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Development Sector

Output Report on ITU-D Question 7/2

Recent progress on strategies and policies concerning human exposure to electromagnetic fields

Study period 2022-2025

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This report was prepared in response to Question 7/2: **Strategies and policies concerning human exposure to electromagnetic fields**, under the overall guidance and coordination of the management team of ITU-D Study Group 2, led by Mr Fadel Digham (Arab Republic of Egypt), as Chair, supported by the following Vice-Chairs: Mr Abdelaziz Alzarooni (United Arab Emirates), Ms Zainab Ardo (Federal Republic of Nigeria), Mr Javokhir Aripov (Republic of Uzbekistan), Ms Carmen-Mădălina Clapon (Romania), Mr Mushfig Guluyev (Republic of Azerbaijan), Mr Hideo Imanaka (Japan), Ms Mina Seonmin Jun (Republic of Korea), Mr Mohamed Lamine Minthe (Republic of Guinea), Mr Víctor Antonio Martínez Sánchez (Republic of Paraguay), Ms Alina Modan (Romania),[1] Mr Diyor Rajabov (Republic of Uzbekistan),[1] Mr Tongning Wu (People's Republic of China), and Mr Dominique Würges (France).

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1 Stepped down during the study period.

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Executive summary

Wireless technologies, including mobile phones, tablets and other wireless devices, have become an indispensable part of everyday life. They enable people around the world to access the Internet and enjoy its benefits. As radio-frequency electromagnetic fields (RF-EMF) are widely used in telecommunications, each new generation of wireless technology (as well as new applications such as the Industrial Internet of Things (IIoT) and non-terrestrial networks (NTNs)) has given rise to concerns about potential health hazards linked to RF-EMF exposure.

The Radiocommunication Sector (ITU-R) and the Telecommunication Standardization Sector (ITU-T) of the International Telecommunication Union (ITU) focus their efforts on the technical aspects of RF-EMFs, while the ITU Telecommunication Development Sector (ITU-D) focuses on human exposure-related strategies and policies. The present report covers a specialist area and refers to scientific expert bodies and opinions to provide context. RF-EMF exposure is an important topic for policymakers who want to protect the public while avoiding unnecessarily restrictive policies with a potentially negative impact on the provision of RF-EMF services.

ITU works with the International Electrotechnical Commission (IEC) to ensure alignment of the technical content of RF-EMF compliance standards for mobile phones and base stations. The accurate assessment of active 5G antennas requires the application of power reduction factors. RF-EMF assessments of base station sites indicate low levels of exposure – relative to the international guidelines – that have not changed significantly over time.

Over the last two or three decades, the health effects of mobile phones and networks have been studied in depth; no substantiated evidence has been found linking RF-EMF exposure levels below the thresholds set by international bodies with any health risks. Most international organizations support these findings.

ITU Member States are sovereign and set their own national standards for EMF exposure; most national regulations around the world are based on the technology independent guidelines developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Certain countries also impose restrictions on the deployment of transmitters within a certain distance from specific types of facilities, such as hospitals or schools. However, measurement studies in countries with and without restrictive policies show that exposure from all RF-EMF sources remains significantly below the ICNIRP limits. This suggests that such policies are not required to achieve low RF-EMF exposure levels and may restrict the development of community infrastructure. Concerns about potential future health risks have led some countries to recommend limitations on the use of wireless sources by certain population groups. Although there is no substantiated evidence of any adverse health effects, these groups might unnecessarily take precautions to restrict RF-EMF exposure at work and in their day-to-day lives.

Administrations are encouraged to follow the ICNIRP Guidelines on Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz) (ICNIRP (2020) Guidelines), the Institute of Electrical and Electronics Engineers (IEEE) standards, or the exposure limits set by their own experts. The best practice for administrations that choose to apply international RF-EMF exposure limits is to restrict exposure levels to below the thresholds set in the ICNIRP (2020) Guidelines.

Administrations have many decisions to make when developing or updating national EMF policies on exposure limits. In addition to setting exposure limits, they must also consider how to ensure compliance. While, in many cases, this is done through operator self-declaration, alternative methods, such as third-party assessments, also exist. When developing national policies, it is also important to ensure effective communication with the public. The main purpose of risk communication is to keep people informed and establish mutual trust.

Abbreviations and acronyms

Abbreviation	Term
2G	second generation mobile technology
3G	third generation mobile technology
4G	fourth generation mobile technology
5G	fifth generation mobile technology[2]
DC	duty cycle
EMF	electromagnetic field
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IIoT	Industrial Internet of Things
IoT	Internet of Things
MSS	mobile satellite service
NTN	non-terrestrial networks
RF	radio-frequency
RF-EMF	radio-frequency electromagnetic field
SAR	specific energy absorption rate
SG	study group
WHO	World Health Organization
WP	working party
WPT	wireless power transfer

2 While care was taken in this document to properly use and refer to the official definition of IMT-generations (see Resolution ITU-R 56 of the ITU Radiocommunication Assembly on naming for international mobile telecommunications), parts of this document contain material provided by the ITU membership, which refers to the frequently used market names "xG". This material cannot necessarily be mapped to a specific IMT-generation, as the underlying criteria applied by the membership are not known, but in general, IMT-2000, IMT-Advanced, IMT-2020 and IMT-2030 are known as 3G/4G/5G/6G, respectively.

Chapter 1 – Introduction

1.1 Background

Wireless technologies – including mobile phones, tablets and other wireless devices – have become an indispensable part of everyday life. They enable people around the world to access the Internet and enjoy its benefits. Over the past decade, it has become increasingly challenging for 3G and 4G networks to support new applications and operate in new settings, such as smart homes and buildings; smarter and cleaner cities; self-driving cars, road safety and other intelligent transport systems; 3D video; cloud-based work and entertainment; remote medical services; virtual and augmented reality; and massive machine-to-machine communications for industry automation and manufacturing.

During the study period, 5G (IMT-2000) networks were deployed in many regions to provide connectivity for the above-mentioned services. RF-EMFs are widely used in telecommunications, and each new generation of wireless technology has given rise to concerns regarding the potential hazards of human EMF exposure. Previously, the emitters used in wireless technology generally operated below 6 GHz. However, owing to increasing demand for higher data rates, better quality of service and lower latency, the next generation of wireless technology is planned to operate at frequencies above 6 GHz, or even into the "millimetre-wave" range (30-300 GHz).

Extensive research carried out over the last two or three decades into the health effects of EMF exposure from mobile phones has revealed no increased health risk at exposure levels below the limits set by international bodies. Although there has been more research into RF fields at lower frequencies, a number of studies have also examined the effects of RF fields at frequencies above 6 GHz. The results of these studies confirm that RF fields from 100 kHz to 300 GHz have a primarily thermal effect on human tissue. As their frequency increases, RF fields penetrate less into body tissues; for frequencies above 6 GHz, the depth of penetration is relatively short, with surface heating being the predominant effect. Given public concerns over the planned roll-out of 5G and millimetre-wave technologies, it is important to determine whether environmental exposure levels have a negative impact on human health.

Based on established mechanisms, international organizations have developed standards and guidelines to limit human exposure. Most of the exposure guidelines for RF fields are based on the latest scientific knowledge and aim to prevent any harmful exposure to RF fields. Most national guidelines around the world are based on the guidelines developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). In the frequency range 6 GHz- 300 GHz, the ICNIRP Guidelines prevent excessive heating of the surface of the skin and the eye.

While ITU does not set maximum levels of human exposure to electromagnetic fields, as those thresholds are set by competent bodies, it references their standards and recommendations in its own recommendations, followed by many Member States. ITU Member States are sovereign and set their own national standards for exposure to electromagnetic fields.

The recent, large-scale roll-out of 5G has required studies into potential effects of RF-EMF exposure on human health, as well as efforts to harmonize standards, implement good practices to mitigate exposure and ensure an effective risk communication approach. Stakeholders have been actively involved in the process, and many documents have been published on the subject. However, public concerns remain, as people want to ensure that all potential health impacts have been thoroughly investigated. As a consequence, some countries (and regions) are adopting far stricter RF-EMF limits, on precautionary grounds, which may impact the deployment of wireless networks. Although there is no scientific evidence for enacting different exposure limits in different countries, national regulations – influenced by social, economic and political factors – have priority status in their countries.

To summarize, the following challenges need to be addressed:

- Studies on how RF-EMFs interact with biological tissues show that frequencies from 100 kHz-300 GHz can heat human tissue. However, penetration depth decreases as frequency increases, with the predominant effect being the heating of superficial tissue. New physical metrics, measurement protocols and methods to mitigate the exposure should be proposed.
- International organizations have proposed new guidelines for RF-EMF exposure, supported by the World Health Organization (WHO), while some countries (and cities) have adopted far stricter RF-EMF limits, which may negatively impact the deployment of radio services. Nevertheless, national regulations have priority status at the national level, and are influenced by social, economic and political factors.
- Initiatives have been launched to raise awareness and educate the public regarding human exposure to electromagnetic fields from new and emerging wireless radio systems. However, appropriate methods to manage public risk perception have yet to be identified.

1.2 Scope of the report

ITU allocates global radio spectrum and satellite orbits, develops the technical standards that ensure seamlessly connected networks and technologies, and works to secure and improve access to information and communication technologies (ICTs) for underserved communities worldwide.

The Radio Regulations, which cover all generations of mobile technologies, govern the global use of radio-frequency spectrum (bands of radio-frequencies) and satellite orbits for a wide variety of wireless services, on a harmonized basis, to avoid harmful interference, ensure interoperability and reduce the cost of services and devices, through the resulting economies of scale.

ITU Recommendations refer to international standards, guidelines and recommendations on measuring and monitoring electromagnetic fields and mitigating exposure, most of which have been developed by other competent international bodies.

The present report, produced by the ITU Telecommunication Development Sector (ITU-D), covers a specialist area and refers to scientific expert bodies and opinions to provide context. It is important for policymakers, as unnecessarily restrictive policies, regulations and approaches negatively affect the provision of radio services. The report focuses on science-based policies, guidelines, regulations and assessments of human exposure to RF-EMFs, without entering into the specialized field of biology. For reference, 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.

The previous report, namely the Output Report on ITU-D Question 7/2 for the study period 2018-2021 on policies, guidelines, regulations and assessments of human exposure to radio-frequency electromagnetic fields, collected and disseminated information concerning exposure to RF-EMFs to support national administrations of ITU Member States, particularly in developing countries, and to advance appropriate national regulations. It helped administrations to keep abreast of and respond to public concerns related to RF-EMF. The present report focuses on science-based policies, guidelines, regulations and assessments relating to human exposure to RF-EMFs, based on the updated international RF-EMF exposure limits set by the International Commission on Non-Ionizing Radiation Protection (in the ICNIRP (2020) Guidelines) and the Institute of Electrical and Electronics Engineers (in standard IEEE C95.1-2019), among others. It includes guidelines based on real-life case studies of ITU-D members; their experiences and lessons learned can help people to know that they are protected and informed when connecting to digital services.

As research on EMF exposure is ongoing, it is useful to review the previous version of the Output Report on ITU-D Question 7/2, including to take new data into account. For example, during the period under review (2022-2025) the international EMF limits were updated, following the revision of the ICNIRP Guidelines (2020), with implications for the regulatory framework. Revisions to internationally recognized standards, such as IEEE C95.1-2005 standard (see IEEE C95.1-2019) have been taken into account in the present report and new case studies included to reflect national RF-EMF activities carried out during the study period. An ITU-D workshop on EMF, held in May 2023 on international, regional and national policies concerning human exposure to electromagnetic fields, provided significant insights into the topic; distinguished international RF-EMF experts from various organizations, including WHO, ICNIRP, GSMA and ITU, as well as regional experts (including from the southern Africa region) and representatives of national governments (China), shared their knowledge. At a workshop on recent developments relevant to EMF policy formulation, held on 8 May 2024, experts from Australia, Federative Republic of Brazil, Republic of Colombia, Israel, GSMA, IEC, China Mobile Communications Co. Ltd. and ITU-T shared their insights. Participants had the opportunity to learn about and discuss current national activities on human exposure to RF-EMFs, as well as international efforts to harmonize EMF exposure limits. The above-mentioned workshop sessions contributed to the implementation of the Question 7/2 workplan, and were addressed to representatives of ministries, regulators, telecommunication operators, universities and general education institutions, telecommunication equipment manufacturers, research and design institutes, software developers and other stakeholders from ITU Member States, Sector Members and Associates.

Chapter 2 – International activities on RF-EMF exposure (since 2022)

2.1 ITU activities

2.1.1 ITU resolutions on human exposure to electromagnetic fields

The ITU framework on electromagnetic fields (EMF) is underpinned by the following ITU resolutions:

- Resolution 176 (Rev. Bucharest, 2022) of the Plenipotentiary Conference on measurement and assessment concerns related to human exposure to electromagnetic fields;
- Resolution 62 (Rev. Kigali, 2022) of the World Telecommunication Development Conference on the assessment and measurement of human exposure to electromagnetic fields;
- Resolution 72 (Rev. New Delhi, 2024) of the World Telecommunication Standardization Assembly on measurement and assessment concerns related to human exposure to electromagnetic fields.

Based on the revision of Resolution 62 (Rev. Kigali, 2022) and review of Question 7/2, the present report updates and revises the Output Report on ITU-D Question 7/2 for the study period 2018-2021, and incorporates new case studies relating to the adoption of the international standards, including the ICNIRP (2020) Guidelines and IEEE C95.1-2019, as well as material on national policies, assessments and exposure limits.

2.1.2 ITU Sector activities

The three ITU Sectors, namely the Radiocommunication Sector (ITU-R), the Telecommunication Standardization Sector (ITU-T), and the Telecommunication Development Sector (ITU-D) carry out complementary EMF activities. ITU-D works on strategies and policies on human exposure to EMF while ITU-T and ITU-R focus on the technical and measurement-related aspects of RF-EMFs; ITU-R works on EMF measurements from base stations to assess human exposure and ITU-T assesses existing and emerging technologies[3] to ensure compliance with EMF limits for the general public and workers.

During the study period, productive, intersectoral cooperation on EMF improved Question 7/2 deliverables, and the Output Report on ITU-D Question 7/2 for the study period 2018-2021 has been cited several times. ITU-R and ITU-T publications that refer to the Output Report on ITU-D Question 7/2 for the study period 2018-2021 include:

- Recommendation ITU-T K.91 (01/2024) on guidance for assessment, evaluation and monitoring of human exposure to radio-frequency electromagnetic fields; Appendix I on exposure limits builds on the Output Report on ITU-D Question 7/2 for the study period 2018-2021 .

[3] For example, international mobile telecommunications (IMT) systems: the current IMT-2000, IMT-Advanced and IMT-2020 as well as IMT for 2030 and beyond.

- Recommendation ITU-R (SG 6) BS.1698-1 (05/2023) on evaluating electromagnetic fields from terrestrial broadcasting transmitting systems to assess human exposure to non-ionizing emissions; the text refers to Recommendation ITU-T K.91 (01/2024), noting that Appendix I thereto specifies the ICNIRP (2010) and (2020) guidelines in force, elaborates the tables and figures of ICNIRP (2020), details the IEEE C95.1-2019 standard and explains the simultaneous exposure to multiple sources.
- Report ITU-R (SG 1) SM.2452-1 (07/2022) on electromagnetic field measurements to assess human exposure.

2.1.2.1 ITU-D activities

ITU-D activities on EMF are carried out by Study Group 2 on ITU-D Question 7/2 on strategies and policies concerning human exposure to electromagnetic fields.

2.1.2.2 ITU-R activities

ITU-R plays a decisive role in establishing technical requirements for measuring RF-EMFs and identifying spectrum for next generation networks in the field of international mobile communications (IMT).[4] Based on Resolution 176 (Rev. Bucharest 2022) of the Plenipotentiary Conference, the most relevant ITU working party (WP) to study RF-EMFs is ITU-R WP 1C on spectrum monitoring, within Study Group 1 under ITU-R Question 239/1 on EMF measurements to assess human exposure. ITU-R also approved Report ITU-R SM.2452-1 (07/2022) on electromagnetic field measurements to assess human exposure and the ITU-R Handbook on Spectrum Monitoring (previous edition published in 2011; next edition with significant updates foreseen in 2026), a highly relevant text that identifies methodologies to measure EMF; section 5.6 of the handbook specifically focuses on non-ionizing radiation measurements.

2.1.2.3 ITU-T activities

ITU-T activities on EMF are carried out by ITU-T Study Group (SG) 5, through WP 1/5[5] on electromagnetic compatibility (EMC), lightning protection, EMF and circular economy under Question Q3/5 on human exposure to electromagnetic fields (EMFs) due to digital technologies.[6] The ITU-T webpage outlines its activities on human exposure to electromagnetic fields from radio systems and mobile equipment. ITU-T SG 5 has been particularly active in developing recommendations on protection from, and the measurement/computation of, RF fields. The ITU-T K-series Recommendations (and related supplements) form part of a comprehensive suite of ITU Recommendations/standards to address realistic concerns about exposure to RF-EMFs from networks and devices. Information on the ITU-T Study Group 5 EMF estimator software tool is provided Recommendation ITU-T K.70 (2020), Amendment 1 (12/2021).

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4 See Resolution ITU-R 56-3 (Geneva, 2023) of the ITU Radiocommunication Assembly on naming for international mobile telecommunications (IMT), which states in *resolves 1* "that the term 'IMT-2000' encompasses also the enhancements and future developments of IMT 2000 (…)."

5 See SG5 – ITU study group structure (Study Period 2022-2024).

6 See ITU-T Study Group 5, Working Party 1/5 presentation on recent activities at ITU-T on EMF, given as part of the ITU-D workshop on recent developments relevant to EMF policy formulation, held in Geneva on 8 May 2024.

2.1.2.4 Cooperation with international organizations (in addition to ITU-T and ITU-R)

ITU-D cooperates closely with international organizations on EMF. The following entities participated in the ITU-D workshops held in May 2023 and May 2024:

- World Health Organization (WHO)
- International Commission on Non-Ionizing Radiation Protection (ICNIRP)
- International Electrotechnical Commission (IEC)
- Institute of Electrical and Electronics Engineers (IEEE)
- GSM Association (GSMA).

2.2 WHO and ICNIRP activities

The WHO Radiation and Health Unit works to strengthen radiation protection for the general public, patients and workers worldwide. It provides WHO Member States with evidence-based guidance, tools and technical advice on public health issues related to ionizing and non-ionizing radiation.[7] On 16 June 2002, WHO published a handbook on establishing a dialogue on risks from electromagnetic fields.

The WHO International EMF Project, launched in 1996, has a mandate to assess the health and environmental effects of exposure to radio-frequency (RF) fields, electromagnetic fields (EMFs) and static fields; its research results are incorporated into WHO's Environmental Health Criteria (EHC) monographs.

WHO is currently carrying out a risk assessment of radio-frequency electromagnetic fields, to be published as a monograph in its Environment Health Criteria (EHC) series. Health risk assessments are based on in-depth critical reviews conducted by independent, scientific peer-review groups. They are usually undertaken when new data become available that would substantially change an existing assessment, public concerns arise relating to the health or environmental impact of an agent because of increased exposure, or an appreciable time period has elapsed since the previous assessment.

As noted at the ITU-D workshop[8] on international, regional and national policies concerning human exposure to electromagnetic fields held on 8 May 2023, the work of the WHO Radiation and Health Unit covers both ionizing and non-ionizing radiation. The WHO informed workshop participants that international organizations have published exposure guidelines on EMFs. Many countries currently follow the guidelines recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and/or the Institute of Electrical and Electronics Engineers (IEEE), through its International Committee on Electromagnetic Safety. These guidelines are not technology-specific and cover radio-frequencies up to 300 GHz.

In January 2025, ICNIRP published a statement on gaps in knowledge relevant to the ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (100 kHz to 300 GHz).

[7] World Health Organization, Radiation and health unit.

[8] Emilie van Deventer from the World Health Organization gave a presentation on WHO's recent activities on EMF and health at the ITU-D workshop on international, regional and national policies concerning human exposure to electromagnetic fields, held in Geneva on 25 May 2023.

According to Arqiva (United Kingdom), in its contribution to the ITU-R WP 6A meeting in March 2025:

"This publication aims to encourage research into these knowledge gaps, as this would assist ICNIRP in further developing guidelines and setting revised recommendations on limiting exposure to RF-EMFs (100 kHz to 300 GHz)".

The ICNIRP statement identified the following data gaps to be addressed as a matter of urgency:

- Issues concerning the relationship between RF-EMF exposure and heat-induced pain;
- Clarification of the relationship between whole-body exposure and a core temperature increase for frequencies from 100 kHz to 300 GHz, as a function of exposure duration and combined EMF exposures;
- Adverse effect thresholds and thermal dosimetry for a range of ocular structures;
- Pain thresholds for contact currents for a range of exposure scenarios, including associated dosimetry.

Additionally, ICNIRP recommended a range of additional dosimetry studies to support future research and improve the application of RF-EMF exposure restrictions in future guidelines. Moreover, it concurred with the Output Report on ITU-D Question 7/2 for the study period 2018-2021, noting that proposed research to close knowledge gaps might have an impact on the ICNIRP Guidelines; as a result, it was important to monitor progress.

2.3 IEEE and IEC activities

2.3.1 Institute of Electrical and Electronics Engineers (IEEE)

The latest versions of IEEE standards should be used:

- 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 Techniques.
- 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.

Operating under the rules and oversight of the IEEE Standards Association Standards Board, the International Committee on Electromagnetic Safety (ICES) is responsible for developing standards for the safe use of electromagnetic energy in the range of 0 Hz to 300 GHz range relative to the potential hazards of exposure of humans, volatile materials, and explosive devices to such energy; standards for products that emit electromagnetic energy by design or as a by-product of their operation; and standards for environmental limits. These standards include:

- IEEE/IEC 62209-1528-2020 – Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-worn wireless communication devices – Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 GHz).
- IEEE C95.3-2021 – Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 300 GHz. This standard provides guidelines for measuring and computing electromagnetic fields to assess human exposure.

- IEEE C95.7-2022 – Standard for Electromagnetic Energy Safety Programs, 0 Hz to 300 GHz. This standard offers recommendations for developing and implementing radio-frequency (RF) safety programmes.
- IEEE/IEC 62704-1-2017 – International Standard for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body from Wireless Communications Devices, 30 MHz to 6 GHz: General requirements for using the finite-difference time-domain method for SAR calculations. This standard provides guidelines for computational techniques to determine SAR.
- IEEE 1308-2023 – IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters – 10 Hz to 3 kHz. This standard specifies requirements for instruments used to measure magnetic flux density and electric field strength.

2.3.2 International Electrotechnical Commission (IEC)

IEC technical committee 106 (TC 106)[9] (on methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure) covers the whole frequency range, from 0 Hz to 300 GHz.

Scope of TC 106:

- To prepare international standards on measurement and calculation methods to assess human exposure to electric, magnetic and electromagnetic fields;
- The task includes: characterization of the electromagnetic environments with regard to human exposure; measurement methods, instrumentation and procedures; calculation methods; assessment methods for the exposure produced by specific sources; basic standards for other sources; assessment of uncertainties. It applies to basic restrictions and reference levels;
- Excluded are: the establishment of exposure limits; mitigation methods which have to be dealt with by the relevant product committees; electrical safety (however, the issue of contact current related to the indirect effect of human exposure to electromagnetic fields is included).

TC 106 working groups (WGs) and project teams (PTs):

- WG 8: Addressing methods for assessment of contact current related to human exposures to electric, magnetic and electromagnetic fields
- WG 9: Addressing methods for assessment of Wireless Power Transfer (WPT) related to human exposures to electric, magnetic and electromagnetic fields
- PT 62764-1: Determining procedures for the measurement of field levels generated by electronic and electrical equipment in the automotive environment with respect to human exposure
- PT 63480: Assessment of human exposure to electromagnetic fields from radiative wireless power transfer systems: measurement and computational methods (frequency range of 30 MHz to 300 GHz)

IEC/IEEE joint working groups (JWGs) and joint maintenance teams (JMTs):

- JWG 11: Computational methods to assess the power density in close proximity to the head and body linked to IEEE

[9] Based on a presentation by Wenhua Ma from China Mobile Communications Co. Ltd., entitled "An introduction to the EMF standards in IEC" given during the ITU-D workshop on recent developments relevant to EMF policy formulation, held in Geneva on 8 May 2024.

- JWG 12: Measurement methods to assess the power density in close proximity to the head and body linked to IEEE
- JWG 13: Measurement procedures to determine the specific absorption rate (SAR) linked to IEEE
- JMT 14: Revision of IEC/IEEE 62209-1528
- JMT 62209-3: Revision of IEC 62209-3 as joint IEC/IEEE standard
- JWG 62209-5: Methods for validation of SAR measurement systems for hand-held and body-mounted wireless communication devices
- JWG 63184: Human exposure to electric and magnetic fields from wireless power transfer systems linked to IEEE.

Relevant IEC standards and technical reports:

- IEC 62232:2025 (Edition 4): Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure
- 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 62905:2018 (Edition 1.0, 06/02/2018): Exposure assessment methods for wireless power transfer systems
- IEC TR 63167:2024 (Edition 2.0, 07/08/2024) Assessment of contact current related to human exposure to electric, magnetic and electromagnetic fields.

Other important IEC standards and reports:

- IEC/IEEE 62209-1528:2020: 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 – Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 GHz).

During an ITU-D workshop[10] on recent developments relevant to EMF policy formulation, held on 8 May 2024, it was announced that the fourth edition of IEC 62232 had been approved by all the national committees and was being prepared for publication. The technical content remains unchanged from the third edition. The fourth edition includes minor corrections and editorial updates to improve readability and align the document with the IEC technical report (TR 62669:2025) on case studies supporting IEC 62232 international standard. The ITU and IEC protocols for assessing technologies such as 5G with beamforming and beam steering antennas have been aligned. The methods can be applied to the ICNIRP or IEEE EMF exposure limits.

Wireless communication device standards:

- IEC/IEEE 62209-1528:2020 (Primary Device SAR Measurement Standard): An amendment was introduced, addressing key areas such as hand SAR, motion sensors, time-averaged specific absorption rate (TAS), proximity sensors, and clauses related to separation distance.
- **Restructuring of the device SAR standards series:** Discussions were held to restructure the device SAR standards series. IEC/IEEE JWG 13 developed a high-level structure for the new series, and the proposal was circulated to IEC National Committees and IEEE for

[10] See presentation by Jafar Keshvar, from IEEE/ICES, on recent developments on EMF Regulations in Europe and IEC/IEEE standards topical issues.

feedback. The proposed restructuring was approved by IEC National Committees and the IEEE/ICES Administration Committee. The new structure consists of three normative standards and one informative standard, each published separately.

- **Establishment of IEC/IEEE 62209-5**: A new joint committee, IEC/IEEE 62209-5, has been established. This committee will focus on developing generic methods for the validation of SAR measurement systems used for hand-held and body-mounted wireless communication devices.
- IEC/IEEE 62704-4:2020[11] international standard (SAR calculations) 30 MHz – 6 GHz, May 2020
- IEC/IEEE 63195-1:2022[12] international standard (measurement procedure) 6 – 300 GHz, December 2022

The main international measurement standards for measuring the SAR in the human head and body are IEC/IEEE 62209-1528:2020 and IEC 62209-3:2019. The latter is currently under revision, and will be published as a dual – logo IEEE/IEC standard.

2.4 Good practices and international RF-EMF exposure limits

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

[11] IEC and IEEE. IEC/IEEE 62704-4:2020. Determining the peak spatial-average specific absorption rate (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.

[12] IEC and IEEE. IEC/IEEE 63195-1:2022. Assessment of power density of human exposure to radio frequency fields from wireless devices in close proximity to the head and body (frequency range of 6 GHz to 300 GHz) – Part 1: Measurement procedure.

Chapter 3 – Developments relating to exposure to radio-frequency (RF) fields

Various country initiatives were outlined during the study period, reflecting the efforts of national governments and regulators to address public questions in an open and informative manner. Many governments have chosen to introduce exposure limits, primarily based on the ICNIRP (2020) Guidelines, as part of efforts to establish or refine their national regulatory frameworks and address issues as they arise. This approach is actively supported by industry, which welcomes the adoption of internationally harmonized exposure limits and measurement standards, such as those developed by IEC, to accurately assess compliance with exposure limits.

3.1 National initiatives

The Output Report on ITU-D Question 7/2 for the study period 2018-2021 provided guidance to administrations on the adoption of national RF exposure limits based on the thresholds specified in ICNIRP (2020) Guidelines (see Chapter 4 of the present report for further details). The ICNIRP (2020) Guidelines contain several updates relevant to 5G (termed IMT) and future technologies.

Several governments, including those of Australia[13] and Colombia,[14] which had already adopted the ICNIRP (1998) Guidelines, incorporating them into national regulations or standards, also adopted updated regulations based on the ICNIRP (2020) Guidelines.

China translated the ICNIRP (2020) Guidelines into Chinese to increase awareness of the scientific rationale behind the exposure limits and to help to address any questions that may arise. As part of efforts to take technological developments into account, the Government updated its previous (2007) mandatory standard for RF-EMF exposure from mobile phones (GB21288-2007), which used the SAR limits set out in the ICNIRP (1998) Guidelines. The revised SAR standard (GB21288-2022) specifies the applicable spectrum and defines absorbed power density, as well as the frequency-dependent limits for various parts of the body. In its contributions and workshop presentations, China Mobile Communications Co. Ltd. provided an overview of the Chinese regulatory framework for base station construction. [15] The Environmental Protection Law of the People's Republic of China (2015) governs the construction of all projects (including base stations) in China and environmental impact assessments are regulated by the revised Environmental Impact Assessment Law of the People's Republic of China (2018). Environmental monitoring measures are covered by Decree No. 39 of the Ministry of Information Industry (2007) on pollution control measures for electronic information products. Base stations are required to comply with the limits prescribed in standard GB/T 8702-2014.[16]

13 ITU-D SG2 workshop presentation Q7/2-2024-01 by Australia.
14 ITU-D SG2 workshop presentation Q7/2-2024-03 by Colombia.
15 ITU-D SG2 Document SG2RGQ/73 from China.
16 ITU-D SG2 workshop presentation Q7/2-2023-04 by China.

Romania[17] is seeking to address questions through a website featuring the output of 200 broadband monitoring fixed sensors located in Bucharest and around the country (www.monitor-emf.ro). The sensors operate around the clock, and the website allows users to view the data produced over days, months, or the previous year. In addition to measuring exposure levels at fixed locations, the national regulator *Autoritatea Nationala pentru Administrare si Reglementare* (ANCOM) also performs mobile measurements in areas close to educational institutions, hospitals, public institutions and other public buildings, with the results also available via the website. As noted in their contribution:

> *"To date, all measurements performed for over 10 years by ANCOM with both types of equipment (fixed and mobile) show that the emissions from Romania are far below the maximum limits established by the national legislation."*

The Republic of Benin[18] outlined the legislative and regulatory decrees in force relating to EMF, including an interministerial order from 2021 requiring base station sites to be located at least 100 metres away from sensitive locations such as schools and hospitals. The Administration applies ICNIRP reference levels, but with an additional 40 per cent reduction factor, while noting that no measurements have exceeded the 2021 limits set by the regulator.

Brazil outlined its national measurement programme, implemented under the provisions of article 13 of Law No. 11.934 of 2009, which requires base stations to be measured and reassessed for compliance every five years. The previous version of the law also required site sharing if the proposed site was located less than 500 metres from another station (unless technical or other limitations applied); this article has since been deleted. A measurement approach was introduced that accounted for aggregated exposure from multiple sources located on or near the site. Developing that approach was the first step; the second was to determine where to carry out the actual measurements, taking into account factors such as the location of estimated maximum exposure, densely populated areas or whether any hospitals or schools were located nearby. These factors influence where the actual measurements are taken. The telecommunication regulator in Brazil, the *Agência Nacional de Telecomunicações* (ANATEL) carries out representative statistical sampling to confirm base station compliance. As in other countries, Brazil[19] has never found a base station that does not comply with the EMF reference levels. On a related note, Linhares *et al.*, 2021 demonstrated that the maximum exposure at ground level due to simultaneous exposure from an "infinite" number of typical base stations is less than 3 per cent of the limit. Brazil emphasized in its concluding comments that EMF assessments can be very time-consuming and that regulations should be as simple as possible.

The Republic of the Congo[20] highlighted some of the challenges facing African nations as a consequence of the rapid take-up of mobile communications services and the need for national mobile networks to keep up with consumer demand. The Government has prepared a draft regulatory text based on the ICNIRP (2020) Guidelines and is developing an RF-EMF assessment protocol. The Republic of the Congo notes that across Africa, countries adopting RF-EMF limits include: Republic of Kenya (based on ICNIRP (2020) Guidelines, adopted in 2022 under the Nuclear Regulatory Act No. 29 of 2019); Kingdom of Morocco (based on ICNIRP (2020) Guidelines, adopted in 2022 by the telecommunication regulator); Senegal (based on ICNIRP (2020) Guidelines, adopted in 2021 by the telecommunication regulator); and Togo (based on

17 ITU-D SG2 Document 2/152 from Romania.
18 ITU-D SG2 Document 2/198 from Benin.
19 ITU-D SG2 workshop presentation Q7/2-2024-02 by Brazil.
20 ITU-D SG2 Document 2/274 from the Republic of the Congo.

ICNIRP (1998) Guidelines, adopted in 2022 by the telecommunication regulator). Moreover, the South African Department of Health recommends the ICNIRP limits.

In the Republic of Uganda, the most recent national base station EMF survey undertaken, between April 2021 and March 2022 by the Uganda Communications Commission (UCC),[21] found that the highest mean value was 0.008 per cent of the ICNIRP power density reference levels. The survey covered 360 single, shared or collocated sites (in this context, meaning two or more base stations in the same location, or within 70 metres of each other). While there was a slight difference in EMF levels between the three types of sites, with the collocated site values being slightly higher than the other two, there was no appreciable difference among the results. In Uganda, the regulatory framework for telecommunications includes roles for the Ministry of Information and Communications Technology and National Guidance, the Uganda Communications Commission, the National Environment Management Authority and public infrastructure providers.

Côte d'Ivoire[22] undertook a measurement campaign during the 2024 African Cup of Nations that covered all matches and fan zones. The measurement period covered the 3 hours before a given match, the duration of the match itself, and up to 1 hour after the match. While RF-EMF levels increased during matches, the levels observed during all matches complied with the limit values.

Benin,[23] Morocco, and Kenya have also undertaken RF-EMF measurements. No base station measurements in publicly accessible locations have been found to exceed national EMF limits.[24]

The National Communications Authority of Ghana[25] developed its capability to independently assess RF-EMF exposure from base stations up to 6 GHz and use the results as the scientific basis for risk communication. In doing this, the national communications authority requires that RF-EMF sources – FM/AM, TV transmissions and cellular base stations comply with the limits set out in the ICNIRP (1998) Guidelines. Measurements at 240 points in Suhum municipal district, in the eastern region of Ghana showed an average level that was 0.00004 per cent of the ICNIRP public limit. The national communications authority also established a type approval laboratory to test and measure user equipment, such as mobile devices and tablets, for compliance with EMF limits.

In 2022, Egypt[26] established a national committee, consisting of the National Telecom Regulatory Authority, the Environmental Affairs Agency, the Ministry of Health and Population and the National Telecommunication Institute. Following stakeholder consultations, updated guidelines for installing macro and micro (small cell) base stations were adopted. The ICNIRP (2020) Guidelines were adopted, with the condition that a single antenna does not exceed 5 per cent of the limit. Macro site antennas can be placed on rooftops with secure access, except for in hospitals. The base of a tower must be at least 12 m from the fence of any school. To reduce the potential of interference affecting medical equipment, small cells with effective isotropic radiated power of less than 10 W that meet certain mounting criteria can be deployed in hospitals.

21 ITU-D SG2 Document SG2RGQ/77 from Uganda.
22 ITU-D SG2 Document SG2RGQ/189 from Côte d'Ivoire.
23 ITU-D SG2 Document 2/198 from Benin.
24 ITU-D SG2 Document 2/274 from the Republic of the Congo.
25 ITU-D SG2 Document 2/78 from Ghana.
26 ITU-D SG2 Document SG2RGQ/133 from Egypt.

In the Central African Republic,[27] the law on electronic communication provides a framework for adopting subsidiary legislation on RF-EMF compliance. The national regulator, the *Autorité de Régulation des Communications Electroniques et de la Poste* (ARCEP), has the authority to enforce ITU recommendations on EMF exposure. However, no regulatory provisions currently exist to penalize non-compliance by operators. The Central African Republic intends to implement all ITU Recommendations pertaining to EMFs, and to collaborate with other standard-setting organizations to avoid duplication.

In Haiti, the telecommunication regulator, the *Conseil National des Télécommunications* (CONATEL)[28] adopted the limits set out in ICNIRP (1998) Guidelines, based on Recommendation ITU-T K.52, and rules for the siting of antennas that include approval procedures, inspection intervals and sanctions for non-compliance.

The Republic of Indonesia[29] introduced SAR limits for phones based on the ICNIRP (2020) Guidelines for head, trunk and limbs, using international testing methods. These limits will be extended to various other devices, such as laptops, wearables and virtual reality devices. The Government of Indonesia would welcome workshops to harmonize EMF regulations across countries.

Israel[30] outlined its policies in relation to both base station exposure limits – 10 per cent of the limits set out in the ICNIRP (1998) Guidelines for areas of prolonged exposure and 30 per cent for short-stay locations such as on rooftops,[31] and for SAR limits for devices – accepting either 1.6 W/kg in 1 g or 2 W/kg in 10 g, the former applying to devices from the United States of America and the latter to devices from Europe. The Ministry of Environmental Protection is responsible for the approval and monitoring of base station compliance.

In Hungary, the National Media and Infocommunications Authority (NMHH)[32] is developing a system to calculate RF-EMF levels from transmitters, as an alternative to in situ measurements, that will take into account existing environmental RF-EMF sources and automatically generate the aggregated RF-EMF exposure at a given location. However, exact data on transmit site configurations need to be verified as, for example, antenna positions and 3D building maps are not available in all locations. This leads to uncertainties that affect the accuracy of calculations. Hungary advises that results produced by mass calculation systems are not consistently reliable in terms of meeting uncertainty requirements. However, if adapted, they can be used to create heat maps for public information and to efficiently identify locations for measurements.

3.2 Developments relating to specific RF-EMF exposure scenarios

This section includes updated information on RF-EMF exposure from various technologies, applications and devices, as well as on exposure in settings such as schools and hospitals.

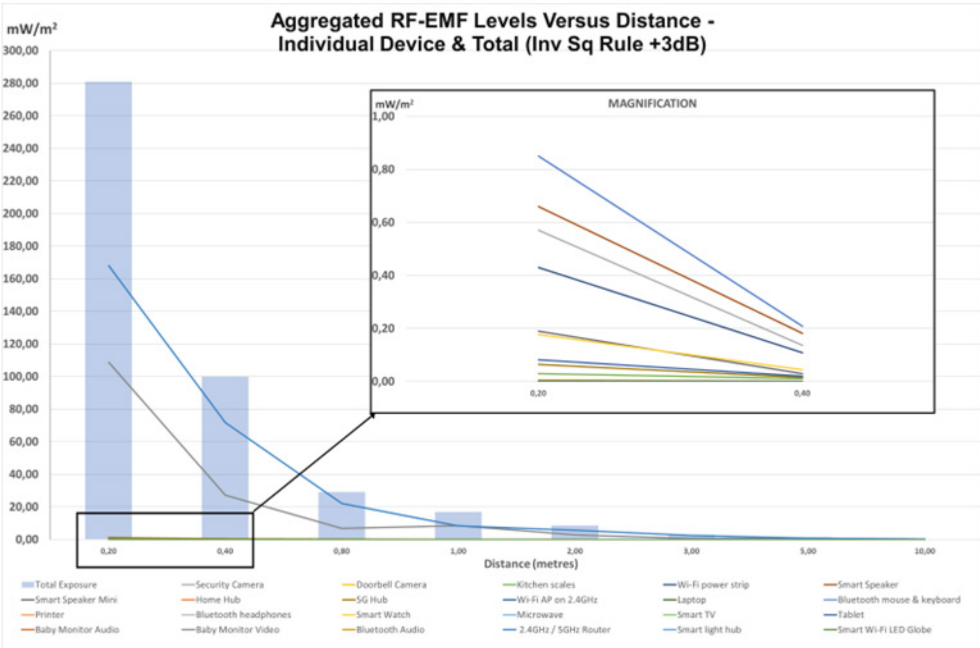
27 ITU-D SG2 Document 2/129 from the Central African Republic.
28 ITU-D SG2 Document SG2RGQ/122 from Haiti.
29 ITU-D SG2 Document SG2RGQ/193 from Indonesia.
30 ITU-D SG2 workshop presentation Q7/2-2024-04 by Israel and ATDI.
31 The presentation explains that the health threshold set by the Ministry of Environmental Protection is based on the ICNIRP (1998) Guidelines. However, the Ministry applies reductions relating to possible unknown health risks and negative phenomena whose existence is in scientific doubt. The Ministry continues to use the ICNIRP (1998) Guidelines as the European Union has not yet moved to adopt the ICNIRP (2020) Guidelines. Some European Union member states have adopted the ICNIRP (2020) Guidelines.
32 ITU-D SG2 Document 2/257 from Hungary.

3.2.1 RF-EMF exposure from the Internet of Things (IoT) and smart devices

As there are predicted to be more than 39.6 billion IoT devices in use by 2033, with roughly 60 per cent of these being consumer devices, questions may understandably arise concerning human EMF exposure when people are in such close proximity to so many devices.

Research papers published on the topic have included McKenzie *et al.*, 2023, which described testing 12 devices in a laboratory environment under conditions simulating high user activity, and Joyner *et al.*, 2024, which assessed EMF levels produced by 55 devices, across 23 device categories, at distances extending to 10 m – namely distances that might typically be experienced within a home environment. In both of these studies, the duty cycle (DC) of the devices was an important consideration, as the devices do not transmit continuously. For example, a "smart globe" was estimated to have a DC of only 0.011 per cent, while a 5G hub router had a DC of 86.5 per cent while in heavy use. The highest measured levels for each of the 23 device categories over various distances are indicated in Figure 1 below. The graph also plots the total cumulative exposure (blue bars) at each distance measured if each device were simultaneously transmitting at that distance (which is rarely the case). Not surprisingly, the highest exposure levels would occur at the closest distance, namely 20 cm. Even at this distance, the total cumulative exposure arising from 23 simultaneously transmitting devices amounted to 280 mW/m^2, equivalent to 2.8 per cent of ICNIRP limits for the general public of 10 W/m^2 at 2.45 GHz – or to put it another way, around 36 times below the ICNIRP power density limits.[33]

Figure 1: Aggregated RF-EMF levels versus distance for individual devices and in total (the international public exposure limit at 2.45 GHz is 10 000 mW/m^2)



Based on these studies and other research focusing on the measurement of environmental background levels of other RF sources such as TV, radio and base stations, the Mobile & Wireless

[33] The transmit frequency of the 23 IoT devices was measured in the 2.45 or 5 GHz band. The ICNIRP (2020) Guidelines set limits that are the same at both frequencies. The measurements were taken at distances of 20 cm or greater, so the ICNIRP (2020) Guidelines Table 5 reference levels for the general public at 2-300 GHz apply, and are equal to 10 W/m^2 (equivalent to 10 000 mW/m^2).

Forum[34] developed the RF Estimator tool (www.mwfai.org/RFEstimator.cfm). The tool takes the highest measured or predicted RF-EMF levels of any device measured within typical smart home device categories, also allowing for the inclusion of nearby or neighbouring Wi-Fi networks, as well as background RF-EMF levels from nearby mobile networks. The tool produces a theoretical maximum estimate for the user relative to the devices, distances and environmental conditions based on the assumption that all the devices selected are transmitting in free-space (with no obstacles between the transmitter and receiver) and simultaneously (which in reality is rarely, if ever, the case). Such tools allow anyone interested in doing so to obtain an indicative RF-EMF exposure estimate for their home or apartment.

3.2.2 EMF exposure from industrial IoT devices and beam wireless power transfer (Beam WPT)

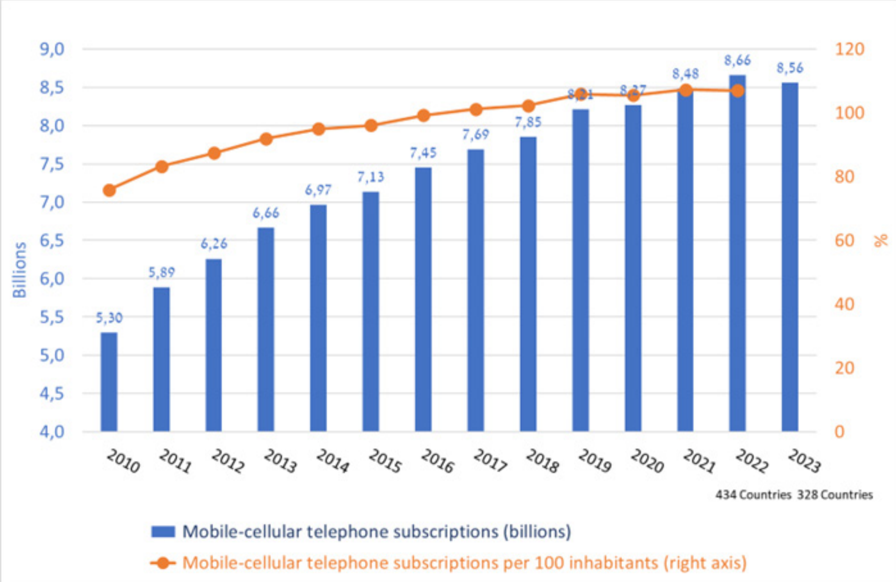
Wireless charging is becoming an increasingly familiar concept to consumers. However, while consumers need to bring their device or wearable into contact with a charging device to initiate energy transfer, Beam WPT[35] is an emerging application that transfers energy at a distance via a radio-frequency beam, enabling devices to charge without the need for any cabling. This is especially useful in industrial IoT settings, where it may be challenging to get cabling in place in the first instance, or connect devices with cabling once they are deployed.

3.2.3 EMF exposure from mobile phone to satellite communications

As can be seen in Figure 2, the number of cellular base stations around the world continues to grow**.** Based on ICT indicators, the ITU DataHub tracks mobile-cellular subscriptions and world-average cellular penetration per 100 inhabitants. The latest data, retrieved on 4 May 2025, indicate that in 2022 there were 8.66 billion subscribers and circa 110 cellular telephone subscriptions per 100 inhabitants. As an indication, roughly one cellular mast is required for every 1 000 subscribers, and it is estimated that there are more than 8 million macro base stations around the world.

[34] ITU-D SG2 document 2/315 from the Mobile & Wireless Forum IVZW.
[35] ITU-D SG2 Document 2/192 from the Telecommunications Management Group, Inc.

Figure 2: Global mobile-cellular telephone subscription rate



Until recently, communication via satellite required specialized devices designed for relatively specific use; both the terrestrial terminal and the service were expensive. The rapid growth in low-Earth and middle-Earth orbit, as well as geostationary-satellite orbit (LEO, MEO and GEO), satellite networks has brought the first "hybrid" satellite/terrestrial cellular services onto the market, meaning that a smartphone unable to connect to a terrestrial network can connect to a satellite for limited, mostly emergency-related communications purposes.[36] Another important application is IoT connectivity in rural and remote areas (Inaltekin *et al.*, 2024). Depending on regulatory rules and commercial arrangements, communication may occur over dedicated mobile satellite service (MSS) spectrum or terrestrial mobile network spectrum.

Several device manufacturers have begun incorporating satellite communications services into their latest mobile phone models, enabling satellite connectivity when the device is out of range of other networks. While services are currently restricted to primarily emergency use, recent updates have already extended their range to include limited-character-size text-based messaging, thus significantly expanding people's options for keeping in touch with family, friends and work – even in the most remote parts of the globe.

The current service arrangements require the user to stand outside and hold the phone upwards to enable the device to locate a satellite to which it can connect. On-screen instructions guide the user through the process and inform them when a connection has been achieved.

RF-EMF exposure considerations for non-terrestrial networks (NTNs) have been outlined by Fellan *et al.*, 2023. Path loss from the satellite to the ground and requirements to minimize interference means that downlink RF-EMF levels will be very low relative to human exposure limits.

Traditional satellite phones generally employ an antenna that extends beyond the user's head during use. This is due to several factors, including the need for an unobstructed antenna to connect to a satellite, which can be located anywhere in the sky, and to comply with SAR requirements for RF exposure. As satellite connectivity is integrated into mobile handsets,

36 ITU-D SG2 Document 2/317 from the Mobile & Wireless Forum IVZW & GSM Association.

compliance with relevant national RF exposure limits will still need to be demonstrated through SAR testing. The 3rd Generation Partnership Project (3GPP) specifies, in document TS 38.101-5 on user equipment radio transmission and reception, that the maximum device transmit power for NTN use is 23 dBm, the same as for terrestrial smartphones. Depending on the device use cases and available services, if it cannot provide voice communications when used against the head, or other services that can be operated when in contact with the body, the applicable SAR limits apply to the limbs rather than the head or body, specifically ICNIRP's 4 W/kg over 10 g of contiguous tissue, unless national requirements stipulate a different limit. If the device can support voice communications or other services that can be used when in contact with the body, then compliance with head and/or body SAR limits is also necessary.

As a related example, in 2022 the French regulatory authority (*Agence Nationale des Fréquences* – ANFR) measured uplink RF-EMF levels from a 14.5 GHz Starlink communication antenna. The highest level measured was 9 V/m (1 m on the axis of the beam), with a level of 0.7 V/m at 2 m, and less than 1 V/m outside the parabola. All these readings were below the limits set out in the ICNIRP (2020) Guidelines of 61 V/m for the relevant frequencies. It is important to note that this type of equipment transmits at 4 W – significantly higher than mobile phones – yet the measured values remain low.

Satellite functionality in mobile devices has vast potential for enabling users to stay connected anywhere across the globe. Although at present it is primarily limited to emergency communications, this capability is expected to grow and become more widely accessible in devices. However, although this represents an enhancement in device functionality, RF-EMF compliance remains unchanged, meaning that any devices incorporating such functionality must still be tested to ensure they meet the relevant exposure limits.

3.2.4 RF-EMF exposure in the vicinity of schools

There has been long-standing interest in the issue of RF exposure in schools,[37] and a number of studies have been published documenting exposure levels within and around schools. For example, Karipidis *et al.*, 2017 published a study measuring Wi-Fi levels both inside and outside classrooms at 23 Australian schools, situated in both metropolitan and rural areas. The study included all RF-EMF sources, with the authors noting that "all the RF levels measured in the 23 schools were significantly lower than the exposure reference levels set by the ICNIRP Guidelines." Specifically for Wi-Fi, they found that the average (typical) and maximum (peak) RF levels from Wi-Fi in areas occupied by students in the classroom were approximately 0.0001 W/m^2 and 0.01 per cent of the ICNIRP power density reference level, respectively.

Meanwhile, Panagiotakopoulos *et al.*, 2023, undertook RF-EMF exposure assessments in a sample of 661 schools in urban, semi-urban, and rural areas of Greece. Measurements of the total electric field strength from all sources, including Wi-Fi, mobile base stations and radio and television broadcasts, indicated that the mean electric field strength value for Greek schools from all emitting sources in the 27 MHz to 3 GHz range was 0.42 V/m.

Two studies have been published on exposure within university settings, where both Wi-Fi and mobile device usage is considerably higher than in standard school settings. At the University of Pristina in Kosovo, Berisha *et al.*, 2023 used both broadband and frequency-selective measurements inside classrooms, student dormitories, and the cafeteria, as well as outside

[37] ITU-D SG2 Document 2/316 from the Mobile & Wireless Forum IVZW.

measurements. They found mean values of 0.41 V/m in faculty facilities, 0.88 V/m in dormitory areas, and 0.97 V/m in the cafeteria, while the mean value outside was 1.67 V/m from all sources. As noted by the study authors, all the measurements were well below ICNIRP Guidelines. At the University of Castilla-La Mancha in Spain, Ramirez-Vazquez *et al.*, 2023 compared Wi-Fi exposures in and around the Faculty of Computer Science Engineering undertaken in 2017, 2018 and 2019 with different locations, also measured in 2022. They found that, from 2017 to 2019, the measured values decreased. Measurements were undertaken in classrooms, both with and without students present, during the measurement periods.

3.2.5 RF-EMF exposure in the vicinity of hospitals

Location of base stations near hospitals[38] has given rise to questions about RF-EMF levels and the possibility of interference affecting medical equipment. In two separate studies conducted in Spain, one at the Hospital Universitario de Canarias by Hernández *et al.*, 2024, and the second at the Instituto de Salud Carlos III – a public health research centre in Madrid – by Ramos *et al.*, 2023, researchers measured RF signals at 11 and 10 locations around the facilities, respectively, over several months.

At the Hospital Universitario de Canarias, the researchers stated:

> *"Consistent with earlier research findings, similar conclusions emerge. Generally, radiofrequency electromagnetic field (RF-EMF) exposure levels across a wide frequency spectrum remain very low in typical daily life situations. These exposure levels consistently fall well below 1 V/m…"*

And at Instituto de Salud Carlos III, the researchers concluded:

> *"It can be seen that the evolution and densification of (base stations) can increase exposure levels, but in any case do not exceed the 1% of ICNIRP reference levels, which remains significantly low when compared with the threshold values provided by the standards and guidelines."*

The authors noted that the results reflected the total exposure levels from all sources at a single point in time (i.e. worst-case scenario).

A further study was undertaken in Spain by Calvente *et al.*, 2017 at the Hospital Universitario de Granada. The authors noted that, in addition to wireless communication devices, many medical applications also use RF-EMF, including incubator motors, radiant warmers and syringe pump systems. There are also incidental sources of extremely low EMF levels, which include equipment such as mechanic ventilators, systems for monitoring vital parameters, oxygen therapy devices, and medical aspirators for bodily secretions, among others. The study carried out spot measurements around the care unit and inside the incubators.

Measurements taken inside an incubator, near a window and with a number of medical devices attached to it, for example, resulted in a mean value of 0.81 V/m, with the maximum being 1.58 V/m – and FM radio contributed 0.79 V/m to this mean value.

[38] *Ibid.*

3.2.6 Assessing exposure to radio-frequency electromagnetic fields from 5G (IMT) networks

Radio waves, including millimetre waves used by 5G, are a form of non-ionizing radiation, which does not cause tissue damage.[39] Measurements taken around base stations in a commercial 5G network showed that the contribution from 5G to total environmental RF-EMF exposure was less than 10 per cent, even with 100 per cent induced traffic. The maximum exposure levels were 150-200 times below international limits set by the ICNIRP, ensuring compliance and safety.

3.3 Impact of policies restricting the deployment of telecommunication infrastructure

All of the above-mentioned studies found that RF-EMF exposures – not only from Wi-Fi and mobile communications but from all RF sources – are significantly below the ICNIRP reference levels for the general public, and typically well under 1 per cent of those limits. These results confirm the efficiency of mobile communications networks when deployed to meet coverage and capacity needs, and suggest that exclusionary policies are (a) not required to achieve lower RF-EMF levels and (b) are inefficient, in view of the broad restrictions and limitations they impose on community development.

The low RF-EMF levels reported for schools and hospitals call into question policies on RF-EMF exposure that impose restrictions on telecommunication infrastructure within certain distances (sometimes referred to as "exclusionary zones")[40] from hospitals or schools.

Several important considerations arise in relation to such policies. The first is that if a cellular base station is located on the roof or the external facade of a building, the signal is directed outwards, generally by installing the antenna at a slight downward tilt (typically 2°-10°) below the horizontal axis. This means that while some signal is provided within the facility on which the base station is mounted, the main part of the signal is projected away from the facility. To ensure a good signal within and around the facility for patients, families and staff, a base station is still needed nearby to provide the necessary coverage. Furthermore, it should be noted that proposals to locate a base station on a hospital or other community infrastructure are based on an assessment determining that site to be the best location in the area to provide the necessary service, for example owing to the height or location of the buildings. Avoiding the use of a certain location because of an exclusionary zone may therefore be suboptimal from a radio/network planning perspective and, consequently, for cellular users.

Another aspect to consider is that exclusionary zones limit local community development. Under policies that apply such restrictions on infrastructure, new schools or health facilities cannot be built in locations where a base station has been installed, even if the community needs them. Similarly, particularly in built-up areas, such policies may create communication "gaps" in the network because there are simply no places to build base stations outside the exclusion zones while still providing coverage to the areas in need.

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[39] ITU-D SG2 Document 2/166 from Telefon AB – LM Ericsson.

[40] In this context, "exclusionary zones" may, wrongly, be confused with the "exclusion zone" around a base station – which is often used as an alternative to "compliance boundary", i.e. the zone around a base station outside of which the RF-EMF levels are below the limits. Therefore, caution should be exercised to avoid misunderstanding.

Another aspect to consider is that small indoor cellular base stations and boosters/signal repeaters are often used to provide indoor coverage within buildings when new facilities are being built. These small, low-powered devices minimize transmissions to avoid interference with one another and macrocells while providing good coverage and data connectivity. The existence of exclusionary zones may also prevent the installation and deployment of these efficient and effective devices. For further information, please see the contribution from Egypt[41] outlining the framework for authorizing the installation of small cells inside hospitals.

3.4 RF-EMF exposure from mobile phones

As with base stations, concerns have been raised about the potential health risks of exposure to RF-EMF from mobile phones. Compliance testing of mobile devices is undertaken in laboratories with devices configured to maximum power. In daily use, 3G/4G/5G mobile devices typically operate at less than 1 per cent of their maximum output power levels (Joshi *et al.*, 2020).

The WHO website states that "to date, and after much research performed, no adverse health effect has been causally linked with exposure to wireless technologies" and continues to recommend further research. Researchers at the International Agency for Research on Cancer, a specialized cancer agency of the WHO, along with others (Deltour *et al.*, 2022), analysed glioma (a type of brain tumour) rates in the Nordic countries (Denmark, Finland, Norway, and Sweden) and considered cancer latencies of 10, 15 and 20 years. They concluded[42] that the "increased risks reported in some case-control studies are implausible and likely attributable to biases and errors in self-reported use of mobile phones."

Recent studies of brain tumour trend data have revealed no evidence of any link to mobile phone use, including after decades of use: up to 15 years in Australia (Karipidis *et al.*, 2018); up to 25 years in New Zealand (Elwood *et al.*, 2022); and up to 30 years in Spain (REDECAN, 2022). WHO[43] continues to promote research to address scientific uncertainties, and is conducting a health risk assessment with the 19-member WHO Task Group on Radiofrequency Fields and Health Risks, formed following an open call for experts in 2021 (Verbeek *et al.*, 2021). Systematic reviews supported by WHO and published in *Environment International* show no confirmed evidence of health hazards at levels below the international RF-EMF limits.

People may choose to reduce their personal exposure to radio waves, given that personal device use contributes far more to EMF exposure than far-field sources, such as broadcast transmitters of base stations. Factors that can reduce RF-EMF exposure from mobile phones include increasing the distance between the device and the body, using handsfree devices and using the device in areas with good reception.[44] These and other factors are described in Supplement 13 to the ITU-T K series (12/2021) Recommendations on RF-EMF exposure levels from mobile and portable devices during different conditions of use. WHO does not recommend measures to reduce mobile phone exposure.

41 ITU-D SG2 Document SG2RGQ/133 from Egypt.
42 Deltour *et al.*, 2022, available at https://doi.org/10.1016/j.envint.2022.107487.
43 ITU-D SG2 workshop presentation Q7/2-2023-2 by WHO.
44 ITU-D SG2 Document SG2RGQ/30 from Haiti.

Chapter 4 – Developing RF-EMF policies for radio transmitters

Administrations have many decisions to make when developing or updating their domestic policies on electromagnetic field (EMF) exposure limits.[45] Most national policies are based on the RF-EMF exposure guidelines produced by ICNIRP. Some countries maintain exposure limits that predate the above-mentioned guidelines or apply limits that include additional reduction factors or other restrictions, such as on antenna locations. In addition to exposure limits, administrations must also consider how to ensure compliance. While in many cases this is done through operator self-declaration, examples of alternative methods, such as third-party assessments, also exist. ITU-D[46] carried out a regional assessment for Europe on EMF exposure limits and risk communication challenges, and the ITU Office for Europe produced an outcome report from an ITU Regional Forum for Europe in 2020 on 5G strategies, policies and implementation. National policies also need to include effective communication with the general public. The current chapter outlines the applicable international guidance and national experience across all of these domains.

4.1 Developing a national legal framework on EMF

The deployment of new generations of wireless technologies has raised public concerns in some countries regarding human exposure to environmental RF-EMF. The first step in establishing EMF protection measures is adopting EMF limits and the ICNIRP Guidelines are widely used. The Output Report on ITU-D Q7/2 for the study period 2018-2021 states that "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 the ICNIRP (2020) Guidelines." In an article on the implications of the ICNIRP (2020) Guidelines on the RF-EMF compliance boundary of base stations, Colombi *et al.*, 2022 demonstrated that 2G/3G/4G/5G base stations, from small cells to macro sites, which comply with the ICNIRP (1998) Guidelines limits will also comply with those set out in the ICNIRP (2020) Guidelines.

The International Radiation Protection Association established ICNIRP[47] in 1993 to develop and disseminate science-based advice on limiting exposure to non-ionizing radiation. As a not-for-profit, non-governmental organization, ICNIRP is in official relations with WHO and the International Labour Organization and operates independently, free from industry influence. To ensure transparency, members' declarations of interest are publicly available on its website. According to ICNIRP, at low levels, RF exposure has no effect on human health. However, at high levels, it can be harmful, as demonstrated by the example of RF burns, which can penetrate deep into the body. ICNIRP advice is primarily disseminated through guidelines that set out rules to avoid unsafe RF exposure without unduly limiting the beneficial uses of RF. These guidelines seek to balance the benefits and risks of RF. An updated version of the guidelines was published in 2020 and covers the frequency range of 100 kHz to 300 GHz. The guidelines

[45] For additional information, see Haim Mazar, *Radio Spectrum Management: Policies, Regulations, Standards and Techniques*. Chichester, West Sussex: John Wiley & Sons, Ltd., 2016. See Chapter 9.7 (revised in April 2021) on RF hazards limits and their impact on mobile network planning.

[46] ITU-D SG2 Document 2/48 from BDT.

[47] ITU-D SG2 workshop presentation Q7/2-2023-2 by ICNIRP.

aim to provide protection against adverse health effects under realistic exposure conditions. They set out "basic restrictions" related to RF exposure within the body and "reference levels" for RF in the environment, which are conservatively derived to ensure safety. The guidelines aim to protect people from all adverse health effects, regardless of the mechanism, and account for all realistic types of exposure, including long and short-term exposure, different signal types (e.g. pulsed, CW, 2G, 3G, 4G, 5G). Some exposure situations, such as medical applications of RF, fall outside the scope of the guidelines. The guidelines are designed to keep everyone, including children and adults, safe, providing a safety margin above the lowest level of exposure known to cause harm.

In 2019, the Institute of Electrical and Electronics Engineers (IEEE) produced a set of updated RF-EMF limits. It is worth noting that some countries have established different national limits, for example, standard GB21288-2022 in China. Table 1[48] lists the basic restrictions established by the ICNIRP (2020) Guidelines, and standards IEEE C95.1-2019 and GB21288-2022, respectively. As can be seen from the table, while the restrictions are not identical, the restrictions set out in the documents are broadly aligned.

Table 1: Basic restrictions for EMF exposure from 100 kHz to 300 GHz set out in different guidance documents

Guidance document	Exposure scenario	Frequency range	Whole-body SAR (W/kg)	Local SAR[1] (W/kg)	Local SAR[2] (W/kg)	Power density (W/m^2)
ICNIRP 2020	**Occupational**	100 kHz – 6 GHz	0.4	10	20	–
ICNIRP 2020	**Occupational**	> 6 GHz – 300 GHz	0.4	–	–	100
ICNIRP 2020	**General public**	100 kHz – 6 GHz	0.08	2	4	–
ICNIRP 2020	**General public**	> 6 GHz – 300 GHz	0.08	–	–	20
C95.1-2019	**Persons permitted in restricted environments**	100 kHz – 6 GHz	0.4	10	20	–
C95.1-2019	**Persons permitted in restricted environments**	> 6 GHz – 300 GHz	–	–	–	100
C95.1-2019	**Persons in unrestricted environments**	100 kHz – 6 GHz	0.08	2	4	–
C95.1-2019	**Persons in unrestricted environments**	> 6 GHz – 300 GHz	–	–	–	20

48 ITU-D SG2 Document SG2RGQ/68 from China.

Table 1: Basic restrictions for EMF exposure from 100 kHz to 300 GHz set out in different guidance documents (continued)

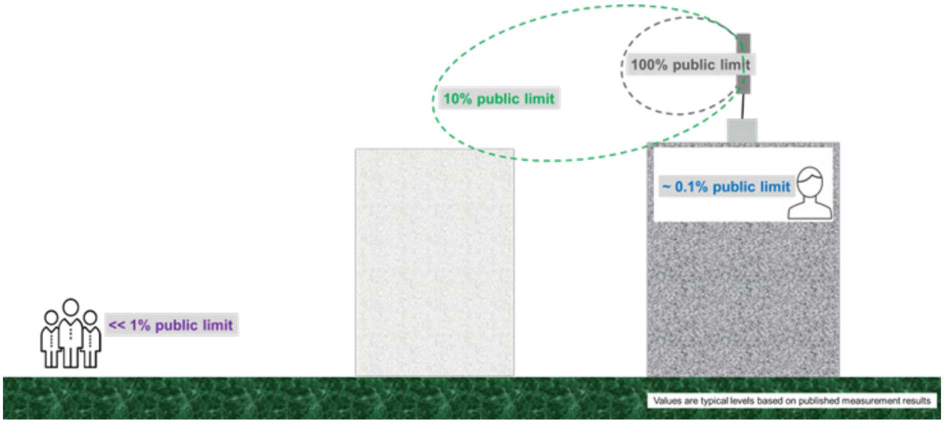
Guidance document	Exposure scenario	Frequency range	Whole-body SAR (W/kg)	Local SAR¹ (W/kg)	Local SAR² (W/kg)	Power density (W/m²)
GB21288-2022	**Occupational**	100 kHz – 6 GHz	–	10	20	–
		> 6 GHz – 300 GHZ	–	–	–	100
	General public	100 kHz – 6 GHz	–	2	4	–
		> 6 GHz – 300 GHz	–	–	–	20

- "–" signifies "not applicable" and does not need to be taken into account when determining compliance.
- Whole-body SAR is to be averaged over 30 min.
- Local SAR¹: refers to local head and torso SAR in the ICNIRP (2020) Guidelines, C95.1-2019 and GB21288.
- Local SAR²: refers to local limbs SAR in both the ICNIRP (2020) Guidelines and GB21288; refers to local limbs and pinnae SAR in C95.1-2019.
- Local SAR and power density exposures are to be averaged over 6 min.
- Local SAR is to be averaged over a 10-g cubic mass.
- In the ICNIRP (2020) Guidelines and GB21288-2022, power density (absorbed) is to be averaged over a square 4-cm^2 surface area of the body. Above 30 GHz, an additional constraint is imposed, namely that exposure averaged over a square 1-cm^2 surface area of the body is restricted to two times that of the 4-cm^2 restriction.
- In C95.1-2019, power density (epithelial) is to be averaged over any 4 cm^2 of body surface at frequencies between 6 GHz and 300 GHz. 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 values of the 4-cm^2 restriction by a factor of 2, with an averaging area of 1 cm^2.

In Brazil,[49] Law No. 11,934/2009 establishes that the EMF limits in Brazil will follow WHO recommendations, and in the absence of WHO exposure limits, ICNIRP limits apply. In contrast, some countries and regions have their own regulations and limits on RF-EMF exposure, which differ to the limits proposed by the ICNIRP. Arbitrary restrictions have operational impacts related to access to rooftops or nearby buildings as shown in the following figure for an arbitrary 10-fold reduction in the limit.

[49] ITU-D SG2 workshop presentation Q7/2-2024-02 by Brazil.

Figure 3: Compliance zones increase with restrictive limits (power density limits represented)

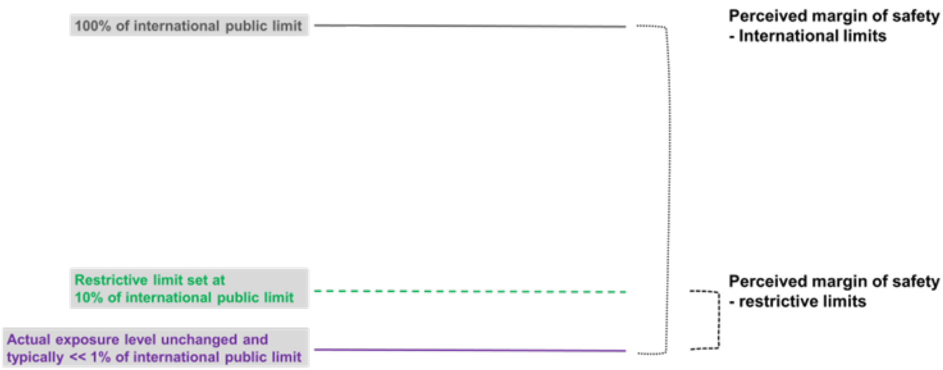


According to the ICNIRP (2020) Guidelines, applying limits that are arbitrarily set below the international EMF guidelines has no proven health benefits. Furthermore, there is no impact on the typical RF-EMF levels in the community, as Figure 5 in the GSMA (2020) document on adopting international RF-EMF guidelines shows. In Supplement 14 to the ITU-T K-series of Recommendations on the impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment attention is drawn to the fact that restrictive RF-EMF limits impact the ability to deploy 4G/5G networks.

There is evidence that the public generally perceives RF-EMF exposure relative to the limit as a safety margin rather than a threshold; public concern increases when the perceived margin of safety is reduced (Wiedemann *et al.*, 2008).[50] In the case of applying arbitrary reductions to exposure limits, the perceived margin of safety is reduced, as shown in the diagram below.

Figure 4 shows that there is a larger perceived margin of safety when using the international power density limit for public exposure (the 100 per cent line) than would be the case if a ten-times more restrictive power density limit was in place (the 10 per cent line), because the typical level of exposure from mobile networks is the same, regardless of the regulatory limits set (see Figure 5 in the GSMA report on adopting international RF-EMF exposure guidelines GSMA (2020)).

Figure 4: Perceived risk increased when limits are reduced (power density limits represented)



[50] ITU-D SG2 Document SG2RGQ/81 from GSMA.

The legal basis for RF-EMF limits may differ between countries and use approaches based on telecommunication, environmental or occupational safety legislation. An important benefit of adopting national RF-EMF limits is the application of consistent rules throughout a given country.

Recognizing the wide range of national EMF exposure limits set by different countries, WHO[51] is conducting a survey to collect data on current national standards and key policy actions. The survey aims to gather information on exposure to RF fields in three specific contexts: personal, environmental, and occupational. Survey responses will be used to update the findings of a WHO survey carried out in 2012 (Dhungel *et al.*, 2015). The ultimate goal of the survey is to inform and potentially harmonize risk management policies relating to RF-EMF exposure on an international level, to ensure that they are based on the latest scientific evidence and effectively protect public health.

4.2 Risk communication, risk management and EMF misinformation

There is a long history of EMF information and disinformation, stretching back as far as the introduction of electric lighting (to replace gas); each new generation of mobile technology has given rise to public safety concerns in some countries. Today, in the era of social media, it is far easier to produce and spread misinformation than to refute it.

Concerns about potential health risks in the future have led some countries to introduce restrictions on antenna siting or recommend limits on the use of wireless sources for certain population groups. It is often claimed that these actions are justified precautionary measures. However, a systematic review found that information on precautionary measures actually increased public concern (Boehmert *et al.*, 2020):

> "Taken together, the overall picture suggests an increase in risk perception due to precautionary recommendations. This effect is presumably not intended and perceived as a cost by many communicators. We thus encourage risk communicators to take both potential benefits and costs into account when deciding whether or not to recommend precaution."

Even though there is no substantiated evidence of any adverse health effects, this perception of heightened risk might lead certain groups – such as pregnant women – to unnecessarily take precautions to restrict their RF-EMF exposure at work and in their day-to-day lives. GSMA[52] also cautions against using precautionary language when communicating with the public, in view of the lack of any credible scientific evidence to support the need for precautionary measures, as that approach could increase public concerns and potential non-EMF risks.

4.2.1 Risk communication

Risk communication[53] is defined as the real-time exchange of information, advice and opinions between experts/officials and people facing hazards threatening their survival, health or economic or social well-being. The main purpose of risk communication is to keep people informed and establish mutual trust. Risk communication is a two-way process, not a one-way means of disseminating information. It may occur in an environment of high attention and low

[51] ITU-D SG2 Document 2/340 from WHO and ITU-D SG2 workshop presentation Q7/2-2023-2 by WHO.
[52] ITU-D SG2 Document SG2RGQ/81 from GSMA.
[53] ITU-D SG2 Document 2/47 from China.

trust. The issue of risk communication was raised during the previous study period for ITU-D Question 7/2, namely 2018-2021.

As the ICNIRP Guidelines were developed on the basis of a thorough review of all published scientific literature on various aspects of EMF exposure, they constitute a reliable source of information, advice and opinions that experts or officials can share with the public. Making science-based information available to the public can reduce levels of (unnecessary) concern about RF-EMF exposure. An example of this approach is the Chinese Administration's work, in consultation with ICNIRP, to translate the ICNIRP Guidelines (2020) into Chinese, in order to increase public awareness of existing exposure limits and to address people's queries and concerns.[54]

The approach adopted by Australia[55] involves supporting research, undertaking RF-EMF assessments, providing public information and engaging with international health authorities within the framework of the Enhanced Electromagnetic Energy Program. The "Talk to a Scientist" programme, which enables the public to directly contact a radiation expert from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), receives approximately 800 enquiries each year. The programme helps to keep abreast of concerns raised by the public and complements other communication activities, such as campaigns utilizing social and traditional media and public engagement activities, including seminars and educational sessions in schools. ARPANSA scientists contribute to various standards committees, working groups and research consortia at the national and international levels. This engagement ensures that Australian science and public health advice remain accurate, up-to-date and consistent with global good practices. ARPANSA is also a WHO collaborating centre for radiation protection.

Other examples of risk communication include, in 2018 and 2021, joint campaigns by the *Autorité de Régulation des Communications Electroniques et de la Poste* (ARCEP Benin)[56] and the *Associations des Consommateurs Partenaires* to deliver RF-EMF education sessions throughout the country. In 2023, ARCEP Benin also organized an international conference, working together with the National Academy of Sciences, Arts, and Letters.

The Republic of the Congo highlighted that while network infrastructure growth improves connectivity and benefits the economy, national governments struggle to adopt standards, exercise regulatory control over infrastructure deployment and ensure that they are able to respond to public questions about EMF exposure when infrastructure is deployed rapidly. Therefore, they highlighted the importance of strengthening regulatory frameworks, raising public awareness and promoting international collaboration, activities in all of which the ITU plays a central role.

Ghana[57] engages in risk communication by organizing awareness-raising programmes and using measurement results to educate the public. Planned future steps include developing a tracking system to monitor public perception of and attitudes towards the siting of telecommunication masts. Senegal[58] also runs awareness-raising workshops, including a 2023 event, organized with the Ministry of Health.

[54] *Ibid*.
[55] ITU-D SG2 workshop presentation Q7/2-2024-01 by Australia.
[56] ITU-D SG2 Document 2/198 from Benin.
[57] ITU-D SG2 Document 2/78 from Ghana.
[58] ITU-D SG2 Document 2/274 from the Republic of the Congo.

ITU[59] has contributed to ongoing efforts to revise the WHO[60] document on establishing a dialogue on risks from electromagnetic fields (first published in 2002).

As previously discussed, during the study period the ITU membership undertook measurement campaigns to demonstrate and ensure compliance with EMF exposure limits. The GSMA[61] website contains information on 5G RF-EMF surveys conducted by the academic community, governments and mobile network operators; the survey results show that the maximum 5G EMF levels recorded are typically less than 1 per cent of international public limits.

The measurement programme undertaken by the Uganda Communications Commission[62] included interviews with members of the public, which revealed that approximately 40 per cent of those surveyed were concerned about possible health risks, and that a person's level of education had no bearing on concerns. The results of the survey were used to inform the drafting of a brochure (in English and local languages) to improve consumer awareness.

In many countries, network operators also play an important role in addressing these concerns. As an example, China Mobile Communications Co. Ltd.[63] provided information on their public communication initiatives, including community outreach and measurement campaigns.[64] The company has also introduced a science publicity bus, equipped with professional equipment for monitoring and educating the public on EMF. It emphasizes that RF-EMF levels below accepted limits pose no health risk and advocates for improved communication to prevent panic and protect public health without hindering industry development.

Although measurement campaigns can play an important role in addressing public concerns, good risk communication requires a comprehensive approach, in order to understand people's concerns and to address them.

4.2.2 Risk management

In a document submitted on Question 7/2, China Mobile Communications Co. Ltd.[65] provided an overview of IEC EMF standardization activities and joint activities with IEEE. ITU and IEC have developed technical standards (Recommendation ITU-T K.100 (06/2021), international standard IEC 62232:2025) and technical report IEC TR 62669:2019) with aligned content for assessing RF-EMF levels from mobile network antennas. The IEC 62232:2025 standard covers various assessment methods, including field strength and SAR measurements, calculation methods, and report requirements. The IEC TR 62669:2019 technical report features case studies relating to safety assessments in different base station scenarios.[66] Many countries now base their national technical requirements on these standards. In its 2021 publication on EMF exposure compliance policies for mobile networks and workshop presentation on the need to address mobile and wireless network EMF exposure,[67] GSMA recommends 12 good practice policies for RF-EMF

59 ITU-D SG2 Document 2/48 from BDT.
60 ITU-D SG2 workshop presentation Q7/2-2023-02 by WHO.
61 ITU-D SG2 workshop presentation Q7/2-2023-05 by GSMA.
62 ITU-D SG2 Document SG2RGQ/77 from Uganda.
63 ITU-D SG2 Document 2/297 from China Mobile Communications Co. Ltd.
64 ITU-D SG2 Document 2/298 from China Mobile Communications Co. Ltd.
65 ITU-D SG2 Document SG2RGQ/199 from China Mobile Communications Co. Ltd. and workshop presentation Q7/2-2024-07 by China Mobile Communications Co. Ltd.
66 ITU-D SG2 Document 2/173 from China.
67 ITU-D SG2 workshop presentation Q7/2-2023-05 by GSMA.

compliance, which include adopting international (ICNIRP) RF-EMF limits and ITU/IEC technical standards, with efficient approaches to compliance monitoring.

In a workshop presentation, the IEEE International Committee on Electromagnetic Safety (ICES)[68] described the ongoing development of base station and mobile phone compliance standards. Joint IEC/IEEE working groups (JWGs) and maintenance teams (JMTs) have been established. JWG 11 focuses on computational methods to assess power density in close proximity to the head and body, JWG 12 and JWG 13 work on measurement methods and procedures to assess power density and determine the SAR, respectively, and JWG 63184 deals with human exposure to electric and magnetic fields from wireless power transfer systems.

The presentation also highlighted that the Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) was mandated by the European Commission to assess the need for a technical revision of the annexes to Council Recommendation 1999/519/EC on the limitation of exposure of the general public to electromagnetic fields, in the light of the latest scientific evidence. The SCHEER's definitive opinion, published in June 2023, confirmed that there is no moderate or strong evidence for adverse health effects from existing technology at levels below the limits set out in European Council Recommendation 1999/519/EC. However, the committee recognized that the new dosimetric quantities and limits introduced by ICNIRP in 2020 would provide more effective protection against risks posed by emerging technological applications. As a result, SCHEER advised revising the annexes to the Council Recommendation to include these new criteria. The revisions are expected to be adopted in 2025.

Examples of how ITU and IEC standards have been applied include Brazil's use of Recommendation ITU-T K.100 (07/2019) to perform a theoretical evaluation of base stations; the introduction in Colombia[69] of simplified assessment procedures, based on Recommendation ITU-T K.100 (06/2021) and Annex C to Recommendation ITU-T K.70 (12/2021) – including for active 5G antennas where a power reduction factor[70] is applied to account for the difference between the theoretical power and the actual maximum RF-EMF power; and the development by the Chinese authorities of environmental standard HJ 1151-2020 on the monitoring method for electromagnetic radiation environment of 5G mobile communication base stations, which includes a six-minute averaging time for 5G base station. The Chinese standard also includes a simplified approach to the calculation of safe distances for 4G and 5G base stations, using smart antennas with changing beam directions.

4.2.3 EMF misinformation

As in many other countries, in Ghana[71] rumours and claims circulated linking the COVID-19 virus to 5G, with the potential to derail the gains made over the years in communications technology adoption. Authorities engage in risk communication by organizing awareness-raising programmes and using measurement results to educate the public. Future steps include developing a tracking system to monitor public perception and behaviour towards the siting of communication masts. In early 2020, about 2 per cent of COVID-19 misinformation articles in

[68] ITU-D SG2 workshop presentation Q7/2-2024-06 by IEEE International Committee on Electromagnetic Safety.
[69] ITU-D SG2 workshop presentation Q7/2-2024-03 by Colombia.
[70] The power reduction factor is a statistical multiplier applied to account for the fact that for beam-forming antennas the actual time-averaged power transmitted by antenna segment(s) is less than the theoretical maximum.
[71] ITU-D SG2 Document 2/78 from Ghana.

the United States[22] related to 5G. A survey carried out in sub-Sahara Africa in April/May 2020 by Ovenseri-Ogbomo *et al.*, 2020 found that approximately 7 per cent of respondents believed that 5G was responsible for the pandemic. The authorities in Romania[72] identified similar public misunderstandings about 5G and made available verified information via the website infocentru.ancom.ro. The Romanian telecommunication regulator ANCOM conducted an internal pilot study on 5G base station levels and found that exposures remained below national norms.[73] As GSMA[74] noted in its contribution, despite a WHO statement indicating that there was no link between EMF and the COVID-19 pandemic, these false beliefs continued to circulate. In January 2022, a PERITIA survey across six European countries found that 14 per cent of respondents thought that COVID-19 symptoms were linked to 5G.

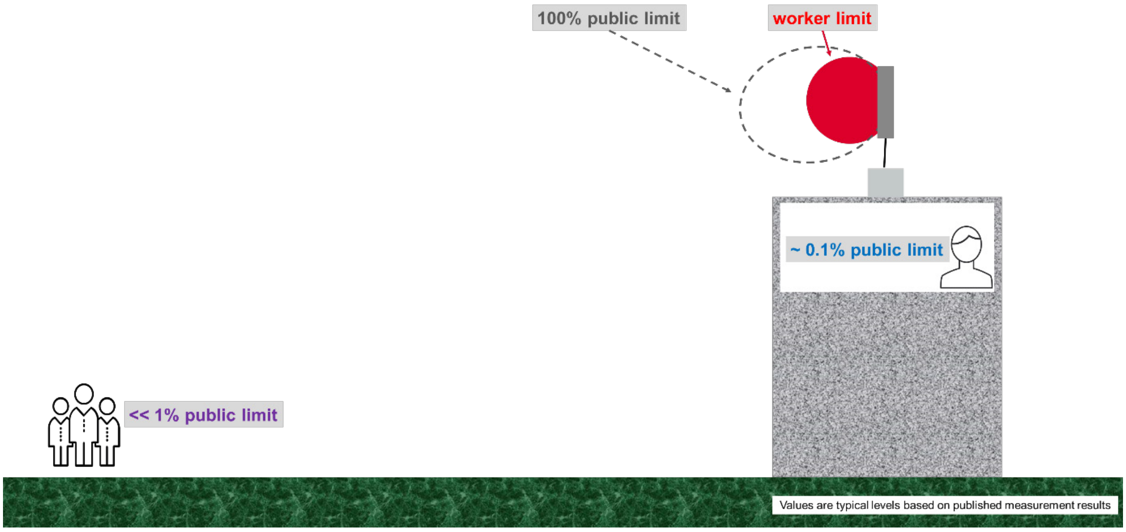
4.3 Methodologies for assessing RF-EMF exposure

As noted elsewhere in the present report, ITU and IEC have developed technical standards for assessing RF-EMF exposure from mobile network antennas and other EMF sources. In their contribution on assessing exposure to radio-frequency electromagnetic fields from 5G networks, Telefon AB – LM Ericsson[75] noted that accurate assessment of active 5G antennas requires the use of power reduction factors as described by IEC and ITU. In a 5G network using massive MIMO (multiple input, multiple output) base stations, the antenna patterns change rapidly, and beams are formed to optimize transmission to the served devices. Power reduction factors account for this variability over the exposure limit averaging time as specified by ICNIRP (6 or 30 min.) and provide a more accurate assessment than using classical calculation methods. Network equipment manufacturers have developed software to implement these methods. Measurements around base stations equipped with massive MIMO technology and operating in the 3.5 GHz band in a commercial 5G network showed that the 5G network's contribution to overall RF-EMF environmental exposure was below 10 per cent, even with fully induced traffic. Furthermore, the highest exposure levels from the 5G base stations were significantly lower, namely 150 to 200 times below the ICNIRP Guidelines. ITU ICT infrastructure activities include support for the roll-out of sustainable 5G technology. As GSMA pointed out, transmitter RF-EMF licensing can be based on operator self-declarations or third-party permitting procedures.

RF-EMF assessments of base station sites in the general environment show low levels of exposure relative to the international guidelines and confirm that these levels have not changed significantly over time. When RF-EMF levels are assessed closer to the antennas, compliance zones may exist where levels exceed public or worker limits; access to such areas is restricted (Elbasheir *et al.*, 2023). Exposure levels in rooms below the antennas are reduced by the directivity of the antenna and building attenuation (Reese *et al.*, 2022), as can be seen in Figure 5 below.

72 ITU-D SG2 Document 2/152 from Romania.
73 In Romania, EMF exposure is regulated by Order No. 1193/2006 of the Minister of Public Health, which aligns with Recommendation 1999/519/EC of the Council of the European Union, and is based on the ICNIRP Guidelines.
74 ITU-D SG2 workshop presentation Q7/2-2023-05 from GSMA.
75 ITU-D SG2 Document 2/166 from Telefon AB – LM Ericsson.

Figure 5: RF-EMF levels around base stations (with power density limits depicted)



Indoor base stations generally do not exceed RF-EMF limits at distances greater than 0.2-0.3 m because the transmit power is very low.

The results of RF-EMF monitoring of networks operating for more than a decade in Europe (Iakovidis *et al.*, 2022) and sample site measurements conducted over many years in African countries (Joyner *et al.*, 2014) show that environmental RF-EMF levels remain low relative to international exposure limits.

4.4 Conclusion

Administrations[76] must take political, social and economic concerns into account when developing public policies on EMF exposure. Risk management measures fall under three categories: adoption of RF-EMF limits (international or local); implementation of compliance rules (permit- or declaration-based, using calculations and/or measures); and communication initiatives (focusing on target audiences and stakeholder responsibilities).

In the absence of national limits – or when frequencies of interest are not covered by existing rules – regulators and industry should, as good practice, apply the exposure limits set out in the ICNIRP (2020) Guidelines. This recommendation is supported by WHO,[77] ITU-T[78] and ITU-D.[79] Contributions submitted during the study period show that many countries have already taken this step. To date, there is no substantiated evidence of any increased health risk for people living near fixed transmitters or using mobile devices that comply with the limits set by international bodies.

There is a misconception that precautionary measures offer health benefits; ICNIRP makes clear that there is no evidence of adverse health effects at exposure levels below the limit values set out in its guidelines. Neither is there any evidence that additional precautionary measures carry any health benefits. In fact, restrictive EMF limits have the potential to increase public concern

[76] ITU-D SG2 workshop presentation Q7/2-2024-05 by GSMA.
[77] WHO (2006). Framework for Developing Health-based EMF Standards.
[78] Recommendation ITU-T K.52 (08/2024), providing guidance on complying with limits for human exposure to electromagnetic fields.
[79] Output Report on ITU-D Question 7/2 for the study period 2018-2021.

and the need for more antennas, which can complicate co-location and have a negative impact on service quality.

The transition from conventional to increased use of active antennas in 4G and 5G mobile networks highlights the importance of updating RF-EMF assessment methods. International technical documents, such as Recommendations ITU-T K.52 (08/2024) and ITU-T K.100 (08/2024), and technical standards IEC 62232:2025 and IEC TR 62669:2019, provide guidance on up-to-date assessment methods.

While EMF misinformation continues to circulate and public concerns about RF-EMF exposure remain, targeted public awareness campaigns – an approach adopted by many countries – are needed. National authorities, industry and other trusted stakeholders need to ensure that accurate, science-based information is available to concerned members of the public, in a clear and accessible format. Once the WHO Task Group on Radiofrequency Fields and Health Risks has completed its work, the deliverables will constitute an important source of EMF information, to be disseminated by trusted national experts and stakeholders in the future.

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

Contributions on Question 7/2

Web	Received	Source	Title
2/398	2025-04-22	BDT Focal Point for Question 4/2 and 7/2	BDT report on the implementation of ICT Infrastructure work since the last ITU-D Study Group meeting
2/364 (Rev.2)	2025-05-09	Co-Rapporteurs for Question 7/2	Draft Output Report on Question 7/2
2/340	2024-11-12	World Health Organization	Consumer protection against exposure to electromagnetic waves
2/326	2024-10-29	GSM Association	Proposed draft content for Chapter 4 of the Question 7/2 Final Report 2022-2025
2/325	2024-10-29	GSM Association	Proposed draft content for Executive Summary of the Question 7/2 Final Report 2022-2025
2/317	2024-10-28	Mobile & Wireless Forum IVZW, GSM Association	Satellite communications from cellular devices – Contribution for Chapter 3.2 of the Final Report of Question 7/2
2/316	2024-10-28	Mobile & Wireless Forum IVZW	Latest developments – schools and hospitals – contribution for Chapter 3 of the Final Report of Question 7/2
2/315	2024-10-28	Mobile & Wireless Forum IVZW	IoT exposures in the smart home – studies and estimating tool – contribution for Chapter 3.2 of the Final Report of Question 7/2
2/314	2024-10-28	Mobile & Wireless Forum IVZW	Proposed draft content for Chapter 3 of the Question 7/2 Final Report 2022-2025
2/298	2024-10-22	China Mobile Communications Co. Ltd.	Risk management of base station electromagnetic radiation safety in China
2/297	2024-10-22	China Mobile Communications Co. Ltd.	Risk communication with public on base station electromagnetic radiation
2/283	2024-11-01	Co-Rapporteurs for Question 7/2	Draft Output Report on ITU-D Question 7/2
2/274	2024-09-26	Congo (Republic of the)	Consumer protection against exposure to electromagnetic waves
2/257	2024-09-20	Hungary	Development of a mass calculation system for RF electromagnetic fields at NMHH
2/253	2024-09-19	BDT Focal Points for Questions 1/1, 2/1, 5/1, 4/2 and 7/2	BDT report on the implementation of ICT Infrastructure work since the last ITU-D Study Group meeting

(continued)

Web	Received	Source	Title
2/237	2024-08-18	China	Proposed Chapter 1 for the Final Report of Question 7/2
2/235	2024-08-14	Co-Rapporteur for Question 7/2	Output Report on ITU-D Question 7/2, revised draft Chapter 2 – International activities on RF-EMF exposure since 2022
2/233	2024-08-06	Co-Rapporteurs for Question 7/2	Annual progress report for Question 7/2 for November 2024 meeting
RGQ2/219	2024-05-08	SG2 Coordinators on WTDC Resolution 9	Proposed liaison statement on implementation of Resolution 9 on improving digital skills and human exposure to electromagnetic fields
RGQ2/199 +Ann.1	2024-04-16	China Mobile Communications Co. Ltd.	An introduction to the EMF standardization activities in IEC/IEEE
RGQ2/194	2024-04-16	BDT Focal Points for Questions 1/1, 2/1, 5/1, 4/2 and 7/2	BDT report on the implementation of ICT Infrastructure work since the last ITU-D Study Group meeting
RGQ2/193	2024-04-16	Indonesia	Limit of Specific Absorption Rate (SAR) in Indonesia
RGQ2/189	2024-04-15	Côte d'Ivoire	Assessment of the level of exposure of people to Non-Ionizing Radiation (NIR) during the 2024 African Cup of Nations (CAN) in Côte d'Ivoire
RGQ2/180	2024-04-13	Co-Rapporteur for Question 7/2	Output Report on ITU-D Question 7/2, draft Chapter 2 – International activities on RF-EMF exposure since 2022
RGQ2/179	2024-04-12	GSM Association	Proposed draft content for Chapter 4 of the Question 7/2 Final Report 2022-2025
RGQ2/136 +Ann.1	2024-03-02	ATDI	Workshop on recent developments relevant to EMF policy formulation material for Final Report Chapters 3 and 4
RGQ2/133	2024-03-01	Egypt	Collaborative regulatory framework for electromagnetic radiation management for Egypt's mobile stations
RGQ2/122	2024-02-29	Haiti	Regulatory decision on limit values for human exposure to electromagnetic fields in Haiti
RGQ2/105	2024-02-03	China, ATDI	Revised table of contents for Question 7/2 Final Report
2/198	2023-10-20	Benin	Benin's experience in protecting populations against the effects of non-ionizing radiation from radio sites
2/192	2023-10-16	Telecommunications Management Group Inc.	Enabling smart sustainable cities and communities through wireless power transmission via radiofrequency beam (beam WPT)

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Web	Received	Source	Title
2/189	2023-10-16	BDT Focal Points for Questions 1/1, 2/1, 5/1, 4/2 and 7/2	BDT report on the implementation of ICT Infrastructure work since the last ITU-D Study Group meeting
2/173	2023-10-11	China	Content related to electromagnetic radiation risk assessment of base stations in IEC standards
2/166 +Ann.1	2023-10-11	Telefon AB – LM Ericsson	Assessing exposure to radio frequency electromagnetic fields from 5G networks
2/161	2023-10-09	Vice-Chairs, ITU-D Study Group 1, Vice-Chair, ITU-D Study Group 2, Co-Rapporteur for Question 7/2	Implementation of Resolution 9 across ITU-D Study Groups' Questions
2/152	2023-10-04	Romania	Assessment of human exposure to radio-frequency (RF) electromagnetic field (EMFs) levels in Romania
2/136 (Rev.1)	2023-09-18	ATDI	Proposed draft liaison statement from ITU-D Study Group 2 Question 7/2 to ITU-T Study Group 5 Working Party 1/5, ITU-R Working Parties 1C and 6A on strategies and policies concerning human exposure to electromagnetic fields
2/129	2023-09-12	Central African Republic	Human exposure to electromagnetic fields created by radio systems and mobile devices
2/127	2023-09-07	Co-Rapporteurs for Question 7/2, Vice-Rapporteur for Question 7/2	Annual progress report for Question 7/2 for October-November 2023 meeting
2/100	2023-08-21	China, ATDI	Revised table of contents for Question 7/2 Final Report
RGQ2/87	2023-05-23	Co-Rapporteurs for Question 7/2	Proposed draft liaison statement to ITU-T SG 5, ITU-R SG1 and WP 1B (copy to ITU-R WPs 1C, 4A, 5A, 5B, 5C, 5D, 6A, 7B) on questions of mutual interest and implementation of the WTDC Resolution 9 (Rev. Kigali, 2022)
RGQ2/81	2023-05-12	GSM Association	Implications for mobile networks and risk perception of RF-EMF policy choices and precautionary language
RGQ2/77 +Ann.1	2023-05-08	Uganda	Status and strategies of EMF management and miscommunication in Uganda
RGQ2/73	2023-05-09	China	China Mobile Communication Base Station Electromagnetic Radiation Management Policies and Standards
RGQ2/72	2023-05-09	China Mobile Communications Co. Ltd.	Drafted content of Chapter 2 of the final report of Question 7/2

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Web	Received	Source	Title
RGQ2/69	2023-05-08	China	Proposed Chapter 1 for the final report of Question 7/2
RGQ2/68	2023-05-08	China	Revision on limits for human local exposure to electromagnetic fields emitted by mobile phones in China
RGQ2/49	2023-04-25	BDT Focal Points for Questions 1/1, 2/1, 5/1, 4/2 and 7/2	BDT report on Future Network and Digital Infrastructure work including activities, and resources since the last ITU-D Study Group meetings
RGQ2/45	2023-04-02	Kenya, ATDI	Resolution 9 (Rev. Kigali, 2022) implementation, ITU-R and ITU-D collaboration – Participation of countries, particularly developing countries, in spectrum management
RGQ2/30	2023-03-31	Haiti	Factors related to exposure level to EMF for mobile phones in use
2/TD/9	2022-12-08	Co-Rapporteurs for Question 7/2	Proposed workplan and table of contents for Question 7/2
RGQ2/1	2022-11-23	Ghana	Managing human exposure to electromagnetic field radiation from telecommunication base stations
2/78	2022-11-23	Ghana	Managing human exposure to electromagnetic field radiation from telecommunication base stations
2/48	2022-10-18	BDT Focal Points for Questions 1/1, 2/1, 5/1, 4/2 and 7/2	BDT report on the implementation of ICT Infrastructure work since the last ITU-D Study Group meeting
2/47	2022-10-30	China	Risk communication by translating the ICNIRP Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz) into Chinese: an example of cooperation by stakeholders of different professions
2/46	2022-10-17	Inter-Sector Coordination Group (ISCG)	Mapping of ITU-D Questions to ITU-T Questions and ITU-R Working Parties
2/2 +Ann.1	2022-11-25	Telecommunication Development Bureau	Resolution 2 (Rev. Kigali, 2022) Establishment of study groups + Full text of all ITU-D Study Group 1 and 2 Questions in Annex 1

Incoming liaison statements for Question 7/2

Web	Received	Source	Title
2/224 +Ann.1-3	2024-07-08	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D Study Group 2 Question 7/2 on collaboration matters related to EMF
2/223	2024-07-08	ITU-R Working Party 1B	Reply liaison statement from ITU-R Working Party 1B to ITU-D Study Group 2 Question 5/2 and Question 7/2 on tables of Contents of the Final Reports of ITU-D Question 5/2 and Question 7/2
2/222	2024-07-02	ITU-R Working Party 1C	Reply liaison statement from ITU-R Working Party 1C to ITU-D Study Group 2 Question 7/2 and ITU-T Study Group 5 Question 3/5 on human exposure to RF-EMF
RGQ2/102 +Ann.1	2023-12-20	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D Study Group 2 Question 7/2 on collaboration matters related to EMF
2/96 +Ann.1	2023-07-18	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D Study Group 2 Question 7/2 on collaboration matters related to EMF
RGQ2/18 +Ann.1	2023-03-21	ITU-R Working Party 6A	Liaison statement from ITU-R Working Party 6A to ITU-D Study Group 2 Question 7/2 on revision of Recommendation ITU-R BS.1698
2/50 +Ann.1	2022-11-08	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D Study Group 2 Question 7/2 on collaboration matters related to EMF
2/31 +Ann.1	2022-09-28	ITU-R Working Party 6A	Liaison statement from ITU-R Working Party 6A on revision of Recommendation ITU-R BS.1698-0
2/24	2022-07-18	ITU-R Working Party 1C	Liaison statement from ITU-R Working Party 1C to ITU-D Study Group 2 Question 7/2 on electromagnetic field measurements to assess human exposure
2/23 +Ann.1	2022-07-05	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D Study Group 2 Question 7/2 on collaboration matters related to EMF for ITU-D Q7/2 and to ITU-R working parties
2/16	2021-03-31	ITU-R Working Party 6A	Liaison statement from ITU-R Working Party 6A to ITU-D Study Group 2 Question 7/2 on revision of Recommendation ITU-R BS.1698-0
2/9 +Ann.1	2021-12-21	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D Study Group 2 Question 7/2 on collaboration on matters related to EMF
2/4	2021-10-27	ITU-R Working Party 6A	Reply liaison statement from ITU-R Working Party 6A to ITU-T Study Group 5 on work related to environment energy efficiency and the circular economy and new areas of study

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