



5G, the Internet of Things (IoT) and Wearable Devices

What do the new uses of wireless technologies mean for radio frequency exposure?

September 2023



About the GSMA

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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1

Context

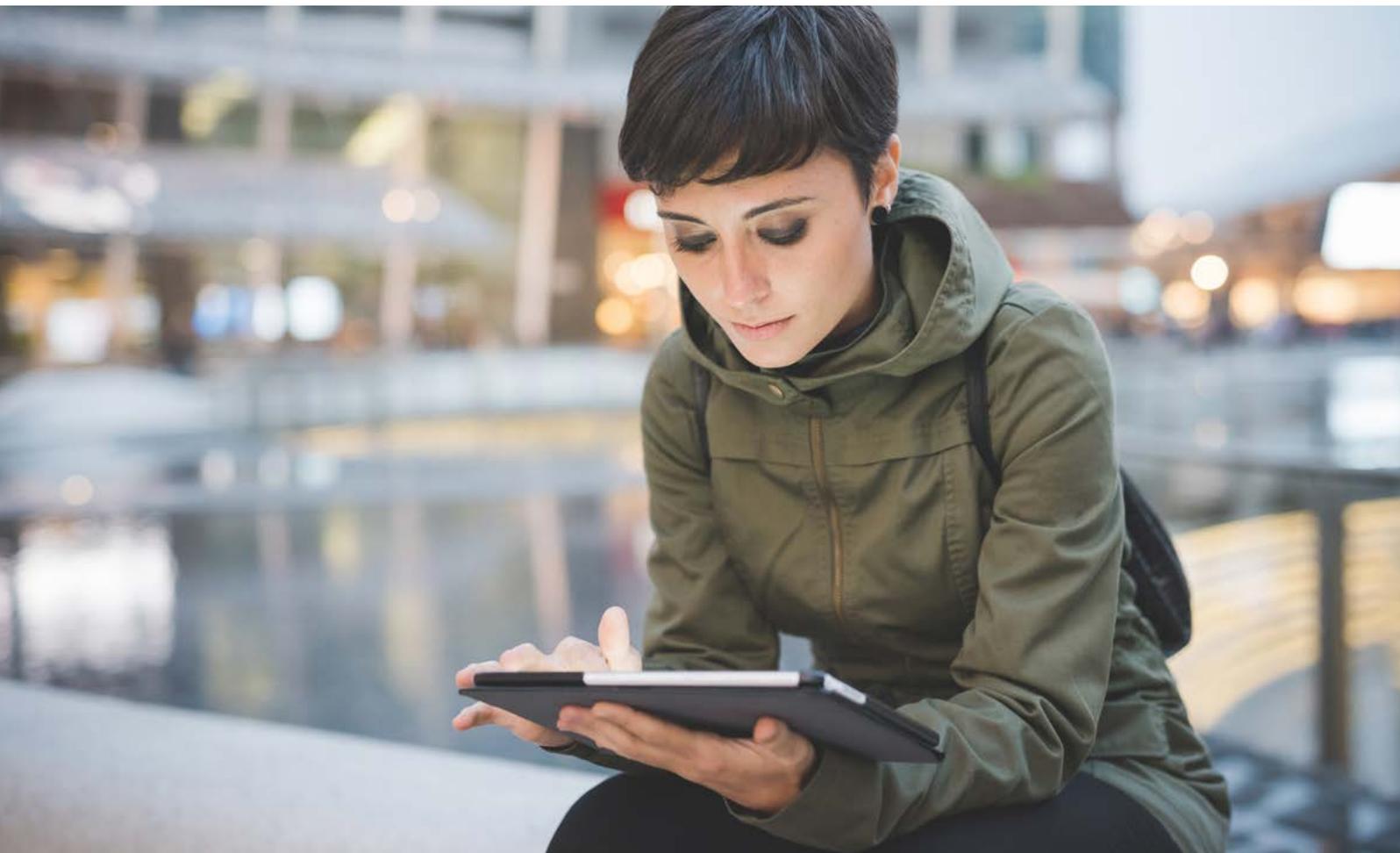


Increased mobile connectivity will transform society, enabling changes in the way we live and do business, through new applications of wireless technology such as Fifth Generation (5G) mobile technology; the Internet of Things (IoT), also known as machine-to-machine (M2M) communications; and wearable devices. The GSMA has produced this publication to address questions related to exposure to radio frequency (RF) signals used by these networks and devices.

Wireless networks and devices exchange information (eg, voice or data) via RF signals – a form of electromagnetic energy, also called electromagnetic fields (EMFs). RF signals 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.

New applications, such as 5G, wireless IoT and wearable devices, are designed to comply with existing exposure limits. The international exposure guidelines have been developed as a result of 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 (including children) against all established health hazards.

This booklet starts with answers to general questions and then follows with sections specific to 5G, IoT and wearable devices. Resources for further information and a table of abbreviations are included at the end.





2

General questions



Are new exposure limits needed for these new applications of wireless technologies?

No, current international guidelines are also applicable to the new wireless applications. International exposure guidelines have been developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)¹. ICNIRP is an independent non-governmental organization formally recognised by WHO.

The ICNIRP RF signal exposure guidelines 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 WHO² recommends that countries adopt the ICNIRP guidelines.

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

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. ICNIRP concluded that the 1998 limits provide protection for all mobile technologies, including 5G. The 2020 guidelines introduce better and more detailed guidance, in particular, for frequencies above 6 GHz.

The ICNIRP strongly recommends that countries update to the ICNIRP 2020 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: EMF Standards and Guidelines²



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)³



1. <http://www.icnirp.org/>
 2. <https://www.who.int/teams/environment-climate-change-and-health/radiation-and-health/protection-norms>
 3. <https://www.icnirp.org/en/applications/5g/index.html>

What is the scientific basis for the international exposure guidelines?

The international exposure guidelines protect the public from all established health effects of exposure to radio waves. They are independent of the technology or the signal used. 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.

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

The international guidelines include substantial reduction factors so that the allowable limits are much lower than the level where the first scientifically-established adverse health effects occur. They are recommended by the WHO, the Council of the European Union and the International Telecommunications Union (ITU).

The consensus among public agencies in charge of assessing scientific knowledge is that these limits are protective and they do not recommend adopting any other limits.

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

The WHO⁴ strongly promotes the use of international standards that provide the same or similar level of health protection for all people and endorses the guidelines of the ICNIRP.

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.

ICNIRP concludes that *'there is no evidence that additional precautionary measures will result in a benefit to the health of the population.'*

Restrictive limits do not lead to lower exposures in public areas. They make mobile network deployment less efficient, make co-location of antennas difficult and 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 Union⁵



4. WHO, Framework for developing health-based EMF standards, 2006. Available at <https://www.who.int/publications/i/item/9241594330>

5. The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment. ITU-T K.Supplement 14. September 2019. (The IEEE guidelines are similar to those of ICNIRP).

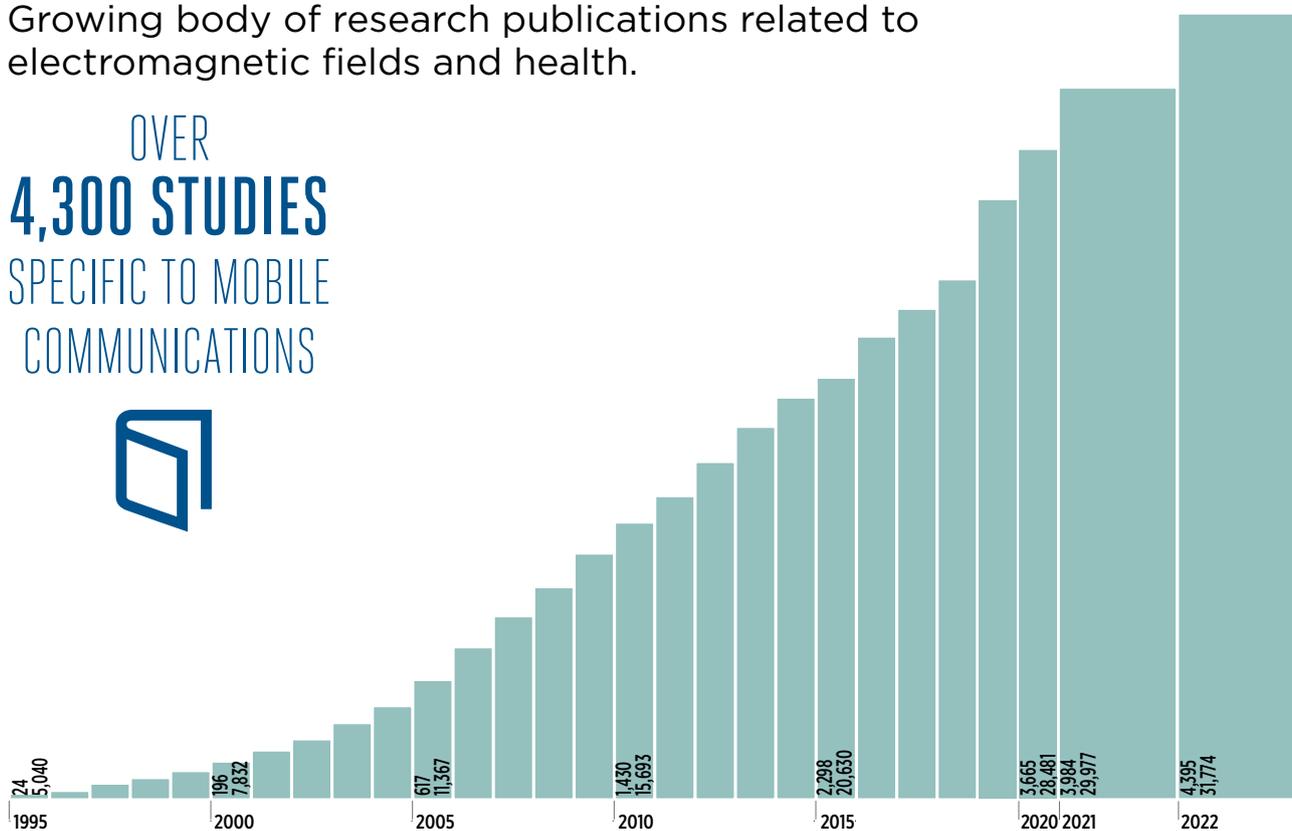
What kind of research exists regarding the possible health risks of exposure from these new wireless technologies and applications?

As can be seen in Figure 1 there is a significant and ever growing body of research publications related to EMFs and health. The vertical bars show the total number of publications for all frequency ranges. The number of studies specific to mobile communication frequencies is given by the smaller number near the year axis. 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>

Figure 1

Growing body of research publications related to electromagnetic fields and health.

OVER
4,300 STUDIES
SPECIFIC TO MOBILE
COMMUNICATIONS



Data from www.emf-portal.org (status December 2022). Smaller number refers to 'mobile communications' studies, larger number to 'all frequency ranges'. Figure used with permission of the Mobile & Wireless Forum.

The radio signal exposure characteristics of the new wireless applications are similar to those of existing mobile technologies. In particular, the new applications use similar transmission powers and operate in similar frequency ranges. A European Commission expert committee⁶ has concluded that current knowledge

about how 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 wireless technology for the whole frequency range.

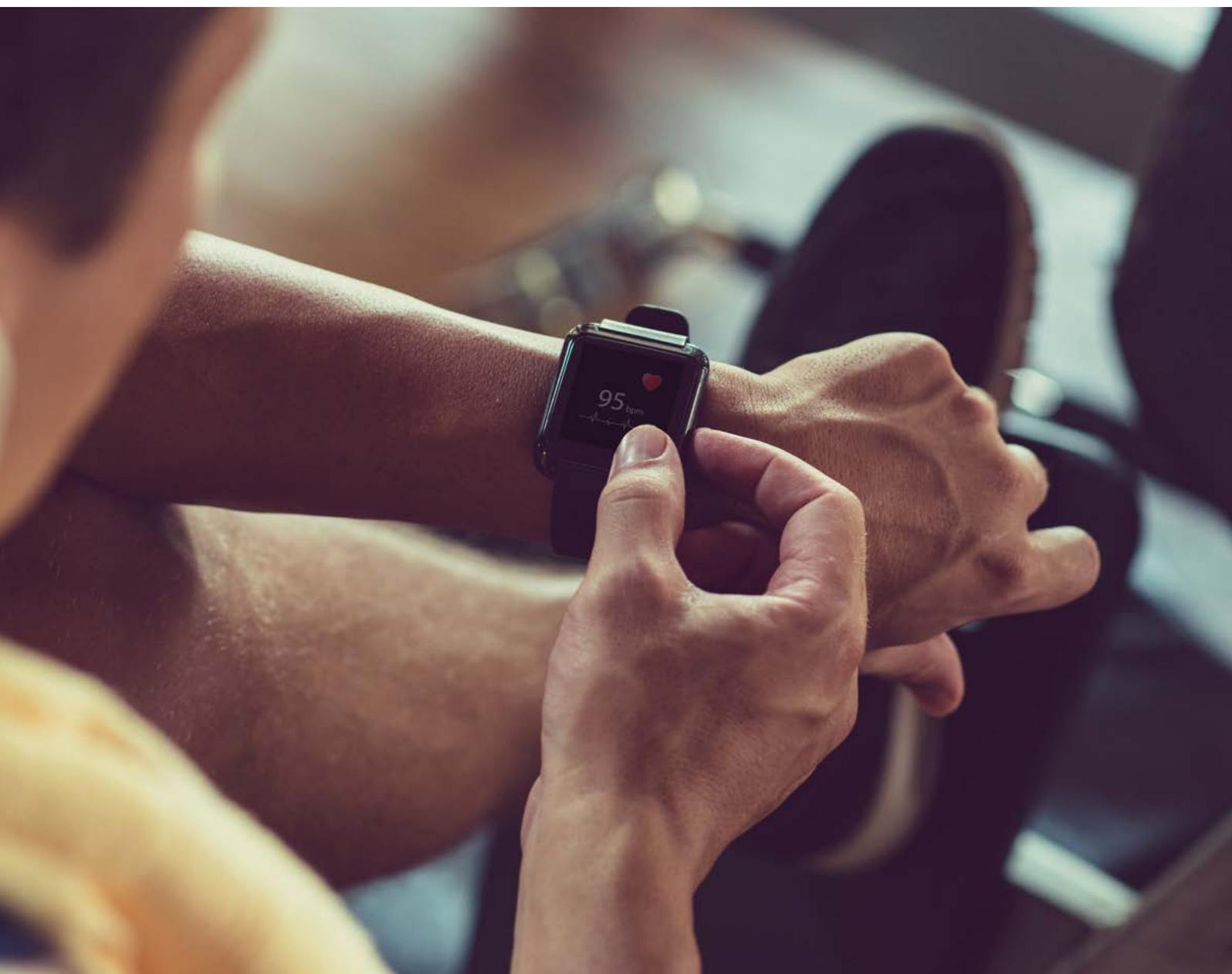
6. Final opinion on potential health effects of exposure to electromagnetic fields (EMF), Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), adopted on 27 January 2015. SCENIHR explains that at the frequencies used for mobile services, RF energy absorption and subsequent tissue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

How is new EMF research evaluated?

No single scientific study is definitive and each one should be considered on its own strengths and weaknesses and in the context of the total body of knowledge. There have been many expert reviews⁷ of the available research on radio signals and health. Scientific research is subject to potential errors, technical biases and uncertainties. When weighing the

evidence for potential health effects, scientists consider different aspects before drawing their conclusions.

The main conclusion from World Health Organization reviews is that EMF exposures below international guidelines have no known health consequences.



7. <https://www.gsma.com/publicpolicy/emf-and-health/expert-reports>

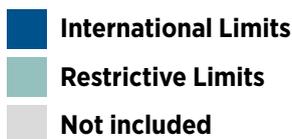
Does the growing use of wireless mean that exposure is continuing to increase and, therefore, we are at more risk?

There may be a small localised increase when 5G 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, including 5G, are designed to minimise power to reduce system interference. In summary, with the addition of 5G transmitters, the total exposure to radio waves will remain very low relative to the international exposure limits.

Based on measurements of existing wireless technologies it is expected that there will be no significant increase in overall exposure. As is evidenced in Figure 2, data from 47 measurement studies conducted in sixteen European countries between 2002 and 2017 shows no notable increase in personal exposure to radio signals. Another important observation is that there were no distinct differences between measured levels in countries with restrictive limits and those countries with the international limits.

Figure 2

No obvious increase in radio wave levels



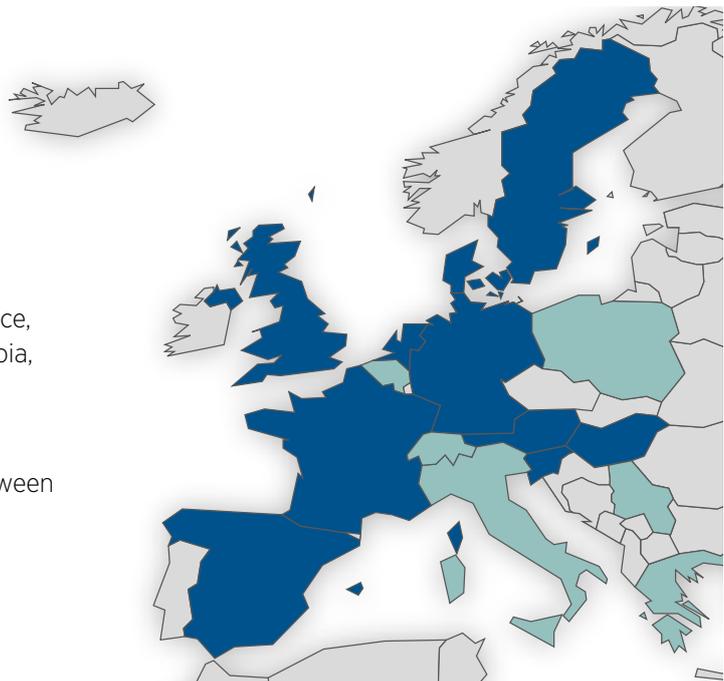
Data from 47 measurement studies⁸

Measurements in sixteen countries:

Austria, Belgium, Denmark, France, Germany, Greece, Hungary, Italy, Spain, Poland, the Netherlands, Serbia, Slovenia, Sweden, Switzerland, United Kingdom

Measurements made 2002 to 2017

There was no indication of distinct differences between countries, exposure levels were similar with the international or restrictive limits.



Personal measurement with volunteers studies do not indicate a notable increase in personal RF-EMF exposure, as mean levels are comparable to those reported in a previous review.



8. Radiofrequency Electromagnetic Field Exposure in Everyday Microenvironments in Europe: A Systematic Literature Review. Sagar et al., *Journal of Exposure Science & Environmental Epidemiology*. 28(2):147–60. March 2018 (<http://dx.doi.org/10.1038/jes.201713>) Public Exposure to Radiofrequency Electromagnetic Fields in Everyday Microenvironments: An Updated Systematic Review for Europe. Jalilian et al., *Environmental Research*. 176:108517. September 2019. (<https://doi.org/10.1016/j.envres.2019.05.048>)

Several studies have shown that the exposure levels from mobile networks have remained 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 Europe, North America and Africa. Even where there is evidence of an increase in some local areas due to improved wireless coverage, the overall levels remain a fraction of the international guidelines.

Analysis⁹ of measurements conducted over 10 years in more than 25 countries across the world shows that the mean level of environmental RF signals from mobile communications systems are typically less than

$0.1 \mu\text{W}/\text{cm}^2$ (microwatts per centimetre squared¹⁰). For comparison the recommended international limit for the public at the widely used mobile communications frequency of 900 MHz is $450 \mu\text{W}/\text{cm}^2$. Therefore, typical exposures are many thousands of times below the exposure limit for the public.

Many of the new wireless applications in the areas of IoT and wearable devices operate at very low powers and often transmit only intermittently.

Note also that for all wireless technologies, the exposure from antennas decreases rapidly with distance.

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 electromagnetic fields as possibly carcinogenic to humans (Group 2B), see Figure 3. 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.

RF signals are classified in the same IARC group as eating pickled vegetables (i.e. that there was limited evidence that they could cause cancer in humans). Eating processed meat falls in a higher classification than radio signals (i.e. there is stronger evidence that they might cause cancer in humans).

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

The IARC classification was based on limited evidence related to wireless devices used close to the head. There is uncertainty as to how to interpret the available data. In regard to environmental sources (such as mobile network base stations, broadcast antennas, Wi-Fi networks) and the exposure of RF workers, the evidence was judged to be inadequate.

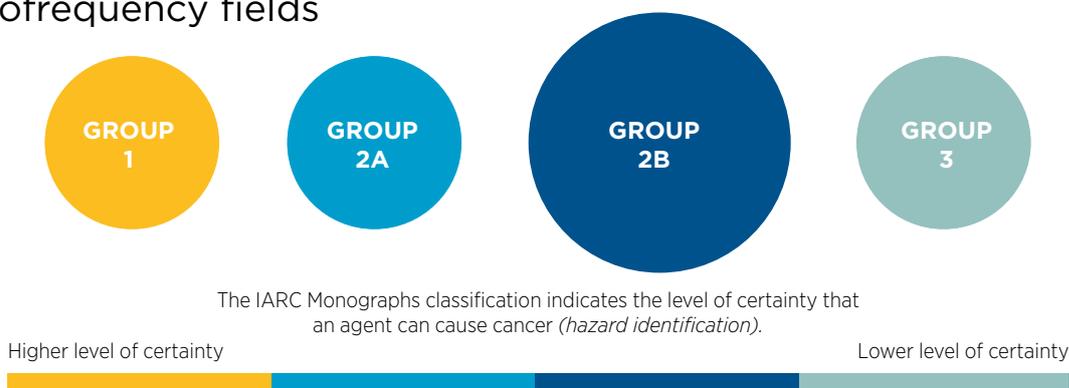
The WHO is conducting an overall risk assessment of all health outcomes related to RF exposure.

9. Comparative International Analysis of Radiofrequency Exposure Surveys of Mobile Communication Radio Base Stations, Rowley et al., *Journal of Exposure Science and Environmental Epidemiology*, 22(3):304–315, May/June 2012 (<http://dx.doi.org/10.1038/jes.2012.13>)

10. This is a unit for measurements of RF exposure in terms of power density.

Figure 3

Understanding the IARC Monographs classification of radiofrequency fields



What is the advice from the World Health Organization on mobile phones and health?

The position of the WHO¹¹ in regard to health effects from mobile phones is that:



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.



In respect of long-term effects WHO says:



While an increased risk of brain tumors 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.



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

I've heard that children could be at greater risk so how can they be protected if there are RF signals everywhere?

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

studies specific to children and this topic remains an active research area. The international exposure guidelines have been 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 Administration¹²



Although a substantial amount of research has been conducted in this area, there is no convincing evidence that RF field exposure below guideline levels causes effects in adults or children.

United Kingdom Health Protection Agency¹³



There is no scientific evidence for a negative influence of exposure to electromagnetic field of mobile telephones, base station antennas or Wi-Fi equipment on the development and functioning of the brain and on health in children.

Health Council of the Netherlands¹⁴



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. WHO has concluded that current scientific evidence does not justify specific measures for groups such as children and pregnant women.

12. <https://www.fda.gov/radiation-emitting-products/cell-phones/children-and-cell-phones>

13. Health Effects from Radiofrequency Electromagnetic Fields – RCE 20, Advisory Group on Non-ionising Radiation (AGNIR), Health Protection Agency, April 2012.

14. Health Council of the Netherlands. Influence of radiofrequency telecommunication signals on children's brains. The Hague: Health Council of the Netherlands, 2011; publication no. 2011/20E

I'm still 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 signals 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 TALK TIME

Should I buy a shielding device to protect my home and my family from these signals?

No. The RF signal level from wireless networks and devices is already low and typically a lot less than the limit values. WHO¹⁵ warns: *“The use of commercial devices for reducing radiofrequency field exposure has not been shown to be effective.”*



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 Administration¹⁶



In 2015 the DGCCRF¹⁷ (the French General Directorate for Competition Policy, Consumer Affairs and Fraud Control) investigated the sale of “shielding” devices for mobile phones. They concluded that the selling of these 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 recognized. In 2021,

consumers in the Netherlands¹⁸ were warned against using an anti-5G ‘negative ion’ pendant that emitted ionizing radiation.

The Australian government agency ARPANSA¹⁹ ‘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.’

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

16. <https://www.fda.gov/radiation-emitting-products/cell-phones/reducing-exposure-hands-free-kits-and-other-accessories>

17. <http://www.economie.gouv.fr/dgccrf/enquete-sur-dispositifs-anti-ondes-pour-telephone-mobile>

18. <https://english.autoriteitnvs.nl/latest/news/2021/12/16/do-you-have-a-quantumpendant-anti-5g-pendant-or-a-negative-ion-jewellery-item-or-sleep-mask-if-so-store-it-away-safely>

19. <https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiationsources/reducing-exposure-to-mobile-phones#protective>

3

Questions and answers related to 5G

Introduction to 5G

As well as the prospect of being much faster than existing technologies, 5G holds the promise of applications with high social and economic value, leading to an increasingly connected society in which mobile will play an ever more important role in people's lives.

As shown in Figure 4, two of the key technical characteristics are the speed of data transmission (the

throughput) and the time taken for the data to be transmitted across the network (the delay – also termed latency). Many applications can be supported on existing 4G networks but some will require 5G.

The key requirements for 5G are shown in Figure 5. These requirements include higher data rates and higher capacity with shorter latency as well as reductions in energy use and greater system efficiency.

Figure 4

5G supported services matrix

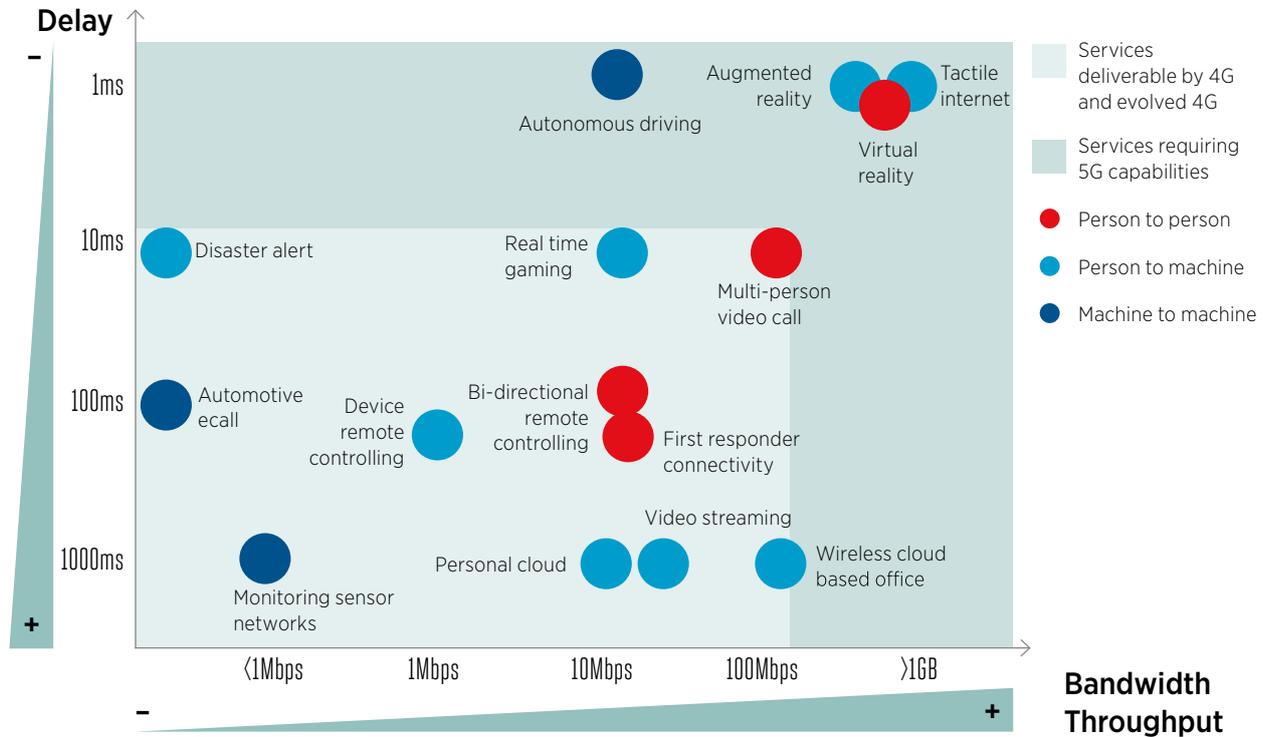
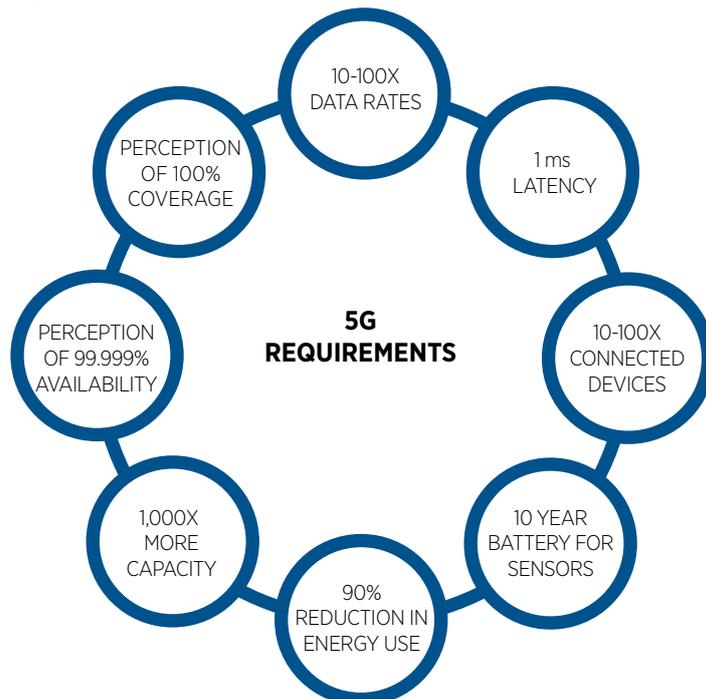


Figure 5

5G Requirements

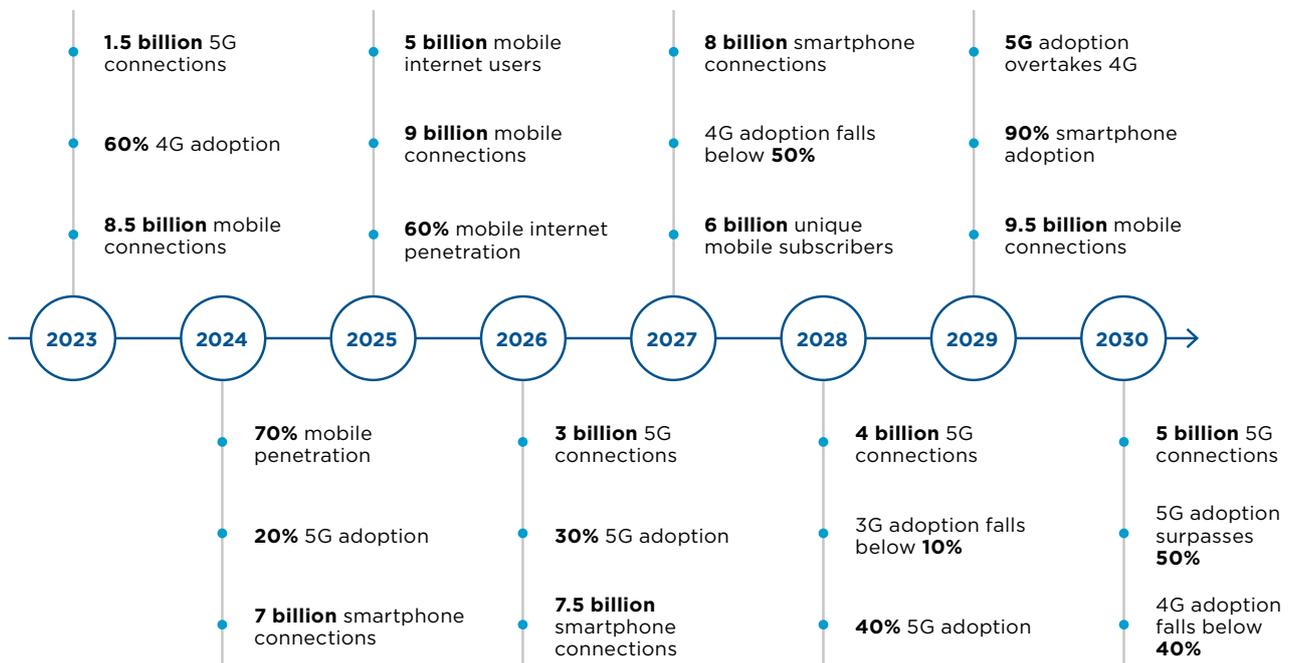


While 5G offers superior performance over 4G, both will coexist into the 2030s as the bedrock of next generation mobile networks. 5G networks will utilise and integrate a mixture of spectrum and access networks to meet customers' capacity and coverage needs.

As the latest and most capable mobile network, 5G will underpin the growth of the digital economy in many countries. This explains a lot of the government-backed activities around the world that seek to influence or accelerate the pace of 5G deployment and commercialisation.

Figure 6

Key milestones for the mobile industry to 2030 (Source: GSMA Intelligence)



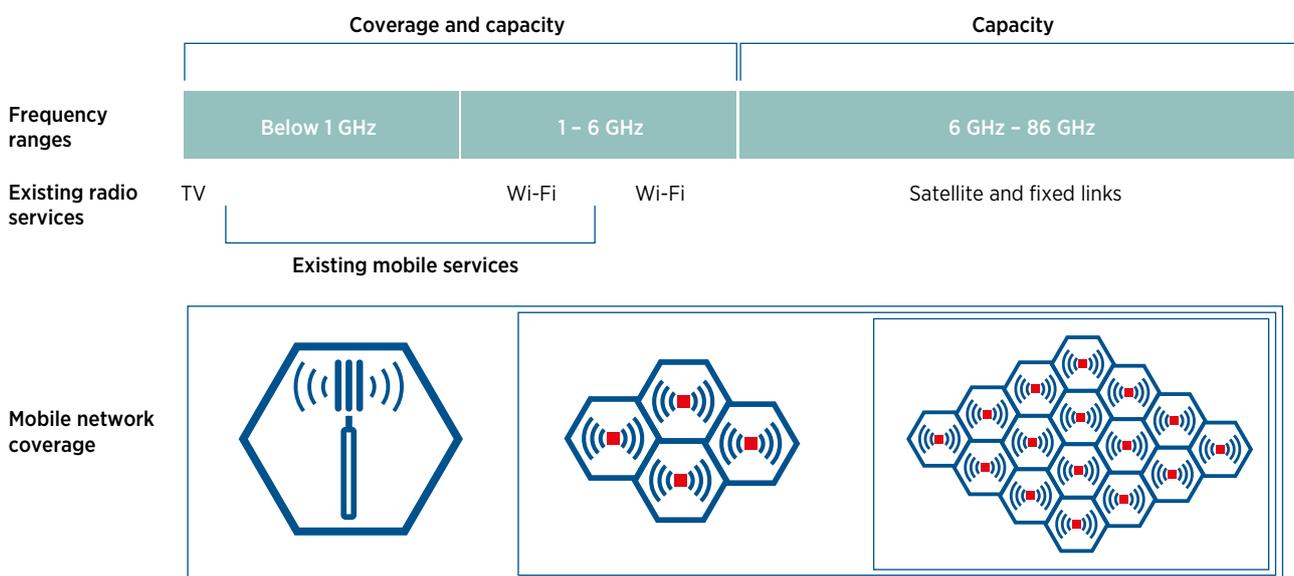
As shown in Figure 6, there is significant momentum around 5G, with 5 billion connections forecast by 2030, more than 50% of global connections.

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 experiments and future deployment will use frequencies already covered by existing exposure standards.

Figure 7

5G needs spectrum within three key frequency ranges



As can be seen in Figure 7, 5G needs spectrum within three key frequency ranges to deliver widespread coverage and support all the planned services. The three ranges are: Sub-1 GHz, 1-6 GHz and above 6 GHz.

- Sub-1 GHz will support widespread coverage across urban, suburban and rural areas and help support IoT services through better in-building coverage.
- 1-6 GHz offers a good mixture of coverage and capacity benefits. This includes spectrum within the 3.3-3.8 GHz range which is expected to form the basis of many initial 5G services.
- Above 6 GHz is needed to meet the ultra-high broadband speeds planned for 5G. A focus will be on bands above 24 GHz (28 GHz has been identified for 5G in the USA).

Some of the potential bands for 5G are at similar frequencies to mobile technologies already in use. The 3G and 4G mobile technologies of today typically operate in several bands between 700 MHz and 2.7 GHz. Wi-Fi operates at 2.45 and 5 GHz. This also means that many existing antennas sites can be reused for 5G.

Higher frequencies, such as 24-86 GHz, are mostly used today by the mobile and satellite industries for other purposes. These high frequencies are also known as millimetre-waves (mmW or mmWaves). The millimetre-wave frequencies will be used for capacity in conjunction with increased small cell deployments.

At these frequencies RF energy is absorbed superficially by the body, mostly by the skin (to a depth of only 1 to 10 mm). Biological effects of these frequencies have been studied previously and new studies are underway using millimetre wave exposures.



The use of mmWave frequencies for 5G will comply with the international exposure guidelines and typical levels will be similar to existing mobile services.

For additional information see the GSMA publication 5G millimetre wave safety.²⁰



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 Agency²¹



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.

The World Health Organization²²



Does higher data rates mean higher network exposures?

Assessments of 5G networks show exposure levels that are similar to existing mobile services. The typical maximum measured 5G EMF level across the surveys is less than 1% of the international public limits.

One of the goals of 5G deployments is to provide much higher data rates. This is needed to meet the high expectations and demands customers place on mobile communication applications and services both in their professional and private life.

Private 5G networks are possible, using network slicing or spectrum licensing. These are covered by the same RF-EMF limits as public 5G networks.

With the introduction of new technologies, there may be a small increase in the 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.

For more information on assessments of 5G EMF levels see www.gsma.com/emf

20. <https://www.gsma.com/publicpolicy/resources/emf-safety-and-5g-mmwave-networks>

21. <https://www.arpansa.gov.au/news/world-first-reviews-5g-radio-waves>

22. www.who.int/news-room/q-a-detail/5g-mobile-networks-and-health

Will 5G replace the earlier mobile network technologies?

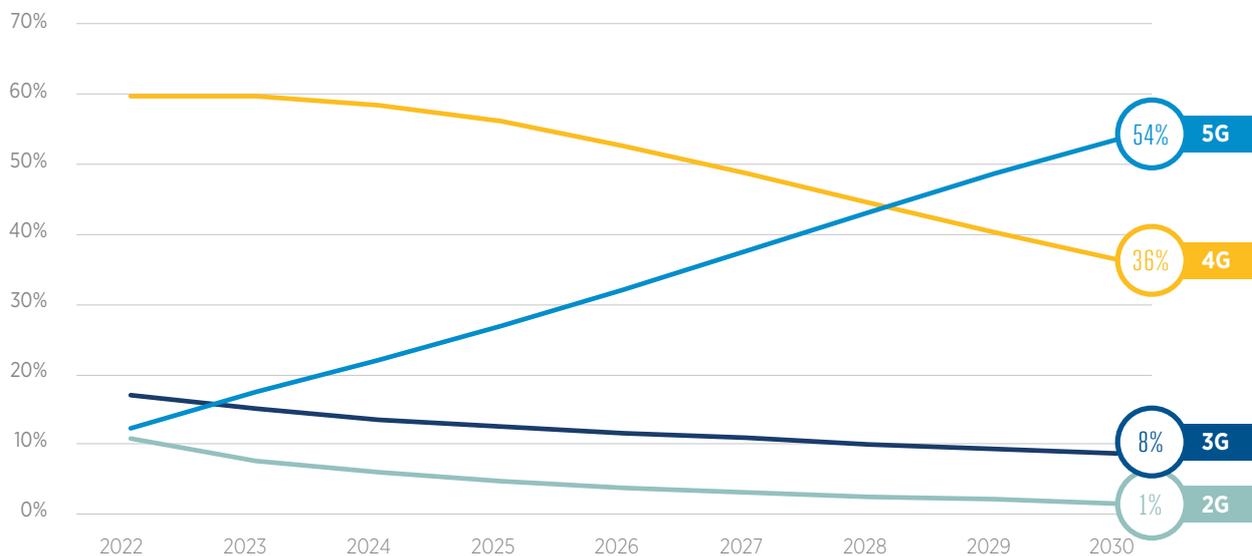
As consumers expect to be able to use their mobile devices virtually everywhere, initially 5G is likely to be deployed in parallel with existing mobile technologies. Early 5G deployments will be in locations where it is needed to supplement the capacity of current

networks. Further rollouts will occur as demand dictates. We can see how this has happened with 4G deployments in Figure 8. This also means continuity of service for customers who can continue to use their devices on existing networks.

Figure 8

Percentage of connections (excluding licensed cellular IoT)

(Source: GSMA Intelligence)



The GSMA generally supports the removal of technology restrictions to enable new mobile technologies to be deployed within the same frequency bands as existing technologies. Where governments allow flexibility in the choice of technology, network operators may deploy 5G in the frequencies currently

used to provide mobile services. In some cases this may be a replacement for existing mobile technologies and in other cases it will be an additional radio technology. If a new license, with additional fees, is required before 5G based services can be provided this may delay rollout.

Are testing standards in place for 5G devices and networks?

Many initial 5G deployments will be 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 will also apply to 5G devices. For 5G devices operating in

frequency bands higher than those used by current mobile phones, new test procedures were developed by the International Electrotechnical Commission (IEC) Technical Committee 106.

Does 5G mean an antenna on every street corner and inside all buildings? What will that mean for the visual environment?

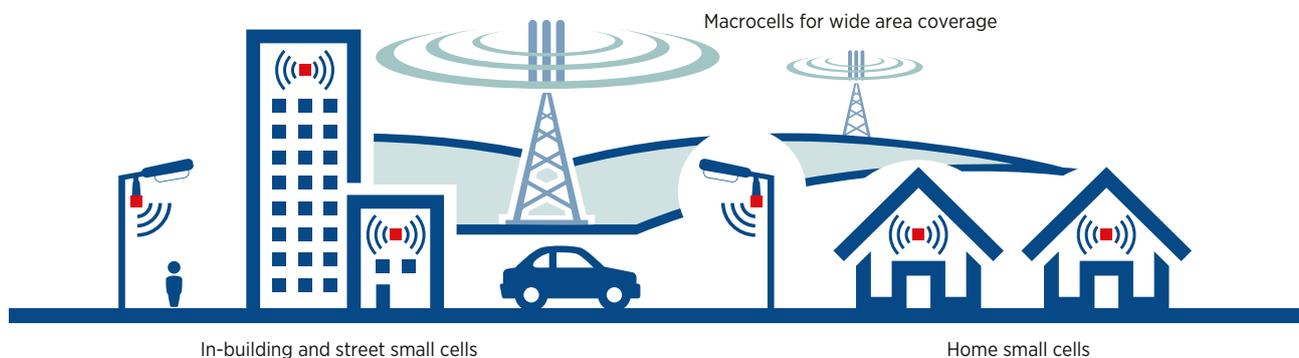
The coverage and capacity objectives of 5G combined with advanced antenna technologies means that some new antennas are likely to be required. Where possible an operator will place these antennas at an existing site and at other times new locations will be required.

Mobile networks today consist of a mix of macrocell sites to provide wide area coverage and small cells to improve localised coverage and increase capacity.

These are termed heterogeneous networks or ‘hetnets’, see Figure 9. ‘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. More information can be found in the GSMA publication *Improving wireless connectivity through small cell deployment*.

Figure 9

Representation of heterogeneous mobile network (“hetnet”)



Over the next few years, the number of small cell installations will increase. 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 the phone will operate more efficiently, improving the available data rate and reducing the exposure of the user.

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.

Will 5G network antennas look similar to what we already see in towns and cities, on rooftops and in fields?

Many of the antennas used for 5G will look similar to those already present in the environment. Advanced antenna technologies such as beam-forming require the use of arrays of antennas to optimise the delivery of the wanted radio signal to connected mobile devices. Conventional antennas provide coverage

similar to how a floodlight illuminates a wide area. The new antennas are like a flashlight providing coverage where it is needed and reducing unwanted signals. Smart antennas increase capacity and improve efficiency.

Figure 10

Advanced antenna technologies



As shown in Figure 10, a conventional base station antenna transmits a radio signal to a wide area regardless of how many users are connected. Smart beam forming antennas transmit radio signals only to connected users reducing interference and exposure. Beamforming involves combining the signal from multiple antennas to improve performance. However, operation at higher frequencies means that the size of

many of the antennas is expected to be similar to that of existing installations.

This smart antenna technology is also called massive MIMO (Multiple-Input Multiple-Output). Operator tests have shown that smart antennas can serve many more users for the same amount of spectrum bandwidth.

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

Smart antennas for 5G networks produce lower time averaged exposure for the same source characteristics than conventional antennas. Where regulatory authorities allow the use of updated assessment methods this can result in smaller compliance zones. The size and shape of compliance zones will be evaluated and implemented according to international technical standards.

New approaches to assess RF compliance provide greater accuracy and are applicable to all mobile technologies. Smart antenna technologies produce a number of narrow beams that change with call requirements. These changing beams require new approaches to assessing compliance as existing methods would significantly overestimate the size of the compliance zones

Mobile network antennas are typically directional. Compliance zones extend in front of the antenna

and a small distance above and below. If an antenna could be accessible to the public, then there are signs and barriers to advise them of the antenna, and how to proceed safely. 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.

Mobile networks are designed to use only the power needed to provide quality services. Too much power would cause interference and affect all users. One of the goals of 5G is a substantial increase in network energy efficiency. Some of features being considered include reducing the power of transmitters when they are not in use and implementing sleep modes. Another approach, is to reduce the amount of signaling needed to maintain connectivity.

Is 5G dangerous for the environment?

The same limit values that protect people also protect the environment. The report of an international workshop on EMF and the environment concludes that there is 'no proven scientific evidence of adverse effects in animals or plants under realistic environmental conditions' due to low-level radio signals.²³

In addition, the Antenna Bureau in the Netherlands (Antennebureau) has also refuted conspiracy-theorist

claims that 5G tests harmed birds.

One of the goals of 5G is a 90% reduction in energy use. This will be achieved by reducing the power of transmitters when they are not in use, implementing sleep modes and reducing the amount of signaling needed to maintain connectivity.

23. 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>)

I have read social media articles linking the spread of COVID-19 with 5G. Is this true?

No. 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 maintains that COVID-19 is spread through respiratory droplets when an infected person coughs, sneezes or speaks.

5G mobile networks do not spread COVID-19 and the GSMA urges governments around the world to take swift action against disinformation, vandalism and threats against mobile networks.

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. They may be mounted on street lights or inside buildings, where over 80% of mobile usage occurs in developed markets. Measurements of 4G small cells by the French spectrum agency²⁴ and a study²⁵ of

almost 100 small cell sites in South Africa, the Netherlands and Italy found that levels in nearby areas remained well below the international safety guidelines and about the same as the level due to the macro network.

How do you respond to the petitions calling for 5G to be stopped?

The science 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.”²⁶



24. Rapport technique sur les déploiements pilotes de petites antennes en France pour favoriser l'accès au très haut débit mobile. L'Agence nationale des fréquences (ANFR). December 2018.

25. Measurement of EMF exposure around small cell base station sites, van Wyk, et al., *Radiation Protection Dosimetry*, 184(2):211-215, August 2019

26. European Commission response to questions from the European Parliament, May 2019.

4

Questions and answers related to Internet of Things (IoT)



Introduction to IoT

The Internet of Things (IoT) describes the coordination of multiple machines, devices and appliances connected to the Internet through multiple 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. Mobile IoT technology connects machines, devices and appliances wirelessly to deliver services with limited direct human intervention. A wide variety of monitors and sensors are now being equipped with wireless connectivity enabling smart wireless applications in healthcare, agriculture and services such as water and electricity.²⁰

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.

Commercial wireless networks for IoT applications have already been deployed in some countries. Mobile IoT refers to low power wide area (LPWA) 3GPP standardised secure operator managed IoT networks in licensed spectrum. Existing cellular networks have evolved to deliver service to new devices providing complete IoT connectivity. 5G will support massive IoT and enable applications based on ultra-reliable, low-latency communications.

Are testing standards in place for IoT devices and networks?

IoT devices operating above 30 MHz and below 6 GHz will be covered by existing international technical compliance testing standards for wireless devices and networks. Where the devices are operating at higher frequencies they will be covered by the updated testing standards that are under development for 5G devices.

Some IoT devices will be exempt from testing because their very low power combined with intermittent transmission, see Figure 11, means that they are certain to comply with the relevant exposure limits.

EXAMPLE:

Assume a Narrowband IoT (NB IoT)²¹ device able to transmit 10 to 25 kbits of data for a time duration of 450 ms with a maximum peak power of 200 mW and a duty cycle of 10 %. This would be more data than required for many IoT applications. If this data transmission occurs every minute the average power transmitted over this period is 0.15 mW.

$$\frac{0.45}{60} \times 200 \times 0.1 = 0.15 \text{ mW}$$

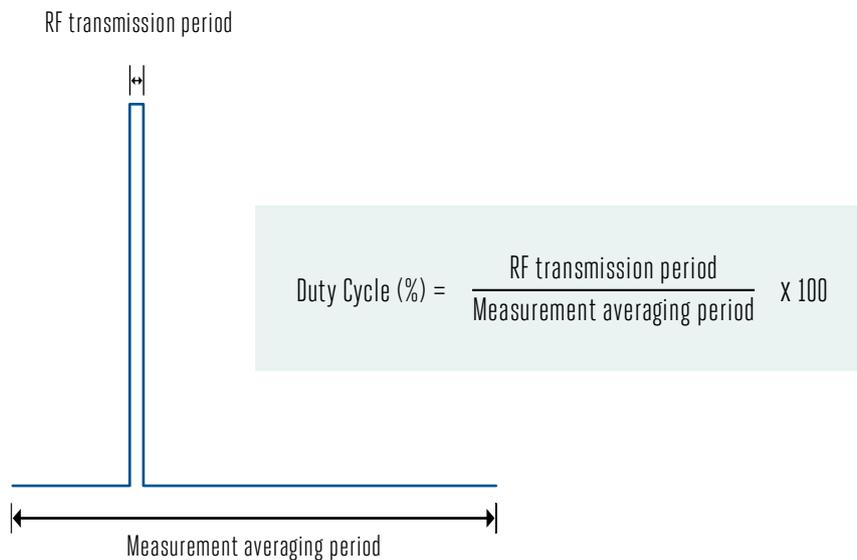
This is more than 100 times below the threshold power of 20 mW at which testing is required by some standards. Such a device would not require compliance testing.

20. Further information is available in the GSMA publication *Smart meters: Compliance with radio frequency exposure standards*.

21. NB-IoT is a standards-based Low Power Wide Area (LPWA) technology developed to enable a wide range of new IoT devices and services. NB-IoT significantly improves the power consumption of user devices, system capacity and spectrum efficiency. It is designed to provide connectivity for devices and applications that require low mobility and low amounts of data transfer

Figure 11

Illustration of a NB-IOT device duty cycle



Some toys now have radio transmitters installed, are these safe?

These transmitters are regarded as safe as they are required to comply with relevant exposure limits. The radio transmitters in toys are generally low power and short range and many use familiar technologies such as Wi-Fi and Bluetooth.

Some of these devices may be powered by harvesting energy from the radio signals all around us. If that is possible what does it mean for my exposure?

As the level of RF signals in the environment is low this is only suitable for devices with very low energy requirements. The ability to extract energy from ambient radio signals has a major advantage in reducing the need for batteries or significantly extending battery life. A specialised circuit converts

some of the ambient RF energy into electrical power to charge a battery. This may be useful for very low power devices, such as sensors that could be positioned in large numbers to monitor the environment or traffic, and which transmit small amounts of data at intervals.

How will 5G support the Internet of Things?

5G is optimised to support the Internet of Things (IoT) in three major areas. Low data rate IoT applications such as sensors or identification trackers with long service lifecycles and that may need to be connected over very long distances will use recently developed 3GPP technologies. As standards evolve, 5G will make it possible to manage large numbers of such connected objects even more effectively. 5G can support new high

speed IoT applications, for example 4K cameras and control of drones. A new opportunity enabled by 5G is critical IoT applications requiring unparalleled reliability (99.999%) and extremely low latency (1 ms minimum). Example applications include connected vehicles, health equipment and industrial applications such as remote control of machines.

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

Even if there are a large number of connected objects in the future, levels of exposure to radio waves will not change significantly as connected objects will be very low power and will transmit only intermittently. In general, the quantity of data to be exchanged will be very small. It is very important for many connected objects (IoT) applications that use of energy is minimised to extend battery life. 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.

5

Questions and answers related to wearable devices

A background image showing several hands wearing smartwatches. The image is overlaid with a semi-transparent teal filter. The hands are positioned in a way that suggests they are being checked or adjusted, with one hand holding a smartwatch to another's wrist.

Introduction to wearable devices

With the rapid evolution of consumer lifestyles, wearable devices, such as smart watches and fitness bands, have increasingly become part of the everyday life. Wearable devices incorporate electronics, software, sensors and connectivity, often using a wireless technology. From a relatively low base, the wearables

market is growing rapidly, presenting opportunities in a number of sectors, such as health, household, textiles and construction. While these devices are currently used for entertainment and other tasks like monitoring physical activity, there are also increasing examples of devices for use in healthcare applications.

Is it safe to wear these 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 at intervals and over short distances, for example, to a nearby smartphone, tablet or laptop.



RF transmitters in wearable devices operate at extremely low power levels and normally send signals in streams or brief bursts (pulses) for a short period of time. As a result, wearable devices expose the user to very small levels of RF radiation over time.

United States Centers for Disease Prevention and Control²²



Some devices will be 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.

22. <https://www.cdc.gov/nceh/radiation/wearable.html>

Are testing standards in place for wearable devices?

Wearable devices operating above 30 MHz and below 6 GHz will be covered by existing testing standards for wireless devices. Where the devices are operating

at higher frequencies they are covered by the testing standards that are applicable to 5G devices.

What about children wearing RF transmitting devices, for security or entertainment?

The radio transmitters in such devices are generally very low power and relatively short range. When tested they are required to comply with national or international exposure limits. When watching a video

the device is mostly receiving information and only transmits information for brief periods. Other types of devices such as personal trackers also transmit for short periods of time.



I have seen devices advertised for use with babies, for example, sleep monitors, are they safe?

The radio transmitters in baby monitors are generally low power and relatively short range. When tested they

are required to comply with national or international exposure limits.

Are smart watches safe to use when driving?

Driver distraction is an important risk factor for accidents and the role of mobile phones in this regard has been the subject of extensive research and regulation. The GSMA recommends against activities that involve drivers taking their eyes off the road. Driver distraction can also occur without taking your eyes off the road. Some governments recommend that calls that are complex or demanding should not be taken while driving.

There is little published research assessing the specific impact of smart watches on driver distraction. In many countries it is illegal to use a mobile phone while driving unless used with an appropriate hands-free

kit. A hands-free device can reduce the physical effort to make and receive calls, however, it alone does not make using a mobile phone while driving safe. Drivers should always keep both eyes on the road and not read, write or send messages or look at the Internet. Also, they should not email or take notes during a call while driving.

Both operators and automakers have been active in efforts to promote compliance with national laws and responsible mobile phone use by drivers. There are many examples of educational campaigns, often aimed at particular driver segments such as inexperienced drivers.

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 – 5G Radiofrequency - RF EMF	https://www.icnirp.org/en/applications/5g/index.html
International Telecommunications Union (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	1st to 5th generation mobile communication technologies
EMF	Electromagnetic field
GHz	Giga-Hertz
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	kilo bits seconds
LPWA	Low Power Wide Area
M2M	Machine-to-Machine
Mbps	Megabits per second
MHz	Megahertz
MIMO	Multiple-Input Multiple-Output
mmW	millimetre-wave (mmWave)
ms	millisecond
mW	milliwatt
NB-IoT	Narrowband IoT
RF	Radio frequency
WHO	World Health Organization
Wi-Fi	Wireless Fidelity, wireless networking technology





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