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Study Group 2 Question 7

Policies, guidelines, regulations and assessments of human exposure to radio-frequency electromagnetic fields

Output Report on ITU-D Question 7/2

Policies, guidelines, regulations and assessments of human exposure to radio-frequency electromagnetic fields

Study period 2018-2021

Policies, guidelines, regulations and assessments of human exposure to radio-frequency electromagnetic fields: Output Report on ITU-D Question 7/2 for the study period 2018-2021.

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Executive summary

This report produced by the ITU Telecommunication Development Sector (ITU-D) under ITU-D Question 7/2 ("Strategies and policies concerning human exposure to electromagnetic fields") covers a specialist area and refers to scientific expert bodies and opinions to provide context. It is significant to policy-makers, as unnecessarily restrictive policies, regulations and approaches have a negative effect on the provision of radio services. There are countless studies on radio-frequency electromagnetic field (RF-EMF) risks. This report focuses on science-based policies, guidelines, regulations and assessments in respect of human exposure to RF-EMF, without entering the biological arena. The World Health Organization (WHO) established the International EMF Project to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz.[1]

In March 2020, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published an update to the ICNIRP (1998) Guidelines.[2] The Institute of Electrical and Electronics Engineers (IEEE) also published the updated C95.1-2019 standard in October 2019.[3] The ICNIRP and IEEE limits are largely harmonized, and the power-density limits for whole-body exposure to continuous fields are identical above 30 MHz.

The vast majority of countries have adopted RF-EMF exposure limit values based on the ICNIRP Guidelines or IEEE standards; however, some countries have decided to adopt additional measures in order to protect their population. The use of different exposure limits in different countries has raised public concerns. Administrations are encouraged to follow the guidelines set by the science-based ICNIRP and IEEE expert groups, or limits set by their own experts. The best practice for administrations that choose to use international RF-EMF exposure limits is to limit the exposure levels to the thresholds specified in ICNIRP (2020) Guidelines.

RF-EMF exposure monitoring activities are quite widely undertaken around the world. These activities consistently show low levels of RF-EMF in public areas from mobile network antennas and that the levels do not change significantly over time nor differ between countries, regardless of whether the international or more restrictive RF-EMF limits are adopted. In terms of human exposure, there are no technical reasons to restrict the siting of base stations around kindergartens, schools and hospitals, since existing exposure guidelines incorporate safety margins to protect all members of the community.

From the weight of scientific evidence it remains that there is no indication of any adverse health effects from the use of mobile phones or wireless devices. The highest exposure received by the general public is from handheld devices such as mobile phones. Specific energy absorption rate (SAR) measurements for compliance purposes under laboratory conditions with devices configured to operate at maximum powers show values close to the limits. However, the compliance SAR values reported for each model of mobile phone overstate real-life exposure levels. In reality, the devices operate at significantly lower power levels, especially in areas of good reception.

1 WHO. Electromagnetic fields (EMF). The International EMF Project
2 ICNIRP (2020). RF EMF Guidelines 2020
3 IEEE (2019). IEEE C95.1-2019. IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz.

The first 5G NR (New Radio) version was officially released in December 2017. Due to the characteristics of multiple-input multiple-output (MIMO) and millimetre-wave technologies used in the 5th generation mobile communication system, it is urgent to evaluate RF-EMF levels. A pioneer study indicated that the maximum time-averaged power per beam direction was found to be well below the theoretical maximum, and lower than what was predicted by the existing statistical models. Risk communication is also an important method to reduce unnecessary public concerns about RF-EMF exposure. WHO and ITU constantly promote the exchange of knowledge between countries and regions.

The report includes case studies of activities by several countries to limit human exposure to EMF and to effectively raise the awareness of the different stakeholders.

Abbreviations and acronyms

3G	third-generation mobile technology
4G	fourth-generation mobile technology
5G	fifth-generation mobile technology
AP	access point
BDT	Telecommunication Development Bureau
BS	base station
DRL	dosimetric reference limit
EIRP	equivalent isotropic radiated power
EMF	electromagnetic field
ERL	exposure reference level
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICT	information and communication technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
ITU-D	ITU Telecommunication Development Sector
ITU-T	ITU Telecommunication Standardization Sector
ITU-R	ITU Radiocommunication Sector
IMT	International Mobile Telecommunications
MIMO	multiple-input multiple-output
NIR	non-ionizing radiation
NR	New Radio (5G)
RBS	radio base station
RF	radio frequency
RF-EMF	radio-frequency electromagnetic field
SAR	specific absorption rate
SI	International System of Units

(continued)

WHO	World Health Organization
WTDC	World Telecommunication Development Conference
WTSA	World Telecommunication Standardization Assembly

Chapter 1 – Introduction

1.1 Background

The proliferation of cellular base stations and wireless fixed installations around the world, public dislike of large antenna structures and the concern in some countries about possible electromagnetic field (EMF) hazards has led to constraining legislation and regulations to ensure protection of the public.[1] Human hazards have become a significant health issue for regulators, service providers and wireless equipment suppliers. Populations are exposed to different sources of radio-frequency electromagnetic fields (RF-EMF), the levels of which change due to traffic data services, quality-of-service (QoS) requirements, network coverage and capacity extension, and the introduction of new technologies. Limits for RF human exposure contain restrictions on exposure that are intended to assist those with responsibility for the safety of the general public and workers. The dominant sources of human exposure to RF-EMF are transmitters operating on or in close vicinity to the body, such as handheld devices and near-field wireless sources for workers (see the mandate of ITU-D Question 7/2 handed down by the World Telecommunication Development Conference (WTDC-17)).[2] The World Health Organization (WHO) states that: "The use of commercial devices for reducing radiofrequency field exposure has not been shown to be effective".[3]

Wireless communication services use frequencies in RF ranges of the electromagnetic spectrum, which are much lower frequencies than ionizing radiation, such as X-rays or Gamma-rays.[4] RF waves do not have enough energy to either break molecular bonds or cause ionization of atoms in the human body; whence their classification as non-ionizing radiation (NIR). The short-term heating capabilities of high-level RF-EMF exposure (e.g. microwave ovens) are well known. The question is whether there are some other long-term health effects, such as cancer. While some studies have indicated the possibilities of non-thermal effects in living organisms, they have never been substantiated.

Some countries (and cities) adopt more restrictive RF-EMF limits which negatively impact the deployment of radio services, but do not reduce typical public RF-EMF exposure levels.[5,6] The International Commission on Non-Ionizing Radiation Protection (ICNIRP) RF-EMF exposure Guidelines are backed by WHO and constitute the current scientific consensus: "*WHO*

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1 Haim Mazar (2016). Radio Spectrum Management: Policies, Regulations, Standards and Techniques. Chichester, West Sussex: John Wiley & Sons, Ltd., 2016. See Chapter 9, pp. 359–397.

2 ITU. ITU-D study groups. Question 7/2

3 WHO. Newsroom. Fact sheet N°193. Electromagnetic fields and public health: mobile phones. October 2014.

4 Electromagnetic radiation at frequencies above the ultra-violet band are classified as "ionizing radiation" because when incident on matter they have enough energy to effect changes in the atoms by liberating ionizing electrons and thus altering their chemical bonds. Ionizing radiation occurs at frequencies above 2 900 THz (2 900×1012 Hz). This frequency limit corresponds to a wavelength of about 103.4 nm and minimum ionization energy of 12 eV.

5 Sanjay Sagar et al. (2018). Radiofrequency electromagnetic field exposure in everyday microenvironments in Europe: A systematic literature review. *Journal of Exposure Science & Environmental Epidemiology*, 28(2):147–60, March 2018.

6 Hamed Jalilian et al. (2019). Public exposure to radiofrequency electromagnetic fields in everyday micro-environments: An updated systematic review for Europe. *Environmental Research*, 176:108517, September 2019.

encourages the establishment of exposure limits and other control measures that provide the same or similar level of health protection for all people. It endorses the guidelines of ICNIRP and encourages Member States to adopt these international guidelines".[7] Nevertheless, national regulations have priority status in their countries and, under the influence of social, economic and political factors, the values adopted in each country may vary.

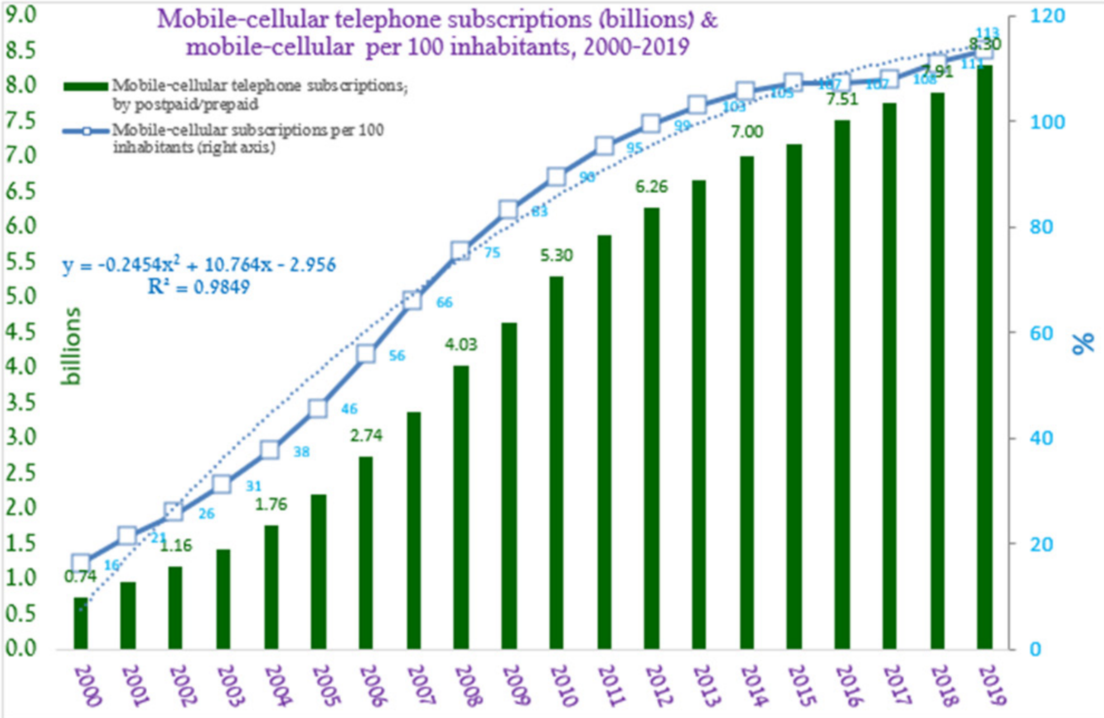
Some of the public remain concerned and claim that not all possible health effects were studied. An analysis of the balance between cost and potential hazards is essential. It is scientifically impossible to prove absolute safety (the null hypothesis) of any physical agent;[8] and it is also impossible to prove the negative (that something does not exist). While absolute proof does not logically exist, national regulators are placed under public pressure. To answer this dilemma, some countries say that they apply the precautionary principle to restrict possible human hazards. Application of the precautionary approach and the "as low as reasonably achievable" (ALARA) concept to the RF-EMF health-risk management problem may replace the two-state risk management model (above/below the threshold), allowing the introduction of other factors.

It is a trade-off between the remaining uncertainty (and the damage in the case that the worst case turns out to be true) versus implementing stricter requirements (that require additional resources and cause reduced quality of service) and other wider societal impacts.[9] WHO advises that if regulatory authorities react to public pressure by introducing precautionary limits in addition to the already existing science-based limits, they should be aware that this undermines the credibility of the science and exposure limits.[10] The ICNIRP (2020) Guidelines say that there is no evidence that additional precautionary measures will result in a benefit to the health of the population.[11] It is important to involve all stakeholders in community-awareness activities – government agencies, the private Internet sector, non-governmental organizations, community groups and the general public.

Evidence of the proliferation of cellular base stations around the world can be gleaned from **Figure 1** (based on ITU indicators),[12] which depicts mobile-cellular subscriptions and world-average cellular penetration per 100 inhabitants, years 2000 to 2019. The 24th Edition/December 2020 indicates that there were 8.3 billion subscribers in 2019 and 111 cellular telephone subscriptions per 100 inhabitants. As an indication, roughly every 1 000 subscribers need one cellular mast,[13] and it is estimated that there are more than 8 million base stations around the world.

7 WHO (2006). Framework for Developing Health-Based EMF Standards, pp. 7-8.
8 IEEE (2005). IEEE C95.1-2005. IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, p. 2.
9 Olivia Wu et al. (2012). Mobile Phone Use for Contacting Emergency Services in Life-threatening Circumstances. *The Journal of Emergency Medicine*, 52(3):291–298.e293, March 2012.
10 WHO (2002). Health Topics. Electromagnetic fields. Establishing a dialogue on risks from electromagnetic fields
11 ICNIRP (2020). International Commission on Non-Ionizing Radiation Protection (ICNIRP). RF EMF Guidelines 2020. Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz) 2020. *Health Physics*, 118(5):483-524, May 2020.
12 ITU. World Telecommunication/ICT Indicators Database
13 Haim Mazar (2016). Radio Spectrum Management: Policies, Regulations, Standards and Techniques. Chichester, West Sussex: John Wiley & Sons, Ltd., 2016. See Chapter 9, Section 9.7.2

Figure 1: Global mobile-cellular telephone subscription rate



Source: Haim Mazar, adapted from ITU indicators (24th Edition/December 2020)

1.2 Scope of the report

This ITU-D report under Question 7/2 covers a specialist area and refers to scientific expert bodies and opinions to provide context. It is significant for policy-makers, as unnecessarily restrictive policies, regulations and approaches have a negative effect on the provision of radio services. There are many studies on EMF risks.[14] This report focuses on science-based policies, guidelines, regulations and assessments in respect of human exposure to RF-EMF, without entering the biological arena. WHO, the United Nations specialized agency for global health, established the International EMF Project in 1996 to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz.[15]

The 2017 Final Report of ITU-D Study Group 2 Question 7/2 on "Strategies and policies concerning human exposure to EMF" from the 6th study period (2014-2017)[16] is significant. The 2017 report collected and disseminated information concerning exposure to RF-EMF to support national administrations of ITU Member States, particularly in developing countries, and to advance appropriate national regulations. It assisted administrations in listening to, and responding to, public concerns related to RF-EMF.

There are many reasons to revise the previous Final Report on Question 7/2. Following the revision of the ICNIRP Guidelines in March 2020, the international EMF limits were updated; and these changes have implications for the regulatory framework. Also, IEEE Standard C95.1-2005

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14 RWTH Aachen University. Internet information platform EMF-portal.
15 WHO. Electromagnetic fields (EMF). The International EMF Project
16 ITU-D. Final Report on ITU-D Question 7/2 for the study period 2014-2017. Strategies and policies concerning human exposure to electromagnetic fields. ITU, 2017.

has been revised (see IEEE C95.1-2019).[17] New case studies are included in the present report to reflect national activities on RF-EMF. The October 2018 ITU-D workshop on EMF provides significant insights.[18] Moreover, there are fruitful activities on RF-EMF within the three ITU Sectors (ITU Radiocommunication Sector (ITU-R), ITU Telecommunication Standardization Sector (ITU-T) and ITU-D) through:

- Resolution 176 (Rev. Dubai, 2018) of the Plenipotentiary Conference, on measurement and assessment concerns related to human exposure to EMF.
- Resolution 72 (Rev. Hammamet, 2016) of the World Telecommunication Standardization Assembly (WTSA), on measurement and assessment concerns related to human exposure to EMF. This resolution may be revised again at the next WTSA in 2022.
- Resolution 62 (Rev. Buenos Aires, 2017) of the World Telecommunication Development Conference (WTDC), on assessment and measurement of human exposure EMF, and revised Question 7/2, on strategies and policies concerning human exposure to EMF.[19]

Based on the revision of WTDC-17 Resolution 62 and the revision of Question 7/2, the present report updates and revises the 2017 Final Report on Question 7/2 and incorporates new material on national policies, assessments and exposure limits, such as the ICNIRP (2020) Guidelines and IEEE C95.1 (2019).

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17 IEEE (2019). IEEE C95.1-2019. IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz.

18 ITU. ITU-D Session on modern policies, guidelines, regulations and assessments of human exposure to RF-EMF, Geneva, 10 October 2018.

19 WTDC (Buenos Aires, 2017). Final Report. ITU, 2018.

Chapter 2 – ITU activities

2.1 Resolution 176 (Rev. Dubai, 2018) of the Plenipotentiary Conference

The Plenipotentiary Conference provides the ITU framework on EMF. Resolution 176 (Rev. Dubai, 2018)[20] *resolves to instruct the Directors of the three Bureaux*:

1. to collect and disseminate information concerning exposure to EMF, including on EMF measurement methodologies, in order to assist national administrations, particularly in developing countries, to develop appropriate national regulations;
2. to work closely with all relevant organizations in the implementation of this resolution, as well as Resolution 72 (Rev. Hammamet, 2016) of WTSA and Resolution 62 (Rev. Buenos Aires, 2017) of WTDC, in order to continue and enhance the technical assistance provided to Member States.

In addition, it *instructs the Director of the Telecommunication Development Bureau, in collaboration with the Director of the Radiocommunication Bureau and the Director of the Telecommunication Standardization Bureau*

1. to conduct regional or international seminars and workshops in order to identify the needs of developing countries and build human capacity in regard to measurement of EMF related to human exposure to these fields;
2. to encourage Member States in the various regions to cooperate in sharing expertise and resources and identify a focal point or regional cooperation mechanism, including if required a regional centre, so as to assist all Member States in the region in measurement and training;
3. to encourage relevant organizations to continue undertaking necessary scientific studies to investigate possible health effects of EMF radiation on the human body;
4. to formulate necessary measures and guidelines in order to help mitigate possible health effects of EMF radiation on the human body;
5. to encourage Member States to conduct periodic reviews to ensure that ITU recommendations and other relevant international standards related to the exposure to EMF are followed.

2.2 Resolution 62 (Rev. Buenos Aires, 2017) of WTDC

WTDC Resolution 62 (Rev. Buenos Aires, 2017) *instructs ITU-D Study Group 2* to cooperate with ITU-T Study Group 5 and ITU-R Study Groups 1, 4, 5 and 6, in order to achieve the following goals:

i) collaborate with ITU-T Study Group 5 in particular to update the mobile EMF guide application relating to human exposure to EMF and the guidance on its implementation, as a matter of high priority;
ii) contribute to the organization of seminars, workshops or training on the subject of EMF;
iii) ensure wide dissemination of ITU publications and literature on EMF issues;

[20] ITU. Final Acts of the Plenipotentiary Conference (Dubai, 2018). ITU, 2019.

iv) contribute to preparation of the guide on the use of ITU-T publications on electromagnetic compatibility and safety and on measurement methodologies, the need for measurements to be performed by a "qualified and certified radio engineer or technician" and the criteria for this "qualified radio engineer or technician", as well as system specifications;

v) continue to cooperate with WHO, ICNIRP, IEEE and other relevant international organizations with regard to awareness and dissemination of information to the membership and the public.

Therefore, this report refers to the updated resolution adopted by the Plenipotentiary Conference in Dubai, 2018, the updated resolution and Question adopted by WTDC-17 in Buenos Aires, 2017 and the latest ICNIRP Guidelines and IEEE standard.

2.3 Resolution 72 of WTSA and deliverables of ITU-T Question 3/5

The 2016 World Telecommunication Standardization Assembly (WTSA-16), held in Hammamet, Tunisia, agreed on revisions to the WTSA resolution on human exposure to EMF – Resolution 72 (Rev. Hammamet, 2016).[21] ITU-T activities on EMF are carried out in ITU-T Study Group 5 under Question 3/5 ("Human exposure to electromagnetic fields (EMFs) due to digital technologies").[22] ITU-T Recommendations on EMF appear in the ITU-T K-series.[23]

21 WTSA (Hammamet, 2016). Resolution 72 (Rev. Hammamet, 2016), on measurement and assessment concerns related to human exposure to EMF.

22 ITU-T Study Group 5. List of Questions and rapporteurs (study period 2017-2020).

23 ITU-T. ITU-T K-series Recommendations.

Chapter 3 – Updated international RF-EMF exposure limits

3.1 General

Managing compliance with human exposure limits for EMFs is a significant health and safety issue for regulators, service providers and wireless equipment suppliers. There is a large variation among countries on the regulations and the specific implementation measures for protecting the general public and workers from RF-EMF originating from transmitters: *"WHO encourages the establishment of exposure limits and other control measures that provide the same or similar level of health protection for all people. It endorses the guidelines of ICNIRP and encourages Member States to adopt these international guidelines"*.[24]

RF-EMF exposure monitoring activities are quite widely undertaken around the world; however, the scale and scope of the monitoring activities are very diverse. These activities consistently show low levels of exposure in public areas from mobile network antennas and indicate that the levels do not change significantly over time nor differ between countries, and are similar regardless of whether international or restrictive RF-EMF limits are adopted.[25, 26]

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has revised its 1998 ICNIRP Guidelines for Limiting Exposure to Time-varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz).[27] Following an extensive public consultation process in which ITU provided 32 comments as an inter-Sectoral response, the final ICNIRP Guidelines were published in 2020. On 4 October 2019, the Institute of Electrical and Electronics Engineers (IEEE) published C95.1-2019 "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 0 Hz to 300 GHz", an update to IEEE C95.1-2005 standard.

Irrespective of the finalization of these RF-EMF 'Guidelines' and 'standard', owing to perceived uncertainties several legislative bodies have enacted additional measures, for example adopting limits that are more restrictive than the limits of ICNIRP, or advising personal steps to reduce exposures. Measurements show that typical RF-EMF exposure levels in public areas are not reduced by adopting more restrictive limits. A survey from the European Commission found that restrictive limits and other precautionary measures are associated with higher levels of public concern. The migration from GSM to 3G/UMTS and later mobile technologies is also a way to reduce exposure to RF-EMF from devices due to more efficient power-control algorithms.[28]

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24 WHO (2006). Framework for Developing Health-Based EMF Standards, pp. 7-8

25 Hamed Jalilian et al. (2019). Public exposure to radiofrequency electromagnetic fields in everyday micro-environments: An updated systematic review for Europe. *Environmental Research*, 176:108517, September 2019.

26 Jack Rowley et al. (2012). Comparative international analysis of radiofrequency exposure surveys of mobile communication radio base stations. *Journal of Exposure Science and Environmental Epidemiology*, 22(3):304–315, May/June 2012.

27 ICNIRP (1998). Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz) 1998.

28 ITU-T. Series K Supplement 13 (05/2018). Radiofrequency electromagnetic field (RF-EMF) exposure levels from mobile and portable devices during different conditions of use.

The national authority for assigning frequencies and environment protection or public health may be responsible for verifying compliance. The local planning authority and town councils may also be responsible for the process. In order to demonstrate compliance, the applicant (transmitter operator) should provide relevant information. Some authorities adopt predictive modelling to calculate the exposure levels or compliance zone around the antenna.

Random sample measurements may be used to monitor RF-EMF levels around a transmitter, especially in areas of community interest (such as schools and hospitals), at the initiative of the authorities or in response to concerns raised by the general public. However, specific requirements for such locations are not supported by scientific evidence and, as noted in **Section 4.3**, measurements consistently show low levels of exposure in public areas from mobile network antennas.

Administrations are encouraged to follow the guidelines set by the science-based ICNIRP and IEEE expert groups, or limits set by their own experts. It is strongly recommended to adopt harmonized international standards and EMF exposure limits. **It should be emphasized that IEEE C95.1-2019 and ICNIRP 2020 Guidelines are largely harmonized**.

3.2 ICNIRP (2010) and (2020) Guidelines in force

3.2.1 Overview

The ICNIRP Guidelines are as follows:

1. ICNIRP (1998): Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz).
2. ICNIRP (2010): Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz).[29]
3. ICNIRP (2020): Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz).

The limits below 100 kHz are the ones published in ICNIRP (2010). **With the publication of the 2020 RF Guidelines, the 1998 Guidelines have become obsolete.**

1. ***How ICNIRP (2020) Guidelines were prepared***: Identify scientific data on effects of exposure; determine effects considered both adverse to humans and scientifically substantiated; identify minimum exposure levels needed to produce harm; and apply reduction factors that are more stringent for the general public than for workers. This results in exposure restrictions with a large margin of safety.
2. The ***scientific basis***: Major reviews and original papers evaluate adverse health effects on nerve stimulation (up to ~10 MHz, limits from 2010 Guidelines) and heating (from ~100 kHz). There is no evidence for cancer, electromagnetic hypersensitivity, infertility or other health effects. The identified adverse health effects are deep body temperature increases above 1 °C and local tissue temperature above 41 °C.
3. ***Physics and temperature***: Different quantities are used to correlate with temperature, depending on frequency and duration of exposure. For example, for continuous local exposures, absorbed energy rate (SAR) at lower frequencies (≤ 6 GHz), and absorbed power density at higher frequencies (> 6 GHz).

[29] ICNIRP (2010). Guidelines for limiting exposure to time- varying electric and magnetic fields (1 Hz – 100 kHz)

3.2.2 Elaborating the tables and figures of ICNIRP (2020)

This section details the tables (Tables 1, 5 and 6) of ICNIRP (2020) that are most relevant for the Question 7/2 report. The following figures (not from the Guidelines) depict the values. Underlined text[30] indicates the significant parameter. Comparisons with ICNIRP 2010 (for frequencies lower than 100 kHz) are inserted.

Table 1: (ICNIRP Table 1) Quantities and corresponding SI units used in the Guidelines

Quantity	Symbol*	Unit
Absorbed energy density	U_{ab}	joule per square meter (J m^{-2})
Incident energy density	U_{inc}	joule per square meter (J m^{-2})
Plane-wave equivalent incident energy density	U_{eq}	joule per square meter (J m^{-2})
Absorbed power density	S_{ab}	watt per square meter (W m^{-2})
Incident power density	S_{inc}	watt per square meter (W m^{-2})
Plane-wave equivalent incident power density	S_{eq}	watt per square meter (W m^{-2})
Induced electric field strength	E_{ind}	volt per meter (V m^{-1})
Incident electric field strength	E_{inc}	volt per meter (V m^{-1})
Incident magnetic field strength	H_{inc}	ampere per meter (A m^{-1})
Specific energy absorption	SA	joule per kilogram (J kg^{-1})
Specific energy absorption rate	SAR	watt per kilogram (W kg^{-1})
Electric current	I	ampere (A)
Frequency	f	hertz (Hz)
Time	t	second (s)

* *Italicized* symbols represent variables; quantities are described in scalar (not vector) form because direction is not used to derive the basic restrictions or reference levels.

Table 2 and **Table 3** (from ICNIRP 2020 Tables 5 and 6, respectively) detail reference levels for exposure, to 'electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)'.

[30] The underlined text in this section does not appear as underlined in the original tables.

Table 2: (ICNIRP Table 5) Reference levels for exposure, averaged over 30 minutes and the whole body

Exposure scenario	Frequency range	Incident E-field strength; E_{inc} (V m^{-1})	Incident H-field strength; H_{inc} (A m^{-1})	Incident power density; S_{inc} (W m^{-2})
Occupational	0.1 – 30 MHz	$660/f_M^{0.7}$	$4.9/f_M$	NA
	>30 – 400 MHz	61	0.16	10
	>400 – 2000 MHz	$3f_M^{0.5}$	$0.008f_M^{0.5}$	$f_M/40$
	>2 – 300 GHz	**NA**	**NA**	**50**
General Public	0.1 – 30 MHz	$300/f_M^{0.7}$	$2.2/f_M$	NA
	>30 – 400 MHz	s27.7	0.073	2
	>400 – 2000 MHz	$1.375f_M^{0.5}$	$0.0037f_M^{0.5}$	$f_M/200$
	>2 – 300 GHz	**NA**	**NA**	**10**

Notes (from ICNIRP 2020):
1. 'NA' signifies 'not applicable' and does not need to be taken into account when determining compliance.
2. f_M is frequency in MHz.
3. S_{inc}, E_{inc} and H_{inc} are to be averaged over 30 minutes over the whole-body space. Temporal and spatial averaging of each of E_{inc} and H_{inc} must be conducted by averaging over the relevant square values (see Eqn. 8 in Appendix A for details).
4. For frequencies of 100 kHz to 30 MHz, regardless of the far-field/near-field zone distinctions, compliance is demonstrated if neither E_{inc} or H_{inc} exceeds the above reference level values.
5. For frequencies of >30 MHz to 2 GHz: (a) within the far-field zone: compliance is demonstrated if either S_{inc}, E_{inc} or H_{inc} does not exceed the above reference level values (only one is required); S_{eq} may be substituted for S_{inc}; (b) within the radiative near-field zone, compliance is demonstrated if either S_{inc}, or both E_{inc} and H_{inc} do not exceed the above reference level values; and (c) within the reactive near-field zone: compliance is demonstrated if both E_{inc} and H_{inc} do not exceed the above reference level values; S_{inc} cannot be used to demonstrate compliance, and so basic restrictions must be assessed.
6. For frequencies of >2 GHz to 300 GHz: (a) within the far-field zone: compliance is demonstrated if S_{inc} does not exceed the above reference level values; S_{eq} may be substituted for S_{inc}; (b) within the radiative near-field zone, compliance is demonstrated if S_{inc} does not exceed the above reference level values; and (c) within the reactive near-field zone, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.

Table 3: (ICNIRP Table 6) Reference levels for local exposure, averaged over 6 minutes

Exposure scenario	Frequency range	Incident E-field strength; E_{inc} (V m^{-1})	Incident H-field strength; H_{inc} (A m^{-1})	Incident power density; S_{inc} (W m^{-2})
Occupational	0.1 – 30 MHz	$1504/f_M^{0.7}$	$10.8/f_M$	NA
	>30 – 400 MHz	139	0.36	50
	>400 – 2000 MHz	$10.58f_M^{0.43}$	$0.0274f_M^{0.43}$	$0.29f_M^{0.86}$
	>2 – 6 GHz	NA	NA	200
	>6 – <300 GHz	NA	NA	$275/f_G^{0.177}$
	300 GHz	NA	NA	100
General Public	0.1 – 30 MHz	$671/f_M^{0.7}$	$4.9/f_M$	NA
	>30 – 400 MHz	62	0.163	10
	>400 – 2000 MHz	$4.72f_M^{0.43}$	$0.0123f_M^{0.43}$	$0.058f_M^{0.86}$
	>2 – 6 GHz	NA	NA	40
	>6 – 300 GHz	NA	NA	$55/f_G^{0.177}$
	300 GHz	NA	NA	20

Notes (from ICNIRP 2020):
1. 'NA' signifies 'not applicable' and does not need to be taken into account when determining compliance.
2. f_M is frequency in MHz; f_G is frequency in GHz.
3. S_{inc}, E_{inc} and H_{inc} are to be averaged over 6 minutes, and where spatial averaging is specified in Notes 6-7, over the relevant projected body space. Temporal and spatial averaging of each of E_{inc} and H_{inc} must be conducted by averaging over the relevant square values (see Eqn. 8 in Appendix A for details).
4. For frequencies of 100 kHz to 30 MHz, regardless of the far-field/near-field zone distinctions, compliance is demonstrated if neither peak spatial E_{inc} or peak spatial H_{inc}, over the projected whole-body space, exceeds the above reference level values.
5. For frequencies of >30 MHz to 6 GHz: (a) within the far-field zone, compliance is demonstrated if one of peak spatial S_{inc}, E_{inc} or H_{inc}, over the projected whole-body space, does not exceed the above reference level values (only one is required); S_{eq} may be substituted for S_{inc}; (b) within the radiative near-field zone, compliance is demonstrated if either peak spatial S_{inc}, or both peak spatial E_{inc} and H_{inc}, over the projected whole-body space, does not exceed the above reference level values; and (c) within the reactive near-field zone: compliance is demonstrated if both E_{inc} and H_{inc} do not exceed the above reference level values; S_{inc} cannot be used to demonstrate compliance; for frequencies >2 GHz, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.
6. For frequencies of >6 GHz to 300 GHz: (a) within the far-field zone, compliance is demonstrated if S_{inc}, averaged over a square 4-cm^2 projected body surface space, does not exceed the above reference level values; S_{eq} may be substituted for S_{inc}; (b) within the radiative near-field zone, compliance is demonstrated if S_{inc}, averaged over a square 4-cm^2 projected body surface space, does not exceed the above reference level values; and (c) within the reactive near-field zone, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.
7. For frequencies of >30 GHz to 300 GHz, exposure averaged over a square 1-cm^2 projected body surface space must not exceed twice that of the square 4-cm^2 restrictions.

In its introduction, ICNIRP (2020) states: "*This publication replaces the 100 kHz to 300 GHz part of the ICNIRP (1998) radiofrequency Guidelines, as well as the 100 kHz to 10 MHz part of the ICNIRP (2010) low-frequency Guidelines*". The paragraph 'Scientific basis for limiting radiofrequency exposure 100 kHz to 10 MHz EMF frequency range: Relation between the present and other ICNIRP Guidelines' specifies that ICNIRP (2010) and ICNIRP (2020) are based on different biological mechanisms: the first on nerve stimulation and is instantaneous below 10 MHz, the second on thermal effect, produced by power over time; averaging is diverse. Below 100 kHz, ICNIRP (2010) should be applied. Between 100 kHz and 10 MHz both mechanisms may exist, in that case, the stringent value for every frequency should be followed.

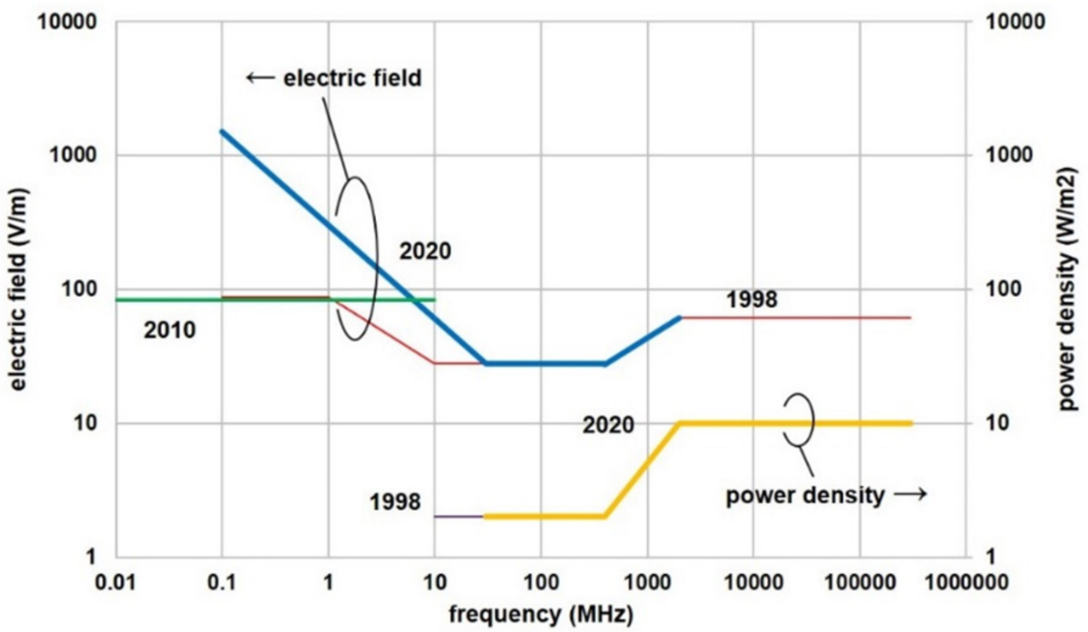
Moreover, ICNIRP (2020) Table 8 states (pay attention to the bold text) "*reference levels for **local exposure** to EMFs from 100 kHz to 10 MHz (unperturbed rms values), for **peak values**, the occupational limit is 170 V/m and the general public is 83 V/m*".

Figure 2, **Figure 3**, **Figure 4** and **Figure 5** from ICNIRP appear in the "Differences between the ICNIRP (2020) and previous guidelines",[31] which are clearer but could not be included in the Health Physics publication. The units of the two y-axes (i.e. electric field and power density) are independent of each other. Local exposure reference levels were not given in the ICNIRP (1998) and ICNIRP (2010) Guidelines. The reference levels of ICNIRP (2020) stop for electric field at frequencies above 2 000 MHz, and start for power density above 30 MHz (see ICNIRP Tables 6 and 7 and **Figures 2, 3, 4** and **5**).

The four following figures[32] have similarities. The whole-body levels are for 30 minutes averaging and the local levels for 6 minutes. To focus the reader and depict the differences, the titles are simplified: 'from 100 kHz to 300 GHz frequency range' is not repeated and the specifics are underlined.

Figure 2 below depicts the significant changes below 30 MHz between ICNIRP (1998), ICNIRP (2010) and ICNIRP (2020); moreover, there is extensive discontinuity at 100 kHz: 83 V/m (ICNIRP 2010, Table 4) versus $300/f_M^{0.7} = 300/0.1^{0.7} \approx$ 1 500 V/m (ICNIRP 2020, Table 5).

Figure 2: Whole-body average reference levels for the general public for the ICNIRP (1998), ICNIRP (2010) and ICNIRP (2020) Guidelines

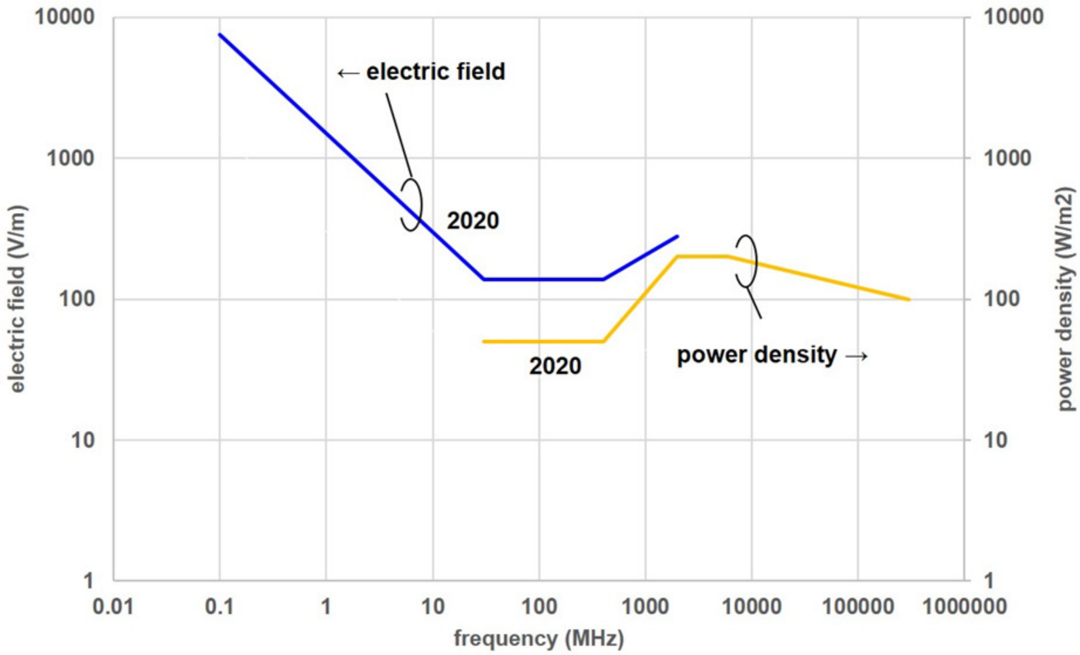


31 ICNIRP. Differences between the ICNIRP (2020) and previous guidelines

32 Retrieved on 1 November 2020 from: https://www.icnirp.org/en/differences.html

For the general public ICNIRP (2010) Table 4, **83 v/m** and ICNIRP (2020) Table 5, $300/f_M^{0.7}$ intersect at **6.27** MHz. As the overall reference levels for the entire frequency range to be observed in practice are the lower ones for every frequency, the green ICNIRP (2010) line should be followed, and for higher frequencies the blue ICNIRP (2020) line. See **Figure 7** and **Figure 8**, where the ICNIRP (2020) limits below 6.27 MHz are truncated for the general public, and at 6.94 MHz for occupational exposure.[33] As ICNIRP (1998) is obsolete, ICNIRP (2010) is most relevant for frequencies 100 kHz and lower; the reference levels below 100 kHz for the general public are 83 V/m (ICNIRP (2010)).

Figure 3: ICNIRP (2020) reference levels for the general public applying to local exposures ≥6 min



[33] ICNIRP (2010) Table 3 and ICNIRP (2020) Table 5 intersect at 6.94 MHz, exposure limit 170 V/m, for occupational exposure.

Figure 4: Whole-body average reference levels for workers for the ICNIRP (1998), ICNIRP (2010) and ICNIRP (2020) Guidelines

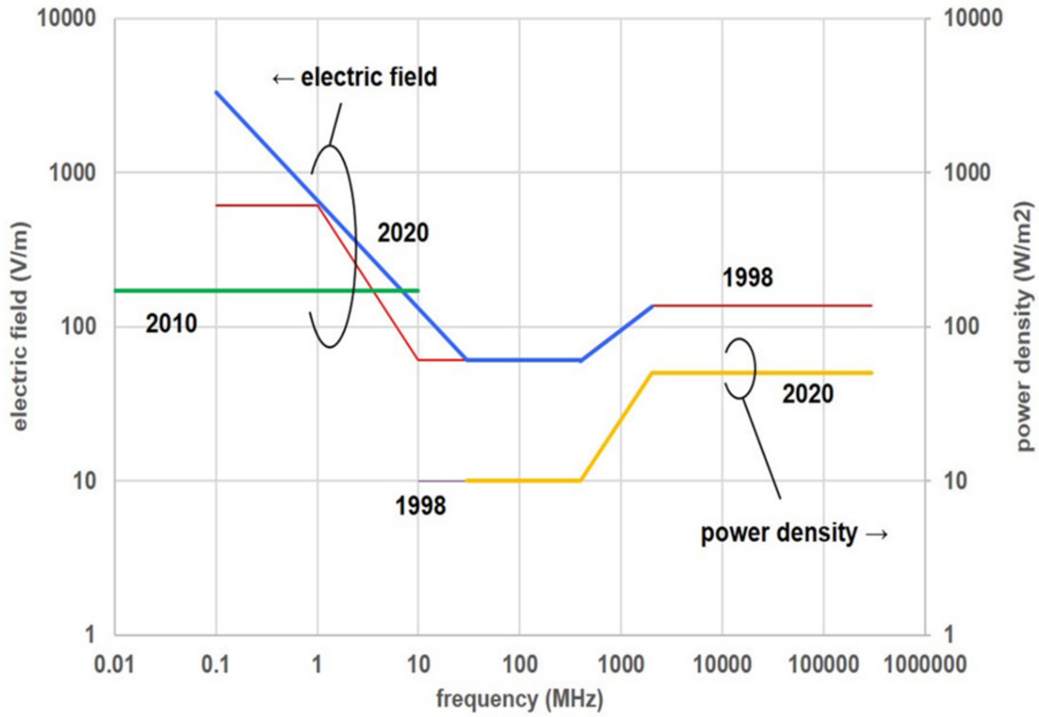


Figure 5: Reference levels for workers applying to local exposures ≥6 min for ICNIRP (2020) Guidelines

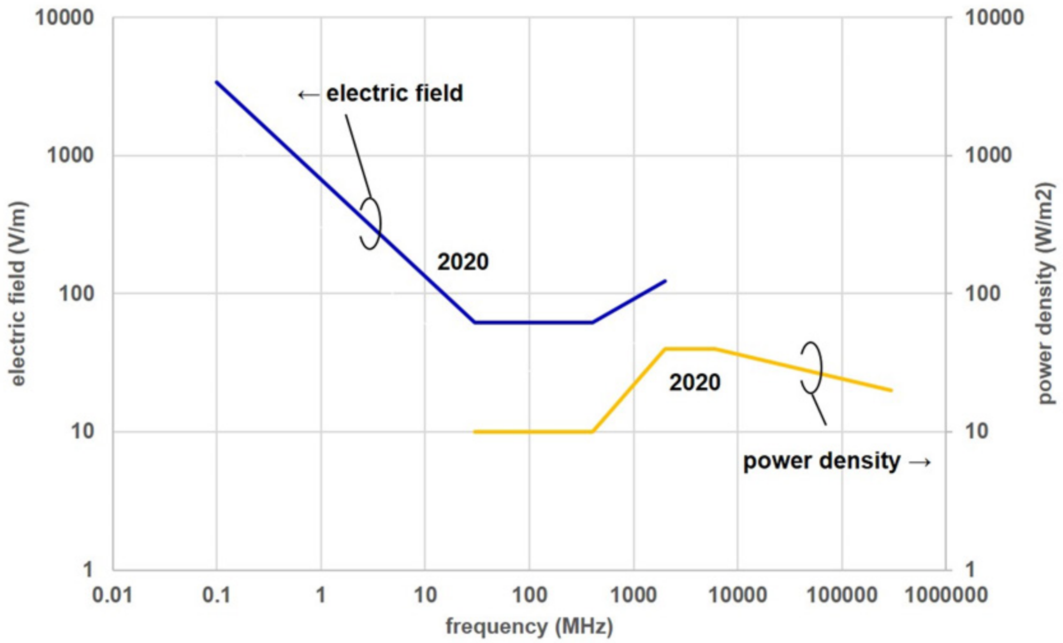


Table 4[34] provides an overview of the basic restrictions contained in the ICNIRP (2020) Guidelines.

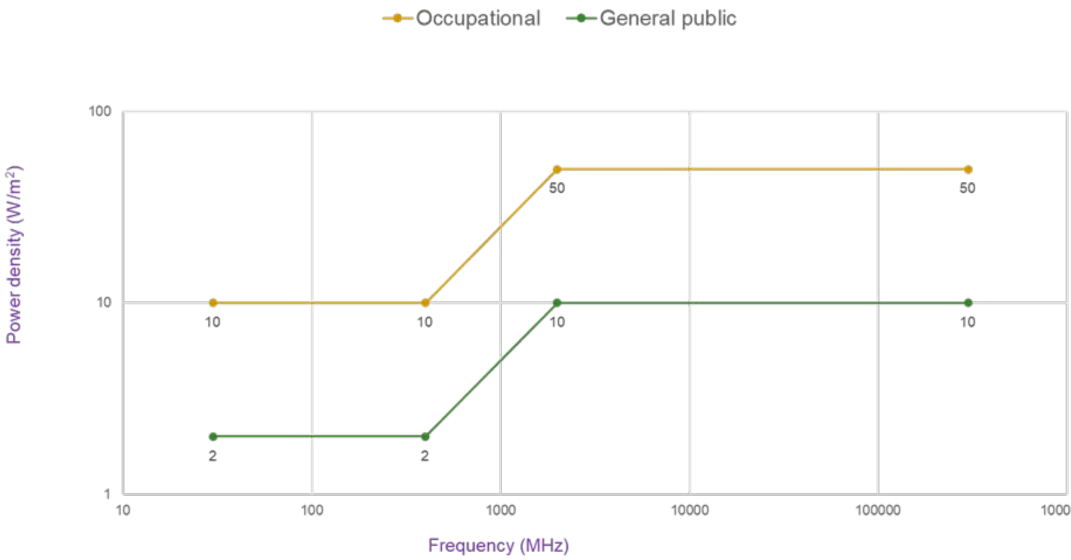
Table 4: ICNIRP (2020) Guidelines in brief – Basic restrictions

Parameter	Frequency range	ΔT	Spatial averaging	Temporal averaging	Health effect level	Reduction factor	Workers	Reduction factor	General public
Core ΔT	100 kHz-300 GHz	1°C	WBA (whole body average)	30 min	4 W/kg	10	0.4 W/kg	50	0.08 W/kg
Local ΔT (head and torso)	100 kHz-6 GHz	2°C	10 g	6 min	20 W/kg	2	10 W/kg	10	2 W/kg
Local ΔT (limbs)		5°C	10 g	6 min	40 W/kg	2	20 W/kg	10	4 W/kg
Local ΔT (head and torso, limbs)	>6-300 GHz 30-300 GHz	5°C	4 cm^2 1 cm^2	6 min 6 min	200 W/m^2 400 W/m^2	2	100 W/m^2 200 W/m^2	10	20 W/m^2 40 W/m^2

Note: ΔT is the change in temperature.

The following two figures depict the differences between the ICNIRP (2020) **field-strength** and **power-density** exposure levels of **occupational** and **general-public** exposure, averaged over **30 minutes** and the **whole body**. The power-density ratio of 5 in ICNIRP (2020) Table 5 (e.g. at 30 – 400MHz, Watts ratio 50/10) results in a V/m ratio 61.0/27.7 = 2.2 ≈sqrt (5).

Figure 6: Comparing ICNIRP (2020) Table 5, power density for occupational and general public exposures 30 MHz-300 GHz



As between 100 kHz and 10 MHz, the stringent value for every frequency should be followed, the following Figure depicts ICNIRP (2020) exposures, trunked where ICNIRP (2010) exposures

[34] The Table and the three following figures have been prepared by the author of this chapter, Co-Rapporteur for Question 7/2.

apply: for 'occupational' below **6.94 MHz** (**170 V/m**) ICNIRP (2010) Table 3, and for the general public below **6.27 MHz (83 V/m**), ICNIRP (2010) Table 4.

Figure 7: Comparing ICNIRP (2020) Table 5, field strength for occupational and general public exposure, 0.1 MHz–2 000 MHz, limited below ≈7 MHz by ICNIRP (2010) Tables 3 and 4

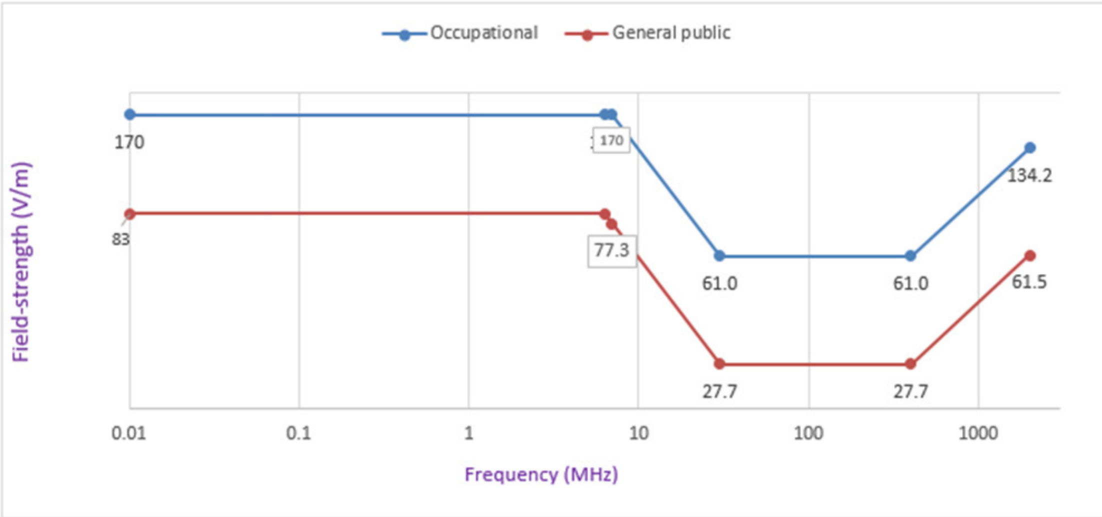
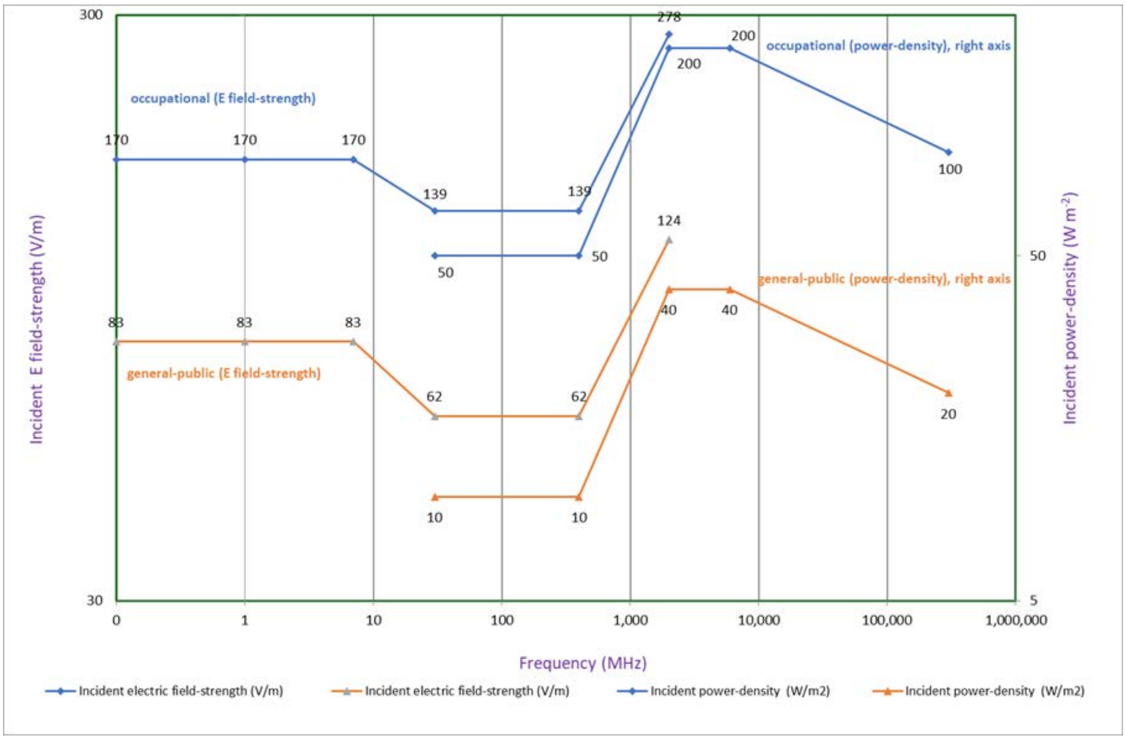


Figure 8 compares local exposures of incident electric field strength and power density, averaged over 6 minutes. As between 100 kHz and 10 MHz, the stringent value of ICNIRP (2010) or ICNIRP (2020) for every frequency should be followed, below 7 MHz the ICNIRP (2010) limits apply.

Figure 8: Comparing occupational and general public exposures in ICNIRP (2020) Table 6



Note: The units of the two y-axes (i.e., incident electric field strength and power density) are independent of each other.

3.3 IEEE C95.1-2019

The 2019 version of the C95.1 standard is free for download from the IEEE Get Program. A summary of the differences between the 2019 version and the prior versions has been published in IEEE Access.[35]

3.3.1 Reference levels: safety factors applying 100 kHz - 6 GHz; thermal effects[36]

- Whole body averaged (WBA)
  Behavioural effects in animals over many frequencies, threshold at 4 W/kg, before dividing by:
  10x – 0.4 W/kg for upper tier (restricted environments)
  50x – 0.08 W/kg for lower tier (unrestricted environments – general public)
- Localized exposure (averaged in 10 g)
  Cataract observed in rabbits, threshold at 100 W/kg, before dividing by:
  10x – 10 W/kg for upper tier
  50x – 2 W/kg for lower tier
- SAR is averaged over 30 minutes for WBA exposure and 6 minutes for local exposure
- Epithelial power density through body surface is averaged over 6 minutes.

3.3.2 Dosimetric reference limits and exposure reference level[37]

Table 5 and **Table 6** specify dosimetric reference limits (DRLs) below and above 6 GHz. No continuity at 6 GHz.

Table 5: C95.1-2019 (Table 5) – Dosimetric reference limits, DRLs (100 kHz to 6 GHz)

Conditions	Persons in unrestricted environments, SAR (W/kg)[a]	Persons in restricted environments, SAR (W/kg)[a]
Whole-body exposure	0.08	0.4
Local exposure[b] (head and torso)	2	10
Local exposure[b] (limbs and pinnae)	4	20

[a] SAR is averaged over 30 minutes for whole-body exposure and 6 minutes for local exposure.
[b] Averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube). The averaging volume of 10 g of tissue would be represented as a 10 cm^3 cube (approximately 2.15 cm per side)

[35] William Bailey et al. (2019). Synopsis of IEEE Standard C95.1™-2019 "IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz". *IEEE Access*, 7, 171346-171356
[36] See IEEE (2019), p. 57
[37] See IEEE (2019), Tables 5 to 8, Figures 3 and 4.

Table 6: C95.1-2019 (Table 6) – DRLs (6 GHz to 300 GHz)

Conditions	Epithelial power density (W/m^2)[a,b,c]	
	Persons in unrestricted environments	Persons permitted in restricted environments
Body surface	20	100

[a] Epithelial power density through body surface is averaged over 6 minutes.
[b] Averaged over any 4 cm^2 of body surface at frequencies between 6 GHz and 300 GHz (defined as area in the shape of a square at surface of the body).
[c] Small exposed areas above 30 GHz: If the exposed area on the body surface is small (< 1 cm^2 as defined by −3 dB contours relative to the peak exposure), the epithelial power density is allowed to exceed the DRL values of Table 6 by a factor of 2, with an averaging area of 1 cm^2 (defined as area in the shape of a square at the body surface).

Table 7 and **Table 8** do not provide the electric and magnetic field strengths above 400 MHz.

Table 7 details exposure reference level (ERLs) for whole-body exposure of persons in unrestricted environments, averaging time 30 minutes.

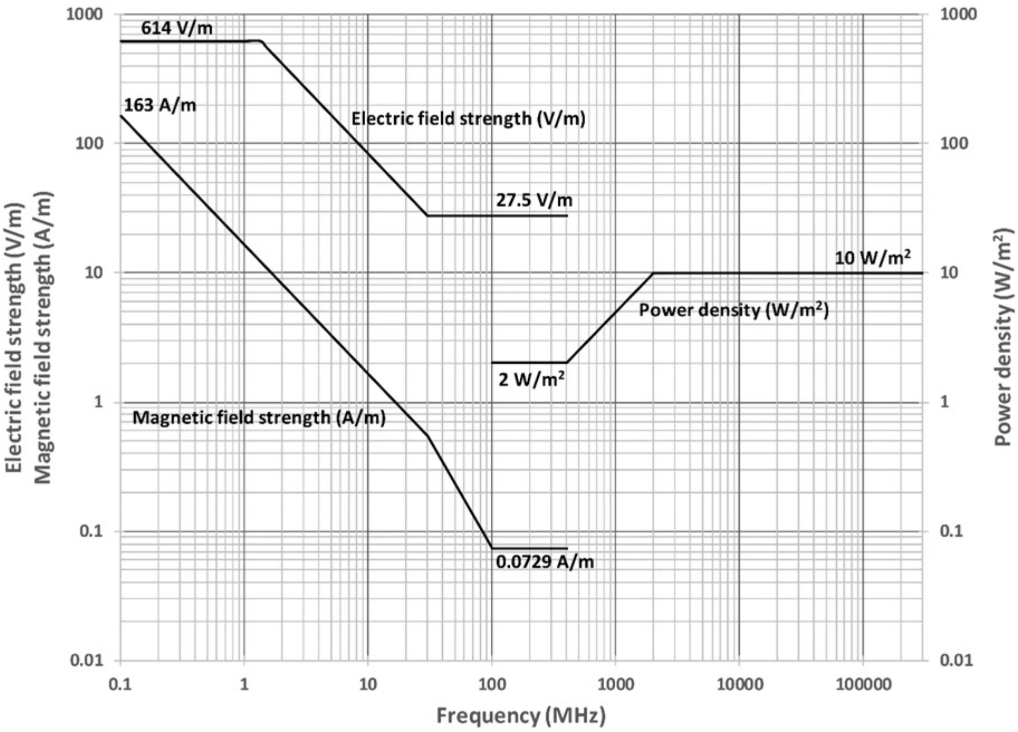
Table 7: C95.1-2019 (Table 7) – Exposure Reference Level, ERLs (100 kHz to 300 GHz)

Frequency range (MHz)	Electric field Strength (*E*)[a,b,c] (V/m)	Magnetic field strength (*H*)[a,b,c] (A/m)	Power density (*S*)[a,b,c] (W/m^2)	
			S_E	S_H
0.1 to 1.34	614	$16.3/f_M$	1 000	$100\ 000/ f_M^2$
1.34 to 30	$823.8/f_M$		$1\ 800 / f_M^2$	
30 to 100	27.5	$158.3/f_M^{1.668}$	2	$9\ 400\ 000 / f_M^{3.336}$
100 to 400		0.0729	2	
400 to 2000			$f_M/200$	
2000 to 300 000			10	

Note–S_E and S_H are plane-wave equivalent power density values, based on electric or magnetic field strength respectively, and are commonly used as a convenient comparison with ERLs at higher frequencies and are sometimes displayed on commonly used instruments.
[a] For exposures that are uniform over the dimensions of the body, such as certain far-field plane-wave exposures, the exposure field strengths and power densities are compared with the ERLs in IEEE 95.1 Table 7. For more typical non-uniform exposures, the mean values of the exposure fields, as obtained by spatially averaging the plane-wave-equivalent power densities or the squares of the field strengths, are compared with the ERLs in Table 7.
[b] f_M is the frequency in MHz.
[c] The *E*, *H*, and *S* values are those rms values unperturbed by the presence of the body.

Figure 9 depicts Figure 3 of C95.1-2019 – Graphical representations of the ERLs in Table 7 of IEEE standard, electric and magnetic fields and plane-wave-equivalent power density – Persons in **unrestricted** environments.

Figure 9: C95.1-2019 (Figure 3) EMFs and power density in unrestricted environments



Note:[38] At frequencies below 30 MHz, the wavelength is longer than 10 metres. There is no resonance with our body (shorter than 2 metres). We are not an obstacle to the signal, and only a small part of the RF energy enters our body.

Table 8 details Table 8 of IEEE C95.1-2019: ERLs for whole-body exposure of persons permitted in restricted environments (100 kHz to 300 GHz), averaging 30 minutes.

[38] This note does not appear in the IEEE 95.1 standard.

Table 8: C95.1-2019 (Table 8) – ERLs in restricted environments (100 kHz to 300 GHz)

Frequency range (MHz)	Electric field Strength (E)[a,b,c] (V/m)	Magnetic field strength (H)[a,b,c] (A/m)	Power density (S)[a,b,c] (W/m²)	
			S_E	S_H
0.1 to 1.0	1 842		9 000	
1.0 to 30	1 842/f_M	16.3/f_M	9 000 / f_M^2	100 000 f_M^2
30 to 100	61.4		10	
100 to 400		0.163	10	
400 to 2000			f_M/40	
2000 to 300 000			50	

Note – S_E and S_H are plane-wave equivalent power density values, based on electric or magnetic field strength respectively, and are commonly used as a convenient comparison with ERLs at higher frequencies and are sometimes displayed on commonly used instruments.

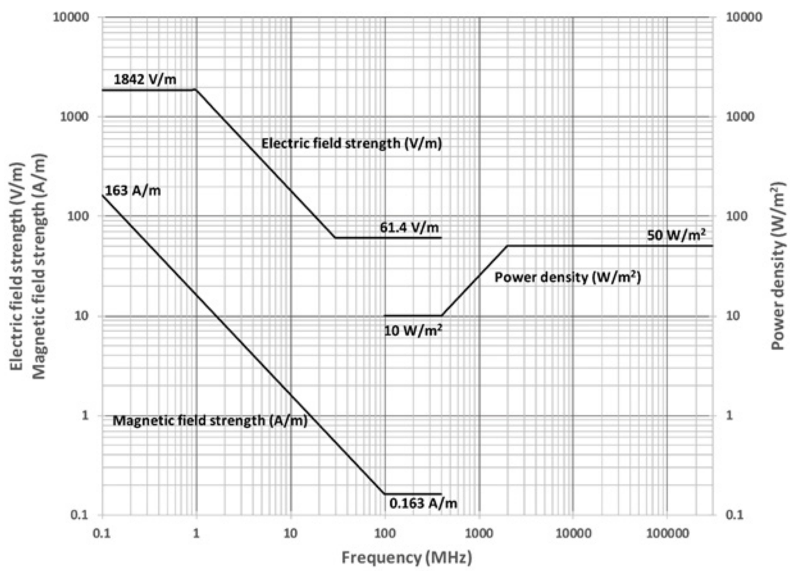
[a] For exposures that are uniform over the dimensions of the body, such as certain far-field plane-wave exposures, the exposure field strengths and power densities are compared with the ERLs in IEEE 95.1 Table 8. For more typical non-uniform exposures, the mean values of the exposure fields, as obtained by spatially averaging the plane-wave-equivalent power densities or the squares of the field strengths, are compared with the ERLs in Table 8.

[b] f_M is the frequency in MHz.

[c] The E, H, and S values are those rms values unperturbed by the presence of the body.

Figure 10 depicts Figure 4 of C95.1-2019: Graphical representations of the ERLs in IEEE (Table 8) for electric and magnetic fields and plane-wave-equivalent power density – Persons permitted in **restricted** environments.

Figure 10: C95.1-2019 (Figure 4) EMF and power density in restricted environments



Source: Adapted and reprinted with permission from IEEE. Copyright IEEE 2019. All rights reserved.

3.3.3 Compare and contrast ICNIRP (1998), IEEE 95-1 (2019) and ICNIRP (2020)

3.3.3.1 IEEE C95.1 (2019) and ICNIRP (2020) Guidelines are largely harmonized

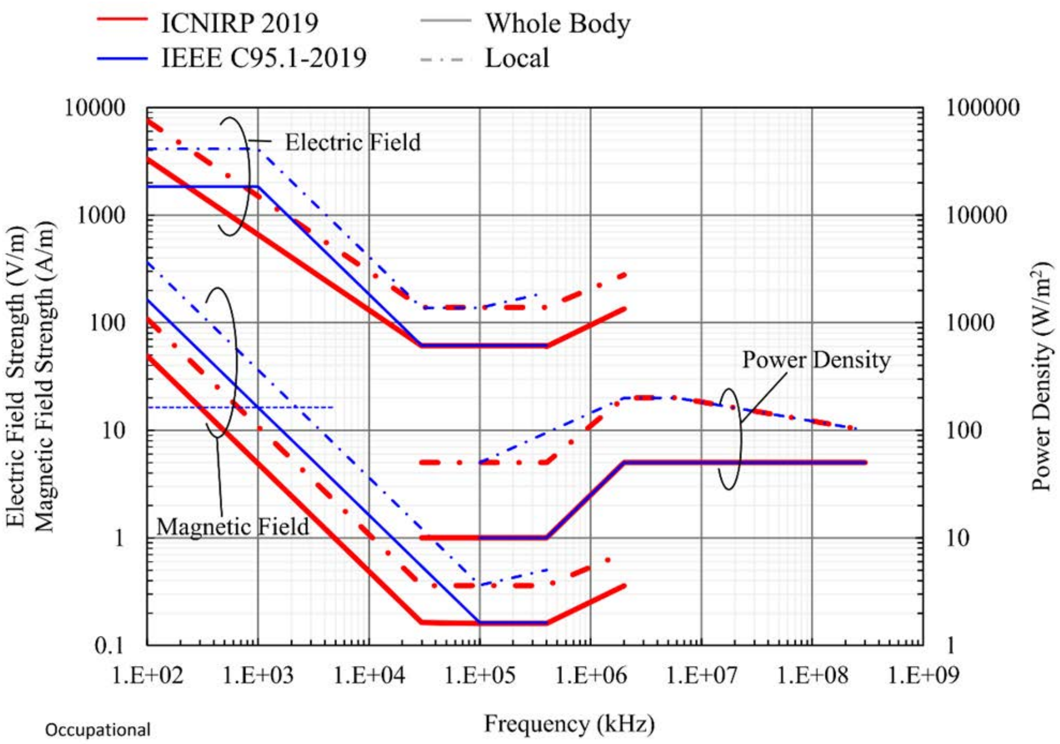
The ICNIRP Guidelines (1998 and 2020) and the IEEE Standard (2019) separate persons in unrestricted environments (general public) and persons permitted in restricted environments (occupational). The basic restrictions and the reference levels for **power density** of ICNIRP (2020) and the IEEE Standard for whole-body exposure to continuous fields **above 30 MHz are identical**!

- SAR equals 2 W/kg for general public and 10 W/kg for occupational.
- Exposure reference levels equals at:
  - 400 to 2 000 MHz $f_M/200$ W/m^2 for general public and $f_M/40$ W/m^2 for occupational
  - 2 000 to 300 000 MHz 10 W/m^2 for general public and 50 W/m^2 for occupational

The following three figures illustrate that IEEE C95.1 (2019) and ICNIRP (2020) Guidelines are **largely harmonized**.

Figure 11 compares the reference limits (RLs) between ICNIRP and IEEE for occupational exposure.

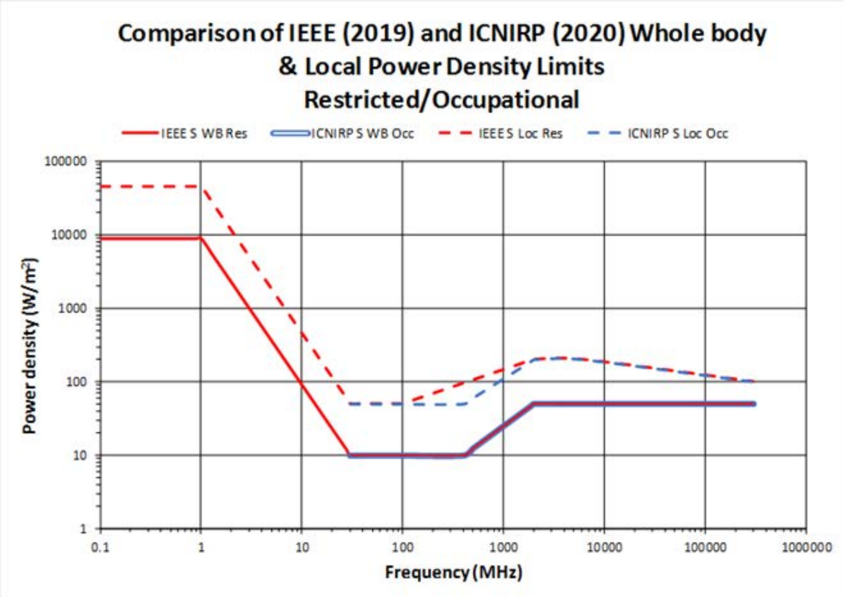
Figure 11: Reference limits (RLs) between ICNIRP and IEEE for occupational exposure



Source: Akimasa Hirata[39]

[39] Akimasa Hirata. Human Exposure Standards and Compliance Assessment– 5G and Beyond. Keynote speaker at the EMC Europe 2020 *plenary open session*, 23 September 2020. N.B. The figure indicates ICNIRP 2019 instead of ICNIRP 2020.

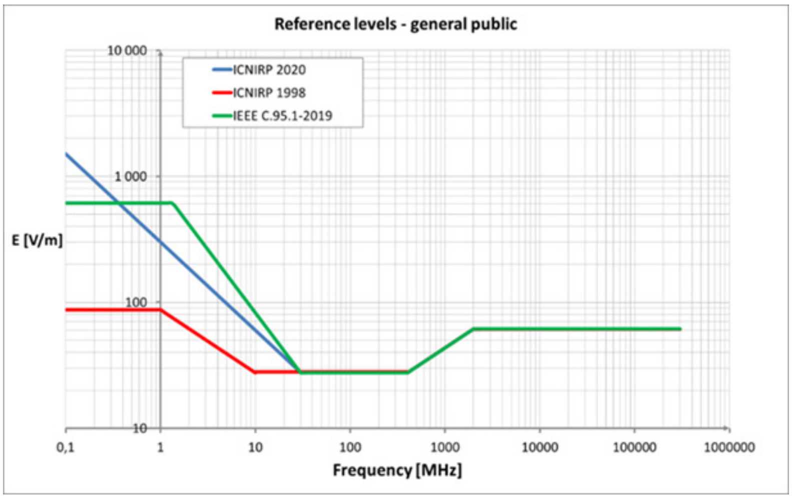
Figure 12: IEEE C95.1 (2019) versus ICNIRP (2020) whole body and local exposure limits



Source: IEEE/ICES Ric Tell, 4 June 2020

Figure 13 compares the ICNIRP (1998), IEEE (2019) and ICNIRP (2020) reference levels for the general public. Clarification: The reference levels of ICNIRP (2020) stop electric field at frequencies above 2 000 MHz; however, electric-field units and V/m measurements are convenient for many administrations, as they monitor field strengths and not power density. As between 100 kHz and 10 MHz, the stringent value of ICNIRP (2010) or ICNIRP (2020) for every frequency should be followed, below 6.27 MHz the general public limit is 83 V/m.

Figure 13: Reference levels – general public for ICNIRP (1998), IEEE (2019) and ICNIRP (2020)



Source: Fryderyck Lewicki[40]

[40] F Lewicki. Electromagnetic fields and 5G implementation. ITU Seminar for Europe and CIS on Spectrum Management and Broadcasting, 2 July 2020.

3.3.3.2 ICNIRP (1998), ICNIRP (2020) and IEEE 95.1 (2019) limits applicable to cellular handsets

The general public receives the highest exposure from handheld devices such as mobile phones, which deposit most of the radio frequency (RF) energy in the brain and surrounding tissues. Typical exposures to the brain from handsets are several orders of magnitude higher than those from mobile-phone base stations on rooftops or from terrestrial television and radio stations. As far as exposure levels are concerned, a distinction is made between the fixed radiating transmitters of the base stations and portable handsets. The far-field[41] exposure from fixed wireless stations relative to power density (or field strength) limits is practical to analyse (easily simulated and measured). On the other hand, the handset is used in proximity to the user's body, meaning that the body, in conjunction with the handset design, has a strong impact on the RF-EMF in the near-field.[42] The specific absorption rate (SAR)[43] relates to the internal electric field and, by extension, the temperature rise due to the absorbed RF-EMF. SAR is mainly used to define the threshold limits for sources used close to the body, including handsets and notebooks.

Manufacturers follow international compliance testing standards to ensure that, when tested, the device operating at maximum power will comply with relevant international or national limits. The handset works at higher output power in the most conservative conditions (obstacles or long distance to base station), and at minimum output power in the best connection conditions (line of sight propagation and close to the base station). The maximum SAR level for different mobile phones varies according to technology and many other factors, for example, SAR is also influenced by technical parameters, such as the antenna used and its placement within the device.

Table 4 of ICNIRP (1998) stated that localized SAR (head and trunk) from 10 MHz to 10 GHz and localized SAR (head and trunk) from 100 kHz to 10 MHz are **2.0 (W kg^{-1})**, averaged over 10 g tissue, for members of the public. The ICNIRP (2020) local SAR restrictions (100 kHz to 6 GHz) are given in ICNIRP (2020) Table 2 "Basic restrictions for electromagnetic field exposure from 100 kHz to 300 GHz, for averaging intervals ≥6 min." and summarised in this Report **Table 4**: ICNIRP (2020) Guidelines in brief – . The values are unchanged compared to ICNIRP (1998): **2.0 (W kg^{-1})**.

ICNIRP (2020) introduces a new basic restriction (S_{ab}, absorbed power density) from 6 to 300 GHz of 20 W/m^2 for the public; see ICNIRP (2020) Tables 1 and 2. Additional reference levels for local exposure averaged over 6 minutes are given in ICNIRP (2020) Table 6. Whether the basic restriction or the reference level should be used for compliance is determined by Notes 5 and 6 of Table 6 (see the underlined Notes of **Table 3** in this Report). These new basic restrictions/reference levels are relevant for International Mobile Telecommunications (IMT) 5G devices operating at higher frequencies.

[41] Based on Recommendation ITU-T K.61, Recommendation ITU-T K.91 defines far-field as "that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. In the far-field region, the field has predominantly a plane-wave character, i.e. locally uniform distribution of electric field strength and magnetic field strength in planes transverse to the direction of propagation".

[42] Based on Recommendation ITU-T K.52, Recommendation ITU-T K.91 defines near-field as "the near-field region exists in the 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".

[43] SAR is the time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass contained in a volume element of a given mass density. See also Recommendation ITU-T K.52.

IEEE C95.1 (2005), p. 78, stated: "The peak spatial average SAR values have been changed from 1.6 W/kg and 8 W/kg for exposure of the public and exposures in controlled environments to 2 W/kg and 10 W/kg, respectively." A similar sentence appears in IEEE C95.1 (2019), p. 72. Therefore, the 1995 SAR level 1.6 W/kg was changed in 2005 and stays at 2 W/kg in IEEE C95.1 (2019). **Table 5**: C95.1-2019 (Table 5) – Dosimetric reference limits, DRLs (100 kHz to 6 GHz) in this Report specifies for local exposure (head and torso) 2 W/kg for persons in unrestricted environments. IEEE C95.1-2019 explains (pp. 112-113) that the reason for the change is a move from the purely dosimetry-based rationale of the earlier standard to adopt the biologically-based ICNIRP rationale.

3.4 Additional international references

3.4.1 ITU-T Recommendations and their relevant K supplements

ITU-T Study Group 5 (Environment, climate change and circular economy) has been particularly active in developing recommendations for protection from, and the measurement/computation of, RF fields. The list below features the most relevant EMF ITU-T Recommendations (standards), along with related supplements.[44]

- ITU-T K.52: Guidance on complying with limits for human exposure to electromagnetic fields
- ITU-T K.61: Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations
- ITU-T K.70: Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations
- ITU-T K.83: Monitoring of electromagnetic field levels
- ITU-T K.90: Evaluation techniques and working procedures for compliance with exposure limits of network operator personnel to power-frequency electromagnetic fields
- ITU-T K.91: Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields
- ITU-T K.100: Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service
- ITU-T K.113: Generation of radiofrequency electromagnetic field level maps
- ITU-T K.122: Exposure levels in close proximity of radiocommunication antennas
- ITU-T K.145: Assessment and management of compliance with radio frequency electromagnetic field exposure limits for workers at radiocommunication sites and facilities.

As this list demonstrates, there is already a comprehensive suite of ITU Recommendations/standards to address realistic concerns about exposure to RF-EMF from networks and devices.

The ITU-T K-series supplements include:

- K Suppl. 1: ITU-T K.91 – Guide on electromagnetic fields and health
- K Suppl. 4: ITU-T K.91 – Electromagnetic field considerations in smart sustainable cities
- K Suppl. 9: 5G technology and human exposure to radiofrequency electromagnetic fields
- K Suppl. 13: Radiofrequency electromagnetic field (RF-EMF) exposure levels from mobile and portable devices during different conditions of use

[44] ITU-T. ITU-T K-series Recommendations.

- K Suppl. 14: The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment
- K Suppl. 16: Electromagnetic field compliance assessments for 5G wireless networks
- K Suppl. 19: Electromagnetic field (EMF) strength inside underground railway trains
- K Suppl. 20: ITU-T K.91 – Supplement on radiofrequency exposure evaluation around underground base stations

Thanks to the fruitful work of Study Group 5, the ITU-T K-series Recommendations and their related K supplements are revised regularly. The latest versions can be found at https://www.itu.int/itu-t/recommendations/index.aspx?ser=K.

3.4.2 Report ITU-R SM.2452

ITU Radiocommunication Sector Report ITU-R SM.2452,[45] on electromagnetic field measurements to assess human exposure, published in June 2019, provides information on significant measurements. The report in its introduction stresses that: "The proliferation of wireless installations of all types around the world obligates careful measurements". The Table of contents reproduced below highlights the topics covered in this all-important report from ITU-R:

3.4.3 International Electrotechnical Commission Standards

These are the recently updated standards and technical reports of the International Electrotechnical Commission (IEC)[46] published in 2018/19:

- IEC TR 62669:2019 Edition 2.0 Case studies supporting IEC 62232 – Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure (5G update)
- IEC TR 63170:2018 Edition 1.0 (15.08.2018) Measurement procedure for the evaluation of power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 100 GHz (5G applications)
- IEC PAS 63151:2018 Edition 1.0 (15.01.2018) Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from handheld and body-mounted wireless communication devices – Vector measurement-based systems (Frequency range of 30 MHz to 6 GHz)

[45] ITU-R. Report ITU-R SM.2452. Electromagnetic field measurements to assess human exposure.
[46] International Electrotechnical Commission (IEC). https://www.iec.ch/homepage

- IEC TR 62905:2018 Edition 1.0 (06.02.2018) Exposure assessment methods for wireless power transfer systems
- IEC TR 63167:2018 Edition 1.0 (05.06.2018) Assessment of contact current related to human exposure to electric, magnetic and electromagnetic fields

Other important IEC standards and reports include:

Standards:

- IEC 62209-1 (2016): Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Part 1: Devices used next to the ear (Frequency range of 300 MHz to 6 GHz)
- 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.

Reports:

–	IEC TR36170[47]	Technical Report 6–100GHz,	July 2018
–	IEC/IEEE 62704-5[48]	Int Std (Calc) 6–100 GHz,	May 2020
–	IEC / IEEE 63195-1[49]	Int Std (Meas) 6–100 GHz,	December 2020

The main international measurement standards for measuring the SAR in the human head are IEC 62209-1 and IEEE 1528.

3.4.4 Institute of Electrical and Electronics Engineers (IEEE)

- IEEE 1528 (2003): IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Technique
- IEEE Standard C95.1-2005: Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
- IEEE C95.1-2019: IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz.

3.4.5 Summary – Best practices, international RF-EMF exposure limits

Administrations are encouraged to follow the ICNIRP Guidelines or IEEE Standard, or limits set by their own experts. The best practice for administrations that choose to use international RF-EMF exposure limits is to limit the exposure levels to the thresholds specified in ICNIRP (2020) Guidelines.

[47] IEC. IEC TR 63170:2018. Measurement procedure for the evaluation of power density related to human exposure to RF fields from wireless communication devices operating between 6 GHz and 100 GHz.

[48] IEC and IEEE. IEC/IEEE 62704-5. Determining the Peak SAR in the Human Body from Wireless Communications Devices, 30 MHz - 6 GHz: Part 4: General Requirements for Using the finite element method (FEM) for SAR Calculations.

[49] IEC and IEEE. IEC/IEEE 63195-1. Measurement procedure for the assessment of power density of human exposure to RF fields from wireless devices operating in close proximity to the head and body – Frequency range of 6 GHz to 300 GHz.

Chapter 4 – Policies to limit exposure to radiofrequency fields

With the deployment of 5G wireless networks, human exposure to the resultant electromagnetic fields (EMF) has raised public concerns in some countries. This chapter summarizes the main regulatory measures for RF-EMF exposure adopted by different countries and presents national practices for exposure limits.

4.1 Guidelines for national regulation

Different RF-EMF limit systems coexist in the world.[50] IEEE published its revised version of IEEE C95.1 in October 2019.[51] Previous versions of the standard were adopted by American Samoa, Bolivia, Micronesia, Guam, Iraq, the Marshall Islands, the Northern Mariana Islands, Palau, Puerto Rico, the United States and the United States Virgin Islands to assess the exposure from radio transmitters. Bolivia, Canada, Cuba, India, the Islamic Republic of Iran, Iraq, Panama, the Republic of Korea, the United States and Viet Nam adopted limits based on the IEEE C95.1-1992 standard to evaluate the near-field exposure from mobile phones or two-way radios.

In March 2020, ICNIRP's revised RF-EMF Guidelines were published by *Health Physics*.[52] The ICNIRP (1998) RF-EMF Guidelines are the safety limits used by the largest number of nations and regions in the world. The differences between the 2020 version and the 1998 version of the ICNIRP Guidelines have been published online.[53] In February 2021, Australia became one of the first countries to implement the ICNIRP (2020) guidelines in a national standard.[54]

WHO acknowledges both the ICNIRP Guidelines and the IEEE standard on its website, but promotes the adoption of ICNIRP Guidelines. The two standardization groups have performed many activities towards harmonization of the standards. The IEEE C95.1-2019 and the ICNIRP (2020) limits are largely harmonized, and the power-density limits for whole-body exposure to continuous fields are identical above 30 MHz. The 2019 version of the C95.1 standard has the same limits for near-field exposure as the ICNIRP (2020) Guidelines.

Some countries apply exposure limits that are much more conservative than those recommended by ICNIRP, for example Belgium, Italy, Luxembourg and Switzerland. The Russian Federation traditionally adopts a stringent limit system. India adopted the ICNIRP standard, but in September 2012 it changed the limits to 1/10 of the ICNIRP standard for far-field exposure sources. China has a different approach to setting its exposure limits, which are also much more restrictive than the ICNIRP recommended limits.

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50 WHO. The Global Health Observatory

51 IEEE (2019). IEEE C95.1-2019. IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz.

52 ICNIRP (2020). International Commission on Non-Ionizing Radiation Protection (ICNIRP). RF EMF Guidelines 2020. Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz) 2020. *Health Physics*, 118(5):483-524, May 2020.

53 ICNIRP. Differences between the ICNIRP (2020) and previous guidelines

54 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). ARPANSA releases new Australian radio wave safety standard, 25 February 2021.

4.2 National practices for ensuring compliance with exposure limits

With the increasing popularity of mobile devices, a large number of base stations need to be constructed to improve the quality of communications and satisfy the growing demand for wireless data. The technical characteristics of 5G make this challenge more prominent. Therefore, many countries have established a series of practices on ensuring compliance with exposure limits.

With the advancement of wireless communication technology from 2G to 4G, international operators carried out planning and implemented infrastructure sharing to minimize the number of base stations/antennas and to reduce construction costs. For example, in 2014 China established a large-scale infrastructure construction and maintenance enterprise – China Tower Corporation Limited (China Tower).[55] The company was founded by the three major operators, and is responsible for providing infrastructure. The operators share the tower for co-siting, and China Tower coordinates requirements from the three operators and makes a comprehensive plan for installing antennas, which could reduce unnecessary RF-EMF exposure to inhabitants.

Burundi[56] adopted an appropriate legal framework for managing telecommunication infrastructure, which makes it possible to organize the installation of telecommunication antennas and masts efficiently. As part of these initiatives, Burundi, in collaboration with ITU, has established a legal framework for the appropriate management of telecommunication infrastructure sharing in Burundi, which will have positive effects in this sector at the regulatory, technical and financial levels. Lastly, the introduction of guidelines containing limits and thresholds will make it possible to ensure compliance with exposure limits.

Haiti[57] has taken steps to ensure stringent verification of deployment of the wireless infrastructure needed for nationwide coverage by the National Telecommunications Council (CONATEL) to regulate the proliferation of radiocommunication installations across the country.

Senegal[58] is aware of the concern about the impact of non-ionizing waves on populations through the various studies being carried out by international organizations. Senegal carried out measurement campaigns to evaluate the RF-EMF exposure and acquired equipment to control and monitor the levels of electromagnetic fields across the country. The CEM-RNI (*Champ Électromagnétique – Rayonnements Non-Ionisants*) measurement campaigns in densely populated urban areas of Senegal were conducted according to the recommendations contained in the ITU-R spectrum monitoring manual, the ITU-T K-series Recommendations, ITU-D guidelines and the ICNIRP Guidelines.

To create a transparent and accountable ecosystem of information sharing on mobile towers and RF-EMF exposure compliances, the Department of Telecommunications (DoT) of India[59] has launched a web portal known as "Tarang Sanchar" to generate confidence and conviction with regard to safety and harmlessness of mobile towers, clearing myths and miscommunication.

Ghana[60] has used type approval to safeguard telecommunication/ICT devices, users and networks. The Ghana Type-Approval laboratory, being the first of its kind in the West African

[55] ITU-D SG2 Document SG2RGQ/68 from China
[56] ITU-D SG2 Document 2/271 from Burundi
[57] ITU-D SG2 Document 2/255 from Haiti
[58] ITU-D SG2 Document SG2RGQ/50 from Senegal [in French]
[59] ITU-D SG2 Document SG2RGQ/71 from India
[60] ITU-D SG2 Document SG2RGQ/82 from Ghana

subregion, is set up not only for domestic market surveillance, but also to serve as an equipment testing hub open to regulators and vendors within the African region.

Guinea[61] has taken measures through its Posts and Telecommunications Regulatory Authority (ARPT) to deal with this issue of national concern. Regarding non-ionizing radiation, guidelines have been drawn up by the regulator. Following the acquisition of various technical tools needed to take regular measurements of radiation levels, the project to establish a laboratory to monitor radio equipment compliance was under study. Campaigns to measure EMF exposure were carried out regularly, and the results made available on ARPT's website.

Risk communication is also an important method to reduce public concerns about RF-EMF exposure. WHO and ITU have set up plans for electromagnetic radiation risk communications. They constantly promote the exchange of knowledge on EMF exposure between countries and regions in various aspects, such as standard-setting, research activities, periodic summary of research results, reports and organizing symposiums.

The ITU Telecommunication Development Bureau (BDT)[62] provided insight to national activities via presentations made at the Regional Seminar for Europe and the CIS on "5G Implementation in Europe and CIS: Strategies and Policies Enabling New Growth Opportunities" held from 3 to 5 July 2018 in Budapest, Hungary.

4.3 Impact of IMT-2020 (5G) on EMF

The first 5G NR (New Radio) version was officially released at the 78th plenary meeting of the 3GPP RAN (Radio Access Network) on 21 December 2017, making it the first commercially deployable 5G standard in the world. At present, the 5G frequency range defined by 3GPP is divided into Frequency Range 1 (FR1) and Frequency Range 2 (FR2). FR1 is usually termed sub-6 GHz, or below 6 GHz. At present, 3.5 GHz is one of the mainstream bands of 5G applications. However, 3GPP has also defined other available bands to facilitate flexible deployment. FR2 range is mainly high frequency, which is commonly referred to as millimetre wave. Its penetration ability is weak but bandwidth is sufficient and there is no interference source. Its spectrum is clean, and it will be widely used in the future.

Due to the characteristics of multiple-input multiple-output (MIMO) and millimetre-wave technologies used in the 5th generation mobile communication system, it is urgent to evaluate its RF-EMF levels. A pioneer study[63] indicated that the maximum time-averaged power per beam direction was found to be well below the theoretical maximum, and lower than what was predicted by the existing statistical models.

MIMO technology refers to the simultaneous use of multiple transmit and receive antennas, so that signals can be transmitted and received through multiple antennas at the transmitter and receiver, thereby improving communication quality. Without increasing spectrum resources and antenna transmit power, it multiplies system channel capacity, yielding obvious advantages. It is regarded as the key technology of next-generation mobile communications.

61 ITU-D SG2 Document 2/292 from Guinea
62 ITU-D SG2 Document SG2RGQ/40+Annex from BDT
63 Davide Colombi et al. (2020). Analysis of the Actual Power and EMF Exposure from Base Stations in a Commercial 5G Network. *Applied Sciences* (35), 10:5280

A model for time-averaged realistic maximum power levels for the assessment of RF-EMF exposure for 5G radio base stations (RBS) employing massive MIMO is proposed.[64] The model is based on a statistical approach and developed to provide a realistic conservative RF exposure assessment for a significant proportion of all possible downlink exposure scenarios (95th percentile). Factors such as RBS utilization, time-division duplex, scheduling time and spatial distribution of users within a cell are considered. The model is presented in terms of a closed-form equation. For an example scenario corresponding to an expected 5G RBS product, the largest realistic maximum power level was found to be less than 15 per cent of the corresponding theoretical maximum. For far-field exposure scenarios, this corresponds to a reduction in RF-EMF limit compliance distance by a factor of about 2.6. Results are given for antenna arrays of different sizes and for scenarios with beam forming in both azimuth and elevation.

Further, the Swiss Federal Institute of Metrology (METAS) has introduced a code-selective EMF measurement method for 5G NR.[65] For this measurement, the specific 5G signals, i.e. SSBs (Synchronization Signal/PBCH Block) and PCIs (Physical layer Cell ID), are decoded and measured. By applying the antenna factor of the directive measurement antenna and summing all SSBs per PCI, a reliable and unique result in mV/m per PCI can be derived. It provides all the details, enabling operators and infrastructure suppliers to find the best compromise between adhering to country-specific EMF exposure limits and providing optimized network coverage and capacity, and national administrations to check the limits.

A WHO Q&A on 5G mobile networks and health indicates that "provided that the overall exposure remains below international guidelines, no consequences for public health are anticipated."[66]

Responding to public concerns, a series of measurement campaigns have been carried out. In February 2020, Ofcom published the results of measurements of EMF exposures close to sixteen 5G-enabled base stations showing RF-EMF levels at a total of 22 5G sites in 10 UK cities, including also measurements for 2G, 3G and 4G.[67] All locations were at small fractions of the reference levels for public exposure in ICNIRP Guidelines.[68] The French National Frequency Agency (ANFR) regularly publishes data for 5G site deployment on its website[69] and the measurement results can be located online.[70] Optimization for the coexistence technologies of 4G and 5G has also been simulated.[71]

It has been agreed that 5G operating above 10 GHz (6-10 GHz as transition frequency for local exposure) will not utilize specific absorption rate (SAR) for partial body exposure but power density as the basic restriction, because it is difficult to determine a meaningful volume for SAR evaluation at very shallow penetration depth. However, ICNIRP kept whole-body average SAR limits as an additional basic restriction for whole body exposure up to 300 GHz. The ICNIRP

64 Björn Thors et al. (2017). Time-averaged realistic maximum power levels for the assessment of radio frequency exposure for 5G radio base stations using massive MIMO. *IEEE Access*, 5, 19711-19719

65 Federal Institute of Metrology (METAS), Switzerland (2020). Technical Report: Measurement Method for 5G (New Radio) NR Base Stations up to 6 GHz, 18 February 2020). See also ITU (2020) below.

66 ITU (2020). Background Paper - Implementing 5G for good: Does EMF matter?, p. 21. ITU Regional Forum for Europe: 5G strategies, policies, and implementation, 22-23 October 2020.

67 Ofcom, United Kingdom (2020). Electromagnetic Field (EMF) measurements near 5G mobile phone base stations: Summary of results. 21 February 2020.

68 Ibid., p. 37.

69 *Agence nationale des fréquences* (ANFR), France: https://www.anfr.fr/en/home/

70 ANFR. Cartoradio: The map of radio stations and wave measurements.

71 ANFR. News. Simulation de l'exposition aux ondes créée par la téléphonie mobile en zone urbaine dense, tenant compte de l'évolution envisagée en 4G et 5G. 15 September 2020.

(1998) Guidelines use incident power density as reference levels, which does not take the reflection or transmission of energy on the boundary into account, nor does it consider the heat transfer between tissues or between tissues and the environment. The ICNIRP (2020) Guidelines also introduce absorbed power density as a basic restriction at higher frequencies (>6 GHz). In the future, temperature may be regarded as an acceptable parameter to prove the safety of RF-EMF exposure (as in the magnetic resonance imaging industry) because it is more relevant to actual damage.

Zhao et al. (2015)[72] studied RF electromagnetic field exposure of phased array for mobile devices operating at 15 GHz and 28 GHz. Thors et al. (2016)[73] conducted a series of simulations on RF-EMF exposure from array antennas in 5G mobile communication equipment between 10 GHz and 15 GHz. In order to meet the main RF-EMF exposure criteria, the maximum transmit power of the array antennas deployed in user equipment and low-power wireless base stations in 5G mobile communication systems is being investigated, taking into account factors such as frequency, array size, distance from the human body, scanning range and array topology. The results are of great value to the design of mobile communication systems using array antennas with beamforming capability. In order to allow greater power levels, it is necessary to direct the transmitted energy away from the human body through implementable technical solutions. According to the applicable RF-EMF exposure standard, the maximum transmit power level and the maximum equivalent omnidirectional radiation power of 5G mobile communication systems may change greatly. This inconsistency may lead to different access conditions in different markets. Joshi et al. (2020)[74] collected data from commercial 5G networks in Australia and the Republic of Korea and found that median device transmit power levels were 1 per cent of the maximum and comparable to 4G devices.

4.4 Exposure to other short-range devices emitters, such as Wi-Fi and Bluetooth

Other indoor RF-EMF sources, such as Wi-Fi, Bluetooth and various wireless connectivity devices such as routers and wireless chargers, also create RF-EMF exposure – and this needs to be further clarified.

The exposure created by such products depends mainly on the transmitted power. The standards of wireless local area networks (WLAN) established by IEEE can already provide data rates of up to 72 Mbit/s in a single channel. In Europe, systems operating in the 2.4 GHz band have a maximum power of 100 mW. Personal exposure to Wi-Fi signals presents the same general characteristics as the exposure from base stations (far field) and mobile phones (near field). Whereas the near-field exposure from Wi-Fi devices connected to the router is mostly limited in time and is highest for body parts that are the closest to the device, the far-field exposure due to the router is a whole-body exposure. In a measurement of access points (APs) touching a flat phantom filled with tissue-simulating liquid, Kühn et al. (2006)[75] reported

72 Kun Zhao et al. (2015). EMF exposure study concerning mmwave phased array in mobile devices for 5G communication. *IEEE Antennas and Wireless Propagation Letters*, 1-1.

73 Björn Thors et al. (2016). Exposure to RF-EMF from array antennas in 5G mobile communication equipment. *IEEE Access*, 4, 7469-7478.

74 Paramananda Joshi et al. (2020). Actual output power levels of user equipment in 5G commercial networks and implications on realistic RF EMF exposure assessment. *IEEE Access*. Online: 9 November 2020.

75 Sven Kühn et al. (2006). Assessment of human exposure to electromagnetic radiation from wireless devices in home and office environments. *Proceedings of the 7th International Symposium on Electromagnetic Compatibility*, Barcelona, Spain, 4-8 September 2006.

that the maximum 10 g averaged SAR was less than 1 W/kg. They also reported a maximum power density of approximately 3 mW/m^2 at a distance of 1 m and 40 mW/m^2 at a distance of 0.2 m from an access point. At the same distances, Foster reported 1 mW/m^2 and approximately 180 mW/m^2 respectively. It should be stressed that all the values given above are below the reference level of 10 W/m^2, specified in the ICNIRP (1998) RF-EMF Guidelines. The numerical studies of Martínez-Búrdalo et al. (2009)[76] have also confirmed that the maximum local SAR values are within the ICNIRP basic restrictions for the general public. At 2.4 GHz, using a power of 100 mW and a duty factor of one (100 per cent), the highest local SAR value in the head was calculated as 5.7 mW/kg. However, in reality, the duty factor is even smaller.

Bluetooth operates at 2.4 GHz with an output power of only 1 mW, which is one-millionth of the power used by microwave ovens. It is 1/200 of the power of 5G mobile phones. Moreover, only a small part is absorbed by the human body, so the exposure is negligible.

The conclusions currently given by experts from WHO and IEEE are that the RF-EMF exposure of Bluetooth products has not been found to have any adverse effects on the human body.

[76] M. Martínez-Búrdalo et al. (2009). FDTD assessment of human exposure to electromagnetic fields from Wi-Fi and Bluetooth devices in some operating situations. *Bioelectromagnetics*, 30(2):142-51.

Chapter 5 – Formulating national EMF policies on exposure limits

The vast majority of countries have adopted RF-EMF exposure limit values based on the ICNIRP Guidelines or IEEE standards. However, due to a perception of uncertainty about potential adverse effects of EMF on health and interpretations of the precautionary principle, some countries have decided to adopt additional measures in order to protect their population. These measures include, among others, adoption of a legal framework, public awareness campaigns, setting exposure limits, maps for the calculation of field strength around transmitters and publication of results on the web.

5.1 Legal framework

To ensure the adequate protection of the population from non-ionizing radiation at the national level, Member States should ensure that there is a legislative framework in place. The WHO International EMF Project has already developed "Model Legislation" that provides a sample legal framework for use at the national level. It comprises a "Model Act", a "Model Regulation" and an "Explanatory Memorandum" describing the approach to the Act and its Regulations.[77]

To date, more than 40 countries have put in place national legislative frameworks covering static, low-frequency and high-frequency fields for the general public and workers on either a mandatory or voluntary basis. The details of these different legal frameworks can be accessed from the WHO website.[78]

In some countries, legislation has also been enacted to introduce restrictions on the use or placement of devices and supporting infrastructure. Such measures include prohibiting advertising of cell phones to children under a certain age, prohibiting or limiting wireless in nursery or primary schools, and establishing zones around community infrastructure such as hospitals or schools where infrastructure cannot be built. Such measures are often described or justified on "precautionary" grounds, but Member States should be very cautious about enacting such measures in the absence of any scientific evidence. WHO recommends that "an analysis of the balance between cost and potential hazards is essential", and calls for "strict adherence to existing national or international safety standards".[79] Such standards, based on current knowledge, are developed to protect everyone in the population with a large safety factor.

5.2 Establishment of standards

To complement a national legal framework, countries should also adopt RF-EMF exposure standards that the legal framework can give effect to.

[77] WHO. Health Topics. Electromagnetic fields. Model Legislation
[78] WHO. Data. Global Health Observatory data repository. Public health and the environment. EMF: Legislative status – Data by country
[79] WHO. What are electromagnetic fields?

As of June 2018, 44 countries have established national RF standards. Those standards cover the range from static to low and high frequencies for both general public and workers.[80]

As with the "Model Legislation", WHO has also issued a "Framework for Developing Health-based EMF Standards". WHO indicates that the Framework "addresses how to develop science-based quantitative EMF exposure limits" and "is intended for national advisory and/or regulatory bodies that are either developing new standards for EMF or reviewing the basis of their existing standards".[81]

Most countries that have adopted national standards have done so on the basis of the recommendations of ICNIRP. The ICNIRP Guidelines were updated in 2020. IEEE C95.1-2019 is a similar standard relating to EMF exposure limits. While there are some differences between the two, they are largely harmonized in their approach and recommendations.

5.3 Assessment of concerns related to human exposure to RF-EMF

People have different societal concerns related to exposure to RF-EMF. In fact, societal concerns are the risks or threats from hazards which impact on society.[82] They perceive a hazard from EMF they cannot personally detect, but they tolerate the activity because of the benefits they get from it. The population only has perception on a social activity, but they cannot provide details on the way it can impact them positively or negatively.

In an analysis of the risk and benefits of common activities, three tentative principles provide a quantitative instrument:

1. The public is willing to accept voluntary risks (e.g. skiing, handset RF exposure) about 1 000 times greater than involuntary risk (e.g. natural disasters, base station RF exposure) that provide the same benefit.[83]
2. The acceptability of risks appears to be roughly proportional to the real and perceived benefits, to the cube (third power) of the benefits.
3. The acceptable level of risk is inversely related to the number of persons exposed to that risk (more than 3 billion cellular subscribers).[84]

The same source indicates the social amplification which increases the perceived direct risk effect quantitatively and qualitatively. Media are entities that amplify the societal concerns related to EMF, and therefore increase anxiety within societies.

5.4 Public awareness

There is a need to inform the general public about the science-based RF-EMF exposure limits, their conservativeness and why these limits protect against all known adverse health effects of exposure. In order to dispel myths about RF-EMF exposures, the public also need to be aware

80 WHO. Global Health Observatory data repository. Public health and the environment – EMF. Existence of standards – Data by country

81 WHO (2006). Framework for Developing Health-Based EMF Standards

82 Health and Safety Executive (HSE) (2001). Reducing Risks, Protecting People. Sudbury: HSE Books, p.12; quoted by David Ball and Sonja Boehmer-Christiansen (2007). Societal Concerns and Risk Decisions. *Journal of Hazardous Materials* 144, pp. 556-63 (p.557)

83 Paul Slovic (2000). The Perception of Risk, London: Earthscan. Slovic found (pp.121-36) that the data does not support the quantitative formulation; people are willing to accept high involuntary risks with large benefits. However, he sets this useful law, with some drawbacks to this method (pp. 45,81)

84 Haim Mazar (2008). An analysis of regulatory frameworks for wireless communications, societal concerns and risk: The case of radio frequency (RF) allocation and licensing (pp. 43-46). Boca Raton, 2009.

of the science-based RF-EMF exposure limits in place, and that a substantial amount of research has been carried out regarding wireless systems and health. They should also know that WHO is involved in this matter and has issued fact sheets regarding EMF issues, including mobile terminals, base stations and wireless networks.

In relation to mobile terminals and devices, ITU-T K-series Supplement 13 describes the various factors that determine the level of RF-EMF exposure measured as specific absorption rate (SAR) and expressed in watts per kilogram (W/kg), which is the metric used in the frequency range between 100 kHz and 10 GHz.[85] Based on this technical information, practical guidance is provided for users of mobile devices. It also states that the consensus of expert groups is that when observing the international exposure limits, scientific evidence does not show any danger to users of mobile devices from RF-EMF exposure, including children and teenagers. The testing methods used for mobile device compliance are designed to be conservative for adults and children (see **Sections 5.5** and **6.4**).

In order to inform the population with regard to base stations, some administrations publish the positions of transmission sites on a regular basis, including radio and TV stations as well as cellular base stations. In some cases, these public databases depict the power density or field strength around the base station. This approach promotes openness and transparency regarding information on exposure levels, using databases as a tool to address public concerns that have not been analysed independently. Australia publishes EMF reports for all base stations on the RF National Site Archive,[86] which is agreed by the Industry Association and the regulator. Moreover, for public awareness, see the Australian Mobile Telecommunications Association (AMTA) RF safety programme.[87]

5.5 Exposure limits in areas around kindergartens, schools and hospitals

As noted in the previous section, Recommendation ITU-T K.91[88] states that, with respect to human exposure, currently there are no technical reasons to restrict the locating of base stations around kindergartens, schools and hospitals. This is due to the fact that existing exposure guidelines incorporate safety margins to protect all members of the community. It notes that using the mobile telephone within areas of good reception also decreases exposure as it allows the device to transmit at reduced power.

In some countries, rather than prohibiting base stations in these areas, the exposure limits have been arbitrarily reduced further than those recommended in international standards, while in others, the focus has been on banning the use of devices altogether in these locations. Irrespective of whether such provisions focus on infrastructure or devices (or both), they are based on public perceptions rather than science and cannot be scientifically justified.

Surveys indicate that countries which have taken such measures display the highest levels of concern.[89] Rather than alleviating the concerns, however, these measures give credibility to

85 ITU-T. Series K Supplement 13 (05/2018). Radiofrequency electromagnetic field (RF-EMF) exposure levels from mobile and portable devices during different conditions of use.
86 Australian Mobile Telecommunications Association (AMTA). Radio Frequency National Site Archive (RFNSA)
87 AMTA. Mobile Networks Safety
88 Recommendation ITU-T K.91 (01/2018). Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields.
89 European Commission (2010). Eurobarometer. Report. Electromagnetic fields

apprehensions, even if they are said to be only "precautionary". Thus, the general public seems to perceive precaution as an indicator of an underlying danger rather than an aid to feeling safer.[90]

5.6 Assessment of RF-EMF exposure around transmitters

While undertaking actual field measurements is very useful, they are also time-consuming and expensive. An alternative or at least a complementary measure is to allow calculations of field strength to be undertaken using methods described in international technical standards from ITU and IEC (see **Section 3.4**). The Australian regulator ARPANSA states that calculated environmental levels typically exceed measured values by factors of 10 to 1 000 or even more.[91]

When considering the effects of multiple mobile technologies at a site, a realistic maximum can be determined by considering separately broadcast signals and the effects of traffic demand on the different technologies present at a site.[92] In the case of MIMO antennas for 4G/LTE, computed values may exceed measured values unless the effects of beam steering and time division duplex (TDD) are considered.[93] This is also true for 5G (see **Section 4.3**).

5.6.1 Calculation of RF-EMF exposure

The calculation of RF-EMF levels is a parameter that should be known and analysed in order to better protect and reassure the population living near the installations that are sources of field RF-EMF exposure. Among the telecommunication installations that transmit RF-EMF, two examples are considered in this context:

- digital TV transmitters;
- cellular transmitters.

For two main reasons:

- quantity of power emitted;
- number of transmitters installed in the vicinity of the population.

5.6.1.1 Calculated field strength around digital TV (DTV) transmitters

The following analysis refers to UHF Channel 22 (in Region 1):

- 478-486 MHz (centre RF 482 MHz);
- transmitter of 60 000 Watts EIRP (equivalent isotropic radiated power);
- 60 m above ground level.

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90 Christoph Boehmert et al. (2020). A systematic review of health risk communication about EMF from wireless technologies. *Journal of Risk Research*. Published online 20 April 2019.

91 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). ARPANSA environmental EME reports

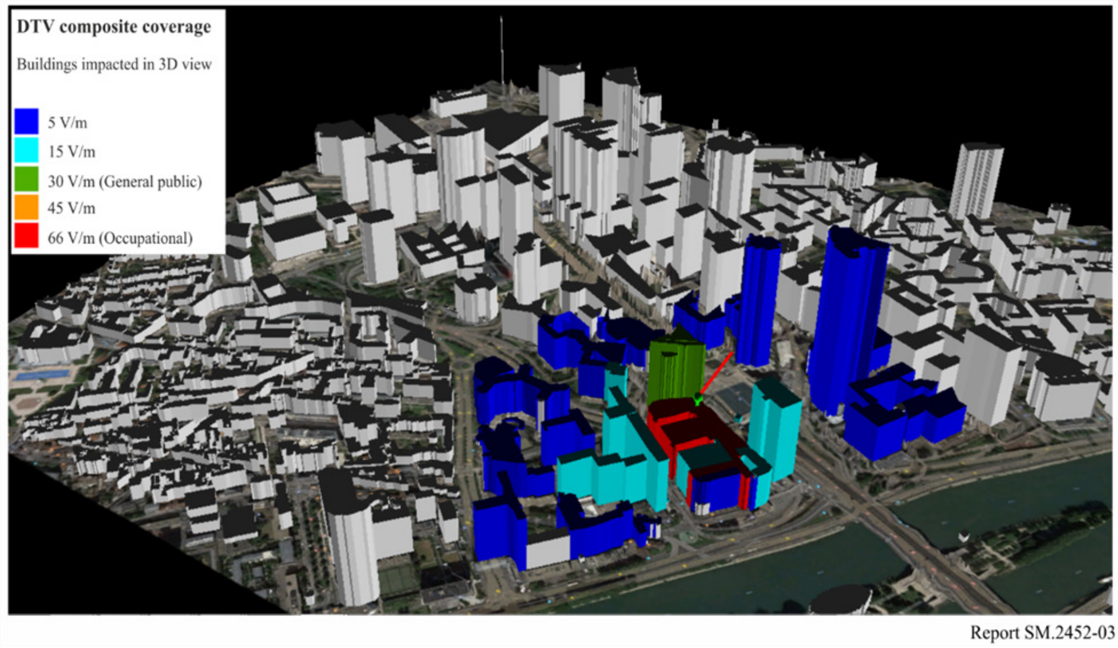
92 Zaher Mahfouz et al. (2011). Influence of traffic variations on exposure to wireless signals in realistic environments. *Bioelectromagnetics*, 33(4):288–297, May 2012.

93 Rob Werner et al. (2019). A Comparison between Measured and Computed Assessments of the RF Exposure Compliance Boundary of an In-Situ Radio Base Station Massive MIMO Antenna. *IEEE Access*, 7(170682 – 170689), 25 November 2019.

At 482 MHz the electric field-strength (FS) ICNIRP general public exposure reference level equals 30 V/m: $1.375f^{1/2}$ (MHz) = $1.375 \times 482^{1/2}$. The FS (V/m) ICNIRP occupational exposure reference level is 66 V/m: $3f^{1/2}$ (MHz) = $3 \times 482^{1/2}$.

Figure 14 depicts the electric field contours overlaid on buildings in three-dimensional view.

Figure 14: Three-dimensional DTV general public and occupational RF-EMF exposure contours



Source: Report ITU-R SM.2452, Figure 3

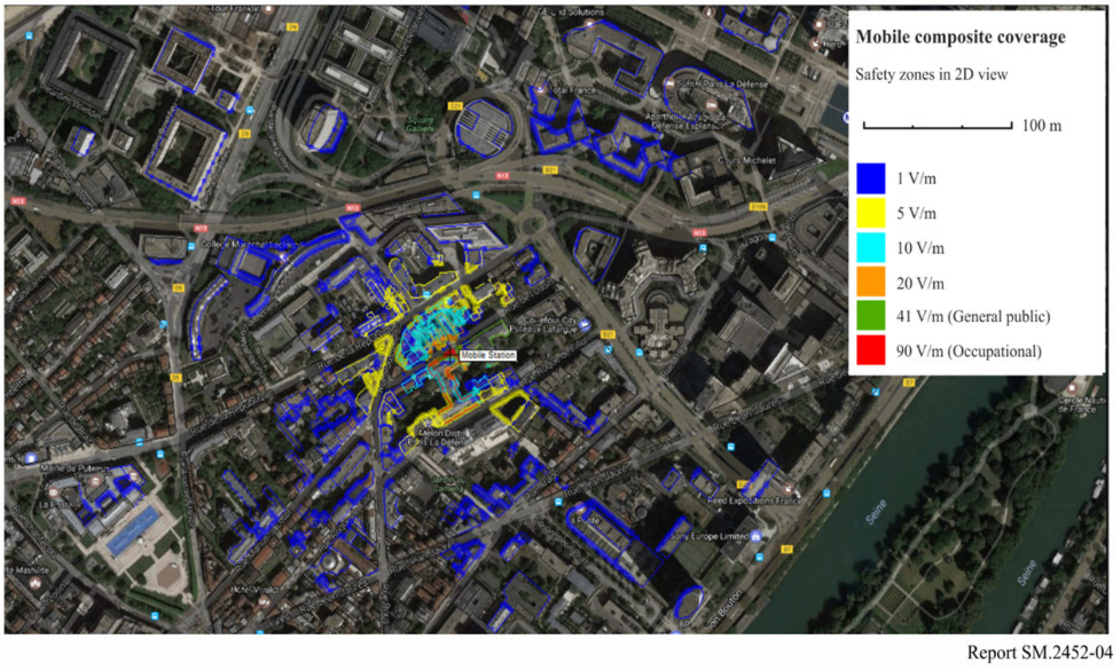
5.6.1.2 Field strength around mobile network transmitters

Even if it is significant, the simulation disregards the elevation pattern of the antenna. Actually, for mobile network base stations, below the transmitter, the antenna gain is low. A two-dimensional view taking into account the elevation pattern may confuse the viewer. At 900 MHz, 30 metres above the roof, for maximum downlink power of 100 W and antenna gain (including losses) of 17 dBi, EIRP is 5 kW, the receiver is 1.5 m above ground level (AGL).

The ICNIRP (1998) and ICNIRP (2020) general public reference level is 41 ($1.375f^{1/2} = 1.375 \times 30$) V/m and the occupational reference level is 90 V/M: $3f^{1/2}$ (MHz); the field-strength (FS) scales are 1, 5, 10, 20, 41 (general public) and 90 (occupational) V/M. In this study, only the signal from base stations to the mobile device is considered. The cellular patterns may be non-directional in azimuth, or sectoral (such as three 120^0 sectors).

Figure 15 depicts the electric field-strength contours overlaid on buildings. Building colour corresponds to the maximum FS received on a given point of the building (i.e. maximum FS on facades).

Figure 15: Two dimensional satellite view of cellular exposure distances



Source: Report ITU-R SM.2452, Figure 4

5.6.2 Measurement of RF-EMF exposure

As described in ITU-T K.91 Supplement 4,[94] compliance with public or worker (occupational) RF-EMF exposure limits can be assessed through calculation or measurement. Detailed guidance on assessments is provided in technical standards produced by ITU and other international organizations, such as the International Electrotechnical Commission (IEC) or the European Committee for Electrotechnical Standardization (CENELEC). In some cases, national requirements may be specified based on international technical standards.

Measurements may be required for complex sites with multiple transmitters or many reflecting objects, for example a rooftop with many antennas that have overlapping transmission patterns. Both broadband and frequency selective equipment can be used for the assessment (ITU-T K.6,[95] ITU-T K.100,[96] IEC 62232[97]). Measurements conducted with broadband equipment, however, might lead to overly conservative results. If the exposure level in areas accessible to the general public is found to be above the limits by means of broadband measurements, then compliance should be verified with frequency selective equipment. Otherwise, the mitigation techniques described in Recommendation ITU-T K.70 should be applied.[98]

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94 ITU-T. ITU-T K.91 Supplement 4 (09/2018). Electromagnetic field (EMF) considerations in smart sustainable cities.

95 ITU-T. Recommendation ITU-T K.61 (01/2018). Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations.

96 ITU-T. Recommendation ITU-T K.100 (07/2019). Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service.

97 IEC. 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.

98 ITU-T. Recommendation ITU-T K.70 (01/2018). Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations.

5.6.3 Presentation of results on websites

In order to inform the population, as well as potential buyers and tenants, of the exact positions of sources of RF-EMF exposure, a few administrations of ITU Member States publish on a regular basis the exact positions of transmission sites, such as radio and TV stations and cellular base stations.

The specific information found on these websites is position of transmitting antenna; technical parameters (such as frequency, power, antenna gain and elevation above ground); and exposure level. Further information on the presentation of calculated and measured RF-EMF exposure levels may be found in Recommendation ITU-T K.113[99] and Report ITU-R SM.2452.

5.6.4 Simplified assessment procedures for base station sites

As described in Section 8 of Recommendation ITU-T K.100, simplified assessment procedures based on IEC 62232 can be used to identify an antenna installation that is known to be in compliance 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 and relevant sources with respect to the general public.

The simplified assessment procedures are based on knowledge of the equivalent isotropic radiated power (EIRP), depending on the EIRP level and antenna installation characteristics, such as mounting height, main lobe direction and distance to other ambient sources as specified in Table 8-1.3 of ITU-T K.100. If the criteria are met, the installation is compliant.

[99] ITU-T. Recommendation ITU-T K.113 (11/2015). Generation of radiofrequency electromagnetic fields (RF-EMF) level maps.

Chapter 6 – Human exposure to EMF from base stations and handsets

This chapter deals with human exposure to EMF from two very common sources: base stations and handsets. Of course, all radiocommunication systems, such as TV, AM and FM radio broadcasting, paging services, cordless phones, emergency services and rural/country communication systems, use RF-EMF to facilitate communication.

The chapter examines the results from measurement campaigns to assess base station exposure levels undertaken around the world, many of which have used ITU Recommendations in their protocols. It then considers the exposure from handsets before reviewing the science and current advice on RF exposure for children.

6.1 International comparison of base station exposure levels

There have been several studies that compared the RF measurement data from mobile phone base stations in different countries. The first study[100] investigated more than 173 000 measurements from 2000 onwards in more than 20 countries across five continents. The second study[101] contained almost 260 000 measurement points from seven African countries over two time periods, from 2001 to 2003 and 2006 to 2012. The third paper[102] involved an analysis of more than 50 million data points from the Italian national RF monitoring network that was operational between 2002 and 2006 (see **Figure 16** below).

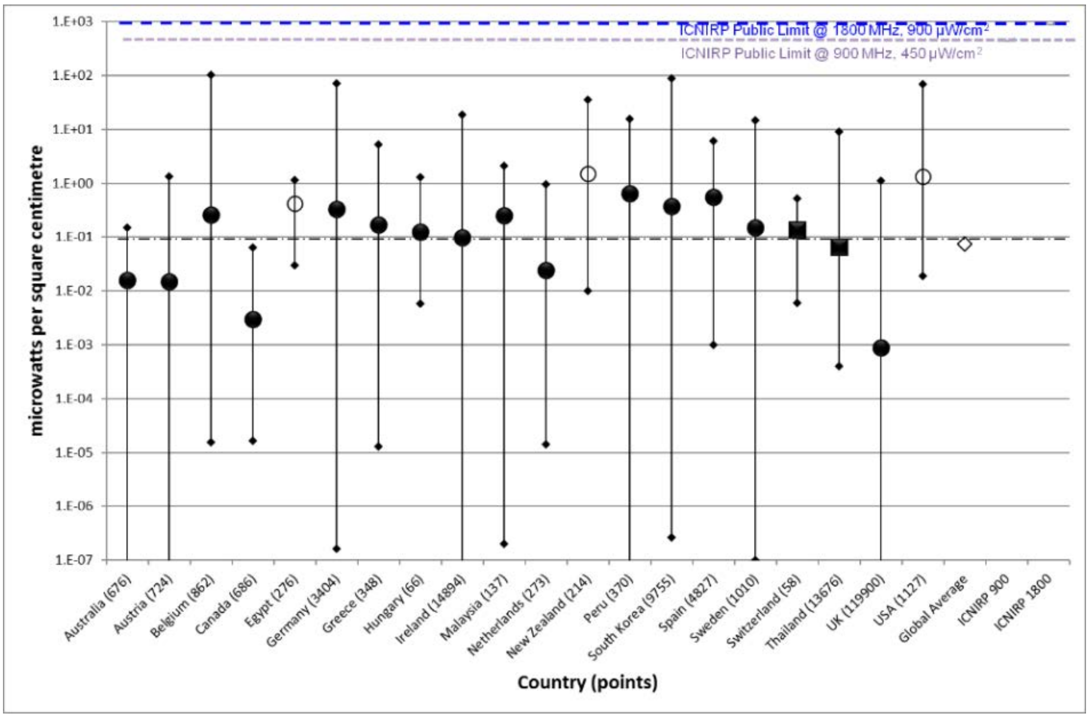
Figure 16 depicts averages of all the survey data for each of the 20 countries with the number of measurement points for each country in brackets. For comparison, the global weighted average is marked with a dot-dashed line (- **.** -) through (◊) and the ICNIRP reference levels for the public at 900 and 1800 MHz are also plotted.

[100] Jack Rowley et al. (2012). Comparative international analysis of radiofrequency exposure surveys of mobile communication radio base stations. *Journal of Exposure Science and Environmental Epidemiology*, 22(3):304–315, May/June 2012.

[101] Ken Joyner et al. (2013). National Surveys of Radiofrequency Field Strengths from Radio Base Stations in Africa. *Radiation Protection Dosimetry* (2013), 1–12.

[102] Jack Rowley and Ken Joyner (2016). Observations from national Italian fixed radiofrequency monitoring network. *Bioelectromagnetics* (February, 2016), 37(2):136-9.

Figure 16: RF-EMF survey data (20 countries)



Key: minimum (♦), maximum (♦) and narrowband average (●), broadband average (○) or mixed narrowband/broadband average (■)

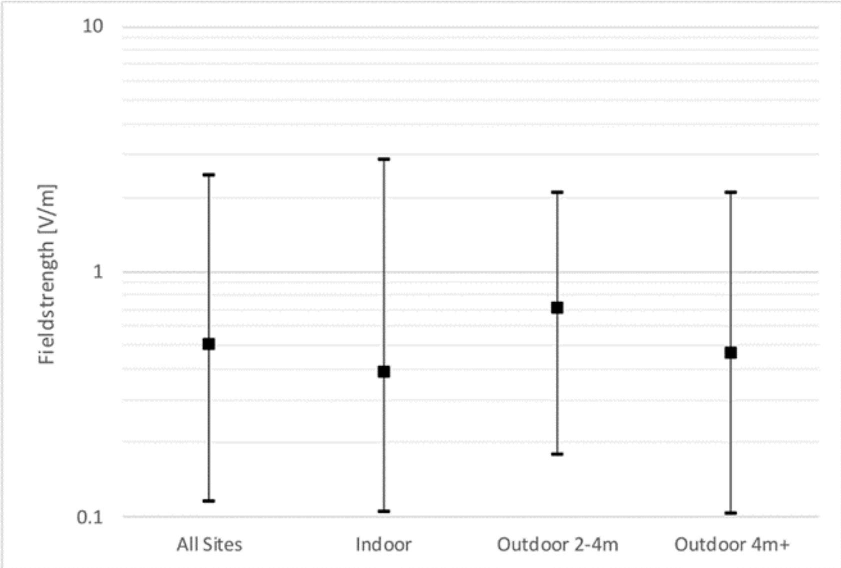
Other novel measurement approaches, such as that proposed by Huang et al. (2016),[103] which involved an assessment of exposure using both uplink and downlink exposure to create a new metric called Exposure Index (EI), also found that "*all the EI values are far below the international standard limits for human exposure*". Rowley and Joyner (2012) also investigated the temporal trends of the various technologies and countries.

As small cells are playing an increasingly important role in adding additional capacity in high-density areas and will play an even more important role in 5G networks, studies have also been undertaken to measure the RF fields from these sites. Van Wyk et al. (2019)[104] undertook measurements in Italy, the Netherlands and South Africa that involved installations typically used at bus stops, advertising signage and inside buildings. As many as 295 measurements were taken around 98 small cells in the three countries and the results are shown below.

[103] Yuanyuan Huang Y. et al. (2016). Comparison of Average Global Exposure of Population Induced by a Macro 3G Network in Different Geographical Areas in France and Serbia. *Bioelectromagnetics* (2016), 37:382-390.

[104] Martinhus et al. (2019). Measurement of EMF Exposure around Small Cell Base Station Sites. *Radiation Protection Dosimetry*, Vol. 184, Issue 2, 20 August 2019, pp.211-215.

Figure 17: Field-strength measurement results in V/m for the 98 small cell sites measured



According to the authors, *"the results show that all the measured EMF exposure levels are well below the general public limits as specified by ICNIRP"*. They also noted that their results were consistent with other national measurement studies, such as those undertaken in France as well as the studies discussed above.

The key findings from all of these studies are that, irrespective of the country, the year and the mobile technology, RF fields at ground level were only a small fraction of the international human RF exposure recommendations. Importantly, environmental levels have remained essentially constant despite the increasing number of base stations and deployment of additional mobile technologies.

The results of all of the studies and the measurement results further support the advice provided by WHO[105] in relation to base stations and wireless technologies: *"Considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects"*.

6.2 Exposure levels from handsets

The SAR value[106] is a measure of the amount of RF energy absorbed by the body when using a mobile phone.

For regulatory compliance testing, SAR is measured at maximum power levels under laboratory conditions according to measurement standards, which prescribe the testing positions and all operational characteristics of the mobile phone, including maximum transmit power.

105 WHO (2006). Health Topics. Electromagnetic fields and public health. Fact Sheet No. 304. Base stations and wireless technologies

106 SAR stands for specific absorption rate. Detailed information on SAR can be found at: http://www.sartick.com

The SAR values reported for each model of mobile phone overstate real-life exposure levels because the applicable standards are conservative.[107] Furthermore, in reality, the devices operate at significantly lower power levels, adapting constantly to use the minimum power required to make and receive a call, in order to maximize battery life. Several studies[108],[109] of mobile phones in everyday use have shown that when used to talk while walking around a major city or inside city buildings, smartphones typically operate at a small fraction of their maximum power output. In the paper by Gati et al. (2009), the researchers observed that 90 per cent of all the collected measurements, including those taken indoors and outdoors, were less than 4 dBm, which is about 1 per cent of the maximum emitted power. As a result, they concluded: "*The real exposure due to mobile phones in terms of Specific Absorption rate (SAR) is well below (100 times below) the normative values given at the maximum powers*".

The output power data for about 7 000 4G devices connected to 41 LTE radio base stations located in rural, suburban, urban, and indoor environments in Sweden were presented in a recent publication: "*More than 300 000 power samples were collected. In rural environments, the 95th percentile time-averaged output power values were found to be 2.2 per cent of the maximum available power, while the corresponding values were less than 1 per cent in other environments. The mean output powers in all the environments were found to be less than 1 per cent of the maximum available output power. These values are in line with results obtained for 3G UE despite an almost tenfold increase in the achievable peak data throughput. These findings show that knowledge of realistic power levels is important for accurate assessment of the realistic exposure from modern smartphone devices*".[110]

The RF exposure standards have been established to specify the maximum allowed SAR for wireless communication devices, such as mobile phones which incorporate an additional safety factor to ensure that all users, including children, pregnant women and older persons, can safely use these devices. From an investigation of the regulatory requirements for over 200 countries, there are essentially only two applicable standards and regulatory regimes: 150 countries have adopted the ICNIRP limits of 2 W/kg measured in biological tissue equivalent weighing 10 g[111],[112] and 28 countries have adopted the US Federal Communications Commission (FCC) limits of 1.6 W/kg measured in biological tissue equivalent weighing 1 g.[113] There are 50 countries for which no regulatory information is available. However, where no limits are mandated, manufacturers apply the ICNIRP limits, which are consistent with Recommendation ITU-T K.52.[114]

107 Mobile Manufacturers Forum (MMF). Viewpoint. Conservativeness of mobile phone SAR measurements. November, 2011.

108 Tomas Persson et al. (2012). Output power distributions of terminals in a 3G mobile communication network. *Bioelectromagnetics*, Vol. 33, pp. 320-325, 2012.

109 Azzedine Gati et al. (2009). Exposure induced by WCDMA Mobile Phones in Operating Networks. *IEEE Trans on wireless communications,* Vol. 8 No. 12, 2009.

110 Paramananda Joshi et al.(2017). Output Power Levels of 4G User Equipment and Implications on Realistic RF-EMF Exposure Assessments. *IEEE Access*, Vol. 5, pp. 4545-4550, 2017.

111 Most national limits are formally based on ICNIRP (1998)

112 ICNRP. ICNIRP Statement on the Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). *Health Physics*, 2009. 97(3): pp. 257-258.

113 FCC. Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation, in *47 CFR Parts 1, 2, 15, 24 and 97*, FCC, Editor. 1996: Federal Register.

114 ITU-T. Recommendation ITU T K.52 (01/2018). Guidance on complying with limits for human exposure to electromagnetic fields.

6.3 National SAR measurements

As stated above, there are essentially only two applicable standards and regulatory regimes: ICNIRP and FCC. Even in countries where no regulatory requirements are specified, manufacturers apply the ICNIRP limits.

National regulatory agencies have three different approaches to ensuring compliance of devices. In Europe there is a presumption of conformity based on harmonized standards and a focus on post-market surveillance, whilst in North America and many countries in the Asia and the Pacific region the process is based on pre-market approvals. In some other countries in this region, there is an ongoing audit of manufacturers and importers of devices. The SAR values for devices are available from manufacturers' websites as well as from many national regulatory agencies.

6.4 RF exposure and children

Among the many research areas studied is the issue of whether there are differences between the absorption of RF-EMF in adults and children. Papers by Schönborn et al. (1998),[115] Kuster and Balzano (1992),[116] Hornbach et al. (1996)[117] and Meir et al. (1997)[118] have found that there are no significant differences between the absorption of RF in adults and children. Gandhi and Kang (2002)[119] and Bit-Babik et al. (2005)[120] have reported similar SAR patterns in the heads of adults and children, in contrast to the results shown in a much earlier study by Gandhi et al. (1996),[121] which were due to improper scaling of the size and colour. Foster and Chou (2014)[122] also reviewed the dosimetry and concluded that with regard to compliance of handsets with regulatory limits there is no clear evidence for age-related differences in exposure in terms of peak spatial average SAR in the head.

In terms of health agencies that have looked at this issue, the United States Food and Drug Administration (FDA) has stated that: "*Current scientific evidence does not show a danger to any users of cell phones from RF energy, including children and teenagers. There are also simple steps that anyone, including children and teenagers, can take if they would like to reduce RF exposure:*

- *Reduce the amount of time spent using the cell phone*
- *Use speaker mode, head phones, or ear buds to place more distance between the head and the cell phone.*"[123]

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115 Frank Schönborn et al. (1998). Differences in Energy Absorption between Heads of Adults and Children in the Near Field of Sources. *Health Physics*, Vol. 74, pp. 160-168, 1998

116 Niels Kuster and Q. Balzano (1992). Energy Absorption Mechanism by Biological Bodies in the Near Field of Dipole Antennas above 300 MHz. *IEEE Transactions on Vehicular Technology*, Vol. 41, No. 1, February 1992

117 V. Hombach et al. (1996). The Dependence of EM Energy Absorption upon Human Head Modelling at 900 MHz. *IEEE Transactions on Microwave Theory and Techniques*, Vol. 44, No. 10, October 1996

118 Klaus Meier et al. (1997). The Dependence of Electromagnetic Energy Absorption upon Human-Head Modelling at 1800 MHz. *IEEE Transactions on Microwave Theory and Techniques*, Vol. 45, No. 11, November 1997

119 Om Gandhi and Gang Kang (2002). Some Present Problems and a Proposed Experimental Phantom for SAR Compliance Testing for Cellular Telephones at 835 and 1900 MHz. *Phys. Med. Biol.* 47: 1501–18

120 G. Bit-Babik et al. (2005). Simulation of Exposure and SAR Estimation for Adult and Child Heads Exposed to Radiofrequency Energy from Portable Communication Devices. *Radiation Research* 163: 580–90

121 Om. Gandhi et al. (1996). Electromagnetic Absorption in the Human Head and Neck for Mobile Telephones at 835 and 1900 MHz. *IEEE Transactions on Microwave Theory and Techniques.* 44**:** 1884–97

122 Kenneth Foster and Chung-Kwang Chou (2014). Are Children More Exposed to Radio Frequency Energy from Mobile Phones than Adults? *IEEE Access* vol. 2, pp. 1497-1509.

123 FDA. Children and teens and cell phones.

Some groups sponsored by other national governments have advised that children be discouraged from using cell phones for non-essential calls, or not at all. For example, the Stewart Report from the United Kingdom made such a recommendation in December 2000.[124] In this report, a group of independent experts noted that no evidence exists that using a cell phone causes brain tumours or other ill effects. Their recommendation to limit cell phone use by children to essential calls only was strictly precautionary; it was not based on scientific evidence that any health hazard exists. It is also worth remembering that at the time of the recommendation, the United Kingdom applied similar exposure limits, which generally did not distinguish between workers and the public, and that adopting ICNIRP's Guidelines was also recommended as a precautionary measure.[125]

The Health Council of the Netherlands,[126] which has also looked into this issue, has concluded that: "There is no scientific evidence for a negative influence of exposure to electromagnetic field of mobile telephones, base station antennas or Wi-Fi equipment on the development and functioning of the brain and on health in children."

In a publication entitled NIR and Children's Health,[127] ICNIRP stated as follows: "*Although many research studies addressing the possible effects of NIR on human health have been published and a plethora of scientific meetings taken place, the evidence for such effects remains uncertain and particularly with regard to the health of children.*"

From the same source: "*In recent years, the results of many epidemiological and biological studies have provided the principal input to health risk assessments and cancer reviews on EMFs carried out by the World Health Organization (WHO) in Geneva, by the International Agency for Research on Cancer (IARC) in Lyon and by various national agencies. IARC has also recently assessed the carcinogenicity of ultraviolet radiation and sunbeds as have a number of national agencies.*

As reflected in these Proceedings, the science addressing this issue is multidisciplinary bringing together expertise in the fields of medicine, epidemiology, biology, electrical and telecommunications engineering, computational physics and risk management.

The reviews, research papers and discussions in this volume did not reveal new health-related age-specific sensitivities of children, but some uncertainties which are methodologically difficult to address, are still remaining particularly for childhood leukemia. While the scientific evidence for adverse effects of exposure to ultraviolet radiation is much clearer and it is accepted that excessive and/or prolonged/repeated exposure is a significant risk factor in causing skin cancers and eye diseases, research is needed to further clarify mechanisms of disease that would provide a better basis for methods of protection, particularly with regard to young people.

These Proceedings should be of interest to scientists and of value to governmental agencies for policy development and in considering research agendas to fill gaps in knowledge."

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[124] UK national Archives. Independent Expert Group on Mobile Phones (IEGMP), chaired by Sir William Stewart (2000). Mobile Phones and Health.

[125] See paragraph 28 of the House of Commons Select Committee on Trade and Industry. Trade and Industry - Tenth Report

[126] Health Council of the Netherlands (2011). Influence of radiofrequency telecommunication signals on children's brains. The Hague: Health Council of the Netherlands, 2011; publication no. 2011/20E. ISBN 978-90-5549-859-8.

[127] ICNIRP. Non-Ionizing Radiation (NIR) and Children's Health. Proceedings of an International Joint Workshop organized by COST/ICNIRP/WHO/EuroSkin and hosted by INIS on 18-20 May 2011, Ljubljana, Slovenia. *Progress in Biophysics & Molecular Biology* (107)3:311-482 (2011)

The conclusions are consistent with the following statement from WHO: *"Present scientific evidence does not indicate the need for any special precautions for the use of mobile phones. If Individuals are concerned, they might choose to limit their own or their children's RF Exposure by limiting the length of calls, or by using "hands-free" devices to keep mobile phones away from the head and body."*

In addition, WHO states: *"A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use."*[128]

In summary, the weight of scientific evidence attests that there is no evidence of any adverse health effects from the use of mobile phones or wireless devices. Consistent with the WHO advice for parents or individuals who are concerned, there are a number of options to limit their or their children's exposure by reducing use of the device and the length of calls, or by using "hands-free" devices to keep devices away from the head and body.

[128] WHO. Newsroom. Fact sheets. Electromagnetic fields and public health: mobile phones

Chapter 7 – Case studies

7.1 Background

The very rapid development of telecommunications/ICTs is resulting in the ubiquitous presence in the environment of electromagnetic fields (EMFs). This is a source of concern in some countries regarding the possible public health effects of prolonged exposure. As a result of the rapid growth of electronic communications and the exponential proliferation of sources of radio-frequency electromagnetic fields (RF-EMFs), many questions have been raised, and many complaints have been received by operators and government agencies responsible for radiocommunications/ICTs.

Governments are aware of the need to adopt measures to provide information or responses to concerns of the public, and in doing so refer to ITU Recommendations or national regulations in order to introduce various practices on ways to limit RF-EMF exposure. The aim is to generate confidence in the safety and harmlessness of mobile masts as well as dispelling myths and misunderstandings in order to create a transparent and accountable ecosystem for sharing information and compliance with RF-EMF exposure standards.

Some countries are establishing limits based on the ICNIRP Guidelines, others are carrying out studies and adopting additional restrictions.

Thus, several countries have taken measures to limit human exposure to RF-EMF and to effectively raise the awareness of the different stakeholders on how to handle the issue with regard to best practices to be adopted by the government, service providers and the public.

WHO and ITU have produced plans for communicating RF-EMF risks with an emphasis on exchanges of information on the various aspects of RF-EMF hazards between countries and regions, including the development of standards, research, regular summaries of research results, reports and holding symposiums.

The various contributions received in the course of the work under ITU-D Study Group 2 Question 7/2 and that carried out by ITU-T Study Group 5 have made it possible to identify the practices adopted by various countries to effectively take account of the different concerns involved.

7.2 Country initiatives

The different initiatives shared for taking effective account of issues relating to RF-EMF exposure can be recapitulated as follows:

- introduction of regulations establishing thresholds and limits for EMF exposure;
- EMF measurement campaign;
- awareness-raising campaign on practices to be adopted;
- introduction of tools for communication between the government and the public to inform the latter of action taken and respond to concerns;
- studies on the impacts of RF-EMF.

7.2.1 The case of Burundi[129]

Burundi is aware that the introduction of a legal and regulatory framework conducive to the development of telecommunications ensures better quality of service and better living conditions for people. The policy of encouraging telecommunication infrastructure sharing also helps to reduce the perceived effects of human exposure to RF-EMF. The perceived risk from electromagnetic fields is an issue often raised by the public. Burundi's telecommunication regulation and enforcement agency (*Agence de régulation et de contrôle des télécommunications* - ARCT) has established guidelines setting threshold values and limits with which operators are required to comply when setting up base stations for the deployment of telecommunication networks.

Infrastructure sharing reduces the proliferation of base stations by ensuring that antennas are grouped together on pylons, which are clearly identified at locations that fully comply with relevant norms. Accordingly, ARCT has:

- raised operators' awareness of the need to share infrastructure in order to optimize and reduce costs;
- raised public awareness of the need to respect operators' installations in order to prevent acts of sabotage and vandalism to telecommunication networks;
- conducted inspections of technical and operational compliance of telecommunication operators' equipment;
- developed guidelines on telecommunication infrastructure sharing.

7.2.2 The case of the Central African Republic[130]

The total liberalization of the telecommunication/ICT sector in the Central African Republic, with the presence of four mobile telephony operators (Telecel, Moov, Azur and Orange) and the incumbent operator Socatel having a fixed monopoly, has resulted in a proliferation of base station antennas in the capital Bangui and in most provincial cities. This anarchic introduction of base stations results in a certain negative perception about the effects of RF-EMF among the population. Faced with this problem, the Government has created a national radiation protection agency (*Agence nationale de radioprotection* - ANR) whose mission is to develop a policy and strategy to tackle the problem.

In order to remedy this deficiency, the Government, through its telecommunication regulator (*Agence de régulation des télécommunications* – ART), adopted a set of regulations as an initial measure requiring operators to have recourse to infrastructure-sharing arrangements. Unfortunately, the implementation of these regulations by the operators and enforcement by ART have been problematic.

ART is responsible for collecting a percentage of the operators' turnover, which is intended to help the affected population. The agency is unfortunately finding it hard to operate as a result of the reluctance of operators to contribute to the funds it needs.

Nevertheless, a number of measures are being taken, and include:

- raising operators' awareness of the need to share infrastructure in order to optimize and reduce costs;

[129] ITU-D SG2 Document 2/42 from Burundi
[130] ITU-D SG2 Document SG2RGQ/42(Rev.1) from the Central African Republic [in French]

- raising public awareness of the need to respect operators' installations in order to prevent acts of sabotage and vandalism to telecommunication networks;
- conducting inspections of technical and operational compliance of telecommunication operators' equipment;
- developing guidelines on telecommunication infrastructure sharing;
- acquiring the equipment needed to monitor RF-EMF;
- setting up a call centre to receive and process consumer complaints effectively.

7.2.3 The case of Senegal[131]

Aware of the perception regarding the impact of RF-EMF on the population as a result of various studies already carried out by international agencies, Senegal is conducting campaigns to measure RF-EMF exposure through its telecommunication and postal regulator (*Autorité de régulation des télécommunications et des postes* – ARTP). Senegal has procured equipment for the control and monitoring of RF-EMF levels in its national territory and carried out RF-EMF measurement campaigns.

The campaigns to measure RF-EMF in Senegal's densely populated urban areas have been conducted in accordance with the recommendations set out in the ITU-R Handbook on Spectrum Monitoring, related ITU-T K-series Recommendations, ITU-D guidelines and ICNIRP Guidelines.

According to the country's current Telecommunications Code, international guidelines and the recommendations of ITU, ICNIRP and similar agencies, operators must comply with certain requirements pertaining to radiation limits, security perimeter distances, testing of equipment before installation and bringing into service, approval of tests by the regulator and reporting of RF-EMF levels to the regulator. In accordance with this principle, the regulatory authority provides radio equipment importers with certification of compliance with international standards.

Once the campaign is completed, the public will have a reliable overview available to individuals and corporate bodies. Finally, a consultation and coordination strategy will be implemented with all mobile phone operators and private independent network operators with a view to ensuring permanent monitoring of radio facilities and applying recommendations and guidelines on permissible RF-EMF levels for each technology.

7.2.4 The case of China[132]

China applies environmental limits that differ from international recommendations for base station electromagnetic fields, although the exposure limits for mobile devices and the method of measurement generally comply with international standards. China's contribution summarizes studies on the effects of electromagnetic fields in China in this context:

- China applies environmental EMF limits that differ from international recommendations because previous standards have been superseded, and because of the results of national studies and of risk assessments (based on future technologies)
- Exposure limits for mobile devices conform to international standards
- The measurement method used generally conforms to international standards
- The trend is towards adoption of international limits

[131] ITU-D SG2 Document SG2RGQ/50 from Senegal [in French]
[132] ITU-D SG2 Document SG2RGQ/68 from China

7.3 Recapitulation of best practices

Table 9: List of best practices

Actions	Implementation plan	Country
Establishment of regulations setting threshold values and limits for EMF exposure with which operators are required to comply when setting up base stations for the deployment of telecommunication networks	Follow ICNIRP guidelines in general	Senegal, Burundi, India, Central African Republic, Sudan
	Apply environmental EMF limits that differ from international recommendations because of the results of national studies and of risk assessments	China, Côte d'Ivoire
	Publish laws to supervise the effects of base stations on human health and the surrounding environment	China, Senegal, India, Cameroon, Hungary, Côte d'Ivoire
	Have specialized agencies responsible for assessment and approval for installation or relocation of the base station	Central African Republic
Campaigns to measure EMF and SAR of equipment	Acquire the equipment needed to monitor EMF	China, Senegal, Central African Republic, Côte d'Ivoire, Sudan
	Conduct ongoing monitoring of radio installations to ensure compliance with the RF-EMF levels permitted for each technology	China, Central African Republic, Senegal, Burundi, Côte d'Ivoire, Sudan
	Verify SAR of equipment	Cameroon
Awareness-raising campaign on practices to be adopted	Raise public awareness in order to handle RF-EMF questions more effectively	Burundi, Haiti, India
	Raise public awareness to ensure that operators' installations are not banned	Cameroon, Central African Republic
Dissemination of information	Publish relevant information and measurement results on the website of government authorities	India
	Set up a call centre to receive and process consumer complaints effectively	Central African Republic
	Install visible notices informing the community as a whole of the level of compliance of radio stations with RF-EMF human exposure limits	Colombia
Studies on the impacts of electromagnetic radiation	Carry out studies on the effects of EMF	China, Republic of Korea

Annexes

Annex 1: List of contributions and liaison statements received on Question 7/2

Contributions on Question 7/2

Web	Received	Source	Title
2/411	2021-03-02	Co-Rapporteurs for Question 7/2	Draft proposal for the future of Question 7/2
2/392 (Rev.1)	2021-02-17	ATDI (France)	Draft Liaison Statement to ITU-T Q3/5, ITU-R WPs 1A, 1C, 5A, 5B and 6A
2/363	2021-01-11	China, GSMA, ATDI (France)	Proposed revisions to the Final Report for Question 7/2 to WTDC-21
RGQ2/TD/23	2020-10-08	Mobile & Wireless Forum	MWF comments to SG2RGQ/218(Rev.1)
RGQ2/TD/22	2020-10-08	Mobile & Wireless Forum	MWF comments to SG2RGQ/209
RGQ2/TD/21	2020-10-07	Co-Rapporteurs for Question 7/2	Working Document – Updated Draft Output Report for Question 7/2
RGQ2/TD/20	2020-10-07	Co-Rapporteurs for Q7/2	Proposed liaison statement from ITU-D Study Group 2 Question 7/2 to ITU-T Q3/5, ITU-R Working Parties 1A, 1C, 4A, 5A, 5B, 5C, 5D, 6A, 7A and 7B on updates on new EMF limits
RGQ2/TD/19	2020-09-30	GSMA	GSMA comments to SG2RGQ/229
RGQ2/TD/18	2020-09-30	GSMA	GSMA proposed revisions to SG2RGQ/209
RGQ2/TD/17	2020-09-30	GSMA	GSMA comments to terminology for electromagnetic fields and health
RGQ2/TD/16	2020-09-30	GSMA	GSMA comments to Report for Question 7/2 to WTDC-2021: Revision of Chapters 1, 2, 3 and Annexes 1, 2, 3
RGQ2/246	2020-09-04	ATDI (France)	Report for Q7/2 to WTDC-2021: Revision of Chapters 1, 2, 3 and Annexes 1, 2,3
RGQ2/229	2020-08-18	Senegal	Chapter 7: Case studies and national practices based on contributions
RGQ2/218 (Rev.1)	2020-07-31	Haiti	Terminology for electromagnetic fields and health

(continued)

Web	Received	Source	Title
RGQ2/209	2020-06-11	China	Revisions to draft Chapter 4 of the Final Report for Question 7/2
2/324 + Ann.1	2020-02-07	BDT Focal Point for Question 7/2	Development of EMF Guidelines for the Arab region – update
2/292	2020-01-09	Guinea	Strategy and methodology for assessing the level of exposure of the general public to non-ionizing radiation in the Republic of Guinea
2/289	2020-01-08	ATDI (France)	Report for Q7/2 to WTDC-2021: Revision of Chapters 1, 2, 3 and Annex 2
2/288	2020-01-08	Mobile & Wireless Forum, GSMA	Proposed revisions and updates to Draft Report of ITU-D Question 7/2
2/284	2020-01-07	GSMA	Comments on RF-EMF exposure topics discussed at Question 7/2 meeting, October 2019
2/276	2020-01-03	China	Overview of new "IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz"
2/275	2020-01-09	Senegal	Chapter 7: Case studies and national practices based on contributions
2/271	2019-12-31	Burundi	Legal framework for telecommunication infrastructure sharing as a way to reduce human exposure to electromagnetic emissions in Burundi
2/267	2019-12-27	Central African Republic	Strategies and policies concerning human exposure to electromagnetic fields
2/255	2019-12-16	Haiti	CONATEL strategies for protecting consumers against exposure to electromagnetic fields
2/253	2019-12-16	Democratic Republic of the Congo	Strategies and policies concerning human exposure to electromagnetic fields
RGQ2/TD/15	2019-10-17	Co-Rapporteurs for Question 7/2	Proposed text for outgoing liaison statement from ITU-D Study Group 2 Question 7/2 to ITU-T SG5 and ITU-R working parties
RGQ2/TD/11	2019-10-02	Côte d'Ivoire	Periodic assessment of the level of exposure of people to Non-Ionizing Radiation (NIR) and risk reduction in Côte d'Ivoire
RGQ2/191	2019-09-24	Hungary	10 years' experience in EMF exposure assessment technics, applied methods and strategies for the next 3 years at NMHH

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Web	Received	Source	Title
RGQ2/181	2019-09-23	China	Update of electromagnetic radiation environmental monitoring standards for mobile communication base stations in China
RGQ2/180	2019-09-23	China	Revisions to draft Chapter 4 of the Final Report for Question 7/2
RGQ2/177 + Ann.1	2019-09-20	BDT Focal Point for Question 7/2	Development of EMF guidelines for the Arab region
RGQ2/158	2019-09-06	India	Multi-dimensional approach to mitigating EMF concerns in India
RGQ2/157	2019-09-05	Co-Rapporteurs for Question 7/2	Draft consolidated report for Q7/2 to WTDC-21
RGQ2/142	2019-08-14	ATDI (France)	Status of the Q7/2 Report to WTDC-21
RGQ2/140	2019-08-12	Central African Republic	Strategies and policies concerning human exposure to the ionizing effects of electromagnetic fields
RGQ2/137	2019-08-02	Cameroon	Strategies and policies concerning human exposure to electromagnetic fields: the case of Cameroon
RGQ2/133	2019-07-28	Senegal	Chapter 7: Case studies and national practices based on contributions
RGQ2/123	2019-07-09	Haiti	Electromagnetic wave awareness-raising campaign
2/TD/21	2019-03-28	Co-Rapporteur for Question 7/2	Proposed liaison statement from ITU-D Study Group Q7/2 to ITU-T and ITU-R Study Groups on strategies and policies concerning human exposure to EMF
2/205	2019-03-11	Mali	Stratégies et politiques concernant l'exposition des personnes aux champs électromagnétiques : cas du Mali
2/163	2019-02-06	Mobile & Wireless Forum	Contribution for Chapter 6 of the report: Modern Policies, Guidelines, Regulations and Assessments of Human Exposure to RF-EMF
2/160	2019-03-11	China	Policies to limit exposure to radiofrequency fields
2/151	2019-01-30	Central African Republic	Contribution by the Central African Republic to Question 7/2 on exposure to electromagnetic fields
2/150	2019-01-29	Haiti	National EMF activities on exposure limits
2/147	2019-01-28	ATDI (France)	Output Report on Question 7/2, Chapter 3: Updated international RF-EMF exposure limits

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Web	Received	Source	Title
2/137	2019-01-15	ATDI (France)	Output report of Question 7/2, revised "Chapter 2 - ITU activities"
RGQ2/TD/7	2018-10-01	Russian Federation	ITU-D SG1 and SG2 coordination: Mapping of ITU-D Study Group 1 and 2 Questions
RGQ2/82	2018-09-18	Ghana	Ghana's Type Approval Regime - a sustainable approach to connecting and protecting users of telecommunications/ICTs and networks through conformance assessment
RGQ2/71	2018-09-18	India	Tarang Sanchar: Department of Telecommunications (DoT) India new web portal to monitor radiation compliance by telecommunication service providers and generate awareness
RGQ2/68	2018-09-17	China	Recent research activities and the update of EMF standards in China
RGQ2/50	2018-09-03	Senegal	Campagne nationale de mesure de la densité des champs électromagnétiques et d'évaluation des rayonnements non-ionisants au Sénégal
RGQ2/45	2018-08-27	ATDI (France)	Draft 7th study period report on Question 7/2: chapters 1 and 2
RGQ2/42 (Rev.1))	2018-08-24	Central African Republic	Stratégies et politiques concernant l'exposition des personnes aux champs électromagnétiques
RGQ2/41 + Ann.1	2018-08-22	BDT Focal Point for Question 7/2	Outcome report: EMF and 5G rollout Expert Meeting, Rome, November 2017
RGQ2/40 + Ann.1	2018-08-22	BDT Focal Point for Questions 1/1, 1/2, 2/1 and 7/2	Regional Seminar for Europe and CIS on "5G Implementation in Europe and CIS: Strategies and Policies Enabling New Growth Opportunities", Budapest, July 2018
RGQ2/20 +Ann.1	2018-08-09	BDT Focal Point for Question 7/2	ITU activities on EMF
RGQ2/19 + Ann.1	2018-08-08	Hungary	Report on the ITU-D Study Groups related Experts' Knowledge Exchange
RGQ2/18 + Ann.1	2018-08-06	ATDI (France)	ITU inter-Sectoral response to the public consultation of the Draft ICNIRP Guidelines on limiting exposure (100 kHz to 300 GHz)
2/85 + Ann.1	2018-04-23	BDT Focal Point for Question 7/2	Electromagnetic field level and 5G roll-out expert meeting
2/47	2018-03-15	India	Mandating adoption of harmonized, electromagnetic fields/radiofrequency (EMF/RF) exposure limit across the nations based on the international guidelines

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Web	Received	Source	Title
2/42	2018-03-01	Burundi	Strategy for telecommunication infrastructure sharing as a way to reduce human exposure to electromagnetic emissions in Burundi
2/38	2018-04-20	China, ATDI (France)	Proposed Table of Content for the Report of Question 7/2
2/37	2018-04-20	China, ATDI (France)	Proposed work plan (2018-2021) for Question 7/2

Incoming liaison statements for Question 7/2

Web	Received	Source	Title
2/364	2020-12-09	ITU-R Working Party 1C	Liaison statement from ITU-R Working Party 1C to ITU Study Group Question 7/2 on revision of Report ITU-R SM.2452-0 on EMF measurements to assess human exposure
2/360	2020-11-19	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D SG2 Q7/2 on work being carried out under study in ITU-T Q3/5
2/354	2020-10-14	ITU-R Working Party 6A	Liaison statement from ITU-R Working Party 6A to ITU-T Study Group 5 (copy to ITU-D SG2 Q7/2) on EMF exposure from bonded cellular devices
RGQ2/287	2020-07-14	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D SG2 Q7/2 on work being carried out in ITU-T SG5 on human exposure to EMF from ICTs
RGQ2/203	2020-02-18	ITU-T Study Group 5	Liaison statement from ITU-T SG5 to ITU-D SG1 and SG2 on information on WTSA-20 preparation
RGQ2/TD/14 + Ann.1	2019-10-11	ITU-T Study Group 5	Liaison statement from ITU-T SG5 to ITU-D SG2 Q7/2 on work being carried out under study in ITU-T SG5 Q3/5
RGQ2/117	2019-06-18	ITU-R study groups – Working Party 1C	Liaison statement from ITU-R WP 1C to ITU-D SG2 Q7/2 on electromagnetic field measurements to assess human exposure
RGQ2/115 + Ann.1	2019-06-14	ITU-T Study Group 5	Liaison statement from ITU-T SG5 to ITU-D SG2 Q4/2 and Q7/2 on work being carried out under study in ITU-T Study Group 5 Question 3/5
2/119 + Ann.1	2018-10-16	ITU-T Study Group 5	Liaison statement from ITU-T SG5 to ITU-D SG2 Q7/2 on collaboration in RF-EMF, EMC and particle radiation effects
RGQ2/TD/6 + Ann.1	2018-09-28	ITU-T Study Group 5	Liaison statement from ITU-T SG5 to ITU-D SG2 Q7/2 on ITU inter-Sectoral response to "ICNIRP Public Consultation of the Draft ICNIRP Guidelines on Limiting EMF Exposure (100 kHz to 300 GHz)"
RGQ2/TD/4	2018-09-28	ITU-T Study Group 5	Liaison statement from ITU-T SG5 to ITU-D SG2 Q7/2 on work being carried out under study in ITU-T Q3/5 (reply to LS ITU-R WP1C, 1C/169-E (Annex 10) and ITU-D SG2, 2/116-E)
RGQ2/7	2018-06-29	ITU-R study groups – Working Party 1C	Liaison statement from ITU-R WP1C to ITU-D SG2 Q7/2 on the Preliminary Draft New Report ITU-R SM.[EMF-MON]

(continued)

Web	Received	Source	Title
RGQ2/6 + Ann.1	2018-06-04	ITU-T Study Group 5	Liaison Statement from ITU-R SG5 to ITU-D SG2 Q7/2 on the work which is under study in ITU-T Question 3/5
2/34	2017-11-29	ITU-T Study Group 5	Liaison Statement from ITU-T SG5 to ITU-D SG2 Question 7/2 on information about work that is being carried out which is under study in ITU-T Q3/5
2/33	2017-11-28	ITU-T Study Group 5	Liaison Statement from ITU-T SG5 to ITU-D study groups on setting environmental requirements for 5G/IMT-2020
2/27	2017-11-24	ITU-T Study Group 5	Liaison Statement from ITU-T SG5 to ITU-D SG2 Question 7/2 on information about work being carried out under study in ITU-T Q3/5
2/26	2017-11-24	ITU-T Study Group 5	Liaison Statement from ITU-T SG5 to ITU-D SG2 Question 6/2 and Question 7/2 on Operational Plan for Implementation of WTSA-16 Resolutions 72 and 73 (Hammamet, 2016), and Resolution 79 (Dubai, 2012)
2/22	2017-11-24	ITU-R study groups - Working Party 1C	Liaison Statement from ITU-R Working Party 7C to ITU-D Study Group 2 Q7/2 on a preliminary draft new Report ITU-R SM.[EMF-MON]
2/8	2017-11-22	ITU-T Study Group 5	Liaison Statement from ITU-T SG5 to ITU-D study groups on ITU-T Study Group 5 lead study group activities

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