

Recommendation

ITU-T K.153 (09/2023)

SERIES K: Protection against interference

Guidance on determining the compliance boundaries (exclusion zones) of radio transmitter installations



Recommendation ITU-T K.153

Guidance on determining the compliance boundaries (exclusion zones) of radio transmitter installations

Summary

Exclusion zones are described by the compliance boundaries around radio base stations and transmitting stations in which the electromagnetic fields may exceed the radio frequency electromagnetic field (RF-EMF) exposure limits. The general public shall not have access to those areas. Exclusion zones are also defined for occupational exposure. Those areas are generally positioned on rooftops in urban or suburban locations. Their shape and dimensions may differ depending on the regulations.

Recommendation ITU-T K.153 includes information on how the exclusion zones should be determined based on the data concerning operating frequencies and equivalent isotropically radiated power (EIRP) on each of the operating frequencies. It also includes information on cases in which there are no exclusion zones. For example, on masts, especially in rural areas, there is no need for any materialization as the general public does not have access to this zone and access for workers is also limited and usually exists only in the front of the transmitting antennas. Furthermore, some other transmitters do not need any compliance boundary as the installed power level is so low that they are compliant even when touching the transmitter.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T K.153	2023-09-06	5	11.1002/1000/15596

Keywords

Compliance boundaries, compliance distances, exclusion zones, exposure to RF EMF, radio base station, transmitting station.

* To access the Recommendation, type the URL <https://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents/software copyrights, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the appropriate ITU-T databases available via the ITU-T website at <http://www.itu.int/ITU-T/ipr/>.

© ITU 2023

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

Table of Contents

	Page
1 Scope	1
2 References.....	1
3 Definitions	2
3.1 Terms defined elsewhere.....	2
3.2 Terms defined in this Recommendation.....	2
4 Abbreviations and acronyms	2
5 Conventions	2
6 General.....	3
7 Transmitting equipment with no compliance boundaries.....	4
8 Compliance zone in the multiple sources' environment	4
9 Conclusions	5
Appendix I – Comparison of the exclusion zone distances as a function of EIRP and frequency	6
Appendix II – Exclusion zone around 5G beam-forming (AAS) antennas	10
Appendix III – Exclusion zones in different documents and countries	12
Bibliography.....	14

Recommendation ITU-T K.153

Guidance on determining the compliance boundaries (exclusion zones) of radio transmitter installations

1 Scope

This Recommendation provides guidance on how to determine the exclusion zones (compliance boundaries) i.e., distances in which electromagnetic field (EMF) exposure limits for the general public or workers may be exceeded of a base station (BS) or other transmitting stations. In many situations, it is important to evaluate the areas in which the presence of people shall be excluded or limited because of the radio frequency electromagnetic field (RF EMF) exposure. This Recommendation provides guidance for different types of mobile BS (macro, micro, small, etc.) and other transmitting stations in areas around transmitting antennas considering the International Commission on Non-Ionizing Radiation Protection (ICNIRP) RF EMF exposure limits. Guidance on the appropriate RF-EMF limits to be applied to workers at radiocommunication sites and facilities or where such facilities are located at another site (for example, a rooftop antenna installation on a non-telecommunication building) is provided in [ITU-T K.145].

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 (2021), *Guidance on complying with limits for human exposure to electromagnetic fields.*
- [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.91] Recommendation ITU-T K.91 (2022), *Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields.*
- [ITU-T K.100] Recommendation ITU-T K.100 (2021), *Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service.*
- [ITU-T K.122] Recommendation ITU-T K.122 (2016), *Exposure levels in close proximity of radiocommunication antennas.*
- [ITU-T K.145] Recommendation ITU-T K.145 (2020), *Assessment and management of compliance with radio frequency electromagnetic field exposure limits for workers at radiocommunication sites and facilities.*
- [IEC 62232] IEC 62232 (2022), *Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure.*
- [IEC 62479] IEC 62479 (2010), *Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz - 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.

3.1.2 base station (BS) [ITU-T K.100]: Fixed equipment for radio transmission used in cellular communication or wireless installation for local area networks.

3.1.3 compliance distance [ITU-T K.70]: Minimum distance from the antenna to the point of investigation where the field level is deemed to be compliant to the limits.

3.1.4 compliance boundary (exclusion zone) [IEC 62232]: Surface of arbitrary shape defining a volume outside of which the applicable limit condition is not exceeded.

3.1.5 equivalent isotropically radiated power (EIRP) [ITU-T K.70]: The EIRP is the product of the power supplied to the antenna and the maximum antenna gain relative to an isotropic antenna.

3.1.6 exposure limits [ITU-T K.70]: 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.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAS	Advanced Antenna System
BS	Base Station
EIRP	Equivalent Isotropically Radiated Power
EMF	Electromagnetic Field
GSM	Global System for Mobile communications
IMT-2020	International Mobile Telecommunication-2020 (5G, New Radio)
MIMO	Multiple-Input Multiple-Output
NR	New Radio (IMT-2020, 5G)
POI	Point of Investigation
RBS	Radio Base Station
RF	Radio Frequency
SAR	Specific Absorption Rate

5 Conventions

None.

6 General

The terms "compliance boundary" and "exclusion zone" have very similar meaning and in this Recommendation will be used interchangeably. The compliance boundary shall be established based on radio frequency electromagnetic field (RF EMF) exposure limits, considering all operating frequencies at the rated or configured maximum transmitted power and in free space conditions. For this purpose, measurements or calculations may be used.

Depending on the frequency range and relevant regulations the proper exposure metric should be selected. In most cases the electric field strength or power density is appropriate. In some cases, if the most exact evaluation is required the specific absorption rate (SAR) is used [IEC 62232].

There are different compliance boundary shapes that may be used [IEC 62232]. It is possible to define compliance boundaries in different ways depending on the needs and the required accuracy. In practice, compliance boundaries with simple shapes are preferred and sufficient. This means that in many directions they provide more conservative compliance distances to the transmitting antennas than the real one. This is because the evaluation of the exact exclusion zones (called "iso-surface compliance boundary") is very complex, especially in multi-operator and multi-frequency environments, and normally gives no additional value in comparison with the much more simple approach (simpler shapes) with a certain level of overestimation.

The power density or radio frequency (RF) field strength may be calculated in all directions around the base station (BS) or transmitting station using chosen computation methods: cylindrical and spherical formulas, synthetic modelling or full wave analysis, depending on the acceptable level of the overestimation. Full wave analysis is the most accurate computation method and allows evaluation of the smallest, so called, iso-surface [IEC 62232] exclusion zone. An iso-surface compliance boundary requires post-processing and the use the applicable RF exposure limit as the iso-surface value.

Compliance boundaries are zones around a BS or transmitting station where the RF EMF exposure levels may exceed the limits and where general public or workers shall not have access. These zones are generally positioned on rooftops in urban or suburban locations. Their shape and dimensions are harmonized and computed using an appropriate tool considering the activated frequencies and the radiated equivalent isotropically radiation power (EIRP), see Figure 1.

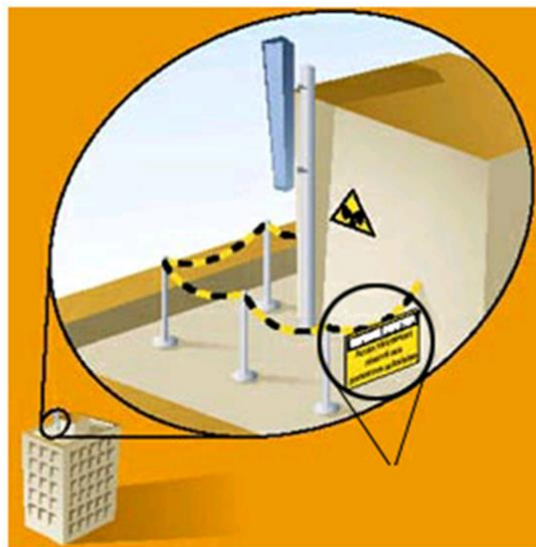


Figure 1 – Example of compliance materialization

Note that not all sites need to have a materialized physical compliance boundary with fences and notice signs, etc. For example, those on masts especially in rural areas do not need any

materialization as the general public and even workers do not have access to this zone. Furthermore, some other transmitters do not have any compliance boundary (so called "touch compliance") as the installed power is so low that they are compliant even when touching the transmitter (example: indoor antennas, IoT, handsets, Femto cells, etc.) [IEC 62479].

The compliance boundary shall be evaluated for maximum EIRP or for actual maximum transmitted power or EIRP value(s) using a power reduction factor if the equipment that is in operation is able to implement the actual maximum approach [IEC 62232], [ITU-T K.100].

In Appendix II tables and charts are included in which compliance distances are presented for the frequencies used in radiocommunication and for the ICNIRP RF EMF exposure limits. These tables and charts may be helpful for quick estimation of the real exclusion zones.

The shape of the exclusion zones may be defined in different ways depending on the needs and relevant regulations [IEC 62232]. Examples of the possible exclusion zones are presented in Appendix III.

In a typical BS, or other transmitting station operating with many antennas and on many frequencies, the exclusion zone has the form of the complex sum of the exclusion zones determined for each frequency. Clause 8 presents the method of determining the resultant exclusion zone based on the exclusion zones from the individual exclusion zones.

There is an additional difficulty in the evaluation of the exclusion zones for the BS using beam forming antennas. This is because the real exposure varies over time and additional statistical averaging is required in order to evaluate the real maximum exposure level. More information may be found in [IEC 62232] and in Appendix I.

7 Transmitting equipment with no compliance boundaries

Some equipment under test (EUT) are known to be compliant with relevant exposure limits without the necessity to follow general or comprehensive exposure assessment processes. This is relevant, for example, because of the low power transmitted or because of the position of the transmitters or antennas (EUT and relevant sources) with respect to the general public. Such EUT are covered by the Installation class E0 [ITU-T K.100], [IEC 62232] and covering equipment compliant with [IEC 62479]. In this case, there is no need for evaluation of the compliance boundaries.

8 Compliance zone in the multiple sources' environment

In a multi frequency environment that is currently typical, the important issue is the possibility of calculating the resultant compliance for all sources operating simultaneously. In such a case, there are many emissions from one localization or one antenna tower. In many antennas available on the market, a number of independent antennas are comprised inside one antenna panel.

In case of a multi frequency environment, the distance r to the border of the compliance zone, on the azimuth angle φ and elevation angle θ , is equal to the distance in which the condition formulated in the equation (1) is achieved [ITU-T K.52], [ITU-T K.91], [IEC 62232], [b-ICNIRP]:

$$\frac{S_1(\varphi,\theta)}{S_{lim1}} + \frac{S_2(\varphi,\theta)}{S_{lim2}} + \dots + \frac{S_N(\varphi,\theta)}{S_{limN}} = 1 \quad (1)$$

where:

$S_i(\varphi,\theta)$ power density from source i emitted at azimuth angle φ and elevation angle θ

S_{limi} RF EMF exposure limit for the frequency relevant for the source i

The required distance is present in the equation (1) by the relation presented by r_i in the equation (2):

$$S_{limi}(\varphi, \theta) = \frac{EIRP_i(\varphi, \theta)}{4\pi[r_i(\varphi, \theta)]^2} \quad (2)$$

where:

$EIRP_i(\varphi, \theta)$ equivalent isotropically transmitted power emitted by source i at azimuth angle φ and elevation angle θ

$r_i(\varphi, \theta)$ distance from source i to the border of the compliance zone at azimuth angle φ and elevation angle θ

As we are looking for one compliance distance for all emissions operating simultaneously, the distance $r(\varphi, \theta)$ should be equal for all considered radiating sources. In this way we have:

$$\frac{EIRP_1(\varphi, \theta)}{4\pi[r(\varphi, \theta)]^2 S_{lim1}} + \frac{EIRP_2(\varphi, \theta)}{4\pi[r(\varphi, \theta)]^2 S_{lim2}} + \dots + \frac{EIRP_N(\varphi, \theta)}{4\pi[r(\varphi, \theta)]^2 S_{limN}} = 1 \quad (3)$$

The equation (3) may be written in the form (4):

$$r(\varphi, \theta) = \sqrt{\frac{EIRP_1(\varphi, \theta)}{4\pi S_{lim1}} + \frac{EIRP_2(\varphi, \theta)}{4\pi S_{lim2}} + \dots + \frac{EIRP_N(\varphi, \theta)}{4\pi S_{limN}}} \quad (4)$$

because:

$$r_i^2(\varphi, \theta) = \frac{EIRP_i(\varphi, \theta)}{4\pi S_{limi}} \quad (5)$$

we have:

$$r(\varphi, \theta) = \sqrt{r_1^2(\varphi, \theta) + r_2^2(\varphi, \theta) + \dots + r_N^2(\varphi, \theta)} \quad (6)$$

The result presented in the equation (6) shows that the compliance distances for the multiple radiating sources located in the same point (or close to it) may be calculated using a simple equation based on the compliance distances of each individual source. This equation allows evaluation of the compliance boundary for each required direction (for desired azimuth angle φ and elevation angle θ).

The equation (6) may be helpful for the evaluation of the compliance boundary in a multi frequency environment. If the base station or other antennas are located on the same antenna tower but on the different heights it will be less accurate, but it may give sufficient approximation.

9 Conclusions

Exclusion zones (compliance boundaries) are required to be identified and when needed properly marked in order to prevent entry by the general public or workers. In a typical environment with many sources of RF EMF this may be a complicated task. However, in most cases it is acceptable to identify exclusion zones with a certain level of overestimation (with more conservative compliance distances than the actual distances) and this makes this assessment easier to perform. It is also important that for some RF EMF sources, especially for low power devices, such analysis is not required.

Appendix I

Comparison of the exclusion zone distances as a function of EIRP and frequency

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

The ITU, in accordance with the WHO, recommends the use of the ICNIRP RF EMF exposure limits that are very similar to the IEEE RF EMF exposure limits. Such limits are used in the majority of countries. However, in some countries more restrictive RF EMF exposure limits are used.

In this appendix the comparison of the exclusion zone (compliance boundary) distances for general public and for occupational exposure are presented.

Because of the shape of the exposure limits, information provided here covers three frequency ranges: from 30 MHz to 400 MHz, 900 MHz (as an example for frequencies between 400 MHz and 2 GHz) and for frequencies above 2 GHz.

Table I.1 presents the ICNIRP RF EMF exposure limits that are considered in this appendix. Exposure limits are given for electric field strength and power density, even if relevant regulations are given as power density only. This is because many administrations prefer to monitor and measure electric field strength and not power density.

Table I.1 – ICNIRP RF EMF exposure limits under consideration

	General public ICNIRP reference levels	Occupational exposure ICNIRP reference levels
30 MHz – 400 MHz	27.7 V/m 2.0 W/m ²	61.0 V/m 10.0 W/m ²
900 MHz	41 V/m 4.5 W/m ²	90 V/m 22.5 W/m ²
2 GHz and above	61 V/m 10 W/m ²	137 V/m 50 W/m ²

Compliance distances in front of BS and transmitting antennas

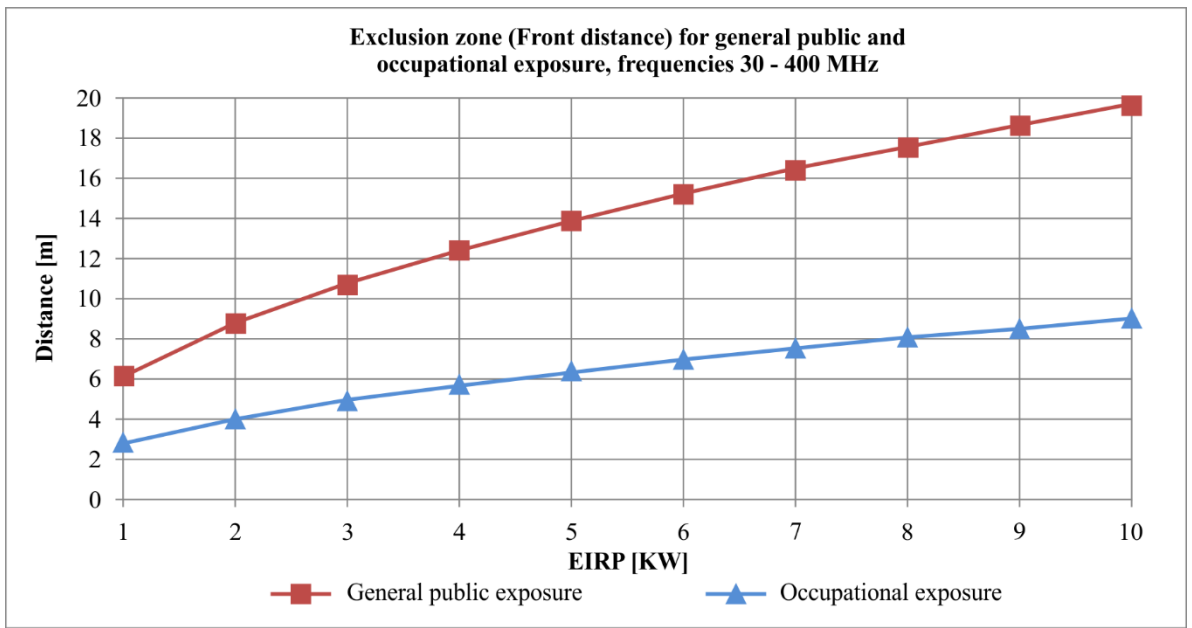
In Tables I.2 to I.4 and in Figures I.1 to I.3 the results of evaluation of exclusion zones for the ICNIRP RF EMF exposure limits in front of transmitting antennas for the overall EIRP from 1 to 10 kW are presented.

Table I.2 – Compliance distances in front of the transmitting antenna: 30 MHz - 400 MHz

	Front distance General public ICNIRP limit 27.7 V/m 2.0 W/m ²	Front distance Occupational exposure ICNIRP limit 61.0 V/m 10.0 W/m ²
EIRP	[m]	[m]
1000 [W] = 60.0 [dBm]	6.21	2.85
2000 [W] = 63.0 [dBm]	8.78	4.03
3000 [W] = 64.8 [dBm]	10.75	4.94

Table I.2 – Compliance distances in front of the transmitting antenna: 30 MHz - 400 MHz

	Front distance General public ICNIRP limit 27.7 V/m 2.0 W/m ²	Front distance Occupational exposure ICNIRP limit 61.0 V/m 10.0 W/m ²
EIRP	[m]	[m]
4000 [W] = 66.0 [dBm]	12.42	5.7
5000 [W] = 67.0 [dBm]	13.88	6.37
6000 [W] = 67.8 [dBm]	15.21	6.98
7000 [W] = 68.5 [dBm]	16.43	7.54
8000 [W] = 69.0 [dBm]	17.56	8.06
9000 [W] = 69.5 [dBm]	18.63	8.55
10000 [W] = 70.0 [dBm]	19.64	9.01



K.153(23)

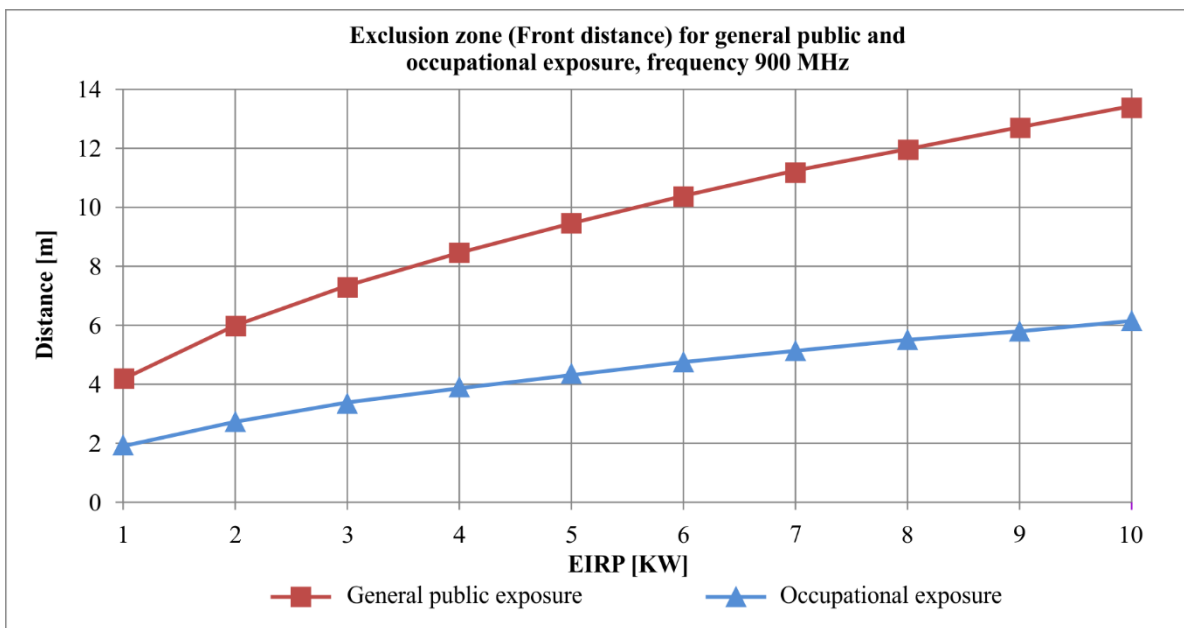
Figure I.1 – Exclusion zone distances in front of the transmitting antenna: 30 MHz – 400 MHz

Table I.3 – Exclusion zone distances in front of the transmitting antenna: 900 MHz

	Front distance General public ICNIRP limit 41 V/m 4.5 W/m ²	Front distance Occupational exposure ICNIRP limit 90 V/m 22.5 W/m ²
EIRP	[m]	[m]
1000 [W] = 60.0 [dBm]	4.21	1.93

Table I.3 – Exclusion zone distances in front of the transmitting antenna: 900 MHz

	Front distance General public ICNIRP limit 41 V/m 4.5 W/m ²	Front distance Occupational exposure ICNIRP limit 90 V/m 22.5 W/m ²
EIRP	[m]	[m]
2000 [W] = 63.0 [dBm]	5.96	2.73
3000 [W] = 64.8 [dBm]	7.3	3.35
4000 [W] = 66.0 [dBm]	8.43	3.86
5000 [W] = 67.0 [dBm]	9.42	4.32
6000 [W] = 67.8 [dBm]	10.32	4.73
7000 [W] = 68.5 [dBm]	11.15	5.11
8000 [W] = 69.0 [dBm]	11.92	5.46
9000 [W] = 69.5 [dBm]	12.64	5.79
10000 [W] = 70.0 [dBm]	13.33	6.11



K.153(23)

Figure I.2 – Exclusion zone distances in front of the transmitting antenna: 900 MHz

Table I.4 – Exclusion zone distances in front of the RBS antenna – above 2 GHz

	Front distance General public ICNIRP limit 61 V/m 10.0 W/m ²	Front distance Occupational exposure ICNIRP limit 137 V/m 50 W/m ²
EIRP	[m]	[m]
1000 [W] = 60.0 [dBm]	2.48	1.14
2000 [W] = 63.0 [dBm]	3.51	1.61
3000 [W] = 64.8 [dBm]	4.29	1.97
4000 [W] = 66.0 [dBm]	4.96	2.27
5000 [W] = 67.0 [dBm]	5.54	2.54
6000 [W] = 67.8 [dBm]	6.07	2.78
7000 [W] = 68.5 [dBm]	6.56	3.01
8000 [W] = 69.0 [dBm]	7.01	3.21
9000 [W] = 69.5 [dBm]	7.44	3.41
10000 [W] = 70.0 [dBm]	7.84	3.59

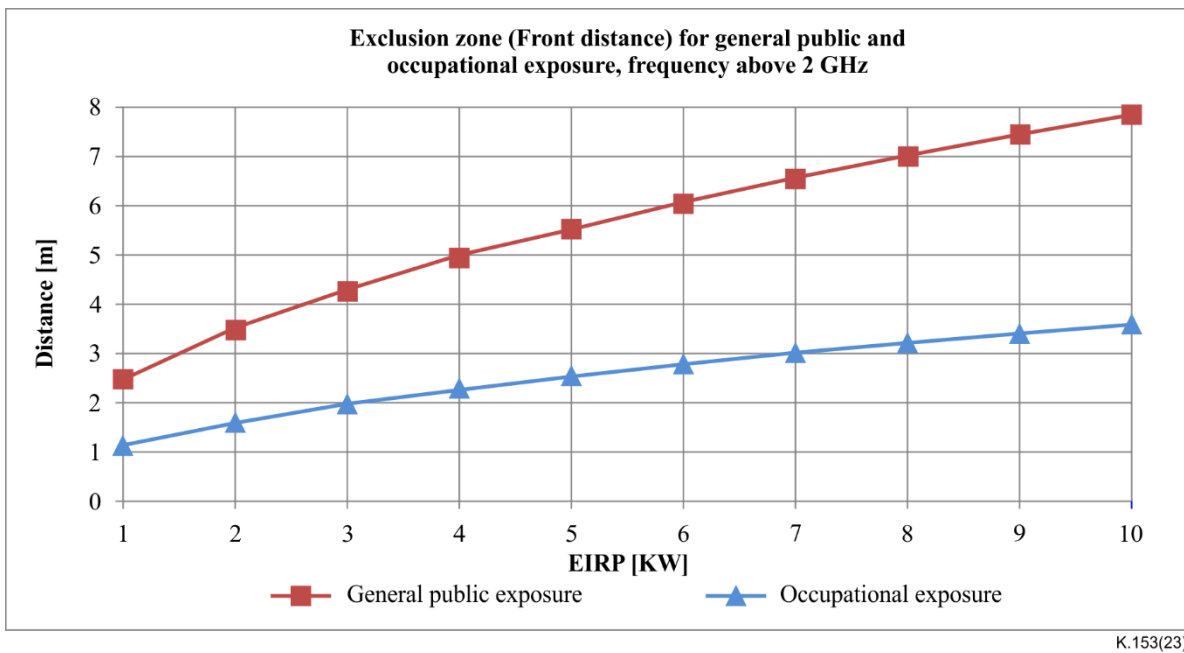


Figure I.3 – Exclusion zone distances in front of the transmitting antenna: 2 GHz and above

The results presented in this appendix are valid in front of all types of transmitting antennas, for the ICNIRP RF EMF exposure limits and for EIRP in the range from 1 kW to 10 kW. However, in the case of 5G BS using beamforming the EIRP should be considered statistically as the exposure level substantially varies in time and space.

In the current standards, the exclusion zones consider the directivity of the radio base station (RBS) antennas and define exclusion distances in other directions, such as the back and side of the RBS antenna.

Appendix II

Exclusion zone around 5G beam-forming (AAS) antennas

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

IMT2020 (5G, NR) beam-forming antennas use different patterns depending for example on the location of the connected users and the type of their activity concerning the use of the mobile equipment [IEC 62232], [ITU-T K.100], [ITU-T K.70], [b-ITU-T K-Sup.9]. Therefore, the actual exclusion zone could not be established in a deterministic way, as its shape varies greatly over time. A statistical approach to take into account the time-averaged antenna patterns, based on assumption that all possible beams are used with the same probability, may be considered as a description of the power distribution around such antennas, but other approaches may be used [IEC 62232].

Therefore, the BS advanced antenna system (AAS) antenna compliance boundary can be assessed based on its traffic envelope radiation pattern. An example of such envelope radiation pattern is presented in Figure II.1 (horizontal, vertical and 3D patterns).

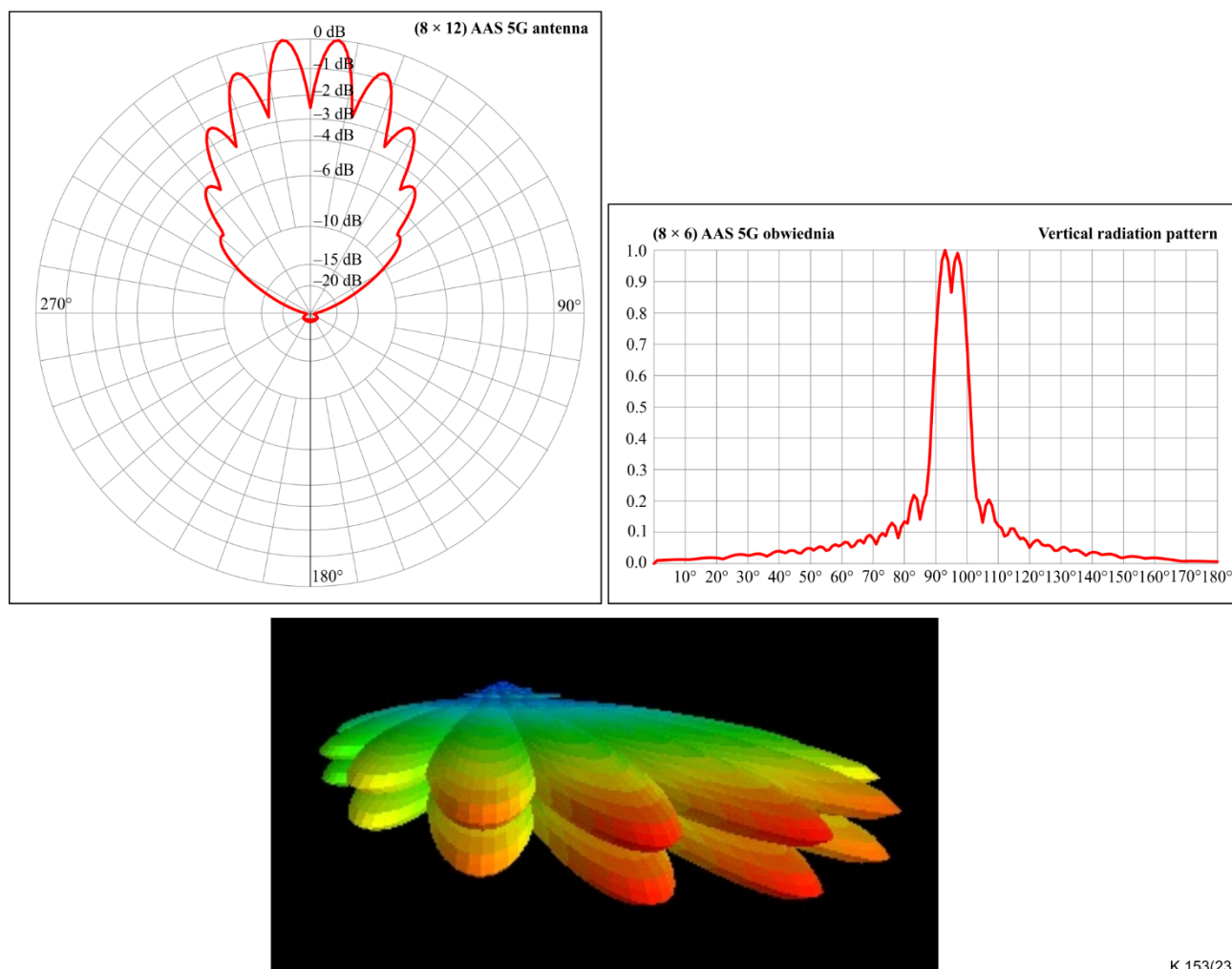


Figure II.1 – Example of the field strength in relation to ICNIRP exposure limits for the 64T64R, $8 \times 4 \times (1 \times 3) \times 2$ AAS 5G antenna, 3.6 GHz, envelope of traffic beams. Antenna mechanical position is pointed to 0° azimuth

K.153(23)

For IMT2020 (5G NR), the broadcast signal contribution to the RF EMF exposure can be neglected, as its fraction in whole signal level is small.

The compliance boundary of massive multiple-input multiple-output (MIMO) or beam steering may be evaluated in a more simplified way as it is defined in clause 6.1.5.7 of [IEC 62232].

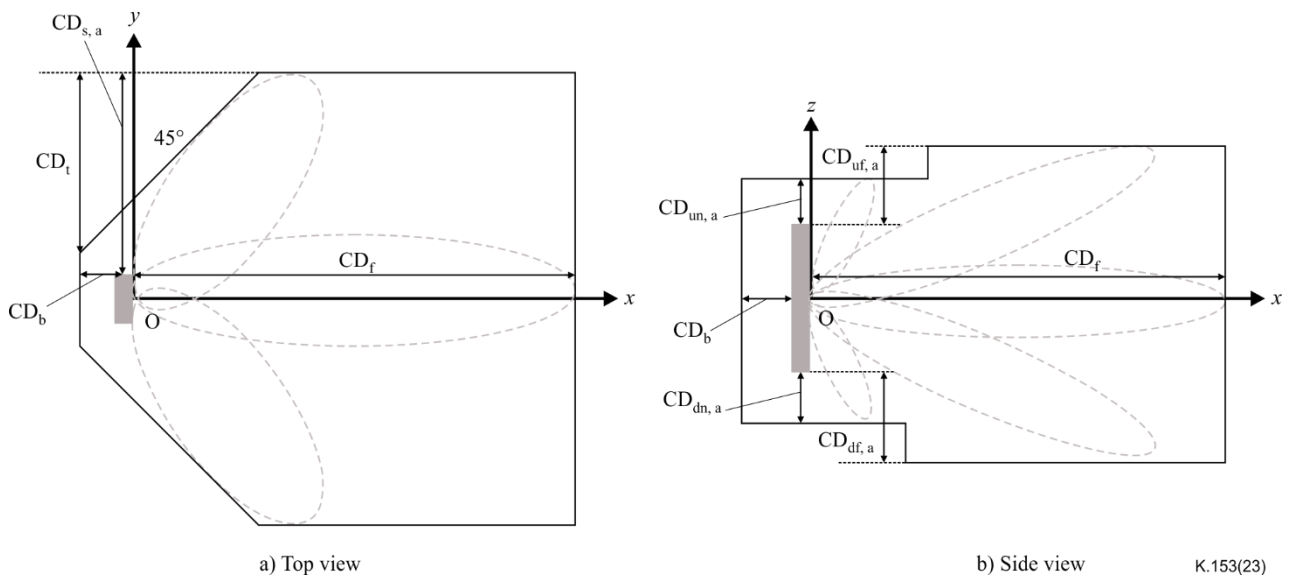


Figure II.2 – Example of compliance boundary shape for BS antennas with beam steering

Appendix III

Exclusion zones in different documents and countries

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

In Figures III.1 to III.5 the shape of the exclusion zones around RBS antennas that are proposed in [IEC 62232], in France and in Spain are presented.

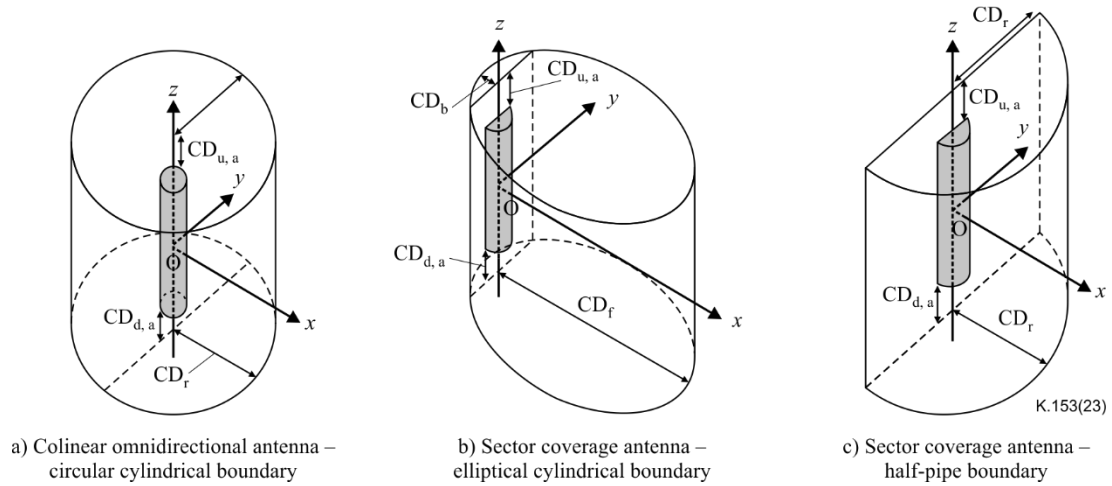


Figure III.1 – Example of circular cylindrical compliance boundaries [IEC 62232]

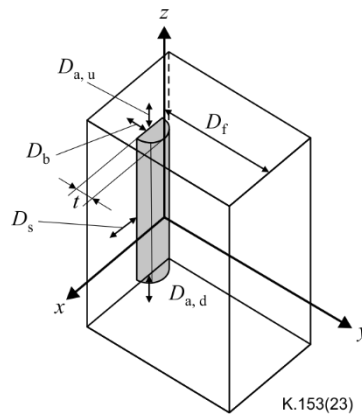


Figure III.2 – Example of box shaped compliance boundary [IEC 62232]

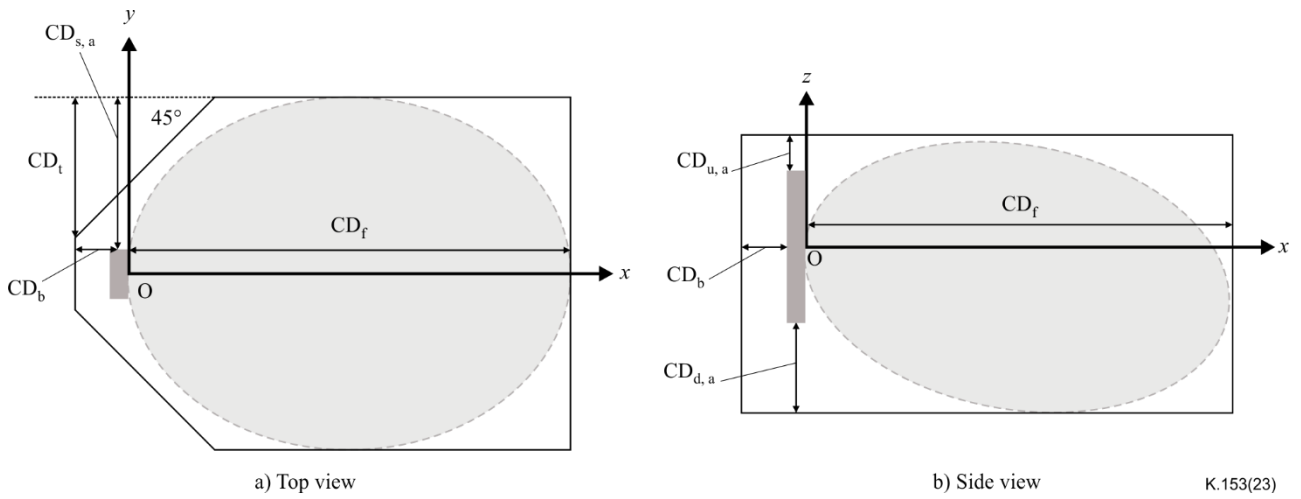


Figure III.3 – Example of truncated box shaped compliance boundary [IEC 62232]

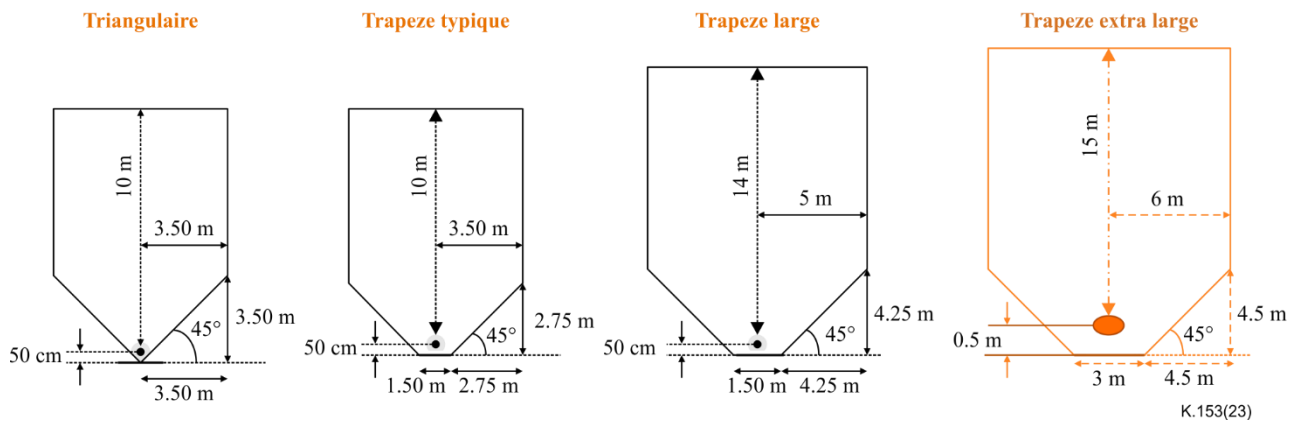


Figure III.4 – Example of exclusion zones applied in France

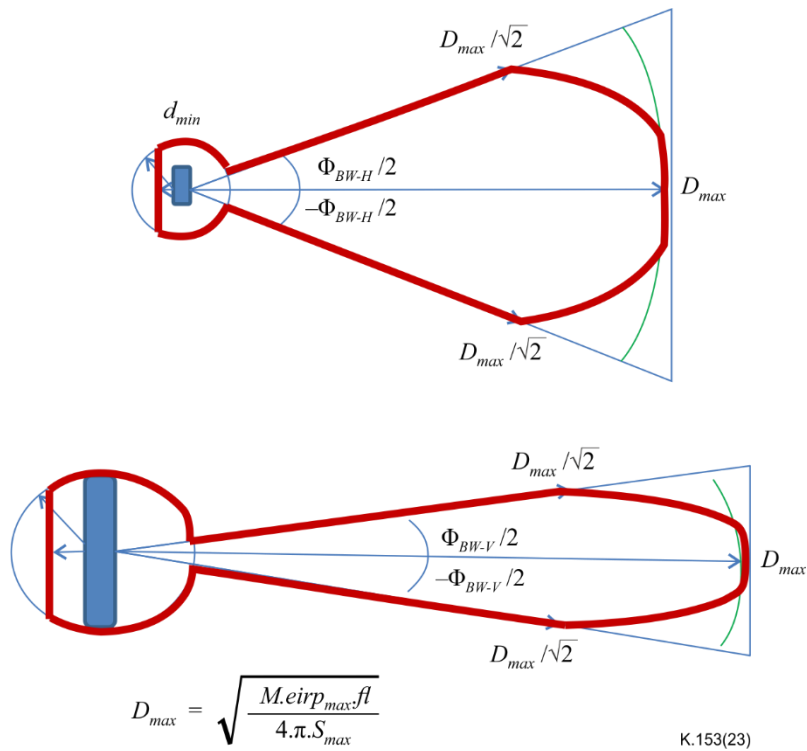


Figure III.5 – Example of exclusion zones applied in Spain

Bibliography

- [b-ITU-T K-Sup.9] ITU-T K-series Recommendations – Supplement 9 (2019), *5G technology and human exposure to radiofrequency electromagnetic fields*.
- [b-ITU-T K-Sup.16] ITU-T K-series Recommendations – Supplement 16 (2022), *Electromagnetic field compliance assessments for 5G wireless networks*.
- [b-ICNIRP 1998]² ICNIRP – International Commission on Non-Ionizing Radiation Protection (1998), *Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)*. *Health Physics* – Volume 74 – Issue 4 – pp. 494-522.
<https://journals.lww.com/health-physics/citation/1998/04000/guidelines_for_limiting_exposure_to_time_varying.13.aspx>
- [b-ICNIRP 2020] ICNIRP – International Commission on Non-Ionizing Radiation Protection (2020), *Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)*. *Health Physics*, 118(5), pp. 483-524.
<<https://www.icnirp.org/cms/upload/publications/ICNIRPrfqi2020.pdf>>
- [b-IEEE C95.1] IEEE Std C95.1:2019, IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, *Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz*.

² When reference [b-ICNIRP] is used, it applies to [b-ICNIRP 1998] and [b-ICNIRP 2020].

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems