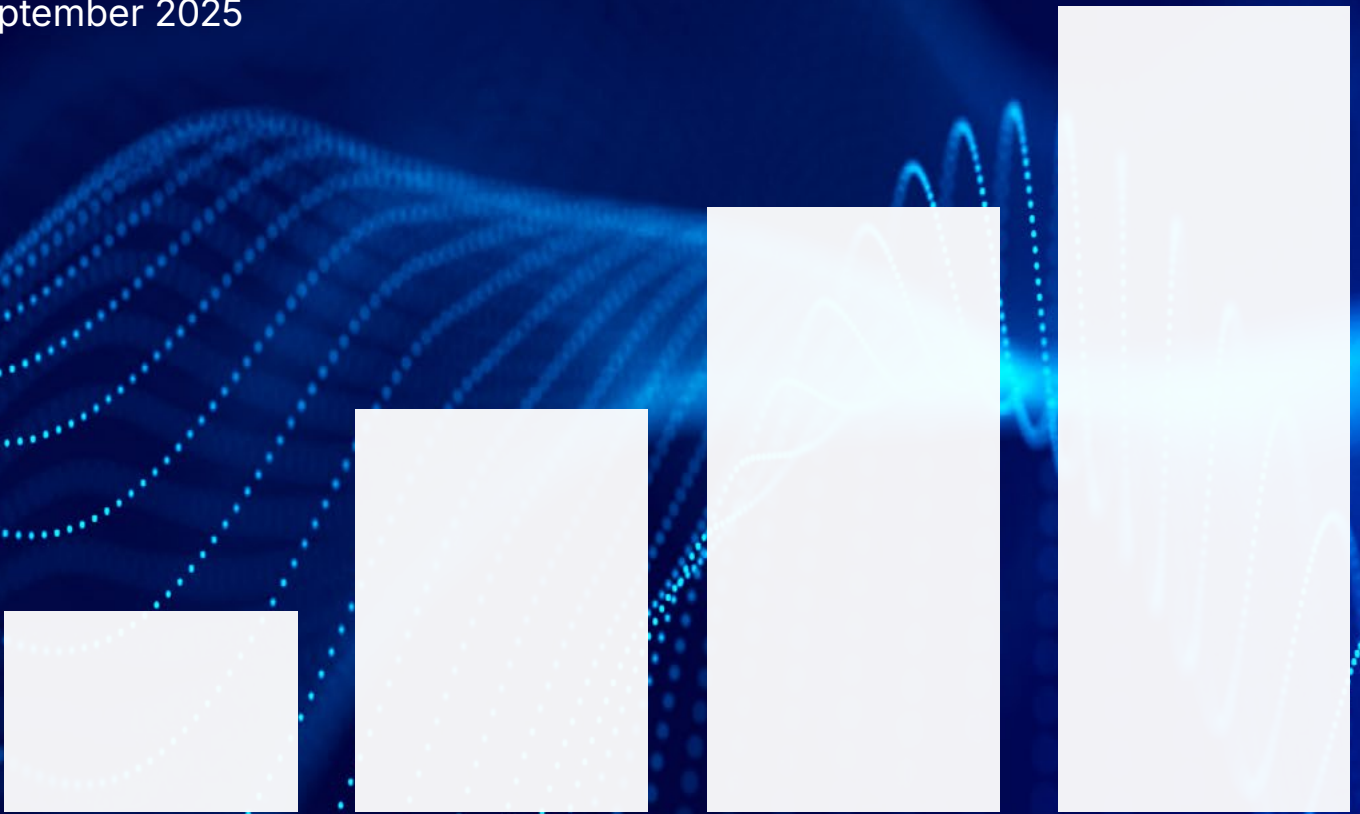


Mobile Technology Evolution: Information on radiofrequency electromagnetic field exposure

September 2025





The GSMA is a global organisation unifying the mobile ecosystem to discover, develop and deliver innovation foundational to positive business environments and societal change. Our vision is to unlock the full power of connectivity so that people, industry and society thrive. Representing mobile operators and organisations across the mobile ecosystem and adjacent industries, the GSMA delivers for its members across three broad pillars: Connectivity for Good, Industry Services and Solutions, and Outreach. This activity includes advancing policy, tackling today's biggest societal challenges, underpinning the technology and interoperability that make mobile work, and providing the world's largest platform to convene the mobile ecosystem at the MWC and M360 series of events.

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Context



Increased mobile connectivity is transforming society, enabling changes in the way we live and do business, through new applications relying on mobile networks. Mobile network technologies continue to evolve from 5G (the 5th generation of mobile technology) to 5G Standalone and 5G-Advanced; and the future 6G with its potential for enhanced computing, wireless positioning and sensing capabilities¹. The GSMA produced this publication to address questions about exposure to the radiofrequency (RF) electromagnetic fields (EMFs) used by mobile networks and connected devices. The first document section deals with the mobile technology roadmap. This is followed by the Internet of Things (IoT) and wearable devices. The final section looks at general questions about RF-EMF exposure.

Wireless networks and devices exchange information (e.g., voice or data) via radio waves – a form of electromagnetic energy. Radio waves are part of

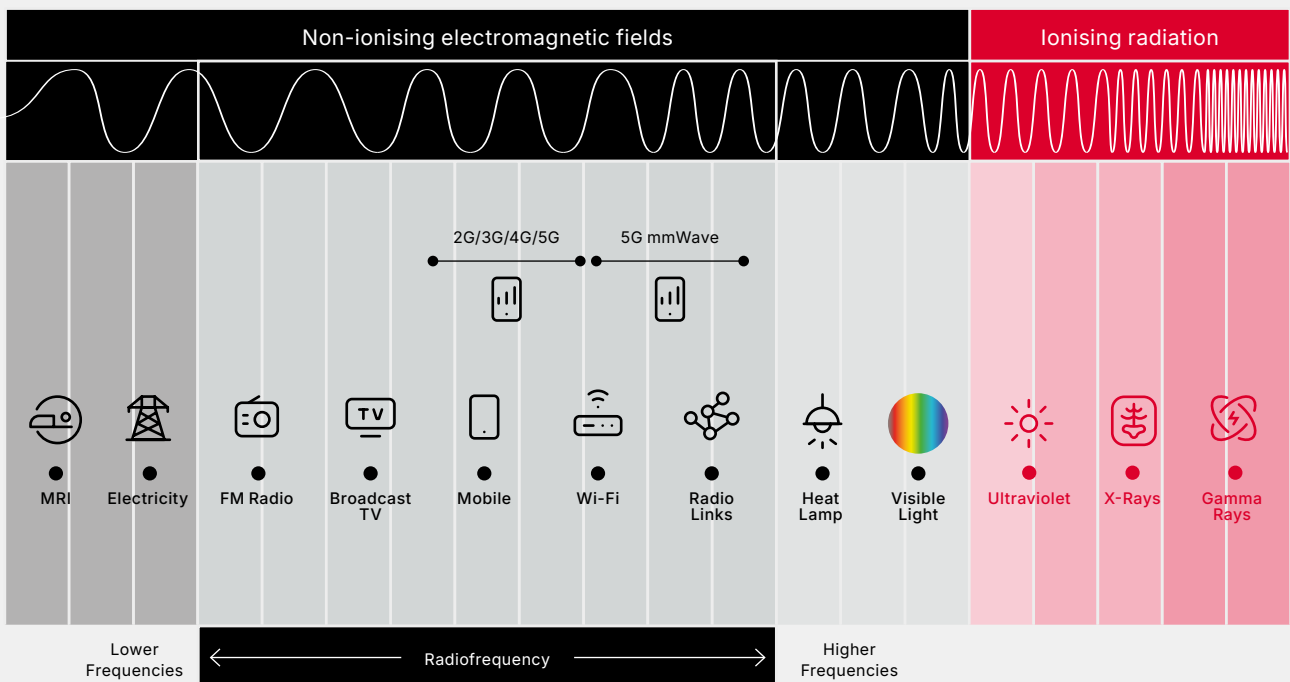
everyday life, emitted both by natural sources like the Sun and the Earth; and by artificial sources such as: wireless networks, TV and broadcast radio. Radio waves are non-ionising, which means that they cannot directly impart enough energy to a molecule to break or change chemical bonds. They are different from x-rays, which are part of the ionising portion of the electromagnetic spectrum. See Figure 1 for additional information.

Mobile technologies are designed to comply with RF-EMF exposure limits. The international exposure guidelines are based on the work of researchers for many decades. The guidelines are not technology specific and are periodically reviewed. The consensus of reviews by independent public health authorities, expert groups and the World Health Organization (WHO) is that these guidelines provide protection for all people against all established health hazards.

Figure 1

The electromagnetic spectrum showing 5G and other radio signals

International radiofrequency guidelines (100 kHz to 300 GHz)



¹ Known as Integrated Sensing And Communications (ISAC). Pre-standards research work is underway, for example at ETSI, <https://www.etsi.org/committee/2295-isac>

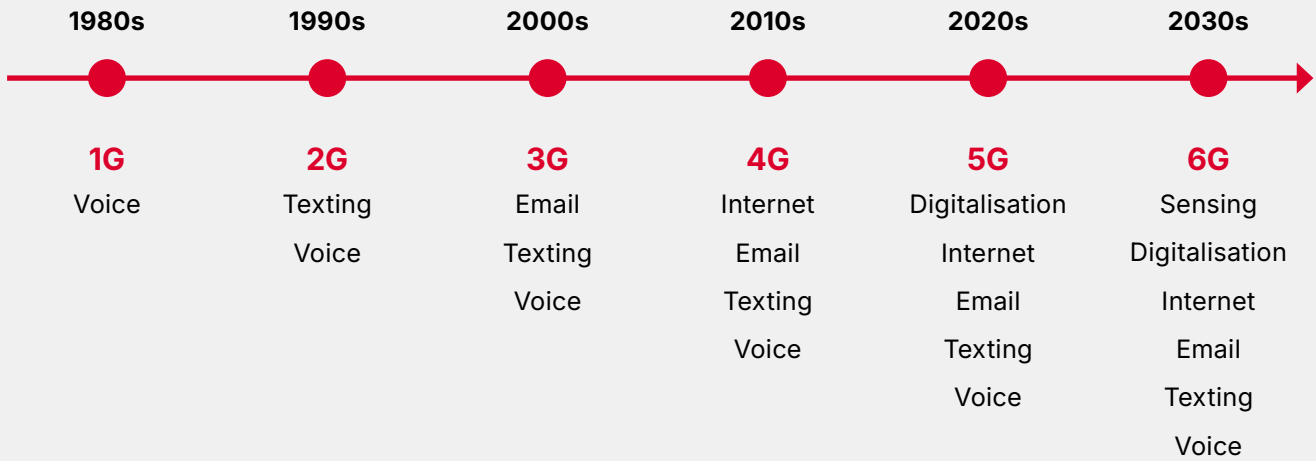
Mobile technology roadmap



As 2G and 3G networks are being phased out, the main current mobile technologies are 4G and 5G. 5G was launched in 2019, with the standardisation work on 5G-Advanced starting in 2022. Work is underway to define the next phase of mobile technology evolution (6G) that is expected to launch in the 2030s. This is a continuation of mobile technology evolution as seen in Figure 2.

Figure 2

Mobile technology evolution



5G

5G New Radio (NR) is the current generation of mobile technology offering higher data rates and lower latency (less delay) connections compared to 4G. 5G utilises and integrates a mixture of spectrum and radio access networks to meet users' capacity and coverage needs.

Initial 5G deployments are generally in parallel with existing mobile technologies, and often in locations where the technology is needed to supplement the capacity of current networks. This allows users to continue using their devices without interruption. Further rollouts occur as demand dictates. A similar

pattern happened previously during the rollout of 3G and 4G.

Both 4G and 5G will coexist into the 2030s when the next evolution of mobile technologies (6G) is expected to be deployed.

Private 5G networks are possible, using network slicing (virtual network on top of physical network) or spectrum licensing. These networks are covered by the same RF-EMF limits as public 5G networks.



5G-Advanced

The second phase of 5G is termed 5G-Advanced². It provides performance improvements, better network management and greater efficiency, and enhancement for specific use cases. This includes further integration of satellite (non-terrestrial network - NTN) access.

5G-Advanced provides all kinds of smart connectivity, including services that focus on uplink communication and connect people moving at high velocities, such as those on trains and on planes. Towards the end of the 5G roadmap network sensing of objects is expected to become available.

5G-Advanced supports dynamic switching between different massive MIMO (mMIMO) antenna configurations to increase network efficiency and reduce power consumption. 5G-Advanced also supports

user equipment (UE) enhancements that improve link-budgets for both terrestrial and satellite connections. Sidelink enhancements include mechanisms to support device-to-device communication, which is useful for public safety, industrial applications, and vehicle-to-everything (V2X) services.

One of the key stepping stones to 5G-Advanced is the deployment of standalone 5G networks. Many initial 5G deployments are in non-standalone mode, where the 4G core network supports the 5G radio access. The increased rollout of 5G standalone networks is likely to be followed by the first major wave of 5G-Advanced deployments. However, that doesn't mean that all operators will deploy these technologies throughout their networks.



² Find out more at <https://www.gsma.com/solutions-and-impact/technologies/networks/5g-network-technologies-and-solutions/5g-advanced/>

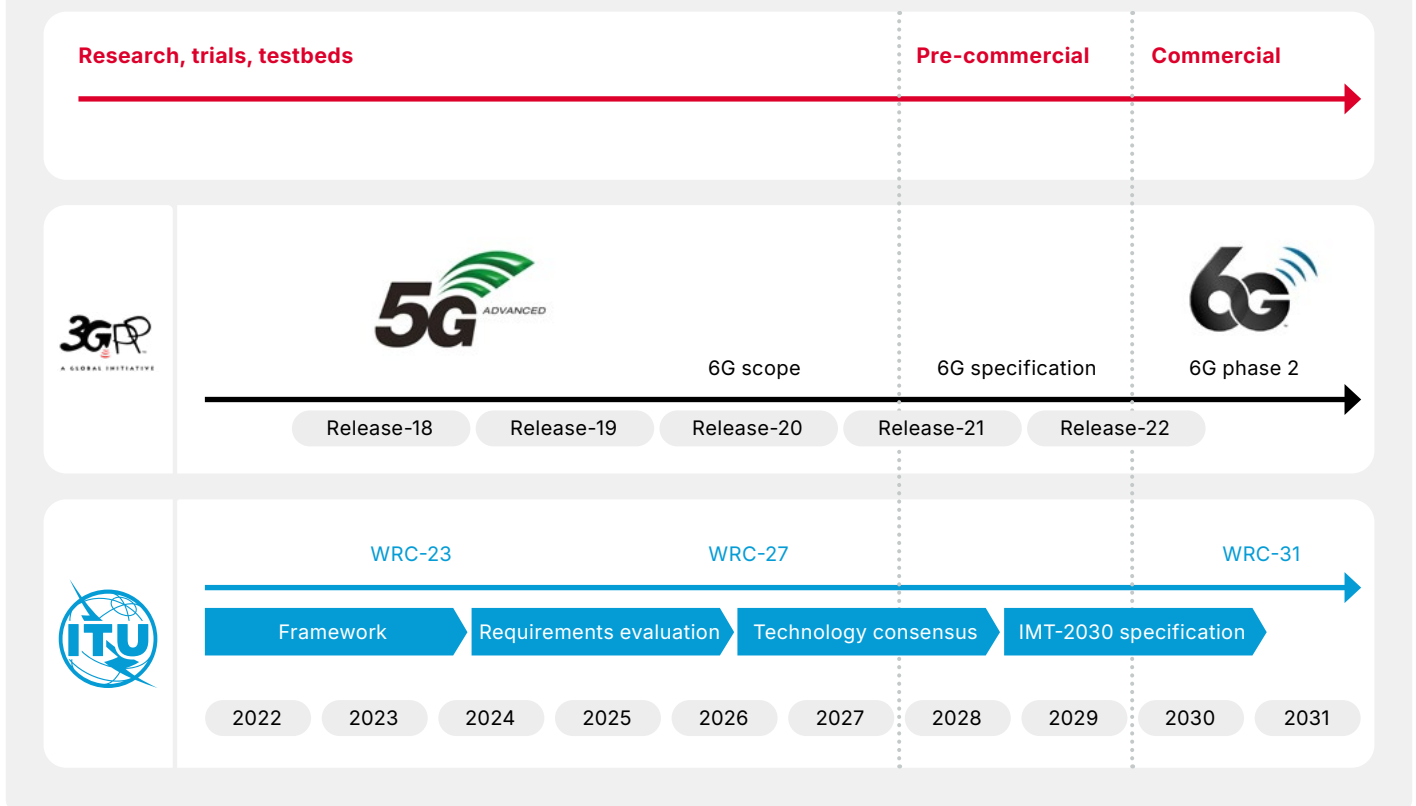


Beyond 5G to 6G

Even as 5G continues to be developed, the technical standards forum 3GPP, the International Telecommunications Union (ITU) and academic researchers are working to define the next mobile technology evolution, IMT-2030 in ITU speak, and which 3GPP terms 6G.

New and enhanced capabilities are expected for the next phase of mobile technology evolution. Exactly what those parameters will be are currently under discussion. The specifications for IMT-2030/6G are likely to be finalised in the late 2020s with commercial launches in the 2030s as shown in Figure 3.

Figure 3
5G and beyond 6G timeline forecast



Since the 1990s the ITU defines requirements for each mobile technology generation. In 2022, ITU³ set out a roadmap for the mobile technology generation (IMT-2030)⁴ to follow 5G. The ITU roadmap includes defining technical performance requirements, and a technology evaluation process, which will lead to adoption of IMT-2030 specifications around 2030. The ITU technical requirements are expected to be a combination of enhancements to existing technologies and new capabilities.

The standards development forum 3GPP produces the technical specifications for each mobile technology starting with 3G. The specifications are developed as Releases (Rel), and there can be more than one release for each mobile technology as the capabilities evolve. 3GPP Rel-15 was the first 5G specification ready for implementation. Rel-18 defines 5G-Advanced. A 3GPP workshop in late 2024 defined a timeline with 6G studies in Rel-20 to be completed by 2027 with the 6G technical specification expected in Rel-21 by the end of 2028⁵.

³ IMT towards 2030 and beyond (IMT-2030), ITU-R, <https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/pages/default.aspx>

⁴ IMT-2000, IMT-Advanced and IMT-2020 correspond to 3G, 4G and 5G respectively.

⁵ This is a forecast by some industry stakeholders, 3GPP plans to decide the Rel-21 timeline no later than June 2026.

Spectrum for mobile communications

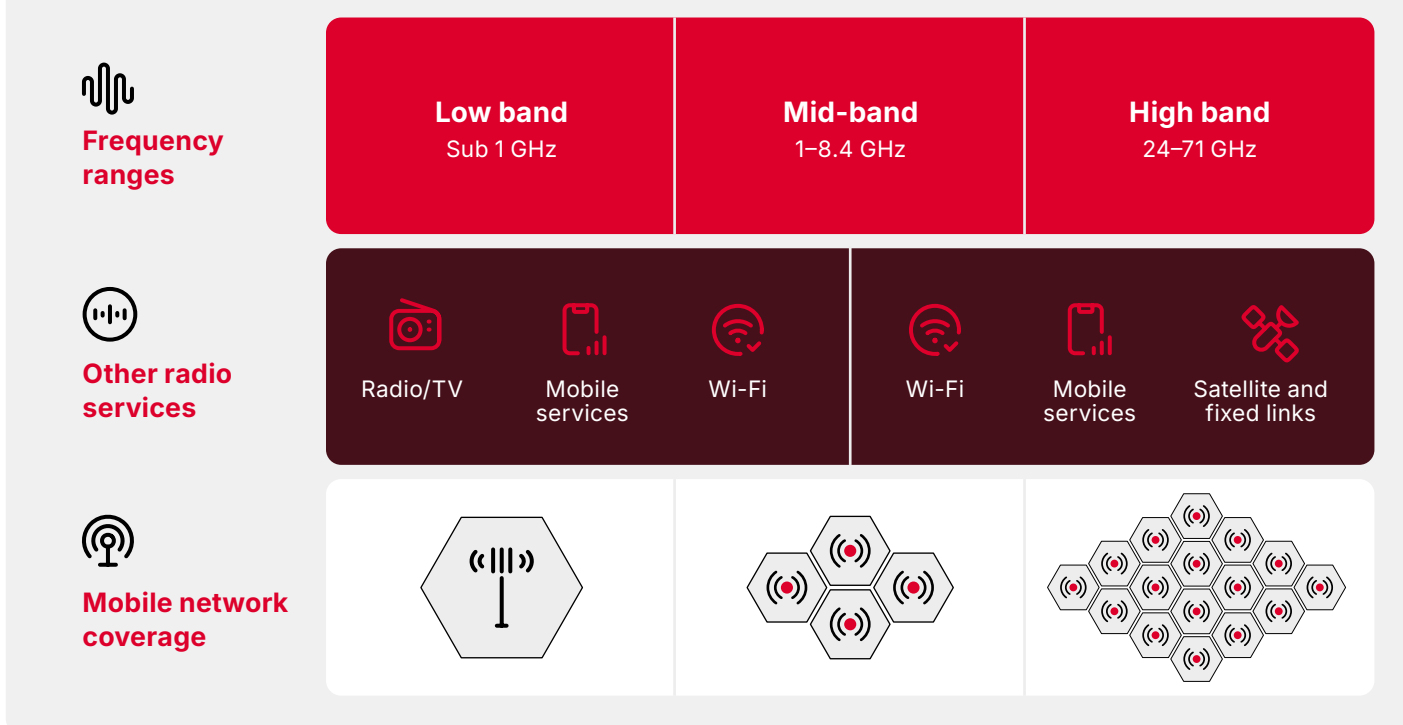
Consumers are realising the potential of 5G as it matures. The 5G launch band at 3.5 GHz is used by most networks for initial services but increased availability of harmonised spectrum will be required to meet growing demand. Figure 4 shows how 5G can be deployed in spectrum in three key frequency ranges to deliver widespread coverage and support enhanced services. The three ranges are: sub-1 GHz (low bands), 1–8.4 GHz (mid-bands) and above 24 GHz (high bands).

- Expanding low-band spectrum as much as possible is vital to giving rural communities equitable access to the services available in urban areas and pushing towards digital inclusion goals.

- Mid-band spectrum has been the main driver of 5G launches so far and is expected to help realise the largest portion of 5G's socio-economic benefits in the next decade. Meeting spectrum needs in this range is vital to 5G's future and requires a clear spectrum roadmap from policymakers.
- High-band spectrum can complement low and mid-band spectrum implementations in dense urban areas, where required, and can provide fibre-like connectivity through FWA. It can also be used for high-capacity industrial applications. mmWave helps ensure reliable, high-capacity networks in high-density locations, such as stadiums and transport hubs.

Figure 4

5G can be deployed in three key frequency ranges



The 3.5 GHz band is a new mobile band used for 5G launches, but 5G also uses spectrum bands that are refarmed from older mobile technologies. This means that many existing sites can be reused for 5G antennas. Older mobile technologies typically operate in several spectrum bands between 700 MHz and 2.7 GHz, all of which may be put into use for 5G in due course. However, 5G also needs new spectrum in wide channels like the 3.5 GHz band.

The GSMA supports technology neutrality, which enables new mobile technologies to be deployed in the bands used by older technologies. Long-term spectrum roadmaps, along with affordable technology neutral licences, are necessary to drive network investments.

What new frequency ranges are planned for mobile communications?

3GPP currently specifies 5G NR in two frequency ranges (FRs):

- FR1: frequencies in the spectrum range from 410 MHz to 7.125 GHz
- FR2: frequencies in the spectrum range from 24.25 GHz to 71 GHz.

Not all the frequencies for which 3GPP specifications exist are available in all countries.

Recently, the World Radiocommunication Conference in 2023 (WRC-23) identified the 6 GHz band (6.425–7.125 GHz) for mobile services. Testing and commercial licensing are underway for this band in different parts of the world.

In the future, WRC-27 will consider spectrum in various bands including 4.4–4.8 GHz, 7.125–8.4 GHz and 14.8–15.35 GHz to cater for expanding mobile connectivity needs. This spectrum will be brought into use in the 2030s to cater for future capacity.

Researchers are exploring the potential of even higher frequencies, from 90 to 300 GHz, referred to as sub-terahertz (sub-THz) frequencies. These experimental frequencies offer large bandwidths, but limited range, and could support specific use cases. Currently, sub-THz frequencies are not specified for 6G by international technical standardisation bodies.

All the current and proposed mobile technology frequency ranges from 100 KHz to 300 GHz are covered by the ICNIRP (2020) guidelines.



Do the antennas used for 5G networks and future mobile technologies look similar to those on existing sites?

Many of the antennas used for 5G are the same or look similar to those already present in the environment. In some cases, operation at higher frequencies means that the size of antennas can be reduced. 5G and future mobile technologies can make greater use of antennas with more advanced beamforming capabilities. Beamforming involves combining the radio signal from multiple small antenna elements to improve performance. Higher frequencies allow for more small antenna elements for the same overall antenna size. This can mean an increased antenna gain that compensates for the higher propagation loss.

As shown in Figure 5, a conventional base station antenna transmits a radio signal to a wide area regardless of how many users are connected, similar to how a floodlight illuminates a wide area. Advanced antennas with beamforming transmit radio signals to connected users reducing network interference and RF-EMF levels in other directions, like a flashlight providing light where it is needed. These antennas increase network capacity and improve efficiency.

The beamforming technology is also called massive MIMO (mMIMO - Multiple-Input Multiple-Output), where massive refers to the large numbers of small antenna elements inside each base station antenna. Operator tests have shown that advanced antennas can serve many more users for the same amount of spectrum bandwidth.

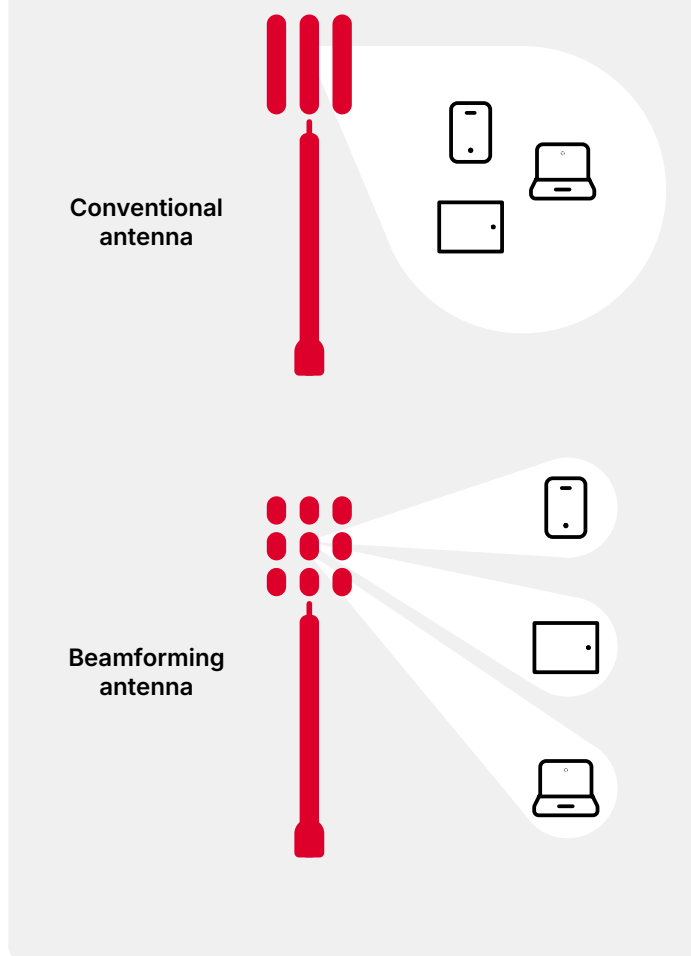
Does the evolution of mobile networks mean an antenna on every street corner and inside all buildings?

The coverage and capacity objectives of 5G combined with advanced antenna technologies and new frequency ranges means that some new antennas are required. Where possible an operator places these antennas at an existing site and at other times new locations are required.

As illustrated in Figure 6 mobile networks consist of a mix of macrocell sites to provide wide area coverage and small cells to improve localised coverage and increase capacity. Satellite (non-terrestrial network - NTN) services may be available to provide supplemental services in areas outside the reach of terrestrial mobile networks.

Figure 5

Advanced antenna technologies

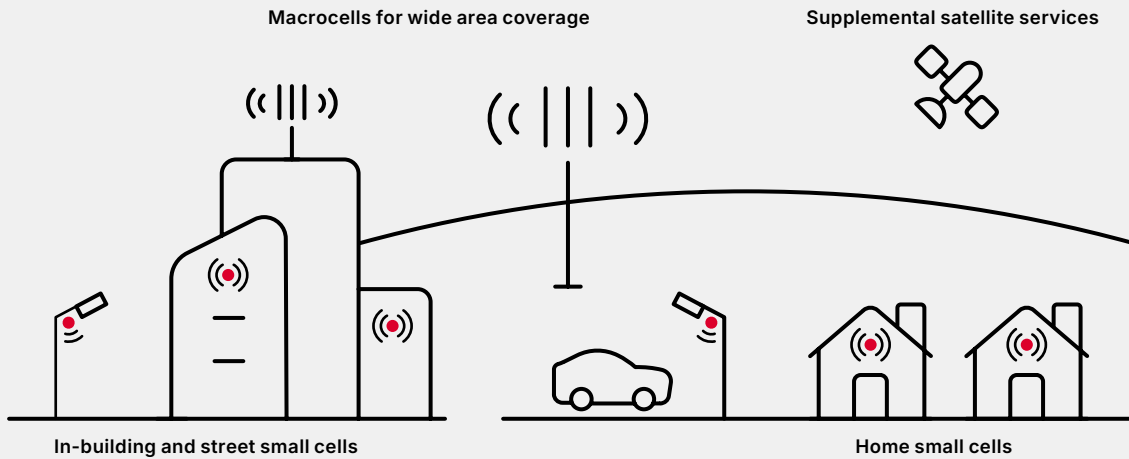


'Small cells' is an umbrella term for operator-controlled, low-powered radio communications equipment (base stations) that provide mobile and internet services within localised areas. Small cells typically have a low visual impact and have a range from ten metres to several hundred metres. Mobile network macrocells typically serve larger areas, up to 15–20 kilometres.

Small cells can be used for both coverage and capacity objectives. As small cells are close to the users of mobile phones, it means that phones operate more efficiently, improving the available data rate and reducing the exposure of the user. Measured RF-EMF levels close to small cells may be increased but overall the levels are similar to those from other mobile network antenna installations.

Figure 6

Representation of the mix of mobile network cell types



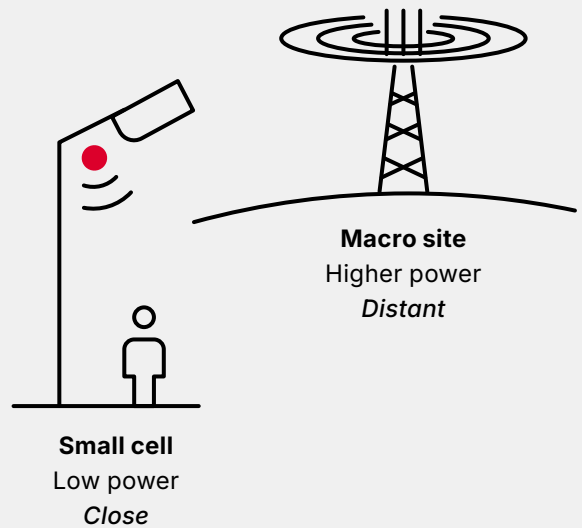
Globally more than 70% of mobile data use occurs indoors. Energy efficient glazing used in modern buildings can substantially reduce radio signals. Dedicated coverage inside buildings may be provided by small cells, in-building coverage (IBC) or distributed antenna system (DAS) approaches.

Site sharing with other radio installations or existing structures, where technically feasible and in line with competition law and licensing conditions, is factored into decisions on the most environmentally appropriate base station solution. This means fewer new sites, saving on cost of equipment and operating the network. Appropriate siting and design may reduce the visual profile of antennas.

Technical studies demonstrate that efficient mobile network deployment involves a mix of macro sites and small cells according to coverage and capacity requirements. It is important that network operators have flexibility with network design to provide the most relevant connection adapted to the needs of users and that operators are not restricted by mandated technical solutions.

Figure 7

RF-EMF levels from small cells are similar to those from macro sites



Internet of Things and wearable devices



The Internet of Things (IoT) describes the coordination of multiple machines, devices and appliances connected to the internet through wired and wireless networks. These include everyday objects such as smartphones, tablets and other consumer electronics, and machines such as vehicles, equipped with IoT connectivity that allows them to send and receive data. Machine-to-machine (M2M) refers to services that are enabled by the communication between two or more machines. The term sensors is being increasingly used, and wireless sensing - using changes in radio waves to detect the environment - is in the 5G and 6G roadmap. Many of the new wireless applications in the areas of IoT and wearable devices operate at very low powers and often transmit only intermittently.

Internet of Things (IoT)

A key design expectation of IoT enabled devices is that they will operate at low powers with battery life of up to 10 years in some applications. This is possible because they will only transmit small amounts of information, using very low power and the transmissions will not be continuous. The transmission interval and the amount of data will depend on the application.

Some consumer devices like smart lighting and toys use familiar technologies such as Wi-Fi and Bluetooth. These transmitters are generally low power and short range.

How is RF-EMF compliance testing done for IoT devices?

IoT devices operating above 30 MHz are covered by existing international technical compliance testing standards for wireless devices and networks.

Some IoT devices will be exempt from testing because their very low power combined with intermittent transmission, see Figure 8, means that they are certain to comply with the relevant exposure limits.

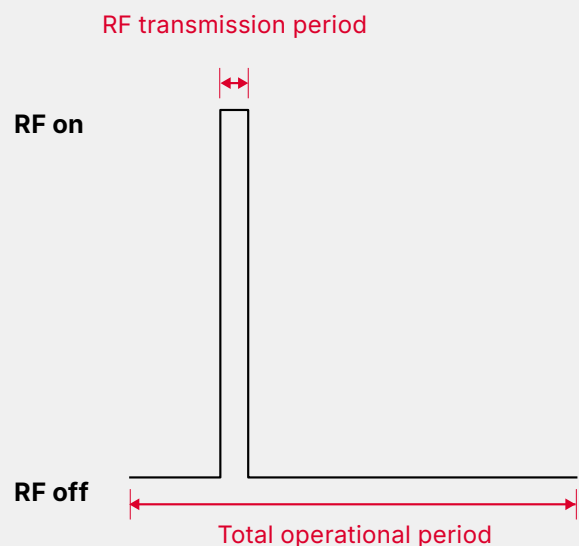
EXAMPLE:

Assume an IoT device able to transmit 10 to 25 kbits of data with a maximum peak power of 200 mW and a duty cycle of 1%. This would be more data than required for many IoT applications. If this data transmission occurs continuously for the six-minute averaging period in the international RF-EMF exposure guidelines the average transmitted power is 2 mW.

This is 10 times below the threshold average power of 20 mW at which testing is required by some standards. Such a device would not require compliance testing.

Figure 8

Illustration of an IoT device duty cycle



$$\text{Duty cycle (\%)} = \frac{\text{RF transmission period}}{\text{Total transmission period}} \times 100$$

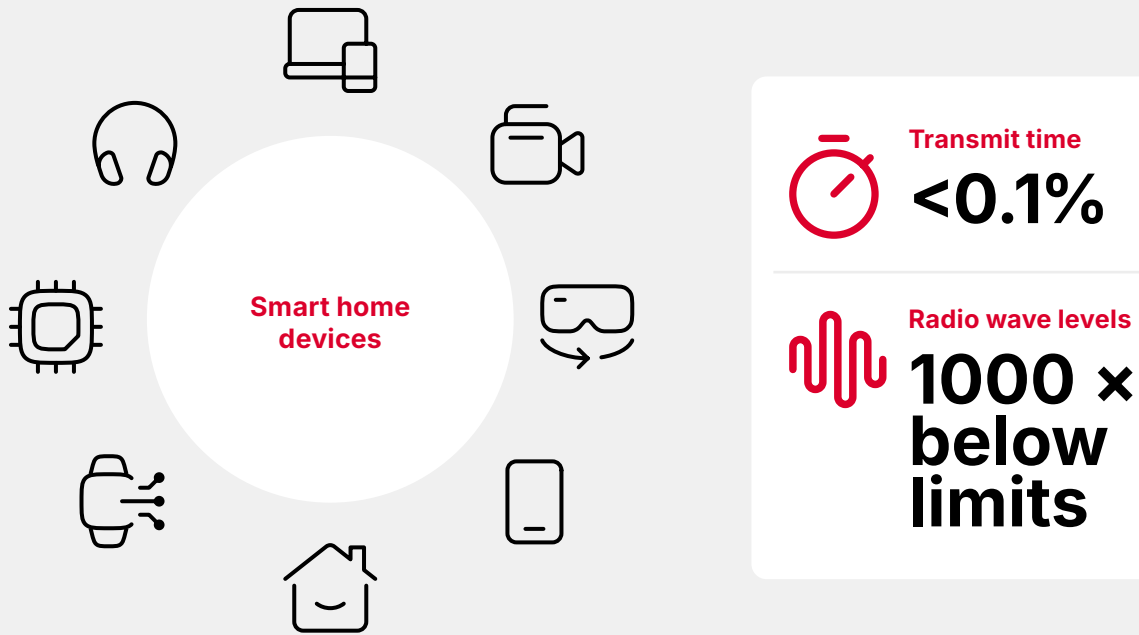
Will large numbers of connected objects increase exposure to radio signals?

The RF-EMF levels do not change significantly even if there are many nearby connected objects as IoT devices are typically low power, transmit only intermittently, use different RF channels, and RF-EMF levels fall-off rapidly

with distance so there is not a direct summation. In general, the quantity of data exchanged by IoT devices is very small. It is very important for many connected object (IoT) applications that energy use is minimised to extend battery life.

Figure 9

Typical smart home device transmit times and radio wave levels



Measurements⁶ of a selection of smart home devices showed that transmissions occurred between 0.01% and 3.1% of the time, with many devices below 0.1%. A Wi-Fi router transmits up to about 10% of the time when streaming a high resolution video. RF-EMF levels measured at 20 cm from the selected devices were well below 0.1% of public limits for many devices.

The RF Estimator tool developed by the Mobile & Wireless Forum provides an estimate of total exposure for multiple devices at different distances based on published data. It can be accessed at <https://www.mwfai.org/RFEstimator.cfm>

⁶ Estimates and measurements of radiofrequency exposures in smart-connected homes, Joyner et al., *Bioelectromagnetics*, 45(7):329-337, October 2024, <https://doi.org/10.1002/bem.22518>



Wearable devices

Portable and wearable devices are a sub-category of IoT devices intended for use close to the human body. The radio transmitters in wearable devices generally operate at very low power to conserve battery life and often use familiar technologies such as Wi-Fi and Bluetooth. Generally, the devices only transmit at intervals and over short distances, for example, to a nearby smartphone, tablet or laptop, and therefore, exposure is very low.

Is it safe to wear wireless devices continuously?

The international exposure limits for the public have been designed to be protective even in the case of continuous exposure, 24 hours a day, 365 days per year.

The radio transmitters in wearable devices generally operate at very low power to conserve battery life and often use familiar technologies such as Wi-Fi and Bluetooth. Generally the devices only transmit for short durations, at intervals, and over short distances, for example, to a nearby smartphone, tablet or laptop.

Wearable devices expose the user to small amounts of RF radiation compared to the international exposure limits set by the International Commission on Non-ionizing Radiation Protection.

US Centers for Disease Control and Prevention (CDC)⁷

Swiss authorities report that measured RF-EMF levels for a sample of wearables using Wi-Fi or Bluetooth are less than 1% of relevant limits.

Are testing standards in place for wearable devices?

Some wearable devices are exempt from testing because their low power or intermittent transmission means that they are certain to comply with the relevant exposure limits. Other devices are tested using international technical standards to ensure compliance.

⁷ Facts About Wearable Technology, CDC, 20 February 2024, <https://www.cdc.gov/radiation-health/data-research/facts-stats/wearable-technology.html>

General questions

This section addresses cross-cutting topics relevant to understanding the overall scientific context, RF-EMF exposure limits, and typical RF-EMF levels from mobile technologies.

Exposure limits

There are international RF-EMF exposure guidelines that form the basis of policy in many countries. However, these are not binding and some countries have in place other restrictions.

What is the scientific basis for the international exposure guidelines?

The international exposure guidelines are maintained by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)⁸. ICNIRP is an independent non-governmental organisation formally recognised by WHO.

The ICNIRP RF-EMF exposure guidelines were developed following reviews of peer-reviewed scientific literature, including research on thermal and non-thermal effects. The ICNIRP guidelines are based on evaluations of biological effects that have been established to have adverse health consequences. The WHO⁹ encourages countries to adopt the ICNIRP guidelines.

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.

World Health Organization (WHO): EMF Standards and Guidelines

The international exposure guidelines are designed to protect all persons (including children) against all established health hazards of exposure to radio waves. They are independent of the wireless technology or the signal used.

After several decades of research the only established mechanism relevant to human health at the frequencies used by mobile technologies is heating of exposed tissue by absorption of RF-EMF energy and this is the basis of the international protection standards. The RF-EMF levels from wireless technologies in everyday use result in negligible temperature rise in the human body.

Acute and long-term effects of RF EMF exposure below the thermal threshold have been studied extensively without demonstrating adverse health effects.

International Commission on Non-Ionizing Radiation Protection (ICNIRP)¹⁰

The international exposure limits vary with frequency as the amount of RF-EMF energy absorbed by the body depends on frequency. The limits ensure that the RF-EMF energy absorbed by the human body complies with an overall limit.

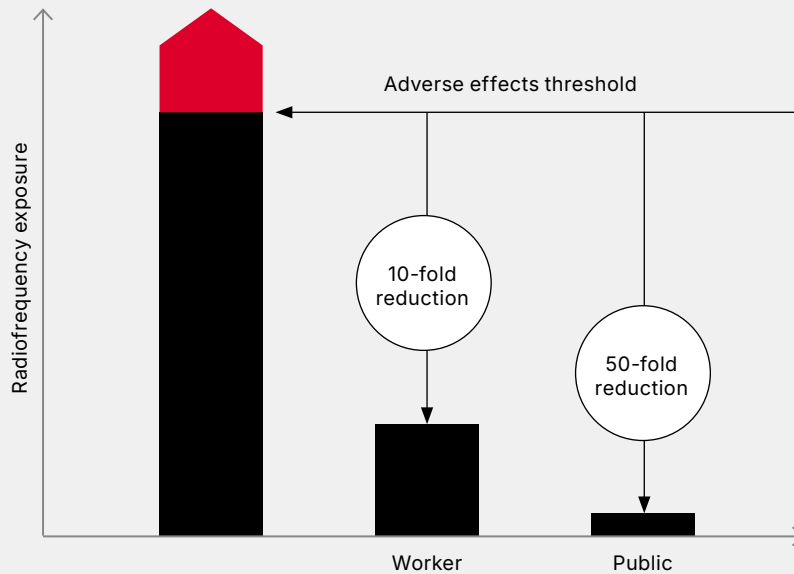
⁸ <http://www.icnirp.org/>

⁹ <https://www.who.int/teams/environment-climate-change-and-health/radiation-and-health/protection-norms>

¹⁰ <https://www.icnirp.org/en/frequencies/radiofrequency/index.html>

Figure 10

Substantial reduction factors in the international RF-EMF limits



Note: whole-body limits for continuous exposure are illustrated

As can be seen in Figure 10, the international RF-EMF limits include substantial reduction factors so that the allowable exposure levels are much lower than the threshold for scientifically-established adverse health effects. The magnitude of the reduction factors differs between whole-body and local exposure limits. The ICNIRP guidelines are recommended by the WHO, the Council of the European Union, the International Telecommunications Union (ITU), and many independent national expert groups¹¹.

The available evidence has been reviewed by many independent expert groups. The GSMA¹² website contains a comprehensive listing of such reports dating back to 1978.

The consensus among public agencies in charge of assessing scientific knowledge is that the ICNIRP limits are protective and they do not recommend adopting any other limits. Information on RF-EMF limits for the public adopted by countries is available from [gsma.com/emf](https://www.gsma.com/emf)

There is no evidence that additional precautionary measures will result in a benefit to the health of the population.

International Commission on Non-Ionizing Radiation Protection (ICNIRP)¹³

¹¹ <https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/regulatory-environment/emf-and-health/expert-reports/>

¹² <https://www.gsma.com/emf>

¹³ <https://www.icnirp.org/en/frequencies/radiofrequency/index.html>

Are new exposure limits needed for new mobile technologies?

No, the international guidelines are applicable to current and new mobile technologies, applications, and frequencies. They apply to mobile communications devices and network antennas, whatever the technology used (2G, 3G, 4G and 5G) and radio and television, including Digital Terrestrial Television (DTT), as well as all sources of radio waves such as Wi-Fi. Mobile networks and devices will continue to comply the international exposure guidelines as 5G evolves to the future 6G.

The ICNIRP guidelines are not technology specific and are periodically reviewed. Therefore, existing health risk assessments are valid independently of the wireless technology (current or future) for the whole RF-EMF frequency range.

Public health agencies and expert groups consistently conclude that the guidelines protect all persons (including children) against all established health risks.

The ICNIRP 1998 guidelines cover all radio frequencies up to 300 GHz. They form the basis of regulatory limits for mobile network antennas and devices in most parts of the world.

In March 2020, ICNIRP published updated guidelines covering all the frequencies used for mobile communications, including for 5G and the frequencies in the mobile technology roadmap, as well as wireless technologies such as Wi-Fi and broadcast services. ICNIRP concluded that the 1998 limits provide protection for all mobile technologies and explains that the 2020 guidelines introduce better and more detailed guidance, in particular, for frequencies above 6 GHz.

The ICNIRP RF EMF guidelines have taken the above considerations into account and protect against all potential adverse health effects relating to exposure to RF EMFs from 5G technologies. This includes potential differences in the effect of RF EMFs as a function of age, health status, and depth of penetration, the effect of both acute and chronic exposures, and it includes all substantiated effects regardless of mechanism.

International Commission on Non-Ionizing Radiation Protection (ICNIRP)¹⁴

The ICNIRP strongly recommends that countries update to the ICNIRP 2020 guidelines and adoption is underway in countries around the world.

Further information on the ICNIRP (2020) guidelines can be found in the GSMA¹⁵ publication *International EMF Exposure Guidelines*.



¹⁴ <https://www.icnirp.org/en/applications/5g/index.html>

¹⁵ https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/gsma_resources/emf-exposure-guidelines/

Why is it necessary to harmonise RF-EMF exposure limits?

Adoption of the ICNIRP guidelines is consistent with the WHO promotion of standards that provide the same or similar level of health protection for all people.

The WHO notes that large disparities between national limits and international guidelines can foster confusion for regulators and policy makers, increase public anxiety and provide a challenge to manufacturers and operators of communications systems who need to tailor their products to each market.

Restrictive limits do not lead to lower average exposures in public areas. As summarised in Figure 11, they make mobile network deployment less efficient, make co-location of antennas difficult, limit the capacity of sites, and may increase the number of antenna sites that are required.

EMF exposure limits that are more strict than the ICNIRP or IEEE guidelines negatively affect all potential levers to enhance the wireless infrastructure and deployment of 5G: spectrum, technology (determining the spectral efficiency) and network topology (number of sites and sectors).

International Telecommunications Union (ITU)¹⁶

Figure 11

Restrictive RF-EMF limits can negatively impact mobile networks



More antennas are needed for equivalent coverage



Colocation of antennas is often not practical



In-building coverage may be reduced



The full potential site capacity can't be deployed



Deployment is delayed and costs increased

¹⁶ The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment. ITU-T K.Supp14. September 2019. (The IEEE guidelines are similar to those of ICNIRP).

Assessing exposure

International technical standards describe methods based on calculation and measurement for assessing RF-EMF exposure from mobile devices and networks. Artificial intelligence (AI) and machine learning (ML) methods are being applied to RF-EMF exposure assessments. Approaches using digital twins (virtual representations of real-world objects) can further simplify RF-EMF compliance for base stations.

Are testing standards in place for 5G devices?

Many 5G deployments are at frequencies similar to existing 3G/4G mobile networks and so the same mobile device compliance measure – the specific absorption rate (SAR) – and limit value also apply to 5G devices. For 5G devices operating in frequency bands higher than those used by current mobile phones, test procedures were developed by the International Electrotechnical Commission (IEC) Technical Committee 106.

Are testing standards in place for 5G networks?

The International Electrotechnical Commission (IEC) and International Telecommunications Union standardisation sector (ITU-T) developed technically aligned standards for assessing RF-EMF levels from all mobile technology networks, including 5G, operating at frequencies up to 300 GHz. The RF-EMF exposure assessment methods are relevant to future mobile technologies.

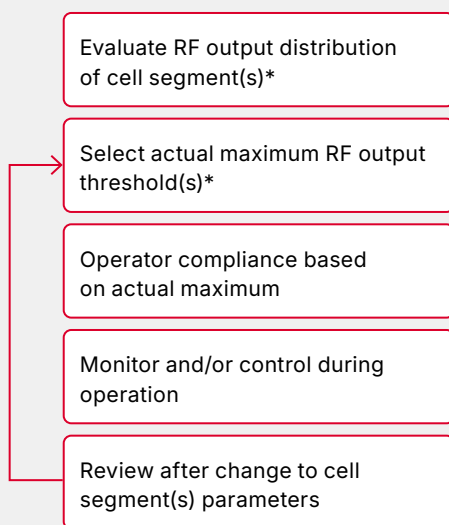
Studies show that the actual transmitted power of 2G, 3G, 4G and 5G base stations during operation is generally below the theoretical maximum time-averaged configured power. Even on sites that combine technologies the realistic maximum is substantially lower than the theoretical maximum.

With 5G and increased use of active antenna systems, the antenna beam direction, gain and transmit power¹⁷ vary in response to traffic resulting in lower time averaged exposures when measured in commercial networks.

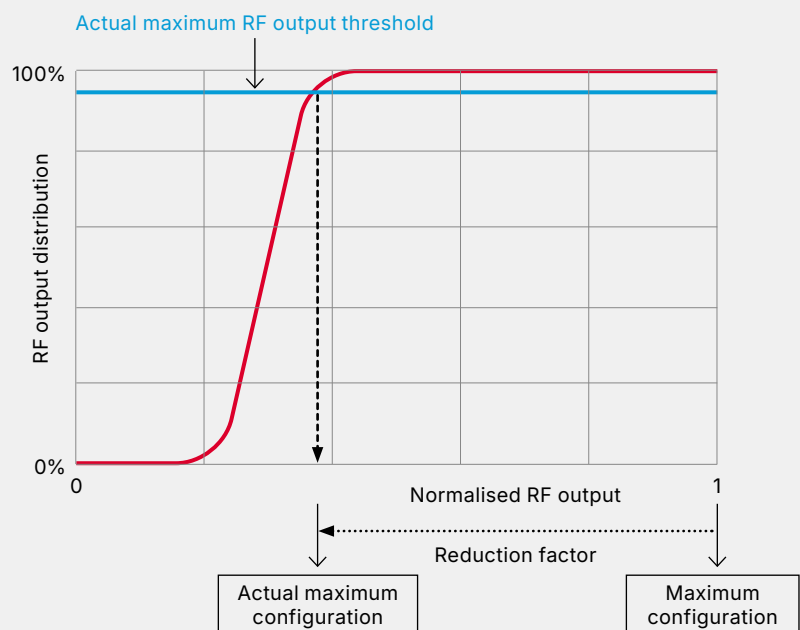
Improved accuracy in the assessment of RF-EMF compliance can be obtained by the application of the actual maximum approach described in IEC and ITU technical standards. This approach is especially important to the accurate assessment of 5G antennas with beamforming capabilities. It can also be used to improve the accuracy of assessments of other mobile technology generations.

Figure 12

Representation of the actual maximum approach



*Can be applied for the total cell or per cell segment for base station with beam steering. See IEC 62232 for details.



¹⁷ The antenna gain and transmit power are combined in the EIRP – Effective Isotropic Radiated Power.

Figure 12 illustrates the main elements of the actual maximum transmitted power or EIRP approach to RF-EMF compliance specified in IEC 62232, these are:

- Operator evaluates the RF output distribution of the cell segment(s).
- Operator selects actual maximum threshold(s) based on the RF output distribution.
- Operator declares RF-EMF compliance using the configured actual maximum power or EIRP (time-averaged value) threshold(s).
- The operator verifies the actual maximum threshold(s) during operation using monitoring counters or control features.
- If the operator intends to change the cell segment(s) parameters in a way that impacts the RF-EMF compliance boundary, the RF-EMF compliance is updated.

It is important to understand that RF-EMF limits are specified with an associated time-averaging interval. The instantaneous RF-EMF level varies in response to site traffic while the actual maximum approach ensures limit compliance on a time-averaged basis.

How will testing standards evolve for the next generation of mobile technologies?

Existing testing standards for mobile devices and networks cover all the frequencies used or planned for mobile services up to 300 GHz. When the next generation of mobile technologies is defined, the application of these methods will be evaluated in test networks and updated if required.

What is the size of compliance zones around 5G network antenna sites?

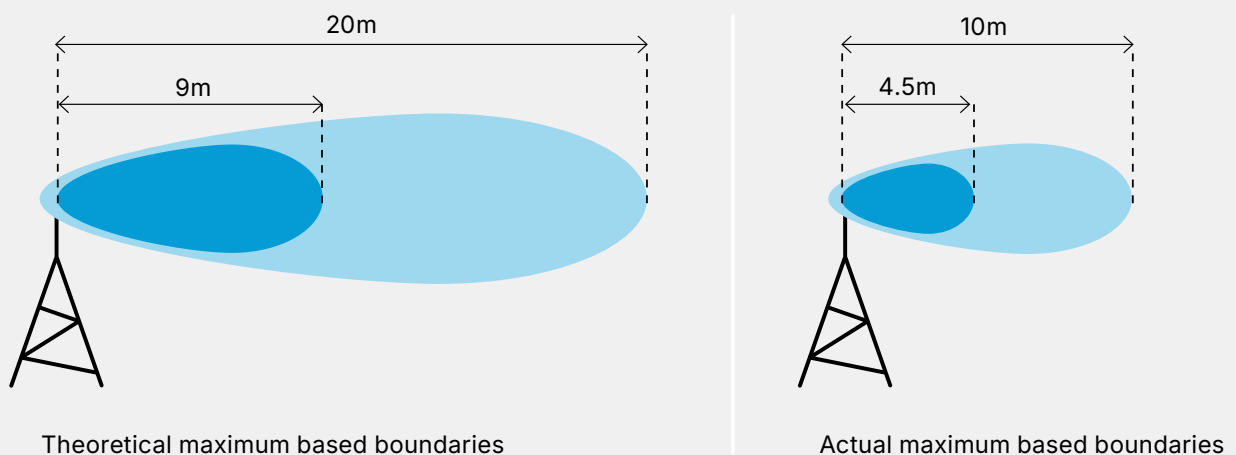
Advanced antennas used by 5G networks produce lower time-averaged RF-EMF exposure for the same source characteristics than conventional antennas. Where regulatory authorities allow the use of assessment methods based on the actual maximum approach this can result in smaller and more realistic compliance zones as shown in Figure 13. The size and shape of compliance zones can be evaluated and implemented according to international technical standards¹⁸.

Mobile network antennas are typically directional, meaning that compliance zones extend in front of the antenna and a small distance above and below. The antennas are positioned so the public cannot access these areas. Access and shutdown procedures for maintenance workers may be agreed between the mobile operator and the landlord of a rooftop or the operator of street lights when the antenna is installed in such places.

Mobile networks are designed to use only the power needed to provide quality services. Too much power would cause interference and affect the services to users. One of the goals of 5G is a substantial increase in network energy efficiency. This can be done by reducing the power of transmitters when they are not in use and implementing sleep modes. Another approach is to reduce the amount of signalling needed to maintain connectivity.

Figure 13

Actual maximum approach results in smaller and more accurate compliance zones



Note: individual site boundary sizes will differ depending on specific site parameters

18 IEC62232 and ITU-T K.100.

Scientific research

The WHO¹⁹ comments that scientific knowledge in the area of EMF and health is more extensive than for most chemicals. Over US\$200million of funding for research has been directed to addressing WHO²⁰ Research Agendas for EMF since 1997.

What kind of research exists regarding the possible health risks of exposure from these new wireless technologies and applications?

As can be seen in Figure 14 there is a very large body of research publications related to EMFs and health. Information on new research and details of individual studies can be found in the EMF-Portal web database maintained by the RWTH Aachen University, Germany: <https://www.emf-portal.org/en>

The radio wave characteristics of existing and evolving mobile technologies are similar. They use similar transmission powers and operate in similar frequency ranges. The frequencies currently used or planned for mobile technologies are covered by the international exposure guidelines.

A European Commission²¹ expert committee concluded that current knowledge about how RF-EMF interacts with the human body can be used to set exposure limits for the whole frequency range up to 300 GHz. Therefore, existing health risk assessments are valid independently of the current or future mobile technology for the whole frequency range.

What is the advice from the World Health Organization on wireless technologies and health?

The position of the WHO in regard to possible health hazards from wireless technologies is that:

To date, and after much research performed, no adverse health effect has been causally linked with exposure to wireless technologies.

World Health organization (WHO)²²

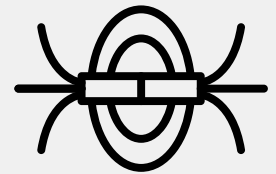
The WHO points out that the health related studies have been performed across the entire radio spectrum but that there are fewer at higher frequency bands. The WHO is conducting an overall risk assessment of all health outcomes related to RF-EMF exposure that is expected to be completed in 2026.

Figure 14

Large body of research on EMF and health

Over

28,500



studies published since 1995 on electromagnetic fields and health with more than

5,300

related to mobile communication



Data from EMF Portal, <https://www.emf-portal.org/>

¹⁹ <https://www.who.int/news-room/questions-and-answers/item/radiation-electromagnetic-fields>

²⁰ <https://www.who.int/teams/environment-climate-change-and-health/radiation-and-health/non-ionizing/emf>

²¹ Final opinion on potential health effects of exposure to electromagnetic fields (EMF), Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), adopted on 27 January 2015. SCENIHR explains that at the frequencies used for mobile services, RF-EMF energy absorption and subsequent tissue heating is the major mechanism.

²² <https://www.who.int/news-room/questions-and-answers/item/radiation-5g-mobile-networks-and-health>





I've heard that RF signals were classified as a possible human carcinogen, what does this mean?

In May 2011 a working group of the International Agency for Research on Cancer (IARC) classified RF-EMF as possibly carcinogenic to humans (Group 2B), see Figure 15. The WHO explains that this is a category used when a causal association is considered credible,

but when chance, bias or confounding cannot be ruled out with reasonable confidence. The IARC classification was based on limited evidence related to wireless devices used close to the head. The evidence for environmental exposures (such as mobile networks and broadcast transmitters) and for worker exposures was regarded as inadequate.

Figure 15

IARC Monographs classification is based on strength of the evidence

IARC Monographs Human Cancer Hazard Classification			
	IARC Group	Typical examples of evidence	Examples of agents
Higher level of certainty ↓ Lower level of certainty	Group 1 Carcinogenic to humans (135 agents)	<i>Sufficient</i> evidence in humans.	 Smoking, exposure to solar radiation, alcoholic beverages, ionizing radiation
	Group 2A Probably carcinogenic (95 agents)	<i>Limited</i> evidence in humans. <i>Sufficient</i> evidence in experimental animals.	 Emissions from high temperature frying, DDT, eating red meat, night shift work
	Group 2B Possibly carcinogenic (323 agents)	<i>Limited</i> evidence in humans. <i>Less than sufficient</i> evidence in experimental animals.	 Gasoline engine exhaust, carpentry and joinery, low frequency magnetic fields, radiofrequency fields
	Group 3 Not classifiable (500 agents)	<i>Inadequate</i> evidence in humans. <i>Inadequate</i> evidence in experimental animals.	 Drinking coffee, crude oil, mercury, paracetamol, static electric or magnetic fields

Agents classified by the IARC Monographs, volumes 1-139, June 2025.

IARC combined group 3 and group 4 in 2019. IARC working groups are encouraged to add that an agent is "probably not carcinogenic to humans" when justified.

The IARC Monographs classification indicates the strength of the evidence that an agent can cause cancer (hazard identification). IARC identifies cancer hazards but does not evaluate the risks associated with specific levels or circumstances of exposure. Hazard identification indicates the strength of the evidence that a substance can cause cancer under some circumstances.

Risk assessment indicates the risk of developing cancer associated with a level of exposure.

RF-EMF was classified in the same IARC group as eating pickled vegetables (i.e. that there was limited evidence that they could cause cancer in humans). It can be noted that eating processed meat falls in a higher classification than radio waves (i.e. there is stronger evidence of cancer in humans).

In 2024, an IARC²³ analysis demonstrated that the increases seen in early epidemiological studies of brain cancer risk could be explained by mobile phone use recall errors among participants. The COSMOS²⁴ study with over 250,000 participants found no evidence that the amount of mobile phone use is associated with brain tumour risk. Analysis of cancer trend data for up to about 30 years of mobile phone use shows no increase in the incidence of brain tumours.

It is important to note that following the IARC classification, the WHO has not recommended any changes to the RF-EMF exposure limits applicable to wireless networks and devices. Further research has been identified to address the scientific uncertainties.

Are children at greater risk from RF-EMF exposures?

There have been many independent scientific reviews and these have consistently concluded that the international guidelines are protective of all persons, including children.

Concern has been expressed with regard to mobile phone use by children. At present, the available body of scientific evidence does not indicate that children may be more vulnerable to RF EME emissions from mobile phones than adults. The ARPANSA Standard used to regulate the emissions from mobile phones, is designed to protect people of all ages and health status against the known harmful effects of exposure to RF EME.

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)²⁵

There are currently fewer studies specific to children and this topic remains an active research area. The international exposure guidelines were developed based on conservative assumptions to be protective of all persons.

Current scientific evidence does not show a danger to any users of cell phones from radio frequency (RF) energy, including children and teenagers.

United States Food and Drug Administration (FDA)²⁶

National authorities in some countries recommend voluntary precautionary restrictions on phone and Wi-Fi use by younger children due to concern about possible greater vulnerability and to limit longer lifetime exposures if there is an unrecognised health risk. The WHO does not recommend specific measures for groups such as children and pregnant women.

23 Effects of recall and selection biases on modeling cancer risk from mobile phone use: Results from a case-control simulation study, Bouaoun et al., *Epidemiology*, 35(4):437-446, July 2024 <https://dx.doi.org/10.1097/EDE.0000000000001749>

24 Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study, Feychting et al., *Environment International*, 185:108552, March 2024 <https://doi.org/10.1016/j.envint.2024.108552>

25 Mobile phones and health, ARPANSA, <https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/mobile-phones>

26 Children and Teens and Cell Phones, FDA, <https://www.fda.gov/radiation-emitting-products/cell-phones/children-and-teens-and-cell-phones>

Is there a connection between 5G and COVID-19?

No. The WHO states that there is no link between 5G and COVID-19, confirming that viruses cannot travel on radio waves and/or mobile networks. The WHO explains that COVID-19 is spread through respiratory droplets when an infected person coughs, sneezes or speaks. There is also no connection between 5G and vaccinations.

More generally the GSMA urges governments around the world to take swift action against disinformation, vandalism and threats against mobile networks.

Are mobile network radio waves harmful for the environment?

Authorities advise that the same RF-EMF limit values that protect people also protect the environment. The report of an international workshop on EMF and the environment organised by German²⁷ authorities concludes that there is 'no proven scientific evidence of adverse effects in animals or plants under realistic environmental conditions' due to low-level radio waves. Authorities have also debunked claims that radio waves harm birds or trees.

The ARPANSA RF Standard is intended for protecting humans against the known harmful effects of exposure to RF EME and does not specifically consider protection of flora and fauna in its underlying principles. Further research is required on the effects of low-level RF EME exposure on plants and animals. However, an assessment of existing research indicates that the exposure limits set within the Standard are adequate in providing protection to the environment.

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)²⁸

One of the goals of 5G is a substantial increase in network energy efficiency. Some ways to do this include reducing the power of transmitters when they are not in use and implementing sleep modes. Another approach, is to reduce the amount of signalling needed to maintain connectivity.

How do you respond to petitions calling for mobile network deployments to be stopped?

The research on RF-EMF exposures mentioned in these petitions is already well known to the international scientific community and has been evaluated by independent expert groups who consistently conclude that the international guidelines protect all members of the public and the environment.

The strict and safe exposure limits for electromagnetic fields recommended at EU level apply for all frequency bands currently envisaged for 5G.

European Commission²⁹

27 Biological Effects of Radiofrequency Electromagnetic Fields above 100 MHz on Fauna and Flora: Workshop Report, Pophof et al., *Health Physics*, 124(1):31-38, January 2023, <https://dx.doi.org/10.1097/HP.0000000000001625>

28 The ARPANSA standard is based on the ICNIRP (2020) guidelines for RF-EMF. Radiofrequency Electromagnetic Energy and the ARPANSA safety Standard, ARPANSA, <https://www.arpansa.gov.au/regulation-and-licensing/regulatory-publications/radiation-protection-series/codes-and-standards/rpss-1-qa#the-environment-animals-and-plants>

29 European Commission response to the 5G Appeal, 12 October 2017.



Exposure levels

Radio wave surveys conducted in many countries around the world and over the decades since the widespread deployment of mobile networks show that typical levels in publicly accessible areas remain a small fraction of the international RF-EMF exposure guidelines.

Does the growing use of wireless networks mean that RF-EMF exposure is increasing?

There may be a small localised increase when a new mobile technology or additional frequency band is added to an existing site or when coverage is provided in a new area. Advances in base station design and new mobile communication technologies provide higher capacity with greater efficiency. All mobile technologies are designed to limit power to reduce system interference. Note also that for all wireless technologies, the exposure from antennas decreases rapidly with distance.

Studies show that the RF-EMF levels from mobile networks remain relatively constant over many years (with small annual variation), across different countries and continents and across different technologies. Similar trends have been found in data for countries in the Asia-Pacific, Europe, Latin America, North America and Africa.

Figure 16 shows trends in environmental RF-EMF levels based on measurements conducted between 2016 and 2023 in the Netherlands, Switzerland, Belgium and

Spain using similar methods.³⁰ The measured RF-EMF level remained a small fraction of the limit values even as global monthly traffic per smartphone increased from about 2 GB in 2016 to more than 17 GB in 2023. The measured levels are also comparable in countries with restrictive limits (Belgium/Switzerland) and in countries with the international limits (the Netherlands/Spain).

During the transition of previous wireless technologies (2G, 3G, 4G) the overall RF-EMF exposure levels remained relatively constant and at a small fraction of the international guidelines.

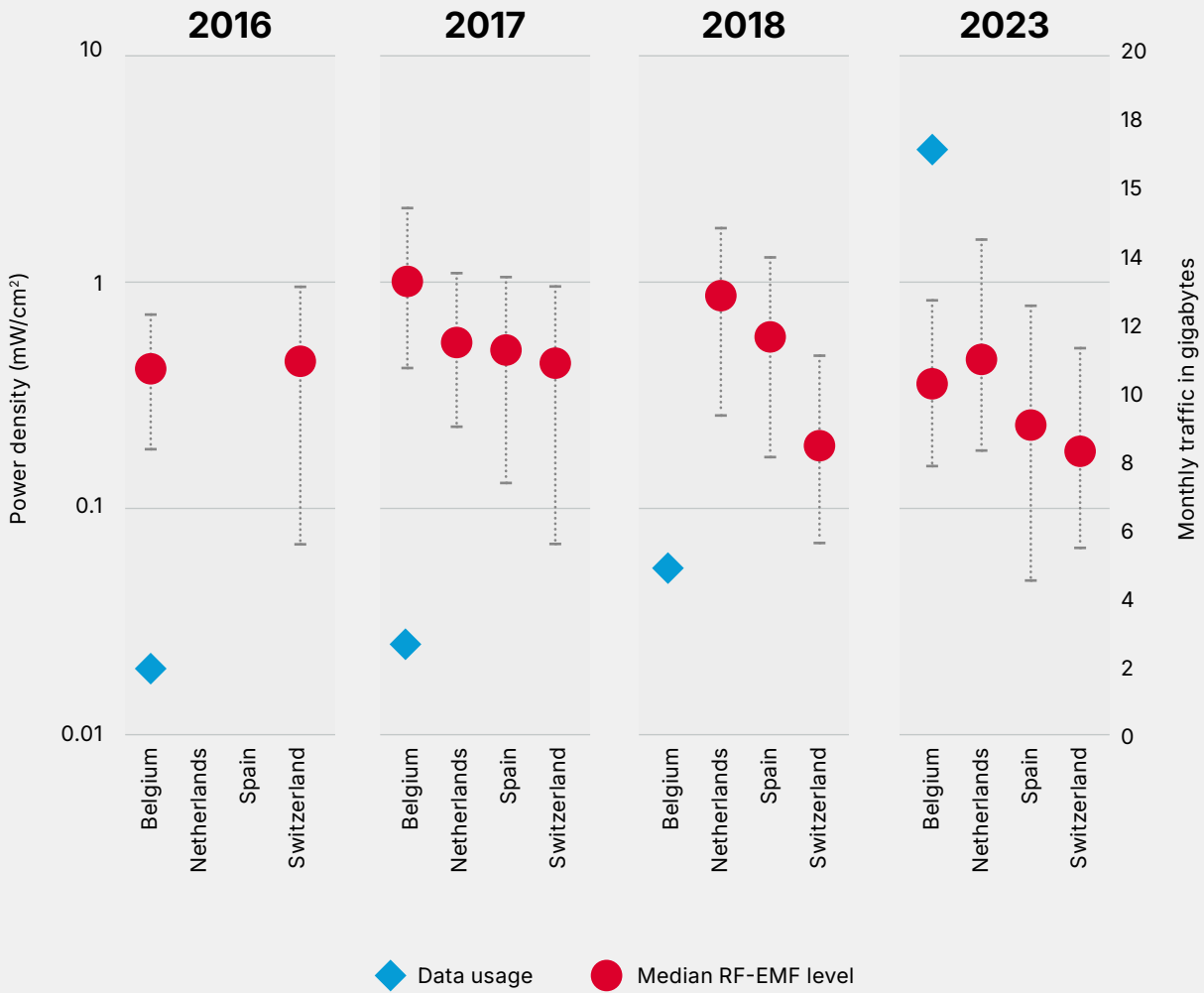
Measurements conducted since the launch of 5G show that the total exposure to radio waves remains very low relative to the international exposure limits. An interactive map on the GSMA³¹ website summarises extensive testing on commercial and test networks by national health agencies, government regulators, academia, test laboratories, mobile operators and manufacturers to determine 5G EMF exposure levels. The typical maximum measured 5G RF-EMF level across the surveys is less than 1% of the international public limits.

³⁰ Temporal Change of Outdoor RF-EMF levels in four European Countries: a Microenvironmental Measurement Study, Beláčková et al., *Environmental Research*, 285(122315), 15 November 2025, <https://doi.org/10.1016/j.envres.2025.122315>

³¹ <https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/regulatory-environment/emf-and-health/safety-of-5g-networks/5g-emf-surveys/>

Figure 16


Mobile traffic increased 8-fold, no change in RF-EMF levels




Bars show 25% to 75% range. RF-EMF levels not available for all countries and years. Worldwide average monthly mobile data traffic per smartphone from Statista.

I am concerned, what can I do to reduce my exposure?


Mobile phones are designed to automatically reduce power to the lowest possible level to make a quality connection. When used in areas of good reception a mobile phone will operate at lower transmit power. For those who are concerned, exposure to radio waves can be reduced by limiting use of wireless devices or increasing the distance between the device and the body.



Better connection



Lower transmit power



Longer battery time

Should I buy a shielding device to protect myself and my family from radio waves?

No. The radio wave level from wireless networks and devices is already low and typically a lot less than the international limit values. The US Food and Drug Administration (FDA) considers claims of health protection to be 'bogus.'

Manufacturers of certain cell phone accessories may claim that an accessory shields the user from emissions or prevents health problems caused by radio frequency radiation. The FDA does not regulate such products and, given the weight of scientific evidence to show that cell phones are safe for use, the Agency considers these claims to be bogus.

United States Food and Drug Administration (FDA)³²

In 2015 the French DGCCRF³³ (General Directorate for Competition Policy, Consumer Affairs and Fraud Control) investigated the sale of 'shielding' devices for mobile phones. The DGCCRF concluded that the selling of such devices is often supported by multiple allegations that need to be verified. In most cases, vendors presented studies on biological and physiological domains that are not officially recognised. In 2021, consumers in the Netherlands³⁴ were warned against using an anti-5G 'negative ion' pendant that emitted ionizing radiation.

The Australian government agency ARPANSA³⁵ '... does not recommend the use of any protective devices other than approved hands-free accessories that let you keep the phone away from the head during use.'

I have heard talk of higher frequencies being used, does that mean higher exposure?

No, higher frequency does not mean higher exposure. Higher frequencies generally mean shorter ranges and due to the increase of the available bandwidth provides for the possibility of higher data rates. Current and possible future frequency bands for mobile services are covered by the international RF-EMF exposure guidelines.

Is there a health risk from millimetre wave 5G?

No, the use of millimetre wave frequencies for 5G complies with the international exposure guidelines. Measurements show that typical levels are similar to existing mobile services.

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.

World Health Organization (WHO)³⁶

At millimetre wave frequencies RF-EMF energy is absorbed superficially by the body, mostly by the skin (to a depth of only a few millimetres). Biological effects of these frequencies have been studied previously and new studies are underway using millimetre wave exposures.

This meta-analysis of the experimental studies also presented little evidence of an association between millimetre waves and adverse health effects. Studies that did report biological effects were generally not independently replicated and most of the studies reviewed employed low-quality methods of exposure assessment and control.

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)³⁷

For additional information see the GSMA³⁸ publication *5G millimetre wave safety*.

32 Reducing Radio Frequency Exposure from Cell Phones, FDA, <https://www.fda.gov/radiation-emitting-products/cell-phones/reducing-radio-frequency-exposure-cell-phones>

33 La Répression des fraudes sanctionne, Que Choisir, 18 May 2016, <https://www.quechoisir.org/actualite-dispositifs-anti-ondes-la-repression-des-fraudes-sanctionne-n9813/>

34 Do you have a 'Quantum Pendant' anti-5G pendant or a 'negative ion' jewellery item or sleep mask? If so, store it away safely, Authority for Nuclear Safety and Radiation Protection (ANVS), <https://english.autoriteitnvs.nl/latest/news/2021/12/16/do-you-have-a-quantum-pendant-anti-5g-pendant-or-a-negative-ion-jewellery-item-or-sleep-mask-if-so-store-it-away-safely>

35 How to reduce exposure from mobile phones and other wireless devices, ARPANSA, <https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/reducing-exposure-to-mobile-phones>

36 Radiation: 5G mobile networks and health, WHO, <https://www.who.int/news-room/questions-and-answers/item/radiation-5g-mobile-networks-and-health>

37 World-first reviews into 5G radio waves, ARPANSA, <https://www.arpansa.gov.au/news/world-first-reviews-5g-radio-waves>

38 https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/gsma_resources/emf-safety-and-5g-mmwave-networks/

Do higher data rates mean higher network exposures?

No, assessments of 5G networks show RF-EMF levels that are similar to existing mobile services. The typical maximum measured 5G RF-EMF level across the surveys is less than 1% of the international public limits.

Higher data rates can mean shorter transmission times to deliver the requested data. In addition, the expanded use of advanced directional antennas delivers the RF-EMF where it is needed and may reduce the level in other directions. Real-world tests and computational studies show that use of beamforming results in lower time averaged RF-EMF levels than conventional antennas for comparable services.

Will large numbers of small cells mean an increase in exposure?

No. Small cells are used by current mobile networks to provide localised coverage or capacity and their use will expand with 5G and beyond. They may be mounted on street lights or inside buildings, where over 70% of mobile usage occurs in developed markets.

RF-EMF measurements near small cells covering 2G, 3G, 4G³⁹, and 5G⁴⁰ technologies show levels that are well below the international guidelines.



39 Measurement of EMF exposure around small cell base station sites, van Wyk et al., *Radiation Protection Dosimetry*, 184(2):211-215, August 2019, <http://dx.doi.org/10.1093/rpd/ncy201>. RF Exposure Assessments in Proximity of Small Cells, Conil et al., 2018 2nd URSI Atlantic Radio Science Meeting (AT-RASC), 28 May -1 June 2018, <https://doi.org/10.23919/URSI-AT-RASC.2018.8471480>

40 RF-EMF Exposure near 5G NR Small Cells, Aerts et al., *Sensors*, 23(6):3145, 15 March 2023, <https://doi.org/10.3390/s23063145>

Do smartphones use higher transmit powers for direct satellite communication?

The technical standards for 5G support non-terrestrial networks (NTN) that can communicate directly with smartphones, known as direct to device (D2D) connectivity. Depending on regulatory licensing and commercial agreements this may be implemented in devices by using dedicated mobile satellite spectrum (MSS) or using the same spectrum as terrestrial (ground-based) mobile services. Approaches may differ between countries to licensing such services.

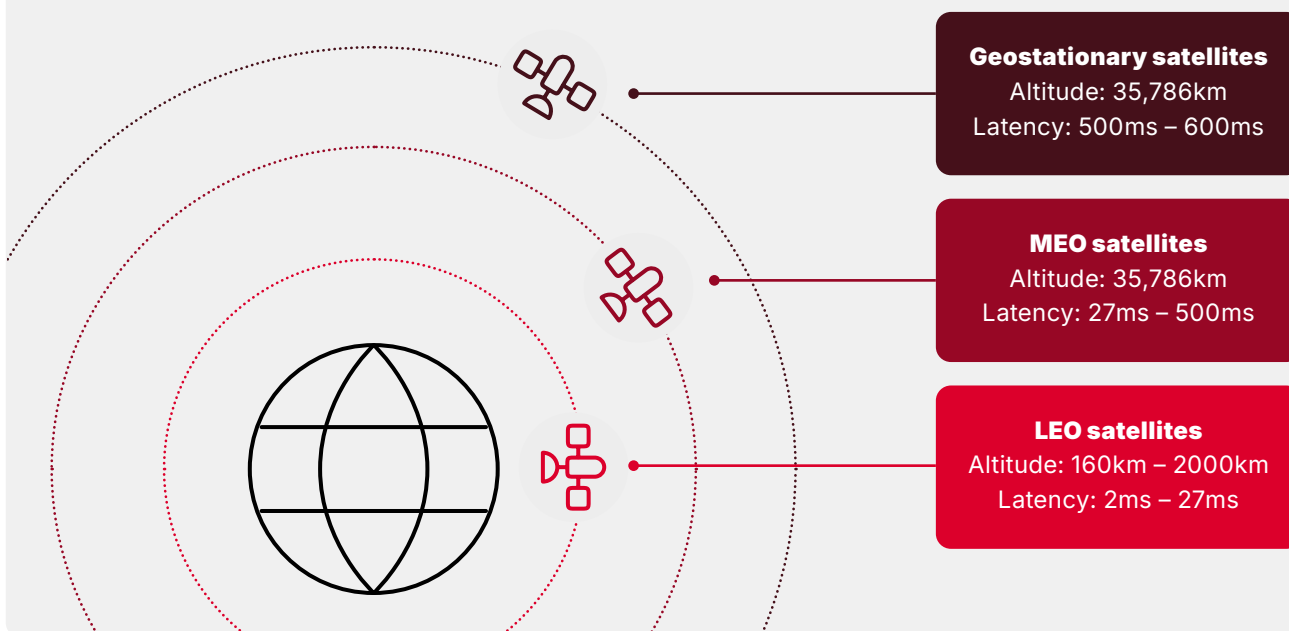
Initial supplemental satellite services are mainly based on emergency use, text-type messaging or IoT connectivity in areas not covered by terrestrial networks.

The maximum device transmit power specified for D2D is the same as for connections to terrestrial mobile networks. Figure 17 shows that phone connections are possible due to the deployment of Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellite constellations with advanced antennas that compensate for the path length between the smartphone and a satellite. Preliminary results indicate that received signal levels for D2D connections are comparable to levels experienced at the cell edge in terrestrial networks. Smartphones that support D2D are tested for compliance with relevant SAR limits.

Pathloss from the satellite to the ground and requirements to minimise interference mean that downlink RF-EMF levels are very low relative to human exposure limits.

Figure 17

Types of satellite orbits: GEOs, MEOs and LEOs



Can 5G interfere with medical devices?

As part of the GIGA FOR HEALTH project researchers from the Institute for High Frequency Technology at the Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen (Germany) tested the 5G system deployed in Düsseldorf University Hospital for compatibility with 30 medical devices representing about 90% of the devices regarded as particularly vulnerable. The researchers⁴¹ reported that none of the medical devices showed any relevant functional impact nor were any

error alarms triggered. A Japanese⁴² study showed that 4G interference results could be used to predict the possibility of interference from 5G at mid-band frequencies. They saw no interference with the tested medical devices at millimetre wave frequencies.

Researchers with the Italian National Institute of Health (ISS) demonstrated that 5G devices⁴³ do not pose significant risks of pacemaker wearers and that 5G base stations⁴⁴ at levels up to the international limits for the public did not cause malfunctions.

41 Interference compatibility tests on critical medical devices against 5G mobile radio for indoor coverage, Schiffarth and Heberling, in The 1st Annual Meeting of BioEM (BioEM 2022), Nagoya (Japan), 2022, pp. 501-503.

42 Research of Electromagnetic Interference with Medical Devices in Hospitals for Mobile Phone and Smartphone Use, Iyama et al., *NTT DOCOMO Technical Journal*, 25(4):April 2024, https://www.docomo.ne.jp/english/corporate/technology/rd/technical_journal/bn/vol25_4/004.html

43 Protection of population and workers with cardiac implantable stimulators from 5G exposure. Part I: mobile terminal exposure, Vivarelli et al., *The European Physical Journal Plus*, 140(1):78, 28 January 2025, <https://doi.org/10.1140/epjp/s13360-024-05945-y>

44 Protection of population and workers with cardiac implantable stimulators from 5G exposure. Part II: base station antennas exposure, Vivarelli et al., *The European Physical Journal Plus*, 140(3):235, 18 March 2025, <https://doi.org/10.1140/epjp/s13360-025-06167-6>

Resources for additional information

These web sites provide useful information for people who may want to know more about these topics.

EMF-Portal	➔ https://www.emf-portal.org/en
GSMA – EMF and Health	➔ https://www.gsma.com/emf
ICNIRP – RF EMF	➔ https://www.icnirp.org/en/frequencies/radiofrequency/index.html
ITU EMF Guide	➔ https://emfguide.itu.int/emfguide.html
WHO – Electromagnetic Fields	➔ https://www.who.int/health-topics/electromagnetic-fields

Abbreviations

1G/2G/3G/4G/5G/6G	1st to 6th generation mobile communication technologies
EME	Electromagnetic energy
EMF	Electromagnetic field
GHz	Gigahertz (10^9 Hz)
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Electrotechnical Commission
IoT	Internet of Things
ITU	International Telecommunications Union
kbits	(or kbps) kilo bits per second
M2M	Machine-to-Machine
Mbps	Megabits per second
MHz	Megahertz (10^6 Hz)
MIMO	Multiple-Input Multiple-Output also mMIMO (massive MIMO).
mmW	millimetre wave (mmWave)
ms	millisecond
mW	milliwatt
RF	Radiofrequency
THz	Terahertz (10^{12} Hz)
V2X	Vehicle-to-everything
WHO	World Health Organization
Wi-Fi	Wireless networking technology

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