Electromagnetic Fields

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The answers to these questions are a faithful summary of the scientific opinion produced in 2009 by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR): *"Health Effects of exposure to Electromagnetic Fields (EMF)"*

The full publication is available at: http://copublications.greenfacts.org/en/electromagnetic-fields/ and at: http://ec.europa.eu/health/opinions2/en/electromagnetic-fields/

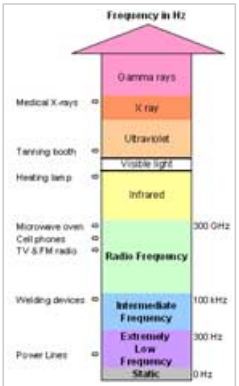
1. Introduction to electromagnetic fields

1.1 What are electromagnetic fields?

Electromagnetic fields are a combination of invisible electric and magnetic fields of force. They are generated by natural phenomena like the Earth's magnetic field but also by human activities, mainly through the use of electricity.

Mobile phones, power lines and computer screens are examples of equipment that generates electromagnetic fields.

Most man-made electromagnetic fields reverse their direction at regular intervals of time, ranging from high **radio frequencies** (mobile phones) through **intermediate frequencies** (computer screens) to **extremely low frequencies** (power lines).



Frequency ranges of electromagnetic fields

The term **static** refers to fields that do not vary with time (i.e. with a frequency of 0 Hz). Static magnetic fields are used in medical imaging and generated by appliances using direct current.

Typical sources of electromagnetic fields

Frequency range	Frequencies	Some examples of exposure sources
Static	0 Hz	video display units; MRI (medical imaging) and other diagnostic or scientific instrumentation; industrial electrolysis; welding devices
ELF [Extremely Low Frequencies]	0-300 Hz	power lines; domestic distribution lines; domestic appliances; electric engines in cars, trains and tramways; welding devices
IF [Intermediate Frequencies]	300 Hz - 100 kHz	video display units; anti-theft devices in shops; hands-free access control systems, card readers and metal detectors; MRI; welding devices
RF [Radio Frequencies]	100 kHz - 300 GHz	mobile telephones; broadcasting and TV; microwave ovens; radar and radio transceivers; portable radios; MRI

Source & ©: Possible effects of Electromagnetic Fields (EMF) on Human Health [see http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf]

1.2 How have the health risks of electromagnetic fields been reassessed?

The review of relevant scientific reports was undertaken, with a focus on articles published in 2007 and 2008, and the studies judged relevant are commented upon in the opinion. Areas where the literature is particularly scarce are pointed out, and an explanation is given why the results of certain studies do not add useful information to the database. This assessment evaluates both potential effects on groups of people who have been exposed to electromagnetic fields in their daily lives (epidemiological evidence) and potential effects observed in laboratory experiments carried out on human volunteers, animals, and cell cultures (experimental evidence).

Based on this combined evidence, the assessment estimates whether there exists a causal link between exposure to electromagnetic fields and some adverse health effects. The answer to this question is not necessarily a definitive yes or no, but expresses the weight of the evidence for a link between an exposure and an effect. If such a link is found, the risk assessment estimates how strong the health effect is and how great the health risk would be for different exposure levels and exposure patterns (dose-response relationship).

The nature and the extent of uncertainties are highlighted and the way in which electromagnetic fields might cause effects (plausible mechanism) are evaluated.

2. What are the sources of exposure to radio frequency fields?

Local wireless computer networks generate radio fields
Credit: Ramzi Mashisho

Devices generating electromagnetic fields in the radio frequency (RF) range (from 100 kHz to 300 GHz) are in widespread use in our society. Key sources of RF fields include mobile phones, cordless phones, local wireless networks and radio transmission towers. They are also used by medical scanners, radar systems and microwave ovens.

Information about the strength of radio frequency fields generated by a given source is readily available and useful in determining compliance with safety limits. But little is known about the exposure of individuals to radio frequency fields, data that are crucial for studies of health effects. Knowledge could be increased through better use of methods such as *exposimeters*, devices carried by individuals to measure their exposure to electromagnetic energy over time. It is furthermore important to consider multi-source exposure and not to focus on single sources, e.g. mobile phone base stations.

The fact that there is a continuous change of technologies, e.g. from analogue to digital TV, and an emergence of new technologies like ultra-wide band (UWB) on the market, leads to changing exposure patterns of the population on a long term scale. Sources of radio waves operate in different frequency bands, and the strength of the electromagnetic field falls rapidly with distance. Over time, a person may absorb more RF energy from a device that emits radio signals near the body than from a powerful source that is farther away. Mobile phones, cordless phones, local wireless networks and anti-theft devices are all sources used in close quarters. Long-range sources include radio transmission towers and mobile phone base stations.

More than 2.5 billion people use mobile phones worldwide. Most mobile communication in Europe uses either GSM or UMTS technology. The European Union has set safety limits on the energy absorbed by the body from exposure to a mobile phone. Mobile phones sold in Europe must undergo standardised tests to demonstrate compliance in accordance with the specifications of the European Committee for Electrical Standardization (CENELEC).

Typical frequencies for devices generating radio frequency fields [see Annex 3, p. 24]

2.1 How high is the exposure from mobile phones and wireless devices?

When exposed to radio frequency fields, the **body absorbs** energy over time. The rate at which energy is absorbed is known as the Specific Absorption Rate (SAR), and it varies throughout the body.

For handheld mobile phones, the exposure is largely confined to part of the head closest to the phone's antenna. The European Union has set a radio frequency safety limit for the human head at a Specific Absorption Rate (SAR) of 2 W (2000 mW) per kilogram of tissue.

Mobile phones are tested assuming worst-case conditions: the rate at which energy is transmitted by a mobile phone operating at maximum power. In practice, the power transmitted during a mobile phone conversation is generally hundreds or thousands of times lower than the maximum power assumed. Indeed, the "power control" feature of a mobile phone automatically reduces the emitted power if higher intensity is not needed for stable

transmission. Moreover, output power depends on whether the user is talking or listening (discontinued transmission mode). No exposure occurs when a mobile phone is switched off. When a phone is in standby mode, the exposure is typically much lower than during operation at maximum power.

GSM phones transmitting at 900 MHz, an important frequency for mobile communication, have a maximum time-averaged power of 250 mW. In accordance with European regulations, the power is averaged over six minutes as GSM phones transmit radio signals in bursts of information rather than continuously.

On average, during a six-minute conversation under worst-case conditions – a mobile phone held to the head and operating at maximum power – the 10 grams of body tissue that absorb most energy would typically absorb between 200 and 1500 mW per kilogram depending on the type of phone.

Other wireless devices used in close quarters, like UMTS mobile phones, cordless phones and wireless networks, also generate radio waves but exposure from these sources is usually lower than from GSM phones.

One DECT cordless handset used by a typical household generates about 10 mW of time-averaged power, much less than a mobile phone operating at maximum power. Cordless handsets need less power than mobile phones because the signals do not have to travel as far to reach the base station – a few meters compared to up to a few kilometers. More power is required for radio communications over greater distances.

Cordless phone base stations are usually no more than a few tens of meters from the handsets. Mobile phone base stations can be kilometres from the mobile phone.

As communication is two-way, there is also the field from the cordless phone base station to consider. The maximum time-averaged power level for a DECT base station is the same as for a mobile phone handset – 250 mW. But the exposure is less because the cordless phone base station is not held to the head, and the field strength falls rapidly with distance.

Most people do not live or work close enough to the mobile phone base station for this field to be a concern. This is discussed further in question 2.2.

The terminal of a wireless computer network (Wireless Local Area Network, WLAN) has a peak power of 200 mW, but the time-averaged power depends on traffic and is usually a lot lower. Near a wireless network station used in homes and offices, the field intensity is typically below 0.5 mW per square meter.

The exposure from wireless systems is therefore typically below that of mobile phones. In certain circumstances, however, the exposure to radio frequency fields from wireless networks or cordless phones can exceed that from GSM or UMTS mobile phones.

Another system that is starting to be used in Europe is UWB, or ultra-wide band. It uses frequencies around 500 MHz, and has applications such as wireless microphones, medical applications and traffic control systems. With such systems, exposures are expected to be well below 0.1 mW per square meter.

Some anti-theft devices expose people to electromagnetic fields of radio and intermediate frequency (question 6 [see http://ec.europa.eu/health/opinions2/en/electromagnetic-fields/l-2/6-intermediate-fields.htm#0]). Increasingly popular, the devices are located at store exits to deter shoplifters. The radio frequency exposure varies depending on the type but is below safety limits if the device is used as directed by the manufacturer. Radio frequency fields are also used in industry, for example for heating or maintaining broadcasting stations.

These systems can expose a worker to levels near or even above European safety limits (Directive 2004/40/EC).

2.2 What is the level of exposure from mobile phone base stations and radio towers?

Mobile phone base stations, like radio transmission towers, are structures designed to support antennas that transmit radio signals. They represent an essential part of the communication networks, linking the individual mobile phones with the rest of the network.

In most European countries, base stations are now ever-present, ensuring mobile communication over large areas.

The field is fairly even over the body and diminishes quickly with distance from the antenna. For such situations, to enable comparison with measured quantities, the European Union recommends maximum field strengths and power densities (reference levels), below which the energy absorbed would be considered safe.

At 900 MHz, an important frequency for mobile communication, the EU recommends that people are not exposed to a field stronger than 4.5 Watts per square meter (power density).

For GSM mobile phone networks, the exposure of the general population is typically much less – at least 100 times lower than the guidelines.

For the newer UMTS networks, measurements of the exposure of the general population are limited as use of these mobile phones is low compared with GSMs. Where exposure has been measured, it was found to be at most a thousandth of a Watt per square meter and usually much less.

Other important sources of radio waves are **radio broadcasting** systems (AM and FM). The maximum values measured in areas accessible to the public are typically below 0.01 Watts per square meter. Close to the fence of very powerful transmitters, exposure of about 0.3 Watts per square meter can be expected in some cases.

As for the new digital **TV broadcasting** technology (DVB-T), an Austrian study registered power densities no higher than 0.04 Watts per square meter and as low as in the millionths of a Watt per square meter. This is similar to the power densities of the older analogue TV broadcasting systems, but as digital systems require more transmitters, higher exposure levels can be expected.

Other sources of long-range exposure to radio frequency fields are civil and military **radar** systems, private mobile radio systems, or new technologies like digital audio broadcasting systems and WiMAX.

2.3 How are radio frequency fields used in medicine?

Doctors use electromagnetic fields in the radio frequency range to heat body tissue, which can ease pain or, at higher temperatures, kill cancer cells. As the aim is a biological effect, the patient’s exposure to radio frequency fields is often well above the recommended limits for the general public. Care must be taken to avoid medical staff exceeding exposure guidelines for workers.

Another common application of radio frequency fields in medicine is magnetic resonance imaging, or MRI, which also uses very strong static magnetic fields (see question 8 [see http://ec.europa.eu/health/opinions2/en/electromagnetic-fields/l-2/8-static-fields.htm#0]). Magnetic Resonance Imaging (MRI) provides three-dimensional images of internal body structures like the brain.

3. Can mobile phones cause cancer?

3.1 Have studies on mobile phone users revealed an increased cancer risk?


More than 2 billion people use mobile phones worldwide Credit: Juha Blomberg

In 2007 and 2008, most studies on cancer in relation to mobile telephone use focused on brain tumours and other tumours in the head because exposure to radio frequency fields from mobile phones is concentrated in a small part of the head near the handset. Tumours investigated included notably a type of benign tumour of the inner ear known as acoustic neuroma and tumours of the salivary glands. A small number of studies investigated the link between exposure to radiofrequency fields from broadcast transmitters and tumour development.

In animal studies, where whole body exposure is sometimes assessed, other forms of cancer were also investigated. In vitro studies aimed to find out if biological effects relevant to cancer development can occur at exposure levels that are typical for mobile telephony.

Previous studies had found no increased risk of brain tumours among people who had been using mobile phones for up to 10 years. For longer duration of use, uncertainties remained as the number of such long-term mobile phone users was still small. Although none of the well-conducted studies indicated a substantial risk increase, they left the possibility open for a small-to-moderate risk increase among frequent mobile phone users, especially for glioma and acoustic neuroma.

The Interphone study, which has not yet been published, pools data from 13 countries and is coordinated by the International Agency for Research on Cancer (IARC). It involves case-control studies that compared the mobile phone use of a group of people with head tumours to that of a similar group who did not have such tumours. Results so far found no increased risk among people who had been using mobile phones for 10 years or more, neither for glioma nor meningioma nor tumours of the parotid gland.

Absorption of radiofrequency fields from mobile phones is concentrated in a small part of the head near the handset. In practice, whether the phone is preferably held to the right or the left side of the head will lead to a different exposure.

Case-control studies compare the mobile phone use of a group of people with head tumours to that of a similar "control group" without such tumours. When patients with a head tumour are asked about their preferred side of phone use, it may be difficult for them to remember and their answers might be biased by the fact that they know which side of their head is affected by the tumour. People in the control group, without such tumour, are less likely to be biased, since they do not know which side of their head will be relevant for analyses. This problem had already been identified in the very first such study which observed an increased tumour risk on the side that was said to be preferred and a decreased risk on the opposite side, whereas there should not have been a decrease in risk on the opposite side compared to the control group. That was found in one study, but there was, in that particular case, no correlation between an increase in exposure and an increase in risk on

the preferred side. It remains unclear whether findings of studies reporting an increased risk of tumours on the preferred side are due to bias alone or also to actual effects.

A number of studies looked into the potential cancer risk of exposure to radio frequency fields from transmission towers. In most cases, no conclusions could be drawn, but some have shown an increased risk of leukaemia in children living close to strong radio or television broadcast transmitters. Two case control studies were recently completed in Korea (2007) and Germany (2008). The Korean study found an increased number of childhood leukemia cases in a 2 km radius of AM radio transmission towers, but no correlation was found between the estimated field strength and the increase in leukaemia. The German study observed no increased risk as a result of exposure from FM and AM transmission towers, during the decade prior to potential dilution from mobile telecommunication networks.

3.2 Have studies on laboratory animals revealed an increased cancer risk?

In the past, a number of studies on laboratory animals looked at the possibility of radio frequency (RF) energy causing cancer, and most found no causal link. One exception was a 1997 study that exposed a strain of mice prone to lymphoma to radio frequency signals similar to those transmitted by GSM-type handsets every day over 18 months. The researchers reported more new lymphoma cases among exposed mice.

Other researchers who carried out a similar experiment in 2002 found no significant effect on the number of new lymphoma cases in mice. Other studies had tested whether exposure to radio frequency fields alone could trigger any type of cancer in normal or genetically predisposed animals. Other studies have investigated whether exposure to RF fields could enhance the development of tumours triggered by cancer-causing chemicals, X-rays or UV radiation. No significant increase in the number of tumour cases has been reported among exposed laboratory animals, but most of these studies used relatively low exposure.

In the last few years, a number of lifetime and long-term exposure studies were performed on laboratory animals by exposing them to 900 MHz GSM signals and other higher frequency signals at higher exposure levels than previous studies. All studies concluded that there was no effect of radiofrequency fields on the risk of developing tumours even at the higher exposures. One study found a reduced survival rate in exposed animals, but this finding remains unexplained.

3.3 Have studies on cell cultures revealed genetic effects?

Scientists have studied a number of possible effects by exposing cell cultures to electromagnetic radiation in the radio frequency range (in-vitro studies). Most of the studies completed prior to 2007 did not provide evidence for any effect of radio frequency field exposure on isolated cells and tissues at an intensity level below the one that causes a warming effect.

Over the last two years, many in vitro studies have been performed in order to assess both the effect on DNA and on other cell components and processes.

One study found that the exposure increased DNA damage in connective tissue cells (fibroblasts), but not in white blood cells (lymphocytes). However, the scientific validity of this study is unclear, making any interpretation of the results difficult at this point.

Another study found changes in the number of certain chromosomes (missing or extra chromosomes) in human white blood cells.

Studies of other cell components have provided mixed results of increases in the activity of certain enzymes, in the presence of free radicals, and the onset of cellular decay. However, there is little agreement between studies, and the health significance of the effects observed remains unclear.

3.4 Discussion on cancer

Studies on users that have had mobile phones for less than ten years indicate no increased risk of developing a brain tumour.

However, due to the relatively recent introduction of mobile phone technology and subsequent widespread use, it is difficult to investigate the risks associated with long-term use through studies on human populations. Few users have had mobile phones for more than ten years.

This prevents firm conclusions related to the use of mobile phones beyond 10 years, as only a few such long term users have been included in studies on cancer. Moreover, estimates of past exposures are uncertain and finding representative study participants is difficult.

The new data released in the last few years have not ruled out the existence of a small cancer risk increase. The data from the complete Interphone study, which should be published in 2009 could shed light on the remaining uncertainties.

Recent studies on human populations provide evidence against an association between exposure to radiofrequency fields from broadcast transmitters and the risk of childhood leukaemia. Exposure from new sources such as mobile phone base stations, cordless phone base stations or wireless networks is generally lower than the ones investigated in studies on radio broadcast towers. Thus, there appears to be no immediate need for further studies related to these sources. However, studies on mobile and cordless phone use among children and adolescents are still completely lacking.

Overall, the results of the new studies are consistent with results from previous studies, and add to the evidence that the radiofrequency fields such as those emitted by mobile phones are not carcinogenic in laboratory rodents.

Different biological effects have been investigated in cell cultures exposed to radiofrequency fields, using a variety of cell types and exposure conditions with diverse outcome. For radio frequency fields that led to an energy absorption below the recommended safety limit for the head (2 W per kg of tissue), in vitro studies have not identified reproducible effects by which carcinogenicity in living systems could be explained.

4. Can mobile phones or base stations trigger headaches or other health effects?

4.1 Have headaches and other symptoms been linked to mobile phones?


Mobile phone base station
Credit: Pyb

Some people complain of headaches, fatigue, dizziness or concentration difficulties, symptoms which have been suggested to be triggered by exposure to radio frequency (RF) fields. Such complaints have raised concern that certain individuals may be more sensitive than others to electromagnetic energy. This self-reported condition has been referred to as electromagnetic hypersensitivity (EHS). Although some new studies provided some indications of a link between radio frequency exposure and single symptoms, taken together, the findings are not consistent. Therefore, the conclusion that scientific studies do not support an effect of radiofrequency fields on symptoms still holds.

The way symptoms are reported varies depending on whether the subjects are aware of being exposed to radio frequency fields or not. Subjects who know they are exposed to some radio frequency fields, e.g. because they use a mobile phone or live near a transmission tower, tend to report more symptoms, whereas double-blind provocations studies where subjects do not know whether they are exposed to radio frequency fields or not do not find a consistent link between radio frequency fields and symptoms.

These results indicate a “nocebo” effect, an effect caused by the expectation or belief that something is harmful (a negative placebo effect).

There is no scientific evidence that humans - be it so-called sensitive groups or healthy control groups - can perceive radio frequency fields better than would be expected by chance.

4.2 Can mobile phones affect the brain?

Because mobile phones come in contact with the head, there have been concerns they could affect the brain. Some scientists have observed small but fleeting changes in the brain functions of people exposed to radio frequency fields, but these do not suggest any harmful consequences.

With the exception of a few findings in otherwise negative studies, there is no evidence that short or long-term radio frequency exposure at levels relevant for mobile telephony can influence processes linked to thought and memory in humans or animals. There is some evidence that radio frequency exposure might influence brain activity or sleep as seen by tests that recorded the electrical impulses in the brain of humans (electroencephalogram). However, certain findings are contradictory and there is a need for further studies into mechanisms that might explain possible effects on sleep and brain activity.

There is no evidence that exposure to radio frequency fields at the levels relevant for mobile telephony have effects on hearing or vision. Furthermore, there is no evidence that this kind of exposure has direct harmful effects on the brain and nervous system. Most studies show the absence of effects on cells that support or surround brain cells and on the blood-brain-barrier. Those that showed effects did not find a dose-response relationship and need to be repeated independently using improved methods.

A number of studies on animals find that relatively strong radio frequency fields can activate glial cells that surround and support brain cells, which could indicate neurological damage after exposure, but exposures at lower levels did not reveal any such effects.

4.3 Have effects of mobile phones on reproduction and development been reported?

Numerous studies have investigated the potential effect on development of animals, including mammals and birds. These studies, reviewed recently, clearly show that radio frequency fields can cause birth defects when the exposure is high enough to significantly raise temperatures in tissue; such exposure would be well above safety guidelines. No consistent evidence of effects has been found at exposure levels that do not cause heating of the tissues.

A large recent Danish study found that seven-year-old children whose mothers had used mobile phones either during or after pregnancy had worse overall scores for behavioural problems. In light of the very low exposure to the children that would occur as a consequence of the mothers' use of the phone during or after pregnancy it is doubtful that radio frequency exposure from mobile telephony could have anything to do with the observed association. Yet, the association remains unexplained at this time. Recent studies have evaluated possible effects of radio frequency fields on the development of animals in the womb at exposure levels associated with the use of mobile phones. However, it is not possible to draw conclusions from these studies because of methodological limitations.

Two studies examined **fertility among men** exposed to radio frequency fields in the Norwegian Navy. One of these studies used questionnaires to assess various self-reported health problems, including infertility, and expert assessments of exposure to radio frequency exposure. Self-reported infertility was more frequent among men working in telecommunications and with radars or sonars who are expected to be more exposed, however objective measures of fertility did not confirm such difference. The other study compared self-reported infertility to self-reported exposures and found a link between the two. However, the self-reported nature of these studies greatly limits their usefulness in drawing conclusions about the potential causal role of radio frequency fields.

A number of other studies have addressed the effects of radio frequency fields on male fertility and male reproductive organs. However, methodological problems prevent any conclusions to be drawn from those.

There are still no substantiated indications of any other health effects.

4.4 Are children more vulnerable to possible effects of mobile phones?

With so many children using mobile phones, there is growing concern about how radio signals may affect them. Some people worry that children could be more vulnerable than adults because their nervous systems are still developing, their brain tissue is more conductive, and their heads might absorb more energy from mobile phones. Also, children who start using mobile phones will have a greater lifetime exposure than people who were adults when they began using mobile phones. Children can also be exposed through other sources, such as the recently introduced DECT baby phones. Few studies have addressed the possible effects of radio signals on children, and extrapolating from adult studies is problematic. One area that deserves investigation would be whether radio frequency radiation can cause childhood brain tumours.

The rate at which children and adults absorb energy is known as the Specific Absorption Rate (SAR), and it varies throughout the body.

International guidelines aim to protect the population against adverse effects by setting maximum SAR values not to be exceeded (referred to as basic restrictions). Because the measurement of the actual SAR within the body is very challenging, reference levels in terms of electric and magnetic field strength were defined, which should ensure compliance.

Computer models were used to estimate internal exposure at field strengths equivalent to reference levels showing that it cannot be ruled out that children could exceed maximum SAR values.

In practice, it is important to realise that actual exposure levels are orders of magnitude below these reference field strengths.

5. Conclusions on mobile phones and radio frequency fields


Few studies have looked at effects on children

Extensive research has been conducted in recent years on how radio frequency fields, including those generated by mobile phones, might affect health. Cancer and a variety of possible effects have been studied, both inside the laboratory and among human populations.

To date studies indicate that a person who has used a mobile phone for up to 10 years does not appear to have a higher risk of brain tumours or other cancers in the head. This also appears to be the case for someone who has used a mobile phone for more than 10 years, but this is still difficult to estimate since few persons have used mobile phones for more than ten years.

New improved studies provide evidence against a link between childhood cancer and exposure to radio frequency fields from broadcast transmitters. Animal studies show that radio frequency fields similar to those from mobile phones do not cause cancer in laboratory animals, and studies at higher exposure levels (up to 4 W/kg) have shown no apparent effects on tumour development. Furthermore, the in vitro studies on cell cultures did not find evidence that radio frequency field exposure contributes to DNA-damage.

It is concluded from three independent lines of evidence (studies on humans, animals, and cell cultures) that exposure to radio frequency fields is unlikely to lead to an increased cancer risk in humans. However, further studies are required to identify whether exposure well beyond ten years to such phones might pose some cancer risk.

Regarding effects other than cancer, research has found no evidence so far that exposure to radio signals could cause self-reported symptoms like headaches and dizziness. There have been indications that there might be adverse effects that are caused by expectations or beliefs that radiofrequency fields and EMF in general are harmful (a nocebo effect). There is no evidence that individuals are able to perceive radio frequency fields.

There is some evidence that radio frequency fields can influence brain activity and sleep in humans. However, the health relevance is uncertain and how this may occur is not yet explained. Further investigation of these effects is needed.

Recent studies have not shown effects of radio frequency fields on human or animal reproduction and development. No new data have been reported that would indicate any other effects on human health.

There is little information on possible effects caused by radio frequency fields in children. Furthermore, there is a lack of information on diseases other than those discussed in this report.

6. Intermediate frequency fields like those from computer screens and anti-theft devices

6.1 What are the sources of intermediate frequency fields (IF fields)?


Cathode ray tube screens generate intermediate frequency fields Credit: Anissa Thompson

In this assessment, intermediate frequency (IF) fields designate electromagnetic fields with frequencies ranging from 300 Hz to 100 kHz, roughly the frequencies that are lower than radio frequencies (RF) and higher than extremely low frequencies (ELF).

The term covers frequencies of the electromagnetic spectrum that are sometimes referred to as very low frequency (VLF) and low frequency (LF).

Applications generating intermediate frequency fields have been increasing in recent years and will likely continue to do so. Examples are some anti-theft devices operated at the exits of shops, induction hotplates, computer and television screens which use cathode ray tubes, compact fluorescent lamps, as well as some radio transmitters. Such fields are also generated by some industrial uses such as welding. In most cases exposure is limited, but for radio transmitters and welding, exposure can be above the recommended limits, so safety precautions should be taken.

Some medical applications lead to exposures in this frequency range, like electrosurgery that uses an electric current to cut or remove tissues and magnetic resonance imaging (MRI) that provides three-dimensional images of internal structures such as the brain.

Typical frequencies for devices generating intermediate frequency fields [see Annex 2, p. 24]

6.2 What possible health effects of intermediate frequency fields have been studied?

Well-known biological effects at the intermediate frequency range are nerve stimulation at the lower end of the range and heating at the upper end of the range. These are explained by the mechanisms known to occur in the radio frequency and extremely low frequency (ELF) ranges.

Very little useful human population data on intermediate field exposure and health risks are available, and laboratory data is still very sparse.

Exposure to intermediate frequency fields at work is in some cases considerably higher than exposure to the general public. However, very little research on intermediate frequencies and health risks in occupational settings or for the general public have been made recently, and no new epidemiological studies have appeared. The data are thus still too limited for an appropriate risk assessment.

In view of the increasing exposure to intermediate frequency fields at the work place, for instance in shops and certain industries, it is important that research in this area is given priority.

7. Extremely low frequency fields like those from power lines and household appliances

7.1 What are the sources of extremely low frequency fields (ELF fields)?


Power lines generate ELF fields Credit: Miguel Saavedra

In this assessment, extremely low frequency (ELF) fields designate electromagnetic fields with frequencies below 300 Hz, the frequencies that are lower than intermediate frequencies. The main source of extremely low frequencies is alternating current carried in power lines, wiring and household appliances. The electromagnetic field generated has the same frequency as the current that causes it, i.e.50Hz or 60Hz (the latter predominantly in US).

Besides power lines and household appliances, important sources of extremely low frequency fields include power plants and substations, welding machines, induction heaters, and railway, tramway and subway systems.

Extremely low frequency fields have an electric and magnetic component:

- An electric field is the force created by the attraction and repulsion of electric charges (the cause of electric flow), and is measured in volts per meter (V/m).
- A magnetic field is a force created as a consequence of the movement of the charges (flow of electricity). The magnitude (intensity) of a magnetic field is usually measured in tesla (T).

The intensity of both electric and magnetic fields decreases with distance from the field source.

ELF **electric** fields tend to be strongest close to high voltage power lines (up to 5 kV/m and in a few cases more), and ELF **magnetic** fields are particularly strong near induction furnaces and welding machines (up to a few mT).

To determine compliance with exposure limits, the maximum possible exposure next to the source must be measured. Maximum exposure is often much higher than average exposure. This is true not just for those who live and work far from the source. Even a lineman who installs or repairs power lines could be expected to have an average exposure on the order of 10 times lower than the maximum. For the general population, the average exposure could be expected to be hundreds or thousands of times lower.

For assessment of compliance with exposure limits, the maximum possible exposure next to devices must be measured. However, the maximum possible exposure next to a specific source is often tens, hundreds or thousands of times higher than the average individual exposure of a person.

For example, for a lineman who installs or repairs electrical lines, the average exposure due to magnetic fields could be more than ten times lower than the maximum exposure close to a transmission line. For the general population which lives and works further away from the source, the difference between maximum and average exposure can be expected to be even greater.

Typical frequencies for devices generating extremely low frequency fields [see Annex 1, p. 24]

7.2 What is the level of exposure to ELF fields?

The **general public** can be exposed to extremely low frequency (ELF) fields from various fixed sources that are operated in our environment, such as power lines.

When people are passing directly below a **high voltage power line**, they can be exposed to an electric field between 2 to 5 kV/m and to magnetic fields of less than 40 µT. The strength of the electric and magnetic field diminishes rapidly with distance to the line.

Low voltage power lines cause much lower exposure (100-400 V/m and 0.5-3 µT), and buried cables virtually none. Power plants and distribution stations are off limits to most people and so are not considered a source of exposure for the general public. The same goes for railway power supply installations. The exposure levels in the areas that are accessible to the public are below safety limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to provide protection against known adverse health effects. At home the magnetic fields tend to be strongest close to certain domestic appliances that contain motors, transformers, and heaters, and fields quickly decrease with distance. For instance, the magnetic field close to a vacuum cleaner is 200 times weaker at 1 m distance than at 5 cm distance (up to 40 µT).

Workers in the electric power industry can be exposed to high levels of electromagnetic fields on the job. Extremely low frequency fields reach or exceed the recommended limits for workers (directive 2004/40/EC). In some areas within power plants and distribution stations, appropriate safety measures are needed. Extremely low frequency (as well as intermediate frequency) fields are also generated by induction and light arc ovens and welding devices, and exposure of workers has to be controlled for such devices. For certain welding devices, magnetic field strengths of up to several hundred µT are possible.

Some **medical applications** that use electromagnetic fields in the extremely low frequency range include: bone growth stimulation to promote the healing of fractures, Transcranial Magnetic Stimulation to trigger brain activity or treat certain health conditions, wound healing, and pain treatment. ELF can also be used for cancer detection through bioimpedance measurements, a non-intrusive diagnostic method.

7.3 Can ELF fields increase the risk of childhood leukaemia and other cancers?

In 2002, the International Agency for Research on Cancer (IARC) classified **ELF magnetic fields** as "possibly carcinogenic to humans" (Group 2B). This was based on statistical studies indicating children are more likely to develop leukaemia if their exposure to extremely low frequency magnetic fields exceeds 0.3-0.4 µT, which would be relatively strong. Experimental studies on animals did not support these findings.

Furthermore, the IARC concluded, there was no evidence for a link between ELF magnetic fields and any other type of cancer.

As far as **ELF electric field**s are concerned, the IARC classified them as **"unclassifiable as to carcinogenicity in humans"**.

The potential link between extremely low frequency fields and childhood leukaemia has been addressed by a number of epidemiological studies, which have not found any conclusive

evidence, and further studies are needed. No new influential study has appeared over the last few years concerning any other type of cancer.

A recent study on human populations suggests a link between defects in DNA-repair systems and childhood leukaemia caused by exposure to extremely low frequency fields at home. There are however too many weaknesses in this study to allow any conclusions to be drawn.

Studies on laboratory animals have shown little evidence that exposure to ELF magnetic fields alone could induce any type of cancer or would affect existing tumours. There is some inconsistent evidence that ELF magnetic fields of about 100 µT may enhance the development of tumours induced by other known carcinogens, but the majority of studies evaluating such combined effects did not find such a link. Results from recent studies are potentially helpful for explaining mechanisms and inconsistencies of previous findings, but they lack confirmation in independent experiments, and are not sufficient to challenge IARC's evaluation that the experimental evidence for carcinogenicity of ELF magnetic fields is inadequate. This means that the experimental studies cannot be interpreted as showing either the presence or absence of a carcinogenic effect because of major qualitative or quantitative limitations.

Laboratory studies on isolated cells and tissues (in-vitro studies) can provide information on mechanisms of damage to cells. At this stage, published in-vitro studies cannot explain epidemiological findings, but do not contradict them either. They have shown many effects of ELF fields, and a large number of cellular components, cellular processes, and cellular systems can conceivably be affected by EMF exposure. The fact that the epidemiological findings of childhood leukaemia are neither supported by experimental studies nor explained by known mechanisms is intriguing and it is of high priority to overcome this contradiction.

7.4 Can exposure to ELF cause headaches or other health effects?

A variety of symptoms, often self-reported, have been suggested to be caused by ELF field exposure: skin redness, tingling and burning sensations, as well as fatigue, headache, concentration difficulties, nausea, and heart palpitation. The term "electromagnetic hypersensitivity" (EHS) has come into common usage based on the reported experience by the afflicted individuals that electric and/or magnetic ELF fields, or vicinity to activated electrical equipment trigger the symptoms. A relationship between ELF field exposure and those symptoms has not been shown in scientific studies.

Over the last few years, studies on electromagnetic hypersensitivity have come to focus on identifying various possible factors influencing the well-being of the group reporting symptoms. It appears that people who reported electromagnetic hypersensitivity, among other things, tended to have specific personality traits, be more anxious and more susceptible to stress, and report more other health complaints when compared to reference groups.

It remains unclear if there is a link between extremely-low frequency field exposure and some neurodegenerative diseases such as Alzheimer's, but some recent data suggests there might be such a link.

Laboratory studies on animals have looked at possible effects of ELF magnetic fields on various parts of the body. Although some studies have observed effects on the nervous system, animal development, and melatonin production, the evidence for such effects was found to be weak and ambiguous, and inadequate for drawing conclusions concerning possible human health risks. Recent studies have suggested a link between magnetic fields and brain activity, but no conclusion can be drawn from this data.

Studies on isolated cells and tissues (in-vitro studies) are rather scarce when it comes to ELF fields and their possible role in diseases other than cancer. The data available suggests that exposure to EMF activates the expression of certain proteins, but the biological significance of these findings is still unclear. There is a need for hypothesis-based in vitro studies to examine specific diseases.

7.5 What can be concluded about ELF fields?

The main conclusions remain unchanged:

ELF magnetic fields have been classified as "possibly carcinogenic" by the International Agency for Research on Cancer (IARC). This conclusion is mainly based on studies on human populations indicating that exposure to relatively strong ELF magnetic fields might be a cause of childhood leukaemia. Laboratory studies on cell tissues have not yet provided an explanation of how exactly these fields might cause leukaemia.

No consistent relationship between extremely low frequency fields and self-reported symptoms such as fatigue, headache, and concentration difficulties has been demonstrated.

For some other diseases, such as cardiovascular diseases, recent research indicates that a link with extremely low frequency fields is unlikely. For yet other diseases, such as those affecting the brain and the spinal cord, the issue of a link to ELF fields remains open and more research is called for.

There is a need for hypothesis-based studies on cell tissues (in vitro studies) to examine specific diseases. It is notable that animal and in vitro studies show effects at exposure to ELF fields at levels (from 0.10 mT and above) that are considerably higher than the levels encountered in the epidemiological studies (μT-levels) which showed an association between exposure and diseases such as childhood leukaemia and Alzheimer's disease. This warrants further investigation.

8. Static magnetic fields like those used in medical imaging

8.1 What are the sources of static magnetic fields?

A magnetic field is a force field created by a magnet or as a consequence of the movement of the charges (flow of electricity). The magnitude (intensity) of a magnetic field is usually measured in Tesla (T or mT).


MRI scanners use static magnetic fields
Credit: Kasuga Huang

Static magnetic fields do not vary over time, and as such do not have a frequency (0 Hz). Examples are the fields generated by a permanent magnet or the Earth's magnetic field.

Man-made static magnetic fields are generated wherever electricity is used in the form of direct current (DC), such as in some rail and subway systems, in industrial processes such as aluminum production, the chloralkali process, and gas welding.

The number of artificial sources of such fields is limited, but there are rapid developments of new technologies producing static fields. The number of people with implanted metallic devices such as pacemakers that can be affected by static magnetic fields is also growing.

One prominent application of strong static magnetic fields is Magnetic Resonance Imaging (MRI) that provides three-dimensional images of soft body tissue such as the brain and the spinal cord. This medical imaging technique uses very powerful permanent magnets, which can lead to high exposure levels both for patients and for operators.

Previous health assessments looked mainly at exposure to static fields alone, but many applications, particularly MRI, can lead to exposure to strong static fields in combination with radio frequency and other fields. Recent studies have thus started to look at different field combinations and their potential effects.

8.2 What possible health effects of static magnetic fields have been studied?

Few studies on human populations are available on the effects of static fields and the available evidence is not sufficient to draw any conclusion about potential health effects of exposure to static magnetic fields.

A large number of experimental studies on cell cultures have been carried out in an effort to detect biological effects of static magnetic fields. Experimental data have established that static magnetic fields can result in changes in the orientation of the forces applied on biological molecules and cellular components with magnetic properties – such as haemoglobin, rhodopsin (visual pigment), free radicals, and nitric oxide. Such changes can affect these biological molecules.

Human volunteer studies indicate possible instantaneous effects on neuronal functioning when moving through a static magnetic field or field gradient as used in clinical practice. These studies need confirmation.

Recent animal studies confirm earlier findings that static magnetic fields of several milliteslas (mT) can have direct effects on neurons. Studies on cell cultures also show that exposure to static magnetic fields in the millitesla range may change membrane properties. These changes may lead to changes in neuronal functioning though the effects seem to be reversible.

The studies on pain reduction in animals by exposure to static magnetic fields in the millitesla range are interesting. The question is whether rodents are an adequate model for humans in this respect, since no pain reduction in humans was observed after exposure to static magnetic fields that were 10 times stronger.

Recent animal experiments show an effect of static fields on blood flow, vessel growth, as well as on growth and development, but some results are contradictory and do not clarify the mixed results of previous studies.

Static fields seem to have an effect on the expression of specific genes in cells of humans and other mammals and these effects may depend on exposure duration and field gradients. Damage to genetic material has been reported, although it seems that these effects can be repaired and are not permanent.

Although a fair number of studies were published in 2007 and 2008, there is still a lack of adequate data for a proper risk assessment of static magnetic fields. More research is necessary, especially to clarify the many mixed and sometimes contradictory results.

Short term effects have been observed primarily on sensory functions for acute exposure. However, there is no consistent evidence for sustained adverse health effects from short term exposure up to several Teslas.

9. What is known about environmental effects of electromagnetic fields?


Migratory birds rely on magnetic fields for orientation
Credit: Michael Hatherly

Field studies on individual animal and plant species living in close proximity to sources of electromagnetic fields are important to determine whether ecosystems might be substantially affected. In addition, such studies may provide information on the potential of electromagnetic fields to cause adverse effects in humans.

Past field studies have mainly focused on wild birds and on potential effects on reproduction and orientation as certain species use magnetic fields for navigation purposes.

Though some new study results have recently been published, overall, the available data remains inadequate for the assessment of possible risks due to environmental exposure to radio frequency, intermediate frequency and extremely-low frequency fields.

9.1 Are there new findings on environmental effects of radiofrequency fields?

Studies indicate that exposure of **wild birds** to radio frequency fields can, under certain circumstances, change their behaviour, reproductive success, growth and development, physiology, and other parameters. However, the changes observed are neither all in the same direction, nor consistent.

Two independent field studies carried out in Spain and Belgium suggest a link between the reduction in house sparrow population in urban areas and exposure to radio frequency fields. However, there are a number of other possible contributing factors, including pollution and loss of preferred food sources, and further investigations are needed. A study showed that there were differences in the relative numbers of two varieties of tits breading near a radar station, a strong source of radio frequencies. One interpretation is that the radio frequency fields may discourage some bird species or encourage others. Another possible explanation is that RF fields modify the reproductive behaviour of insects that serve as food sources for various bird populations.

One study found that adult tufted puffins carrying radio transmitters – so that they may be tracked in the wild – tended to have poorer breeding success and their offspring lower growth rates than puffins without transmitters. The cause of this difference was attributed to the radio frequency fields of 2 to 5 W/m^2 from the transmitters.

9.2 Are there new findings on environmental effects of extremely low frequency fields?

A number of field studies have considered birds of prey living around overhead power lines – that produce extremely low frequency fields – and the birds ability to reproduce. Findings vary widely, and no clear overall conclusion can be drawn. A field study on the effects of the ELF magnetic field of a buried electricity transmission cable showed a reduction of the biological activity in the surrounding soil. The environmental significance of these field studies is uncertain.

Studies on plants, particularly on the potential use of extremely low frequency fields to promote plant growth in nurseries, have shown that ELF magnetic fields can promote the growth of certain plant species. Optimum growth was observed at levels of around 100-150

mT. It is however unclear what the effects are on different plant species, and if it only affects plant growth.

Several laboratory studies on cell cultures have shown detectable effects of extremely low frequency fields in the millitesla range on bacteria, small freshwater crustaceans (Daphnia) as well as bird and chicken tissues.

10. Conclusions on electromagnetic fields

10.1 Conclusions on Radio Frequency (RF) fields

Radio frequency fields (100 kHz - 300 GHz) are for instance generated by mobile telephony and wireless networks.

The question receiving most attention is whether radio frequency field exposure causes cancer.

The balance of epidemiologic evidence still indicates that mobile phone use of less than 10 years does not pose any increased risk of cancer. Regarding longer use, it is still difficult to make an estimate since few persons had used mobile phones for more than ten years.

New improved studies looking into a possible link between radio frequency fields from broadcast transmitters and childhood leukaemia provide evidence against such a link.

Laboratory studies on animals show that radio frequency fields similar to those from mobile phones, alone or in combination with known carcinogens, do not increase the number of cancers in laboratory rodents. Certain studies have also employed higher exposure levels (up to 4 W/kg), still with no apparent effects on tumour development. Furthermore, the in vitro studies on cell cultures found no evidence that radio frequency field exposure could contribute to DNA-damage.

Evidence from studies on humans, animals and cell cultures concur that exposure to radio frequency fields is unlikely to lead to an increase in cancer in humans. However, as the widespread exposure of humans from mobile phones has been shorter than the time needed to induce some forms of cancers, further studies are required to identify whether human exposures to such phones well beyond ten years might pose some cancer risk.

Present scientific knowledge suggests that self-reported symptoms such as headaches, fatigue, dizziness or concentration difficulties affecting some individuals are not linked to exposure to radio frequency fields. These results suggest a “nocebo” effect, an effect caused by the expectation or belief that something is harmful. There is no evidence that individuals are able to perceive radio frequency fields.

There is some evidence that radio frequency fields can influence brain activity and sleep in humans. However, the health relevance is uncertain and how this may occur is not yet explained. Further investigation of these effects is needed. Other studies focusing on different aspects of the nervous system show no or no consistent effects.

10.2 Conclusions on Intermediate Frequency (IF) fields

Intermediate frequency fields (300 Hz – 100 kHz) are generated by sources like computer screens and anti-theft devices.

Exposure to intermediate frequency fields at the work place is in some cases considerably higher than exposure to the general public. However, very little research on intermediate frequency fields and health risks in occupational settings or for the general public has been published and the data are still too limited for an appropriate risk assessment.

In view of the increasing exposure to intermediate frequency fields at the work place, for instance in shops and certain industries, it is important that research in this area is given priority.

10.3 Conclusions on Extremely low frequency (ELF) fields

Extremely low frequency fields (below 300 kHz) are generated by sources like power lines, and electric appliances.

The conclusion that extremely low frequency magnetic fields are a possible carcinogen, chiefly based on childhood leukaemia results, is still valid. Laboratory studies on cell tissues have not yet provided an explanation of how exactly these fields might cause leukaemia.

No consistent relationship between extremely low frequency fields and self-reported symptoms such as fatigue, headache, and concentration difficulties has been demonstrated.

For some other diseases, notably breast cancer and cardiovascular diseases, recent research indicates that a link with extremely low frequency fields is unlikely. For yet other diseases, such as those affecting the brain and spinal cord, the issue of a link to ELF fields remains open and more research is called for.

New epidemiological studies indicate a possible increase in Alzheimer's disease arising from exposure to extremely low frequency fields. Further epidemiological and laboratory investigations of this observation are needed.

Recent animal studies suggested effects on the nervous system for relatively strong fields of 0.10-1.0 mT. However, there are still inconsistencies in the data, and no definite conclusions can be drawn concerning potential effects on human health.

Very few recent in vitro studies on cell cultures have investigated effects from extremely low frequency fields on diseases other than cancer and those available have very little relevance. There is a need for hypothesis-based studies on cell tissues (in vitro studies) to examine specific diseases.

10.4 Conclusions on static magnetic fields

Static magnetic fields are generated by sources such as magnetic resonance imaging (MRI) scanners and appliances using direct current.

Although a fair number of studies have recently been published there is still a lack of adequate data for a proper risk assessment of static magnetic fields. More research is needed, especially to clarify the many mixed and sometimes contradictory results.

Short term effects have been observed primarily on sensory functions for acute exposure. However, there is no consistent evidence for lasting adverse health effects from short term exposure up to several teslas.

10.5 Conclusions on environmental effects

The current database is inadequate for the purposes of the assessment of possible risks due to environmental exposure to radio frequency, intermediate frequency and extremely low frequency fields.

10.6 Research recommendations

To fill the important gaps in knowledge the following research efforts are recommended.

Radio frequency (RF) fields (100 kHz – 300 GHz)

- To study potential cancer risks, a long term cohort study is needed that would follow the health of a large population group and overcome problems of previous assessments, limited to short periods or head tumours.
- Health effects on children of exposure to radio frequency fields should be studied, taking into consideration the fact that the amount and distribution of energy absorbed in children may differ from that in adults.
- The total exposure of individuals to radio frequency fields should be assessed using high quality personal exposimeters, devices carried by individuals to measure their exposure to electromagnetic energy over time.
- Important findings such as those on damage to genetic material or on effects on the nervous system need to be confirmed by additional studies.

Intermediate frequency (IF) fields (300 Hz – 100 kHz)

Data on possible health effects from intermediate frequency fields are sparse. This issue should be addressed both through epidemiological and experimental studies.

Extremely low frequency (ELF) fields (less than 300 Hz)

- Epidemiological studies indicate an increased risk of leukaemia in children exposed to ELF fields. However, there is a lack of supporting evidence for such an effect either in animal models or in vitro studies or mechanistic investigations. This discrepancy must be resolved.
- Epidemiological and experimental investigations of the apparent association between ELF and the development of Alzheimer's disease should be given priority.
- Laboratory studies on animals and cell cultures are needed to determine possible effects at low exposures and establish dose-response relationships.

Static fields (0 Hz)

- A cohort study is recommended that would follow the health personnel dealing with equipment, such as MRI scanners, that generates strong static magnetic fields.
- Experimental studies are also needed on other potential effects, including cancer, damage to genetic material as well as developmental and neurobehavioural effects.

Studies of mechanisms of action in cells and tissues are needed at exposure levels lower than those causing tissue heating for radio frequencies and nerve and muscle excitation

for extremely low frequencies, since there is still no generally accepted model of action of electromagnetic fields at those levels.

Moreover, studies including exposure to combinations of frequencies as well as combinations of electromagnetic fields and other agents are needed.

Annex

Annex 1:

Typical frequencies for devices generating extremely low frequency fields

Extremely low frequency fields	Less than 300 Hz
Railway power supply installations	16 2/3 Hz
Power frequencies	50 Hz (EU) and 60 Hz (US)

Source: GreenFacts based on SCENIHR Health Effects of Exposure to EMF (2009) [see http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf]

Annex 2:

Typical frequencies for devices generating intermediate frequency fields

Intermediate frequency fields	300 Hz - 100 kHz
anti-theft devices	ranging from some tens of Hz to a few GHz depending on the type of system
induction hobs and hotplates	20 to 50 kHz
electric engines and badge readers	about 100 kHz
Radio transmitters operated in the long wave range	30 kHz to 300 kHz
Welding devices	up to a few 100 kHz
Induction heaters	some tens of Hz to some tens of kHz
Electrosurgery systems	some hundred kHz
clinical MRI devices use intermediate frequency fields in addition to static and radio frequency fields	up to 10 kHz

Source: GreenFacts based on SCENIHR Health Effects of Exposure to EMF (2009) [see http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf]

Annex 3:

Typical frequencies for devices generating radio frequency fields

Radio frequency fields	100 kHz to 300 GHz
Radio transmitters operated in the long wave range	30 kHz to 300 kHz
Welding devices	Up to a few hundred kHz
Electrosurgery systems	Some hundred kHz
Clinical MRI devices use radio frequency fields in addition to static and intermediate frequency fields	63 MHz
Mobile telephony: GSM 900	About 900 MHz
Mobile telephony: GSM 1800	About 1800 MHz
Mobile telephony: UMTS 2100	About 2100 MHz
Anti-theft devices	Ranging from some tens of Hz to a few GHz depending on the type of system

Source: GreenFacts based on SCENIHR Health Effects of Exposure to EMF (2009) [see http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf]