

Small cells

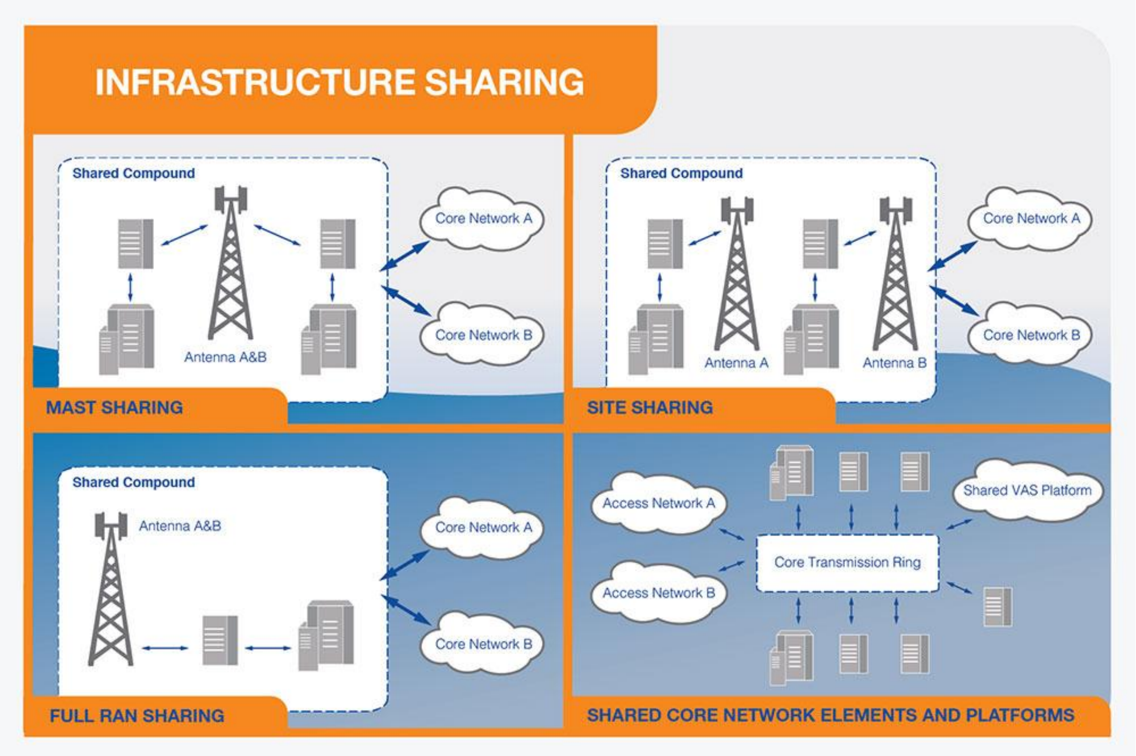


- Small cells are required to extend coverage
- The emitted power of RF EMF is substantially lower than from typical BS's

Radiation from the mobile phone

- Mobile phone is a semi-duplex device. It means that the mobile phone can not transmit and receive at the same time
- During the voice connection the mobile phone is switching from receiving to transmitting mode many times in the way which is not noticeable by for the user
- If during the voice call the user is listening then the mobile phone is not radiating

Sharing and Co-Location

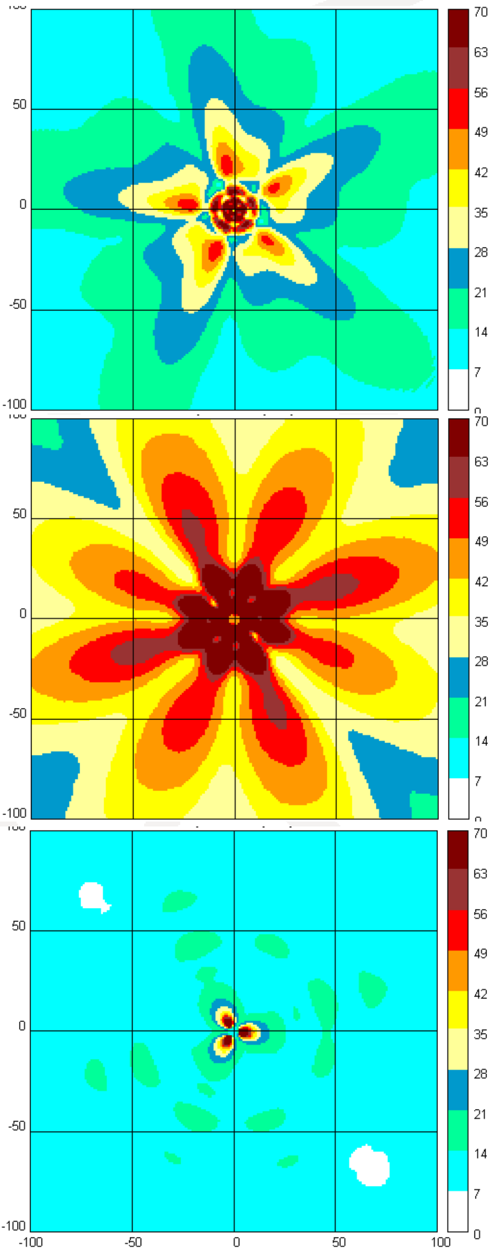


Source, GSMA, Mobile Infrastructure Sharing, (2008).

- Co-location increases exposure level from one site but decreases the number of sites
- There is no simple dependence for exposure level

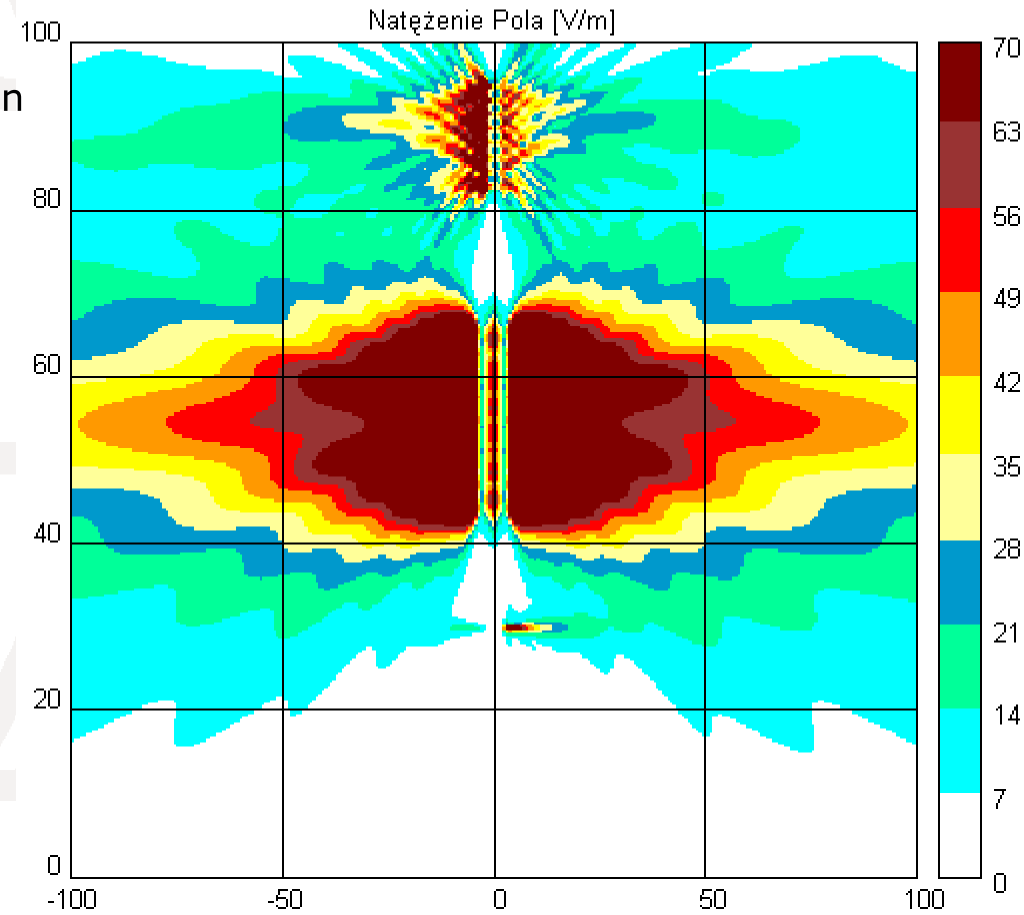
Example of the evaluation of the electric field distribution in the vicinity of the transmitting station

VHF TV (ERP=125kW, h=90m), FM (Total ERP=423kW, h=55m), GSM900 (ERP=1080W, h=30m), GSM1800 (ERP=1120W h=30m)
Total electric field level [V/m]



Vertical cross section
Azimuth 333°

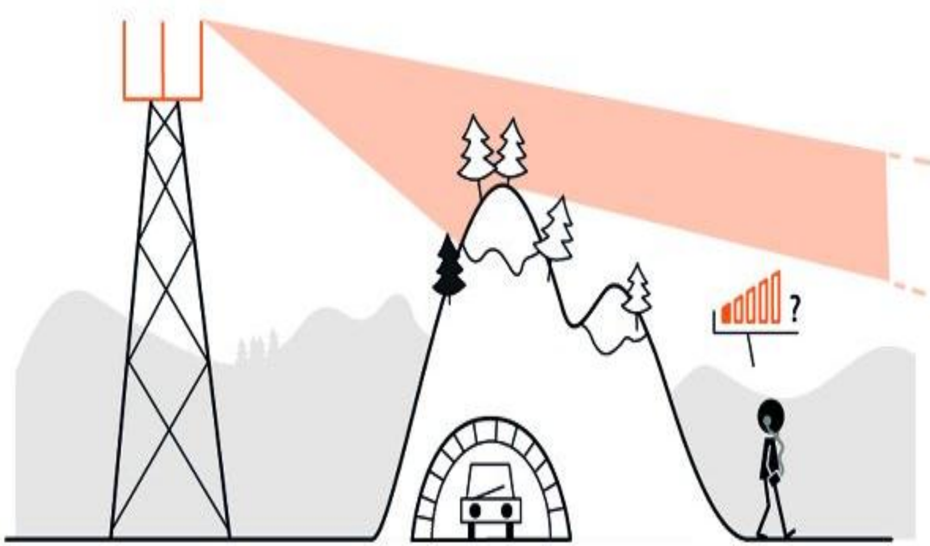
Horizontal cross sections:
h=90 m
h=55 m
h=30 m



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



EMF and SSC

- The wireless communication – indispensable and very widely used in SSC – require that EMF are under control
- The government is responsible for the establishment of the clear and proper regulations concerning EMF
- The service providers are responsible for the good practices in implementation of the wireless services
- ITU is preparing Recommendations and guides that should support such activities

International Telecommunication Union

ITU-T
TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

K.91
(05/2012)

SERIES K: PROTECTION AGAINST INTERFERENCE

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

Recommendation ITU-T K.91

ITU Recommendations concerning EMF

Recommendation ITU-T K.52

Guidance on complying with limits for human exposure to electromagnetic fields

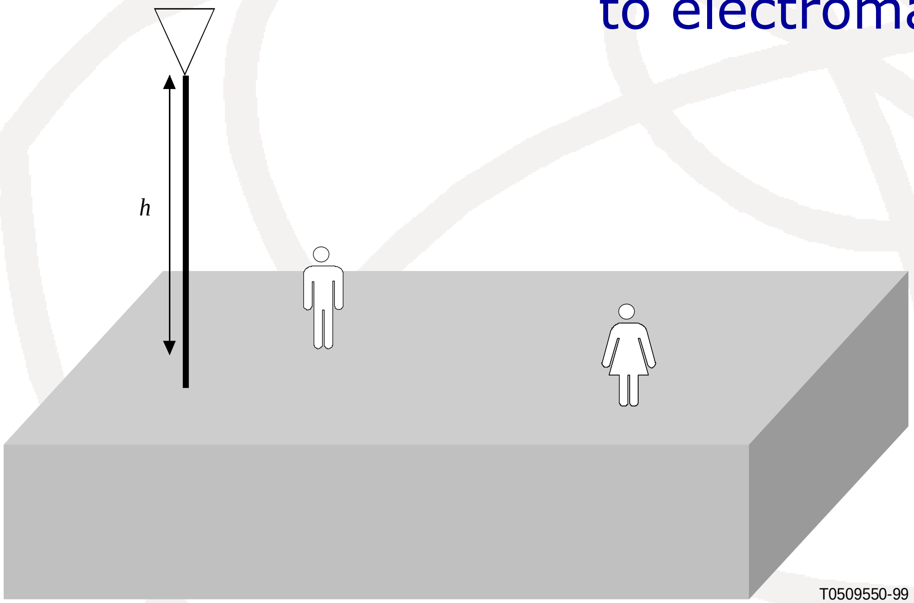


Figure B.1/K.52 – Illustration of the accessibility category 1

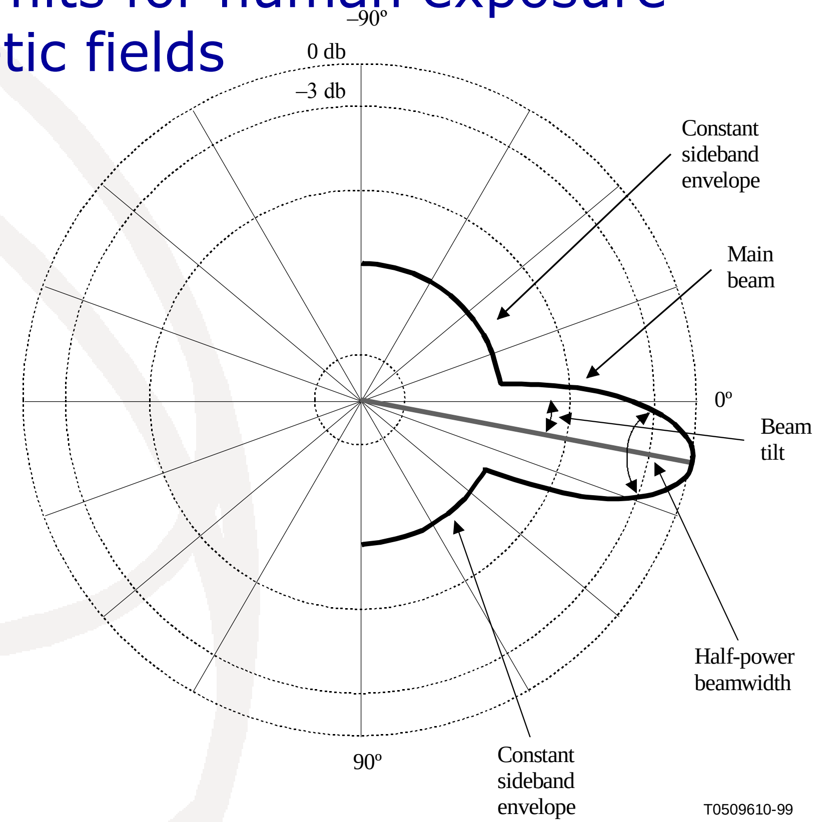
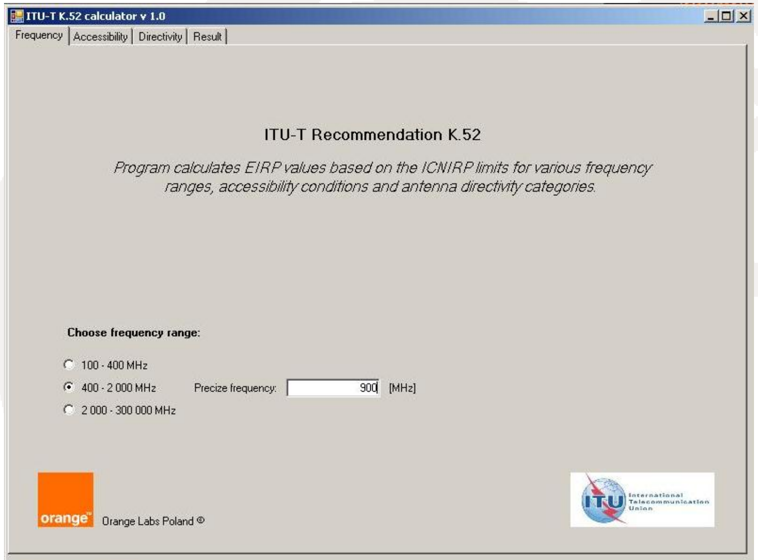


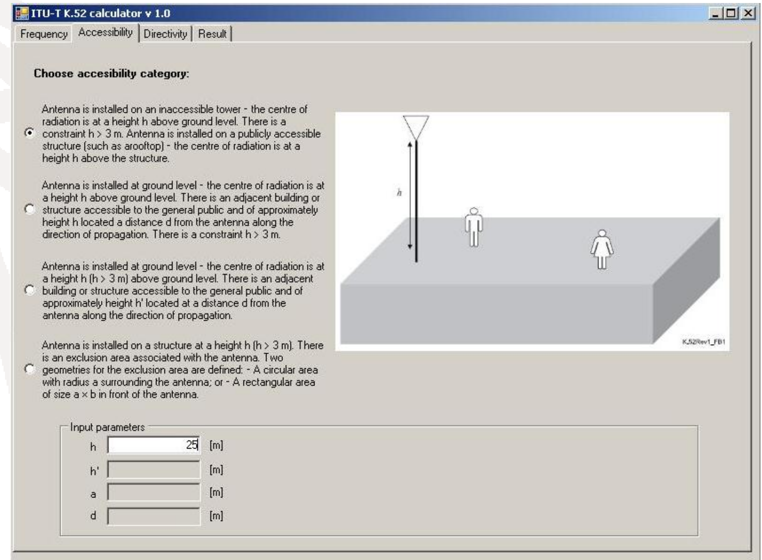
Figure B.7/K.52 – Illustration of terms relating to antenna patterns

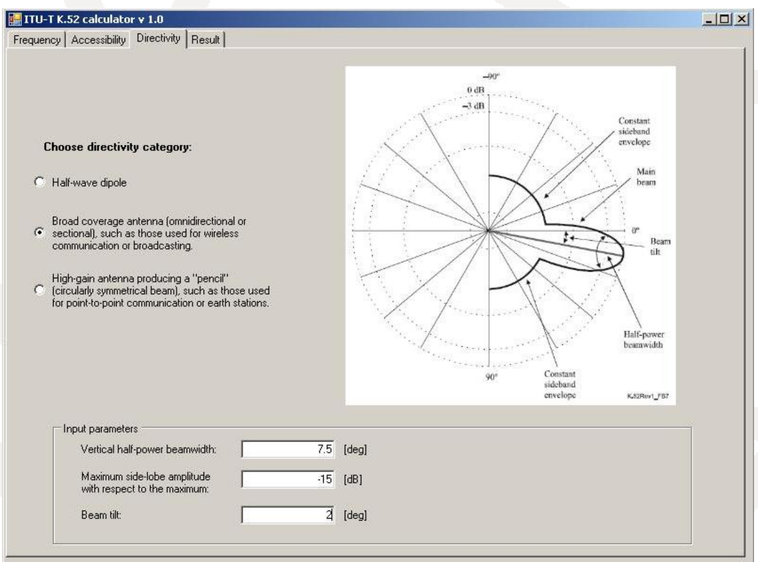
Compliance testing in an easy way:
Accessibility category + directivity category
= maximum EIRP Compliance with ICNIRP limits

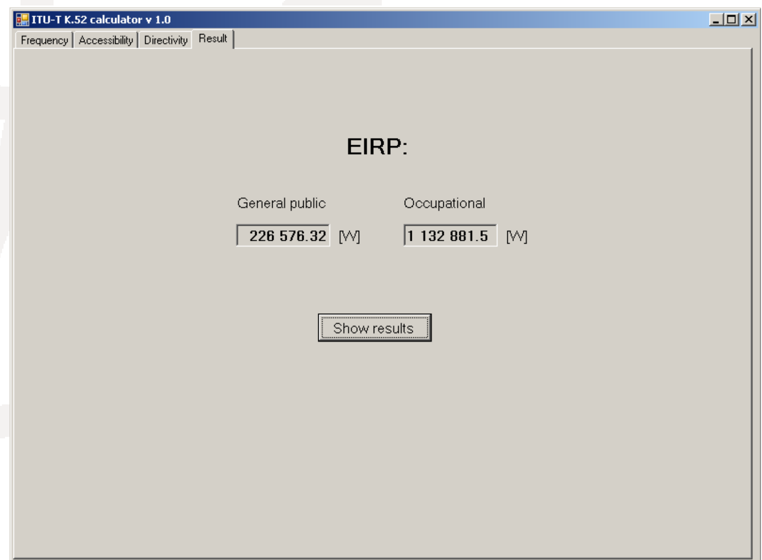
Recommendation ITU-T K.52

Software K.52 Calculator





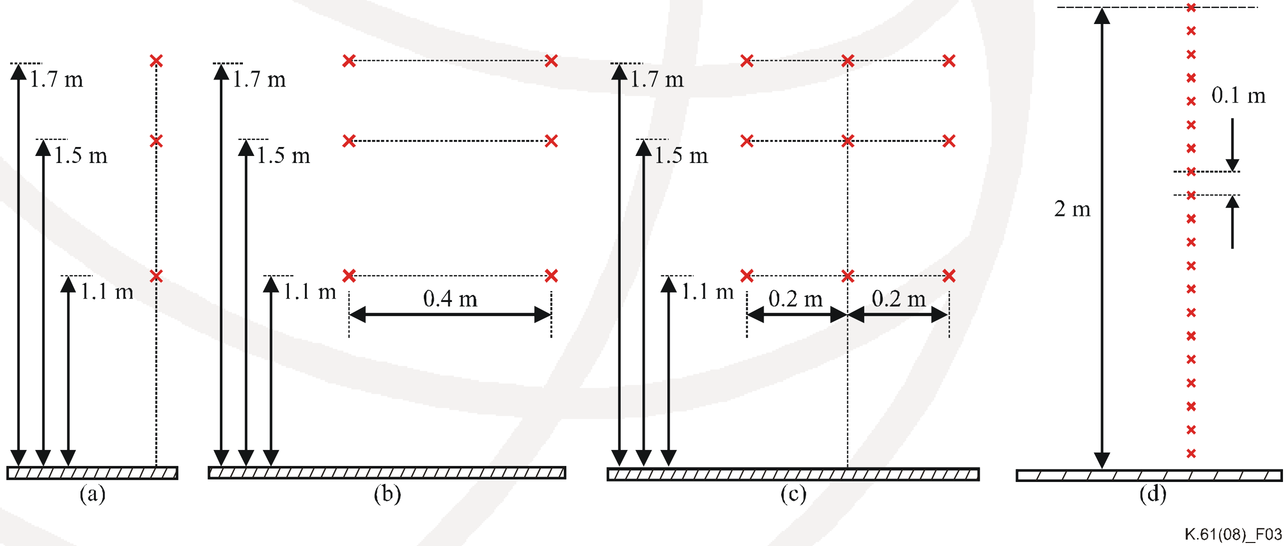




Recommendation ITU-T K.61

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.61

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

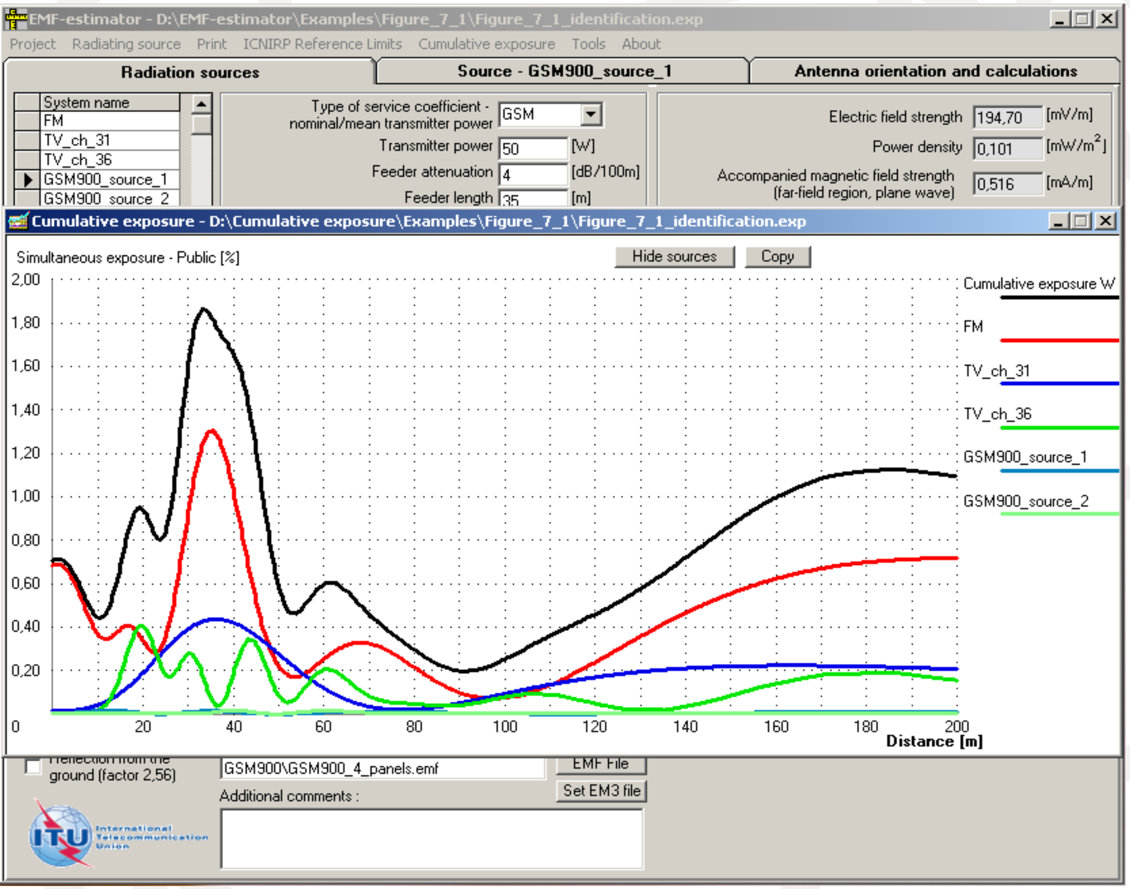
General information concerning measurement and calculation

Table 1/K.61 – Main properties of electromagnetic field in different field regions

	Reactive near-field	**Reactive-radiating near field**	**Radiating near-field**	**Radiating far-field**
Inner boundary	0	λ	3λ	$\mathrm{Max}(3\lambda;2D^2/\lambda)$
Outer boundary	λ	3λ	$\mathrm{Max}(3\lambda;2D^2/\lambda)$	∞
Power density S [W/m^2]	$S \le \lvert E\rvert\lvert H\rvert$	$S \le \lvert E\rvert\lvert H\rvert$	$S = \lvert E\rvert\lvert H\rvert = \frac{\lvert E\rvert^2}{Z_0} = Z_0\lvert H\rvert^2$	$S = \lvert E\rvert\lvert H\rvert = \frac{\lvert E\rvert^2}{Z_0} = Z_0\lvert H\rvert^2$
$E \perp H$	no	no	Locally	yes
Z=E/H	$\neq Z_0$	$\neq Z_0$	$\approx Z_0$	$= Z_0$

ITU-T Rec. K.70, EMF-estimator

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

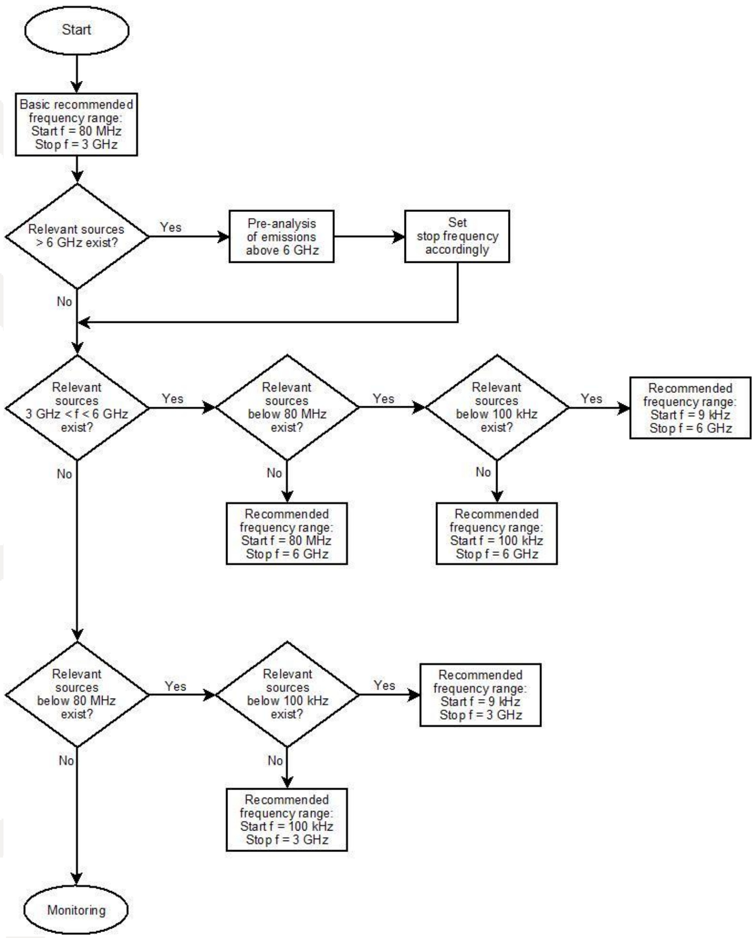


- Modeling of the transmitting antennas
- Importance of the Vertical Radiation Pattern (VRP)
- Identification of the main source of radiation
- Mitigation techniques employed to reduce radiation level – if required
- EMF-estimator – software including the library of examples of transmitting antennas

ITU-T Recommendation K.83

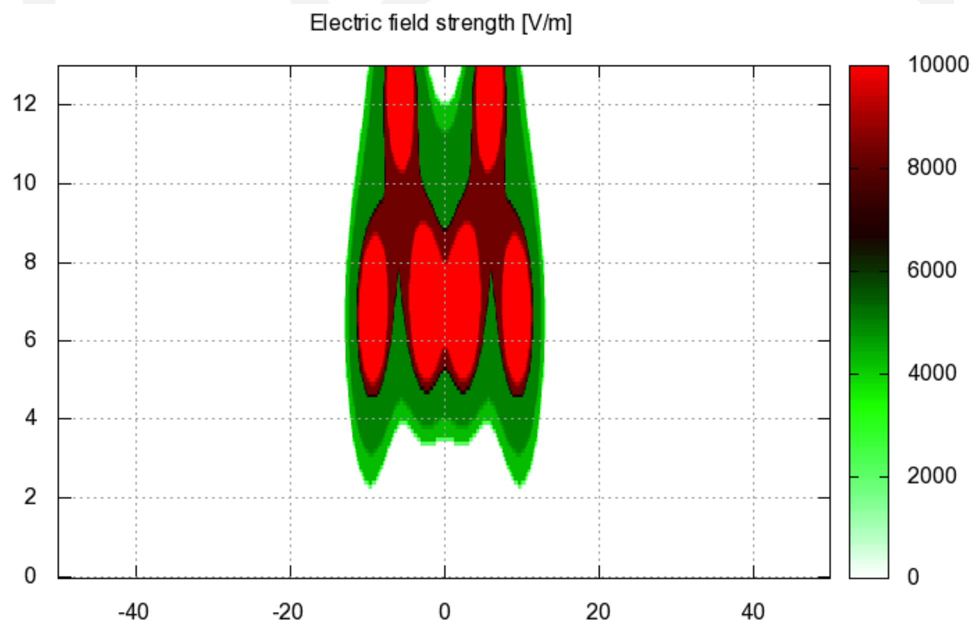
Monitoring of EMF levels

- 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)



ITU-T Recommendation K.90

Evaluation techniques and working procedures for compliance with limits to power-frequency (DC, 50 Hz, and 60 Hz), electromagnetic field exposure of network operator personnel

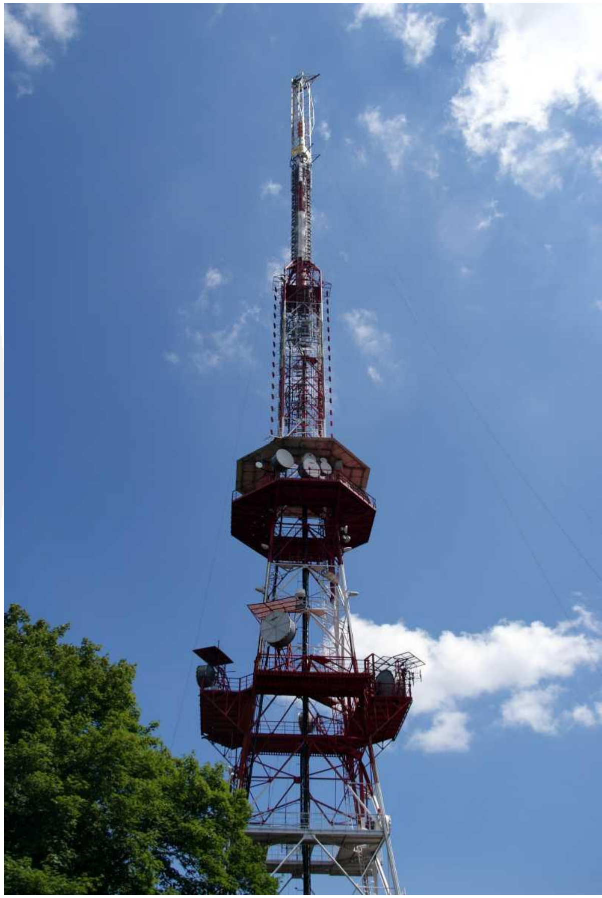


- Guidelines for the compliance with safety limits for the personnel
- EMF in the vicinity of medium-voltage (MV) and high-voltage (HV) power lines at power frequencies (DC, 50 Hz, and 60 Hz)
- Software: EMFACDC

ITU-T Recommendation K.91

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

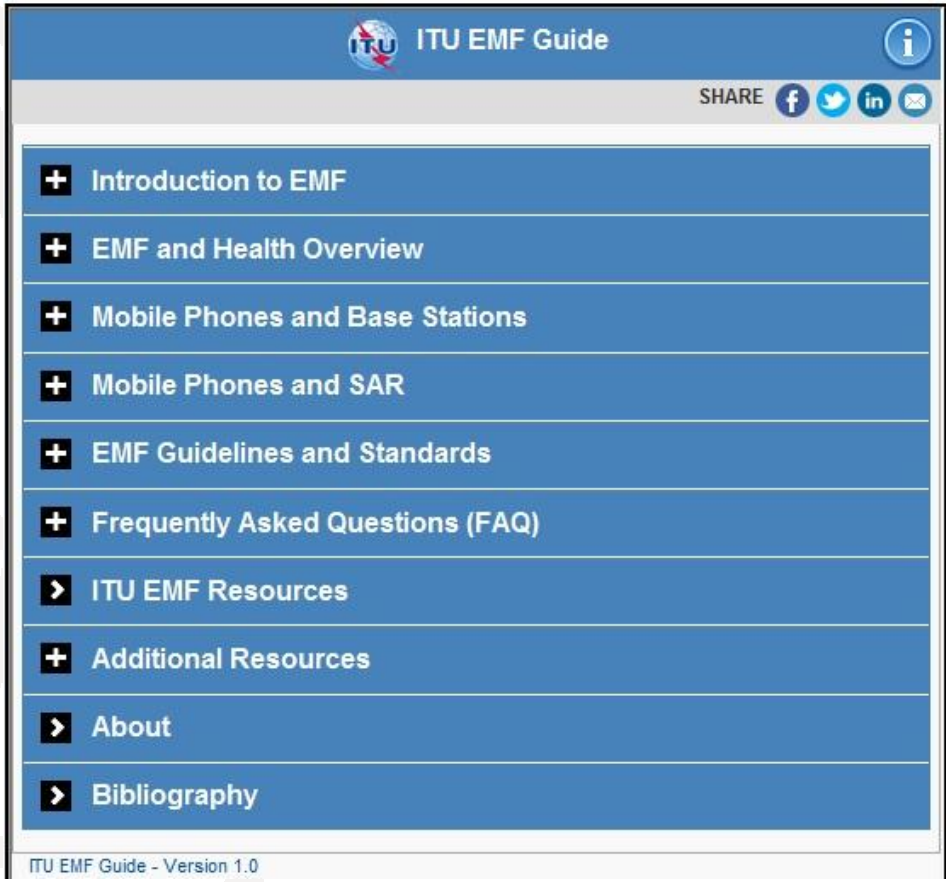
- There are plenty of standards concerning human exposure assessment
- Most of the standards are very general or product oriented
- In real environment there are many sources of radiation operating simultaneously
- Guidance on the assessment of human exposure is required



Supplement 1 to ITU Rec. K91

Guide on Electromagnetic Fields and Health

- Developed to answer the common questions on EMF asked by the public
- Promote EMF information and education resources
- provides information most useful in helping clarify uncertainties concerning EMF



ITU-T Recommendation K.100

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

- This Recommendation is under AAP procedure (it was approved in July 2014)
- The measurement procedure to assess compliance with general public EMF exposure limits
- Simplified assessment procedures to identify those installations which are known to be compliant with EMF exposure limits without measurements

ITU-R Recommendation ITU-R BS.1698

Evaluating fields from terrestrial broadcasting transmitting systems operating in any frequency band for assessing exposure to non ionizing radiation

- Many practical information concerning exposure assessment around AM antennas (LW, MW and SW)
- Guidelines for the exposure assessment in the vicinity of the Fixed Point-to-point antennas

Relationship between carrier, average, peak and maximum instantaneous power, for different classes of emission (worst-case figures)

Class of emission (basic characteristics) (1), (2)	Known power type								
	Carrier power, P_c			Mean power, P_m			Peak power, P_p		
	Factor for the determination of:			Factor for the determination of:			Factor for the determination of:		
	P_c	P_m	P_p	P_c	P_m	P_p	P_c	P_m	P_p
A1A A1B	1	1	1	1	1	1	1	1	1
A*C A*E	1	1.5	4	0.67	1	2.67	0.25	0.38	1
B*B(3) B*E(3) B*W(3)	–	–	–	–	1	1	–	1	1

EMF-estimator

- EMF-estimator is the Annex I to the ITU-T Recommendation K.70
- The last version of the software (04.2011) may be loaded from the:

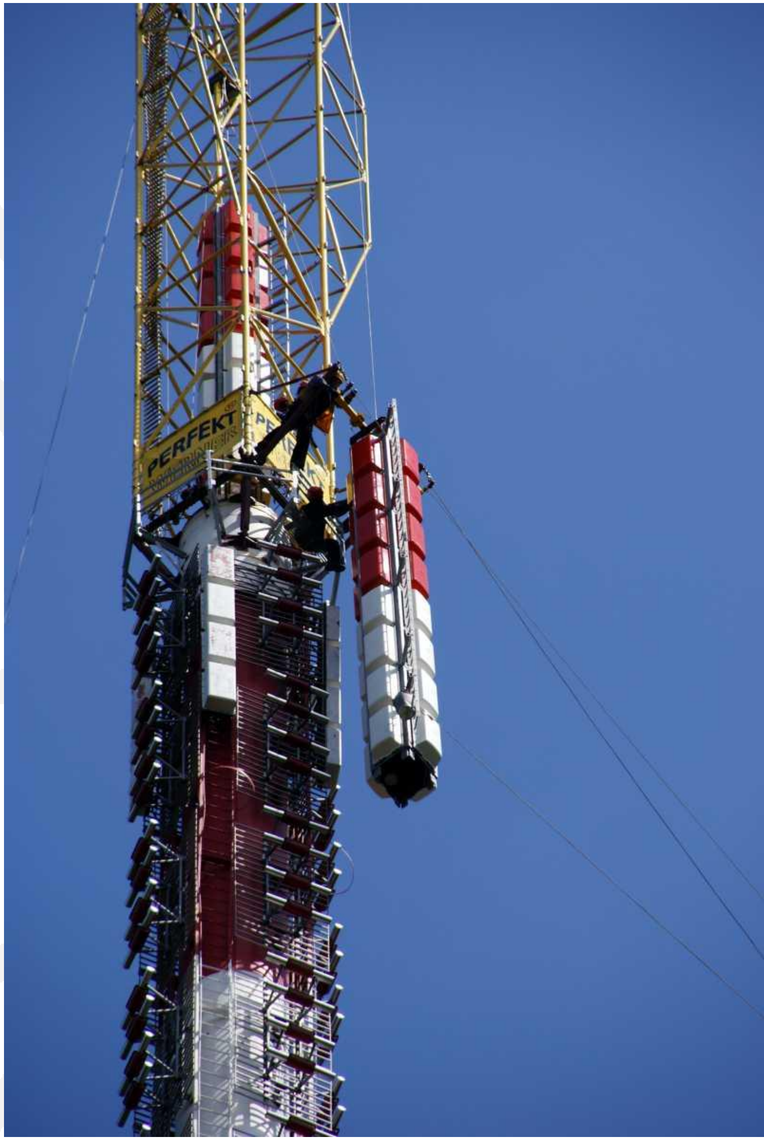
http://www.itu.int/rec/T-REC-K.70-201105-I!Amd2

http://www.itu.int/ITU-T/recommendations/index_sg.aspx?sg=5

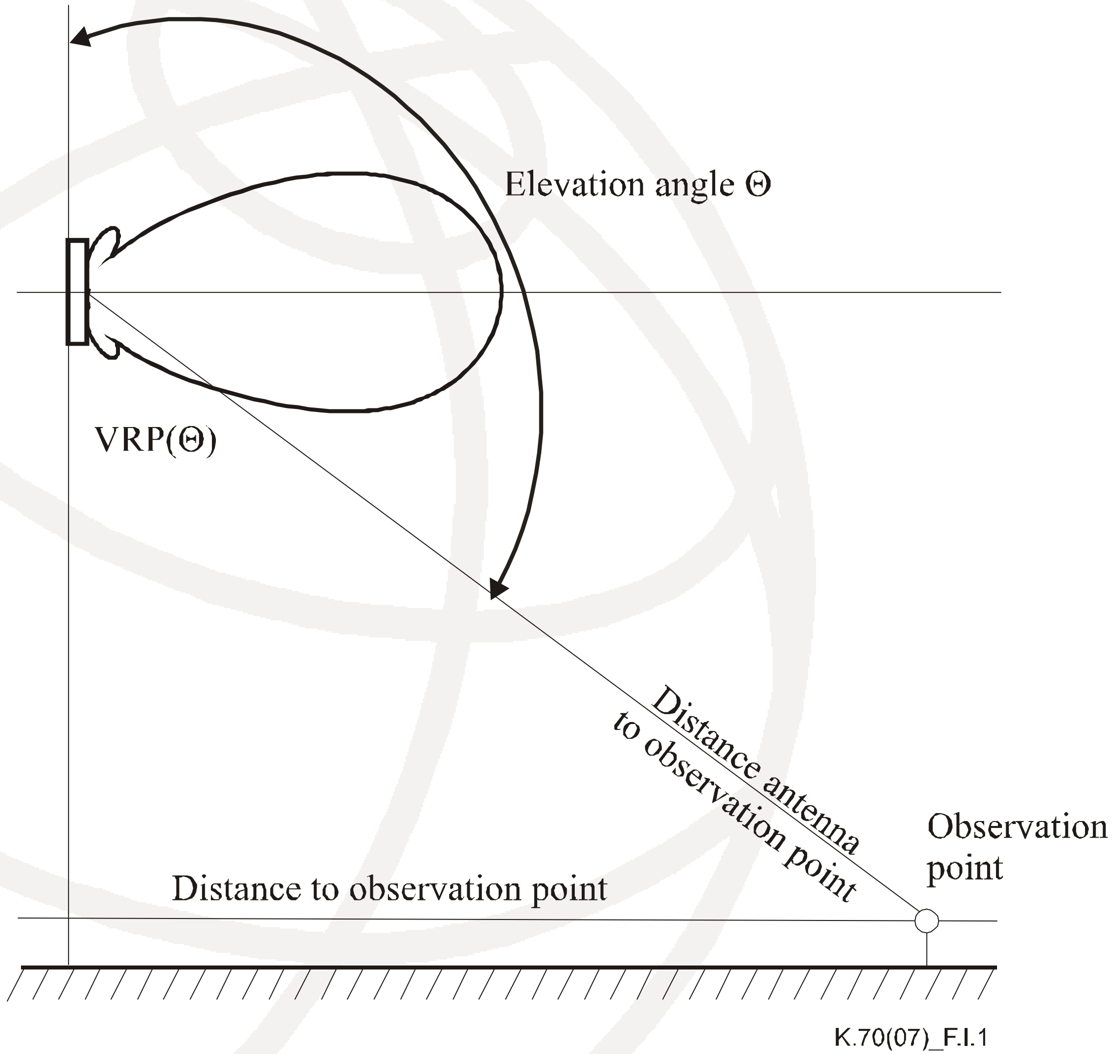
- EMF-estimator is offered by ITU-T since 06.2007
- It is periodically updated / expanded according to the needs (in 2009, 2011 and 2013)

EMF-estimator

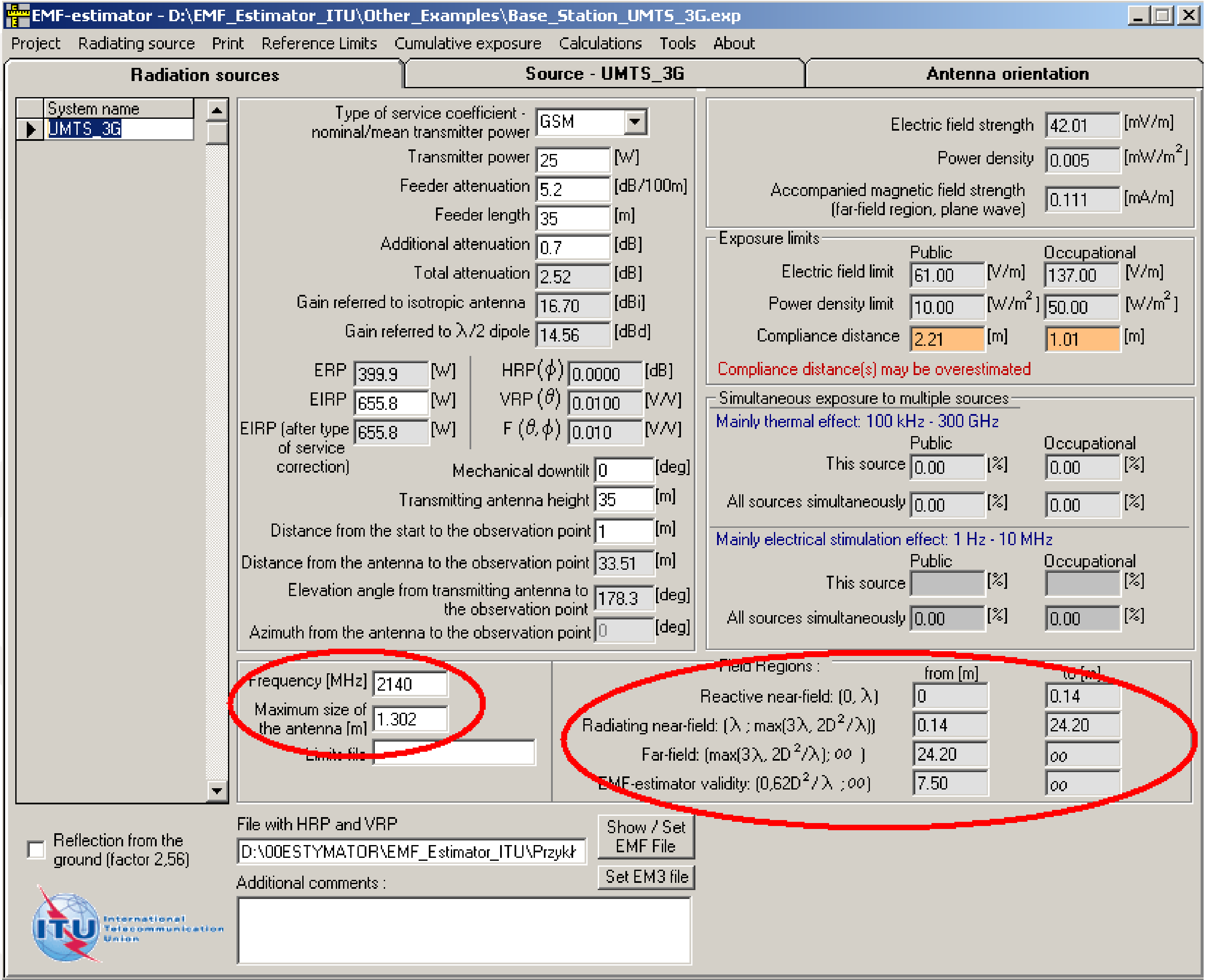
- EMF-estimator applies the point source model so it is fully valid for the far field region
- It can be used in the region of the radiating near-field but with lower accuracy
- It allows for the evaluation of the exposure to the EMF and the comparison with the exposure limits



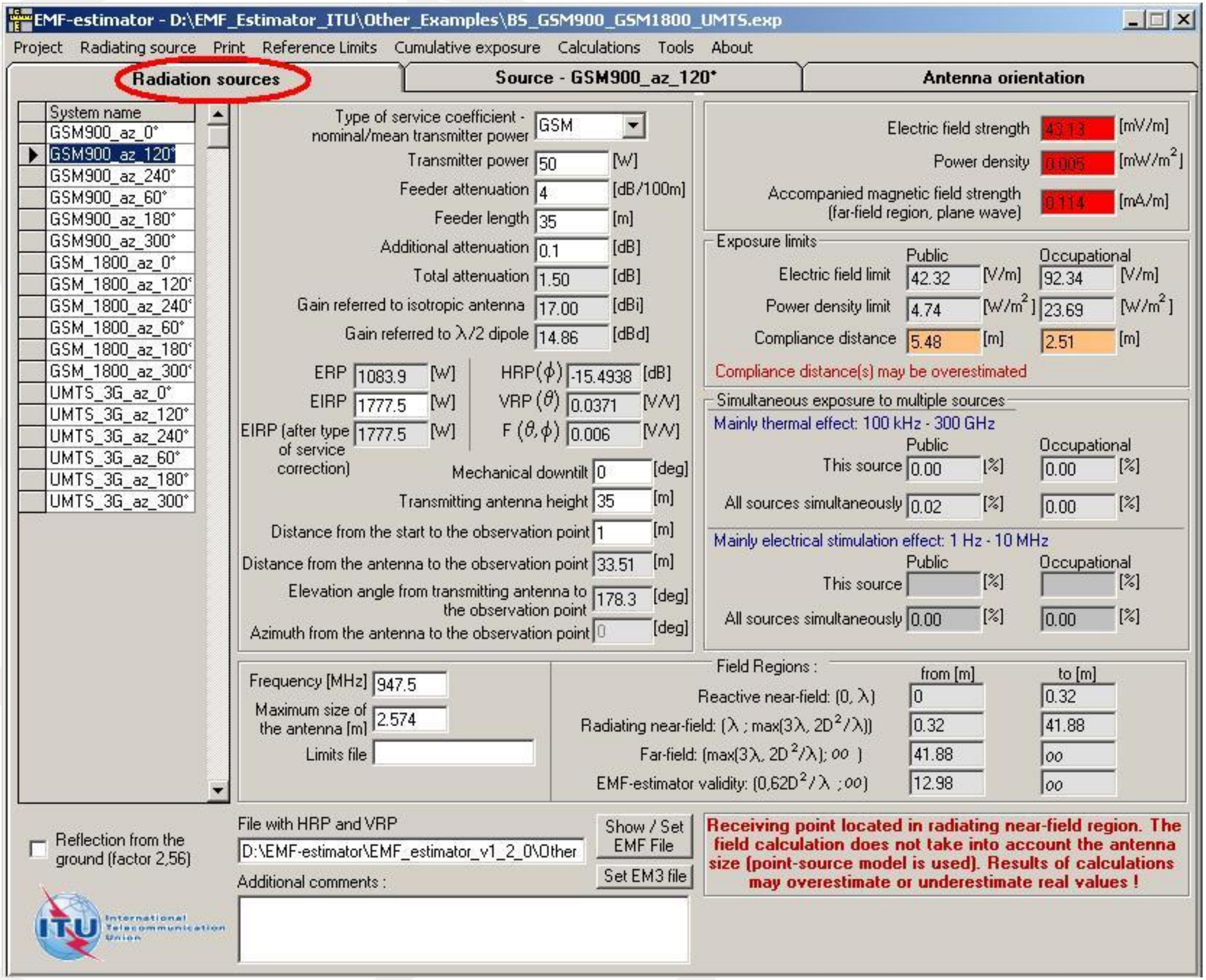
EMF-estimator
Explanation of some terms used in



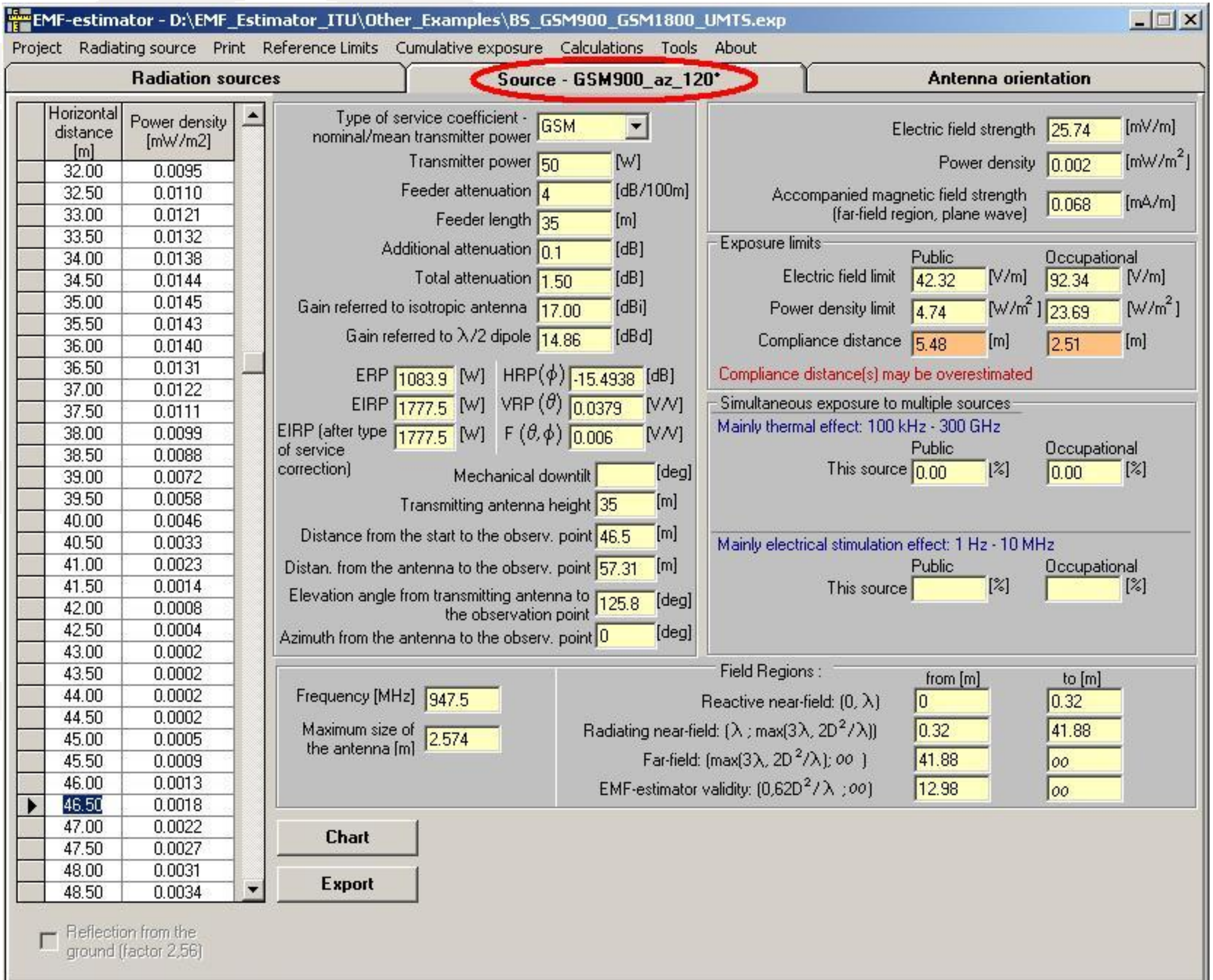
EMF-estimator – validity area



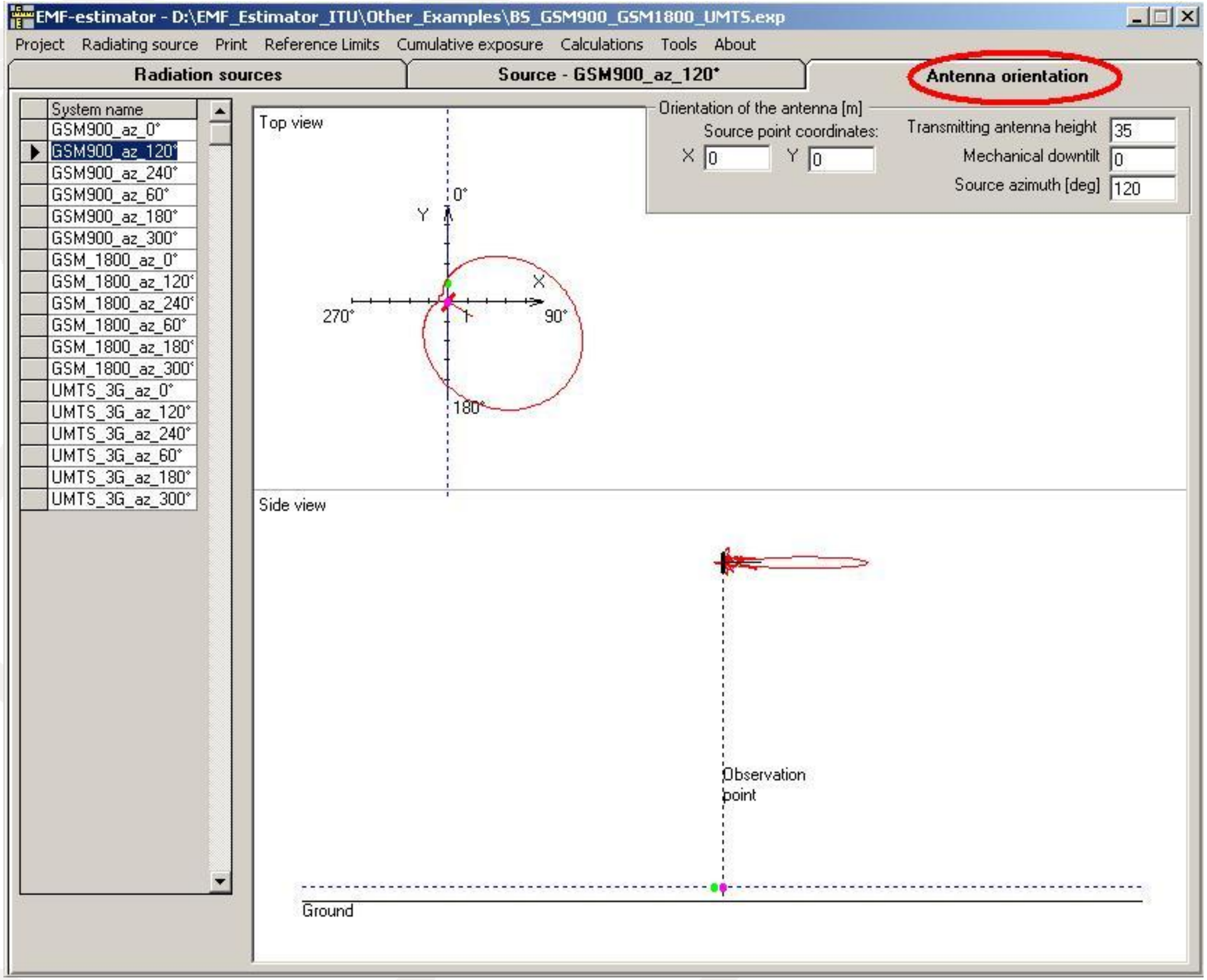
EMF-estimator - Radiation sources



EMF-estimator - Source description

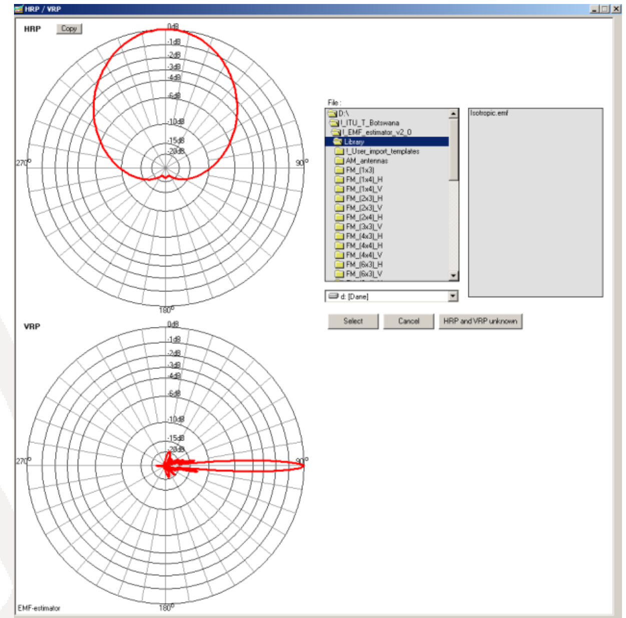


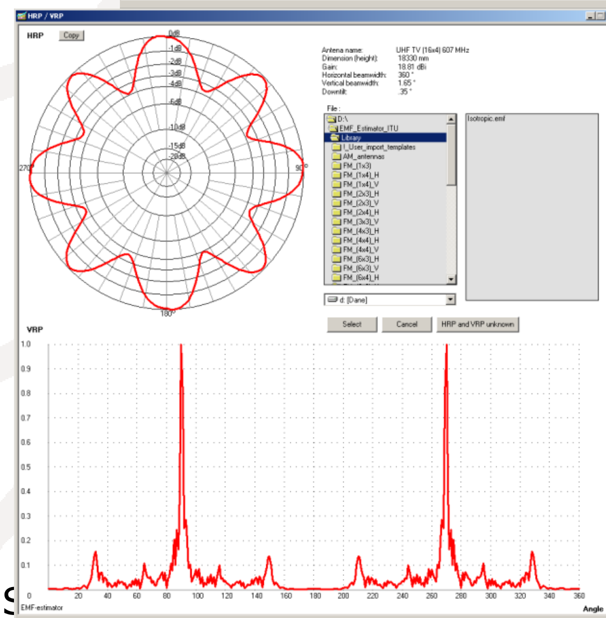
EMF-estimator - Antenna orientation



EMF-estimator Library

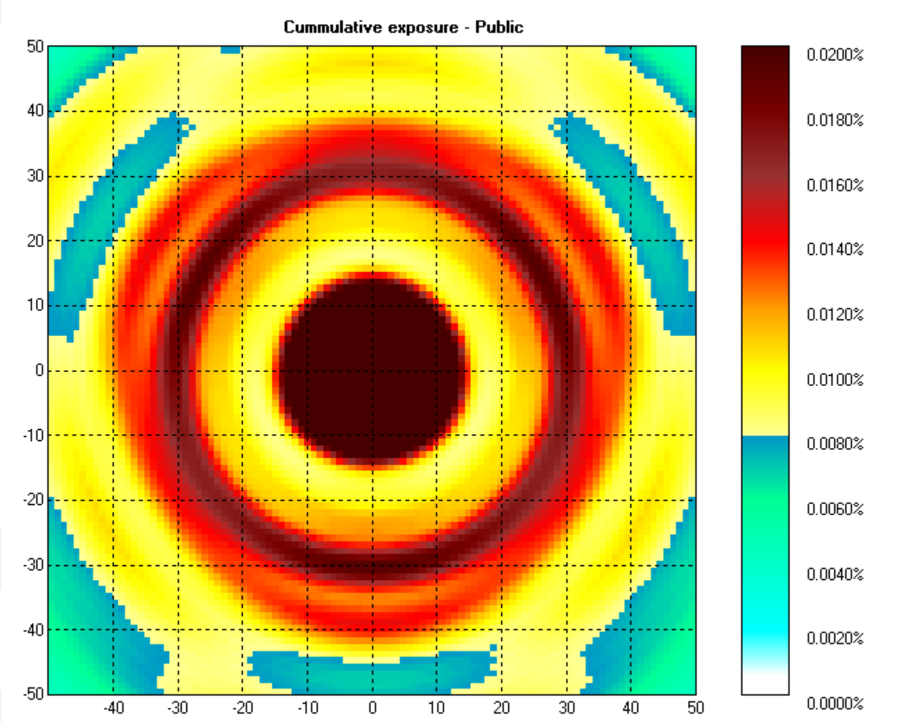
- Current library contains information concerning 124 antennas (56 mobile antennas)
- Examples on the right: Kathrein 739 418 and UHF TV (16x4) EAT402 = 64 panels
- Antenna data depend on frequency and downtilt

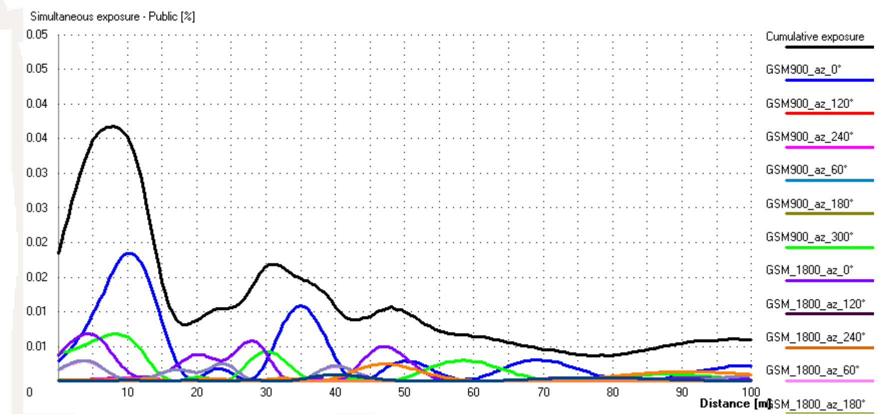


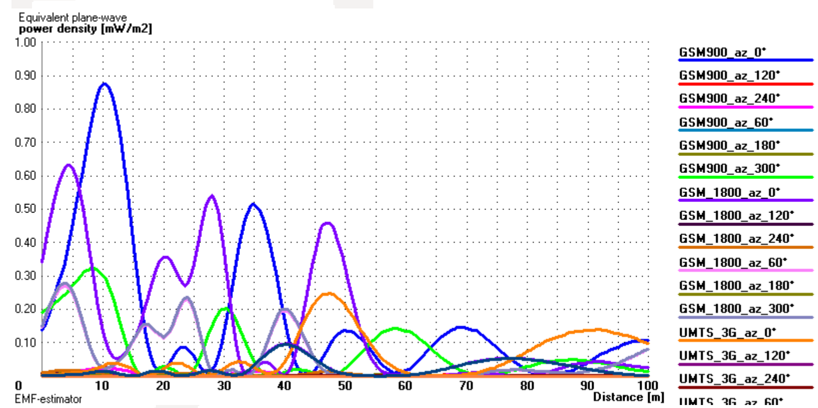


EMF-estimator - examples

- Typical mobile base station (BS)
- 3-sectors, 3-bands, 2 operators
- Line calculation and grid calculation

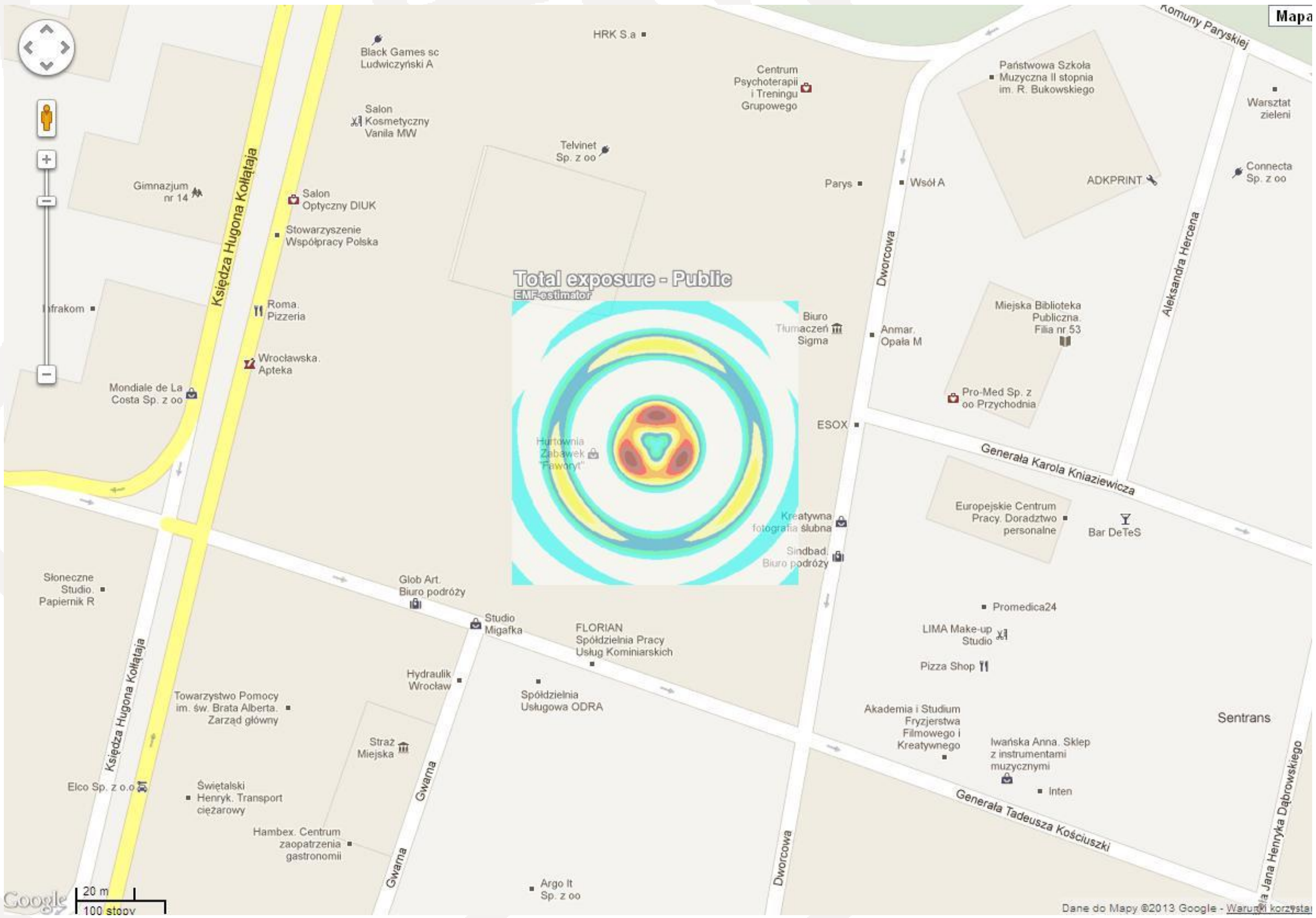






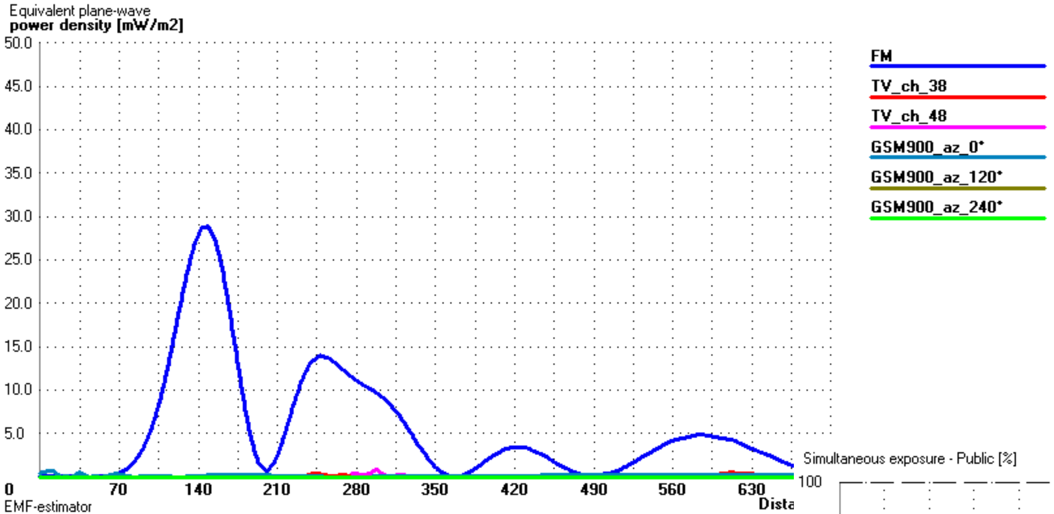
EMF-estimator - examples

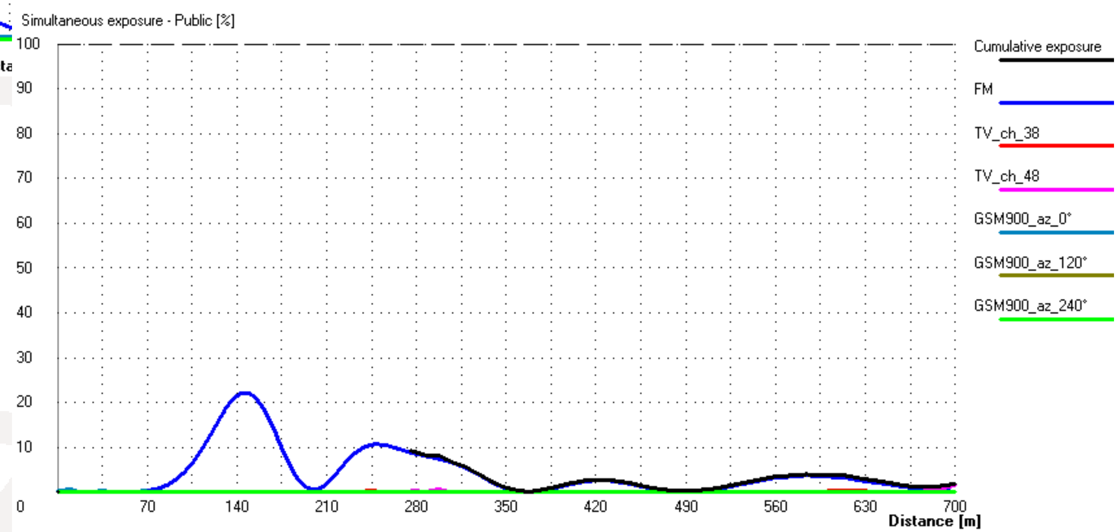
Results on the background from the Google Map



EMF-estimator

Collocation of the mobile BS and broadcasting TS



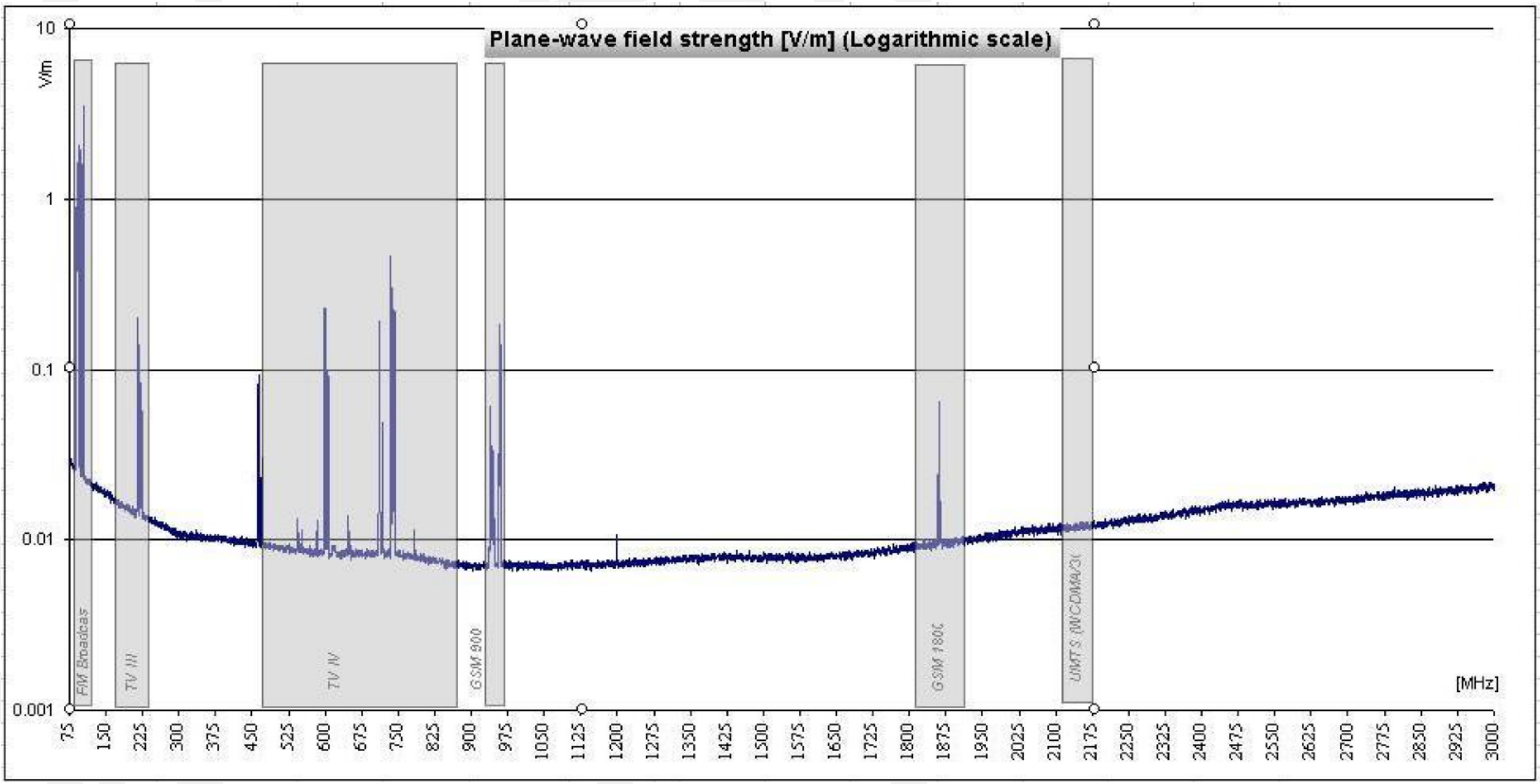


General guidance

- There are many methods to show the compliance
- National regulations are most important
- The simplest method is recommended to be applied first, even if other methods are more accurate
- More sophisticated (and accurate) methods should be used if no compliance is observed by less sophisticated (and accurate method)
- The assessment can be performed either by measurements or by calculations (computer simulations).
  - both have advantages and disadvantages
  - comparable accuracy / uncertainty

Measurement

Example of the result of the frequency selective measurement



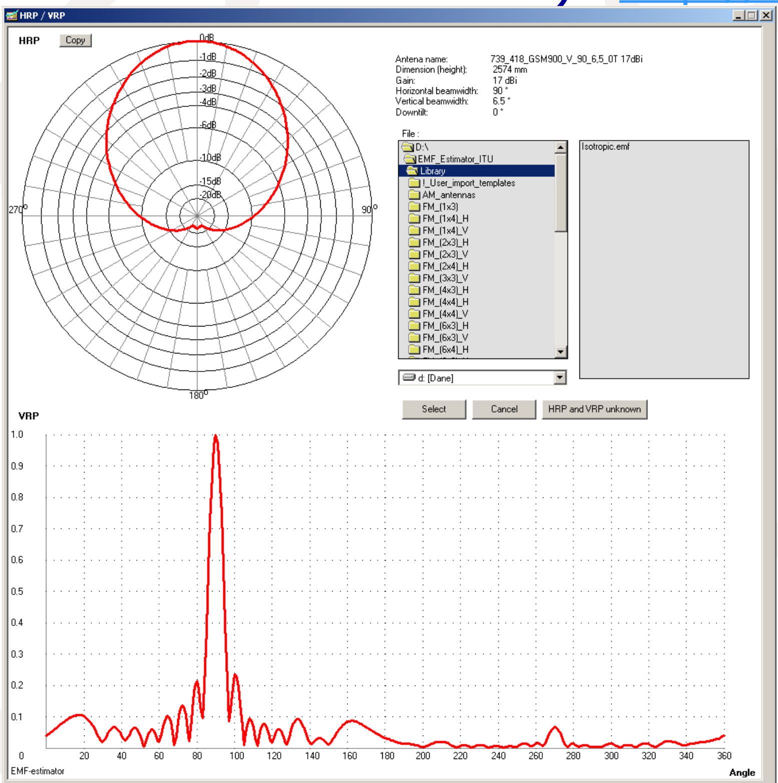
Measurement

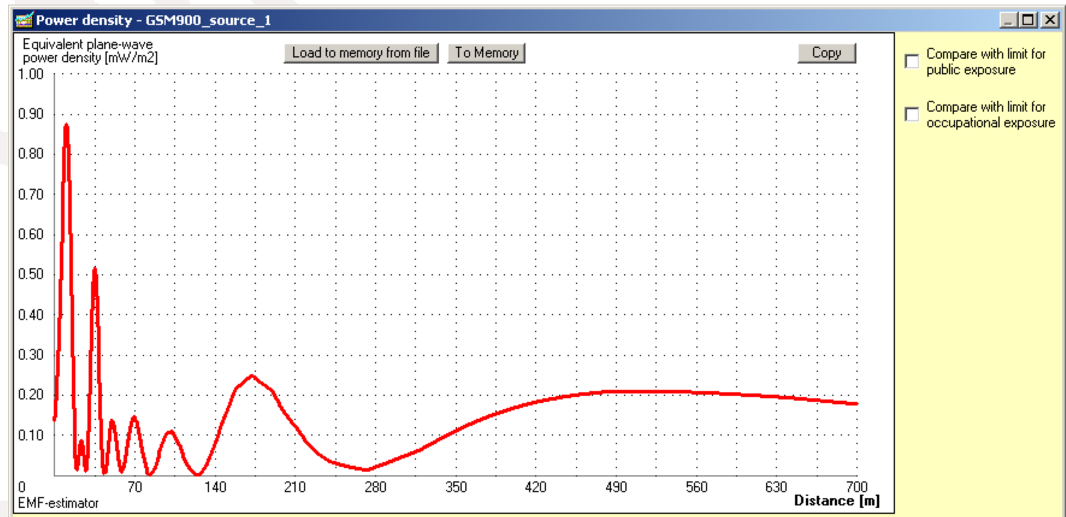
- Example of the results of the frequency selective measurement

Measurement point	Band	Frequency MHz	Reference level V/m	Height m	Measured value V/m	Exposure ratio
4-1	FM broadcast	87,5 – 108	28	1,1	28,5100	1,0367603
				1,5	39,3300	1,9730216
				1,7	42,7800	2,3343474
					Average	1,7813764
	TV III	174 -230	28	1,1	0,4940	0,0003113
				1,5	0,4970	0,0003151
				1,7	0,4775	0,0002908
					Average	0,0003057
	TV IV/V	470 – 862	30	1,1	0,9781	0,0010630
				1,5	0,9163	0,0009329
				1,7	0,9970	0,0011045
					Average	0,0010334
	GSM 900	925 – 960	42	1,1	0,3883	0,0000855
				1,5	0,4025	0,0000918
				1,7	0,4409	0,0001102
					Average	0,0000958
	GSM 1800	1 805 – 1 910	58	1,1	0,4572	0,0000621
				1,5	0,4349	0,0000562
				1,7	0,5181	0,0000798
					Average	0,0000661
	UMTS (WCDMA/3G)	2 110 – 2 170	61	1,1	0,4337	0,0000505
				1,5	0,4328	0,0000503
				1,7	0,4343	0,0000507
					Average	0,0000505
					Sum	1,7829280

Calculations

Far field model (point source model) – EMF-estimator (Appendix to ITU-T Rec. K.70): http://www.itu.int/rec/T-REC-K.70-200905-I!Amd1



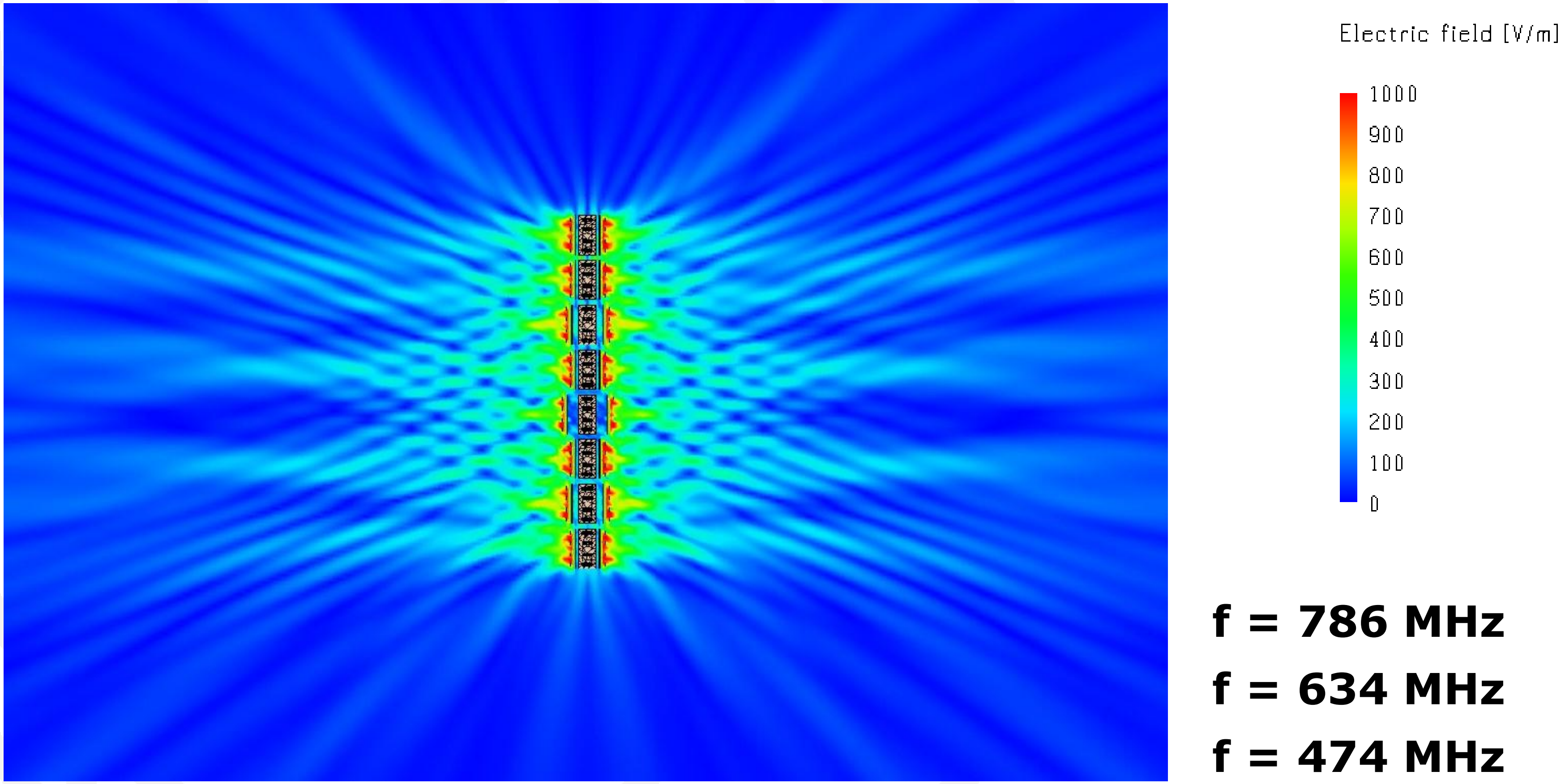


$$E = \frac{\sqrt{30PG_i}}{r} f(\theta,\varphi)$$

- *E [V/m]* - rms electric field strength
- *r [m]* - distance between point of investigation and center of the antenna
- *P [W]* - input average power (W)
- $G_{i\ [dBi]}$ - maximum gain of the transmitting antenna, relative to an isotropic radiator
- $f(\theta,\phi)$ - relative antenna amplitude radiation pattern, ϕ , θ - azimuth and elevation angle

Calculations – Method of Moments (MoM)

- **TV UHF transmitting antenna**
- **Electric field strength distribution, Near-field region, (30 x 20m)**
- **MoM, ~ 27 000 unknowns, computational time ~12 hours**



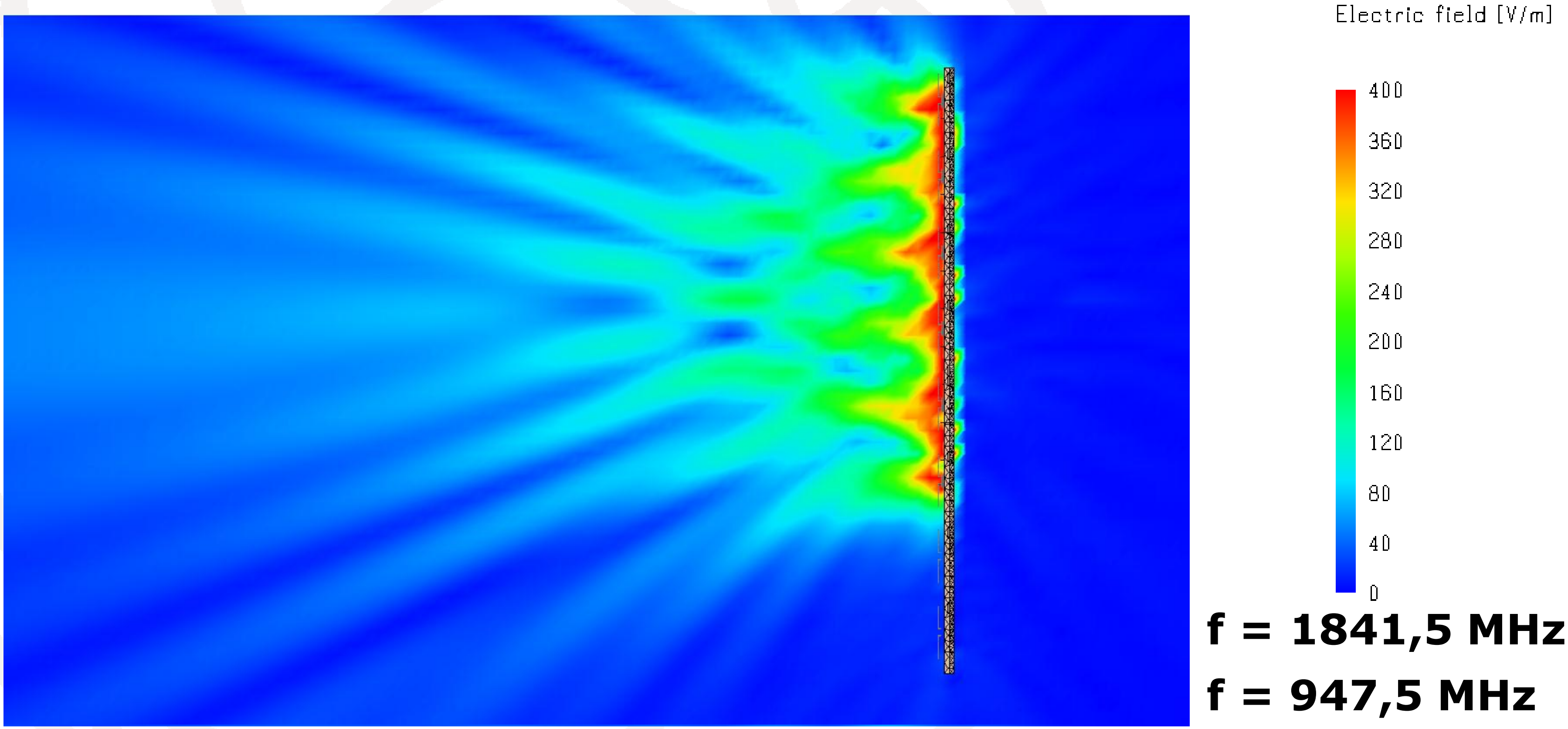
f = 786 MHz

f = 634 MHz

f = 474 MHz

Calculations – Method of Moments (MoM)

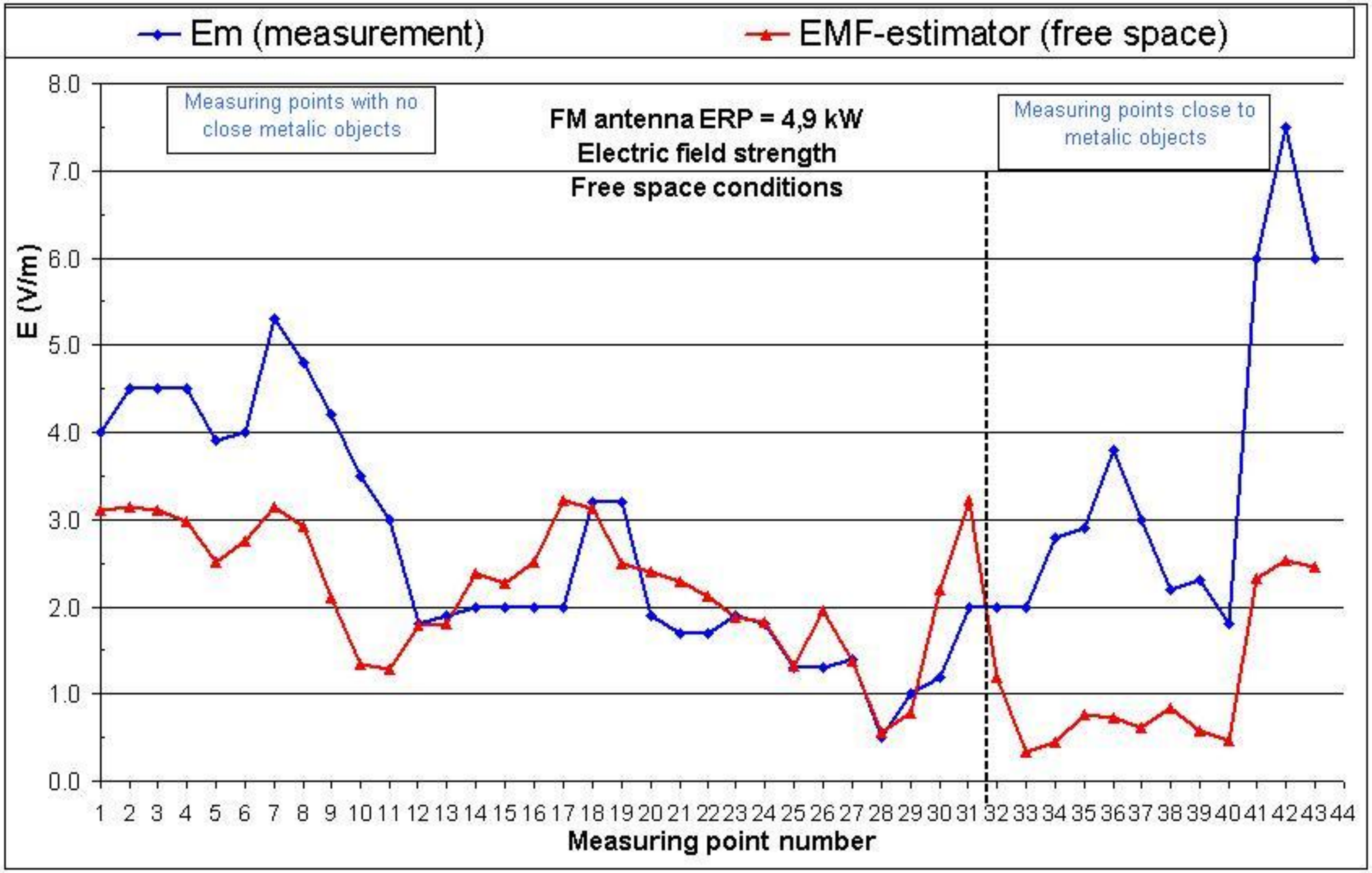
- **GSM 900/1800, Kathrein, polarization X (+45°/-45°)**
- **Electric field strength distribution - Near-field region, (5 x 3m)**
- **MoM, ~2 600 unknowns, computational time ~2 minutes**



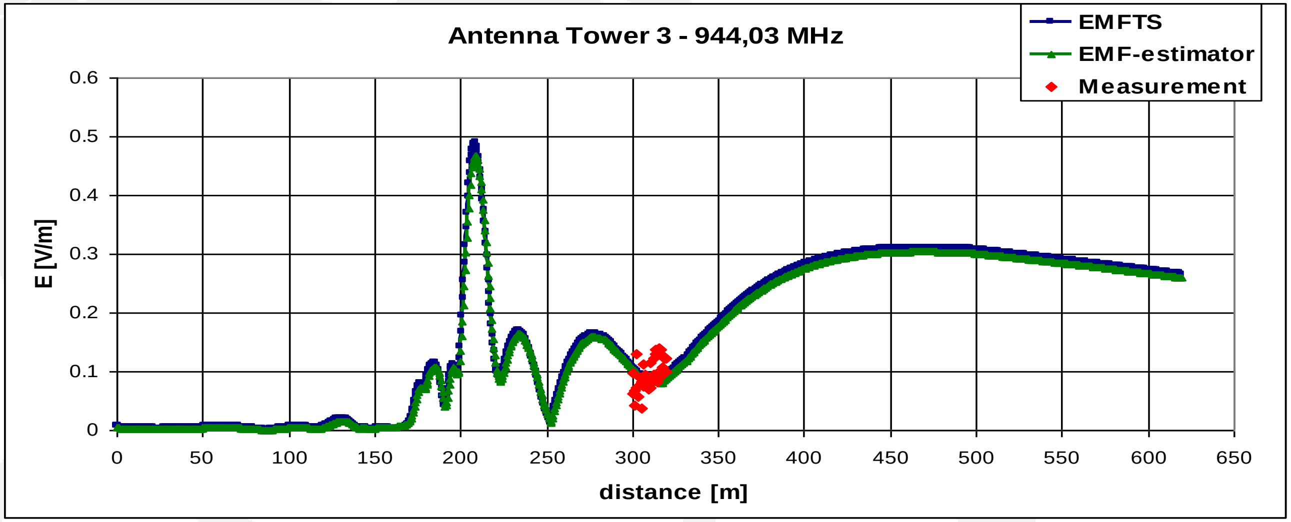
f = 1841,5 MHz

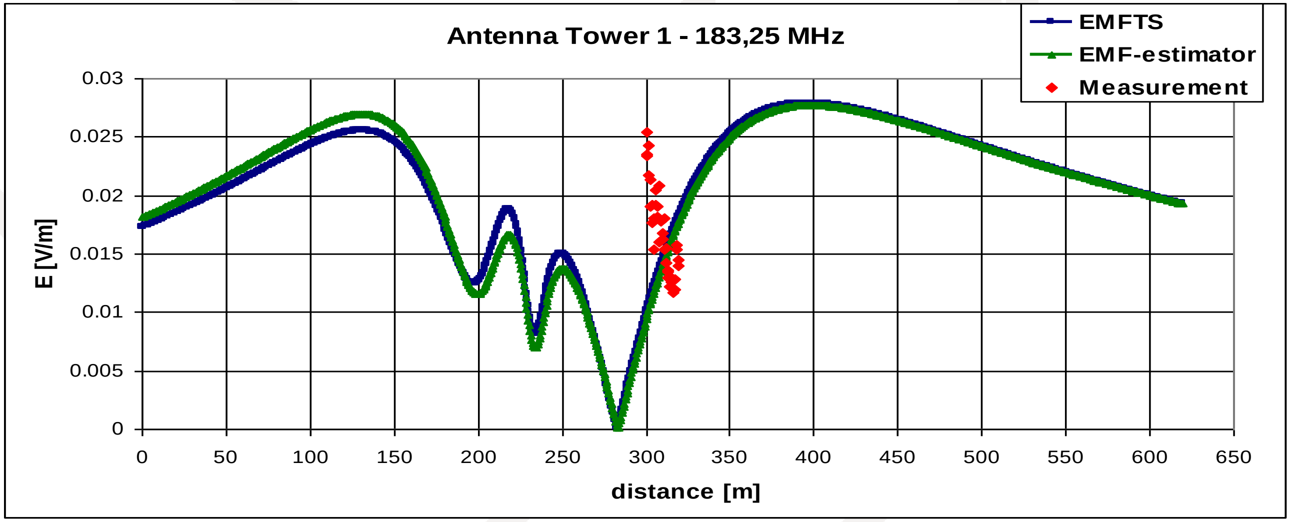
f = 947,5 MHz

Comparison measurement vs. calculation



Comparison measurement vs. calculation





Measurement vs. Calculations

- Human exposure assessment may be done by measurement or calculations
- Both methods have advantages and disadvantages
- Both methods have similar level of uncertainty and accuracy depending on the method and equipment or software used

Multi sources environment

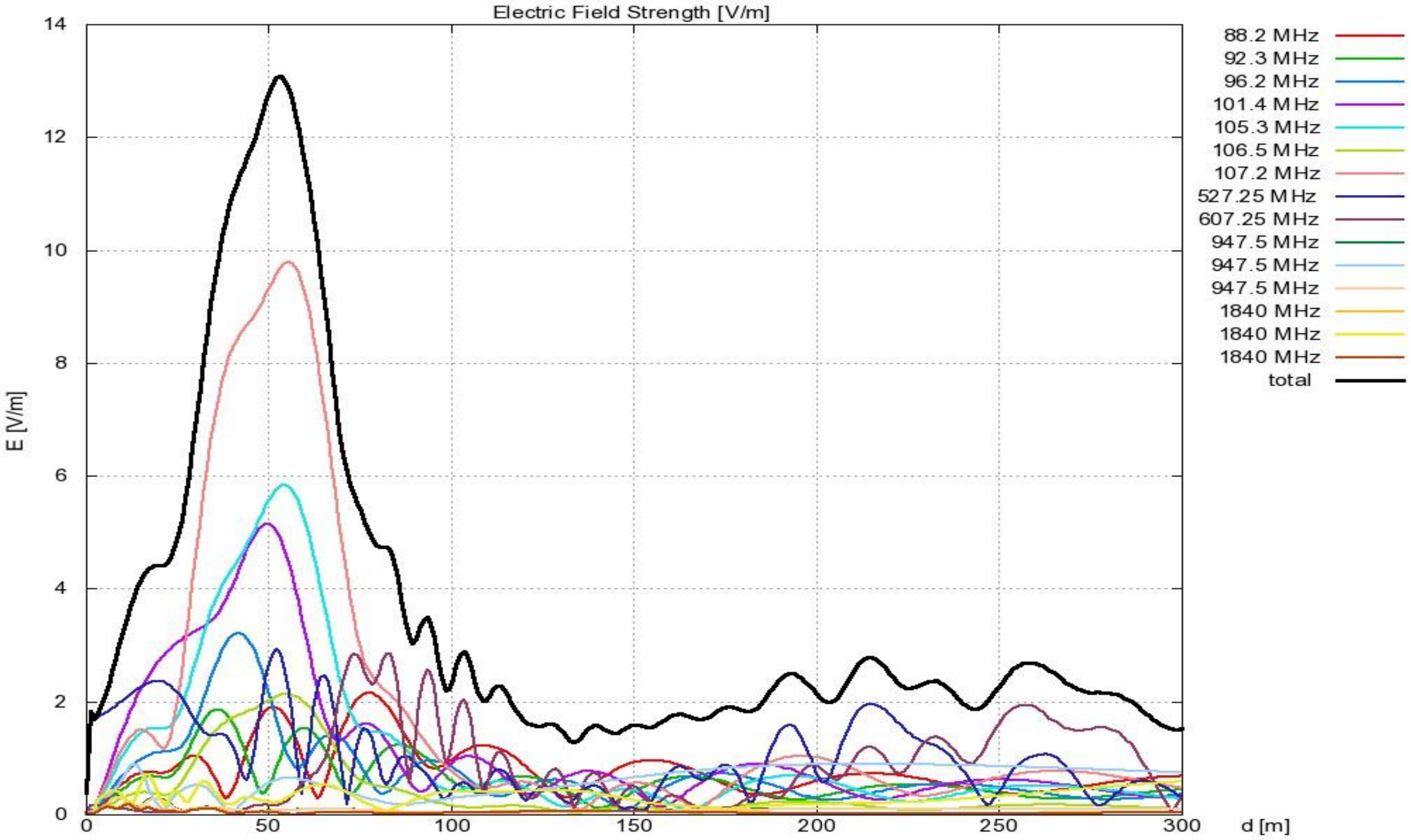
- Many base stations collocated at the same or neighboring towers
- Other radiating systems: broadcasting, radiocommunication, point-to-point fixed systems

Multi sources environment

- Contribution to the cumulative exposure is ERP dependent
- Typical ERP (K.70):
  - Cellular BS: 100-800W /per channel
  - FM: 50W – 120 kW
  - VHF TV: 0,1 – 200 kW
  - UHF TV: 0,1 – 1000 kW
  - UHF DVB-T: 0,1 – 100 kW
  - AM/DRM: 0,1 – 4000 kW
  - WLAN: 0,01 – 1 W
  - Radiocomm.: 10 W – 1 kW

Simultaneous exposure to multiple sources

Total exposure - broadcasting and mobile emissions



Conclusions

- Compliance with EMF exposure limits is a substantial factor in SSC development
- Good communication with public is a very important task
- Efficient deployment of wireless infrastructure reduces the RF EMF from networks and devices
- ITU guidance may be helpful in smooth and safe implementation of wireless systems

Thank you

Questions, Comments?