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Federal Office of Public Health (FOPH)

Mobile phones

Mobile phones (also known as cellular or cellphones) allow communication from any location via a network of base stations. The information is transmitted from the mobile phone to the base station and vice versa via high-frequency electromagnetic fields. Radiation intensity is greatest close to its source, i.e. a mobile phone's antenna. The radiation is only strong while the phone is transmitting, not while it is in idle state. The radiation decreases sharply with distance to the phone.
The **intensity of radiation exposure** during a call depends on various factors:

- A mobile phone emits less radiation when **connection quality** is good than when it is poor. Connection quality is, for example, better outdoors than in a building and it improves with proximity to a base station. The quality of the connection is indicated by a set of bars on the phone's display.
- The proportion of the radiation that is absorbed by the head when making a call varies according to the model of mobile phone. It is expressed by the **specific absorption rate (SAR).** The lower SAR of the device, the lower the radiation that is absorbed by the body. You will find the SAR of your phone either in the instruction manual or on the internet.

To minimize the exposure, our advice is:

- When buying a mobile phone, make sure it has a **low SAR**.
- Either keep your calls **short** or send a text message (**SMS**) instead.
- Use a wireless **hands-free system** (headphone, headset) with a low power Bluetooth emitter to reduce radiation to the head.
- Whenever possible, only use your phone when the **signal quality** is good.

Further advices

- Never use a phone while you are a driving a vehicle, not even with a hands-free kit.
- Be wary of radiation shields and other such protective devices that are claimed to limit exposure to radiation. They may reduce the connection quality and therefore force the phone to transmit at a higher output power.
- People with active medical implants should keep their mobile phone at least 30 cm away from the implant at all times.

Base stations

Detailed information on radiation from base stations can be obtained from the Federal Office for the Environment FOEN or from your cantonal authorities.

Detailed information

1. Technical data

GSM (Global System for Mobile Communication) is a standard protocol for digital mobile communication which is mainly used for telephony and transmission of text messages (SMS). Mobile phones can, however, also be used for sending data or surfing the internet. GPRS (General Packet Radio System) and Edge (Enhanced Data Rate for Global Evolution) are further developments of GSM which make it possible to transfer data at higher rates. UMTS (Universal Mobile Telecommunication System), the new (third) generation in mobile telecommunications, has a higher data transfer rate than GSM and is better suited to data and multimedia services. It is, however, also used for standard telephony and text messaging (SMS). In the medium term, UMTS will supersede the GSM standard.

	GSM		UMTS
Transmission frequency (MHz)	900	1800	2100
Peak output power (mW)	2000	1000	125 - 250
Max. output power (mW)	240	120	125 -250
Power control (Hz)	1 - 2		1500
Pulse repetition frequency (Hz)	217		Current standard (Frequency Division Duplex, FDD): No pulsing for data and telephony
Pulse transmitted in idle state every ... min.	12 -240		5 - 720, currently approx. 33

Table 1: Comparison of GSM and UMTS

Network cells, idle state
The mobile telecommunications network is divided into geographical cells. Each cell contains a base station with which the mobile phone must establish radio contact. As each network cell can only handle a limited number of calls simultaneously, base stations in urban areas need to be more numerous and sited closer together than in rural areas. Base stations that serve a small cell (e.g. in a town or city) generally require less power than those serving large cells (e.g. in rural areas).
GSM: The different mobile phones that communicate via a given base station are time-divided, with each being allocated one-eighth of the transmission time (Figure 1). This results in a pulsed radiation pattern (transmitting: radiation; not transmitting: no radiation). Reception is "hopped" to a different frequency. The cells are grouped into "clusters". When it changes from one cluster to the next, a mobile phone must disconnect from the current base station and connect to a base station in the new cluster. In the idle state, when no call is taking place, the mobile phone continues to receive information from the base station and therefore also knows which network cell it is located in. The phone itself sends a brief signal to register with the base station either as soon as it enters a new network cell or else every 12-240 minutes, depending on the telephone company.
UMTS: The different mobile phones that conduct calls via a base station are not time-divided, but code-divided. The phone transmits continuously during the connection and the radiation is not pulsed. A UMTS network cell is at maximum capacity when the lowest possible output power is being used for all connections. Thus the base station is able to exclude mobile phones that are located at the edge of the coverage area (and can therefore only be reached by transmitting at high power) and assign them to another network cell. The size of the network cell depends on the volume of data transmitted and therefore varies within a certain range.
Mobile phones can be registered with several base stations simultaneously and therefore do not necessarily have to sign on and off when changing cells. As with GSM, phones are continuously registered, even in the idle state.

Output power
It is important to distinguish between peak output power, maximum output power and actual output power. Peak output power denotes the phone's maximum possible power level. Maximum output power indicates its maximum power level within a network, averaged over time. Actual

output power is usually lower than maximum output power. A mobile phone uses a far lower output power level when the radio link to the base station is good than when it is poor. The base station determines the output level at which the mobile phone is to transmit.
GSM: The peak output power is 1 W or 2 W (Table 1). As the phone only transmits for 1/8 of the call time (Figure 1) and, moreover, every 26th pulse is omitted, the maximum output power is 120 mW or 240 mW, respectively. Maximum output power for data transfer via GPRS or Edge is 0.5-1 W, since the phones currently available transmit for ¼ - ½ of the call time. The output power is matched to the connection quality 1 - 2 times per second, which can reduce output power by a factor of 1,000. A further reduction in output power (by around half) can be achieved using DTX (discontinuous transmission), which turns off transmission during pauses in speech.
UMTS: Peak output power and maximum output power during a connection (data and voice) are 250 mW, since transmission is continuous. The output power is matched to the connection quality and available cell capacity 1,500 times per second, which leads to a significant reduction in average output power when the phone is in use compared with GSM (based on the same data transfer rates/calls).

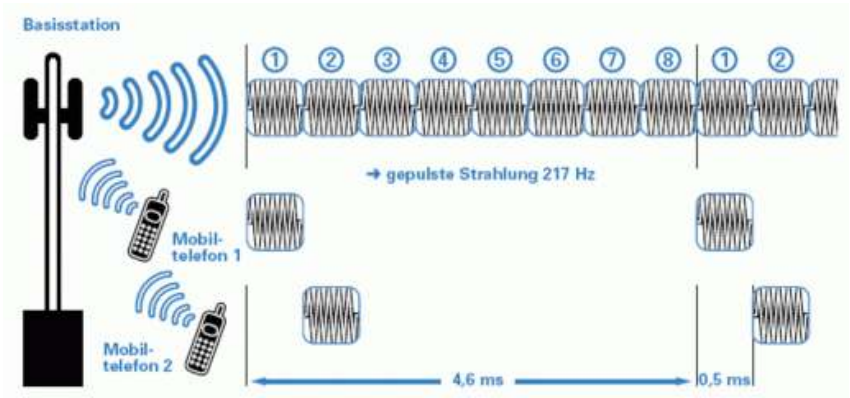

Figure 1: GSM network diagram: The mobile phone only transmits for 1/8 of the call time, which results in a pulsed radiation of 217 Hz.

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2. Exposure measurements

SAR: specific absorption rate

Figure 2: Head phantom for determining the specific absorption rate. Photo source: [2]

Exposure is best quantified using the specific absorption rate (SAR). The SAR (expressed in W/kg) is a measurement of the electromagnetic radiation (W) that is absorbed by the human body (kg). The SAR of each individual phone model is determined using a human head "phantom" (Figure 2) and published on the internet and in the instruction manual. The SAR is measured in a "worst-case" scenario. The 2 W/kg exposure limit [1] recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) is virtually exhausted by some phone models.

Output power
Exposure to radiation is highly dependent on the actual output power level, which is, in turn, largely influenced by the quality of the link to the base station. The radiation can be greatly reduced by walls and windows (double glazing), which explains why the signal quality inside a building is usually poorer than outside. As radiation intensity decreases with distance, signal quality is usually better in towns and cities, where there are many base stations within a small area, than in rural areas (Table 2).
GSM: With GSM, it is not only the quality of the connection that is important, but also the frequency of inter-cell (or inter-cluster) handovers (Table 2). When connecting to the network and switching from one cell (or cluster) to another, mobile phones briefly transmit at maximum output power and this is only slowly reduced.

Comparison	Reduction in output power

outdoors vs. indoors	68 %
urban vs. rural	10 %
stationary vs. moving	45 %

Table 2: GSM: Reduction in electromagnetic radiation in connection with good signal quality and few cell-to-cell handovers [3].

Although power control could mean that the actual output power level is far lower than the maximum output power, several studies show that is this not the case. In an italian study [3], six individuals were monitored for a period of 2-6 months in order to measure the output power levels of GSM mobile phones during everyday use and data were analysed from three providers in Italy. Study [4] analysed a week's data from a Swedish provider. The actual output power level in study [3] corresponds to 67% and 50% of the maximum output power at 900 and 1800 MHz, respectively. This is presumably attributable to frequent cell-to-cell handovers by the base stations, which also occur during stationary calls in order to optimise network capacity [3]. In study [5], frequent increases in output power were sometimes even observed during stationary calls where there were no cell-to-cell handovers and signal quality was good.

		Proportion of time at max. output power **(%), 900/1800 MHz**
Study [4]	urban	25
	rural	50
Study [3]	urban	48 / 39
	rural	60 / 49

Table 3: GSM 900/1800 MHz: Proportion of time during which phones transmit at maximum output power

UMTS: Power control is far more efficient with UMTS than with GSM. Output power is kept to a minimum when a connection is being made and stepped up if necessary. UMTS base stations are likewise grouped into clusters, within which the phone does not need to hand over to another cell. If inter-cell handover is required, the device never ramps up to the maximum power level. However, handovers to GSM are possible in fragmented UMTS networks, and output levels will then typically be higher. Measurements performed in study [5] show actual output power during calls to be substantially below the maximum levels. As the output power is related to the volume of data that the phone is transmitting, a substantially higher output power was measured when uploading files than when making calls, when the volume of data is small (Table 4).

	avg. output power (µW)	**avg. output power (% of max. output power)**
Stationary call	4.6	0.004
Moving call	9.5	0.008
Data upload	135.9	0.11
Data download + call	61.5	0.05

Table 4: Measurment of UMTS output power in different situations [5].

Low-frequency magnetic fields with GSM

With GSM, the mobile phone only transmits and receives for 577 µs every 4.6 ms (Figure 1). In this cycle the current flow within the battery results in a low-frequency radiation component of 217 Hz. The FOPH commissioned a study of the low-frequency radiation components of five different mobile phone models [6]. This mainly involved measuring magnetic-field values many times higher than 217 Hz (Table 5, Figure 3).

		Model 1	Model 2	Model 3	Model 4	Model 5
Magnetic field at a distance of 5mm (µT)	front	4.7	7.25	14.63	6.09	4.94
	back	29.46	31.89	33.68	29.5	28.07

Magnetic field, surface (µT)	front	8.3	12.4	19.3	8.3	11.4
	back	52.8	35.1	66.1	74.8	56.3
SAR (W/kg)		0.826	1.01	1.02	0.438	0.707

Table 5: Low-frequency magnetic fields of GSM mobile phones [6]

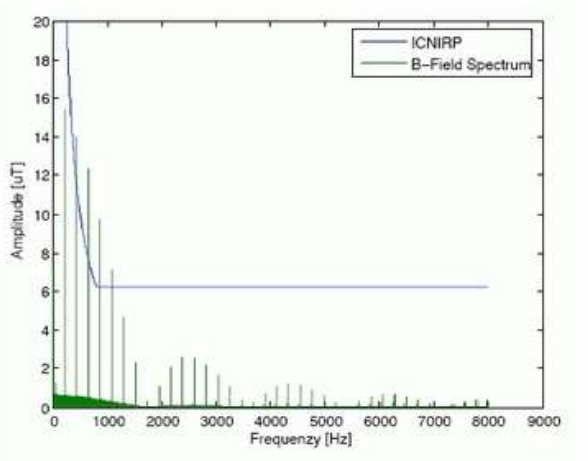

Figure 3: Magnetic field of a GSM mobile phone as a function of frequency and the frequency-dependent ICNIRP exposure limit. Evidence of values many times higher than 217 Hz. Source: [6]

Figure 3 shows the magnetic field of a GSM mobile phone as a function of frequency. The ICNIRP-recommended exposure limit (1) depends on the frequency of the magnetic field and is in several cases many times higher than 217 Hz.
In addition, the DTX feature produces a low-frequency component of 2 Hz and the omission of every 26th pulse (characteristic of GSM systems) results in a component of 8 Hz [7].
A further study investigated the low-frequency magnetic fields (40 - 800 Hz) of seven mobile phones with personal digital assistants (PDAs) during e-mail activities [8]. The magnetic fields measured at the back of the phone ranged from 1-2 µT in the case of one model to 10-60 µT for another.

Hands-free kits, headsets
Wired Headset: As the brain is a sensitive organ, it is wise to use a hands-free kit (headset), since this reduces exposure of the head to radiation. Several studies have compared radiation exposure with and without a headset. Using model calculations and measurements performed at 900 MHz on head phantoms, Bit-Babik et al. [9] showed that radiation exposure to the head is always reduced by headsets. The measurements showed that the SAR in the head when using a headset is 8-20 times lower than when making calls holding the phone to the ear. The radiation is further reduced when the phone and the wire are close to the body, since the body can then also absorb radiation. Troulis et al. [10] have shown in their studies (conducted at 1.8 GHz) that this absorption of radiation by the body reduces the efficiency of the phone, thus increasing the required output power level. It is particularly important that the phone's antenna (usually located on the back of the device) is positioned away from the body so that the signal quality is not impaired. Generally speaking, however, the head - and therefore also the brain - are subject to lower exposure levels when a headset is used. A new study carried out in the framework of the German research programme on mobile telephones [11] found that in worst case conditions using GSM 1800 there was an increase in the SAR value in a small zone of the inner ear, but it also concluded that when a headset is used the overall exposure in the region of the head is reduced. As the testes are also heat-sensitive, mobile phones should not be carried in a front trouser pocket when making calls.
Bluetooth headset: The FOPH commissioned a study of two Bluetooth headsets [12]. Hands-free kits of this type do not use a wire but link to the phone via radio waves (for more information on this topic, see our web page about Bluetooth). The two headsets investigated have specific absorption rates of 0.001 and 0.003 W/kg, which is 34 and 12 times lower than the SAR of the lowest-emission mobile phone currently available. With Bluetooth headsets the radiation exposure to the head is not determined by the position of the phone. It therefore makes more sense to hold the phone away from the body, since this reduces both the output power and radiation exposure to the body.

Bluetooth

Radiation shields
Radiation shields are intended to reduce the SAR in the human body. The problem is that

radiation shielding often also adversely affects signal quality, thereby necessitating higher output power, which in turn serves to increase the SAR value. Furthermore, the life of the battery is reduced. If it is to be of any benefit, a radiation shield must therefore reduce the SAR without impairing the signal quality.
Manning et al. [13] tested several radiation shields in their study. Earpiece pads and shields were found to have only a very small effect. In some cases, the SAR was marginally reduced, whereas in other cases it was marginally increased. The call quality was also only slightly impaired. Although antenna caps did serve to reduce the SAR by up to 99%, they also caused a corresponding deterioration in signal quality. Several shielded cases reduced the SAR without impairing the signal quality, while others reduced the call quality to the same extent as the SAR. The case design is crucial (e.g. whether or not the keypad is also covered).
Oliver et al.[14] tested 9 different small adhesive radiation shields, which were claimed to reduce the SAR. No reduction in SAR was measured with any of the shields tested. Nor did the shields change the location of the peak SAR in the phantom.

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3. Health effects

Verified effects

Low-frequency magnetic fields
Low-frequency magnetic fields penetrate into the human body, where they induce electrical fields and currents. In the presence of very strong magnetic fields, these currents can give rise to acute nerve stimulation [1]. In order to rule out such effects, the International Commission on Non-Ionising Radiation Protection (ICNIRP) has set its recommended exposure limits for magnetic fields at a level that is lower by a factor of 50 than the threshold value for the stimulation of the central nervous system by induced currents. Under certain circumstances, the low-frequency magnetic fields generated by the electronics and the battery currents of mobile phones can exceed these recommended exposure limits [6].

High-frequency electromagnetic fields
High-frequency fields can cause the body to absorb radiant energy and thus lead to an increase in body temperature [1]. Based on current exposure limits, however, the radiation from mobile phones is too weak to cause harmful levels of tissue heating.

Other effects investigated
Several expert groups have evaluated the possible health effects of longer-term or less high-frequency radiation [15, 16]. In May 2011, the World Health Organization (WHO) has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B) based on an increased risk for glioma, a malignant type of brain cancer, associated with wireless phone use in epidemiological studies. This classification means that there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals.

In particular, many studies have investigated the biological and health effects of GSM radiation. Owing to inconsistent results or uncertainty over their relevance to health, it is not currently possible to make a conclusive health assessment in the case of the results listed below:

Effects on the hormonal and immune systems
Hormones are messenger substances which influence the metabolism even in small concentrations. Although researchers have in some cases identified effects on individual hormones as a result of radiation from mobile phones, the inconsistency of the data prevents an assessment of the overall impact on hormonal equilibrium. Nor is it possible to evaluate effects on the immune system owing to a lack of data.

Effects on brain activity
The electrical activity of the brain can be modelled using electroencephalograms (EEGs). The radiation from mobile phones can influence both waking and sleeping brain activity. However, the effects on health of this modified brain activity are unclear.

Perception and processing of stimuli
Whereas older studies have produced evidence to suggest that radiation from mobile telephony might reduce reaction times, this effect only occurs sporadically in more recent studies.

"Microwave hearing"
There is no evidence that radiation from mobile telephony causes people to hear non-existent noises.

Effects on the cardiovascular system
The impact of mobile phone radiation on blood pressure, pulse, heart rate variability and blood

supply to the skin was only investigated in a very small number of studies, which failed to produce consistent results.

Effects on well-being
Interviewees ascribed unspecific symptoms such as fatigue, dizziness, headaches to mobile phone radiation. A consistent relation between unspecific symptoms and mobile phone radiation could not be established in good epidemiological studies [31-34]. However, up to now the long term effects have not been adequately investigated and consequently a definitive assessment of the effects of mobile phone radiation on general well-being cannot be given [35].

Effects on sleep
Several studies investigated the association between mobile phone radiation and sleeping patterns. In laboratory studies, persons were exposed to radiation from mobile phones before going to sleep. In some studies, a relation was found between the exposure prior to sleep and a shorter time to fall sleep [36], as well as a change in the electrical activity of the brain during sleep [37]. However in many studies, no relation could be established between the acute effect of mobile phone radiation on sleep. In epidemiological studies, a consistent relation between the self-reported quality of sleep and the exposure to high frequency radiation was not found [31,33].

Brain tumours in adults
As there is evidence to suggest that high-frequency radiation may have genotoxic and carcinogenic effects, current research efforts are focusing on the question of whether the radiation from mobile phones increases the risk of brain cancer. The majority of the studies conducted to date have failed to identify any such correlations for the first 10 years of mobile phone usage. However, interpretation of the individual studies is hampered by the small study sizes and the long latency period of brain tumours. In a recently published study about brain tumor and mobile phone use (Interphone) [40], an increased risk to suffer from a brain tumor for heavy mobile phone users (30 minutes/day over 10 years) was observed. No increased risk was observed for regular mobile phone users and mobile phone users for more than 10 years. Due to the different uncertainties in data collection and study design, no firm conclusion can be drawn and these possible errors prevent a causal interpretation.

Other tumours in adults
Eyes are also exposed to radiation from mobile phones. Although studies conducted to date on ophthalmic tumours have not produced consistent results, a potential risk cannot be ruled out. A large study was carried out in Denmark in 2006 [38]. The risk of developing cancer (15 different types of tumour were investigated) was calculated for ca. 400 000 persons, who had concluded a contract with a mobile phone operator between 1982 - 1995. No relation between the use of mobile phones and cancer could be established (neither for short-term nor long-term use). Due to the lack of adequate studies, a reliable assessment on long-term effects is not possible.

Brain tumours in children
No data is available about the possible risk of brain tumours among children and adolescents, a rapidly growing mobile-phone user group. The FOPH therefore endorses the International Case-Control Study on Brain Tumours in Children and Adolescents, the results of which should be available in the end of 2010. There is also some uncertainty over the extent to which children's heads absorb radiation and about the effect on the development of nerve tissue and the brain. These uncertainties and the fact that mobile phone usage is beginning at an increasingly young age justify the use of low-emission mobile phones, especially in children and adolescents.

Children and attention deficit disorders
Studies on the attention deficit disorder in children in relation to mobile phones have been published [39]. Indications for an influence of exposure to high frequency radiation and behavioural disorders were indeed found for children and adolescents, although still further studies are needed in order to substantiate this relation and to ensure that other factors are not responsible for these behavioural disorders.

Spermatozoa
It is not possible to make a conclusive assessment of the extent to which fertility is influenced by mobile phone radiation owing to the paucity of studies. The majority of studies investigated the effects of mobile phone radiation on the mobility of spermatozoa. In these studies however, the estimation of exposure to the mobile phone radiation is unsatisfactory. As a precaution, mobile phones should not be positioned close to the genitals when making calls with hands-free devices.

The radiation reduction measures outlined in the introduction are designed to take account of the current gaps in our knowledge of the health effects of mobile phone radiation.

Interference with implants
Mobile phones can interfere with pacemakers (inhibition, stimulation with a false signal, asynchronous pacing) [17, 18, 19]. More recent pacemakers [20, 21], implanted defibrillators [17] and brain stimulators [22] are less susceptible to interference. It is nevertheless advisable to

keep the phone at least 30 cm away from the implant, i.e. do not carry the phone in the breast pocket and hold the phone on the side opposite the implant when making calls [17].

Car accidents
There is evidence that it is dangerous to use a mobile phone while driving a car. Making phone calls while driving significantly increases the risk of a fatal or non-fatal accident [23, 24, 25]. The adverse impact of mobile-phone use on driving behaviour can be likened to driving with too much alcohol (0.8‰) in the blood [26]. The risk does not only increase during the call but also for some time afterwards. The use of a hands-free kit does not reduce this risk.

Do not use a phone while driving a car (either with or without a hands-free kit).

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4. Legal regulations

Mobile phones must comply with CENELEC product standard EN SN 50360 [27]. When measured in accordance with EN50361 [28], the SAR must not exceed the ICNIRP basic restriction [1] of 2 W/kg. For devices that offer several services (e.g. UMTS and WLAN), the SAR for each frequency must be determined individually. If the different systems have SAR peaks at different locations and the proportion of the specific absorption rate caused by the other services is less than 5% then only the SAR of the service with the highest value is counted [29].
The radiation from mobile communications base stations is governed by the Ordinance relating to Protection from Non-Ionising Radiation (NISV) [30].

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Specialist staff: emf@bag.admin.ch
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Federal Office of Public Health (FOPH)
Contact | Legal framework

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