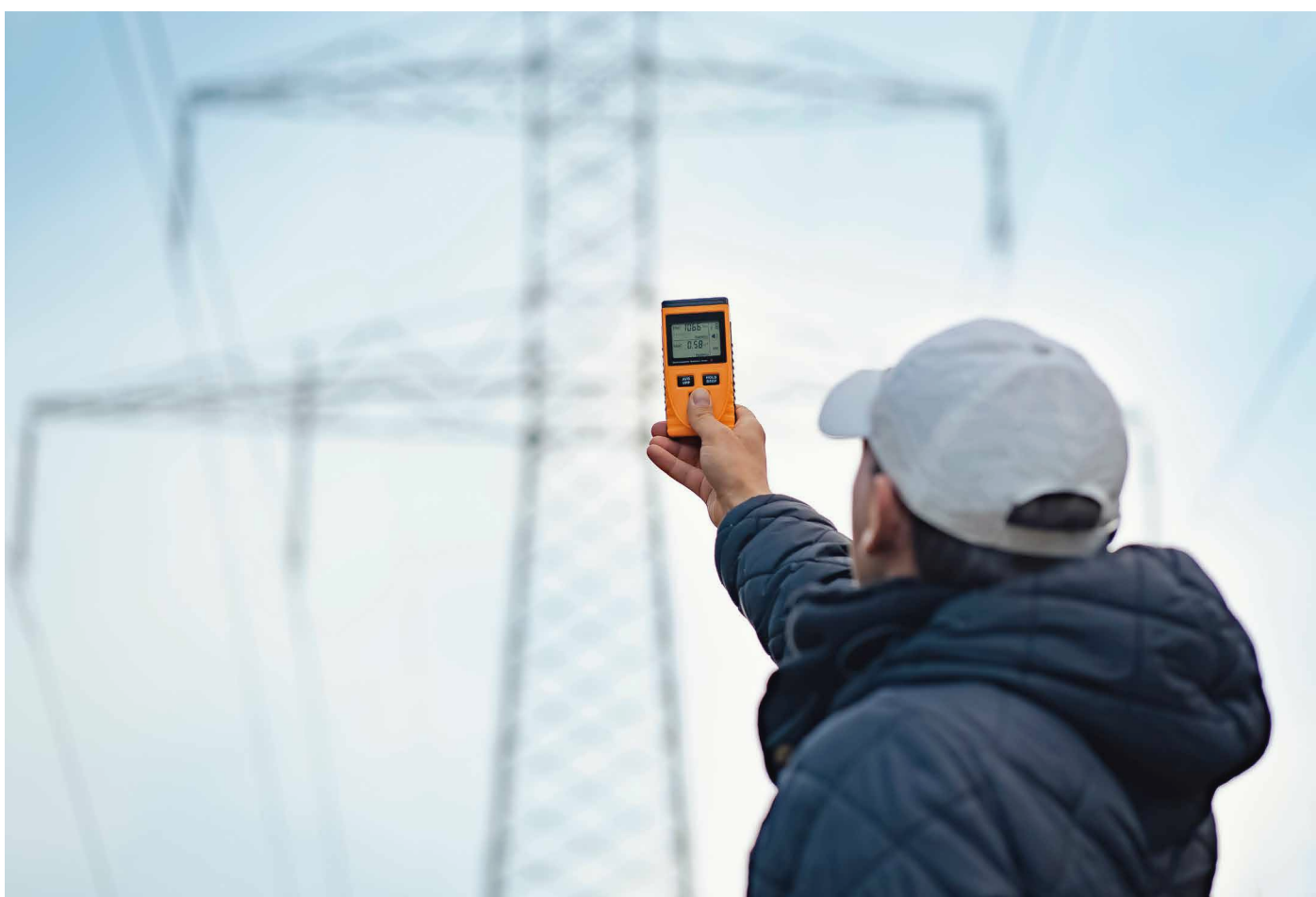


Electromagnetic fields and health



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The IET Engineering Safety Policy panel would welcome any comments you may have on the contents of this fact file and your ideas for future publications. Please get in touch by emailing sep@theiet.org.



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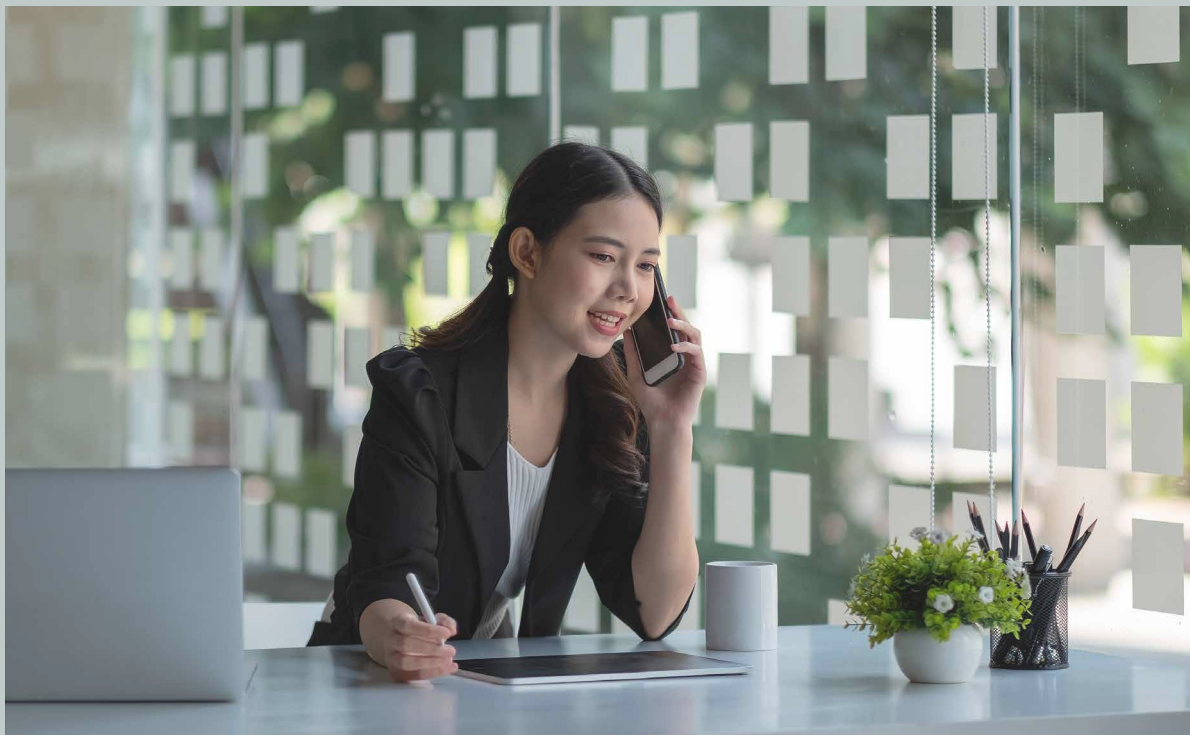
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1. About this fact file



We have been examining the subject of electromagnetic fields (EMFs) carefully for a number of years¹. In light of technological advances, we have updated this fact file to ensure its contents reflect the latest guidelines on user safety. Amongst its contents, the document examines the nature of EMFs and safe levels at different frequencies, and provides links to websites with further information on this subject.

This fact file is written for professionals working in the field of EMFs. However, the paper is also of interest to medical professionals as it concludes that there is no evidence that EMFs, as used in society, cause damage to human health. Based on scientific evidence, the findings should also reassure the general public.

We support the need for ongoing research into the health effects of EMFs to ensure the continued safe use of devices. The existing evidence indicates that there is no need to take precautionary measures, that have a significant impact on lifestyle, for safety reasons.

This fact file is authored by a Working Group that reports to the Engineering Safety Policy Panel.

Examining the facts

Electromagnetic fields are inevitably produced by all electrical systems. Examples include power lines and cables, electrical appliances, wireless local area networks (WLAN), mobile phones and base stations, and TV and radio transmitters. Research into the potential health risks associated with EMFs has been ongoing for more than 30 years and a large body of scientific evidence has been amassed. Initially, research efforts were focused on the fields produced by the electric power distribution system that supplies energy for domestic and industrial use. Since then, studies on the effects of mobile phones and other wireless devices have predominated. A glossary of some of the specialist terms used in the document is provided at the end.

2. What are electromagnetic fields?

Electric and magnetic fields are produced wherever electricity is used. Electric fields are generated by voltages, magnetic fields are produced by currents. In other words, electric fields exist around all wires and electrical devices whenever they are connected to a supply of electricity.

However, magnetic fields are only produced when current flows and hence power is being used. The higher the voltage or the greater the current, the stronger the field produced. At higher frequencies, the electric and magnetic fields become coupled together in a particular relationship. They are then referred to as electromagnetic waves or radio waves.

The units used to measure these phenomena are given in the table (right), along with their multipliers. In theory, any combination of unit and multiplier can be used. However, when describing the levels of fields that are encountered in practice, certain combinations are more common than others, as can be seen in the following sections.

Table of units and multipliers

Units	Multipliers
V - volts - electrical potential	μ - micro - one millionth
A - amperes - electrical current	m - milli - one thousandth
W - watts - power	k - kilo - one thousand
T - tesla - magnetic field	M - mega - one million
Hz - hertz - cycles per second - frequency	G - giga - one thousand million



3. Which frequencies are people exposed to?

The electromagnetic spectrum spans a vast range of frequencies. All frequencies lower than the ultraviolet are referred to as "non-ionising" because they do not have sufficient energy to break chemical bonds.

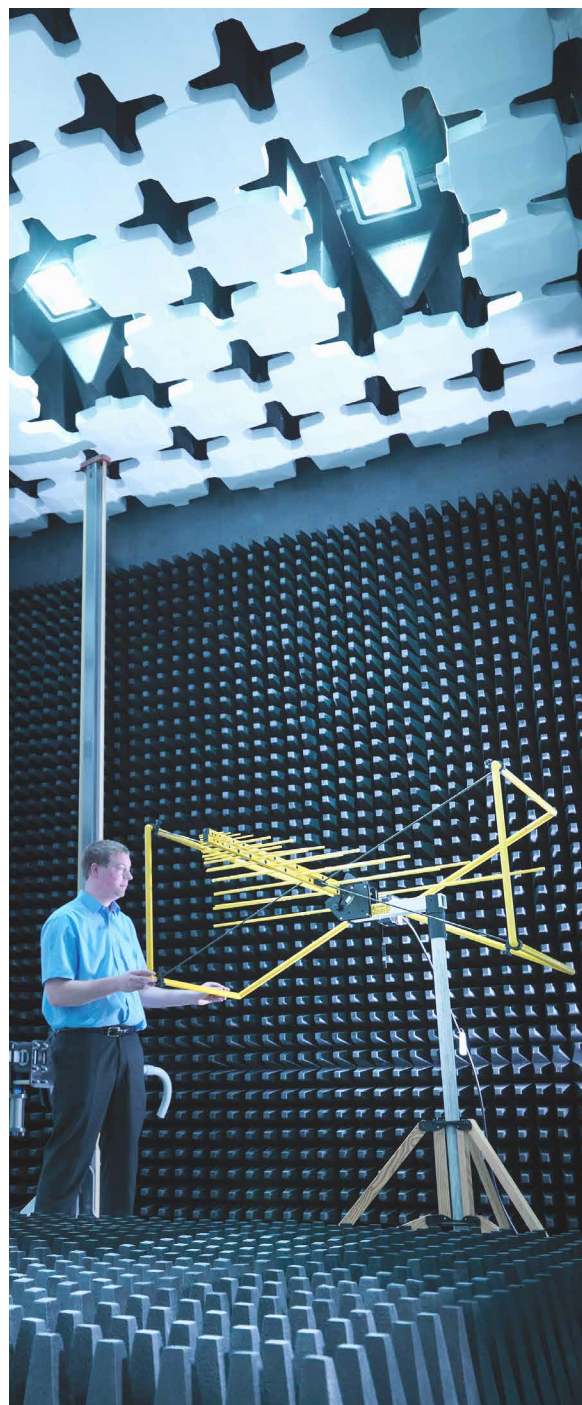
Concerns about EMFs and health have focused largely on two quite separate non-ionising frequency bands. One is 50 or 60 Hz, the frequency of electric power systems. The other is in the hundreds of MHz to the GHz range, where mobile phones and other wireless devices operate. For simplicity, this fact file considers these two ranges of frequencies separately.

Power frequencies

- 50 Hz (Europe) or 60 Hz (America).
- Separate electric and magnetic fields because the frequency is low.
- Electric fields measured in volts per metre (V/m), magnetic fields measured in tesla (T). In practice, kilovolts per metre (kV/m) and microteslas (μT) are often used.

Higher frequencies

- Typically between 0.4 GHz and 5 GHz.
- Electric and magnetic fields are coupled together as electromagnetic or radio waves.
- In air, their intensity is usually measured in watts per square metre (W/m^2). In practice, milliwatts per square metre (mW/m^2) or microwatts per square metre ($\mu\text{W}/\text{m}^2$) are often used due to the low levels.
- A useful quantity to specify the amount of power absorbed by living tissues is the Specific Absorption Rate (SAR), measured in watts per kilogram (W/kg).



4. How are fields produced?



Power frequencies

Background fields in most homes come from low-voltage electric wiring and appliances. The typical background magnetic field levels in homes is in the range 0.01 to 0.2 micro Tesla. Magnetic fields of up to a few tens of micro Tesla can occur very close to appliances. The typical background range for electric fields in UK homes is 1 to 20 V/m and this may increase to a few hundred volts per metre, very close to domestic appliances.³

Stronger fields are produced by high-voltage overhead power lines - up to 10 kV/m and 100 μ T and by mains appliances - up to about 200 V/m and 1000 μ T. These fields have limited range - a few hundred metres at most for power lines, a metre or so for appliances.

A small but growing amount of transmission uses direct current (DC) instead of alternating current (AC). This produces static fields, similar to the earth's natural fields but localised around the cables.⁴

Higher frequencies

All wireless technologies produce fields. These include mobile phones, laptop computers, tablets, wearables, smart home devices and sensors, connected vehicles, Wi-Fi routers and Bluetooth headsets, as well as radar systems, whole body security scanners and broadcast TV and radio. Frequencies for some key examples are given in the spectrum diagram on page 16.

An individual's highest exposure is typically from any mobile device used in close proximity to the body and

typically produce maximum absorbed powers (SAR) in the area of the body they touch, for example the head or limbs. In normal operation, the output power of a mobile device can vary significantly and is normally substantially lower than the maximum power. The SAR from other wireless devices (such as laptops) is typically lower, especially when the antenna is further from your body.

Fields from base stations and other broadcast antennas (such as radio and TV towers) are significantly lower.

Small cell 5G mobile phone base stations produce weaker fields than 3G and 4G masts. In March 2020, the UK's telecoms regulator OFCOM performed EMF measurements at twenty-two 5G masts across the country. The highest level recorded was just 1.5% of the public exposure limit.⁵ Similar surveys have been performed in other countries.

The growth of the Internet of Things (IoT) has led to a proliferation of smart home devices that are connected to the internet via WLANs. IoT devices will usually produce weaker EMFs than other appliances and systems, because they only transmit information periodically and in small amounts, while WLANs have very low power signals, typically 0.1 W.⁶

Wearable devices, which incorporate radio transmitters, sensors and microcomputers, also produce EMFs. Exposure is continuous as long as they are attached to the body. However, wearables typically operate at very low power to conserve battery life and transmit at intervals and over short distances.

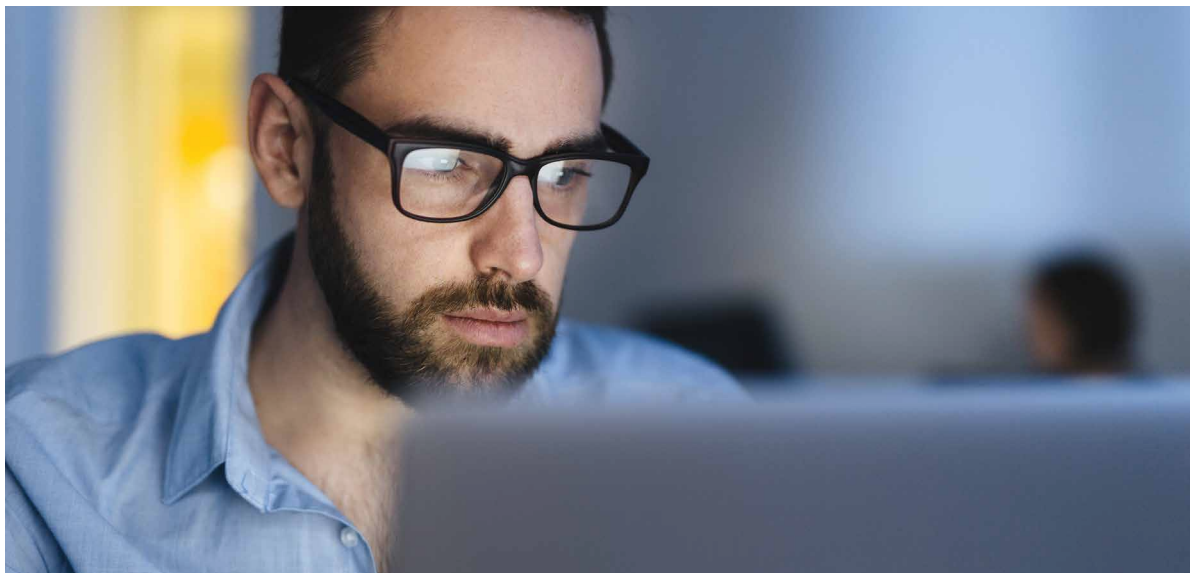
³ Electric and magnetic fields: sources and exposure - GOV.UK (www.gov.uk).

⁴ The 48VDC Realisation Forum (theiet.org).

⁵ EMF measurements near 5G mobile phone base stations – summary of results (ofcom.org.uk).

⁶ Wireless networks (wi-fi): radio waves and health - GOV.UK (www.gov.uk).

5. What is a safe level?



Several governments have adopted exposure limits for EMFs devised by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)⁷, a chartered, non-profit, scientific body that is officially recognised by the World Health Organization (WHO). The ICNIRP guidelines provide both public and occupational limits for both whole body exposure and localised exposure to parts of the body such as the head and torso or the limbs, along with a full scientific rationale for the limits.

Permitted exposure levels for the general public are lower than occupational limits to take account of the wider range of ages and health conditions found across the whole population. They also account for the duration of exposure with public limits being applicable for continuous exposure. On the recommendation of the European Union in 1999, many governments adopted the ICNIRP's 1998 guidelines⁸, which apply to all public exposure levels. ICNIRP subsequently updated their low frequency guidelines in 2010⁹ and their high frequency guidelines in 2020.⁹ These updates take into account new science published since the previous version and address technologies that are now more commonly in use today. As many limit numbers have not changed from the original 1998 publication to the 2010 and 2020 updates, the 1998 guidelines remain widely referenced.

It is anticipated that many countries will update their national regulations in line with the newer ICNIRP guidelines.

Power frequencies

The 1998 ICNIRP exposure guidelines specified a basic restriction for the public which stated that the induced current density in the central nervous system should not exceed 2 mA/m². In the UK, the then Health Protection Agency specified⁸ that this induced current density equates to uniform unperturbed fields of 360 µT for magnetic fields and 9.0 kV/m¹ for electric fields. Where the field is not uniform, more detailed investigation would be needed. Accordingly, these are the field levels with which overhead power lines (which produce essentially uniform fields near ground level) shall comply where necessary. For other equipment, such as underground cables, which produce non-uniform fields, the equivalent figures will never be lower but may be higher and will need establishing on a case-by-case basis in accordance with the procedures specified by the government. ICNIRP issued revised guidelines for electric and magnetic fields from 1 Hz to 100 kHz in 2010.¹⁰

⁷ ICNIRP.

⁸ ICNIR guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields.pdf.

⁹ ICNIRP guidelines for limiting exposure to electromagnetic fields.pdf.

¹⁰ ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields.pdf.



Following a 2013 directive from the European Commission, some governments made the occupational exposure limits in these guidelines legally enforceable through legislation. In the UK, this was through the Control of Electromagnetic Fields at Work Regulations 2016.¹¹

For occupational exposure to power frequencies at 50 Hz, the Low Action Limits are 10 kV/m and 1,000 μ T. In the 2010 guidelines, the basic restriction is given in terms of electric field strength within the body. At 50 Hz, it is 0.8 V/m.

The ICNIRP 1998 guidelines are applied to electricity providers through a voluntary Code of Practice agreed with the government.¹² The code gives reference levels and compliance procedures for overhead power lines, underground cables and electricity sub-stations. The reference levels are frequency-dependent external field strengths that correspond to the ICNIRP's basic restrictions. They are used as a tool to assess the compliance of the electricity supply network through a three-stage process and are not intended to be exposure limits.

The electricity industry complies with these levels and outlines how it does this for both occupational levels¹³ and for public exposure¹⁰ in published documents.

The document¹⁴ provides evidence to demonstrate how overhead power lines and underground cables up to 132 kV and the publicly accessible perimeters of electricity substations, which are designed to always operate below the reference levels, comply with the guidelines. For overhead lines and underground cables at 275 kV and 400 kV, and substations containing air-cored reactors, electricity companies demonstrate compliance on a case-by-case basis. For overhead lines, they also have to comply with phasing requirements.¹⁵

Higher frequencies

At higher frequencies, the basic restriction is given in terms of the Specific Absorption Rate (SAR). For public exposure to frequencies between 10 MHz and 10 GHz,

the average power absorbed by the whole body should not exceed an SAR of 0.08 W/kg. The maximum SAR for the head and torso is 2.0 W/kg, while for the limbs it is 4.0 W/kg.

For occupational exposure, the limit for average power absorbed by the whole body is 0.4 W/kg, while the maximum SAR for the head and torso is 10 W/kg and the maximum SAR for the limbs is 20 W/kg.

Exposure levels below these limits will not cause body temperature to rise by more than 1 °C, which is the threshold for these frequencies given in the ICNIRP 1998 guidelines to prevent health effects. At a frequency of 900 MHz, field levels of up to 4.5 W/m² satisfy this requirement, while at 1.8 GHz, field levels of up to 9.0 W/m² fall within the limit.

The telecoms regulator OFCOM announced on 5 October 2020 that it will make compliance with the ICNIRP EMF public exposure guidelines to a mandatory condition of all licences issued to spectrum users, which include mobile phone, radio and TV operators.¹⁶

The new EMF licence condition, which is being added to the Wireless Telegraphy Act 2006¹⁷, applies to both existing and new licensees. It is due to be introduced following a second consultation, which ended in November 2020, a one-month review period, and publication of the finalised licence condition in due course.

ICNIRP issued revised guidelines for frequencies of 100 kHz to 300 GHz in March 2020.¹⁸ OFCOM is initially making compliance with the 1998 guidelines the baseline for its licence condition. In time, it will switch to the 2020 guidelines after holding a further consultation on the move. The exposure limits in the 2020 guidelines are very similar to those in the previous 1998 guidelines, especially at frequencies below 6 GHz, where many current mobile systems operate.¹⁹ The amended legislation will mean that the public can be confident that mobile phone masts and base stations comply with public exposure limits for EMFs.

¹¹ The Control of Electromagnetic Fields at Work Regulations 2016 (legislation.gov.uk).

¹² Demonstrating compliance with EMF public exposure guidelines: voluntary code of practice - GOV.UK (www.gov.uk).

¹³ Statement of compliance with occupational exposure limits (emfs.info).

¹⁴ Statement of compliance with public exposure limits (emfs.info).

¹⁵ Phasing – How the phasing affects the field produced by an overhead line (emfs.info).

¹⁶ Statement and further consultation: Proposed measures to require compliance with international guidelines for limiting exposure to electromagnetic fields (EMF) - Ofcom.

¹⁷ Wireless Telegraphy Act 2006 (legislation.gov.uk).

¹⁸ ICNIRP guidelines for limiting exposure to electromagnetic fields.

¹⁹ Mobile phone base stations: radio waves and health - GOV.UK (www.gov.uk).

6. What effect do fields have?



The potential health effects of exposure to fields that exceed the ICNIRP guidelines are well established. They include nerve stimulation from direct currents and thermal effects at higher frequencies, both are described in the following sections. Other effects relating to weaker fields that fall below reference levels or to newer technologies have been proposed but lack sufficient supporting scientific evidence.

Power frequency fields

The main effect of these fields is to cause small electric currents to flow in the body. At levels above about 10 V/m in the central nervous system – the brain and the spinal cord – and 6 V/m in the peripheral nervous system, the fields can interfere with the action of nerves or even cause stimulation of nerves and muscles. The ICNIRP limits are designed to prevent this from happening.

Electric fields can also cause micro-shocks when a metal object is touched - much as walking across nylon carpet does. At 50-60 Hz, the threshold for noticing these effects among the most sensitive 10% of volunteers ranges from 2 kV/m to 5 kV/m. The effects can be annoying and painful but are not in themselves dangerous.

Higher frequency fields

If large enough, these fields also induce currents in the body, although nerve stimulation is unlikely at frequencies above 10 MHz. This threshold is far below the frequencies used by mobile phones, which ranged from 800 MHz to 3.4 GHz in 2020.²⁰ The UK telecoms regulator like others has opened up the 700 MHz and 3.6-3.8 GHz bands for 5G mobile networks.²¹

At higher frequencies, EMFs can generate heat in the body, causing body temperature to rise. Exposure to fields that generate temperature rises of more than 1-2 °C can overwhelm the body's thermoregulatory capacity and cause tissue damage. ICNIRP guidelines are designed to limit whole-body exposure to a maximum SAR of 0.08 W/kg, to ensure that the body temperature does not rise by more than 1 °C.²² Taken overall, this heating is similar to that caused by moderate exercise such as a brisk walk or taking a warm bath.

As frequency increases, EMF exposure of the body and the resultant heating becomes more superficial. At frequencies above 6 GHz, which are used by systems such as radar and satellite communications, exposure occurs primarily in the skin and is more easily dispersed into the environment.

OFCOM is planning to open up the lower 6 GHz band – spanning 5.9-6.4 GHz – for Wi-Fi and other wireless networks without the requirement for a licence to meet the growing demand for wireless devices and services.²³

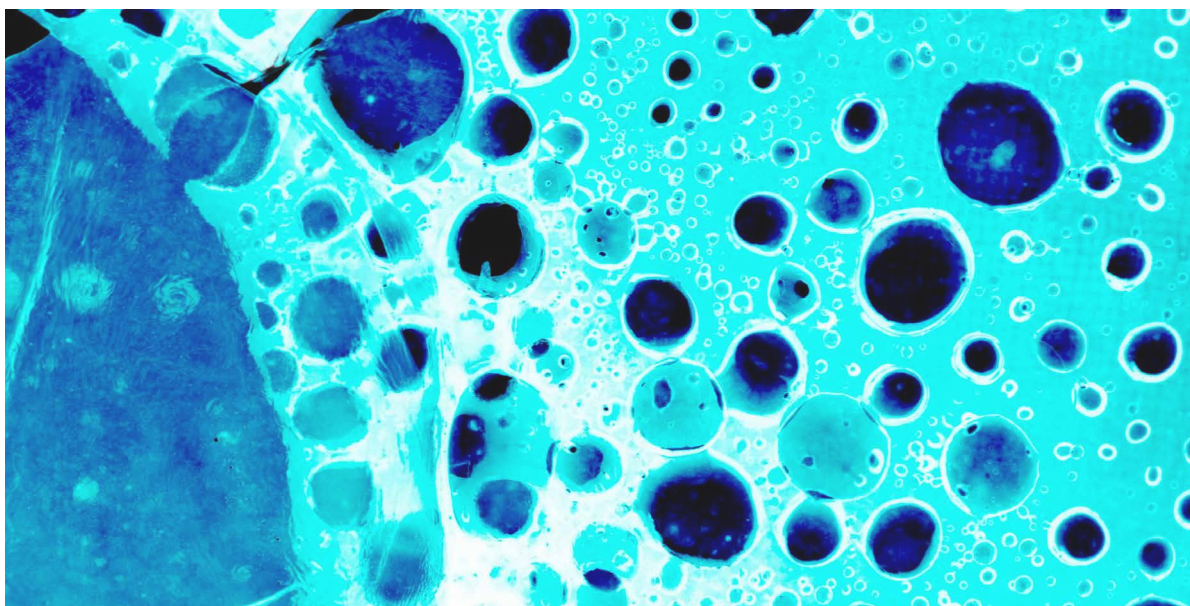
²⁰ 4G | Coverage, What is 4G, Compare deals and more; Ofcom UK Frequency Allocation (UKFAT) Page.

²¹ Ofcom confirms plans for spectrum auction early next year - Ofcom.

²² ICNIRP guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields.pdf.

²³ Statement: Improving spectrum access for Wi-Fi – spectrum use in the 5 and 6 GHz bands - Ofcom.

7. Could weaker fields have health effects?



Power frequencies

For more than 30 years, researchers have been examining whether magnetic fields in homes or from power lines might cause cancer in general and childhood leukaemia in particular. The research has spanned lab studies, including in vivo animal experiments and in vitro experiments on human cells, and epidemiological studies of patterns of disease and exposure among groups of people exposed to fields in everyday life.

Epidemiological studies of magnetic fields and childhood leukaemia have brought mixed results, but pooled analyses of multiple studies have indicated an increased risk of 70-100% for children at time-weighted average residential exposure levels above 0.3-0.4 μ T. These analyses led the International Agency for Research on Cancer (IARC), which is part of The World Health Organization (WHO), to classify extremely low frequency (ELF) magnetic fields, which include those at power frequencies, as "possibly carcinogenic to humans".²⁴

IARC found "limited evidence" that ELF magnetic fields could cause childhood leukaemia, with "inadequate evidence" in relation to all other cancers. It also found there was "inadequate evidence" that electric fields caused cancer.²⁵

Britain's then National Radiological Protection Board (NRPB), now Public Health England (PHE), also reviewed the epidemiological evidence on childhood leukaemia and magnetic fields. It concluded that the findings amounted to "an observation for which there is at present no sound scientific explanation" and "any judgements developed on the assumption that the association is causal would be subject to a very high level of uncertainty".²⁶

The WHO went on to form a Task Group to assess the health risks from ELF fields, which accepted the IARC classification but concluded that, on balance, the evidence related to childhood leukaemia and ELF magnetic fields was not strong enough to be considered causal.²⁷ The WHO found that, overall, the evidence that ELF magnetic fields cause any form of cancer, including leukaemia, is weak, a view endorsed by PHE.²⁸

²⁴ IARC Publications Website - Non-ionizing Radiation, Part 1: Static and Extremely Low-frequency (ELF) Electric and Magnetic Fields.

²⁵ Ofcom confirms plans for spectrum auction early next year - Ofcom.

²⁶ UK Government Web Archive - The National Archives.

²⁷ Radiation and health (who.int).

²⁸ Electric and magnetic fields: health effects of exposure - GOV.UK (www.gov.uk).



The WHO outlined its rationale in a background paper, which states that the epidemiological evidence about childhood leukaemia is weakened by methodological problems, such as potential selection bias.²⁹ Nor is it supported by the results of lab experiments on animals, which have been largely negative. In addition, there are no accepted biophysical mechanisms whereby low-level exposure to magnetic fields could result in the development of cancer. It also points out that average magnetic field exposures above 0.3 μT are rare in residential settings.

As a result of the uncertainty in the science, quoted above, certain practical precautionary measures have been introduced in terms of HV overhead line conductor phasing³⁰ and as an industry Engineering Recommendation.³¹ The UK Government also issued recommendations from an advisory group that first considered optimal phasing and reducing public exposure,³² and secondly considered: net currents in distribution circuits, wiring in multi occupancy buildings and final distribution substations.³³

Higher frequencies

Questions have been asked about the possible relationship between the use of mobile phones and the promotion of tumours in the body, such as in the head. Additionally, if the continuous exposure from base stations can lead to health impacts.

Much research into cancer risks among mobile phone users has been conducted over decades. The Interphone study, which spanned 13 countries, did not find evidence that mobile phone use caused an increased risk of brain tumours, but concluded that the possible effects of long-term heavy use required further investigation.³⁴

The WHO runs the International EMF Project to coordinate and monitor worldwide research into the health and environmental effects of EMFs up to 300 GHz. The WHO has reviewed a large number of studies performed over recent decades to assess whether mobile phones pose a potential health risk. Its position is that to date, no adverse health effects have been established as being caused by mobile phone use.³⁵

Mobile phone base stations produce exposure levels that are comparable to or smaller than those from radio and TV antennas. Studies of base stations have not found evidence that risks of childhood cancers are greater in the vicinity of mobile phone masts.³⁶ In the same vein, studies investigating longer established sources of radio waves, including radio, TV and radar, have not found consistent evidence of health effects.

A growing range of smart-home devices and sensors that use Wi-Fi has been coming onto the market. However, there is no evidence that exposure to radio signals from Wi-Fi and WLANs adversely affects people's health, and exposure levels should be well within public exposure guidelines, according to PHE.³⁷ Nor is there any sign that the incidence of cancer is increasing in response to the rapid uptake of wireless technologies, as would be expected, if there were a link.

There is a growing body of national and international research into the possible health effects of mobile phone technologies, including analogue, GSM, CDMA, 3G (W-CDMA), 4G (LTE), 5G and TETRA, as well as Wi-Fi.³⁸ New technologies increasingly feature in the published literature as they become more widespread. For example, we have published a guide to 5G technology and health for policy makers and planners.³⁹

²⁹ Radiation and health (who.int).

³⁰ ICNIRP guidelines for limiting exposure to electromagnetic fields.pdf; Statement of compliance with occupational exposure limits (emfs.info).

³¹ Engineering Recommendation G92 (emfs.info).

³² Government response to the Stakeholder Advisory Group on extremely low frequency electric and magnetic fields (ELF EMFs) (SAGE) recommendations: Department of Health - Publications (nationalarchives.gov.uk).

³³ Government response to the Stakeholder Advisory group on ELF EMFs: Department of Health - Publications (nationalarchives.gov.uk).

³⁴ IARC Report to the Union for International Cancer Control (UICC) on the Interphone Study.

³⁵ Electromagnetic fields and public health: mobile phones (who.int).

³⁶ No link between childhood cancer and mobile phone base stations or masts - Cancer Research UK - Cancer news.

³⁷ Wi-fi radio waves and health - GOV.UK (www.gov.uk).

³⁸ EMF-Portal | Home.

³⁹ Allaying health concerns regarding 5G and exposure to radio waves (2nd edition) (theiet.org).

8. Can EMFs have any other health effects?



Power frequencies

Some studies have looked at whether magnetic fields that are weaker than those required to induce currents in the central nervous system could have other effects - on electrical activity in the brain, cognition, sleep or mood, for example. Generally, such studies have produced evidence of only subtle or transitory effects at most, while the conditions necessary to elicit such responses are not well defined. ICNIRP has concluded that the evidence from such neurobehavioural research is not sufficiently reliable to provide a basis for human exposure limits.⁴⁰

Higher frequencies

There have been claims that heavy users of mobile phones are more likely to suffer from headache, migraine, memory loss or insomnia. At present, it has not been shown that these symptoms are caused by EMFs. Laboratory studies have suggested that subtle changes in brain-wave activity may occur, but it is not clear whether this has any relevance to health.⁴¹ One

thing, however, can be said with certainty: using a mobile phone while driving is clearly dangerous and should be avoided, as it can distract your attention from driving safely. A driver using a mobile phone is four times more likely to have a serious crash resulting in hospital attendance, a study has shown.⁴² In many countries, the use of a hand-held mobile phone while driving to call or text is illegal. The UK Government is planning to tighten up the law to ban more uses of mobile phone handsets while driving, including taking photos, playing games and scrolling through a playlist.⁴³ In a similar vein, pedestrians can be distracted while using a mobile phone to the point of increasing their risk of an accident.⁴⁴

Are some people particularly sensitive?

With both frequency bands, some people report a variety of symptoms in relation to quite weak fields, a condition commonly known as electro hypersensitivity. A systematic review of medical research into the condition has found no convincing scientific evidence for the symptoms being caused by EMFs.⁴⁵

⁴⁰ ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields.pdf.

⁴¹ EEG Changes Due to Experimentally Induced 3G Mobile Phone Radiation (nih.gov).

⁴² Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study - PubMed (nih.gov).

⁴³ Next steps announced to boost road safety and close mobile phone loophole - GOV.UK (www.gov.uk).

⁴⁴ The incidence of pedestrian distraction at urban intersections after implementation of a Streets Smarts campaign (nih.gov).

⁴⁵ Do people with idiopathic environmental intolerance attributed to electromagnetic fields display physiological effects when exposed to electromagnetic fields? - Wiley Online Library.

9. How can I reduce my exposure, if I wish to?



A large and wide-ranging body of scientific research on the health effects of EMFs has been accumulated over recent decades.

This data does not show evidence of harmful effects at exposure levels encountered by the public and indicates that the risks are minimal. Yet given that some uncertainty remains, it is understandable that people may wish to reduce their personal exposure as a precautionary measure.

We support the need for ongoing research into the health effects of EMFs to ensure the continued safe use of devices, given the speed of technological advance; rapid growth in adoption rates; and increasing duration of everyday exposure. However, existing evidence indicates that there is no reason to take precautionary measures that have a significant impact on lifestyle or undermine the undoubted social benefits of a reliable electricity supply and widespread mobile communications.

Power frequencies

Most countries have an appropriate set of measures to minimise the exposure of the general public that is based on the ICNIRP guidelines and results from a thorough consultation process. Many of the measures are implemented by electricity companies or electricians. Public Health England (PHE) advises that higher than average background fields in homes near to power lines should not be a major consideration when deciding to buy a property as the health risk – if real – is small.⁴⁶

Likewise, the Government considers that the possible health risk is not significant enough to justify moving homes if you already live near a power line. Some electricity companies have provided measurements of magnetic field levels within customers' homes. Although the levels are very small, if you wish to reduce your exposure further, recommended actions include:

- Keep mains appliances such as clock radios at least one metre away from the bed.
- Do not leave electric blankets on overnight.
- Switch off electrical appliances at the mains, when not in use.
- Maintain household electrical wiring in a good condition.

Higher frequencies

For most people, their greatest exposure to higher frequency EMFs comes from the active use of mobile phones when close to the body, with the mobile phone itself being the primary source. How the mobile phone is held to the head and its orientation has a major impact on the strength of the field that a user is exposed to. Mobile phones are designed to automatically reduce power to the lowest possible level for a good-quality connection. As such, they will operate at a lower transmission power when used in areas with good reception from a nearby base station. Information on the Specific Absorption Rate (SAR) of a mobile phone should be available at the point of sale or from the manufacturer's web site. In our guide to 5G technologies, we call for all smartphone manufacturers to publish SAR values in the technical specifications they provide to consumers.⁴⁷ The use of commercial devices for reducing EMF exposure from mobile phones has not been shown to be effective.⁴⁸ PHE advises people to discourage excessive use of mobile phones by children, while adults should make any choices about reducing their exposure from an informed position.⁴⁹ Recommended actions for reducing exposure from a mobile phone include:

- Use a hands-free kit, headset or use the phone on loudspeaker.
- Keep the phone away from your body.
- Consider limiting the number and length of calls you make.
- Make calls where the network signal is strong.

⁴⁶ Electric and magnetic fields: reducing exposure - GOV.UK (www.gov.uk).

⁴⁷ Allaying health concerns regarding 5G and exposure to radio waves (2nd edition) (theiet.org).

⁴⁸ Electromagnetic fields and public health: mobile phones (who.int).

⁴⁹ Radio waves: reducing exposure from mobile phones - GOV.UK (www.gov.uk).

10. How can I find out more?



Advice

A collection of advice leaflets issued by Public Health England (PHE) on exposure to EMFs at power frequencies and higher frequencies as well as static fields is available.⁵⁰ PHE is being replaced by the National Institute for Health Protection.

Information

- The World Health Organization runs an International EMF Project, which provides a wide range of information on EMFs.⁵¹
- The International Commission on Non-Ionizing Radiation Protection issued guidelines on safe exposure limits for EMFs in 1998⁵², 2010⁵³ and 2020.⁵⁴
- The International Telecommunication Union (ITU) maintains a study group that monitors higher frequency EMFs. The ITU makes recommendations on exposure levels and publishes an EMF Guide giving information on EMFs and health.⁵⁵
- RWTH Aachen, Germany's largest technological university, operates an EMF Portal which provides a collection of scientific literature on the effects of EMFs that includes more than 32,000 journal articles.⁵⁶
- The Health Council of the Netherlands has produced specific EMF and 5G information for the public.⁵⁷
- The Code of Practice for the electricity industry in the UK.⁵⁸
- The UK Code of Practice on mobile network development.⁵⁹
- The Australian Government agency ARPANSA had produced advice for the public relating to both power lines and mobile phone and networks.⁶⁰
- The UK Government's Health and Safety Executive provides a guide to The Control of Electromagnetic Fields at Work Regulations 2016.⁶¹
- National Grid Plc provides public information about EMFs on behalf of the UK electricity industry.⁶²
- MobileUK, which represents the UK's four mobile network operators, provides information on mobile phones and health.⁶³
- Reports issued by The IET on diverse aspects of EMFs and health are available.⁶⁴

UK Helplines

- National Grid plc has an EMFs unit that runs a helpline on EMFs from power lines and related infrastructure on behalf of the electricity industry. The unit provides information and takes enquiries from members of the public, including home buyers, vendors and their professional advisers, who may be concerned about equipment near a property. Contact **0845 7023270** or **EMFHelpLine@nationalgrid.com**.
- PHE has a public information access office, which answers general queries on health issues that are submitted to **enquiries@phe.gov.uk**.

⁵⁰ Electromagnetic fields - GOV.UK (www.gov.uk).

⁵¹ Non-ionizing Radiation, Part 1: Static and Extremely Low-frequency (ELF) Electric and Magnetic Fields (who.int).

⁵² ICNIRP guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields 1998.pdf.

⁵³ ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields 2010.pdf.

⁵⁴ ICNIRP guidelines for limiting exposure to electromagnetic fields 2020.pdf.

⁵⁵ ITU EMF Guide.

⁵⁶ EMF-Portal | Home.

⁵⁷ 5G and health | Advisory report | The Health Council of the Netherlands.

⁵⁸ Demonstrating compliance with EMF public exposure guidelines: voluntary code of practice - GOV.UK (www.gov.uk).

⁵⁹ Revised Code of Mobile Best Practice for Deployment in England (webflow.com).

⁶⁰ Sources of radiation | ARPANSA.

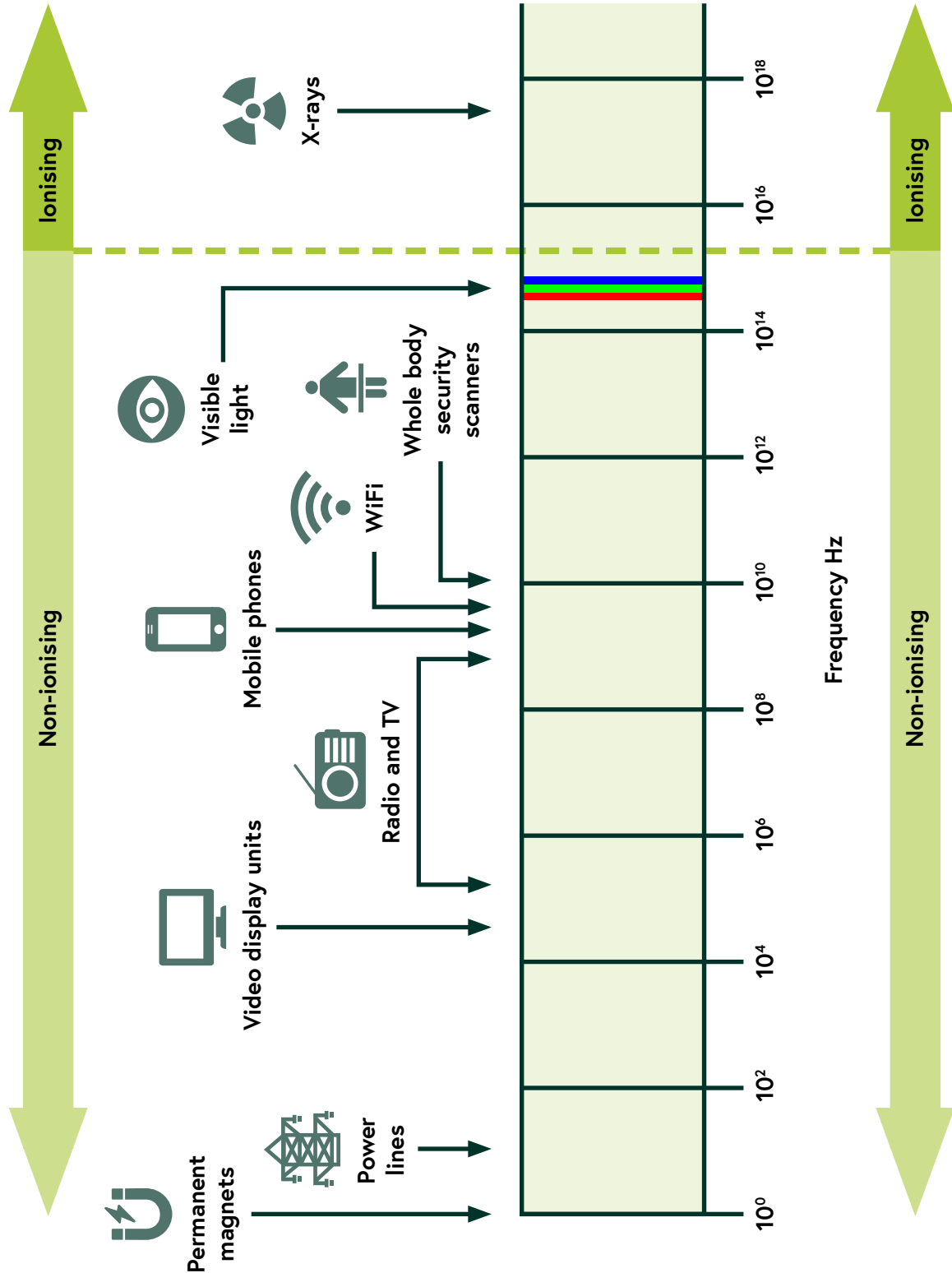
⁶¹ Electromagnetic fields - non-ionising radiation - HSE.

⁶² EMFs.info – Electric and magnetic fields and health.

⁶³ 5G and Health | Mobile UK.

⁶⁴ Engineering safety factfiles (theiet.org).

11. A partial view of the electromagnetic spectrum



12. Glossary of common EMF terminology

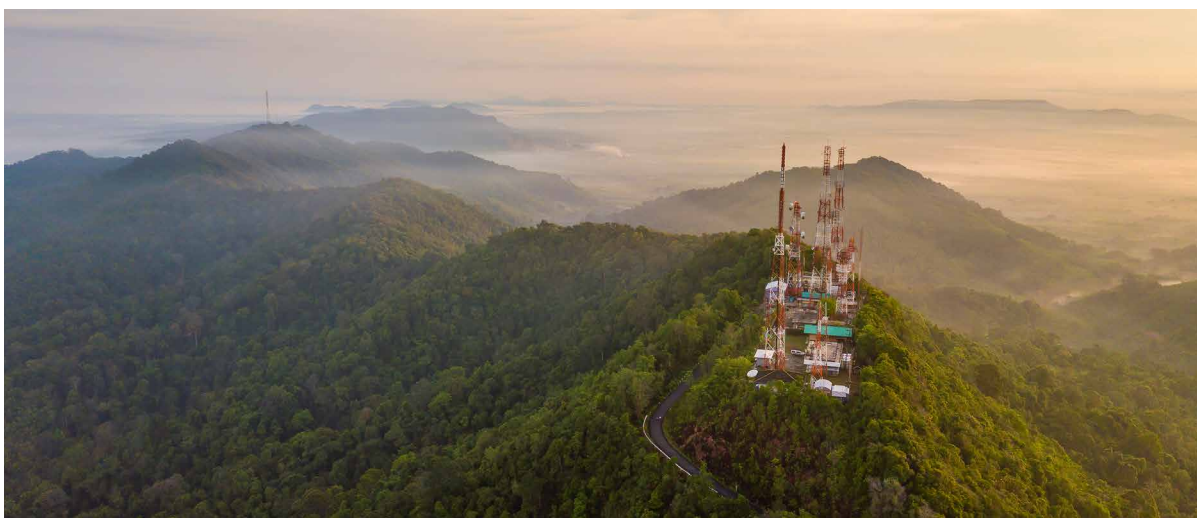
Term	Abbreviation or unit	Meaning (context of factfile)
1G		The first (obsolete) generation of analogue mobile phone technology.
2G		The second generation of mobile phone technology, which is digital and includes GSM and CDMA technologies.
3G		The third generation of mobile phone technology which provides high-speed data UMTS transmission and supports multimedia digital applications such as full-motion video and internet access.
4G		The fourth generation of mobile phone technology for efficient wireless broadband services to smart mobile phones and tablets.
5G		The fifth generation of mobile phone technology, which is the standard for broadband cellular networks that provide both internet and mobile phone services.
Ampere	A	Physical unit of electrical current.
Analogue signal		A signal which doesn't have a discrete digital value; used for the first generation of (non-digital) mobile phone systems.
Antenna		Electrical or magnetic device for propagating and sensing an electromagnetic field, sometimes referred to as an aerial.
Base station		A radio transmitter(s) and receiver(s) installed by an operator to provide a communications service typically used in mobile telecommunications (cellular network). Mobile phones rely on the presence of a nearby base station, with which they communicate, in order to make or receive calls.
Biophysical mechanism		Physical mechanism that affects a biological process.
Bit	b	A bit is the basic unit of digital information in computing and digital communications. A bit can have only one of two values, zero or one, and may therefore be physically implemented with a simple electronic circuit.
Bluetooth		This is the protocol used for short range (few metres) wireless Personal Area Networks in the ISM band from 2400-2480 MHz for fixed and mobile devices.
Broadband		A transmission facility having a capacity sufficient to carry multiple voice, video or data channels simultaneously. Generally used to refer to the delivery of internet services.
Byte	B	The byte is a unit of digital information in computing and telecommunications and consists of eight bits.

Cancer		Class of diseases in which a biological cell, or a group of cells display uncontrolled growth.
CDMA		An abbreviation of Code-Division Multiple Access, a protocol used in 2G networks which uses time division to combine multiple signals into one wireless channel in the mobile phone bands.
Cell		The basic geographic unit of mobile phones/services wireless coverage, each equipped with a low-powered wireless transmitter and receiver. A mobile call moves seamlessly from one cell to another.
Co-location		Placement of multiple antennas on one site.
DECT		An abbreviation of Digitally Enhanced Cordless Technology. A European protocol for short range cordless (wireless) phones often used within houses and offices.
Digital		Electrical signal that is represented by discrete digital values; used for second and all subsequent generations of mobile phone systems.
DSL		An abbreviation of Digital Subscriber Line; a digital line (wire or optical fibre) connection to the service provider's resources.
DTT		An abbreviation of Digital Terrestrial Television; broadcast digital television.
Electric power systems		Systems that generate, distribute or convert electrical power.
Electromagnetic fields	EMFs	Electric and magnetic fields which are caused wherever electricity is used. Electric fields are produced by voltages and magnetic fields are produced by currents.
Electromagnetic spectrum		The physical range of electromagnetic frequencies.
Epidemiology		The study of patterns of health and illness and associated factors within the population.
Frequency	Hz	The number of alternating cycles in any oscillating signal during one second.
General packet radio service	GPRS	A standard for a type of wireless communication which runs at speeds of up to 115,000 bits per second.
Gigahertz	GHz	A unit of frequency equal to one thousand million hertz (or cycles per second).
Global standard for mobile telephony	GSM	The European-originated standard for second-generation (digital) mobile voice-communication systems.
Health Protection Agency	HPA	The former independent body that protected the health and well-being of the UK population; now Public Health England (PHE).
Health Protection Scotland		Scottish equivalent body to the PHE.
Hertz	Hz	Unit of electromagnetic frequency. 1 Hz is the same as 1 cycle/second.

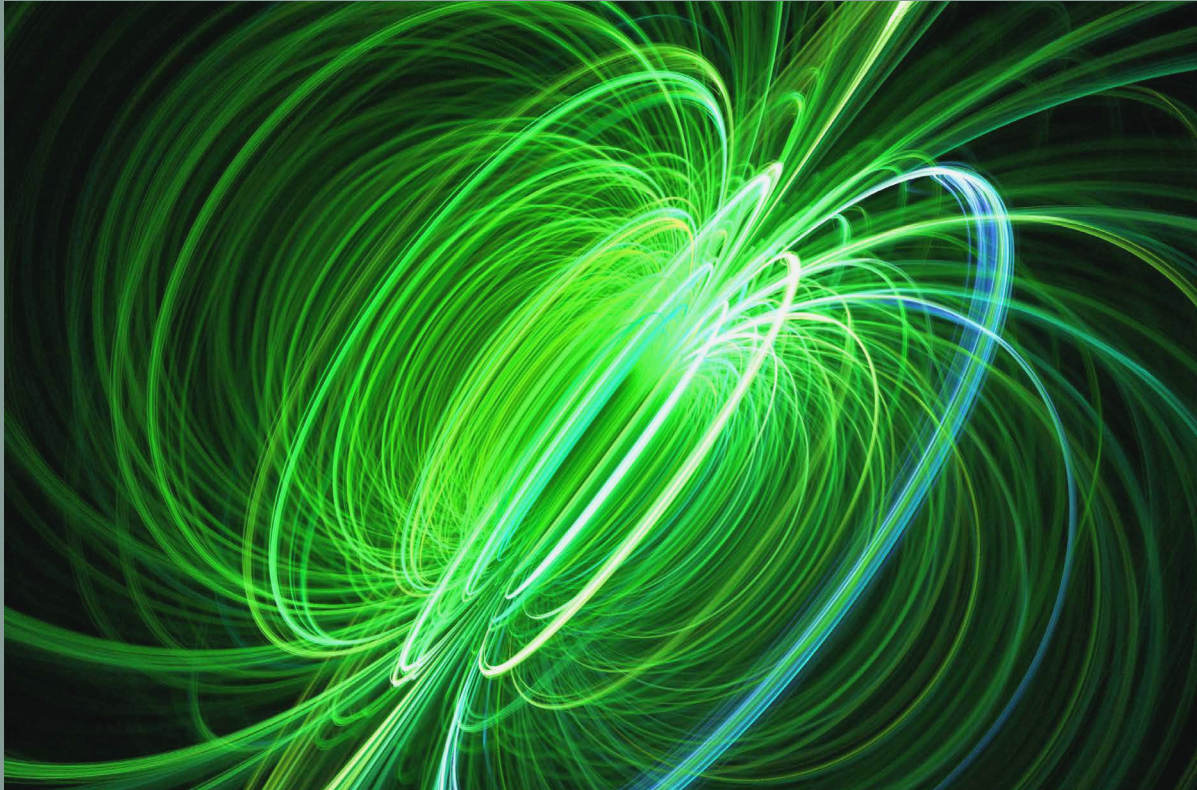
IP		An abbreviation of Internet Protocol. IP specifies the format of digital data packets, and the addressing scheme.
ISM		An abbreviation of industrial, scientific and medical low power wireless digital data communication band 2400-2480 MHz.
Kilohertz	kHz	A unit of frequency equal to one thousand hertz (or cycles per second).
LAN		An abbreviation of Local Area Network; a small data network covering a limited area such as a building or group of buildings.
Leukaemia		A type of cancer of the blood or bone marrow that is characterized by an abnormal increase of white blood cells.
Low-voltage electric wiring		Wiring systems for voltages of less than 400 volts.
LTE		An abbreviation of Long-Term Evolution, the likely update successor to UMTS technologies used in 3G networks. Commonly used to refer to future mobile technologies.
Macrocell		A mobile phone service access node using a mast or other structure supporting a large antenna designed to give large area coverage typically over a few kilometres.
Megahertz	MHz	A unit of frequency equal to one million hertz (or cycles per second).
Microcell		A mobile phone service access node using unobtrusive antennas, designed to give coverage over a small area.
Mobile phone		Hand-held, battery-powered, receiver(s) and transmitter(s) for use with a cellular network(s).
National Institute for Health Protection		A new UK Government body for public health protection and infectious disease capability. This is replacing Public Health England and other health-related bodies.
Network		A combination of hardware and software established and operated for the specific purpose of providing data communications.
Non-ionising		Electromagnetic fields lacking sufficient energy to break chemical bonds.
Packet		A piece of data sent over a packet-switching network, such as the internet. It includes the 'message' data and addresses information about its origin and destination.
PBR		An abbreviation of Private Business Radio (previously known as Private Mobile Radio (PMR)); a private radio communication service installed and operated by businesses and public sector organisations for their workforce.
PDA		An abbreviation of Personal Digital Assistant; often referred to as an electronic diary.
Picocell		A mobile phone service access node using a very small antenna and low power, to give coverage over a very localised area.
PMR		An abbreviation of Private Mobile Radio, see PBR.

Power frequencies		The physical frequency of electrical power systems typically 50 or 60 Hz.
Power lines		The metal wire infrastructure for carrying electricity.
Precautionary measures		Measures taken to avoid or mitigate possible risks before full knowledge of their likelihood and size is available.
Protocol		A standard set of definitions governing how communications are formatted in order to permit their transmission across networks and between devices.
Public Health Agency Northern Ireland		Northern Ireland equivalent body to the PHE.
Public Health England		Executive agency of the Department of Health to protect and improve the nation's health and to address inequalities through working with national and local government, the NHS, industry and the voluntary and community sector. Formerly the HPA.
Public Health Wales		Welsh equivalent body to the PHE.
Radar		System(s) using radio waves to detect remote objects.
Radio frequencies (radio waves)		Electromagnetic fields in a frequency range often used to broadcast radio signals, typically from 100 kHz to 10 GHz.
Smart phone		Wireless phones with advanced data features characterised by the ability to manage, receive and transmit data in addition to voice services.
SMS	SMS	An abbreviation of Short Message Service. It is the transmission of short text-based messages (or 'texts') to and from a mobile or fixed telephone, fax machine and or IP address. Normally it must be no longer than 160 alpha-numeric characters and contain no graphics or images.
Specific absorption rate	SAR	Specification of the amount of power absorbed by living tissue measured in watts per kilogram (W/kg).
Spectrum		A continuous range of frequencies of electromagnetic radiation.
Spread spectrum		A method of transmitting a wireless signal by spreading it over a range of frequencies.
TCP/IP		An abbreviation of Transport Control Protocol (TCP) for Internet Protocol (IP) digital data packets, which establishes a communication connection between a source and destination.
TDMA		An abbreviation of Time Division Multiple Access; a technology that permits the transmission of data by dividing it into time slots (timed packets) such that a plurality of users can be serviced.
Telemetry		The transmission of radio signals containing coded data.
Tesla	T	Physical unit of magnetic field.
Terrestrial trunked radio	TETRA	A professional mobile-radio and two-way transceiver equipment and systems specification designed for use by government agencies, emergency services, (police forces, fire departments, ambulance) for public safety networks, rail transportation staff for train radios, transport services and the military.

Tumour		The name for an abnormal mass, or a solid lesion formed by an abnormal growth of biological cells.
Television and radio transmitters		The electromagnetic field sources intended to broadcast to the population at large.
UHF		An abbreviation of Ultra High Frequency; the radio spectrum range of 300 MHz to 3 GHz.
UMTS		An abbreviation of Universal Mobile Telecommunications System; the third generation (3G) mobile technologies protocol.
UWB		An abbreviation of Ultra-Wide Band; a technology that spreads a signal sparsely over a wide range of frequencies.
VHF		An abbreviation of Very High Frequency; the radio spectrum range of 30 to 300 MHz.
VoIP		An abbreviation of Voice over IP; a set of facilities used to manage the delivery of voice over the internet.
Volt	V	Physical unit of electric potential.
WAN		An abbreviation of Wide Area Network; a term referring to a large network spanning a wide geographical area.
WLAN		An abbreviation of Wireless Local Area Network; a LAN implemented using wireless technology.
Watt	W	Physical unit of electromagnetic field(s) power.
Wi-Fi		Short range (usually less than 30 m) wireless technologies that allow wireless devices to communicate with each other.
WiMax		An abbreviation of Worldwide Interoperability for Microwave Access; a wireless industry coalition to enable multi-media applications for last mile networks typically for broadband access. It is similar to Wi-Fi but with larger range and bandwidth.
Wireless device		A device which receives and transmits electromagnetic fields for communication purposes.



13. Acknowledgements



The IET would like to thank the members of our Engineering Safety Policy Panel and its working groups for their authoritative, unbiased insights and for their time, in the production of this fact file.

12. About the IET



We are the IET - a charitable engineering institution with over **158,000 members in 153 countries** – working to engineer a better world.

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E6D22001/Engineering Safety/0122