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

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

September 2017

About the GSMA
The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with more than 300 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai, Mobile World Congress Americas and the Mobile 360 Series of conferences.

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Contents

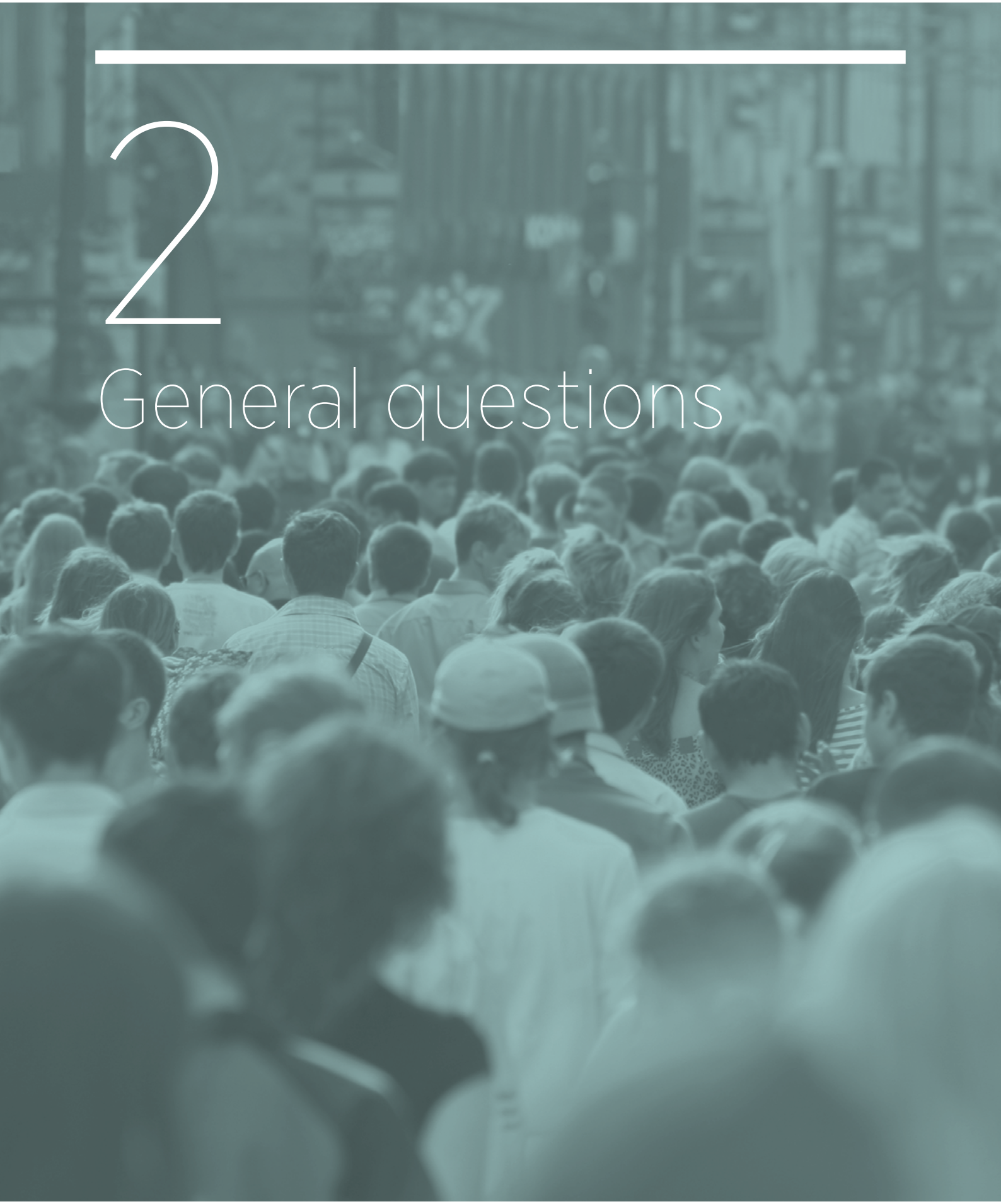
1 Context

There is significant interest in new applications of wireless technology with particular focus on 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, will be 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 WHO recommends that countries adopt the ICNIRP guidelines.

The available evidence has been reviewed by many independent expert groups. The GSMA[2] website contains a comprehensive tabulation of such reports dating back to 1978.

The ICNIRP exposure guidelines for frequencies up to 300 GHz were published in 1998. They are being revised and replaced step by step. Revisions of the static and low-frequency parts are already finalized and published. Currently, ICNIRP is revising the guidelines on limiting exposure EMF in the frequency range 100 kHz - 300 GHz. The updated guidelines are expected in 2018. It may take some time for any changes to be adopted into national regulations. In the meantime, the ICNIRP position is that RF exposure below the established threshold is unlikely to be associated with adverse health effects.

> 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 Guidelines[3]**

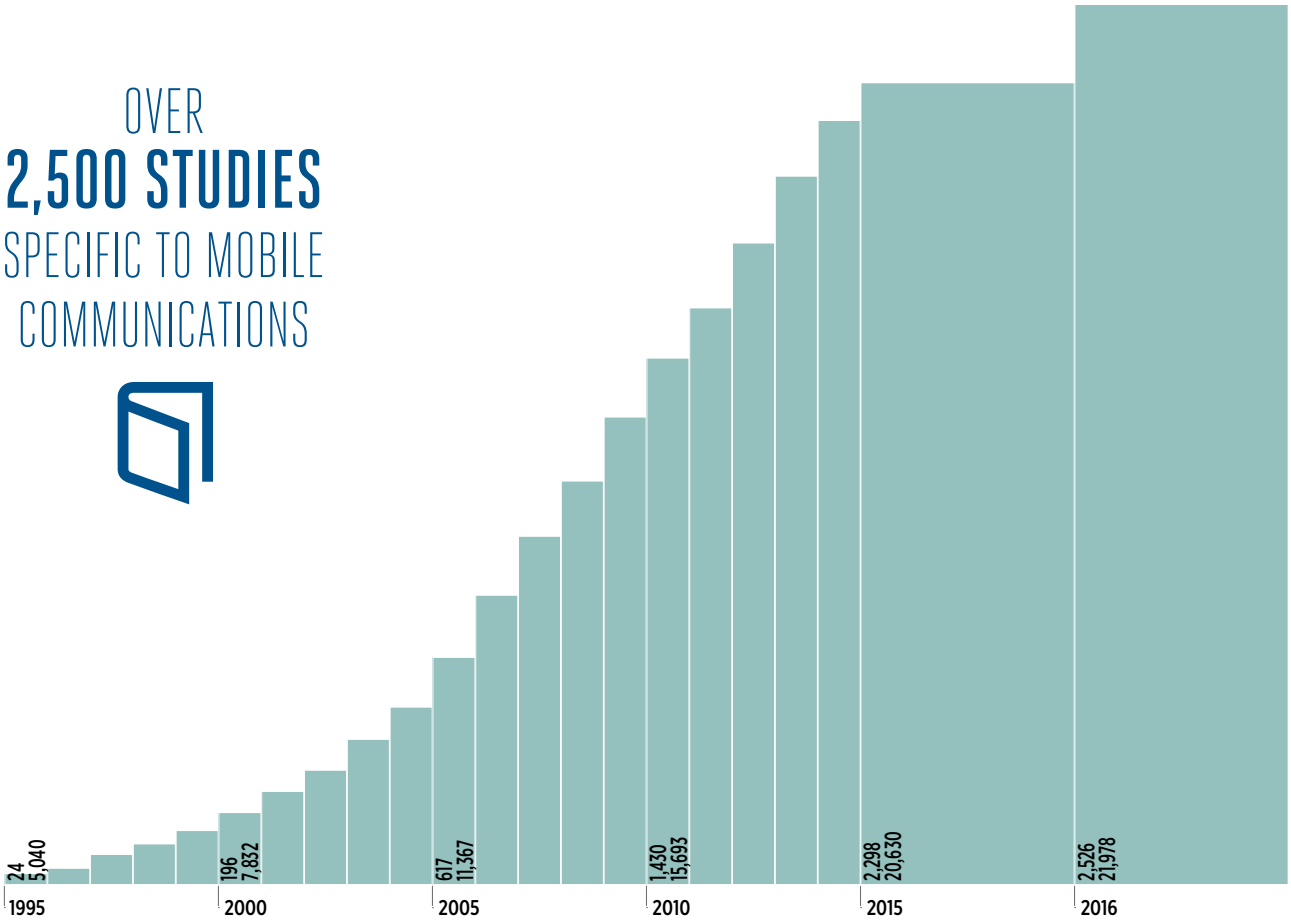
What kind of research exists regarding the possible health risks from exposure from these new wireless technologies and applications?

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

1. http://www.icnirp.org/
2. http://www.gsma.com/publicpolicy/consumer-affairs/emf-and-health/expert-reports
3. http://www.who.int/peh-emf/standards/en/

Figure 1

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



Data from www.emf-portal.org (status December 2016). Smaller number refers to 'mobile communications' studies, larger number to 'all topics' and '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 committee 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.

> Several interaction mechanisms are well established. These enable extrapolation of scientific results to the entire frequency range and wide-band health risk assessment. They have been used to formulate guidelines limiting exposures to EMF in the entire frequency range from static fields to 300 GHz.
>
> **European Commission Scientific Committee** (2015)[4]

4. 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.

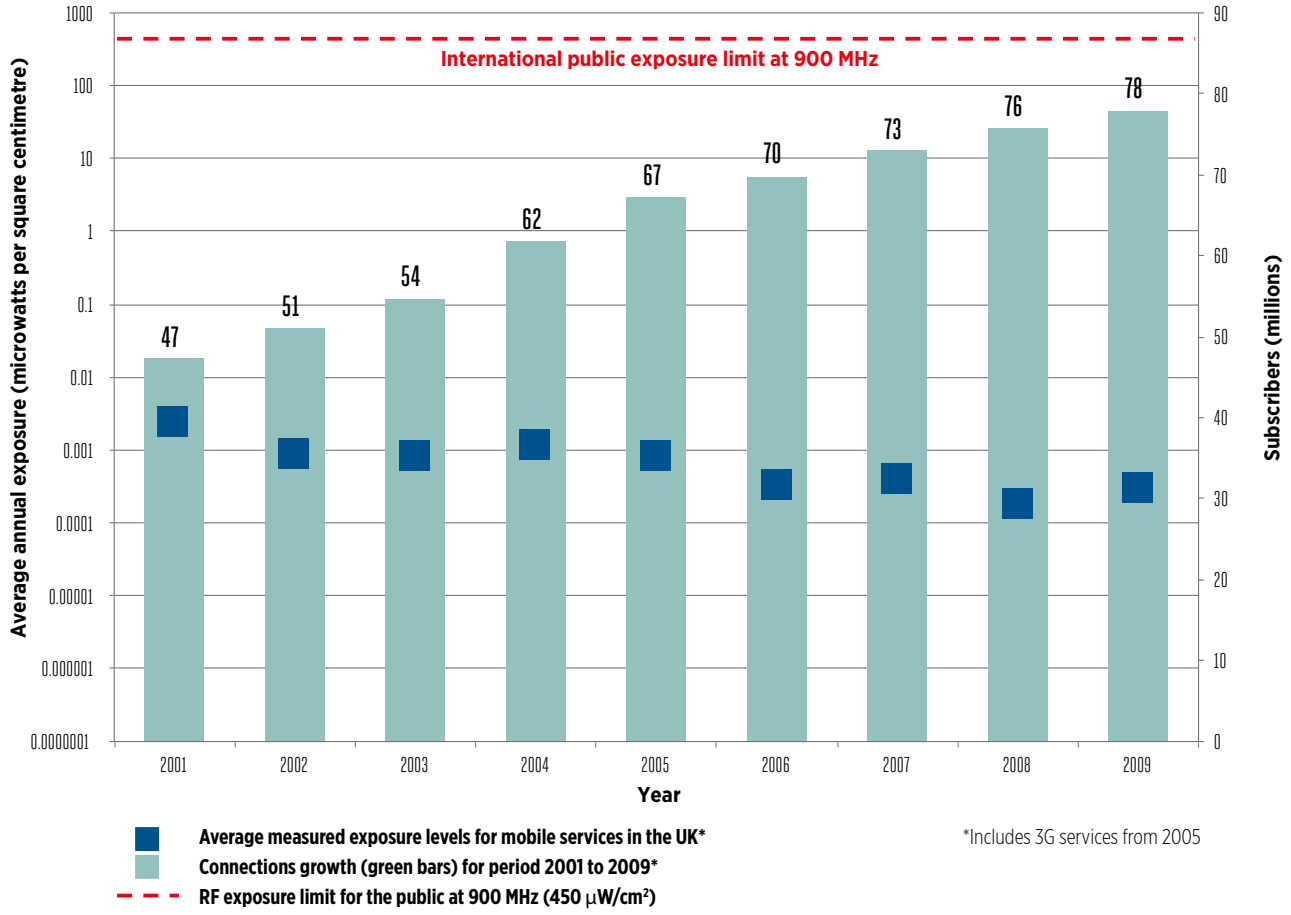
Does the growing use of wireless mean that exposure is continuing to increase and, therefore, we are at more risk?

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 the average measured annual exposure from mobile services in the United Kingdom did not increase during a period when there was substantial subscriber growth and the launch of 3G services in 2005.

Figure 2

Exposure to radio waves in the United Kingdom (2001-2009)[5]



Average measured exposure levels for mobile services in the UK (blue squares) and connections growth (green bars) for period 2001 to 2009. GSM services only 2001 to 2004. GSM and 3G services from 2005. The international (ICNIRP, 1998) RF exposure limit for the public at 900 MHz (450 μW/cm²) is also shown as this is the most restrictive limit in the relevant frequency range. Data sources: GSMA, OFCOM and Wireless Intelligence data.

5. Connections excludes cellular M2M. OFCOM significantly reduced the number of sites measured annually after 2009 and since 2013 measurements are conducted on an ad hoc basis on request with insufficient data for inclusion.

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 other countries in Europe, North America and Africa. 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. 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.

Analysis of measurements conducted over the last 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 μW/cm^2 (microwatts per centimetre squared[6]). For comparison the recommended international limit for the public at the widely used mobile communications frequency of 900 MHz is 450 μW/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). 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.

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 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. The final report termed a 'monograph' is expected in 2018.

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

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

The position of the WHO[7] 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.

7. 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.

> The scientific evidence does not show a danger to any users of cell phones from RF exposure, including children and teenagers.
>
> **United States Food and Drug Administration** (2014)[8]

> 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 Agency** (2012)[9]

> 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 Netherlands** (2011)[10]

National authorities in some countries have recommended 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.

8. http://www.fda.gov/radiation-emittingproducts/radiationemittingproductsandprocedures/homebusinessandentertainment/cellphones/ucm116331.htm
9. Health Effects from Radiofrequency Electromagnetic Fields – RCE 20, Advisory Group on Non-ionising Radiation (AGNIR), Health Protection Agency, April 2012.
10. 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

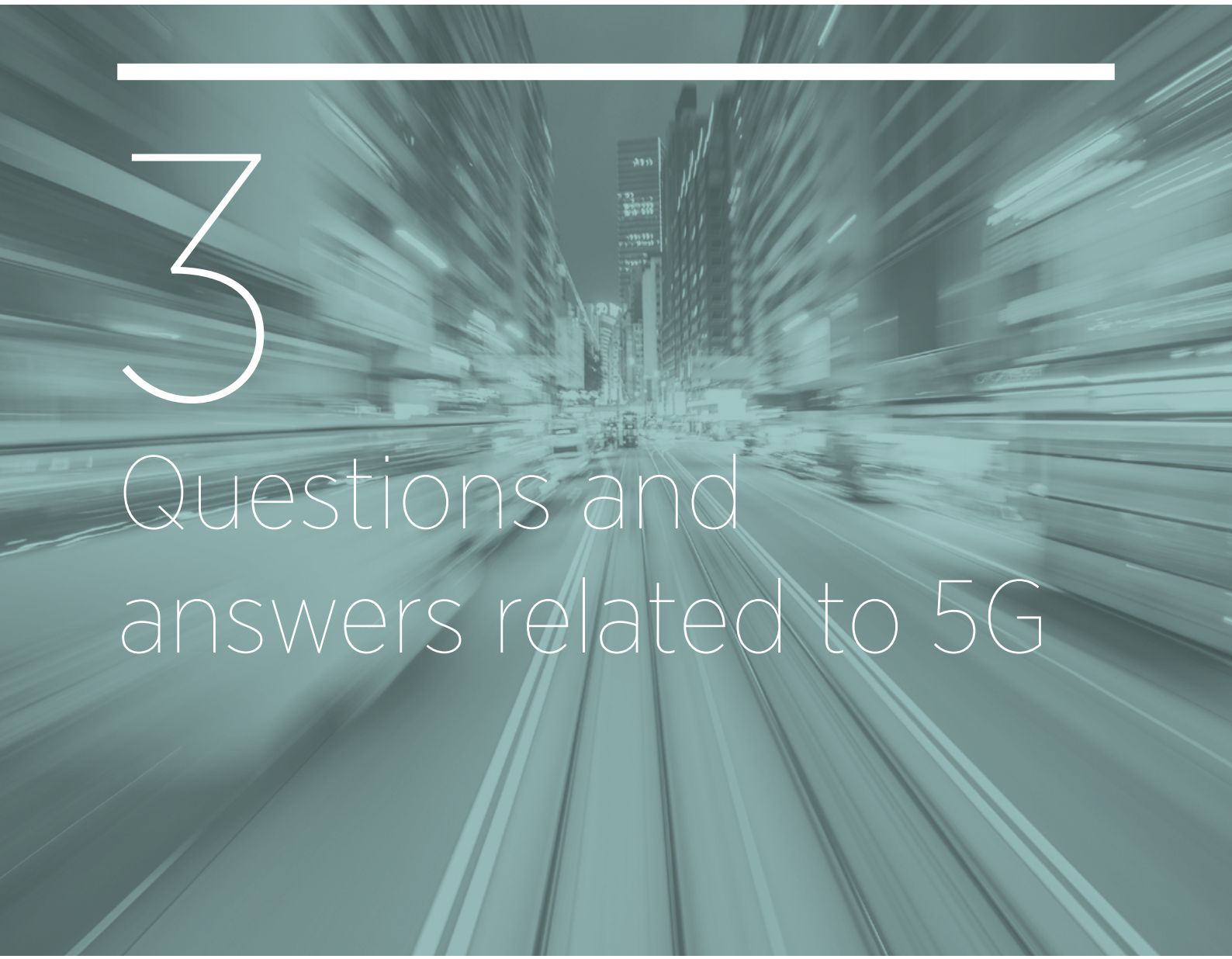
Should I buy a shielding device to protect my home and my family from these signals?

No. The RF signal level from wireless networks and devices is already low and typically a lot less than the limit values. WHO[11] warns: *"The use of commercial devices for reducing radiofrequency field exposure has not been shown to be effective. "*

> Since there are no known risks from exposure to RF emissions from cell phones, there is no reason to believe that accessories that claim to shield the head from those emissions reduce risks. Some products that claim to shield the user from RF absorption use special phone cases, while others involve nothing more than a metallic accessory attached to the phone. Studies have shown that these products generally do not work as advertised. Unlike "hand-free" kits, these so-called "shields" may interfere with proper operation of the phone. The phone may be forced to boost its power to compensate, leading to an increase in RF absorption.
>
> **United States Food and Drug Administration[12]**

In 2015 the DGCCRF[13] (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 addition, the allegations of hazard were often based on a fanciful or entirely invented vocabulary.

11. Electromagnetic fields and public health: mobile phones, WHO Fact sheet N°193, October 2014.
12. http://www.fda.gov/radiation-emittingproducts/radiationemittingproductsandprocedures/homebusinessandentertainment/cellphones/ucm116331.htm
13. http://www.economie.gouv.fr/dgccrf/enquete-sur-dispositifs-anti-ondes-pour-telephone-mobile



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 3, 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 4. These requirements include higher data rates and higher capacity with shorter latency as well as reductions in energy use and greater system efficiency.

Figure 3

5G supported services matrix

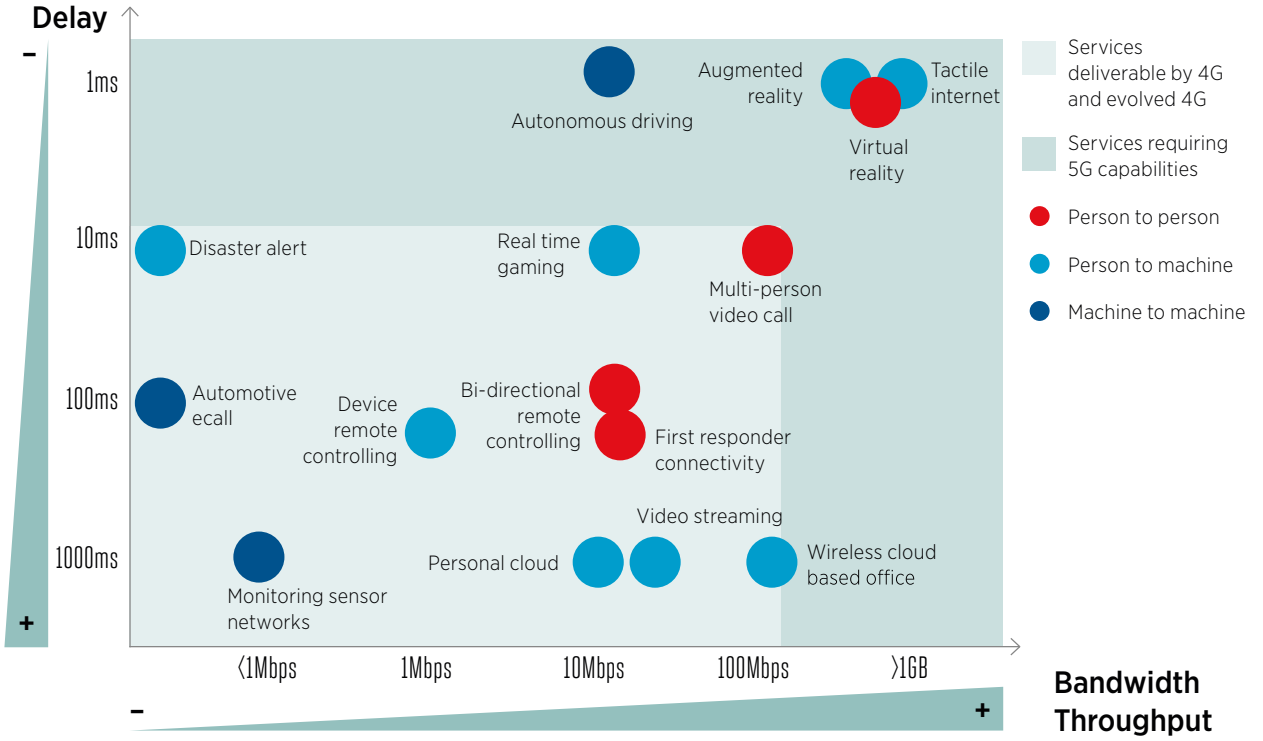
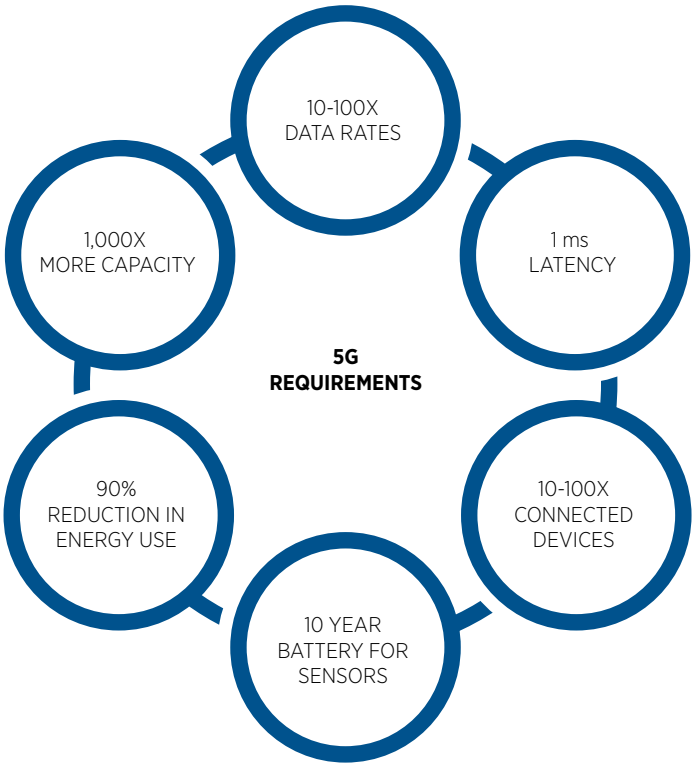


Figure 4

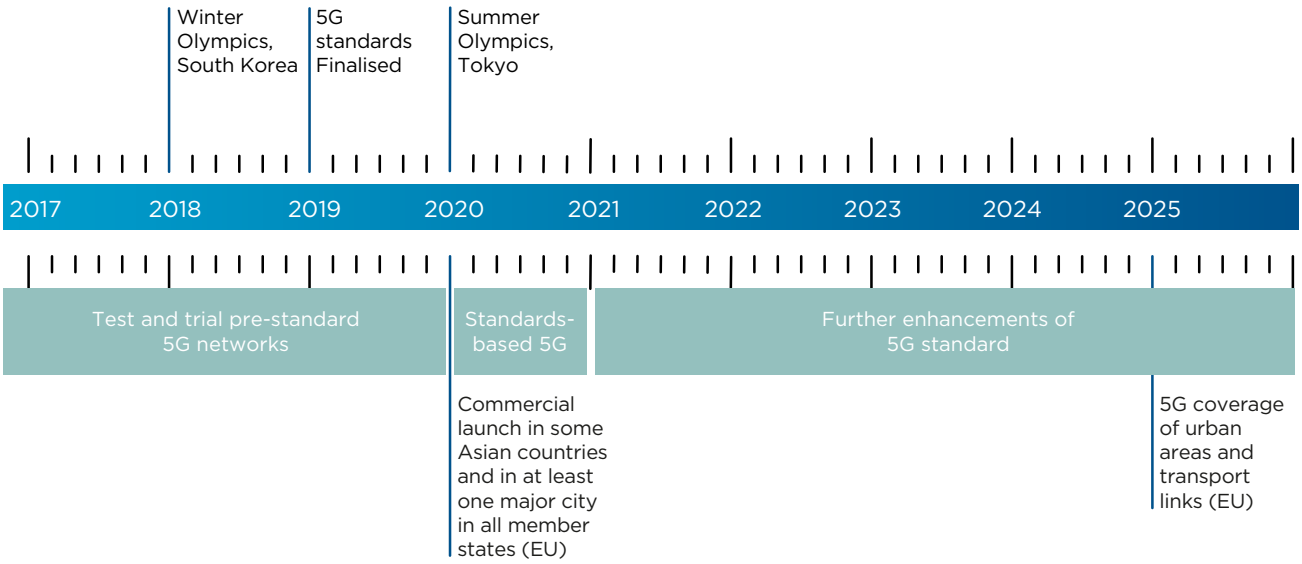
5G Requirements



The mobile industry, academic institutions and national governments are currently actively investigating what technologies could be used for 5G. One approach is to use a blend of pre-existing technologies (2G, 3G, 4G, Wi-Fi and others) to allow higher coverage, availability and network density to support the greater connectivity requirements of the IoT. In addition, a new radio technology may be needed to achieve the low-delay, low-power and high-efficiency objectives. As the standards are still under development it is not possible to be more exact at this time.

Figure 5

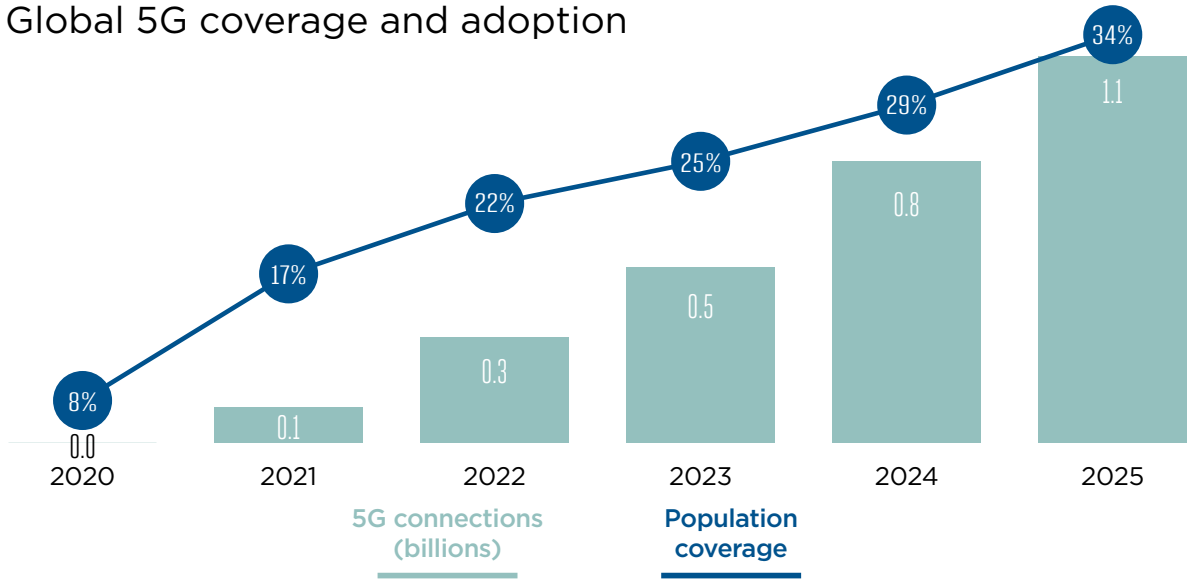
5G timeline



Test networks are already in place in some countries. The capabilities of 5G will be demonstrated at the Winter Olympics in South Korea in February 2018. Following completion of the technical standards for 5G, commercial networks will launch in 2020 in time for the Tokyo Olympics. Widespread availability of 5G services is expected by 2025 as shown in Figure 6.

Figure 6

Global 5G coverage and adoption

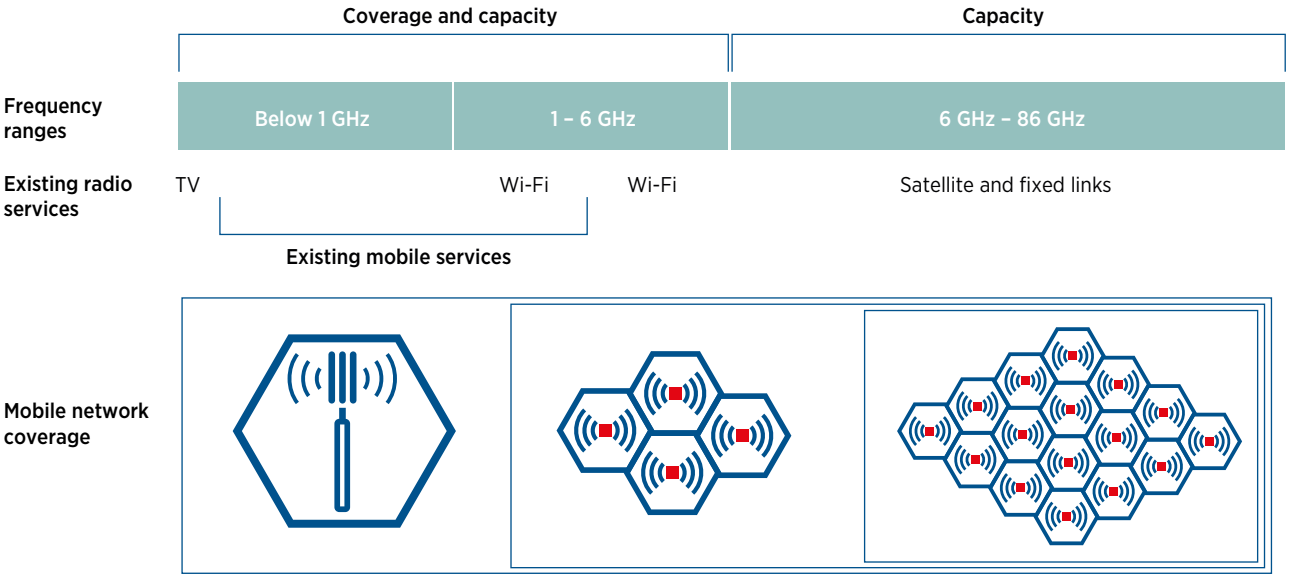


I have heard talk of higher frequencies being used, does that mean higher exposure?

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.

Higher frequencies, such as 24-86 GHz, are mostly used for satellite and point-to-point radio links today. These high frequencies are also known as millimeter waves. The millimetre wave frequencies will be used for capacity in conjunction with massive small cell deployments.

At these frequencies RF energy is absorbed superficially by the body, mostly by the skin. Biological effects of these frequencies have been studied previously and new studies are underway using millimetre wave exposures.

Does higher data rates mean higher network exposures?

Based on the results from current 5G test networks it is expected that the maximum exposure levels will be similar to existing mobile services that use similar transmitter powers. 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.

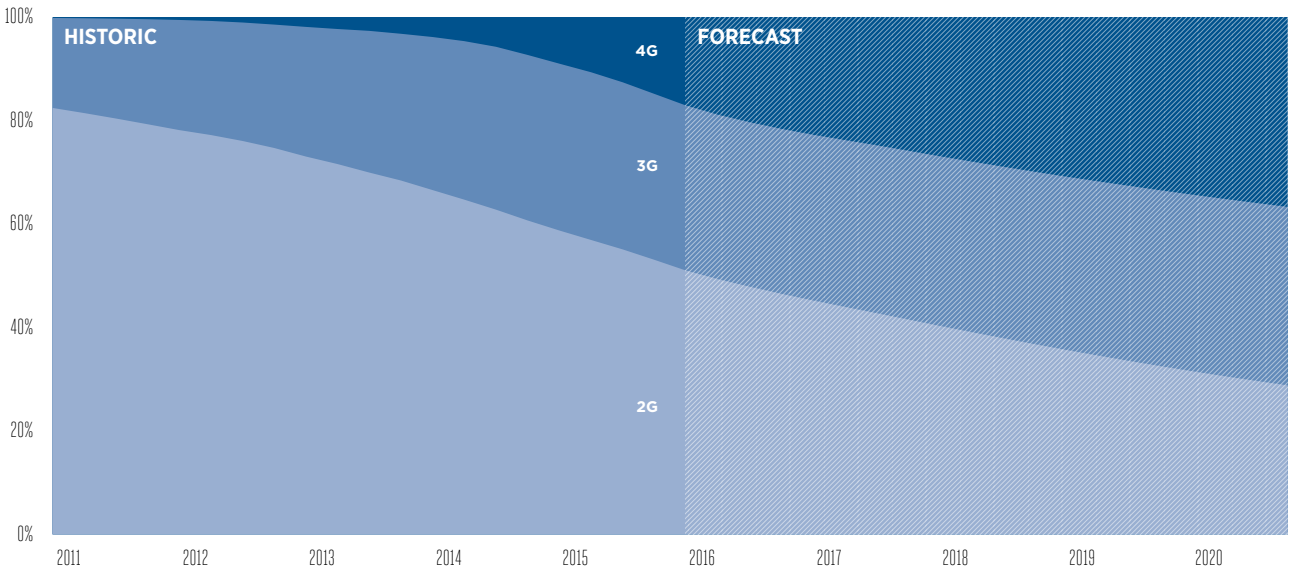
With the introduction of new technologies, there may be a small increase in the level of radio signals due to the fact that new transmitters are active. In some countries deployment of 5G may occur as part of closure of earlier wireless networks. Based on the transition from previous wireless technologies we can expect that the overall exposure levels will remain relatively constant and a small fraction of the international exposure guidelines.

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

Generational shift – projected split of mobile connections base



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?

There are testing standards in place that are valid for 5G network equipment. For 5G devices operating in frequency bands higher than those used by current mobile phones, new test procedures are needed and standardization activities have been initiated by the International Electrotechnical Commission (IEC) Technical Committee 106. Initial testing guidelines are expected to be developed in time for 5G trials in 2018 and will be used as the basis for a final international technical standard to be completed by 2020.

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

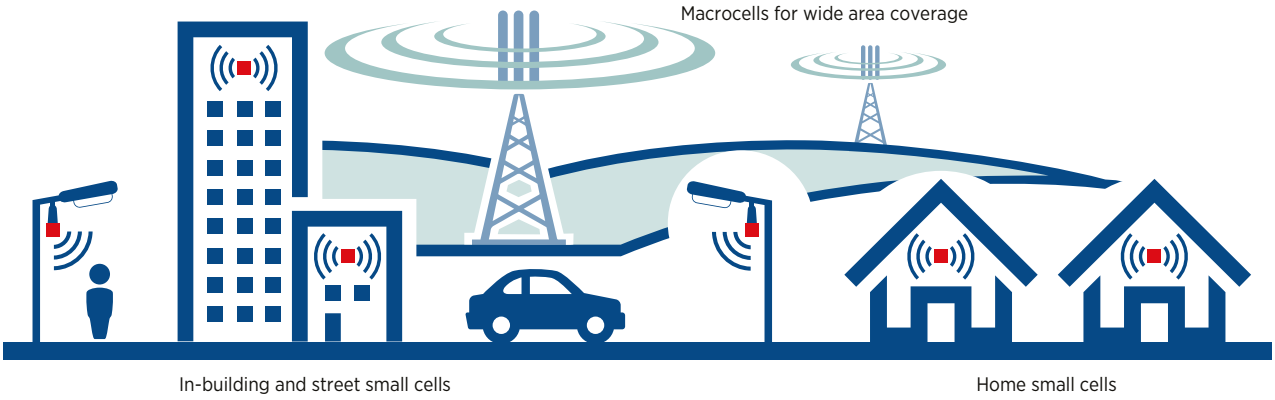
The coverage and capacity objectives of 5G combined with advanced antenna technologies means that some new antennas are likely to be required. Where possible an operator will place these antennas at an existing site and at other times new locations will be required.

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. It has been estimated that there will be in the region of ten small cells per macro site in dense urban areas. 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.

Figure 10

Advanced antenna technologies

Conventional antenna **Beamforming antenna**

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. Advanced beam forming antennas transmit radio signals only to connected users reducing unwanted exposure.

Beamforming involves combining the signal from multiple antennas to improve performance. However, operation at higher frequencies means that while some could be larger, the size of many of the antennas is expected to be similar to that of existing installations.

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

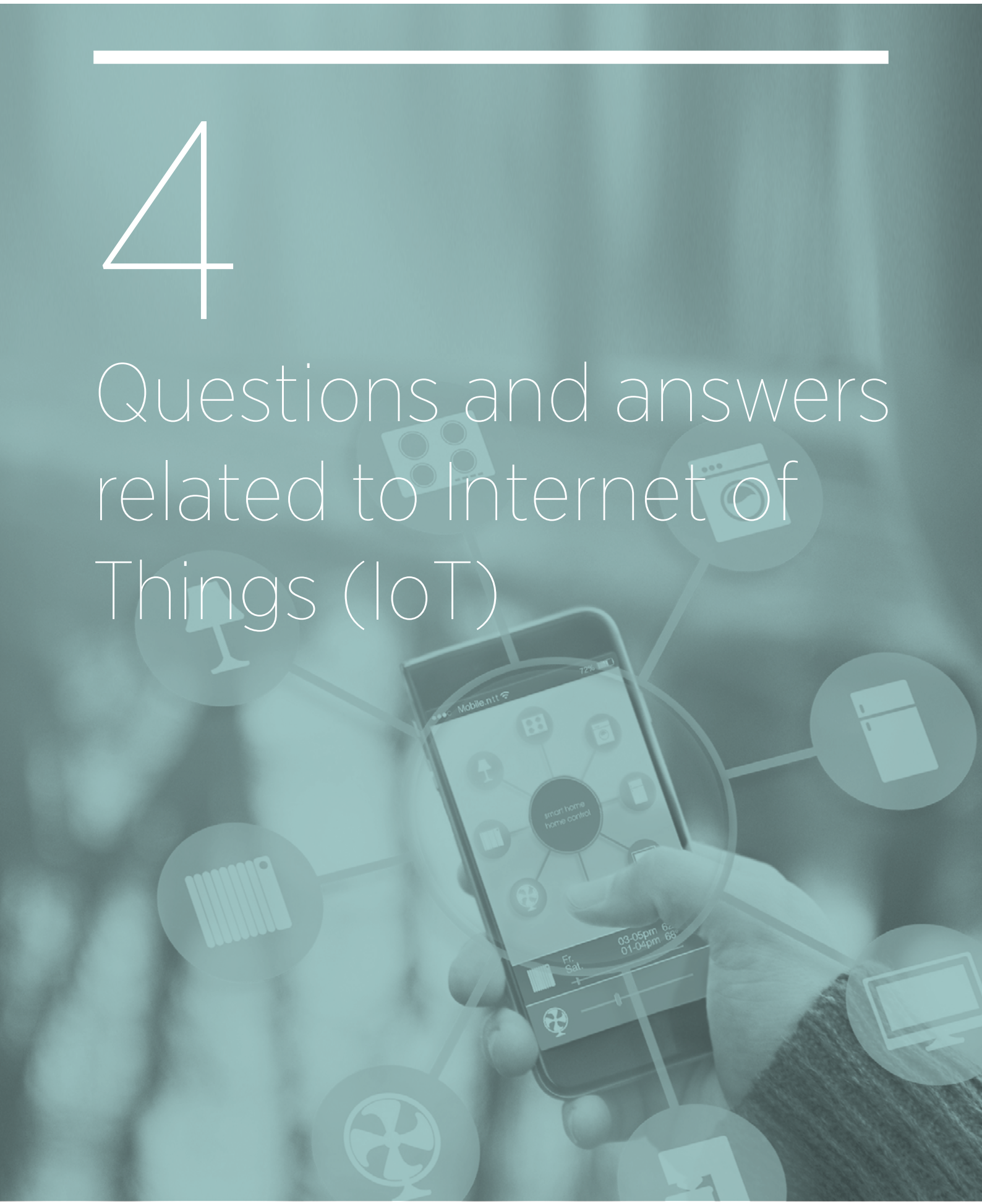
This is a difficult question to answer at this point as the technical standards for the 5G networks and devices are still under development. It is expected that the size of the compliance zone for 5G antennas will be similar to that of other mobile technologies using similar transmitter powers. The size and shape of compliance zones will be evaluated and implemented according to international technical standards.

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.

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. M2M technology connects machines, devices and appliances wirelessly to deliver services with limited direct human intervention. A wide variety of monitors and sensors could also be equipped with wireless connectivity enabling smart wireless applications in healthcare, agriculture and services such as water and electricity.

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. The GSMA is encouraging the adoption of Narrowband IoT (NB-IoT)[14], which is an adaptation of existing 4G/LTE networks and does not require new antenna sites. One of the advantages of NB-IoT is improved coverage within buildings to reach wireless enabled devices such as smart utility meters.[15]

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 NB-IoT 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.

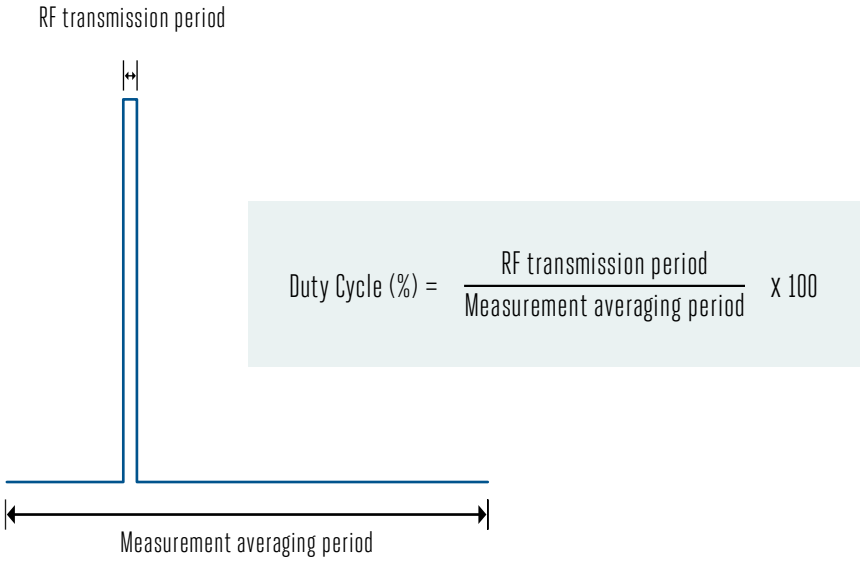
$$\frac{0.45}{60} \text{ X } 200 \text{ X } 0.1 = 0.15 \text{ mW}$$

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.

14. 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
15. Further information is available in the GSMA publication *Smart meters: Compliance with radio frequency exposure standards.*

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.

5 Questions and answers related to wearable devices

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.

Will it be 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 Control**[16]

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.

16. 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 will be covered by the testing standards that are under development for 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 SMS text 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/publicpolicy/consumer-affairs/emf-and-health
ICNIRP – High frequency	http://www.icnirp.org/en/frequencies/high-frequency/index.html
International Telecommunications Union (ITU) EMF Guide	http://emfguide.itu.int/emfguide.html
WHO – Electromagnetic Fields	http://www.who.int/peh-emf/en/

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
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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