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Implementing 5G for Good
Do electromagnetic fields matter?

Implementing 5G for Good: Do electromagnetic fields matter?

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1 Introduction

1.1 The recent landscape

Human exposure to electromagnetic fields (EMF) from radio frequencies (RF) (RF-EMF) has been an element of concern and dispute among the public in some countries for decades, despite the wide availability of international scientific recommendations. As a result of public pressure, or pre-existing standards, some countries apply limit values that are more restrictive than international recommendations,[1] which can lead to delays in antenna deployment, increase people's concerns in regard to the proliferation of antennas and generate higher costs for society.

The COVID-19 pandemic and the related spread of misinformation around fifth-generation (5G) mobile technology has exacerbated this trend and, fuelled by social media, has caused a spate of incidents in a number of countries. Some countries have even reported up to 200 incidents in the first half of 2020, including the burning or destruction of several antenna masts as well as harassment of telecommunication technicians.

In the context of 5G infrastructure roll-out and ensuring the safety of existing infrastructure and continuity of services, the recent increase in incidents poses a significant risk to the deployment of next-generation networks (NGN) and to the operability of existing networks. This risk becomes even more acute when we consider that telecommunication networks have played a fundamental part in securing countries' resilience during the COVID-19 crisis. It is therefore in the interest of the international community to provide clarity on how to address this increasingly relevant issue.

1.2 Purpose of the report

This report does not claim to offer a definitive solution on the topic of RF-EMF, nor convince the public of the reliability of international standards and recommendations. It seeks rather to provide countries with a review of relevant scientific evidence and an outline of the main contemporary challenges relating to RF-EMF that would require coordinated action and communication at national, regional and international level.

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 wide variation among countries in terms of 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"*.[2]

Compliance and monitoring activities on human exposure limits for EMF are quite widely undertaken by regulators around the world, with the involvement of service providers and wireless equipment suppliers, although these activities differ in scale and scope. In general, **all**

1 There are also some countries that retain more restrictive limits that predate the international limits.
2 WHO (2006). Framework for Developing Health-Based EMF Standards, pp. 7-8.

these undertakings commonly and consistently demonstrate **low levels of exposure** in public areas from mobile-network antennas, and that the **levels do not change significantly over time nor differ between countries** and **are similar regardless of whether the international or more restrictive RF-EMF limits are adopted.**[3,4]

5G is the fifth generation of mobile networks, a significant evolution of the fourth-generation (4G) long-term evolution (LTE) networks, which is using radio frequencies partially similar to those used in previous-generation networks. 5G has been designed to meet the extensive growth in data and connectivity that characterizes today's modern society, and tomorrow's innovations, just as previous-generation technologies have supported economic growth and development in the past. To ensure the same level of safety in mobile communications, already existing RF-EMF standards and recommendations for existing frequency bands which are not technology-specific must therefore be applied to 5G.

This report is based on scientific data and references to recent deliverables from the International Telecommunication Union (ITU), the World Health Organization (WHO), the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE). Starting with a broad review of ITU Recommendations, Reports and conference or workshop outcomes, it looks at the existing scientific recommendations in the light of 5G, and addresses the main points of public concern about the deployment of 5G for good. The report therefore asks and addresses the question: Do electromagnetic fields matter in the context of the deployment of 5G mobile networks?

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

4 Jack Rowley and Ken Joyner (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.

2 Review of ITU Recommendations, Reports and conferences, by ITU Sector

2.1 ITU General Secretariat

2.1.1 Context in relation to RF-EMF

The International Telecommunication Union (ITU) is active in the field of RF-EMF across all its three Sectors – the ITU Telecommunication Standardization Sector (ITU-T), the ITU Radiocommunication Sector (ITU-R) and the ITU Telecommunication Development Sector (ITU-D) – and through its General Secretariat. ITU-T and ITU-D studies are performed within the framework of Questions, while ITU-R working parties advance deliverables not necessarily under Questions.

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

At the ITU Plenipotentiary Conference held in Guadalajara, Mexico, in 2010, Member States adopted Resolution 176 (Guadalajara, 2010), which was subsequently revised in Dubai in 2018 as Resolution 176 (Rev. Dubai, 2018), on 'Measurement and assessment concerns related to human exposure to electromagnetic fields'.

Resolution 176 (Rev. Dubai, 2018) provides the ITU framework on EMF. In particular, it:

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) and Resolution 62 (Rev. Buenos Aires, 2017), in order to continue and enhance the technical assistance provided to Member States,

instructs the Director of the Telecommunication Standardization Bureau (TSB), in collaboration with the Director of the Radiocommunication Bureau (BR) and the Director of the Telecommunication Development Bureau (BDT)

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,

instructs the Director of TSB, in collaboration with the Directors of BR and BDT

to participate in the Electromagnetic Field Project, conducted by WHO, as part of collaborative efforts with other international organizations to encourage the development of international standards for EMF exposure.

2.2 ITU Telecommunication Standardization Sector (ITU-T)

2.2.1 Context in relation to RF-EMF

The ITU Telecommunication Standardization Sector (ITU-T) develops international standards, known as ITU-T Recommendations, which act as defining elements in the global infrastructure of information and communication technologies (ICTs). Standards are critical to the interoperability of ICTs and enable global communications by ensuring that countries' ICT networks and devices are speaking the same language. ITU-T Study Group 5 ('Environment, climate change and circular economy') is very active on RF-EMF.

The ITU-T mandate in regard to EMF is enshrined in Resolution 72 (Rev. Hammamet, 2016) of the World Telecommunication Standardization Assembly (Hammamet, 2016) (WTSA-16), on 'Measurement and assessment concerns related to human exposure to EMF'. That resolution:

resolves

to invite ITU-T, in particular Study Group 5, to expand and continue its work and support in this domain, including, but not limited to:

i) publishing and disseminating its technical reports, as well as developing ITU-T Recommendations to address these issues;
ii) developing, promoting and disseminating information and training resources related to this topic through the organization of training programmes, workshops, forums and seminars for regulators, operators and any interested stakeholders from developing countries;
iii) continuing to cooperate and collaborate with other organizations working on this topic and to leverage their work, in particular with a view to assisting the developing countries in the establishment of standards and in monitoring compliance with these standards, especially on telecommunication installations and terminals;
iv) cooperating on these issues with ITU-R Study Groups 1 and 6, and with ITU-D Study Group 2 in the framework of ITU-D Question 7/2;
v) strengthening coordination and cooperation with WHO in the EMF project so that any publications relating to human exposure to EMF are circulated to Member States as soon as they are issued,

instructs the Director of TSB, in close collaboration with the Directors of the other two Bureaux within the available financial resources,

1 to support the development of reports identifying the needs of developing countries on the issue of assessing human exposure to EMF, and to submit the reports as soon as possible to ITU-T Study Group 5 for its consideration and action in accordance with its mandate;

2 to regularly update the ITU-T portal on EMF activities including, but not limited to, the ITU EMF Guide, links to websites, and flyers;

3 to hold workshops in developing countries with presentations and training on the use of equipment employed in assessing human exposure to RF energy;

4 to extend support for developing countries while they establish their regional centres equipped with test benches for continuous monitoring of EMF levels, especially in selected areas where the public has concerns, and transparently provide the data to the general public […];

5 to report to the next WTSA on measures taken to implement this resolution.

2.2.2 ITU-T Study Group 5 Question 3/5

ITU-T EMF activities are undertaken in Study Group 5 Question 3/5, on "Human exposure to electromagnetic fields (EMFs) due to digital technologies".

2.2.3 ITU-T resources relating to EMF and 5G

Table 1: ITU-T Recommendations[5]

N°	Rec.	Title
1)	K.52	Guidance on complying with limits for human exposure to EMF
2)	K.61	Guidance on measurement and numerical prediction of EMF for compliance with human exposure limits for telecommunication installations
3)	K.70	Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations
4)	K.83	Monitoring of EMF levels
5)	K.90	Evaluation techniques and working procedures for compliance with exposure limits of network operator personnel to power-frequency EMF
6)	K.91	Guidance for assessment, evaluation and monitoring of human exposure to radio-frequency EMF
7)	K.100	Measurement of radio-frequency EMF to determine compliance with human exposure limits when a base station is put into service
8)	K.113	Generation of radio-frequency EMF level maps
9)	K.121	Guidance on the environmental management for compliance with radio-frequency EMF limits for radiocommunication base stations
10)	K.122	Exposure levels in close proximity of radiocommunication antennas
11)	K.145	Assessment and management of compliance with radio-frequency EMF exposure limits for workers at radiocommunication sites and facilities

[5] The EMF Recommendations appear in the ITU-T K series

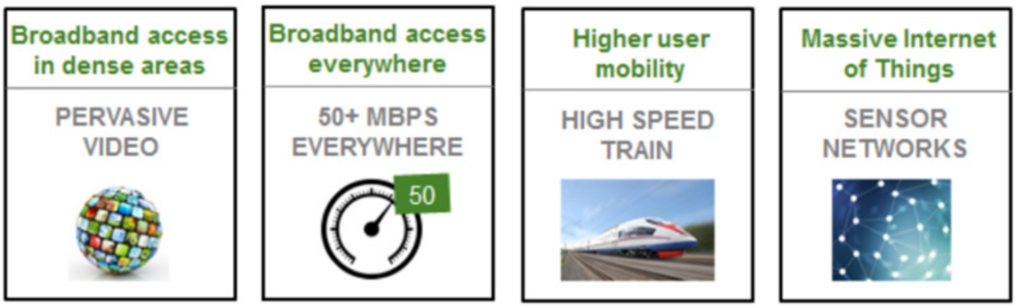
Table 2: ITU-T Supplements[6]

N°	Suppl.	Title
1)	K Suppl. 1	ITU-T K.91 - Guide on EMF and health
2)	K Suppl. 4	ITU-T K.91 - EMF considerations in smart sustainable cities
3)	K Suppl. 9	**5G** technology and human exposure to radio-frequency EMF
4)	K Suppl. 13	Radio-frequency electromagnetic field (RF-EMF) exposure levels from mobile and portable devices during different conditions of use
5)	K Suppl. 14	The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and **5G** mobile-network deployment
6)	K Suppl. 16	EMF compliance assessments for **5G** wireless networks
7)	K Suppl. 19	EMF strength inside underground railway trains
8)	K Suppl. 20	ITU-T K.91 – Supplement on radio-frequency exposure evaluation around underground base stations

2.2.4 Characteristics of 5G emissions detailed by ITU-T

Future mobile communications will increasingly be based on 5G. The deployment of 5G will see the evolution and expansion of existing 4G networks and the introduction of new radio access networks in millimetre wavebands. As a result of the use of much higher frequency ranges (in parallel with the existing ones), the number of base-station antennas will increase substantially. These networks will comprise a range of installations, with smaller cell deployments and advanced antenna technologies. Massive multiple-input multiple-output (MaMIMO) antennas will allow the use of very narrow beams that will direct RF-EMF signals towards the user, with a potential reduction of the surrounding exposure level, different from that of current systems. The number of wireless devices will increase dramatically. New technology allows for the use of more efficient systems that require lower communication signal levels. **Figure 1** below (from ITU-T K Suppl. 9) portrays the main usage of 5G networks.

Figure 1: Main usage for 5G networks, to enhance future mobile communications



[6] Supplements to ITU-T K-series Recommendations appear at K supplements.

The expanded spectrum also includes the millimetre waveband (mmWave) above 30 GHz (in fact, the 26 GHz band is considered in the same way, too). The mmWave frequencies provide localized coverage as they mainly operate over short line-of-sight distances. At mmWave frequencies, RF energy is absorbed superficially by the body, mostly by the skin. Some studies are already underway using these mmWave exposures. The mmWave frequencies will be used in conjunction with increased small cell deployments. There are fewer biological studies on frequencies above 24 GHz. The mmWaves are mostly absorbed in outer skin layers: see **Figure 2**, adapted from Alekseev and Ziskin (2018),[7] and **Figure 5**: Penetration depth becomes shallower in 5G higher RF

Figure 2: mmWaves are mostly absorbed in outer skin layers

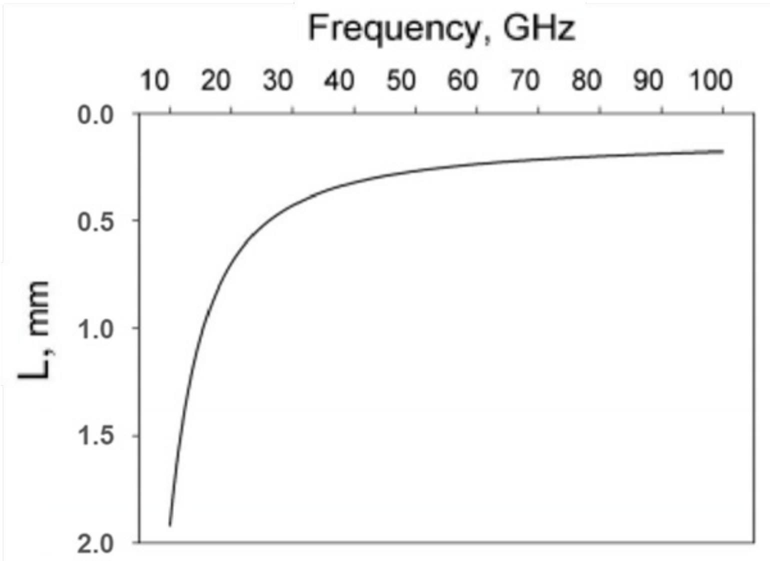


Figure 3 (from K Suppl. 9) details frequency-band allocation.

[7] Stanislav Alekseev and Marvin Ziskin (2018). Biological Effects of Millimeter and Submillimeter Waves. In Ben Greenebaum and Frank Barnes (Eds). *Biological and Medical Aspects of Electromagnetic Fields*, 4th Edition, Chapter 6. CRC Press, Boca Raton, 16 November 2018.

Figure 3: Frequency-band allocation

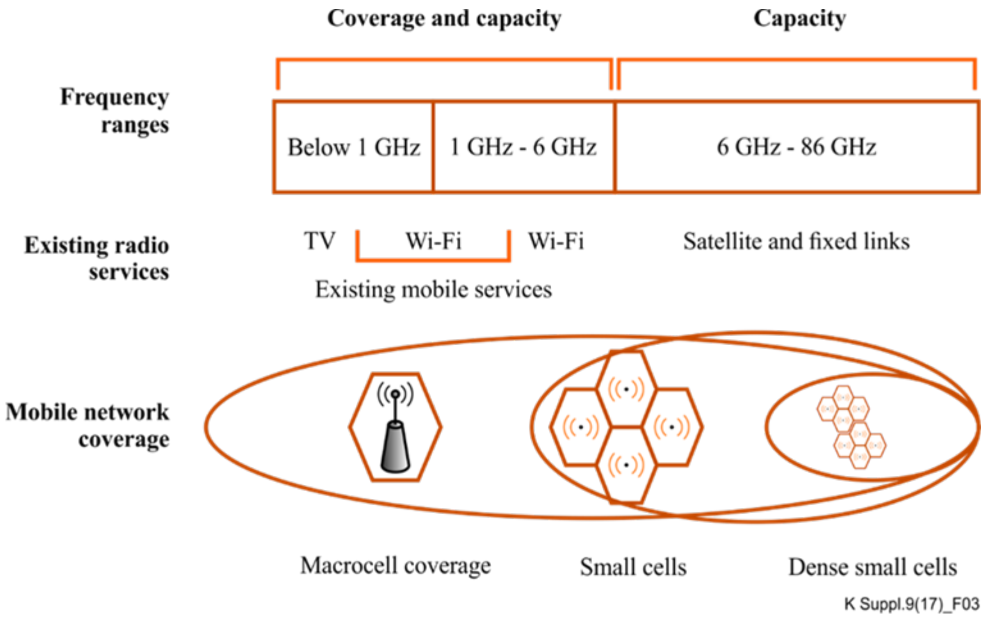
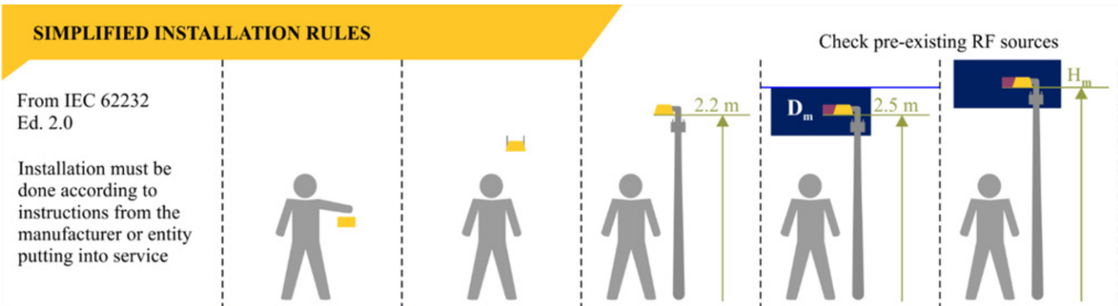


Figure 4 (Figure 7 in K Suppl. 9 and Figure 11 in K Suppl. 16) details simplified installation rules for base-station equipment.

Figure 4: EMF compliance assessments for 5G wireless networks



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

K Suppl.9(17)_F07

The lowest-power devices can be installed with the minimum of design constraints. Touch-compliant equipment (installation class E0), such as residential small cells, can be sited anywhere, much like wireless access points. For higher-power sites, manufacturers' guidelines, minimum height requirements (Hm) and exclusion zones (Dm) must be considered.

2.3 ITU Radiocommunication Sector (ITU-R)

2.3.1 Context in relation to RF-EMF

The ITU Radiocommunication Sector (ITU-R) plays a vital role in the global management of the RF spectrum, which is in demand from a large and growing number of services such as fixed, mobile, broadcasting, satellite, amateur, space research, emergency telecommunications, meteorology, global positioning systems, environmental monitoring and communication services. ITU-R has a decisive impact on establishing technical requirements for measurement of RF-EMF as well as identifying spectrum for NGN in the field of International Mobile Telecommunications (IMT).[8]

Based on the inter-Sector mapping tables on the webpage of the Inter-Sector Coordination Group (ISCG) on issues of mutual interest (under the General Secretariat), the ITU-R Working Parties (WPs) that are related to ITU-D Question 7/2 on EMF are: WP 1A, WP 1C, WP 4A, WP 5A, WP 5B, WP 5C, WP 5D, WP 6A and WP 7B. In the framework of their study groups, those WPs settle the emission parameters that determine RF-EMF exposure levels, such as maximum power and maximum transmitter antenna gain, power control, etc. Based on Resolution 176 (Rev. Dubai, 2018) of the Plenipotentiary Conference, the most relevant WPs for the study of 5G RF-EMF are:

- WP 1C ('Spectrum monitoring'), which addresses the title of Resolution 176 (Rev. Dubai, 2018), namely '**Measurement** and assessment concerns related to human exposure to electromagnetic fields';
- WP 5D ('**IMT** Systems'),[9] which manages the overall radio-system aspects of IMT systems.

2.3.2 ITU-R resources relating to EMF and 5G

EMF measurement activities are accomplished in Study Group 1 under Question 239/1, on 'EMF field measurements to assess human exposure'. Question 239/1 is directly founded on Resolution 176 (Rev. Dubai, 2018) of the Plenipotentiary Conference, and has resulted in Report ITU-R SM.2452, on 'EMF field measurements to assess human exposure', which has the following Table of Contents:

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[8] IMT encompasses IMT-2000, IMT-Advanced and IMT-2020, as specified in Resolution ITU-R 56-2. In this report, 5G and IMT-2020 are used interchangeably.

[9] See Recommendation ITU-R M.2150 (02/2021), on 'Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020)'.

4 References
5 Glossary and abbreviations.

In addition, ITU-R has developed the Handbook on Spectrum Monitoring, which is highly relevant as it identifies methodologies to measure EMF. Section 5.6 of the handbook specifies 'Non-ionizing radiation measurements'.

2.3.3 Identification of IMT frequency bands by the World Radiocommunication Conference (Sharm el-Sheikh, 2019) (WRC-19)

Future mobile communications will deploy more IMT/5G (see **Figure 1**).

In line with the 2020 edition of the ITU Radio Regulations (RR) published on 15 September 2020 and the proposed revision of Recommendation ITU-R M.1036 that is currently under discussion within ITU-R, the frequency bands indicated in **Table 3** are identified in the RR for the deployment of IMT.

Table 3: Footnotes identifying the bands for IMT pursuant to the RR (2020 Edition)

Band	Footnotes in RR Article 5 identifying the bands for IMT		
	Region 1	Region 2	Region 3
450-470 MHz	5.286AA		
470–698 MHz	-	5.295, 5.308A	5.296A
694/698–960 MHz	5.317A	5.317A	5.313A, 5.317A
1 427–1 518 MHz	5.341A, 5.346	5.341B	5.341C, 5.346A
1 710–2 025 MHz	5.384A, 5.388		
2 110–2 200 MHz	5.388		
2 300–2 400 MHz	5.384A		
2 500–2 690 MHz	5.384A		
3 300–3 400 MHz	5.429B	5.429D	5.429F
3 400–3 600 MHz	5.430A	5.431B	5.432A, 5.432B, 5.433A
3 600–3 700 MHz	-	5.434	-
4 800–4 990 MHz	5.441B	5.441A, 5.441B	5.441B
24.25–27.5 GHz*	5.532AB		
37–43.5 GHz*	5.550B		
45.5–47 GHz*	5.553A	5.553A	5.553A
47.2–48.2 GHz*	5.553B	5.553B	5.553B
66–71 GHz*	5.559AA		

*revised at WRC-19

2.4 ITU Telecommunication Development Sector (ITU-D)

2.4.1 Context in relation to RF-EMF

The work of ITU-T and ITU-R is directed at the technical and measurement aspects of 5G RF-EMF, while the ITU Telecommunication Development Sector (ITU-D) concentrates on strategies and policies concerning human exposure.

ITU-D's role in regard to EMF is enshrined in Resolution 62 (Rev. Buenos Aires, 2017) of the World Telecommunication Development Conference (Buenos Aires, 2017) (WTDC-17), on 'Assessment and measurement of human exposure to EMFs', which:

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;
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.

The main ITU-D EMF activities are carried out in ITU-D Study Group 2 under Question 7/2, on : "Strategies and policies concerning human exposure to EMFs". On 19 March 2021, Study Group 2 adopted the Output Report on Question 7/2 for the study period 2018-2021. Section 3.4.5 of that report ('Summary – Best practices, international RF-EMF exposure limits') is most significant, stating that: "*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*". On 1 March 2021, Ofcom in the United Kingdom already adopted the ICNIRP 2020 Guidelines.[10] The ITU-D report Exploring the Value and Economic Valuation of Spectrum, published in the ITU Broadband Series, is also relevant here. ITU-D resources relating to EMF and 5G are detailed in **Table 4**.

[10] See Ofcom 'Guidance on EMF Compliance and Enforcement'. 1 March 2021

2.4.2 ITU-D resources relating to EMF and 5G

Table 4: ITU-D resources relating to EMF and 5G

N°	Deliverable	Label	Title
1)	WTDC-17	Resolution 62 (Rev. Buenos Aires, 2017)[11]	Assessment and measurement of human exposure to EMF
2)	Question 7/2	Final Report 2014-2017	Strategies and policies concerning human exposure to EMF
3)	Question 7/2	Output Report 2018-2021	Policies, guidelines, regulations and assessments for human exposure to RF-EMF
4)	ITU-D ICT statistics	WTID, 24th Edition (December 2020)	Mobile-cellular subscriptions (billions) and world-average cellular-penetration per 100 inhabitants[12]
5)	ITU Regional Forum for Europe	Workshop, 22-23 October 2020	5G Strategies, policies and implementation

[11] See section 2.4.1 Context in relation to RF-EMF

[12] See **Figure 14**: Global mobile-cellular telephone subscriptions and rate. From World Telecommunication/ ICT Indicators Database (WTID) 2020 (24th Edition/December 2020).

3 References to relevant international organizations/ standardization bodies

Figures 5 and **6** (source: Akimasa Hirata)[13] portray power absorption in biological tissues, and how, as frequency increases, the penetration depth becomes shallower. Above 6 GHz, skin surface heating is dominant, and the specific absorption rate (SAR) entry distance is smaller.

Figure 5: Penetration depth becomes shallower in 5G higher RF

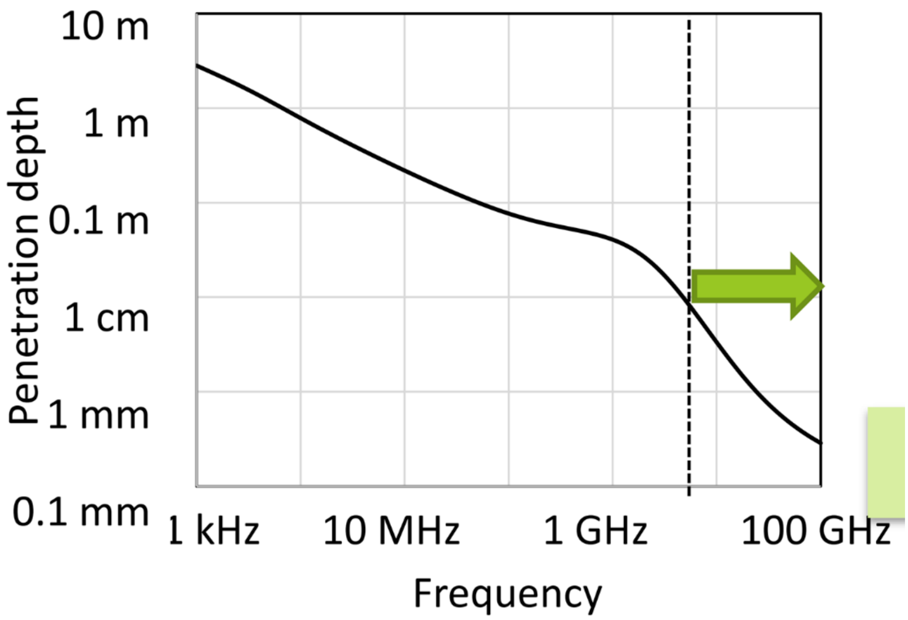
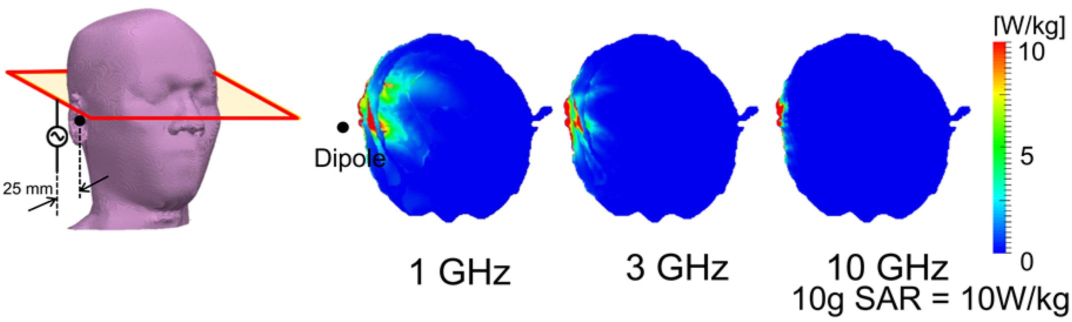


Figure 6: Measured power absorption in biological tissues



[13] Akimasa Hirata (2020). Human Exposure Standards and Compliance Assessment – 5G and Beyond. Keynote speaker at the *EMC Europe 2020 plenary open session*, 23 September 2020.

Two international bodies produce exposure guidelines on RF EMF:

1 International Commission on Non-Ionizing Radiation Protection (ICNIRP)
2 Institute of Electrical and Electronics Engineers (IEEE), through the International Committee on Electromagnetic Safety (ICES).

Many countries currently adhere to the guidelines they recommend.

These guidelines are not technology-specific. They cover radio frequencies up to 300 GHz, including the frequencies under discussion for 5G.[14]

ICNIRP has revised its 1998 Guidelines ('ICNIRP Guidelines for limiting exposure to time- varying electric, magnetic and electromagnetic fields (up to 300 GHz)' (ICNIRP (1998)). Following an extensive public consultation process, in which ITU provided 32 comments as an ITU inter-Sectoral response, the final ICNIRP guidelines were published in March 2020 (ICNIRP (2020)). In October 2019, IEEE also published IEEE Standard 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.

3.1 World Health Organization (WHO)

3.1.1 Context in relation to RF-EMF

The World Health Organization (WHO) works worldwide to promote health, keep the world safe, and serve the vulnerable. On the research and advocacy side, WHO is a fundamental point of reference for the international community when it comes to discussing EMF, as administrations follow WHO recommendations. Although WHO does not produce technical standards for EMF, it works with ICNIRP and IEEE by reviewing academic research and issuing reports for communication and aimed at raising objective awareness among the public around this topic.

According to the WHO definition (1948), 'health' is a "*state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*".

Relevant WHO links are: WHO Health Topics - Radiation, WHO Health Topics - EMF, National regulations on exposure to EMF, WHO Fact Sheets on mobile phones and base stations.

As part of its mission to provide clear information on the topic of EMF, on 27 February 2020 WHO published an information site on 5G mobile networks and health addressing and responding to a number of questions on 5G networks in relation to health risks. Some extracts from that site are reproduced in sections 3.1.2, 3.1.3 and 3.1.4 below.

3.1.2 Exposure levels from 5G infrastructure?

Currently, exposure from 5G infrastructures at around 3.5 GHz is similar to that from existing mobile-phone base stations. With the use of multiple beams from 5G antennas, exposure could be more variable as a function of location of the users and their usage. Given that the 5G technology is currently at an early stage of deployment, the extent of any change in exposure to RF fields is still under investigation.

[14] See WHO. Newsroom. Radiation: 5G mobile networks and health Q&A. What are the international exposure guidelines? 27 February 2020.

3.1.3 What are the potential health risks from 5G?

To date, and after much research performed, no adverse health effect has been causally linked with exposure to wireless technologies. Health-related conclusions are drawn from studies performed across the entire radio spectrum but, so far, only a few studies have been carried out at the frequencies to be used by 5G.

Tissue heating is the main mechanism of interaction between RF fields and the human body. RF exposure levels from current technologies result in negligible temperature rise in the human body.

As the frequency increases, there is less penetration into the body tissues and absorption of the energy becomes more confined to the surface of the body (skin and eye). Provided that the overall exposure remains below international guidelines, no consequences for public health are anticipated.

3.1.4 What is WHO doing?

WHO is conducting a health risk assessment from exposure to radio frequencies, covering the entire RF range, including 5G, to be published by 2022.

WHO will review scientific evidence related to potential health risks from 5G exposure as the new technology is deployed, and as more public health-related data become available.

WHO established the International EMF Project in 1996. The project investigates the health impact of exposure to electric and magnetic fields in the frequency range 0 - 300 GHz and advises national authorities on EMF radiation protection.

WHO advocates for further research into the possible long-term health impacts of all aspects of mobile telecommunications. It identifies and promotes related research priorities. It also develops public-information materials and promotes dialogue among scientists, governments and the public to increase understanding around health and mobile communications.

3.2 International Commission on Non-Ionizing Radiation Protection (ICNIRP) and its Guidelines

3.2.1 Context in relation to RF-EMF

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) aims to protect people and the environment against adverse effects of non-ionizing radiation (NIR). To this end, ICNIRP develops and disseminates science-based advice on limiting exposure to NIR. Experts from different countries and disciplines such as biology, epidemiology, medicine, physics and chemistry work together with and within ICNIRP to assess the risk of NIR exposure and provide exposure guidance. ICNIRP experts base their advice on scientific publications about biological effects and action mechanisms of radiation, for the whole NIR frequency range. ICNIRP's protection advice is formulated in its Guidelines, Reviews and Statements, which are publicly and freely available online. ICNIRP also organizes workshops to inform about current scientific knowledge and to provide an opportunity to advance the dialogue on NIR protection.

ICNIRP Guidelines have been widely adopted in standards and regulations around the world. Where national limits do not exist, or if they do not cover the relevant frequencies, then ICNIRP limits should be used. The following are the ICNIRP Guidelines relevant to 5G:

1 ICNIRP (1998): Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz),

replaced by:

2 ICNIRP (2020): Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz).

Compared to ICNIRP (1998), the ICNIRP (2020) Guidelines provide a better biological rationale, better dosimetry, more details, more complexity and more accuracy, and are overall future-proof. ICNIRP (2020) Guidelines were developed by identifying scientific data on effects of exposure, determining effects considered both adverse to humans and scientifically substantiated, identifying minimum exposure levels needed to produce harm, and finally by applying reduction factors that are more stringent for the general public than for workers. This results in exposure restrictions with a large margin of safety.

Scientific basis: There is no evidence for cancer, electromagnetic hypersensitivity, infertility or other health effects. The identified adverse health effects are only whole-body temperature increase above 1 °C and tissue temperature above 41 °C.

Physics and temperature: Different quantities are used to estimate temperature depending on frequency and duration of exposure. For example, for local exposures: absorbed energy rate, such as SAR, at lower frequencies, and absorbed power density at higher frequencies.

3.2.2 ICNIRP (2020) tables and figures

This section details the ICNIRP (2020) tables (ICNIRP Tables 1, 5 and 6) that are most relevant to this report. As this report refers only to 5G (IMT) frequencies between 450 MHz and 71 GHz,[15] the most relevant rows and columns in the tables will be indicated, so as to focus on the significant values of 5G RF-EMF. The recast Figures depict the values. Underlining indicates the significant parameter.

Table 5: (ICNIRP 2020 Table 1): Quantities and corresponding SI units used in the Guidelines

Quantity	Symbol*	Unit
Absorbed energy density	U_{ab}	joule per square metre (J m^{-2})
Incident energy density	U_{inc}	joule per square metre (J m^{-2})
Plane-wave equivalent incident energy density	U_{eq}	joule per square metre (J m^{-2})
Absorbed power density	S_{ab}	watt per square metre (W m^{-2})
Incident power density	S_{inc}	watt per square metre (W m^{-2})
Plane-wave equivalent incident power density	S_{eq}	watt per square metre (W m^{-2})

15 Note also that 71 GHz is still a much lower frequency compared to ionizing radiation which occurs at frequencies above 2 900 THz (2 900×10^{12} Hz, 2900×10^3 GHz).

Table 5: (ICNIRP 2020 Table 1): Quantities and corresponding SI units used in the Guidelines (continued)

Quantity	Symbol*	Unit
Specific energy absorption	SA	joule per kilogram (J kg^{-1})
Specific energy absorption rate	SAR	watt per kilogram (W kg^{-1})
Frequency	*f*	hertz (Hz)
Time	*t*	second (s)

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

The ICNIRP tables and figures quantify and depict how the exposure depends on the transmitted frequency.

ICNIRP (2020) Tables 5 and 6 detail reference levels for exposure, averaged, to EMF from 100 kHz to 300 GHz (unperturbed rms values). These two tables are reflected in **Tables 6** and **7** below.

Table 6 specifies that the RF-EMF limits for occupational and general-public whole-body exposures increase between 400 and 2 000 MHz and stay steady between 2 and 300 GHz.

Table 6: (ICNIRP 2020 Table 5): Reference levels for exposure, averaged over 30 minutes and the whole body, to electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)

Exposure scenario	Frequency range	Incident power density; S_{inc} (W m^{-2})
Occupational	>400 – 2 000 MHz	$f_M/40$
	>2 – 300 GHz	50
General public	>400 – 2 000 MHz	$f_M/200$
	>2 – 300 GHz	10

Notes:
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} 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).
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}, 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, 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 7 specifies that the RF-EMF limits for occupational and general-public local exposure increase (as in **Table 6** above) between 400 and 2 000 MHz, stay steady between 2 and 6 GHz, and decrease between 6 and 300 GHz.

Table 7: (ICNIRP 2020 Table 6): Reference levels for local exposure, averaged over 6 minutes, to electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)

Exposure scenario	Frequency range	Incident power density; S_{inc} (W m^{-2})
Occupational	>400 – 2 000 MHz	$0.29f_M^{0.86}$
	>2 – 6 GHz	200
	>6 – <300 GHz	$275/f_G^{0.177}$
	300 GHz	100
General Public	>400 – 2 000 MHz	$0.058f_M^{0.86}$
	>2 – 6 GHz	40
	>6 – 300 GHz	$55/f_G^{0.177}$
	300 GHz	20

Notes: (underlined values are the most relevant to 5G)
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} 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).
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.

Table 8 below details the ICNIRP (2020) Basic Restrictions.

Table 8: 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 aver-age)	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			40 W/kg		20 W/kg		4 W/kg
Local ΔT (head and torso, limbs)	> 6–300 GHz	5°C	4 cm^2		200 W/m^2		100 W/m^2		20 W/m^2
	30–300 GHz		1 cm^2		400 W/m^2		200 W/m^2		40 W/m^2

Figures 7 and **8**[16] depict the differences between the 2020 **field-strength** and **power-density** exposure levels for **occupational** and **general-public** exposure, averaged over **30 min** and the **whole body**. The behaviour of the exposures (increase with RF and then steady) is well illustrated. The power-density ratio of 5 in ICNIRP (2020) Table 5 (e.g. at 30 – 400 MHz, Watts ratio 50/10) results in a V/M ratio 61.0/27.7 = 2.2≈√5.

Figure 7: Comparing ICNIRP (2020) Table 5, power density for occupational and general-public exposures, 30 MHz–300 GHz, averaged over 30 minutes and the whole body

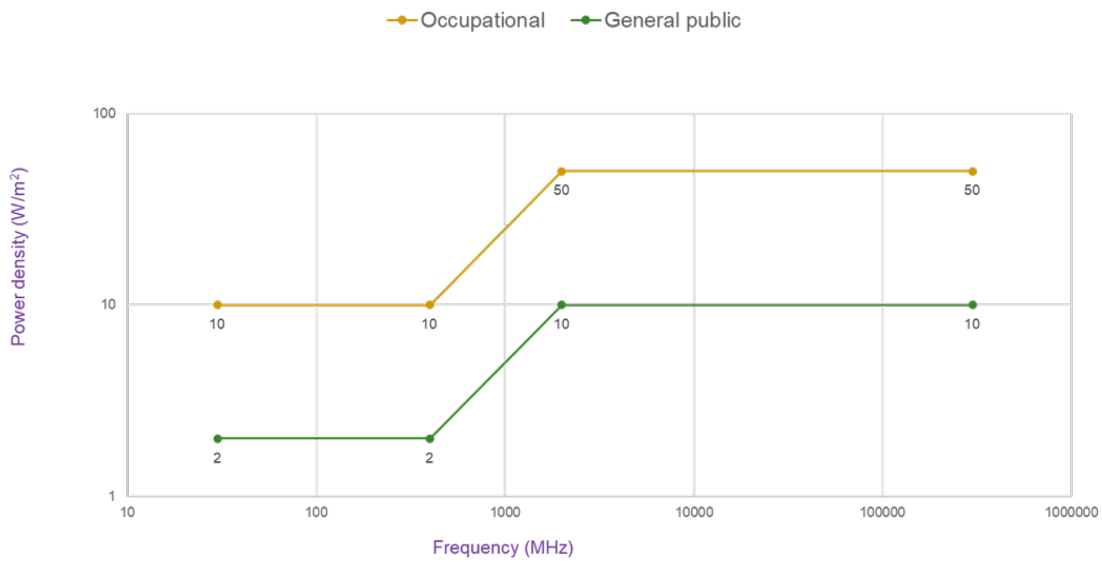
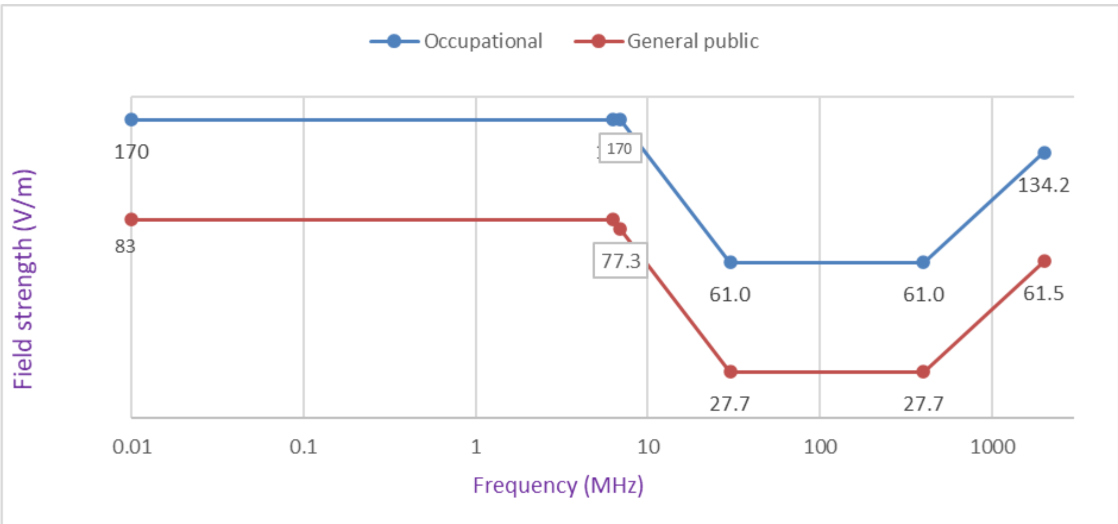


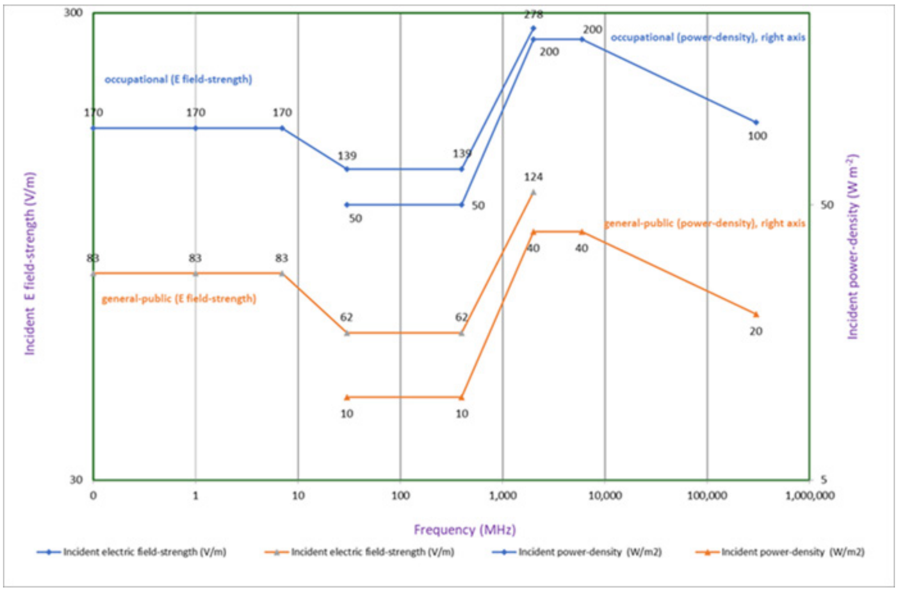
Figure 8: Comparing ICNIRP (2020) Table 5, field strength for occupational and general-public exposure, 0.1 MHz–2 000 MHz, averaged over 30 minutes and the whole body



16 Four different ICNIRP (2020) figures appear in the ICNIRP Differences between the ICNIRP (2020) and previous Guidelines.

Figure 9 summarizes the local exposure limits. Administrations may use it together with **Table 7** (ICNIRP 2020 Table 6): Reference levels for local exposure, averaged over 6 minutes, to electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values).

Figure 9: Comparing occupational and general-public exposures in ICNIRP (2020) Table 6, incident electric field strength and power density; local exposure, averaged over 6 minutes



Note: The unit on the figure's left side is electric field strength (V/m), and on the right side power density (W/m²).

3.3 Institute of Electrical and Electronics Engineers (IEEE) and its standard IEEE C95.1-2019

3.3.1 Context in relation to RF-EMF

The Institute of Electrical and Electronics Engineers (IEEE) is the world's largest technical professional organization dedicated to advancing technology. With an active portfolio of nearly 1 300 standards and projects under development, IEEE is a leading developer of industry standards in a broad range of technologies that drive functionality, capabilities and interoperability. The International Committee on Electromagnetic Safety (ICES), operating under the rules and oversight of the IEEE Standards Association (IEEE SA), is responsible for the development of standards for the safe use of electromagnetic energy by developing exposure limits and product compliance assessment standards in the range from 0 Hz to 300 GHz. ICES develops EMF exposure limits (Technical Committee 95) and product compliance assessment standards (TC 34).

IEEE/ICES TC 95 develops RF-EMF exposure standards for the safe use of electromagnetic energy in the range from 0 Hz to 300 GHz relative to the potential hazards of **exposure of humans**,[17] volatile materials and explosive devices. Such standards are based on established

[17] Including methods for the assessment of human exposure to such fields, and safety levels for human exposure to electric, magnetic and electromagnetic fields.

adverse health effects. IEEE Standard C95.1-2019 is the 'IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz'.

3.3.2 C95.1-2019 reference levels: Safety factors applying 100 kHz - 6 GHz – thermal effects[18]

- 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 (controlled environment)
50x - 0.08 W/kg for lower tier (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 min for WBA exposure and 6 min for local exposure

- Epithelial power density through body surface is averaged over 6 min.[19]

3.3.3 Dosimetric reference limits and exposure reference level[20]

Tables 9 and **10** specify dosimetric reference limits (DRLs) below and above 6 GHz. No continuity at 6 GHz in exposure metrics, but continuity in thermal protection maintained. Note that unrestricted environments SAR 2 (W/kg) is identical to SAR values in IEEE C95.1-2005, ICNIRP (1998) and (2020).[21]

Table 9: (IEEE 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 exposureb (head and torso)	2	10
Local exposureb (limbs and pinnae)	4	20

[a] SAR is averaged over 30 min for whole-body exposure and 6 min 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)

[18] See IEEE C95.1 (2019), p. 57; and consolidation in Haim Mazar (2019). EMF, New ICNIRP Guidelines and IEEE C95.1-2019 Standard: Differences and Similarities. *International Conference: EMF and the Future of Telecommunications*, Warsaw, 3-4 December, 2019, p. 6.

[19] The averaging time is 30 minutes for whole-body RF exposure, and 6 minutes for local exposure; this is different from IEEE C95.1-2005.

[20] See IEEE C95.1-2019, Tables 5 to 8, Figures 3 and 4.

[21] Therefore, 2 (W/kg) is the SAR value that administrations may apply to test 5G cellular equipment.

Table 10: (IEEE C95.1-2019 Table 6): DRLs (6 GHz to 300 GHz)

<table>
<tr><th rowspan="2">Conditions</th><th colspan="2">Epithelial power density (W/m²)[a,b,c]</th></tr>
<tr><th>Persons in unrestricted environments</th><th>Persons permitted in restricted environments</th></tr>
<tr><td>Body surface</td><td>20</td><td>100</td></tr>
</table>

[a] Epithelial power density through body surface is averaged over 6 min.
[b] Averaged over any 4 cm² 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 cm² 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 cm² (defined as area in the shape of a square at the body surface).

Table 11 details exposure reference levels (ERLs) for whole-body exposure of persons in unrestricted environments, averaging time 30 minutes.

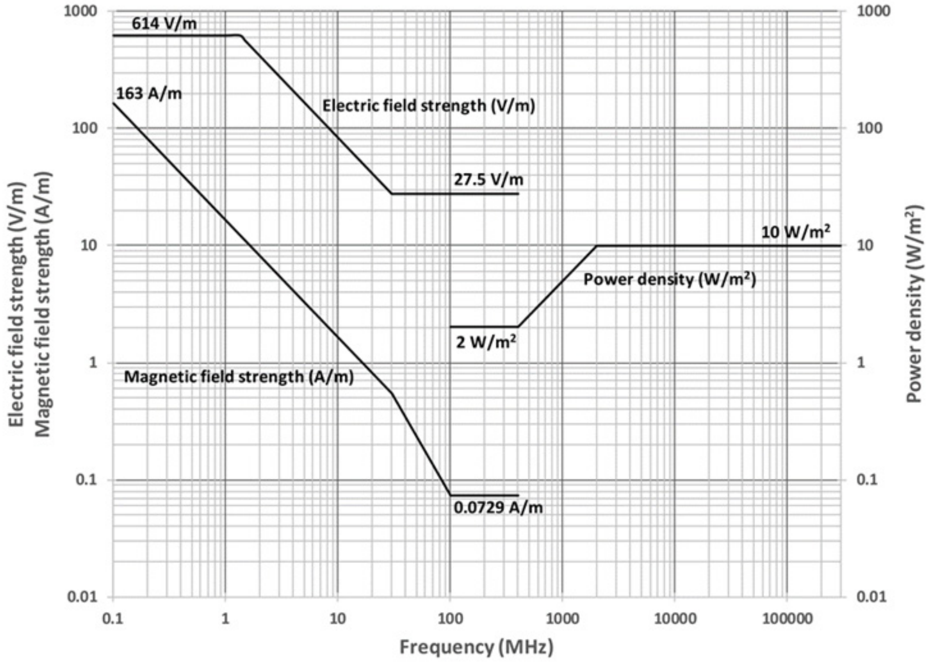
Table 11: (IEEE C95.1-2019 Table 7): Exposure Reference Level, ERLs (100 kHz–300GHz)

<table>
<tr><th rowspan="2">Frequency range (MHz)</th><th rowspan="2">Electric field strength (E)[a,b,c] (V/m)</th><th rowspan="2">Magnetic field strength (H)[a,b,c] (A/m)</th><th colspan="2">Power density (S)[a,b,c] (W/m²)</th></tr>
<tr><th>S_E</th><th>S_H</th></tr>
<tr><td>0.1 to 1.34</td><td>614</td><td rowspan="2">$16.3/f_M$</td><td>1 000</td><td rowspan="2">$100\,000/f_M^2$</td></tr>
<tr><td>1.34 to 30</td><td>$823.8/f_M$</td><td>$1\,800/f_M^2$</td></tr>
<tr><td>30 to 100</td><td rowspan="2">27.5</td><td>$158.3/f_M^{1.668}$</td><td>2</td><td>$9\,400\,000/f_M^{3.336}$</td></tr>
<tr><td>100 to 400</td><td>0.0729</td><td colspan="2">2</td></tr>
<tr><td>400 to 2 000</td><td colspan="2"></td><td colspan="2">$f_M/200$</td></tr>
<tr><td>2 000 to 300 000</td><td colspan="2"></td><td colspan="2">10</td></tr>
</table>

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 10 depicts IEEE C95.1-2019 Figure 3 – 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 10: (C95.1-2019 Figure 3): EMFs and power density – unrestricted environments



It is important to note (not mentioned in the IEEE 95.1-2019 standard) that, at frequencies below 30 MHz, the wavelength is longer than 10 m. There is no resonance with the human body (shorter than 2 m). We are not an obstacle to the signal, and there is low absorption of the RF energy from the body.

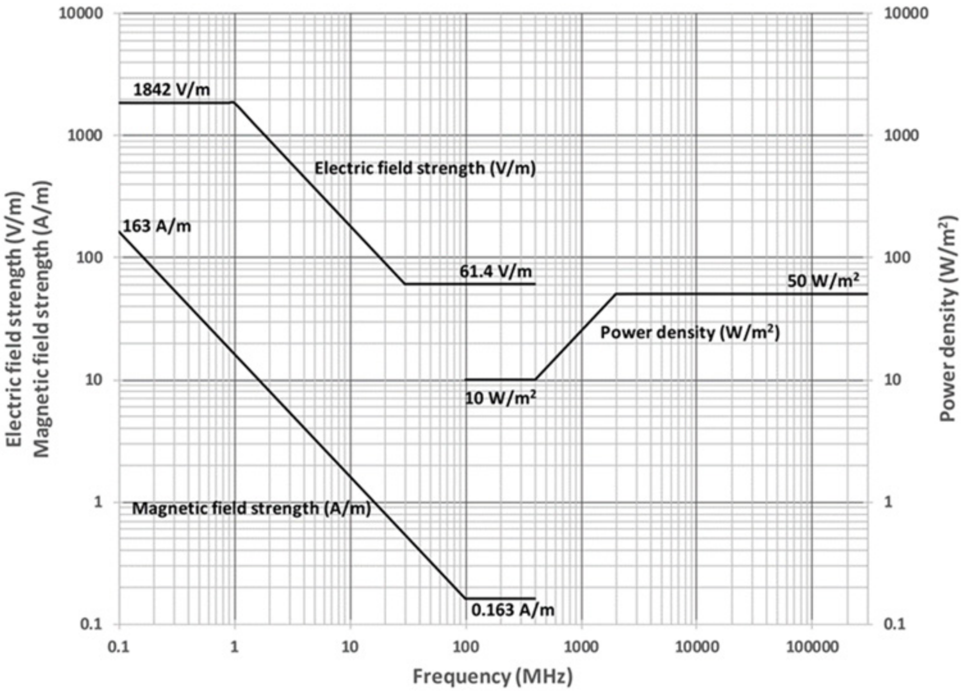
Table 12 details IEEE C95.1-2019 Table 8 – ERLs for whole-body exposure of persons permitted in **restricted** environments (100 kHz to 300 GHz), the averaging time is 30 minutes.

Table 12: (IEEE C95.1-2019 Table 8): ERLs in restricted environments (100 kHz to 300 GHz)

<table>
<tr><th rowspan="2">Frequency range (MHz)</th><th rowspan="2">Electric field strength (E)^{a,b,c} (V/m)</th><th rowspan="2">Magnetic field strength (H)^{a,b,c} (A/m)</th><th colspan="2">Power density (S)^{a,b,c} (W/m²)</th></tr>
<tr><th>S_E</th><th>S_H</th></tr>
<tr><td>0.1 to 1.0</td><td>1 842</td><td rowspan="3">$16.3/f_M$</td><td>9 000</td><td rowspan="3">$100\,000\,f_M^2$</td></tr>
<tr><td>1.0 to 30</td><td>$1\,842/f_M$</td><td>$9\,000 / f_M^2$</td></tr>
<tr><td>30 to 100</td><td rowspan="2">61.4</td><td>10</td></tr>
<tr><td>100 to 400</td><td>0.163</td><td colspan="2">10</td></tr>
<tr><td>400 to 2 000</td><td colspan="2"></td><td colspan="2">$f_M/40$</td></tr>
<tr><td>2 000 to 300 000</td><td colspan="2"></td><td colspan="2">50</td></tr>
</table>

Figure 11 depicts IEEE C95.1-2019 Figure 4 – 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 11: (C95.1-2019 Figure 4): EMFs and power density – restricted environments



3.4 Characteristics of 5G emissions detailed by IEC/IEEE

The International Electrotechnical Commission (IEC) standards on 5G are the following:

- IEC/IEEE 62209-1528 (2020): Measurement procedure for the assessment of specific absorption rate (SAR) of human exposure to RF fields from hand-held and body-worn wireless communication devices - Part 1528: Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 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
- IEC TR62630 (2010): Guidance for evaluating exposure from multiple electromagnetic sources
- IEC TR63170 (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
- IEC/IEEE 62704-1 (2017): Determining the peak spatial-average SAR in the human body from wireless communication devices, 30 MHz to 6 GHz - Part 1: General requirements for using the finite difference time domain (FDTD) method for SAR calculations
- IEC/IEEE 62704-2 (2017): Determining the peak spatial-average SAR in the human body from wireless communication devices, 30 MHz to 6 GHz - Part 2: Specific requirements for FDTD modelling of exposure from vehicle-mounted antennas
- IEC/IEEE 62704-3 (2017): Determining the peak spatial-average SAR in the human body from wireless communication devices, 30 MHz to 6 GHz - Part 3: Specific requirements for using the FDTD method for SAR calculations of mobile phones
- IEC/IEEE 62704-4 (2020): Determining the peak spatial-average SAR in the human body from wireless communication devices, 30 MHz to 6 GHz - Part 4: General requirements for using the finite element method for SAR calculations.

Ongoing:

- 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, expected in August 2021
- IEC/IEEE 63195-2: Determining the power density of the EMF associated with human exposure to wireless devices operating in close proximity to the head and body using computational techniques, 6 GHz to 300 GHz, expected in August 2021.

3.5 Comparing ICNIRP (1998), IEEE C95-1-2019 and ICNIRP (2020)

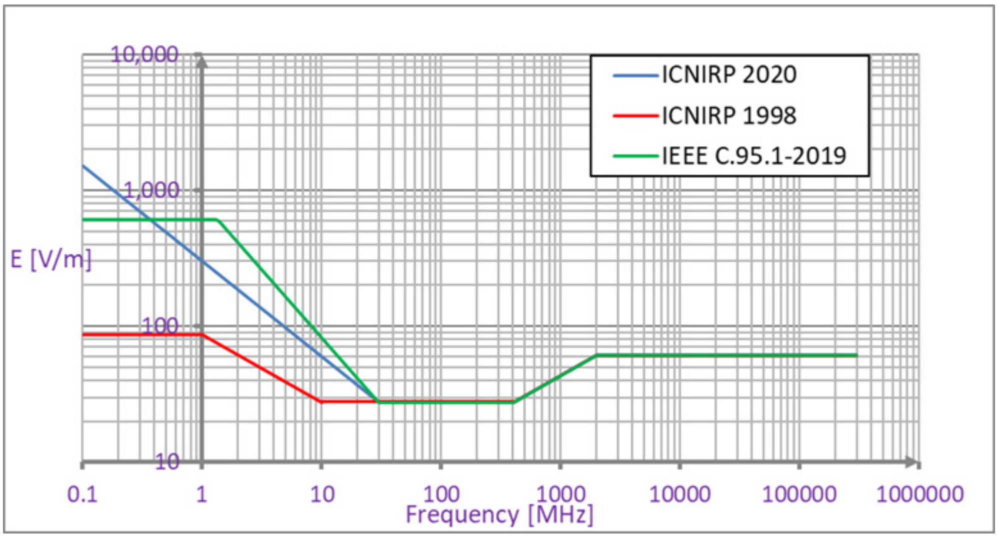
IEEE C95.1-2019 and ICNIRP (2020) Guidelines to limit exposures from base stations and handsets are largely harmonized in regard to limit values, but the terminology differs in some areas. The power-density limits for whole-body exposure to continuous fields are identical above 30 MHz. The 2019 version of the C95.1 standard has the same limits for near-field exposure as ICNIRP (2020) Guidelines, as described in the next two sections.

3.5.1 Comparison for exposure from base stations

Figure 12 is retrieved from a presentation given by Fryderyk Lewicki at the ITU Regional Symposium for Europe and CIS on Spectrum Management and Broadcasting on 2 July 2020.[22]

Note: Reference levels of ICNIRP (2020) stop electric field at RF above 2 000 MHz, and the Figure refers to V/m up to 300 GHz.

Figure 12: ICNIRP (1998), IEEE 95.1-2019 and ICNIRP (2020) reference levels, general public



Note: Some administrations prefer to monitor and measure electric field strength V/m and not power density W/m^2.
Note: Between 100 kHz and 10 MHz, the stringent value of ICNIRP (2010) or ICNIRP (2020) for every frequency should be followed; so, below 6.27 MHz the general-public limit is 83 V/m.

[22] Fryderyck Lewicki. Electromagnetic fields and 5G implementation. *ITU Seminar for Europe and CIS on Spectrum Management and Broadcasting*, Remote meeting, 2 July 2020.

3.5.2 Limits applicable to 5G cellular handsets

The highest exposure to EMF received by the general public comes from handheld devices such as mobile phones, which deposit most of the RF energy in the brain and surrounding tissues. Though they still remain within internationally recommended limits, 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 the portable handsets. The far-field[23] exposure relative to power-density (or field-strength) limits from fixed wireless stations 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.[24] The specific absorption rate (SAR)[25] relates to the internal electric field and, by extension, the temperature rise due to the 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 full 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 GHz are **2.0 (W kg**-1**)**, averaged over 10 g tissue.

Table 8: ICNIRP (2020) *Guidelines in brief – Basic Restrictions* in this report also specifies, for head and torso, frequency range 100 kHz–6 GHz, ΔT 2°C, spatial averaging 10 g, temporal averaging 6 min, health-effect level 20 W/kg, reduction factor 2, workers: 10 W/kg; and reduction factor 10, general public: **2 W/kg**. 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'; the values are unchanged compared to ICNIRP (1998): **2.0 (W kg-1)**.

IEEE C95.1-2005, p. 78, stated that: "*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 (*"The peak spatial-average SAR (psSAR) values were changed in IEEE Std C95.1-2005 from 1.6 W/kg and 8 W/kg for exposure of the*

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23 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*".

24 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*".

25 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.

public and exposures in controlled environments to 2 W/kg and 10 W/kg, respectively") appears in IEEE C95.1-2019, p. 72. Therefore, the 1995 SAR level 1.6 W/kg was changed in 2005, and remains 2 W/kg in IEEE C95.1-2019; see IEEE C95.1-2019 Table 5 – DRLs (100 kHz to 6 GHz).

ICNIRP (2020) introduces a new basic restriction (Sab, absorbed power density) from 6 to 300 GHz of 20 W/m2 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 to ICNIRP (2020) Table 6: see the underlined Notes to **Table 7** (ICNIRP 2020 Table 6): Reference levels for local exposure, averaged over 6 minutes*, to electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)* in this report. These new basic restrictions/reference levels are relevant for IMT 5G devices operating at higher frequencies.

Table 9 (IEEE C95.1-2019 Table 5): Dosimetric reference limits, DRLs (100 kHz to 6 GHz) in this report specifies for common to ICNIRP and IEEE local exposure (head and torso) **2 W/kg** for persons in unrestricted environments (general public).

4 Open issues directly and indirectly related to RF-EMF health hazards

4.1 Context in relation to RF-EMF

Owing to perceived uncertainties, several national legislative bodies have enacted precautionary measures with the intention of reducing exposure to EMF, for example imposing limits that are more restrictive than ICNIRP limits, or advising personal steps to reduce exposures. However, measurements show that typical exposure levels in public areas are not reduced by adopting more restrictive limits. In addition, the ICNIRP (2020) Guidelines state that "*There is no evidence that additional precautionary measures will result in a benefit to the health of the population*". There is evidence, on the other hand, that reducing RF-EMF exposure limits may be associated with higher levels of public concern. The migration from GSM to 3G/UMTS is a way to reduce exposure to RF-EMF from devices, due to more efficient power-control algorithms.

The national authority assigning frequencies and the environment-protection or public-health authorities may be responsible for verifying compliance. The local planning authority and town councils may also be involved in the process. In order to demonstrate compliance, the applicant (transmitter operator) may be required to provide relevant information to one or more authorities, increasing the complexity of the bureaucratic process from the operator's perspective. Some authorities adopt predictive modelling to calculate the exposure ranges or compliance zone around the antenna.

Random sample measurement may be used to monitor RF-EMF levels around a transmitter, with priority given to areas of community interest (schools, hospitals, etc.), at the initiative of the authorities, or on request subsequent to concerns raised by the general public. However, specific requirements for the siting of base stations in such locations are not supported by scientific evidence and measurements consistently show low levels of exposure in public areas from mobile-network antennas.

Compliance with RF-EMF limits is important to regulators, service providers and wireless equipment suppliers. Populations are exposed to different sources of RF-EMF, the levels of which are perceived as increasing due to traffic growth, increased usage of data services, quality-of-service (QoS) requirements, extension of network coverage and capacity, and the introduction of new technologies. Limitations on RF human exposure impose restrictions that are intended to assist those with responsibility for the safety of the general public and workers.

4.2 Open issues directly related to human health hazards

Wireless communication services use electromagnetic waves in RF ranges of the spectrum, which are much lower frequencies compared to ionizing radiation, such as X-rays or Gamma-rays.[26] 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 instant heating capabilities of high-level RF-EMF exposure (e.g. microwave ovens) are well known. The question is whether there are some other enduring health effects at levels of exposure below the ICNIRP limit. While some studies have indicated the possibilities of non-thermal effects in living organisms, they have never been substantiated.

ICNIRP guidelines are backed by WHO, and constitute the current scientific consensus. Some countries (and cities) adopt stricter measures (lower RF thresholds) which lead to severe restrictions on the ability to deploy radio transmitters and which are at odds with those of the international community. Other proposed limits are based on arbitrary choice of reduction factors.

Some of the public have remained concerned, on the basis that there exists no proof that ICNIRP threshold levels are safe, as they claim that not all possible health effects were studied. It is scientifically impossible to prove absolute safety (the null hypothesis) of any physical agent (IEEE C95.1-2005, p.2), since it is impossible to prove the negative (i.e. that something does not exist), so an analysis of the balance between cost and potential hazards is essential to inform policy-makers.

As absolute proof does not logically exist, national regulators are placed under public pressure. To respond to this dilemma, some countries 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 event 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.[27]

As the choice between the two-state risk management model and the precautionary approach has indirect implications for society and the economy, 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.

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[26] 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 12eV.

[27] Olivia Wu et al. (2012). Mobile Phone Use for Contacting Emergency Services in Life-threatening Circumstances. *The Journal of Emergency Medicine*, 42(3):291–298.e3, 1 March 2012.

4.3 Social and economic risks indirectly related to human health hazards

Compared to 4G, 5G – especially at higher frequencies – will rely more heavily on small cells, meaning that a greater number of 5G base stations will be installed. If not addressed, this factor alone may give rise to a number of socio-economic issues, including:

- Spread of misinformation
- Delay in installing base stations (causing harm to operators and delay in service provision)
- Raising the economic cost for society
- Impact on the environment.

Moreover, another element of 5G that may further create misunderstanding is the more intensive use of mmWaves. These frequencies have been used for decades for other wireless applications such as microwave communication, satellite and radar. In this regard, it should be clarified that 5G wireless networks are designed to be efficient: this means that both the network and device transmission power will be low, with the result that levels of RF-EMF for mmWaves in a 5G environment will remain within the ICNIRP/IEEE exposure limits.

It is important to properly address these concerns, and to ensure the efficiency of wireless networks and maintain low RF-EMF levels through the evolution of the current networks and expansion of 5G wireless networks, which constitute the key infrastructure that will underpin a smarter information society.

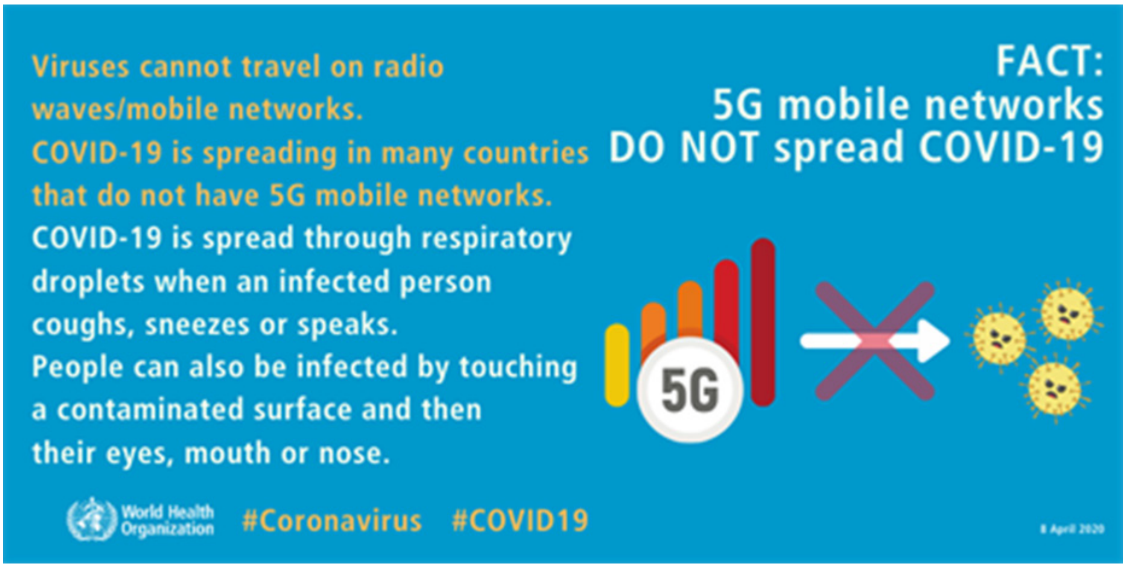
4.3.1 Misinformation

New technologies bring many benefits, but may also raise questions from the public in terms of exposure to RF-EMF. It is important to address these questions and provide information on likely exposure. Public workshops and conferences are a helpful tool in this regard.

With the introduction of new technologies and wireless applications, there may be a change (increase or decrease) in the overall level of radio signals, due to the fact that new transmitters rely on active beamforming. Taking this into account, and based on the transition from previous wireless technologies, we can expect that overall exposure levels will remain similar and will be a small fraction of the international exposure limits. Tissue heating remains the only recognized and substantiated hazard of exposure to mmWaves, based on scientific research to date. However, despite extensive research and communication efforts to allay concerns, there is still some public unease about the possible harmfulness of RF-EMFs from mobile communication equipment.

Conferences and workshops are important for publicizing scientific data on 5G and EMF. However, those who suffer from electrophobia and fear antenna masts will not be convinced by scientific evidence.

Figure 13: 5G mobile networks DO NOT spread COVID-19



WHO[28] makes clear that "*viruses cannot travel on radiowaves/mobile networks*" and that "*5G mobile networks DO NOT spread COVID-19*". ITU has highlighted the importance of "*trusted news and facts*" stating: "*As claims linking 5G technology and the spread of COVID-19 are mounting, ITU stands on the side of science and makes it clear that such claims have no scientific basis whatsoever*".[29]

Responding to public concerns, in February 2020 Ofcom published the results of measurements of EMF exposures close to sixteen 5G-enabled mobile-phone 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:[30]

1. EMF exposure levels from 5G-enabled base stations remain at small fractions of the reference levels for public exposure in ICNIRP (1998) Guidelines , i.e. 400–2 000 MHz: *f* (MHz)/200 (W/m^2), and 2–300 GHz: 10 (W/m^2).
2. The highest level recorded was approximately 1.5per cent of the power-density reference level.
3. At all locations, the largest contribution to the measured levels comes from previous generations of mobile technology (2G, 3G, 4G).
4. The highest level observed in the band used for 5G was just 0.039 per cent of the reference level.

4.3.2 Delays in installing base stations

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. Restrictive exposure limits affect network planning. Co-location and MIMO increase the safety distance if theoretical maximum conditions are applied, and constrain mast construction near buildings. Some countries (e.g. Switzerland) reduce the power-density level by a factor of 100 and indirectly

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28 WHO. Coronavirus disease (COVID-19) advice for the public: Mythbusters – 5G mobile networks.
29 ITU. ITU: No scientific basis between 5G and COVID-19.
30 Ofcom, United Kingdom (2020). Electromagnetic Field (EMF) measurements near 5G mobile-phone base stations: Summary of results. 21 February 2020 (updated 17 April 2020); and Statement and further consultation: Proposed measures to require compliance with international guidelines for limiting exposure to electromagnetic fields (EMF).

restrict the location of cellular base stations.[31] A consequence of restrictive RF-EMF exposure limits is an enforced reduction in the equivalent isotropic radiated power (EIRP) (in order to reduce the RF-EMF exposure near the station) or increase in the distance of the mast from the public. Restrictive RF-EMF exposure limits may be addressed by additional cellular antennas or added RF spectrum.

It is important to have measurement methods in place to assess RF exposure from 5G base stations and monitor that limits are met. The use of active antenna systems (AAS) in particular calls for novel measurement approaches to cope with the varying and dynamic RF configuration of the 5G signal. First proposals have been published.[32] However, a widely accepted standardized approach is still lacking.

4.3.3 Economic cost for society

On the basis of Table 2 in the ITU-D report Exploring the Value and Economic Valuation of Spectrum, the socio-economic and policy factors affecting the RF value are as follows:

1. Socio-economic factors are demographics, population density, income distribution, economic level and growth rate, political stability, absence of corruption and rule of law.
2. Policy and regulation factors include the existence of an independent regulatory agency, favourable investment and customs laws, competition policy, infrastructure sharing, rules of protection of the public against electromagnetic waves, open-access rules, technology neutrality, protection against interference, coverage obligations, spectrum caps, auction rules and bidding credits/set-asides, transparency, licensing framework and dispute-resolution mechanisms.

Restrictive RF-EMF exposure limits imply higher investments in infrastructures and base stations. They achieve the double negative outcome of increasing the need for more antennas and thereby creating additional public concern. In this context, studies show that restrictive limits risk doubling the investment required in the order of billions[33] and block the potential to use spectrum and cater for growing traffic requirements.[34]

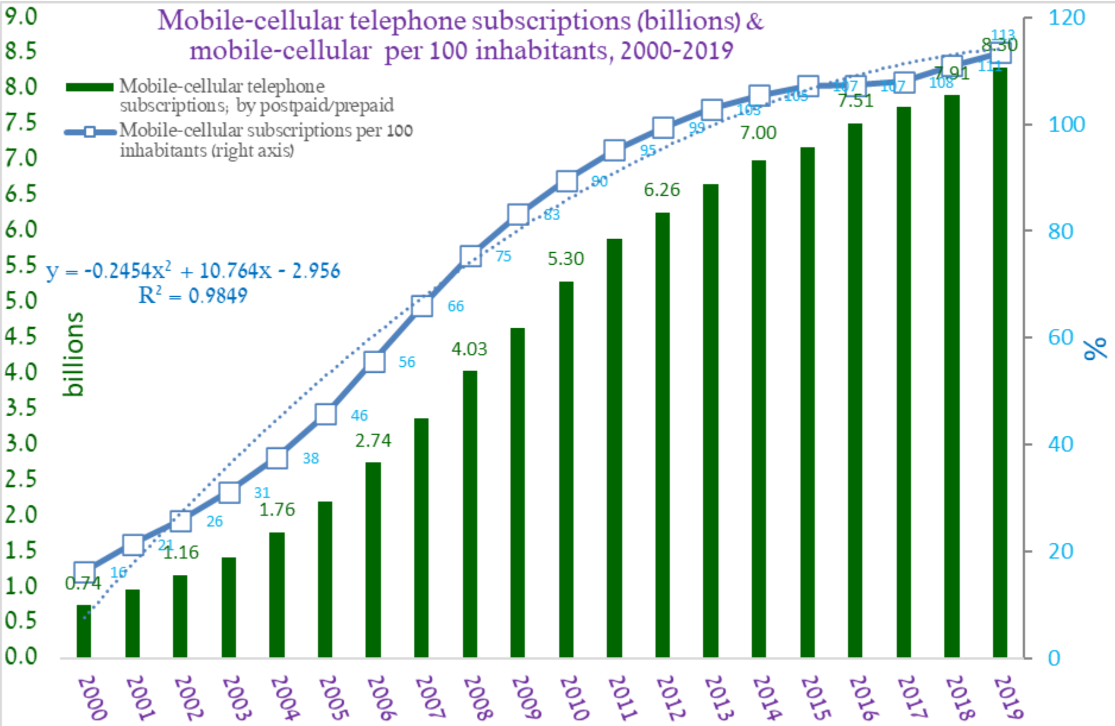
4.4 Number of base stations

The proliferation of cellular base stations and wireless fixed installations around the world, the public dislike of large antenna structures and the growing concern in regard to RF-EMF exposure have led to constraining legislations and regulations to ensure protection of the public.[35]

31 Such limits are usually considered for each mobile system separately
32 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.
33 An example of economic cost for society is found in Italy, which has 100 times stricter power-density limits than the EMF ICNIRP/IEEE limits, i.e. 10 W/m^2 at frequencies 2–300 GHz for 30 min whole-body exposure – see ICNIRP (2020) Table 5 and IEEE (2019) Table 7. A study by Antonio Capone *Limiti di esposizione ai campi elettromagnetici e sviluppo reti 5G* presented to the Italian Parliament in 2019 argues that avoiding the installation of 27 900 5G base stations entails a total additional cost of approximately EUR 4 billion.
34 ITU-T Recommendations. ITU-T K Suppl. 14 (09/2019), on the impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile-network deployment.
35 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.

Evidence on the proliferation of cellular base stations around the world can be gleaned from ITU's World Telecommunication/ICT Indicators Database (WTID).[36] **Figure 14** plots mobile-cellular subscriptions (billions) and world-average cellular penetration per 100 inhabitants, years 2005 to 2019. The 24th Edition/December 2020 of WTID indicates that there were 8.3 billion subscribers in 2019 (and 113 cellular telephone subscriptions per 100 inhabitants). Given that, on average, roughly every 1 000 subscribers need one cellular mast,[37] it may be estimated that there are more than 8 million base stations around the world.

Figure 14: Global mobile-cellular telephone subscriptions and rate



Cellular capacity is limited by RF bandwidth, power and noise; adding RF bandwidth to base stations may decrease the number of base stations and the total RF-EMF exposure.

[36] ITU. ITU-D ICT statistics. World Telecommunication/ICT Indicators Database (WTID) 2020 (24th Edition/December 2020).
[37] Haim Mazar (2016). Op. cit. See Chapter 9, section 9.7.2

5 ITU initiatives and opportunities

5.1 Human capacity building opportunities

As part of its Human Capacity Building operations, ITU has developed a number of online and face-to-face training courses in the field of ICTs targeting regulators and policy-makers, technical and operational staff, as well as students and entrepreneurs.

In the field of EMF, the 2014 *Spectrum Management Training Programme* (SMTP) was prepared by BDT, BR and ITU experts.[38] The programme's courses are designed to broaden the skills of professionals from different backgrounds (engineering, legal, economic, etc.) working in the field of spectrum management (for example, in a national regulatory authority, and providers or operators of wireless communications). In particular, an advanced module on "Electromagnetic Fields and Health", which is part of SMTP, was prepared in April 2020, with the objective of providing a deeper understanding of this area. This SMTP module supports modern spectrum-management students with spectrum engineering foundations in calculating EMF contours around wireless base stations, using 3D propagation and antenna pattern modelling. The advanced module provides specific training on:

- Radiowaves
- RF spectrum and wireless communications
- ITU activities on EMF
- WHO's views
- Non-ionizing radiation, physical quantities and units
- Biological effects
- ICNIRP (2020) and IEEE (2019) EMF levels
- EMF measurements around the world
- Demonstrating compliance and exposure zones
- Engineering: calculating safety distances, far- and near-field
- Total exposures
- Policies and mitigation techniques to reduce human exposure
- Application example practical exercise and quiz, measurement of EMF and preparing for 5G
- Exposure assessment and societal concerns.

More information about the course and about the ITU Academy can be obtained from hcbmail@itu.int.

5.2 ITU workshops, initiatives and recent events related to EMF

ITU is active in sharing knowledge and tools concerning assessment of human exposure to RF-EMF.

[38] ITU (2014). Capacity Building. Report. Spectrum Management Training Programme (SMTP). Geneva, December 2014.

1) ITU Workshop on 'Human Exposure to Electromagnetic Fields (EMFs)' [39]

ITU, together with the Ministry for Economic Development of Italy, organized a workshop on 'Human Exposure to EMFs', which took place on 9 May 2013 in Turin, Italy.

2) ITU Forum: 'EMF – What does it really mean?' [40]

At the invitation of the Dominican Institute for Telecommunications (INDOTEL), ITU-T organized a forum: 'EMF – What does it really mean?', which took place on 4 September 2014 in Santo Domingo. The forum responded to WTSA-12 Resolution 72 (Rev. Dubai, 2012), to provide an overview of EMF issues for policy-makers and other stakeholders, focusing on Latin America, and to identify relevant actions for ITU-T Study Group 5. The forum brought together leading specialists in the field, from top policy-makers to engineers, designers, planners, government officials, regulators, standards experts and others.

3) Expert meeting on 'EMF level and 5G roll-out' [41]

An expert meeting on 'EMF level and 5G roll-out' was held in Rome, Italy, on 2-3 November 2017. The meeting was organized by ITU-BDT in cooperation with the Ministry of Economic Development of Italy, within the framework of the ITU Regional Initiative for Europe on 'Development of broadband access and adoption of broadband'.

4) ITU Forum and training: 'How safe is EMF?' [42]

An ITU-T/R forum and training: 'With ICTs everywhere – How safe is EMF?' was held in Zanzibar, Tanzania, on 10 April 2018.

5) Regional Seminar on '5G implementation in Europe and CIS' [43]

The Regional Seminar on '5G implementation in Europe and CIS: Strategies and policies enabling new growth opportunities' was organized by ITU and hosted by the National Media and Infocommunications Authority of Hungary from 3 to 5 July 2018. The seminar included an experts' knowledge exchange related to the work of the ITU-D two study groups, including on EMF.

6) ITU Workshop on 'Modern policies, guidelines, regulations and assessments of human exposure to RF-EMF' [44]

An ITU-D workshop on 'Modern policies, guidelines, regulations and assessments of human exposure to RF-EMF' was held in Geneva on 10 October 2018.

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[39] ITU-T. ITU Workshop on Human Exposure to Electromagnetic Fields (EMFs). Measurement concerns related to human exposure to EMF. Turin, Italy, 9 May 2013.

[40] ITU-T. ITU Forum: EMF – What does it really mean?. Santo Domingo, Dominican Republic, 4 September 2014.

[41] ITU-D. Expert meeting on Electromagnetic field level and 5G roll-out. Rome, Italy, 2-3 November 2017.

[42] ITU-T. ITU Forum and training: With ICTs everywhere – How safe is EMF?. Zanzibar, Tanzania, 10 April 2018.

[43] ITU-D. ITU Regional Seminar on 5G implementation in Europe and CIS: Strategies and policies enabling new growth opportunities. Budapest, Hungary, 3-5 July 2018.

[44] ITU-D. ITU Workshop on Modern policies, guidelines, regulations and assessments of human exposure to RF-EMF. Geneva, 10 October 2018.

7) ITU Workshop on '5G, EMF and health' [45]

An ITU Workshop on '5G, EMF and health', held in Warsaw, Poland, on 5 December 2017, included a relevant presentation on ATDI coverage and EMF contours, around 5G base stations.

8) International Conference: EMF and the Future of Telecommunications

The International Conference on EMF and the future of telecommunications, held in Warsaw, Poland, on 3-4 December 2019, included two relevant presentations:

a) ITU WRC-19 additional spectrum allocations for IMT-2020 (5G mobile) (3 December 2019)
b) EMF, new ICNIRP Guidelines and IEEE C95.1-2019 standard: Differences and similarities (4 December 2019).

9) ITU-D and PRIDA workshops [46]

The pan-African programme 'Policy and Regulation Initiative for Digital Africa' (PRIDA) and ITU-D provided two recent online capacity-building workshops which included a session on human exposure to EMF:

a) Online English workshop: RF Human Hazards (24 April 2020)
b) Online French workshop: RF Human Hazards (15 May 2020).

10) ITU Seminar for Europe and CIS on 'Spectrum management and broadcasting' [47]

An ITU seminar for Europe and CIS on spectrum management and broadcasting, held on 1-2 July 2020, included a full session on Electromagnetic fields and 5G implementation.

11) UCC Webinar on 'Safety and environmental concerns around telecommunication installations and services in Uganda' [48]

A Webinar on safety and environmental concerns around telecommunication installations and services in Uganda was organized by the Uganda Communications Commission (UCC) on 11 August 2020.

12) ITU Regional Forum for Europe on 5G strategies, policies and implementation [49]

This forum, originally planned to be held in Warsaw, Poland, at the kind invitation of the Ministry of Digital Affairs of Poland, took place virtually on 22-23 October 2020. The forum is organized within the framework of the ITU European Regional Initiative on Broadband Infrastructure, broadcasting and spectrum management adopted by WTDC-17.

[45] ITU-T. ITU Workshop on 5G, EMF and health. Warsaw, Poland, 5 December 2017.
[46] ITU-D. Online capacity-building workshop. Modern Spectrum Management and SMS4DC. English: 20 April-1 May 2020 and French: 11-22 May 2020.
[47] ITU-D. ITU Seminar for Europe and CIS on Spectrum management and broadcasting. Remote meeting, 1-2 July 2020.
[48] Uganda Communications Commission (UCC). Webinar on safety and environmental concerns around telecommunication installations in Uganda. 11 August 2020.
[49] ITU-D. ITU Regional Forum for Europe: 5G Strategies, Policies and Implementation. Virtual meeting, 22-23 October 2020.

6 Conclusions

This report reviews scientific evidence from ITU Recommendations, Reports, conferences, workshops and initiatives developed in the three ITU Sectors, and from the relevant international organizations/standardization bodies: WHO, ICNIRP and IEEE. It details the revisions of IEEE (2019) and ICNIRP (2020) exposure levels, so that administrations may understand the complicated landscape of EMF standards and guidelines. Administrations are encouraged to follow the RF-EMF limits set by the science-based ICNIRP and IEEE expert groups, or thresholds set by their own experts. It is strongly suggested that harmonized international standards and EMF exposure limits be adopted. It should be emphasized that the IEEE C95.1-2019 Standard and ICNIRP (2020) Guidelines are largely harmonized and thus consistent.

Furthermore, the report discusses open questions relating to health hazards, finding that there is no scientific reason to adopt stricter RF-EMF limits for 5G, although research continues to clarify the issue even further. This is particularly necessary in the context of potential socio-economic risks in relation to RF-EMF and 5G, which may materialize in the form of increased misinformation, delays in base-station deployment, higher social costs for society or greater environmental impacts. Understanding the framework of the scientific basis for the harmonized international limits helps and encourages legislation-making bodies to place trust in these limits.

ITU also recommends that administrations make reference to the existing technical documentation and the revised ICNIRP (2020) or IEEE (2019) Guidelines on EMF exposure limits in their transition to 5G. A science-based approach explaining RF-EMF in relation to 5G deployment should support clear information to address the concerns of the public, thereby preventing or limiting the potential pitfalls outlined in this report.

It is sensible to affirm that, yes, discussing RF-EMF does indeed matter to countries' successful and smooth transition to 5G, and better communication around the topic should be coordinated at the national and international levels.

Abbreviations and acronyms

3D	three-dimensional
2G	second-generation mobile technology
3G	third-generation mobile technology
4G	fourth-generation mobile technology
5G	fifth-generation mobile
AAS	active antenna system
ALARA	as low as reasonably achievable
BDT	Telecommunication Development Bureau
BR	Radiocommunication Bureau
BS	base station
COVID-19	coronavirus disease 2019
DRL	dosimetry reference limit
EHS	electromagnetic hypersensitivity
EIRP	equivalent isotropic radiated power
EMF	electromagnetic field
EMR	electromagnetic radiation
ERL	exposure reference level
ERP	effective radiated power
FDTD	finite difference time domain
GSM	Global System for Mobile
ICES	IEEE International Committee on Electromagnetic Safety
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICT	information and communication technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
ISCG	Inter-Sector Coordination Group
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector

(continued)

ITU-D	ITU Telecommunication Development Sector
ITU-T	ITU Telecommunication Standardization Sector
LTE	long-term evolution
MaMIMO	massive MIMO
MIMO	multiple-input multiple-output
M2M	machine-to-machine
mmWave	millimetre waves
NGN	next-generation network
NIR	non-ionizing radiation
PRIDA	Policy and Regulation Initiative for Digital Africa
QoS	quality of service
RF	radio frequency
RF-EMF	radio-frequency electromagnetic field
rms	root mean square
RR	Radio Regulations
SAR	specific absorption rate
SI	International System of Units
SMTP	Spectrum Management Training Programme
TSB	Telecommunication Standardization Bureau
UCC	Uganda Communications Commission
UMTS	Universal Mobile Telecommunication System
WBA	whole body average
WHO	World Health Organization
WP	working party
WRC	World Radiocommunication Conference
WTDC	World Telecommunication Development Conference
WTID	World Telecommunication Indicators Database
WTSA	World Telecommunication Standardization Assembly

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