RF EMF – Exposure Assessment

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Introduction – ITU-T areas of activity in RF EMF

- Best practice and mitigation techniques
- Guidance on RF EMF exposure assessment
- Informative documents (supplements, guides) for professionals and for communication with general public
- Support to developing countries – Resolution 72 (WTSA-16, Hammamet)
- Tools for exposure assessment and compliance considerations
<table>
<thead>
<tr>
<th>IARC Classification</th>
<th>Examples of Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcinogenic to humans (107)</td>
<td>Asbestos</td>
</tr>
<tr>
<td>(usually based on strong evidence of</td>
<td>Alcoholic beverages</td>
</tr>
<tr>
<td>carcinogenicity in humans)</td>
<td>Benzene</td>
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<tr>
<td></td>
<td>Mustard gas</td>
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<tr>
<td></td>
<td>Radon gas</td>
</tr>
<tr>
<td></td>
<td>Solar radiation</td>
</tr>
<tr>
<td></td>
<td>Tobacco (smoked and smokeless)</td>
</tr>
<tr>
<td></td>
<td>X-rays and Gamma</td>
</tr>
<tr>
<td>Probably carcinogenic to humans (59)</td>
<td>Creosotes</td>
</tr>
<tr>
<td>(usually based on strong evidence of</td>
<td>Diesel engine exhaust</td>
</tr>
<tr>
<td>carcinogenicity in animals)</td>
<td>Formaldehyde</td>
</tr>
<tr>
<td></td>
<td>Polychlorinated biphenyls (PCBs)</td>
</tr>
<tr>
<td>Possibly carcinogenic to humans (267)</td>
<td>RF fields</td>
</tr>
<tr>
<td>(usually based on evidence in humans</td>
<td>Coffee</td>
</tr>
<tr>
<td>which is considered credible, but for which other</td>
<td>Gasoline engine exhaust</td>
</tr>
<tr>
<td>explanations could not be ruled out)</td>
<td>Pickled vegetables</td>
</tr>
<tr>
<td></td>
<td>ELF magnetic fields</td>
</tr>
<tr>
<td></td>
<td>Styrene</td>
</tr>
</tbody>
</table>

Source: WHO presentation during ITU-D Q23/1 meeting, April 2012
ITU-T Recommendation K.91

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

- ITU-T „mother” Recommendation on RF EMF
- There are plenty of standards concerning human exposure assessment
- This Recommendation give guidance on the use of other Recommendations or standards
Supplement 1 to ITU Rec. K91

Guide on Electromagnetic Fields and Health

- Developed to answer the common questions on EMF asked by the public
- Promotes RF EMF information and education resources
- Provides the most useful information in helping to clarify uncertainties concerning EMF
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.113

Generation of radio frequency electromagnetic field level maps

- Provides guidance on how to make radio-frequency electromagnetic field (RF-EMF) maps
- Provides guidance for an appropriate public disclosure of the results, in a simple and understandable way
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

- The 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

<table>
<thead>
<tr>
<th>SIMPLIFIED INSTALLATION RULES</th>
</tr>
</thead>
<tbody>
<tr>
<td>From IEC 62232 Ed.2.0</td>
</tr>
<tr>
<td>Installation must be done according to instructions from the manufacturer or entity putting into service</td>
</tr>
</tbody>
</table>

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

Check pre-existing RF sources:

- E0: N/A
- E2: N/A
- E10: N/A
- E100: 5\( D_m \) in main lobe direction 
- E+: \( D_m \) in other directions
General guidance for exposure assessment

- There are many methods to show the compliance.
- National regulations are the 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) methods.
- The assessment can be performed either by measurements or by calculations (computer simulations).
  - both have advantages and disadvantages
  - comparable accuracy / uncertainty
**Measurement**

- Field measurement
  - broadband – cheap but leading to overestimation
  - frequency selective – more expensive and time consuming, requires post processing
- Usually the broadband measurement is performed, frequency selective measurement is the reference – for special cases
Measurement

Example of the result of the frequency selective measurement
Measurement

Example of the signal time variation measurement results
Measurement advantages

- It takes into account all radiating sources with real parameters
- It takes into account the real environment (reflections, antenna supporting hardware, obstacles)
- Takes into account simultaneous exposure in the real way (phase differences of different waves are taken into account)
Measurement advantages

- It can be done with little knowledge about radiating sources (only an initial measurement of the occupied spectrum is required)
- 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

- Isotropic source with maximum EIRP
- Very easy but giving a big overestimation
- Valid for all cases

\[ E = \frac{\sqrt{30EIRP}}{r} \]

- \( E \) [V/m] - rms electric field strength
- \( r \) [m] - distance between point of investigation and center of the antenna
- \( EIRP \) [W] - Equivalent Isotropically Radiated Power
Calculations


\[ E = \sqrt{\frac{30PG_i}{r^2}} f(\theta, \varphi) \]

- \( E \) [V/m] - rms electric field strength
- \( r \) [m] - distance between the point of investigation and center of the antenna
- \( P \) [W] - input average power (W)
- \( G_i \) [dB] - maximum gain of the transmitting antenna, relative to an isotropic radiator
- \( f(\theta, \varphi) \) - relative antenna amplitude radiation pattern, \( \phi \), \( \theta \) - azimuth and elevation angle
Calculations – synthetic model

For antenna systems constructed of sets of identical radiating elements (panels in broadcasting or “patches” in mobile communication)

Requires detailed information concerning the feeding arrangement of the antenna system

\[ E = \sum_{n} \alpha_n \sqrt{30P_n G_n} \frac{e^{j(\gamma_n + \frac{2\pi r_n}{\lambda})}}{r_n} \]

- \( E \) [V/m] - rms electric field strength
- \( r_n \) [m] - distance between point of investigation and center of the n-th panel
- \( P_n \) [W] - input average power to n-th panel
- \( \gamma_n \) [rad] - relative phase of applied voltage at n-th panel
- \( G_n \) [dBi] - n-th panel gain relative to an isotropic antenna towards the point of investigation
- \( \alpha_n \) - weighting coefficient
Calculation – synthetic model

VHF TV (ERP=125kW, h=90m), FM (total ERP=423kW, h=55m), GSM900 (ERP=1080W, h=30m), GSM1800 (ERP=1120W h=30m)
Cumulative exposure [V/m]

Vertical cross-section, azimuth 333°

Horizontal cross-sections:
- h=90 m
- h=55 m
- h=30 m
Calculations – Full wave methods
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

Electric field [V/m]

- f = 786 MHz
- f = 634 MHz
- f = 474 MHz
Calculations – Full wave methods
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

Electric field [V/m]

f = 1841.5 MHz
f = 947.5 MHz
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
Calculations - advantages

- It allows to consider the planned radiating sources (not in operation yet)
- It 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
- Possibility of the calculations for the area with no access (safety reason, no right to access etc.)
Calculations - advantages

- Possibility to obtain data on the dense grid
- Visualization of the results can be easily prepared for the whole considered area (like horizontal or vertical cross-sections)
- Easy consideration of the mitigation techniques

Near-field region (2.5 x 1m), ~36 000 unknowns, computational time ~34.5 hours
Comparison
measurement vs. calculation

FM antenna ERP = 4.9 kW
Electric field strength
Free space conditions

Measuring points with no close metallic objects
Measuring points close to metallic objects

Em (measurement) vs. EMF-estimator (free space)
ITU-T Recommendation 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
EMF-estimator

- Software tool that is Annex I to the ITU-T Recommendation K.70
- The last version of the software (v6.02: 01.2018) may be loaded from the:
  https://www.itu.int/rec/T-REC-K.70-201801-P
- 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 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
Recommendation ITU-T K.52

Guidance on complying with limits for human exposure to electromagnetic fields

Software K.52 Calculator

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
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.122

Exposure levels in close proximity of radiocommunication antennas

- Electric field strength levels that can be expected in close proximity to the broadcasting and radiocommunication antennas
- Important for maintenance personnel and in some cases also for the general public
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
  - Radiocommunication: 10 W – 1 kW
Simultaneous exposure to multiple sources

Examples of calculation and measurement

Total exposure – many radiating sources
Conclusions

- ITU-T Recommendations and Supplements include many tools supporting RF EMF exposure assessment.
- ITU-T encourages all entities to send contributions for the meetings. They may include:
  - proposals of the new work items
  - possible problems to be considered
  - Proposals of the modification of the existing Recommendations
- ITU-T is active in sharing knowledge and tools concerning assessment of human exposure to RF EMF.
Thank you
Questions ?