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SERIES K: PROTECTION AGAINST INTERFERENCE

ITU-T K.91 – Guide on electromagnetic fields and health

ITU-T K-series Recommendations – Supplement 1

Supplement 1 to ITU-T K-series Recommendations

ITU-T K.91 – Guide on electromagnetic fields and health

Summary

The objective of Supplement 1 to the ITU-T K-series Recommendations is to answer questions commonly posed by the public on the electromagnetic field (EMF) phenomenon and to address related concerns.

This *Guide on electromagnetic fields and health* aims to:

- Provide electromagnetic field (EMF) information and education resources suitable for all communities, stakeholders and governments.
- Support clarification of the science by referencing the World Health Organization (WHO) and other stakeholders (see NOTE) that provide information that is particularly useful in helping to clarify scientific uncertainties e.g., in the areas of radio frequency (RF) technology, infrastructure implementation, usage and consequential EMF exposure.

NOTE – The primary reference on EMF and health is the World Health Organization (WHO). The primary reference on EMF assessment methods is the International Telecommunication Union (ITU) and the International Electrotechnical Commission (IEC).

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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5G, base station, EMF, EMF exposure, health, mobile phone, radio frequency.

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

FOREWORD

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

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

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

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

NOTE

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1 Introduction to EMF

1.1 The electromagnetic spectrum

Electromagnetic fields (EMF) have existed in different forms since the birth of the universe. Electromagnetic fields differ from each other in relation to frequency, and visible light is their most familiar form.

Electric and magnetic fields are part of the electromagnetic spectrum which extends from static electric and magnetic fields, through radio frequency (RF), infrared radiation and visible light to X and gamma-rays, see Figure 1.

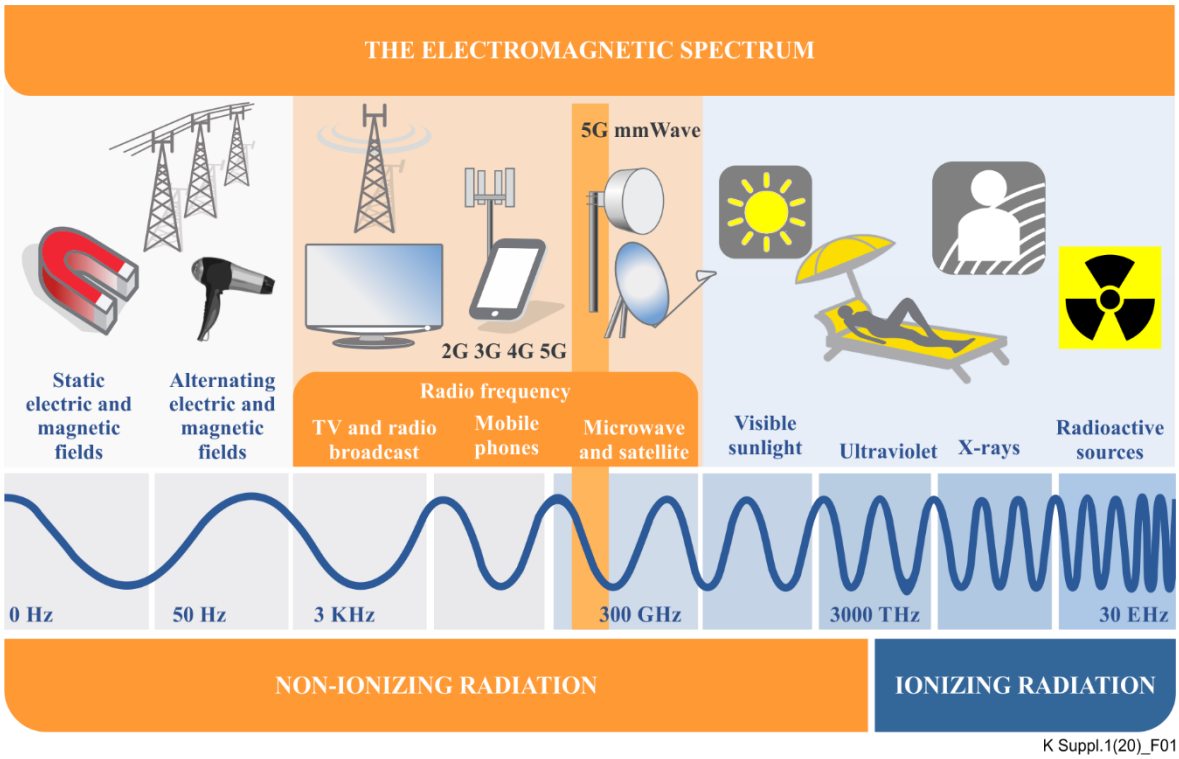


Figure 1 – The electromagnetic spectrum

1.2 What is an electromagnetic field (EMF)?

An electromagnetic field consists of waves of electric and magnetic energy moving together through space. Often the term "electromagnetic field" or EMF is used to indicate the presence of electromagnetic radiation.

1.3 What is a radio frequency (RF) electromagnetic field?

A part of the electromagnetic spectrum extending from the 3 kHz frequency to 300 GHz is referred as radio frequency (RF). Television and radio transmitters (including base stations) as well as microwaves, mobile telephones and radars produce radio frequency fields. These fields are used to transmit information and form the basis of telecommunications as well as radio and television broadcasting all over the world. Many home devices such as cordless phones, baby monitors and radio-controlled toys, Wi-Fi, tablets, smart watches and other wireless devices also transmit EMF at radio frequencies.

1.4 What is ionizing radiation?

Electromagnetic radiation at frequencies above the UV band are classified as "ionizing radiation", because they have enough energy to effect changes in atoms by liberating electrons (ionizing) and thus altering their chemical bonds. X-rays and gamma rays are common forms of ionizing radiation.

Ionizing radiation occurs at frequencies above 2900 THz (2900×10^{12} Hz). This corresponds to a wavelength of about 103.4 nm, which lies near the lower wavelength-edge of the ultraviolet (UV) spectrum.

1.5 What is non-ionizing radiation?

Electromagnetic radiation at frequencies below the UV band are classified as "non-ionizing radiation" because they lack the energy to liberate electrons i.e., to ionize or effect changes in atomic structure. Radio frequency fields are non-ionizing radiations.

2 Overview of EMF and health

2.1 WHO International EMF Project

As shown in Figure 2, wireless communication technology has become an indispensable part of modern society. Mobile phones, tablets and wireless devices have become basic communication tools of everyday life for billions of people around the world and are also common in medical applications. Base stations and telecommunications towers are continuously being erected to provide good quality wireless communications.

Together with the introduction of wireless communication technologies, there has been some degree of public concern about the potential health risks associated with wireless communications including the use of mobile phones and living near base stations.

Figure 2 – Wireless devices in everyday use

Electromagnetic fields (EMFs) of all frequencies represent one of the most common and fastest growing environmental influences. As part of its charter to protect public health and in response to public concern, the WHO established the International EMF Project in 1996. The purpose of the International EMF Project is to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz.

Further information on the WHO International EMF Project is available at www.who.int/peh-emf/about/en/

In terms of EMF and health the WHO notes:

"All reviews conducted so far have indicated that exposures below the limits recommended in the ICNIRP (1998) EMF guidelines, covering the full frequency range from 0-300 GHz, do not produce any known adverse health effect. However, there are gaps in knowledge still needing to be filled before better health risk assessments can be made."

Source: WHO EMF Research – http://www.who.int/peh-emf/research/en/ and WHO Summary of Health Effects www.who.int/peh-emf/about/WhatisEMF/en/index1.html

2.2 Information on mobile phones and health

The WHO notes:

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

While an increased risk of brain tumours is not established, the increasing use of mobile phones and the lack of data for mobile phone use over time periods longer than 15 years warrant further research of mobile phone use and brain cancer risk. In particular, with the recent popularity of mobile phone use among younger people, and therefore a potentially longer lifetime of exposure, WHO has promoted further research on this group. Several studies investigating potential health effects in children and adolescents are underway. *Source https://www.who.int/news-room/fact-sheets/detail/electromagnetic-fields-and-public-health-mobile-phones*

2.3 Information on base stations and health

The WHO notes:

"Considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects."

"Studies to date provide no indication that environmental exposure to RF fields, such as from base stations, increases the risk of cancer or any other disease."

Sources: www.who.int/peh-emf/publications/facts/fs304/en/, http://www.who.int/features/qa/30/en/

2.4 Information on 5G and health

The ICNIRP advises:

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has released new guidelines for the protection of humans exposed to radiofrequency electromagnetic fields. The guidelines cover the upcoming 5G technologies, as well as AM and DAB radio, WiFi, Bluetooth and the currently used 3G/4G mobile phones.

ICNIRP Chairman, Dr Eric van Rongen, said the new electromagnetic field guidelines have taken seven years to develop and are more appropriate than the 1998 guidelines for the higher frequencies that will be used for 5G in the future.

..."The guidelines have been developed after a thorough review of all relevant scientific literature, scientific workshops and an extensive public consultation process. They provide protection against all scientifically substantiated adverse health effects due to EMF exposure in the 100 kHz to 300 GHz range."

...The main changes in the 2020 guidelines that are relevant to 5G exposures are for frequencies above 6 GHz. These include:

- *the addition of a restriction for exposure to the whole body;*
- *the addition of a restriction for brief (less than 6-minute) exposures to small regions of the body; and*
- *the reduction of the maximum exposure permitted over a small region of the body.*

"When we revised the guidelines, we looked at the adequacy of the ones we published in 1998. We found that the previous ones were conservative in most cases, and they'd still provide adeq uate protection for current technologies,"

Dr Van Rongen said.
"However, the new guidelines provide better and more detailed exposure guidance in for the hi gher frequency range, above 6 GHz, which is of importance to 5G and future technologies usin g these higher frequencies. The most important thing for people to remember is that 5G technol ogies will not be able to cause harm when these new guidelines are adhered to." *Source* https://www.icnirp.org/cms/upload/presentations/ICNIRP_Media_Release_110320.pdf

2.5 Information on human exposure guidelines

The WHO notes:

Two international bodies produce exposure guidelines on electromagnetic fields. Many countries currently adhere to the guidelines recommended by:

The International Commission on Non-Ionizing Radiation Protection and,

The Institute of Electrical and Electronics Engineers, through the International Committee on Electromagnetic Safety

*These guidelines are not technology-specific. They cover radiofrequencies up to 300 GHz, including the frequencies under discussion for 5G.*Source:

WHO What are the International Exposure Guidelines – https://www.who.int/news-room/q-a-detail/5g-mobile-networks-and-health

The ICNIRP notes:

The ICNIRP Guidelines on Limiting Exposure to Electromagnetic Fields are for the protection of humans exposed to radiofrequency electromagnetic fields (RF) in the range 100 kHz to 300 GHz. The guidelines cover many applications such as 5G technologies, WiFi, Bluetooth, mobile phones, and base stations.

The 2020 guidelines replace and supersedes the 100 kHz to 300 GHz part of the ICNIRP (1998) radiofrequency guidelines, as well as the 100 kHz to 10 MHz part of the ICNIRP (2010) low-frequency guidelines.

The guidelines have been developed after a thorough review of all relevant scientific literature, scientific workshops and an extensive public consultation process. They provide protection against all scientifically substantiated adverse health effects due to EMF exposure in the 100 kHz to 300 GHz range.

The IEEE notes:

Safety limits for the protection of persons against the established adverse health effects of exposures to electric, magnetic, and electromagnetic fields in the frequency range 0 Hz to 300 GHz are presented in this standard.

These exposure limits are intended to apply generally to persons permitted in restricted environments and to the general public in unrestricted environments.

These exposure limits are not intended to apply to the exposure of patients by or under the direction of physicians and medical professionals, as well as to the exposure of informed volunteers in medical or scientific research studies, and might not be protective with respect to the use of medical devices or implants.

Source https://standards.ieee.org/standard/C95_1-2019.html

2.6 Research on EMF and health

Extensive research has been conducted into possible health effects of exposure to many parts of the electromagnetic spectrum.

As noted by the WHO, in the area of biological effects and medical applications of non-ionizing radiation approximately 25 000 articles have been published over the past 30 years. Despite the feeling of some people that more research needs to be done, scientific knowledge in this area is now more extensive than for most chemicals.

The WHO also references the EMF-Portal (www.emf-portal.org) which is a scientific literature database on the effects of electric, magnetic and electromagnetic fields on human health and biological systems. This open-access website is operated by the Research Center for Bioelectromagnetic Interaction (femu), part of the Institute of Occupational Medicine, RWTH Aachen University, Germany.

The EMF-Portal is, worldwide, the most comprehensive scientific literature database on biological and health-related effects of non-ionizing electromagnetic radiation (frequency range 0-300 GHz) with unrestricted access.

The core of the EMF-Portal is an extensive literature database with an inventory of 31,031 publications and 6,716 summaries of individual scientific studies on the effects of electromagnetic fields, see Figure 3.

Sources:

WHO https://www.who.int/peh-emf/research/database/en/;
EMF Portal https://www.emf-portal.org/en

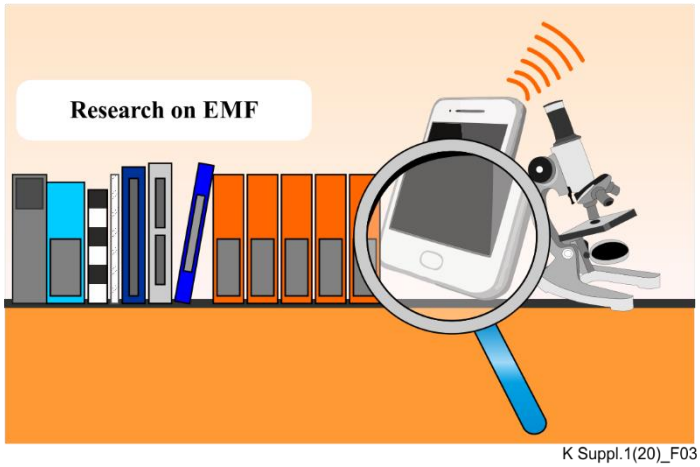


Figure 3 – Research on EMF and health

2.7 Effects of EMF

Biological effect verses adverse health effect

A biological effect occurs when exposure to electromagnetic fields causes some noticeable or detectable physiological change in a biological system which is not necessarily hazardous. An adverse health effect occurs when the biological effect is outside the normal range for the body to compensate and which is detrimental to health or well-being.

What are the effects of RF EMF?

Exposure to radio frequency (RF) EMF at high levels can cause the heating of tissues that leads to an increase in the body temperature. This is known as the thermal effect. Although the body has its effective ways of regulating its temperature, if the RF exposures are too high, the body may no longer be able to cope.

At frequencies above 10 MHz, the first scientifically established effect to occur is heating. At frequencies below 10 MHz, the first effect to be experienced is non-thermal nerve stimulation (a tingling sensation).

2.8 International Agency for Research on Cancer

IARC classification of RF EMF

In May 2011, the WHO/International Agency for Research on Cancer (IARC) classified radio frequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), based on an increased risk of glioma, a malignant type of brain cancer associated with wireless phone use.

The IARC website lists 314 agents classified as group 2B including RF fields, gasoline engine exhaust, pickled vegetables, dry cleaning (occupational exposures in) and extremely low frequency (ELF) magnetic fields.

The IARC provides the following summary of the classification:

"The evidence was reviewed critically, and overall evaluated as being limited among users of wireless telephones for glioma and acoustic neuroma, and inadequate to draw conclusions for other types of cancers. The evidence from the occupational and environmental exposures mentioned above was similarly judged inadequate."

"Limited evidence of carcinogenicity: A positive association has been observed between exposure to the agent and cancer for which a causal interpretation is considered by the Working Group to be credible, but chance, bias or confounding could not be ruled out with reasonable confidence."

"Inadequate evidence of carcinogenicity: The available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of a causal association between exposure and cancer, or no data on cancer in humans are available."

"Given the potential consequences for public health of this classification and findings....it is important that additional research be conducted into the long-term, heavy use of mobile phones. Pending the availability of such information, it is important to take pragmatic measures to reduce exposure such as hands free devices or texting."

Source: IARC press release 31st May 2011 – http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf

Summary of the IARC classification of RF EMF

The WHO has provided the following summary of the IARC classification of radio frequency electromagnetic fields:

"The International Agency for Research on Cancer (IARC) has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), a category used when a causal association is considered credible, but when chance, bias or confounding cannot be ruled out with reasonable confidence".

Source: WHO Fact sheet October 2014 https://www.who.int/news-room/fact-sheets/detail/electromagnetic-fields-and-public-health-mobile-phones

In terms of what the IARC 2B classification means, the WHO summarises this as:

"Possibly carcinogenic to humans is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals".

Source: WHO handbook "Establishing a dialogue on risk from electromagnetic fields"

IARC World Cancer Report 2020

In 2020, IARC published the latest World Cancer Report and with respect to cancer causation says:

*"Because RF-EMF belong to the non-ionizing part of the electromagnetic spectrum, the photon energy is too weak to ionize molecules and thereby cause direct DNA damage. Absorption of RF-EMF is known to heat biological tissue, but a minimal temperature increase below the regulatory limits is not expected to increase the risk of cancer. Despite considerable research efforts, no mechanism relevant for carcinogenesis has been consistently identified to date. '*Source: "http://publications.iarc.fr/Non-Series-Publications/World-Cancer-Reports/World-Cancer-Report-Cancer-Research-For-Cancer-Prevention-2020"

3 Mobile phones and base stations

3.1 How mobile phones and wireless devices work

A mobile phone or wireless device is a low power two-way radio. It contains both a transmitter and a receiver and uses radio frequency fields to send and receive calls, access the Internet and send messages, and data.

When you make a call on a mobile phone or send or receive text messages or data, you are connected to a nearby base station through a radio frequency signal. The base station then communicates with the core of the network to a central exchange to determine where the call is to be forwarded to and then either your call is forwarded to the fixed line network and to an individual fixed land line phone, or if you are calling another mobile phone, your call will be forwarded to another base station and on to the mobile phone you are calling.

When you access data via your mobile device, the central exchange connects you to the Internet, see Figure 4.

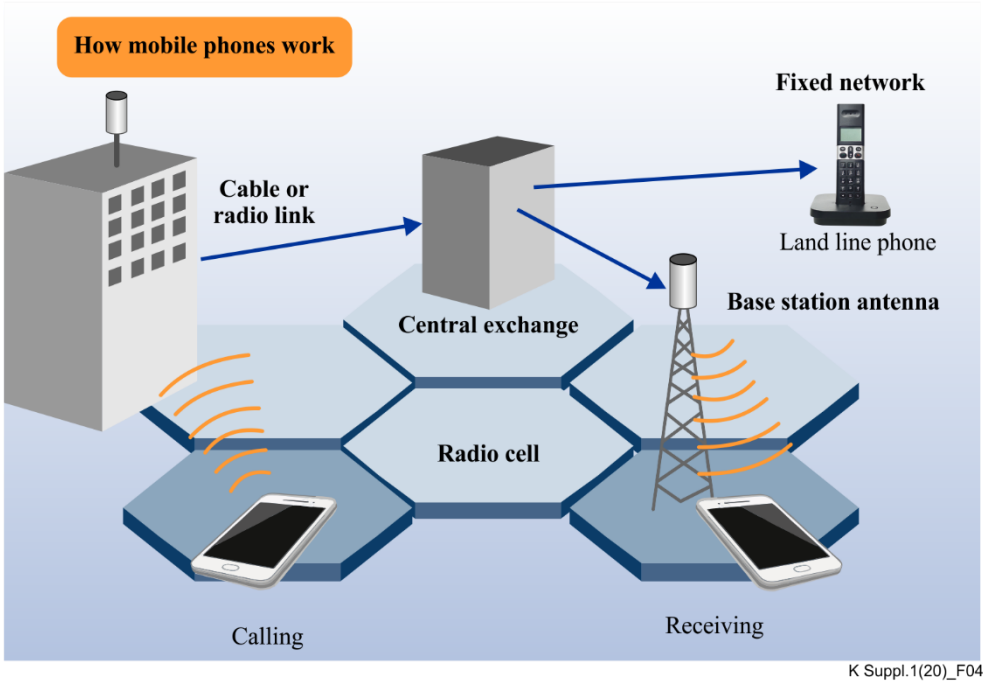


Figure 4 – How mobiles devices and base stations work

Base stations are low-power, multi-channel two-way radios located inside an equipment hut or cabinet. The base station antennas, which transmit and receive the radio signal, can be mounted on transmission towers, poles, roof-mounted structures or as small cells providing localized coverage. Base station radio transmitters typically operate at between 2-50 watts. In rural areas base stations may use additional power amplifiers for the transmitter and receiver to extend coverage.

The location and positioning of the base station antennas are carefully chosen to match the required coverage area. Small base station antennas are often located inside buildings to provide dedicated indoor coverage.

3.2 The generations of mobile communication

The cellular mobile technology was introduced around 1980 and from that time it has evolved as new technologies have been developed. Figure 5 shows the evolution of applications for each technology.

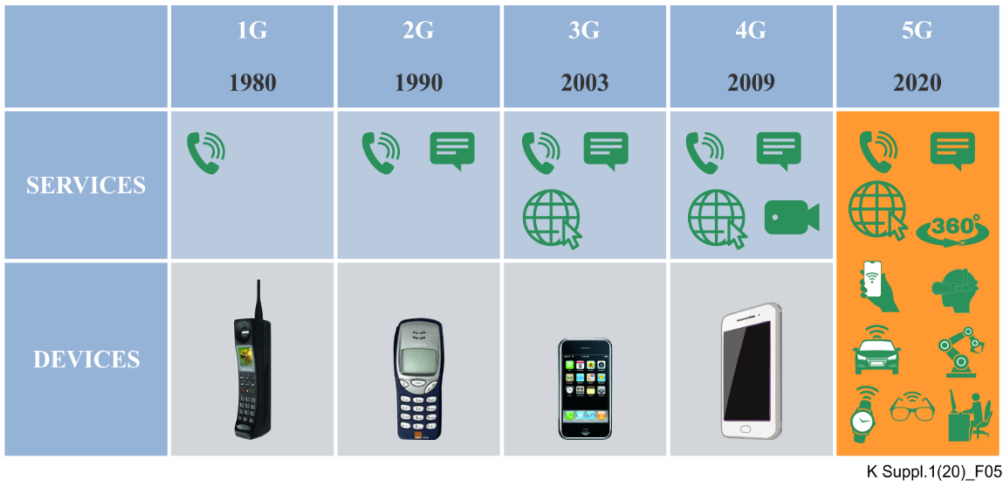


Figure 5 – Evolution of the mobile systems (source: Orange)

The key feature of each new technology is the increased spectral efficiency that allows transmission of more information using the same amount of resources including spectrum as shown in Figure 6.

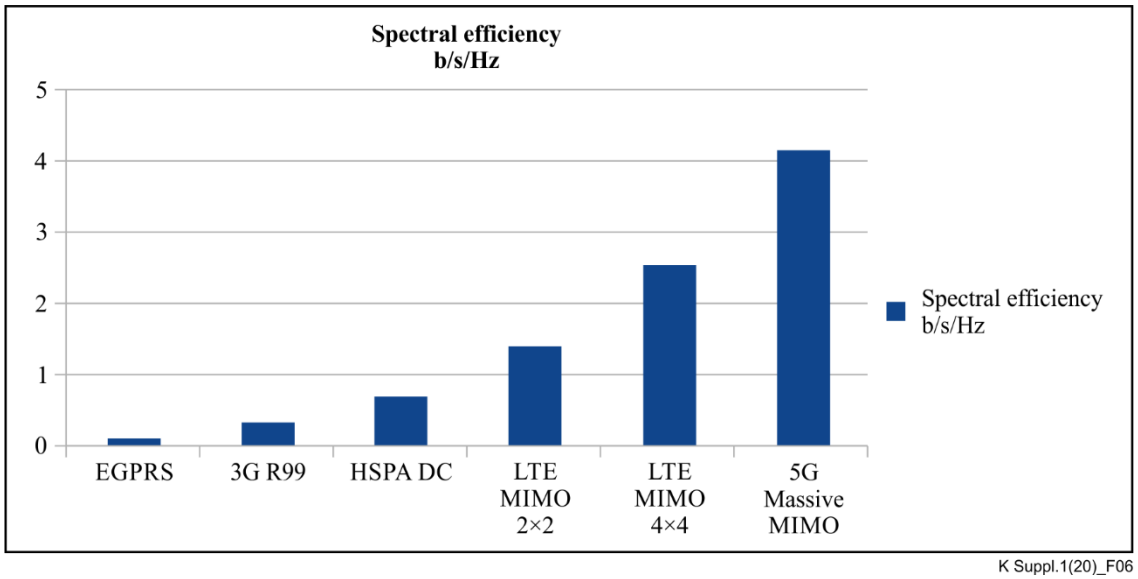


Figure 6 – Comparison of the mobile systems efficiency

3.3 Towers and antennas

It is important to know the difference between antennas and towers. Towers are the structures to support the antennas. Like a street light where the brightness depends on distance from the light and not on its support pole. You need to keep your distance from the antennas that transmit the radio signal and not the towers that hold the antennas.

You also need to be aware of the many different designs of base stations that vary widely in their power and characteristics, affecting their potential for exposing people to RF signals. Research has shown that at ground level, the intensity of radio frequency signals from base stations are typically less than one thousandth of those from mobile phones, see Figure 7.

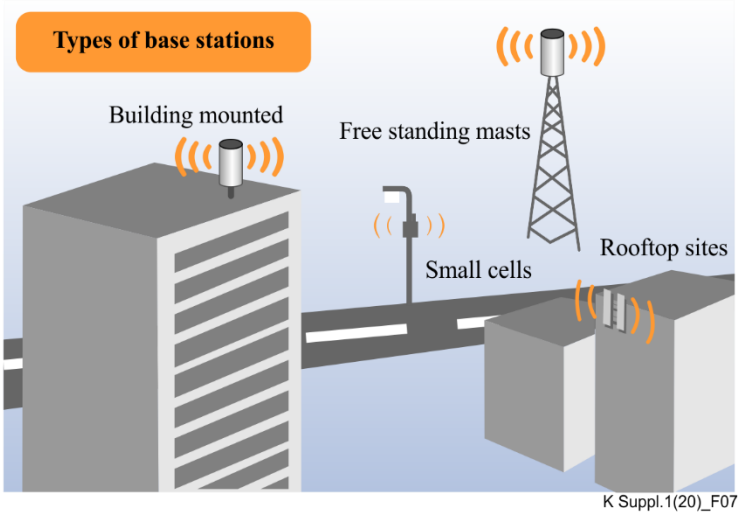


Figure 7 – Types of base stations

3.4 Does the power of a base station vary?

Yes. The power from a base station will vary depending on the number of mobile phone calls and amount data traffic being carried. In addition to the data and mobile phone calls, a pilot signal is continuously transmitted from the base station so that nearby mobile phones and wireless devices can detect the network. See references in clause 5.3 for additional information.

3.5 Mobile phone power transmitters

Mobile phones use low power transmitters that transmit at less than two watts peak. Mobile phones are designed to automatically transmit at the lowest possible power to maintain a quality connection. This feature is known as adaptive power control.

For more information refer to clause 6, Mobile phones and EMF FAQ.

5G and RF EMF

What is 5G?

5G is the 5th generation of mobile networks. 5G has been designed to meet the very large growth in data and connectivity of today's modern society, the Internet of things (IoT) with billions of connected devices, and tomorrow's innovations.

What are the benefits of 5G?

5G technologies are expected to support applications such as smart homes and buildings, smart cities, 3D video, work and play in the cloud, remote medical services, virtual and augmented reality, and massive machine-to-machine communications for industry automation.

There are three major categories of use case for 5G:

Massive machine to machine communications – also called the Internet of things (IoT) that involves connecting billions of devices without human intervention at a scale not seen before. This has the potential to revolutionise modern industrial processes and applications including agriculture, manufacturing and business communications.

Ultra-reliable low latency communications – mission critical including real-time control of devices, industrial robotics, vehicle to vehicle communications and safety systems, autonomous driving and safer transport networks. Low latency communications also opens up a new world where remote medical care, procedures, and treatment are all possible

Enhanced mobile broadband – providing significantly faster data speeds and greater capacity keeping the world connected. New applications, as shown in Figure 8, will include fixed wireless Internet access for homes, outdoor broadcast applications without the need for broadcast vans, and greater connectivity for people on the move.

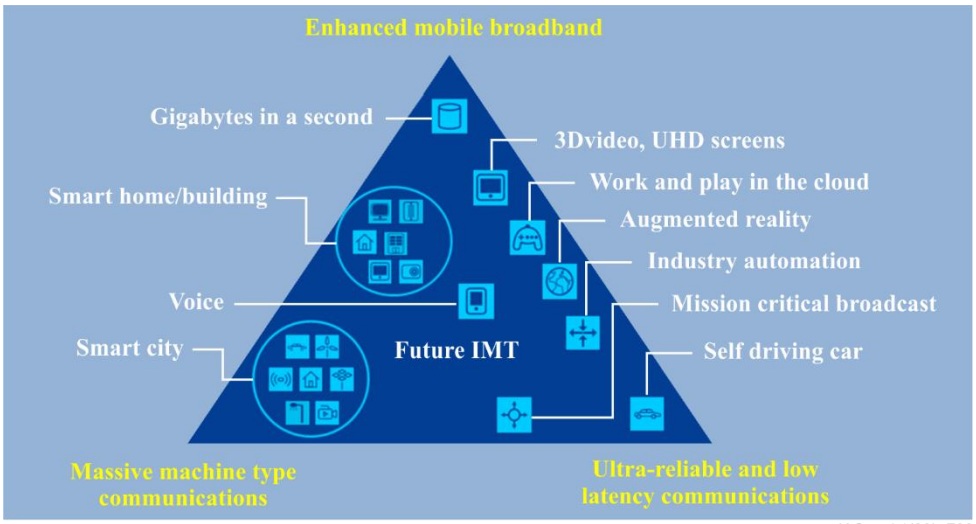


Figure 8 – Future IMT (International Mobile Telecommunication) systems (source: ITU-R M.2083 How Does 5G Work?)

5G will initially operate in conjunction with existing 4G networks, as shown in Figure 9, before evolving to fully standalone networks in subsequent releases and coverage expansions.

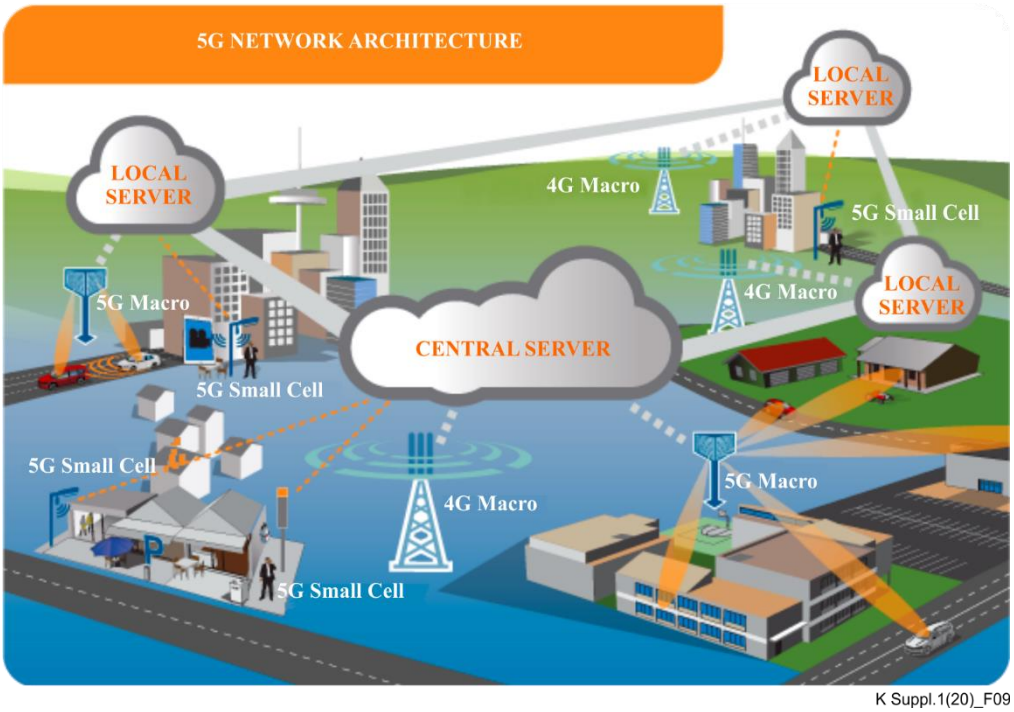


Figure 9 – 5G network architecture illustrating 5G and 4G working together, with central and local servers providing faster content to users and low latency applications

As depicted in Figure 9, a mobile network has two main components: the radio access network (RAN) and the core network.

The radio access network – consists of various types of facilities including small cells, towers, masts and dedicated in-building and home systems that connect mobile users and wireless devices to the main core network.

Small cells will be a major feature of 5G networks particularly at the new millimetre wave (mmWave) frequencies where the connection range is very short. To provide a continuous connection, small cells will be distributed in clusters depending on where users require connection which will complement the macro network that provides wide-area coverage.

5G macro cells will use multiple input, multiple output (MIMO) antennas that have multiple elements or connections to send and receive more data simultaneously. The benefit to users is that more people can simultaneously connect to the network and maintain high throughput. Where MIMO antennas use very large numbers of antenna elements they are often referred to as 'massive MIMO', however, the physical size is similar to existing 3G and 4G base station antennas.

The core network – is the mobile exchange and data network that manages all of the mobile voice, data and Internet connections. For 5G, the 'core network' is being redesigned to better integrate with the Internet and cloud based services and also includes distributed servers across the network improving response times (reducing latency).

Many of the advanced features of 5G including network function virtualization and network slicing for different applications and services, will be managed in the core. Figure 9 shows examples of local cloud servers providing faster content to users (movie streaming) and low latency applications for vehicle collision avoidance systems.

What frequencies does 5G use?

In many countries the initial frequency bands for 5G are below 6 GHz (in many cases in the 3.3-3.8 GHz bands) and similar frequencies to existing mobile and Wi-Fi networks. Additional mobile spectrum above 6 GHz, including the 26-28 GHz bands often referred to as millimetre wave (mmW), will provide significantly more capacity compared to the current mobile technologies. The additional spectrum and greater capacity will enable more users, more data and faster connections. 5G also uses the existing 2G, 3G and 4G low band spectrum for 5G as legacy networks decline in usage and to support future use cases. 5G is the next step in the evolution of the mobile technology and work has started on the development of the 6G standard.

The increased spectrum in the mmWave band will provide localized coverage as they only operate over short distances. Future 5G deployments may use mmW frequencies in bands up to 86 GHz.

Figure 10 shows spectrum used by mobile communication.

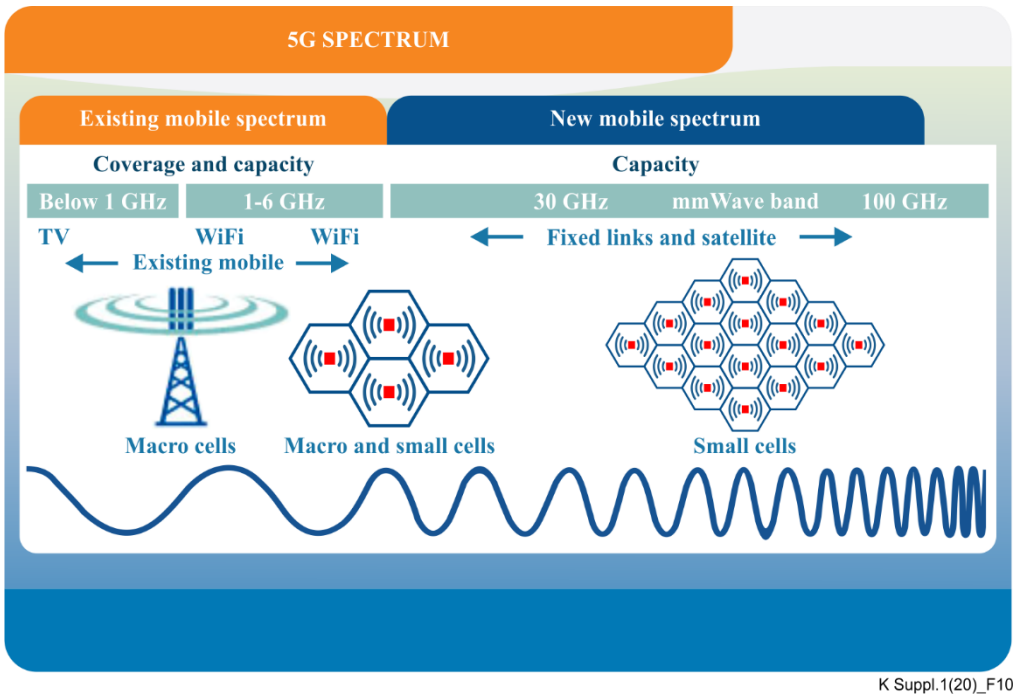


Figure 10 – Spectrum used by mobile communication

What is MIMO beam steering?

Beam steering, as shown in Figure 11, is a technology that allows the massive MIMO base station antennas to direct the radio signal to the users and devices rather than in all directions. The beam steering technology uses advanced signal processing algorithms to determine the best path for the radio signal to reach the user. This increases efficiency as it reduces interference (unwanted radio signals).

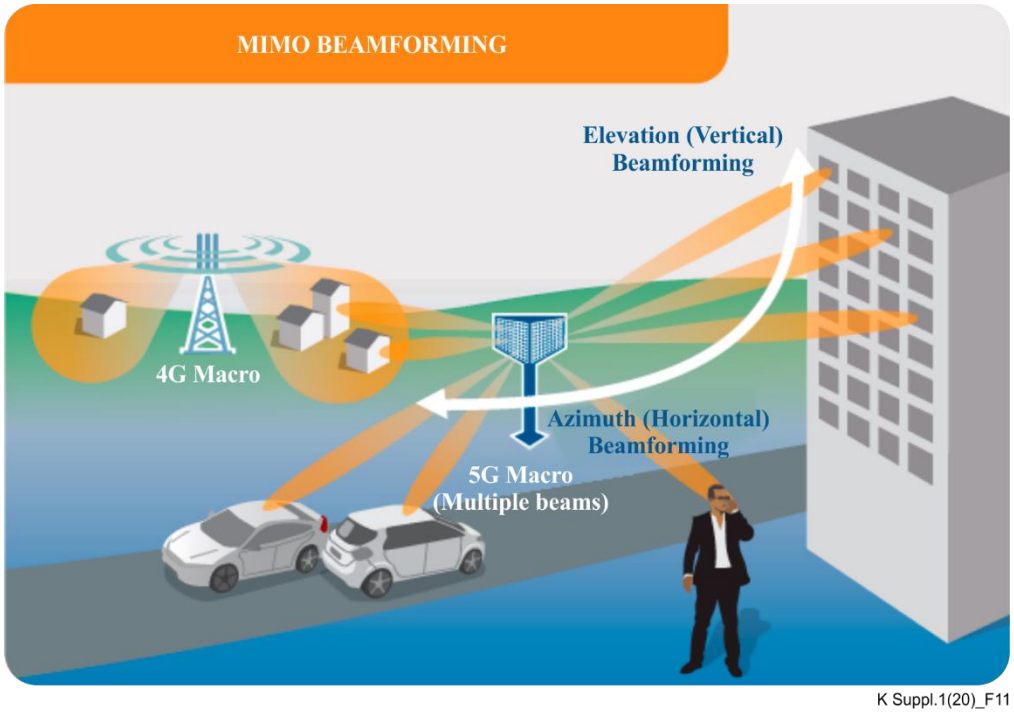


Figure 11 – MIMO beamforming

What are the EMF levels from 5G base stations?

5G networks are designed to be more efficient and will use less power than current networks for similar services.

With the introduction of new technologies, there may be a small increase in the overall level of radio signals due to the fact that new transmitters are active. In some countries deployment of 5G may occur as part of closure of earlier wireless networks.

Based on the transition from previous wireless technologies we can expect that the overall exposure levels will remain relatively constant and a small fraction of the international exposure guidelines.

Initial surveys of 5G networks show very low exposure levels. ITU-T K-series Recommendations - Supplement 9 contains an analysis of the impact of the implementation of 5G mobile systems with respect to the exposure level of electromagnetic fields (EMFs) around radiocommunication infrastructure.

ITU information on 5G

ITU Backgrounder – The ITU provides additional information on 5G in this backgrounder.

4 Mobile phones, SAR and power density

4.1 What is SAR?

Specific absorption rate (SAR) is a measure of the amount of RF energy that is absorbed by tissues in the human body and is expressed in watts per kg (W/kg). This measurement is used to determine whether or not a mobile phone complies with the safety standards or guidelines at frequencies below 6GHz where RF energy is absorbed by tissues in the human body, see Figure 12.

Figure 12 – Mobile phones and SAR

4.2 What is 'power density'?

At frequencies above 6 GHz electromagnetic fields are absorbed more superficially in the human body making SAR assessments less relevant. The ICNIRP and IEEE human exposure guidelines describe human exposure in terms of the power density which is a measure of the power over a given area (W/m^2).

Where a mobile device operates at frequencies below and above 6GHz, both SAR and power density must be assessed to determine compliance with the human exposure guidelines. This will typically apply to 5G devices that also operate in the mmWave frequency bands.

Additional information on 5G

ITU Backgrounder – The ITU provides additional information on 5G in this backgrounder.

4.3 Factors affecting RF-EMF exposure from mobile devices

The exposure from a mobile phone varies considerably during use due to adaptive power control and the connection back to the mobile network. A maximum exposure value measured in a laboratory does not provide sufficient information about the amount of RF exposure under typical usage conditions to reliably compare individual cell phone models. The level of exposure depends on the distance between the person and the mobile and the amount of RF power the mobile transmits.

Mobile devices will attempt to use the minimum amount of energy to provide a reliable service quality while at the same time preserving battery life, actual exposure varies continually depending on a range of factors including:

The distance between the person and the mobile device

RF fields are much weaker even a short distance from a mobile. Keeping the mobile away from the body by using an earpiece or loudspeaker function will significantly reduce exposure.

The distance from the base station

RF EMF from a mobile phone will vary its power level depending on its proximity to a base station using automatic power control. The closer it is to a base station, the less power is required and conversely the further away it is, the more power is required up to the phone's maximum SAR, see Figure 13.

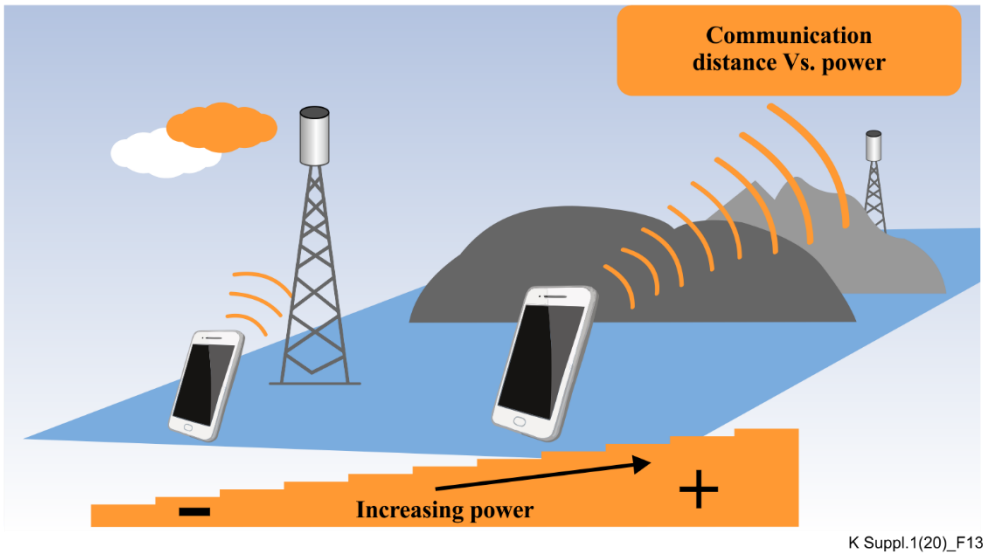


Figure 13 – Distance from base station and increasing phone power (the + indicates higher power from a mobile phone is required) (Note – diagram will be updated)

Obstacles between the user and the base station

If there is a building, wall, hill, tree or other obstruction between the mobile and the base station, the signal received by base station may also be weaker meaning the RF field strength from the mobile must increase so that it can still communicate with the base station.

The service being used

Making a voice call from a mobile phone could lead to greater exposure than sending and receiving data or accessing the Internet. This is because voice calls are generally made with the mobile phone next to the head, while it is typically held away from the body when sending and receiving data. Calls may also take longer than sending data, again increasing exposure. The time taken to write a text or email or to review information already stored on your mobile phone will not result in any significant exposure.

Exposure is related to actual communications with the network, such as during the sending of a message or continuously during a voice call. These higher levels of exposure as a result of a voice call are still less than the ICNIRP guidelines because all phones must comply with international safety standards. For more information refer to clause 5, Relevant EMF guidelines and standards.

Mobile phones are also designed to use the lowest possible power to connect to the nearest base station and automatically adjust the power depending on the environment.

Refer to ITU-T K-series Recommendations – Supplement 13 for additional information.

4.4 How important is the SAR value?

Mobile phone manufacturers must ensure that their products comply with the maximum SAR levels specified in the human exposure guidelines.

Mobile phones are tested for compliance at their highest possible power level through rigorous tests and multiple SAR measurements, therefore SAR values reported for each model of mobile phone tend to significantly overstate real-life exposure levels as they rarely operate at maximum power levels during everyday use.

4.5 How SAR is measured for devices

Each model of mobile phone is tested using internationally agreed testing procedures as outlined in the relevant standards. They are tested using both a 'phantom' head and a separate 'phantom' torso for body-worn measurements. The phantoms are filled with liquids that simulate the electrical properties of human tissue and SAR values are measured with the phone at maximum power at its different operating frequencies and in a range of positions.

A probe in a liquid measures the electric field strength inside the phantom and uses this to determine the maximum SAR value for the model of phone in each particular configuration. As a result, the testing is both complex and time consuming. For full compliance testing, the process can take up to several weeks depending on the model in question.

A video showing the SAR testing procedure is available at:

http://www.emfexplained.info/?ID=25593

4.6 Does SAR vary between mobile phones?

Yes. The maximum SAR level for different mobile phone models can vary because the value is reported for demonstrating compliance with national and international limits. As such they are not directly comparable, but they demonstrate that the devices do comply with the relevant RF exposure limits.

New technologies increase RF efficiency and decrease power; therefore, the EMF exposure from newer technology devices is lower for similar voice or data services.

4.7 Are low SAR mobile phones safer?

No. Variations in the maximum reported SAR reflect different technical parameters such as the antenna used and its placement within the device. However, these variations do not mean that there are variations in safety.

SAR is designed to demonstrate compliance with the relevant national or international limits. The declared maximum SAR value of a phone does not for example reflect the fact that once a call is established the mobile phone will power down to the minimum power level required to reach the base station and maintain a quality call.

4.8 Finding the compliance information for your mobile

The compliance information for a mobile phone should be available from the manufacturer's web site. This information and any other instructions on use should also be printed in the user manual that accompanies each mobile phone. Certain regulatory agencies provide the compliance information of mobile phones on their website.

5 Relevant EMF guidelines and standards

This clause provides information on the relevant EMF human exposure guidelines and compliance assessment standards.

5.1 Human EMF exposure guidelines

A number of national and international organizations have formulated guidelines establishing limits for occupational and general public RF EMF exposure up to 300 GHz.

ICNIRP guidelines	The exposure limits for EMF fields developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) – a non-governmental organization in official relations with the WHO, were developed following reviews of all the peer-reviewed scientific literature, including thermal and non-thermal effects. The guidelines are based on evaluations of biological effects that have been established to have health consequences. The main conclusion from the WHO reviews is that EMF exposures below the limits recommended in the ICNIRP international guidelines do not appear to have any known consequence on health. ICNIRP has an ongoing program to monitor scientific research and ensure the human exposure guidelines are up to date. Visit the ICNIRP web site at http://www.icnirp.org/.
ICES/IEEE safety standards	The Institute of Electrical and Electronics Engineers (IEEE) is a professional association headquartered in New York City that is dedicated to advancing technological innovation and excellence, and includes the International Committee on Electromagnetic Safety (ICES) focused on development and maintenance of EMF safety standards. IEEE C95.1™-2019 – Safety levels with respect to human exposure to radio frequency electromagnetic fields in the frequency range 3 kHz to 300 GHz.

NOTE – The ICNIRP and IEEE guidelines are similar, science based and accepted in many countries around the world.

5.2 Safety factors

The ICNIRP guidelines use a range of mechanisms to ensure that all people are protected from RF EMF exposure. One of these is the use of reduction factors, that ensure that the restrictions are far lower than are required to cause adverse health effects for all people. A reduction factor of 50 has been used for the general public, which results in an exposure that is too low to cause a detectable increase in body core temperature, and so would be protective for all groups. The wide safety margin ensures that any increase in body tissue temperature is negligible.

For workers, the limits are five times higher than those of the general public. The rationale for having lower limits for the general public is that this group includes children, pregnant women, the elderly and other persons of varying health status or susceptibility. In addition exposure might be continuous (24 hours a day) and people may be totally unaware of an exposure.

Recommendation ITU-T K.145 provides guidance on the assessment and management of compliance with radio frequency electromagnetic field exposure limits for workers at radiocommunication sites and facilities.

5.3 ITU standards and guidelines

The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies (ICTs). For over 150 years, the ITU has coordinated the shared global use of the radio spectrum, promoted international cooperation in assigning satellite orbits, worked to improve communication infrastructure in the developing world and established the worldwide standards that foster seamless interconnection of a vast range of communications systems. From broadband networks to new-generation wireless technologies, aeronautical and maritime navigation, radio astronomy, satellite-based meteorology and converging fixed-mobile phone, Internet and broadcasting technologies, the ITU is committed to connecting the world.

The Plenipotentiary Conference which is the top policy-making body of the ITU approved a revised resolution on human exposure to and measurement of electromagnetic fields (Dubai 2018).

Within the Telecommunication Standardization Sector (ITU-T) of ITU, ITU-T Study Group 5 (SG5) is the lead study group on ICT environmental aspects of electromagnetic phenomena and climate change.

SG5's Working Party 1 studies EMF issues under Question 3/5: "Human exposure to electromagnetic fields (EMF) from information and communication technologies (ICTs)". The resulting international standards (ITU-T Recommendations) provide high-level frameworks for the management of human exposure to EMFs emitted by telecommunication equipment (best practice regulatory guidelines) and also offer guidelines for the assessment of human exposure based on existing ITU-T Recommendations and standards produced by other standards development organizations (SDOs).

To achieve these goals, Question 3/5 looks at measuring techniques, procedures and numerical models for evaluating the electromagnetic fields stemming from telecommunication systems and radio terminals.

The ITU has developed the following standards and reports:

Recommendation ITU-T K. 52	Guidance on complying with limits for human exposure to electromagnetic fields
Recommendation ITU-T K.61	Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations

Recommendation ITU-T K.70	Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations
EMF Estimator	EMF Estimator is a software application that implements the methodology described in ITU-T K.70 to calculate the cumulative radio frequency exposure levels in the vicinity of transmitting antennas
Recommendation ITU-T K.83	Monitoring of electromagnetic field levels
Recommendation ITU-T K.90	Evaluation techniques and working procedures for compliance with exposure limits of network operator personnel to power-frequency electromagnetic fields
Recommendation ITU-T K.91	Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields
Recommendation ITU-T K.100	Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service
Recommendation ITU-T K.113	Generation of radiofrequency electromagnetic fields level maps
Recommendation ITU-T K.121	Guidance on the environmental management for compliance with radio frequency EMF limits for radiocommunication base stations
Recommendation ITU-T K.122	Exposure levels in close proximity of radiocommunication antennas
Recommendation ITU-T K.145	Assessment and management of compliance with radio frequency electromagnetic field exposure limits for workers at radiocommunication sites and facilities
Recommendation ITU-R BS.1698	Evaluating fields from terrestrial broadcasting transmitting systems operating in any frequency band for assessing exposure to non-ionizing radiation
Report ITU-D Question 23/1	Strategies and policies concerning human exposure to Electromagnetic fields
ITU-R Handbook	Spectrum monitoring
ITU-T K Suppl. 4	Electromagnetic field considerations in smart sustainable cities
ITU-T K Suppl. 9	5G technology and human exposure to radiofrequency electromagnetic fields
ITU-T K Suppl. 13	Radiofrequency electromagnetic field (RF-EMF) exposure levels from mobile and portable devices during different conditions of use
ITU-T K Suppl. 14	The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment
ITU-T K Suppl. 16	Electromagnetic field compliance assessments for 5G wireless networks
ITU-T K Suppl. 19	Electromagnetic field (EMF) strength inside underground railway trains

5.4 IEC standards

IEC standards are developed by the International Electrotechnical Commission. The IEC is a not-for-profit, non-governmental organization, founded in 1906. The IEC's members are National

Committees and they appoint experts and delegates coming from industry, government bodies, associations and academia to participate in the technical and conformity assessment work of the IEC.

IEC Technical Committee 106 is responsible for preparing international standards on measurement and calculation methods to assess human exposure to electric, magnetic and electromagnetic fields.

A list of the relevant IEC standards is available from the IEC TC106 web site:

https://webstore.iec.ch/ and IEC TC106 dashboard:
https://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID,FSP_LANG_ID:1303,25

NOTE – The IEC and ICNIRP have agreed on the sharing of responsibilities for EMF standards. EMF exposure limits guidelines are developed by ICNIRP and EMF exposure assessment standards developed by IEC.

5.5 IEEE standards

The IEEE also prepares compliance assessment standards for electromagnetic fields in the frequency range 3 kHz to 300 GHz. The relevant IEEE standards for EMF are available from the IEEE website using "EMF" in the search box on the web site.

The IEC and IEEE also have a formal sharing arrangement. Based on the dual-logo agreement between IEC and IEEE, in the future the EMF compliance assessment standards developed by the IEC will also carry the IEEE logo, i.e., will become IEEE standards.

6 Mobile phones and EMF FAQ

6.1 What are the health risks associated with mobile phones and their base stations?

What are the health risks associated with mobile phones and their base stations?

Online Q&A

20 September 2013

Q: What are the health risks associated with mobile phones and their base stations?
A: This is a question which WHO takes very seriously. Given the immense number of people who use mobile phones, even a small increase in the incidence of adverse effects on health could have major public health implications.

Because exposure to the radiofrequency (RF) fields emitted by mobile phones is generally more than a 1000 times higher than from base stations and the likelihood is greater of any adverse effect being due to handsets, research has almost exclusively been conducted on possible effects of mobile phone exposure.

Research has concentrated on the following areas:

- cancer
- other health effects
- electromagnetic interference
- traffic accidents.

Cancer

Based on mixed epidemiological evidence on humans regarding an association between exposure to RF radiation from wireless phones and head cancers (glioma and acoustic neuroma), RF fields have been classified by the International Agency for Research on Cancer as possibly carcinogenic to humans (Group 2B). Studies to date provide no indication that environmental exposure to RF fields, such as from base stations, increases the risk of cancer or any other disease.

Other health effects

Scientists have reported other health effects of using mobile phones including changes in brain activity, reaction times and sleep patterns. These effects are minor and have no apparent health significance. More studies are underway to try to confirm these findings.

Electromagnetic interference

When mobile phones are used very close to some medical devices (including pacemakers, implantable defibrillators and certain hearing aids) there is the possibility of causing interference with their operation. The risk is much reduced for 3G phones and newer equipment. There is also the potential of interference between mobile phone signals and aircraft electronics. Some countries have licensed mobile phone use on aircraft during flight using systems that control the phone output power.

Traffic accidents

Research has shown an increased risk of traffic accidents, some 3-4 times greater chance of an accident, when mobile phones (either handheld or with a "hands-free" kit) are used while driving due to distraction.

Conclusions

While an increased risk of brain tumours from the use of mobile phones is not established, the increasing use of mobile phones and the lack of data for mobile phone use over time periods longer than 15 years warrant further research of mobile phone use and brain cancer risk. In particular, with the recent popularity of mobile phone use among younger people and therefore a potentially longer lifetime of exposure, WHO has promoted further research on this group and is currently assessing the health impact of RF fields on all studied endpoints.

Source – http://www.who.int/features/qa/30/en/

5G mobile networks and health

What is 5G?

5G, or fifth generation, is the latest wireless mobile phone technology, first widely deployed in 2019. 5G is expected to increase performance and a wide range of new applications, including strengthening e-Health (telemedicine, remote surveillance, telesurgery).

What are the main differences between 5G and previous technologies?

5G represents an evolution in telecommunication standards. To enable increased performance, 5G will extend into higher frequencies around 3.5 GHz and up to a few tens of GHz. The higher frequencies are new to mobile phone networks, but are commonly used in other applications, such as point-to-point radio links and body-scanners for security checks.

At these higher frequencies, 5G networks will use a greater number of base stations and of connected objects. 5G will further employ beam-forming antennas to focus signals more efficiently towards the device in use, rather than having the signal spread in broad directions as in current base station antennas.

Exposure Levels

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

What are the potential health risks from 5G?

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

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

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

What are the International Exposure Guidelines?

Two international bodies produce exposure guidelines on electromagnetic fields. Many countries currently adhere to the guidelines recommended by:

The International Commission on Non-Ionizing Radiation Protection and,

The Institute of Electrical and Electronics Engineers, through the International Committee on Electromagnetic Safety

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

What is WHO doing?

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

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

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

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

Relevant links

WHO Radiation health topic

WHO EMF website

National regulations on exposure to EMF

WHO fact sheets

On mobile phones

On base stations

6.2 Do mobile phones emit radiation?

Yes, mobile phones transmit radio frequency fields usually referred to as a radio frequency signal.

6.3 How much power does a mobile phone transmit?

Mobile phones use low power transmitters that are less than 2 watts peak. Mobile phones are designed to automatically transmit at the lowest possible power to maintain a quality connection. This is a feature known as adaptive power control.

6.4 How does adaptive power control work?

Adaptive power control is a process of adjusting the output power level of a mobile phone to match variations in the strength of the signal received from the base station. These variations in signal strength may be caused by changes in distance between the mobile user and the base station and the surroundings of the mobile phone user such as buildings, trees and other obstacles.

The aim of adaptive power control is to adjust the output power of the mobile phone so that the average power received at the base station from each user is generally constant. Adaptive power control works for both the mobile phone and the base station signal.

The mobile phone assesses the strength of the base station signal and communicates that information back to the base station which initiates a series of power control commands that are used to continuously increase or decrease the output power level of the mobile phone. A mobile phone user does not perceive any change in voice and service quality during the call as the power varies.

6.5 Does the EMF from my mobile vary?

Yes. The EMF level from mobile phones will vary during use as they are designed to use the lowest possible power and automatically adjust the power depending on the environment. Mobile phones typically operate well below the maximum possible level.

6.6 What are exposure levels from mobile phones?

RF exposure levels are directly proportional to the actual output power of a mobile phone during a call, or while sending and receiving data. In everyday use, the mobile phone output power is usually significantly lower than maximum output power due to adaptive power control.

Many factors can change the output power of a mobile phone and the intensity of exposure including technology, location, transit and usage of the phone. The output power levels of mobile phones used in rural areas can be higher than in urban areas due to the greater distance to the nearest base station. The average power inside a building can also be higher than outdoors as the building can attenuate the mobile reception. It is also quite common to have dedicated in-building mobile coverage systems these days in which case mobile phones will operate at the lowest possible power.

6.7 What is the typical power of a mobile phone?

The typical output power of a mobile phone ranges from 10 to 100 milli-watts (mW) which takes into account the operation of adaptive power control. Note that in rural areas typical powers may be higher.

References:

1) Output power distributions of terminals in a 3G mobile communication network http://onlinelibrary.wiley.com/doi/10.1002/bem.20710/abstract

2) Determinants of mobile phone output power in a multinational study: implications for exposure assessment.
http://www.ncbi.nlm.nih.gov/pubmed/19465409

6.8 How can I reduce exposure from my mobile?

Mobile phones are designed to operate automatically at the lowest possible power minimizing exposure. However there are some additional steps as outlined by the WHO you can take to further reduce exposure.

The WHO notes that:

> *"In addition to using "hands-free" devices, which keep mobile phones away from the head and body during phone calls, exposure is also reduced by limiting the number and length of calls. Using the phone in areas of good reception also decreases exposure as it allows the phone to transmit at reduced power."*
>
> Source: http://www.who.int/mediacentre/factsheets/fs193/en/

Figure 14 shows personal exposure from mobile devices Refer to ITU-T K-series Recommendations – Supplement 13 for additional information.

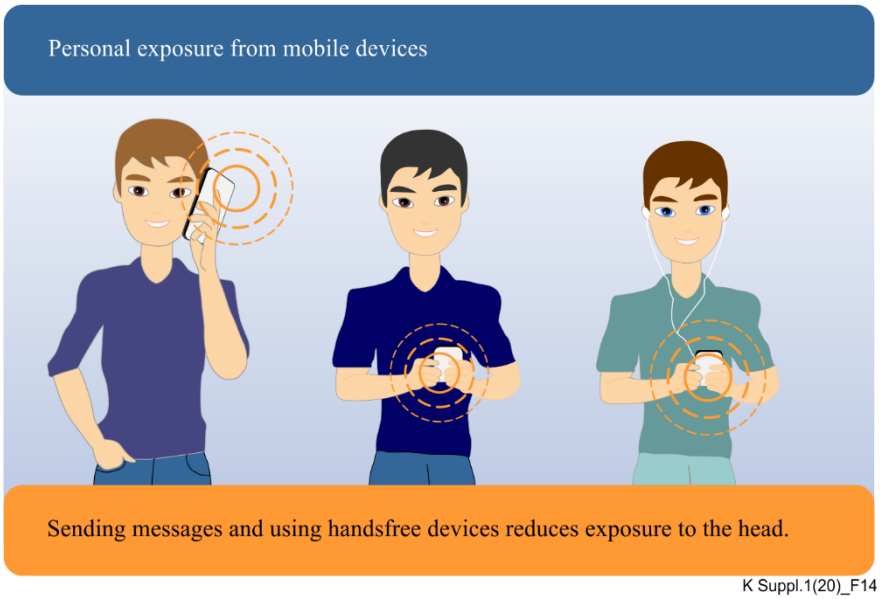


Figure 14 – Personal exposure from mobile devices

6.9 Do mobile phone shields reduce exposure?

No. Mobile phones are designed to use the lowest possible power to connect to the nearest base station and automatically adjust the power depending on the environment.

If a shield or other device is placed on a mobile phone to reduce exposure, the shield will effectively block part of the radio signal (or reception) and the phone will automatically adjust the power to compensate for any loss of signal.

The WHO notes that:

> *"The use of commercial devices for reducing radiofrequency field exposure has not been shown to be effective."*
>
> Source: http://www.who.int/mediacentre/factsheets/fs193/en/

6.10 Do mobiles radiate less EMF when close to a base station?

Yes. Mobile phones use the lowest possible power when in a good reception or coverage area. This is typically when close to a mobile base station as the phone only has to transmit over a short distance back to the nearest base station.

Mobile networks automatically adjust the mobile phone and base station power required to maintain a connection. So mobile phones produce the lowest EMF when in a good coverage area and close to a base station.

6.11 Do mobiles have less EMF when the signal display has full bars?

Yes. Mobile phones operate at the lowest possible power in areas of good reception.

6.12 Does texting have lower exposure compared to calls?

Yes. An SMS message is sent using a very short data transmission and the mobile phone is physically away from the head.

In terms of exposure levels the WHO notes that:

"A person using a mobile phone 30–40 cm away from their body – for example when text messaging, accessing the Internet, or using a "hands free" device – will therefore have a much lower exposure to radiofrequency fields than someone holding the handset against their head."

Source: http://www.who.int/mediacentre/factsheets/fs193/en/

6.13 Are we at a high risk of EMF exposure when using mobile phones inside high speed transportation?

If the mobile phone reception is poorer the EMF transmissions of a handset increases to connect to a base station. Some high speed trains, buses and aeroplanes have inbuilt mobile repeater cells that provide good coverage inside and mobile phones will operate at a lower SAR. Where the high speed transport is further away from good mobile phone reception, the handset power and exposure will increase during calls.

6.14 Is using a mobile phone in the car or at home safer because these constitute a barrier to radiation?

If the mobile network reception is lower inside a car or house, a mobile phone may increase the transmitter power to maintain a quality connection. Mobile phones continuously adjust the transmitter power depending on reception quality and are designed to operate at the lowest power possible.

Mobile phones are tested for compliance to the human exposure standards at their highest possible power level. Variations in transmitter power do not mean that there are variations in safety.

An external car antenna can be used to improve the mobile phone reception and reduce the exposure levels inside a vehicle.

6.15 Are children more vulnerable to the EMF from mobile phones than adults?

This is a very important question and the focus of ongoing research.

The WHO notes that studies into long term health effects are ongoing and to date no causal relationship or health effect has been established for children.

Young children can absorb more EMF primarily due to the physical proximity of a mobile phone when making a call and the relative smaller head size of children.

For additional information refer ITU-T K-series Recommendations – Supplement 13.

A number of health agencies recommend restricted mobile phone use for children. Children can use a headset, hands-free, speaker phone or SMS options to reduce exposure. For examples, please see the list below:

National health agency information on mobile phones and children

Public Health England
http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317133827077

European Commission
http://ec.europa.eu/health/scientific_committees/opinions_layman/en/electromagnetic-fields07/l-2/3-mobile-phones-cancer.htm

The Health Council of the Netherlands
http://www.gezondheidsraad.nl/en/publications

Scientific Council of Swedish Radiation Safety Authority (SSM)
http://www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Stralskydd/2014/SSM-Rapport-2014-16.pdf

US Food and Drug Administration
http://www.fda.gov/radiation-emittingproducts/radiationemittingproductsandprocedures/homebusinessandentertainment/cellphones/ucm116331.htm

The Royal Society of Canada
https://rsc-src.ca/en/expert-panels/rsc-reports/review-safety-code-6-2013-health-canadas-safety-limits-for-exposure-to

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
http://www.arpansa.gov.au/pubs/technicalreports/tr164.pdf

Statement from the Nordic Radiation Safety Authorities
http://www.nrpa.no/dav/1ce2548717.pdf

Swedish Council for Working Life and Social Research (FAS)
http://www.fas.se/en/News/2012/10-years-of-research-on-the-health-risks-of-radiofrequency-fields/

Norwegian Institute of Public Health – Folkehelseinstituttet (FHI)
http://www.fhi.no/dokumenter/6563fe9a33.pdf

Scientific Advisory Committee on Radio Frequencies and Health, CCARS (Spain)
http://www.ccars.es/en/news/there-no-scientific-evidence-wifi-systems-produce-adverse-health-effects-schoolchildren

7 Base stations and EMF FAQ

7.1 What are the EMF levels around base stations?

EMF levels in the community and environment from base stations are typically low and similar to the background levels from other radio transmissions like TV and radio broadcast. Base station antennas are usually mounted on top of structures such as towers, poles and buildings.

The World Health Organization monitors the scientific research on EMF including studies on EMF levels around base stations.

In terms of EMF levels around base stations and in the environment the WHO notes that:

> *"Even today, the phone towers themselves add little to our total exposure, as signal strengths in places of public access are normally similar to or lower than those from distant radio and TV stations."*
>
> *"Many surveys have demonstrated that exposure to electromagnetic field levels in the living environment is extremely low."*
>
> *"Recent surveys have shown that RF exposures from BS range from 0.002% to 2% of the levels of international exposure guidelines, depending on a variety of factors such as the proximity to the antenna and the surrounding environment."*
>
> Source: WHO Typical Exposure Levels in the Home and Environment http://www.who.int/peh-emf/about/WhatisEMF/en/index3.html
>
> Source: WHO Backgrounder 2006 http://www.who.int/peh-emf/publications/facts/fs304/en/

7.2 Is it safe to live near a base station, or to locate base stations near schools?

Yes. It is safe to live near a base station as they operate at low power, produce low EMF exposure levels in public areas and are specifically designed for the environment they are located in.

The WHO notes that:

"Considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects."

"Studies to date provide no indication that environmental exposure to RF fields, such as from base stations, increases the risk of cancer or any other disease."

Source:

WHO Backgrounder 2006 http://www.who.int/peh-emf/publications/facts/fs304/en/
WHO Online Q&A September 2013 http://www.who.int/features/qa/30/en/

In built-up urban and residential areas, base station antennas are typically located above building rooftops or at a sufficient distance from nearby buildings, and small cells are located typically at street level to provide dedicated coverage at lower heights. Low powered base stations are often located inside apartment and city buildings to provide dedicated mobile coverage.

Higher powered base stations are located in rural and country areas to provide extended coverage and are usually mounted on taller structures or towers.

Base stations are designed and operated so that people are not exposed above the recommended limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Measurements of EMF by regulatory authorities in many countries indicate that exposure levels in public areas are typically below the ICNIRP guidelines.

7.3 Do more base stations reduce EMF?

Yes. As a matter of fact, by increasing the number of base stations and locating them near where people use mobile phones actually reduces EMF levels. This is because the mobile phones only need to transmit over a short distance to the nearest base station using less power and the network is also operating more efficiently only needing to communicate with nearby users.

So to minimise EMF requires base stations located close to users.

7.4 Is it safe to locate base stations on hospitals?

Yes. Many hospitals have base stations located on the rooftop and dedicated in-building mobile systems to provide the best coverage inside the hospital. The in-building system means that mobile phones inside the hospital also operate at the lowest possible power.

7.5 Are there restricted areas in front of base station antennas?

Yes. Base station antennas typically have an area directly in front of the antenna where the radio frequency field level will exceed the human exposure limits recommended by ICNIRP. These restricted areas are typically not accessible to the public as the base station antennas are mounted well clear of public areas.

Mobile network operators need to ensure that restricted areas around base stations are incorporated into the site design.

8 EMF exposure limits FAQ

8.1 Who sets the EMF human exposure limits and standards?

Countries set their own national standards for exposure to electromagnetic fields. However, the majority of these national standards draw on the guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). This non-governmental organization, in formal relations with the WHO, evaluates scientific results from all over the world.

Based on an in-depth review of the literature, the ICNIRP produces guidelines recommending limits on exposure. These guidelines are reviewed periodically and updated if necessary.

8.2 Is there a safety margin built into the human exposure limits?

Yes. A safety margin is built into the limits recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The ICNIRP applies a safety factor of 10 to derive EMF worker exposure limits and a factor of 50 to obtain the guideline value for the general public.

The reduction factor is designed to account for any scientific uncertainties, see Figures 15 and 16.

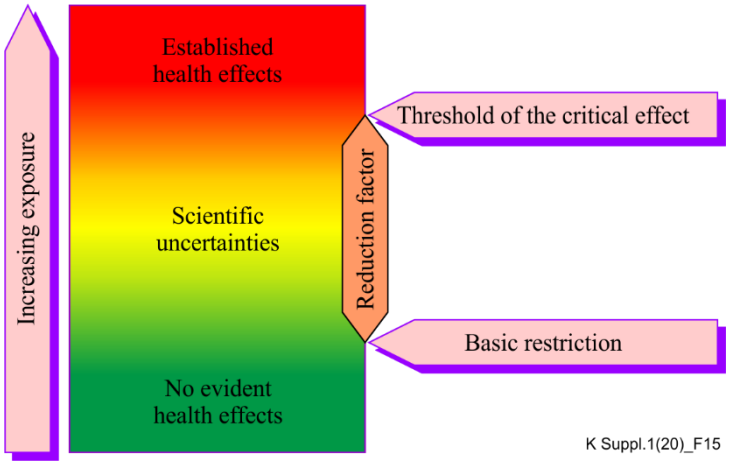
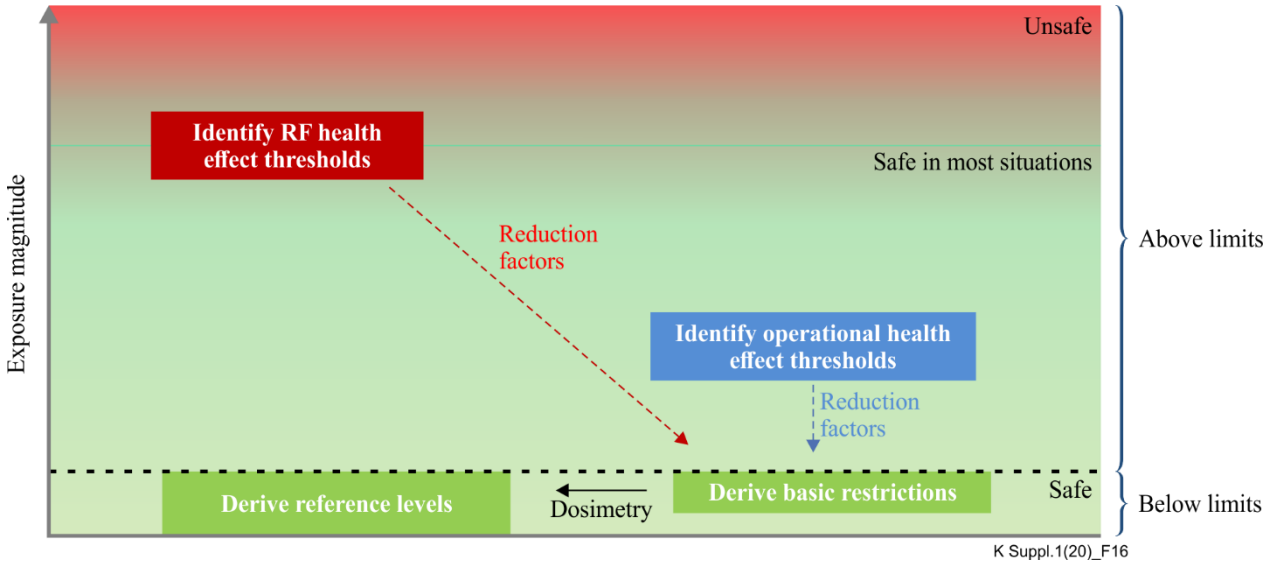


Figure 15 – ICNIRP exposure limits and reduction factor (ICNIRP 1998)



Source – ICNIRP (1998 p. 511, Tables 6 and 7; see section 16.2. Reference Levels)
Source – WHO current standards http://www.who.int/peh-emf/about/WhatisEMF/en/index4.html
Source – ICNIRP (2020 , Tables 5 and 6; see section 16.2. Reference Levels)

Figure 16 – ICNIRP exposure limits and reduction factor (ICNIRP 2020)

8.3 Are children and pregnant women protected by the safety standard?

Yes. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) EMF exposure guidelines are based on careful analysis of the scientific literature and are designed to offer protection for all ages including children and pregnant women against identified health effects of EMF with a large in-built safety margin. The ICNIRP (2020) guidelines say that a pregnant RF Worker should not exceed the public limits to ensure that the fetus complies with the public limits.

8.4 Are people with electronic implants protected by the safety standard?

Not in all cases. Electronic implants usually come with safety information on the risk of potential interference from electrical and electronic equipment including mobile phones and radio transmitters.

Specific radio frequency interference and immunity standards have been developed to provide protection against interference to electronic implants.

People with implants should consult their medical specialist on the risk of interference if they are concerned. The ICNIRP human exposure guidelines are not designed to protect against interference to electronic equipment.

9 EMF myths FAQ

9.1 Is it possible to cook an egg or grains of corn using a mobile phone?

No. The EMF exposure produced by mobile phones is weak and cannot cook an egg or grains of corn. The videos posted on the Internet are made for advertising or entertainment purposes by hobbyists who create a montage by superimposing segments to alter reality or by some companies that market video clips via Bluetooth for commercial purposes.

Although theoretical calculations of the output from mobile phones confirm that these claims are false, a number of international research centres nevertheless conducted the same experiment, under laboratory conditions, in order to reassure people, refute these rumours and remove the anxieties surrounding them.

For a period of 65 minutes, an egg was subjected to a concentrated exposure ten times that of the power output from a mobile phone. When the egg was cracked open, it was found that the energy had had no effect on it. Another entity took 200 mobile phones and placed them adjacent to an egg, with no effect on the egg.

9.2 Is the power output of a mobile phone enough to make the brain boil?

No. The maximum power output of mobile phones is 2 watts and in most cases, much less than that (an average of 0.25 watts).The thermal effect of electromagnetic waves may cause a slight warming of the body, comparable to the warming that results from physical exercise or exposure to the sun's rays. But it cannot make the brain boil.

Note that the heat produced by a mobile phone is not only caused by wireless transmission. Some types of device produce a very slight amount of heat due to battery warming, when used for a long period of time.

9.3 Does use of a mobile phone attract lightning?

It is well known that electric charge-bearing clouds discharge their energy to earth through the closest conductor to the ground, whether a lamppost, electricity pylon, tree, building or person. The probability of a person being struck by a thunderbolt is very small, particularly in places where there are buildings, poles, trees, etc.

Mobile phones, whether in use or not, are not instrumental in exposing people to lightning strikes during rain or thunderstorms. Nevertheless, people should not move about during thunderstorms in places where there are no elevated structures to conduct electricity, such as open country and desert, as they may be exposed to lightning strikes, which often hit the structures or bodies closest to them on the ground.

9.4 Can a mobile phone cause a gas station to catch fire?

No. There is no causal link between the EMF exposure produced by mobile phones and a gas station catching fire. According to information published by the UK-based Institute of Petroleum and a report by the Australian Transport Safety Bureau, there is no evidence to prove that a mobile phone has ever caused a gas station to catch fire.

10 ITU EMF resources

As part of its mandate, the ITU carries out a series of activities on human exposure to electromagnetic fields.

ITU-T activities on EMF

ITU-T EMF Flyer

ITU-T EMF Estimator

ITU-T Recommendations on EMF

11 Additional EMF resources

11.1 WHO resources

WHO EMF Home

WHO Information on 5G

WHO Q&A – Mobile phones and base stations

WHO Fact sheet 193- Electromagnetic fields and public health: mobile phones

WHO Fact sheet 304 – Base stations and wireless networks

WHO Standards and Guidelines

11.2 ICNIRP resources

ICNIRP website

ICNRP EMF publications

11.3 National government resources

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

Japan Ministry of Internal Affairs – Protection from Radio Wave Environment

Korea, National Radio Research Agency

UK Government Information

Health Canada – Safety of cell phones and cell phone towers

U.S. Food and Drug Administration

US Federal Communications Commission – FAQ Wireless Phones

India, Department of Telecommunications

11.4 Non-government organizations

Japan EMF Information Centre (JEIC)

EMF Portal

11.5 General resources

ITU http://www.itu.int

World Health Organization http://www.who.int/

EMF Explained Series http://www.emfexplained.info/

Mobile Wireless Forum http://www.sartick.com/

GSMA http://www.gsma.com/emf

Australian Mobile Telecommunications Association http://www.amta.org.au/

12 About this Guide on electromagnetic fields and health

The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies (ICTs).

This Guide has been developed by ITU with the contribution of its membership which comprises governments, private sector entities and academic institutions.

This Guide will be regularly updated based on new information or research made available by the ITU and WHO.

For additional information, please contact ITU-T Study Group 5 (tsbsg5@itu.int).

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