International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

K.145
(12/2020)

SERIES K: PROTECTION AGAINST INTERFERENCE

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

Recommendation ITU-T K.145

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Summary

Recommendation ITU-T K.145 includes guidance on the protection of workers against radio frequency electromagnetic fields (RF-EMFs) exposure in their working environments. Radio frequency (RF) workers range from installation engineers and tower climbers to R&D personnel and laboratory testing engineers. All of these RF workers are exposed to stronger RF-EMF fields than the general public. There are also RF informed workers who have been provided with information on RF-EMF safe working practices for a site as well as all other workers who are regarded as members of the public for the purposes of RF-EMF exposure limits. This Recommendation provides minimum general safety guidance for telecommunication RF workers around the world.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T K.145	2019-11-13	5	11.1002/1000/14076
2.0	ITU-T K.145	2020-12-14	5	11.1002/1000/14571

Keywords

Expositimeter, exposure assessment, human exposure to RF EMF, RF EMF, RF personal monitor, RF safety, risk assessment, workers safety.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Table of Contents

Introduction

Standards or guidelines limiting human exposure to radiofrequency electromagnetic fields (RF-EMFs) have been developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the Institute of Electrical and Electronics Engineers (IEEE), or in national regulations. In general, these provide different limits for uncontrolled environments (general public) and controlled environments (occupational). Workers are allowed in areas where the RF-EMF exposure levels are higher than the public limits and below the occupational limits provided they are in a controlled work environment, the workers are appropriately trained and informed of the RF-EMF levels, and they follow approved RF-EMF safe working practices.

This Recommendation provides guidance on the assessment and management of compliance with RF-EMF exposure limits for workers at radiocommunication sites and facilities or where such facilities are located at another site (for example, rooftop antenna installation on non-telecommunication building).

Access controls should be in place to ensure that members of the public, which includes workers that have not received information on approved RF-EMF safe working procedures, cannot access areas above the public RF-EMF limits.

Recommendation ITU-T K.145

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

1 Scope

This Recommendation identifies three groups of workers: radiofrequency (RF) workers (for whom RF-EMF exposure is intrinsic to the nature of their work); informed workers (who have been provided with information on RF-EMF safe working practices for a site) and all other workers who are regarded as members of the public for the purposes on RF-EMF exposure limits. It provides guidance on the management of situations where RF workers and informed workers can be exposed under controlled/occupational exposure conditions at levels higher than general population/uncontrolled exposure limits. Reference is made to the difference between general public and occupational limit levels. Good practices are described for workers and employers, including workers, such as pregnant women, and workers with implanted or external medical devices, that can be active or non-active (passive), for whom other limits may apply.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.52] Recommendation ITU-T K.52 (2018), *Guidance on complying with limits for human exposure to electromagnetic fields*.

[ITU-T K.61] Recommendation ITU-T K.61 (2018), *Guidance to measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations*.

[ITU-T K.70] Recommendation ITU-T K.70 (2020), *Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations*.

[ITU-T K.83] Recommendation ITU-T K.83 (2020), *Monitoring of electromagnetic field levels.*

[ITU-T K.91] Recommendation ITU-T K.91 (2020), *Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields*.

[ITU-T K.122] Recommendation ITU-T K.122 (2016), *Exposure levels in close proximity of radiocommunication antennas*.

[ITU-R BS.1698] Recommendation ITU-R BS.1698 (2005), *Evaluating fields from terrestrial broadcasting transmitting systems operating in any frequency band for assessing exposure to non-ionizing radiation.*

[IEC/EN 62232] IEC 62232:2017, *Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure.*

[IEC/EN 62311] IEC/CENELEC 62311:2020, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz-300 GHz).*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 antenna [ITU-T K.70]: Device that serves as a transducer between a guided wave (e.g., coaxial cable) and a free space wave, or vice versa. It can be used to emit or receive a radio signal. In this Recommendation the term antenna is used only for emitting antenna(s).

3.1.2 averaging time (T_{avg}) [ITU-T K.83]: Appropriate time over which exposure is averaged for purposes of determining compliance with the limits.

3.1.3 basic restrictions: Restrictions on exposure to time-varying electric, magnetic and electromagnetic fields that are based directly on established health effects. Depending upon the frequency of the field, the physical quantities used to specify these restrictions are: current density (J), specific absorption rate (SAR) and power density (S).

3.1.4 controlled/occupational exposure [ITU-T K.70]: Controlled/occupational exposure applies to situations where the persons are exposed as a consequence of their employment and in which those persons who are exposed have been made fully aware of the potential for exposure and can exercise control over their exposure. Controlled/occupational exposure also applies to the cases where the exposure is of transient nature as a result of incidental passage through a location where the exposure limits may be above the general population/uncontrolled environment limits, as long as the exposed person has been made fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

3.1.5 electric field strength (E) [ITU-T K.83]: Magnitude of a field vector at a point that represents the force (*F*) on a small test charge (*q*) divided by the charge:

$$E = \frac{F}{q}$$

The electric field strength is expressed in units of volt per metre (V/m).

3.1.6 electromagnetic field (EMF) [ITU-T K.91]: A field determined by a set of four interrelated vector quantities that characterizes, together with the electric current density and the volumic electric charge, the electric and magnetic conditions of a material medium or of a vacuum.

3.1.7 exposure [ITU-T K.83]: Exposure occurs whenever a person is exposed to electric, magnetic or electromagnetic fields.

3.1.8 exposure level: Value given in the appropriate quantity used when to express the degree of exposure of a person to electromagnetic fields or contact currents.

3.1.9 exposure limits: Values of the basic restrictions or reference levels acknowledged, according to obligatory regulations, as the limits for the permissible maximum level of the human exposure to the electromagnetic fields.

3.1.10 far-field region [ITU-T K.83]: Region of the field of an antenna where the radial field distribution is essentially dependent inversely on the distance from the antenna. In this region, the field has a predominantly plane-wave character, i.e., locally uniform distribution of electric field and magnetic field in planes transverse to the direction of propagation.

NOTE – In the far-field region, the vectors of the electric field *E* and the magnetic field *H* are perpendicular to each other, and the quotient between the value of the electric field strength *E* and the magnetic field strength *H* is constant and equals the impedance of free space Z_0.

3.1.11 general population/uncontrolled exposure [ITU-T K.52]: General population/uncontrolled exposure applies to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure.

3.1.12 general public: All non-workers are defined as the general public.

3.1.13 magnetic field strength (H) [ITU-T K.83]: The magnitude of a field vector in a point that results in a force (*F*) on a charge *q* moving with the velocity v:

$$F = q(v \times \mu H)$$

The magnetic field strength is expressed in units of amperes per meter (A/m).

3.1.14 near-field region [ITU-T K.83]: Region generally in proximity to an antenna or other radiating structure, in which the electric and magnetic fields do not have a substantially plane-wave character but vary considerably from point to point. The near-field region is further subdivided into the reactive near-field region, which is closest to the radiating structure and that contains most or nearly all of the stored energy, and the radiating near-field region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complicated in structure.

3.1.15 power density (S) [ITU-T K.83]: Radiant power incident perpendicular to a surface, divided by the area of the surface. The power density is expressed in units of watt per square metre (W/m^2).

3.1.16 radio frequency (RF) [ITU-T K.70]: Any frequency at which electromagnetic radiation is useful for telecommunication.

NOTE – In this Recommendation, radiofrequency refers to the frequency range of 9 kHz – 300 GHz allocated by ITU-R Radio Regulations.

3.1.17 reference levels [ITU-T K.70]: Reference levels are provided for the purpose of comparison with exposure quantities in air. The reference levels are expressed as electric field strength (*E*), magnetic field strength (*H*) and power density (*S*) values. In this Recommendation the reference levels are used for the exposure assessment.

3.1.18 specific absorption (SA) [ITU-T K.52]: Specific absorption is the quotient of the incremental energy (*dW*) absorbed by (dissipated in) an incremental mass (*dm*) contained in a volume element (*dV*) of a given density (ρ_m).

$$SA = \frac{dW}{dm} = \frac{1}{\rho_m}\frac{dW}{dV}$$

The specific absorption is expressed in units of joules per kilogram (J/kg).

3.1.19 specific absorption rate (SAR) [ITU-T K.52]: The time derivative of the incremental energy (*dW*) absorbed by (dissipated in) an incremental mass (*dm*) contained in a volume element (*dV*) of a given mass density (ρ_m).

$$SAR = \frac{d}{dt}\frac{dW}{dm} = \frac{d}{dt}\left(\left(\frac{1}{\rho_m}\frac{dW}{dV}\right)\right)$$

SAR is expressed in units of watts per kilogram (W/kg).

SAR can be calculated by:

$$SAR = \frac{\sigma E^2}{\rho_m}$$

$$SAR = c\frac{dT}{dt}$$

$$SAR = \frac{J^2}{\rho_m \sigma}$$

where:

E	is the rms value of the electric field strength in body tissue in V/m
σ	is the conductivity of body tissue in S/m
ρ_m	is the density of body tissue in kg/m^3
c	is the heat capacity of body tissue in J/kgºC
$\frac{dT}{dt}$	is the initial time derivative of temperature (at t=0) in body tissue in ºC/s
J	is the value of the induced current density in the body tissue in A/m^2

3.1.20 wavelength (λ) [ITU-T K.52]: The wavelength of an electromagnetic wave is related to frequency (*f*) and propagation velocity (*v*) of an electromagnetic wave by the following expression:

$$\lambda = \frac{v}{f}$$

In free space the propagation velocity is equal to the speed of light (*c*) which is approximately 3×10^8 m/s. In body tissue the propagation velocity is reduced by the square root of the relative dielectric constant so that wavelength in tissue is typically 7 times shorter than in free space.

3.1.21 workers [ITU-T K.90]: Persons employed by an employer, including trainees and apprentices but excluding domestic servants.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 active medical device: Medical device relying for its functioning on a source of electrical energy or any source of power other than that directly generated by the human body or gravity.

3.2.2 active implantable medical device (AIMD): Active medical device which is intended to be totally or partially introduced, surgically or medically, into the human body or by medical intervention into a natural orifice, and which is intended to remain after the procedure.

3.2.3 exposimeter: A portable monitoring instrument used to measure the exposure to a physical hazard a person has received over a period of time. Such instruments are designed to measure the accumulated exposure to factors such as radiation, electric and magnetic fields, or noise.

3.2.4 medical device: Instrument, apparatus, appliance, software, material or other article, whether used alone or in combination, together with any accessories, including the software intended by its manufacturer to be used specifically for diagnostic and/or therapeutic purposes and necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of:

- diagnosis, prevention, monitoring, treatment or alleviation of disease,
- diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap,

- investigation, replacement or modification of the anatomy or of a physiological process,
- control of conception,

and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means.

3.2.5 RF personal monitor/RF exposimeter: A portable monitoring instrument used to measure the exposure to radio frequencies a person has received over a period of time.

3.2.6 RF worker: A worker who may be exposed to RF-EMF under controlled/occupational exposure conditions, in the course of and intrinsic to the nature of their work.

3.2.7 RF informed worker: A worker who may be exposed to RF-EMF under controlled/occupational exposure conditions provided with information on RF-EMF safe working practices for a site.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AIMD	Active Implantable Medical Device
E	E-field strength (V/m)
EMF	Electromagnetic Field
GPS	Global Positioning System
H	H-field strength (A/m)
IT	Information Technology
MPE	Maximum Permissible Exposure
PPE	Personal Protective Equipment
RF	Radio Frequency
S	Power density (W/m^2)
SAR	Specific Absorption Rate (W/kg)

5 Conventions

None.

6 Human exposure limits

Several countries and independent organizations have developed limits for both general public (non-controlled) and occupational (controlled) environments. Examples include [b-ICNIRP], [b-IEEE C95.1], and many national authorities such as the Federal Communications Commission (FCC) and the European Directive 2013/35/EU [b-EU Directive], [b-Safety Code 6], etc.

Limits on EMF exposure are called basic restrictions and are based directly on established health effects and biological considerations.

Basic restrictions are expressed at different frequency ranges in terms of internal electric field strength, specific absorption rate (SAR) and power density. The first two of these are not easy to measure, so standards include practical information on measurable levels that correspond to basic restrictions. Examples of measurable levels are the maximum permissible exposures (MPEs) from

IEEE or the reference levels from ICNIRP, expressed as E-field strength (E) for electrical field strength, H-field strength (H) for magnetic field strength, or power density (S).

The rationale to distinguish between members of the general public and workers is that workers are exposed under known conditions, which makes it possible to better control the RF EMF levels and duration of occupational exposures. In addition, workers are usually a healthy adult population with medical monitoring available and can be provided with instructions and training. By contrast, the general population is composed of people with a wide range of health sensitivities, ages and illnesses. The general public will not necessarily have any knowledge of their RF EMF exposure or be able to minimize it.

Limits for general public usually include an additional safety factor from occupational limits.

For the purpose of this Recommendation, the applicable limits are the occupational limits in effect in the country where the work is being done. The International Telecommunications Union (ITU) and World Health Organization (WHO) recommend adoption of the ICNIRP guidelines where no national standard exists. Appendix 1 contains the ICNIRP limits as a reference.

As a general rule, workers shall not exceed the occupational reference levels. Workers described in clause 7.4, shall not exceed the general public reference levels.

In locations only accessible to RF workers, as described in clause 7.2, and RF informed workers as described in clause 7.3, the occupational limits are applied. In locations where non-RF workers, as described in clause 7.1, or non-workers could be reasonably expected to access, the public limits are applicable.

NOTE – In some national regulations there is a relation between exposure limit and duration of exposure for a whole (8 hours) working day.

On a rooftop where signage is in place and access controlled the occupational limits are considered to be applicable. The exception to this would be workers described in clause 7.4, where individual risk assessment would be required.

7 Workers classification

Workers who are under operator control can be divided into those who visit sites but whose work would not be expected to take them into an antenna exclusion zone and those whose work could potentially take them into an antenna exclusion zone, such as antenna riggers.

Workers who visit sites should receive basic RF awareness training as part of a rooftop safety course. Riggers should receive more extensive RF training and the use of RF alerts should be considered.

For the purpose of this Recommendation, workers can be classified into the following types.

7.1 Non-RF workers

Non-RF workers are workers of the telecommunication sector that do not need to find themselves near RF emitters. Examples of non-RF workers are all those that work in a standard office with the normal equipment of computers and other IT equipment, heating/cooling systems, lightning, etc.

Non-RF workers that have not been trained on RF safety have to be considered as general public and cannot access areas with RF emitters. In that case, all accessible areas shall be assessed to comply with the general public limits.

7.2 RF workers

RF workers are all those workers that are likely to be near an RF source as part of their job. Examples are test lab engineers and telecommunication infrastructure maintenance engineers (tower climbers, installation engineers, etc.).

RF workers shall be trained on RF safety, equipped according to the nature of their activities and should not exceed the occupational reference levels.

7.3 RF informed workers

RF informed workers are all those workers who are likely to be near an RF source to carry out their non RF related work. Examples would be air-conditioning engineers or painting employees, etc.

7.4 Workers at particular risk of noncompliance with RF EMF limits

7.4.1 Pregnant women

To reduce the risk of accidental exposure above occupational limits, a pregnant woman should not be exposed to levels of RF fields above the limits of general public exposure. Occupationally exposed women who are pregnant should advise their employers when they become aware of their pregnancy. After such notification, they should not be exposed to RF fields exceeding the general public limits. Pregnancy should lead to at least a reasonable accommodation/adjustment or temporary transfer to non-RF work without loss of employment benefits.

7.4.2 Workers bearing personal medical devices.

Workers may wear implanted or external medical devices that can be active or non-active (passive).

Electromagnetic fields may interfere with active medical devices. On the other hand, RF electromagnetic fields (10 MHz – 300 GHz) can couple with metallic parts of passive medical devices. The effect is an energy concentration around the part that may heat the adjacent tissue.

To avoid RF interference problems with, or effects on the functioning of, or coupling on, medical devices such as metallic prostheses, cardiac pacemakers and defibrillators, cochlear implants and other implants or medical devices worn on the body, such as insulin pumps, workers who wear such passive or active, implanted or external medical devices should not, be exposed to RF field levels exceeding those of general public without evaluation.

This is valid, without any further specific risk assessment, only if the medical device has been tested and provides an accredited immunity up to at least the general public reference levels.

However, not all medical devices, in all circumstances, can be safely worn at the general public reference limit levels. If the wearer of such a medical device has received specific warnings from the responsible physician, based on the fact that the immunity of the medical device and the conditions of use and parameter setting is not compatible with general public reference levels, a specific risk assessment is needed.

If the worker wearing a medical device is an RF worker or RF informed worker, or may be exposed to, or transit through, areas exceeding the general public limits, the case shall be subject to a specific risk assessment.

Additional information on risk assessment of workers wearing medical devices can be found in [b-IEEE C95.7] and in [b-EN 50527-1], [b-EN 50527-2-1], [b-EN 50527-2-2].

8 Protective measures for RF workers and RF informed workers

Employers shall ensure that the exposure of RF workers and RF informed workers to electromagnetic fields does not exceed the occupational limits. Verification of compliance may be based on measurements or evaluations and must be performed when a site changes.

This shall be done through an RF safety program in five steps, as described below:

- Performing risk and exposure assessments.
- Training RF workers.

- Providing information on safety practices to RF informed workers.
- Providing RF workers with the right tools.
- Applying preventive measures (Action Plan).

8.1 Performing risk and exposure assessments

In order to protect workers exposed to electromagnetic fields it is necessary to carry out an effective and efficient risk assessment.

8.1.1 Risk assessment

The risk assessment should be done by taking the following steps:

- Identification of the appropriate exposure limits.
- Identification of the potential RF sources.
- Determination of the need for an RF exposure assessment [ITU-T K.122].
- Determination of the best method.
- Actions taken to mitigate or avoid overexposure.

a) Identification of the appropriate exposure limits.

The applicable exposure limits will depend on the national law as previously explained in clause 6. Otherwise, the use of ICNIRP limits [b-ICNIRP] is advised [ITU-T K.52].

b) Identification of the potential RF sources.

Antennas are the main RF sources in the telecommunications environment. They are called intentional emitters because they use electromagnetic field (EMF) for signal transmission. Types of antennas and their characteristics should be known and considered [ITU-R BS.1698], [ITU-T K.122].

c) Determination of the need for an RF exposure assessment.

Once the intentional emitters have been identified, the need for an RF exposure assessment is determined by checking its frequency of operation, power, gain, radiation pattern, orientation, etc. If the emitter installation is not inherently compliant (sources that comply with exposure limits a few centimetres from the source), an RF exposure assessment is needed.

NOTE – Additional guidance and sources classification may be found in [ITU-T K.52], [ITU-T K.70], [b-ITU-T K.100] and [ITU-T K.122].

d) Determination of the appropriate method.

If an RF exposure assessment is needed, the best method has to be determined. The different evaluation techniques may be classified in calculation methods and measurement procedures.

[IEC 62232] describes both measurement and computation methods.

[ITU-T K.52] describes basic analytical methods, while [ITU-T K.61] provides guidance on the selection of numerical methods. Additional information on calculation methods may be found in [ITU-T K.70].

Measurement procedures and the pros and cons of using broadband or narrowband instruments are also described in [ITU-T K.61].

The expected exposure level in the vicinity of the transmitting antennas may be found in [ITU-T K.122].

e) *Actions taken to mitigate or avoid overexposure.*

[ITU-T K.52] and [ITU-T K.122] may be used to determine if the worker will be in the compliance zone (general public levels are not exceeded), occupational zone (occupational levels are not exceeded), or exceedance zone (where occupational levels are exceeded).

If the RF assessment indicates that the occupational exposure limits might be exceeded, action shall be taken to mitigate or avoid overexposure. Advice is given in clause 8.4.

8.1.2 Exposure assessment

The exposure assessment of RF working places can be done theoretically, by calculation or simulation, or with direct measurements or monitoring. Both have advantages and disadvantages [ITU-T K.91], and those may vary from user to user depending on the previous knowledge on RF EMF, the available equipment and the specific exposure situation.

8.1.2.1 Calculations

In general, calculations are relatively simple in the far-field region of an antenna. The point source model is a simple and very effective computational model for far field calculations. It is assumed that the transmitting antenna is represented only by one-point source, situated in the antenna electric centre and having a radiation pattern of the considered transmitting antenna.

If the relative distance (in relation to a wavelength) is shorter, then more sophisticated and technically difficult methods need to be applied for an accurate assessment of the RF field strength.

Applying far-field computational methods close to antennas in the near field can result in an overestimation of the RF field strength due to the far-field antenna gain being applied.

NOTE – Additional information on calculation methods may be found in [ITU-T K.52], [ITU-T K.61], [ITU-T K.70], [IEC 62232], [b-EN 50413], [IEC/EN 62311], [ITU-R BS.1698], [b-IEEE 1597.1].

8.1.2.2 Measurements and monitoring

Measurements are useful in cases where the fields are difficult to calculate (complex scattering environments or environments with several significant sources of RF EMF), where the calculations yield values that are near the exposure limit threshold or where the real conditions may have changed.

Measurement equipment can be classified in two main groups: broadband and narrowband.

Broadband equipment (electric or magnetic field strength meters) use electric (E) or magnetic (H/B) field probes with a flat or shaped response. The advantage of flat response field probes is that the results are obtained in physical units (e.g., V/m or W/m^2) and may be used for any standard. But in the multi frequency environment and frequency dependent exposure limits it may lead to overestimation of the exposure. The advantage of shaped response probes is that results are expressed as a percentage (%) of a specific exposure limit even in a multi frequency environment.

Narrowband equipment provides more accuracy and frequency selective capabilities. On the other hand, it is more expensive, more difficult to carry and operate, and needs more time to get results.

It is recommended to use first the simplest method (i.e., broadband RF EMF measurement). If the measured exposure level is not in compliance with the reference level, then the frequency selective RF EMF measurement should be used to get more accurate results.

Monitoring can be done with area monitors, used to continuously measure EMF levels at fixed locations or with RF personal monitors (also called exposimeters), which are directly worn on the worker's body.

Additional information on measurement and area monitoring may be found in [ITU-T K.83], [b-ITU-R SM.2452] and [b-ITU-R Spectrum Monitoring].

8.2 Providing information on safety practices to RF informed workers

Informed workers shall be given information regarding RF EMF safety and risk management:

- safe working practices to minimize risks resulting from exposure
- information on the need to follow all signs and comply with all instructions
- provide contact information for requesting switch off if necessary
- contact information on location of full information of safe working practices
- safe working practices to minimize risk of exceeding exposure limits.

8.3 Training RF workers

Workers shall be informed and trained regarding RF safety and risk management, on:

– the values and concepts of the basic restrictions and reference levels,

– the results of the assessments, measurements or calculations of the levels of exposure carried out and the preventive measures taken,

– safe working practices to minimize risks resulting from exposure,

– the associated possible risks: direct and indirect effects,

how to detect adverse health effects of exposure and how to report them,

– the possibility of transient symptoms and sensations related to effects in the central or peripheral nervous system,

– the circumstances in which workers are entitled to health surveillance.

8.4 Providing RF workers with the right tools

8.4.1 Personal protective equipment

Personal protective equipment (PPE) may be used to reduce RF exposure in specific situations. Protective clothing is an example of protective equipment, including gloves, conductive socks and footwear and shielded hoods for protection of the head.

Even when the use of PPE may make it possible to work in field levels over occupational limits, its use may also subject the worker to enhanced RF exposures if improperly employed. For example, when used in extremely intense RF fields, surface arcing may exist on suit materials that are conductive. Hence, care should be used in determining whether RF protective clothing is appropriate for the specific exposure circumstance.

PPE may be not compatible with the use of RF personal monitors as described in clause 8.4.2. The presence of conductive fabric near or around a monitor may lead to wrong measurements.

8.4.2 Personal monitoring

There may be situations where workers may be exposed to RF EMF exposure exceeding occupational limits in places where no assessment has been made, the assessment conditions may have changed, or the assessment could not efficiently consider all possible variables.

In some high field level environments, it will not be possible to remove equipment from service, but a prescribed power reduction can be accomplished before the personnel access the area. If so, it is very important to be sure that the removal from service or the power reduction has in fact taken place. A personal monitor can be a useful tool for checking the transmitter status.

There is also the possibility that a system failure may produce an unexpected exposure. In all those situations workers should have means for a quick check of the RF environment or for personal monitoring.

RF personal monitors (exposimeters) are useful devices and are small and easy to operate. Workers may wear them throughout the working day without interfering with their job. Exposimeters are small electronic devices that integrate a field sensor, electronics control/processing, batteries and exposure warning.

Although personal monitors are quite common, they are not always correctly used. It is important to understand the basic principles and operation modes to avoid false alarms and correctly understand their response.

Exposimeters using isotropic and/or non-isotropic, electric and/or magnetic field sensors are available.

Isotropic exposimeters can be used on or off the body, for measurements or monitoring. When worn, they should have absorbing material on the body side to reduce scattering. When used off the body the absorber should be removed for better accuracy. If the field to monitor comes from the front and back positions, a good solution may be to wear the exposimeter on the outer side of the arm, or on the right or left sides of the waist in order to avoid the shadowing effect of the human body at high frequencies.

It is advisable that the RF personal monitors have low frequency immunity, otherwise they may trigger false alarms near power lines or any other equipment generating strong 50/60 Hz fields.

Exposimeter alarms are based on instantaneous field values, while limits are set for time-averaged values. That makes it difficult for the user to know how long he or she is allowed to stay on site without exceeding the limit. Availability of additional average value of the exposure may be helpful. However the instantaneous value of the exposure is the main factor that should be considered.

After an alert based on the instantaneous values, the RF worker may consider the averaged exposure values too and eventually stay longer for working. There are however two serious aspects to consider for time averaging in RF personal monitors:

(1) Time averaged exposures values will warn too late if the alarm threshold is set close to the 100% exposure limit.

(2) Time averaged exposure values are not valid in case instantaneous values are overloaded.

The first aspect is obvious. When the time averaging exposure values reach the permitted value, there is no additional time to leave.

RF personal monitors should therefore use a threshold of at most 25% to 50% of the permitted exposure values in power density units for alerts based on time averaging.

The second aspect is not so obvious. The dynamic range of RF personal monitors is limited. Instantaneous exposure values somewhere above 100% of the permitted values could overload the monitor.

RF personal monitors which use time averaged exposure values for indication or alert shall therefore evaluate the overload state of the underlying instantaneous exposure values. A time averaged exposure value, which contains any overloaded instantaneous exposure value, shall be marked as invalid and the alert based on the time averaged values shall be raised.

RF personal monitors may have a flat or shaped response. When the worker is in a multi-frequency environment where different frequencies have different reference levels, it may be advisable to use shaped response units, to make it easier for the worker to take the right decision. Flat response units may be used in situations where the frequencies are known and all of them have the same reference level. Otherwise, the lowest reference level should be used, reducing the possibilities of the worker to complete his or her job.

When the worker is in a near-field situation, or in the case of exposure to low frequencies, both E and H-fields should be monitored. That will certainly be the case when near AM/FM broadcast emitters, so exposimeters with E and H-field detection are advised.

Other useful tools that exposimeters may have are dataloggers and global positioning system (GPS). When RF workers have been exposed to levels near or over the occupational limits, it may be useful to check what exact levels, when and where they have been exposed. That information could be very useful to take preventive measures for the future.

8.5 Applying preventive measures (Action Plan)

The risk assessment should include an exposure assessment and development of an Action Plan including preventive measures.

Examples of preventive measures include:

- switching off or reducing the RF power
- other working methods that entail less exposure to electromagnetic fields,
- other working positions in respect to the emitter that reduce RF exposure,
- limitations of the duration and intensity of the exposure conditions,
- the choice of equipment emitting less intense electromagnetic fields,
- the optimization of emitters position, orientation and radiated power,
- the availability of adequate personal protective and personal monitoring equipment,
- use of area monitoring in places likely to experience high exposures,
- the use of interlocks, shielding or similar health protection mechanisms when appropriate,
- appropriate delimitation and access measures, such as signals, labels, floor markings, barriers, in order to limit or control access.

NOTE 1 – Signage should include operator contact details.

NOTE 2 – Site providers should be provided with an information pack which includes information on RF safety and contact details for the operator. Site providers are to be encouraged and expected to contact the operator(s) if personnel under their control are going to be working close to an antenna.

NOTE 3 – Further information on RF safety programs or assessments, training, control, monitoring, PPEs, protection measures, etc. may be found in [b-IEEE C95.7].

Appendix I

Example of the use of an RF exposimeter (RF personal monitor) during telecommunication tower maintenance

(This appendix does not form an integral part of this Recommendation.)

This appendix shows the use of an RF exposimeter (RF personal monitor) by a tower climber, a worker classified in this Recommendation as an RF worker (see definition in clause 3.2.6). In this case, the worker is an employee of a contractor taking care of the maintenance of a group of towers belonging to the CTTI (Telecommunications and Information Technologies Centre) of the Government of Catalonia.

The maintenance the worker is doing is not related to the services installed in the tower but to the tower itself, so the job is being done with all systems on. The worker has no precise information on the power or specificities of the systems installed at each tower, so he will follow general tower safety rules. The RF exposimeter will alert him in case of excessive exposure and will give him the possibility to check if the different services are on or off.

The set-up of the RF exposimeter is as follows:

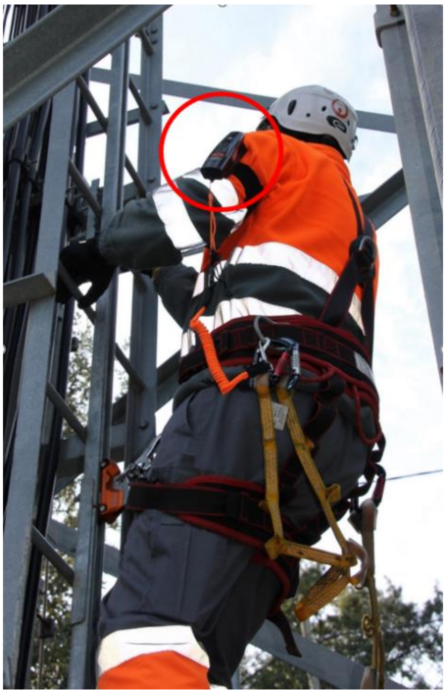
– Reference limit set to ICNIRP 1998 occupational (see Note).

– Averaging sliding window set to 6 minutes.

– First warning level: 100% of limit on instantaneous value.

– Second warning level: to 50% of limit on average value.

The process starts when the worker switches on the RF exposimeter at the base of the tower. That is the relative reference of the internal altimeter. The worker will climb to the top of the tower to inspect the key elements of the tower structure. He will also use the RF exposimeter to check if some of the services are on. See pictures 1 and 2.



Picture 1

The exposimeter provides the instant and average values as a percentage of ICNIRP 1998 occupational associated to date, time, GPS position and altimeter height.

The results of the instant and average percentage values are shown in Figures I.1 and I.2.

The X-axis shows the measurements in percentage of the limit, in logarithmic and linear view.

NOTE – The ICNIRP published its new 2020 RF guidelines after this appendix had been drafted, and the ICNIRP 1998 guidelines became obsolete. However, that does not change the main purpose of this appendix as an example case of use.

Picture 2

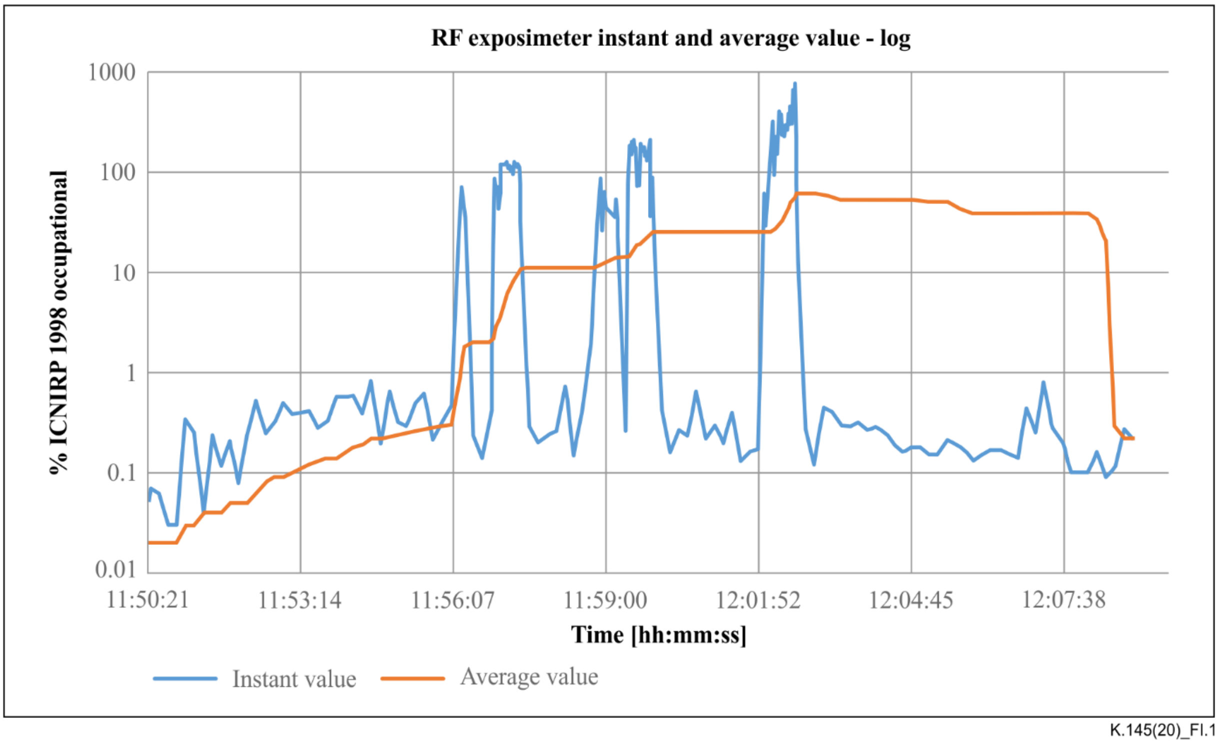


Figure I.1 – Graphical view of the exposure levels during the time the tower climber was in the tower. The exposure levels in % to the limit are displayed in the Y-axis in logarithmic view

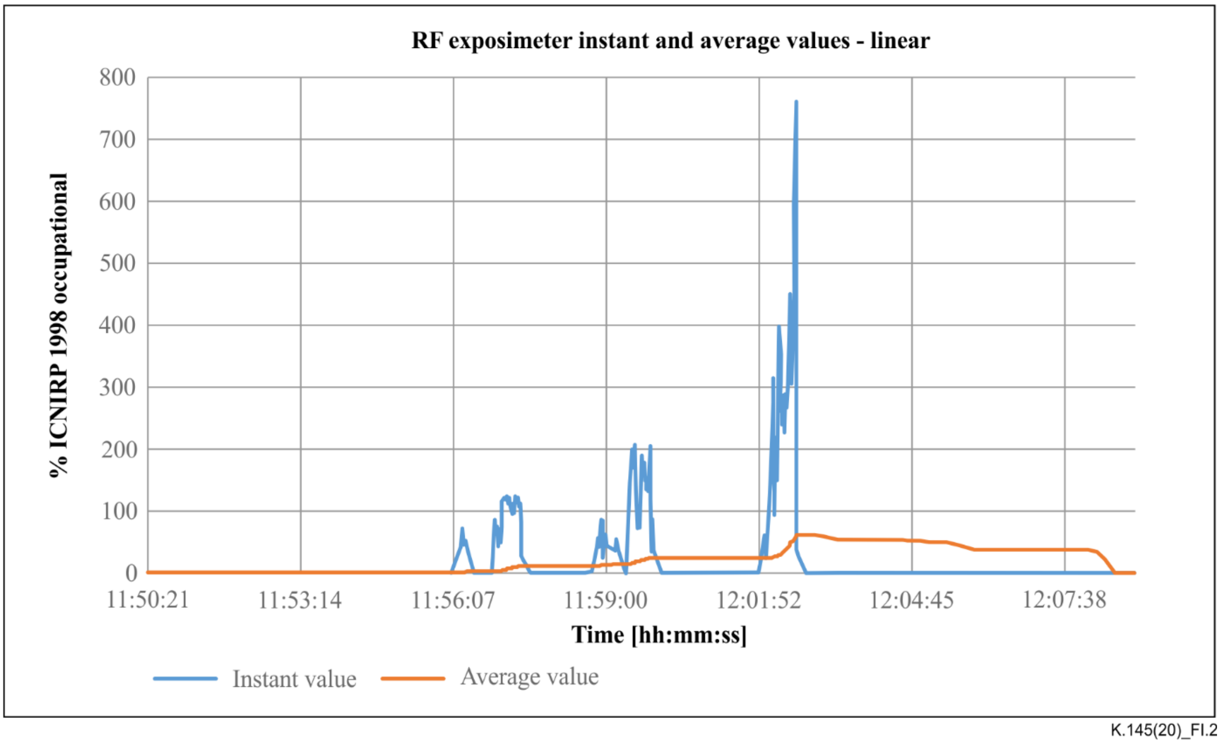


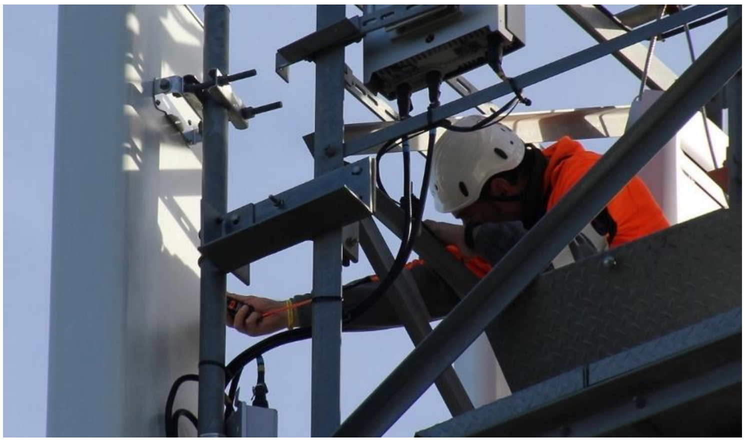
Figure I.2 – Graphical view of the exposure levels during the time the tower climber was in the tower. The exposure levels in % to the limit are displayed in the Y-axis in linear view

The first two peaks at around 11:57 correspond to the digital terrestrial television (DTT) elements at the top of the tower, checked by the worker by taking the exposimeter off his arm and placing it in front of the DTT antenna, in two of the three existing sectors (Picture 2).

The peaks around 11:59 correspond to the worker checking two mobile telephony antenna sectors at the top platform (4th) at a height of 28 m, belonging to Operator A.

The peak around 12:02 corresponds to the worker checking one sector of mobile telephony at the third platform at 23 m, belonging to Operator B.

In this case, the level of the peaks is not relevant because the worker was placing the RF exposimeter in front of the antennas on purpose just to check for the on/off status. The difference in levels is mainly due to the arbitrary position of the exposimeter in front of each antenna. See Picture 3.



Picture 3

It is interesting to see the evolution of the average value in relation to the instant values. It obviously depends on the value and duration of the instant values. Very high instant values during a short time period do not affect the average value very much. However, several high instant value events close together in time, being in the 6-minute averaging sliding window, lead to successive increases of the average value.

The same view can be obtained as a function of height (Figure I.3). In this case the instant and average values while going up and down. Instant values are of course similar when going up and down, while average values are different. They are lower when going up (the 6-minute averaging window is empty), and higher when going down (depending on the last 6-minute values). The average value at the end of the sequence sharply decreases after 6 minutes from the last instant peak value, as expected.

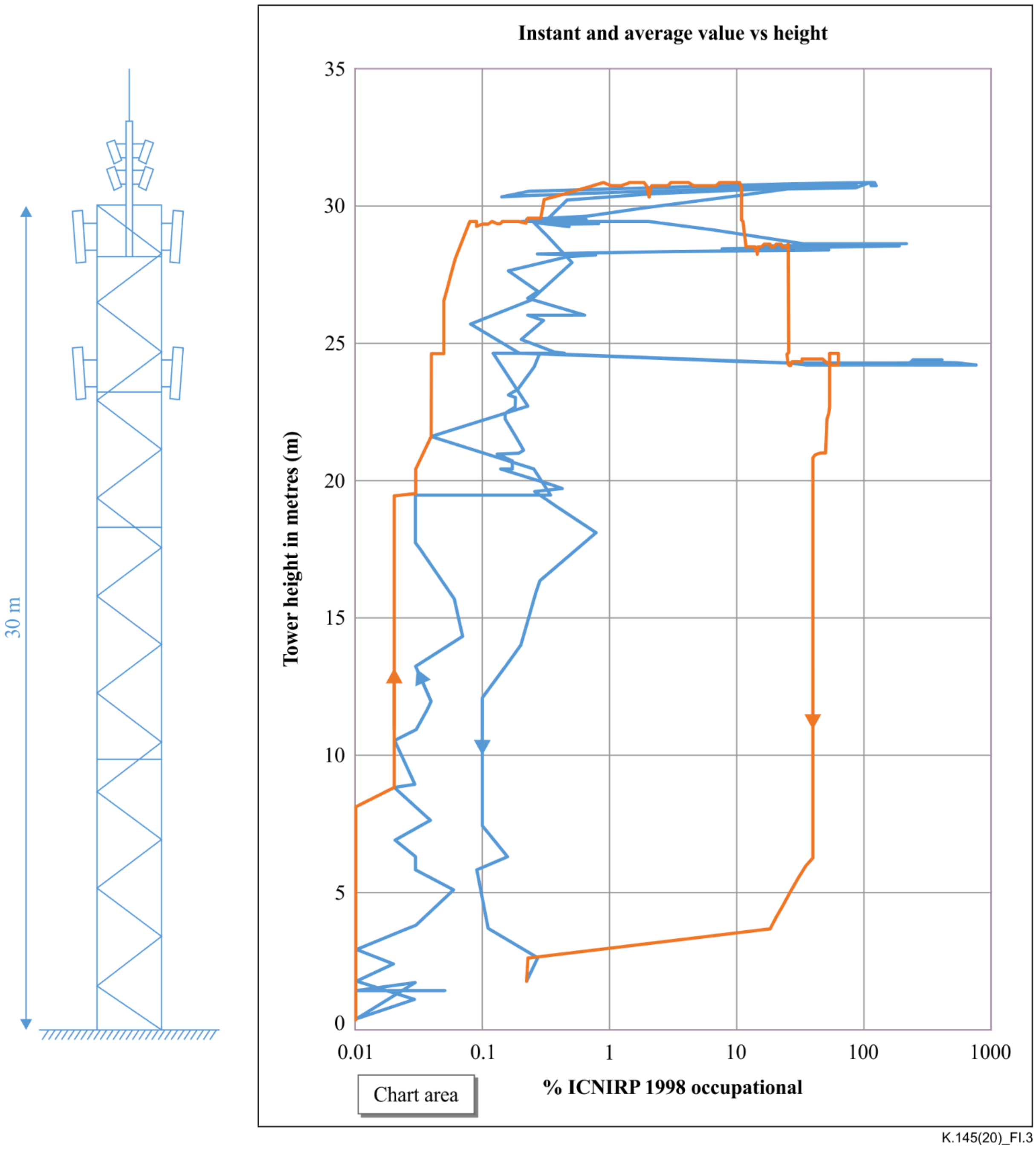


Figure I.3 – Graphical view of the exposure levels (in %, X-axis in logarithmic view) as a function of the height of the tower (in meters, Y-axis)

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Printed in Switzerland
Geneva, 2021