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Mobile phones & Smartphone

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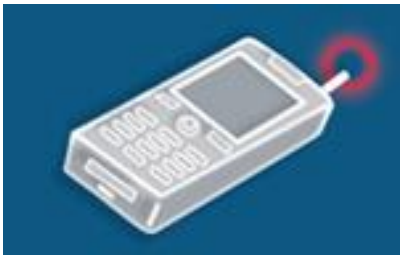

The use of smartphones has grown strongly over the last few years; 97 per cent [1] of the Swiss population aged 16 and above use a mobile phone or smartphone. At the same time the users' behaviour has also dramatically changed: mobile phones are used less for telephone calls, but significantly more for mobile internet applications.

Speech and data are transmitted back and forth via high-frequency radiation between a mobile phone and base stations, whereby the latter make the connection to the downstream telecommunication network. This involves the use of various technologies, such as classical mobile communication, Bluetooth, WLAN. The high-frequency electromagnetic radiation of these technologies leads to the head or the hand of a person being exposed to radiation when the mobile phone is held close to the ear when phoning or in the hand during other applications, such as for example mobile Internet [2]. The electric currents in the electronics and the battery of the mobile phone generate low-frequency electromagnetic fields that likewise penetrate into the head or the hand.

A mobile phone only transmits during a telephone conversation or while data is being transferred. If neither a telephone call nor data transfer is taking place, a switched-on mobile phone will only transmit a signal every couple of minutes to show where it is located at that particular point in time. In the idle state, the radiation exposure is thus negligible. The radiation decreases rapidly as the distance from the device increases.

When the mobile phone is being used, the intensity of the exposure depends on various factors:

- A mobile phone emits less radiation when connection quality is good than when it is poor. For a good connection quality, there need to be as few obstacles as possible to dampen the signal between the base station and the mobile phone. The quality of the connection is indicated by a set of bars on the phone's display.

- Exposure decreases rapidly as the distance increases. This can be achieved through the use of headsets, for example.

- 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 as the specific absorption rate (SAR). The lower the SAR, the lower the radiation that is absorbed by the head. The SAR value that can be found in the instruction manual or on the Internet represents the maximum value of the device; in everyday use the SAR value can be lower [3]. The Federal Office for Radiation Protection publishes a list with the SAR values of mobile phones.

The strengths of the electromagnetic fields depend on the particular technology. Telephoning with UMTS (3G) and LTE (4G) instead of GSM (2G) leads to significantly lower radiation exposure to the head area [2]. UMTS and LTE mobile phones regulate their power much more efficiently than GSM devices. LTE (4G) mobile phones transmit with only 1% of the maximum possible output power on average ("Output Power Levels of 4G User Equipment and implications on realistic RF EMF exposure assessments, 2018") even though much more data can be transmitted than with UMTS.

5G is currently being installed in frequency bands that are already being used for mobile telephony and WLAN.

The effects on health from long-term exposure to high-frequency radiation from mobile phones remain uncertain at present; negative effects from short-term exposure are not expected.

The effects on health from long-term exposure to low-frequency magnetic fields generated by the electronics and batteries also remain uncertain at present; negative effects from short-term exposure are not expected.

The following tips may be helpful, should you wish to reduce your personal exposure from mobile phones or smartphones.

- Use headphones or a wireless head set with a weak Bluetooth transmitter (power class 2 or 3) in order to reduce radiation to the head.
- Preferably use modern radio networks such as LTE (4G) or UMTS (3G), which work with weaker radiation than the older GSM technology. In this regard, check the settings of your mobile phone or contact your sales outlet.
- When inside buildings or in the train, if possible use WLAN for phone calls and data transfer. Check the settings of your mobile phone.
- Be careful with protective and shielding products, which are intended to reduce radiation exposure. When the connection quality deteriorates, the mobile phone is forced to emit higher levels of radiation.
- People with electronic medical **implants** should keep their mobile phone at least 30 cm away from the implant at all times.

Other recommendations:

- **NEVER use a mobile phone when driving a car.** This is also true for conversations via a head set as you may likewise be distracted!
- **NEVER use a mobile phone on foot or on a bicycle when you cross the road or are in traffic**.

1 Base stations

Detailed information on radiation from base stations can be obtained from the Federal Office for the Environment FOEN [4] or from a cantonal NIR office.

More detailed information on 5G is available on the FOEN and OFCOM websites.

2 Overview of Mobile Communication Technologies

GSM (Global System for Mobile Communication) [5] is a standard protocol for digital mobile communication which is mainly used for telephony and transmission of text messages (SMS). GSM is also known as the second generation of mobile telecommunication (2G). 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 or to access the Internet.

The UMTS standard (Universal Mobile Telecommunication System) [6] 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 SMS. It is known as the third generation of mobile telecommunication (3G). With LTE (Long Term Evolution) [7], which represents the fourth generation of mobile communication networks (4G), the data transfer rate was significantly increased once again. 5G is currently in the process of being introduced.

2012 was the peak for the worldwide dissemination of GSM mobile phones. As can be seen in Figure 1, the market share of UMTS and later LTE smartphones has significantly increased in recent years.

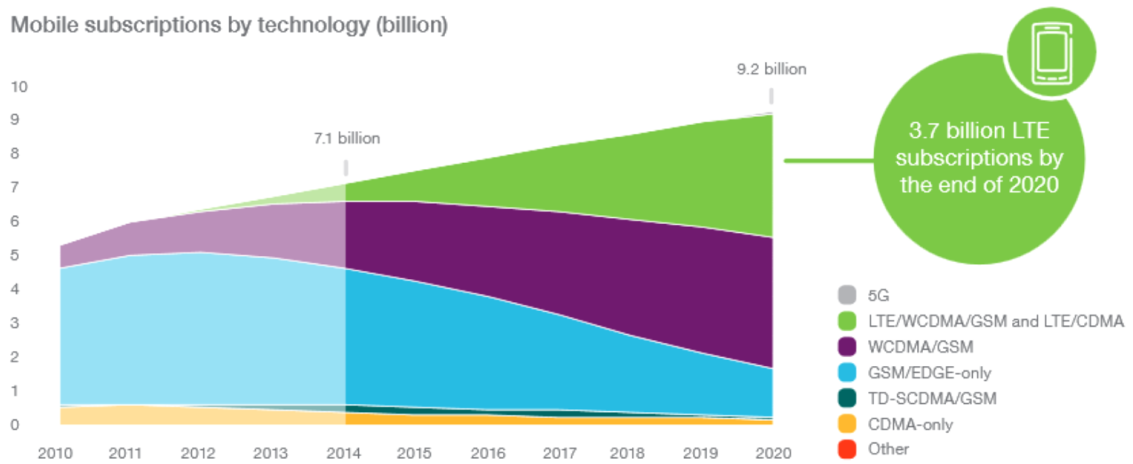

Figure 1: Worldwide development of the various network technologies.

Fundamentally, the LTE standard supports all frequency bands of the existing networks of the 2nd and

3rd generation, but runs mainly in the frequency ranges around 2.6 GHz and 800 MHz (Table 1).

Table 1 illustrates the currently available frequency ranges and their ban widths in Switzerland [5, 6, 7]

Frequency band	Bandwidth	Use	Peak output power	Average output power (typical phone call)
800 MHz	2x30 MHz		250 mW	Rural area: 1.5 mW. In town less
900 MHz	2x35 MHz	2G	2 W	250 mW
1800 MHz	2x75 MHz	until now 2G and 3G	1 W	125 mW
2100 MHz	1x20 MHz 2x60 MHz 1x15 MHz	until now 2G and 3G	250 mW	Rural area: 1.5 mW. In town less
2600 MHz	2x70 MHz 1x50 MHz	until now 3G	250 mW	Rural area: 1.5 mW. In town less
3400-3800 MHz	400 MHz		250 mW	Rural area: 1.5 mW. In town less

3 Brief description of the mode of operation of the various mobile communication technologies

Detailed and further documentation can be found under www.bakom.admin.ch

3.1 Output power

GSM

In ***GSM*** clusters [5] the signals between the mobile phone and the base station are transmitted at a certain carrier frequency as short packets that are sub-divided in eight time slots. The first time slot or control channel communicates the system data of the network to the mobile phone and synchronises the mobile phone with the base station. The control channel is transmitted from the base station the whole time at full power so that the mobile phones can find the clusters when switched on, when roaming or for handovers. Even when no conversation is carried out in the cluster, this carrier is transmitted at full power to all eight time slots. The other 7 time slots can be used for calls.

The radiation exposure from a mobile phone depends strongly on its output power that in turn depends on the quality of the communication connection between the mobile phone and the base station. A mobile phone needs to emit less radiation when the connection quality is good than when it is poor. Poor connections occur mostly inside buildings because the walls and modern energy-saving windows constitute an obstacle to the radiation. In addition, the quality of a communication connection decreases with increasing distance between the mobile phone and the base station. Consequently, the 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).

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. On connecting to the network and when switching from one cell (or cluster) to another, a mobile phone briefly transmits at maximum output power with GSM. After the connection has been made the output power drops, such that the radiation exposure of the caller also decreases.

Table 2: GSM: Reduction in radiation output for connections with good signal quality and few cell-to-cell handovers [9].

Comparison	**Reduction in output power**
outdoors vs indoors	68%
urban vs rural	10%
stationary vs moving	45%

Although power control could mean that the actual output power level of a mobile phone is far lower than its maximum output power, several studies have shown that is this not the case. In an Italian study [9], 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. Despite the possible output reduction, the actual output power level of the mobile phones still corresponded to 67% and 50% of the maximum output power, depending on the frequency band. Similar results were found in a Swedish study [10]. This sub-optimal power regulation 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 [9] (Table 3).

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

		Proportion of time at max. output power (%), 900/1800 MHz
Study [10]	urban	25
	rural	50
Study [9]	urban	48 / 39
	rural	60 / 49

UMTS

UMTS mobile phones regulate their power far more efficiently than GSM devices. When a connection to the network is made they transmit with the lowest possible power and then increase their power as needed for an adequate connection quality. Speech and data transmission with ***UMTS*** employs a transmission method that differs completely from GSM. WCDMA (Wideband Code Division Multiple Access) is a procedure in which all network subscribers communicate on the same frequency. The individual channels are separated from each other by means of a channel code that is attributed to each subscriber when connecting to the network. This procedure fundamentally distinguishes UMTS from other communication systems (GSM, LTE, DECT, TETRA etc.), in which the individual active subscribers are separated from each other in a cell by different frequencies or time slots.

UMTS base stations are grouped into clusters. A mobile phone inside one cluster does not need to hand over to another cell. If inter-cell handover between different clusters is required, the device never ramps up to the maximum power level. However, handovers to GSM are possible in fragmented UMTS networks, and output power levels will then be higher. Measurements of mobile phones [11] showed actual output power during calls with UMTS to be substantially below the possible maximum levels.

As the output power is related to the volume of data that the mobile phone transmits, there results a substantially higher output power when uploading data than when making calls, where the volume of data is small (Table 4).

Table 4: Measurement of UMTS output power in different situations [11].

	Average output power (µW)	Average 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

The maximum output power of UMTS subscriber devices is 250 mW; in practice, however, the actual output powers fall well below this maximum value. According to simulations made by manufacturers and network operators, the average output power of UMTS mobile phones in rural areas was about 1.5 mW and even less in urban areas [12]. Thus, UMTS mobile phones transmit with much less power than GSM mobile phones.

LTE

The LTE-Standard [8] supports all mobile communication frequencies. The most important improvement over the UMTS standard is the introduction of new channel access procedures in the downlink and uplink. These complex procedures enable the system to operate with scalable channel bandwidths from 1.4 MHz to 20 MHz. This allows LTE to be flexibly employed in the relevant allotted bandwidths, and unlike UMTS, does not require a contiguous block of at least 5 MHz or a multiple thereof. The technology is very complex; an optimised and agile distribution of the carrier signals in the time and frequency range affords LTE a clear advantage in terms of efficiency and speed in comparison to previous technologies.

LTE not only has significantly higher data rates and a better spectrum efficiency than its predecessor, but also a shorter latency period (transit time of a data packet from transmitter to receiver). For LTE the latency period is maximum 5 milliseconds, for UMTS the average latency period is from 70 to 140 milliseconds. This has a positive impact on the responsiveness of the network and on real-time services such as for example VoIP (Voice over IP, video applications).

5G

5G is the new international mobile radio standard. 5G permits maximum data rates of 10 GBits/s and lower response times. In the frequency ranges available today, the radio technology of 5G is comparable to that of 4G. The same modulation technology is employed. The available bandwidth is, however, much larger for 5G. The recently auctioned 5G frequency bands are in a frequency range in which today's high frequency telecommunications applications already operate.

4 Exposure measurements

4.1 SAR values from high-frequency radiation

Figure 2: Head phantom for determining the SAR value. Photo source: [13] [13]

Radiation exposure of the body is best quantified using the SAR value (SAR: specific absorption rate). The SAR value (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) in a worst-case scenario and compared with the 2 W/kg exposure limit of the ICNIRP (International Commission on Non-Ionizing Radiation Protection) [14]. Information on the SAR values of individual mobile phones is published on various internet sites, for example: BfS-Link. The exposure limit of 2 W/kg must be observed for all devices that are sold in Switzerland.

In the context of the FP7 project of the EU [2] the radiation exposure from various mobile transmission technologies was measured at various distances from humans. It is clearly evident that the radiation exposure can be reduced when the mobile phone is not held close to the ear and is used at a distance of more than 20 cm. This can be achieved by e.g. a headset. The new transmission technologies also lead to a lower exposure to radiation, thus the SAR is reduced by changing from GSM (2G) to UMTS (3G) to WLAN telephony.

According to the SEAWIND Study (2) the highest exposures to radiation then occur when the mobile phone is carried as a mobile WLAN access point (Tethering) on the body. Data applications with maximum data transfers also generally lead to higher exposures to radiation in comparison to telephone calls (Figure 3).

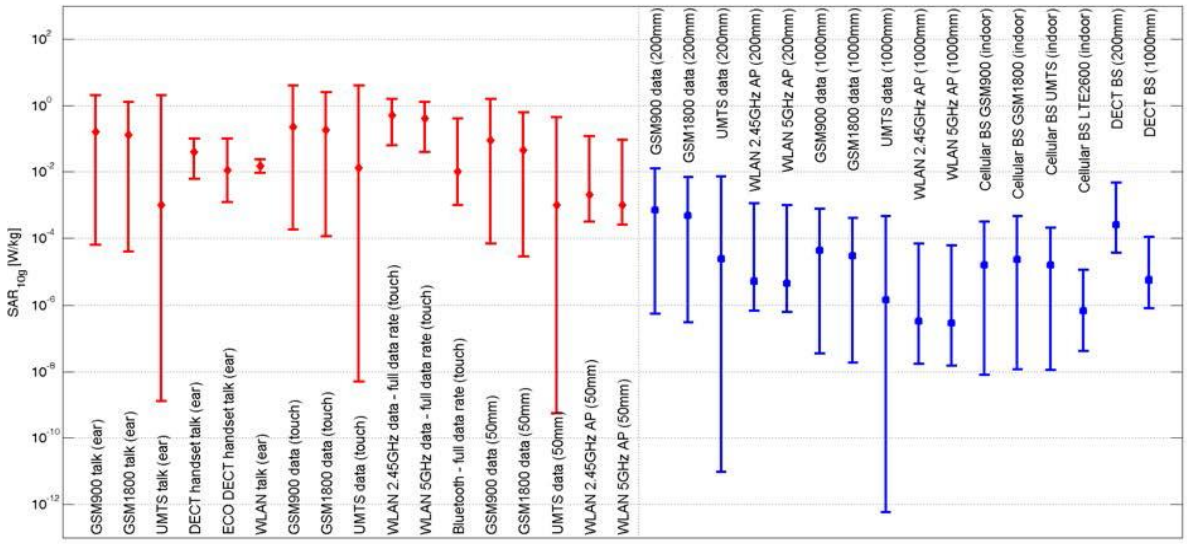

Figure 3: Estimations of radiation exposure from various mobile transmission technologies and at various distances (red: close to the body / blue: at a distance of 20 cm to 1 m).

4.2 Hands-free Kits, Headsets

Wired headsets: Several studies have compared radiation exposure with and without a headset. Using model calculations and measurements performed on head phantoms with GSM 900 MHz, Bit-Babik *et al*. [15] showed that radiation exposure in 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 by holding the phone to the ear. The radiation in the head 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*. [16] showed in their studies (conducted with GSM 1800 MHz) that this absorption of radiation by the body reduces the efficiency of the mobile phone, thereby causing it to radiate more strongly. It is particularly important that the mobile 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 study carried out in the framework of the German research programme on mobile telephones [17] 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 was used the overall exposure in the region of the head was reduced.

4.3 Bluetooth Headset

The FOPH commissioned a study of two Bluetooth headsets [18]. Hands-free kits of this type do not use a wire but link the headphone to the mobile phone via radio waves (for more information on this topic, see our web page about Bluetooth). The two headsets investigated had SAR values of 0.001 and 0.003 W/kg, which is 30, respectively 10 times lower than the SAR value of the lowest-emission mobile phone currently available (SAR 0.03).

4.4 Radiation shields

Manning *et al*. [19] tested several radiation shields. 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*. [20] 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.

4.5 Low-frequency magnetic fields with GSM

With GSM, the mobile phone only transmits and receives for 577 µs every 4.6 ms. 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 [21]. This mainly involved measuring magnetic-field values many times higher than 217 Hz (Table 5, Figure 3).

Table 5: Low-frequency magnetic fields and SAR values of GSM mobile phones [21]

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

Figure 4 shows the magnetic field of a GSM mobile phone as a function of frequency. The limit value [14] recommended by the EU depends on the frequency of the magnetic field. Magnetic fields with frequencies that correspond to multiples of 3 to 5 times the fundamental frequency of 217 Hz exceed the limit value.

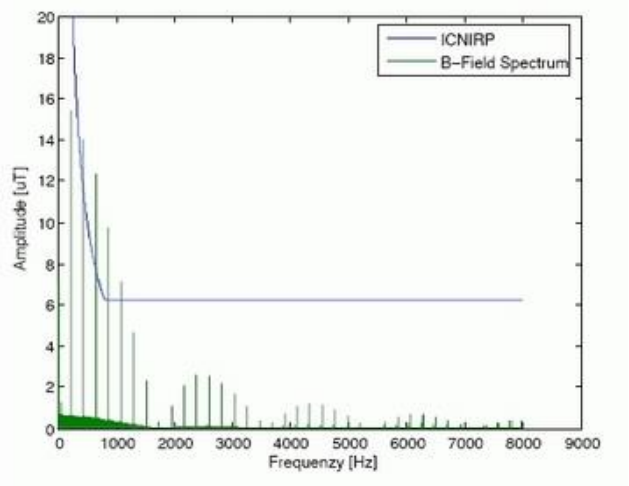

Figure 4: Magnetic field of a GSM mobile phone as a function of frequency. The fundamental frequency is 217 Hz. The multiples of the fundamental frequency can be clearly seen. The magnetic field that corresponds to the limit value recommended by the European Union for magnetic fields is shown in blue. Source: [21]

5 Effects of Health

5.1 Cancer

Low-frequency magnetic fields

Low-frequency magnetic fields are generated in mobile phones by battery currents and the electronics. Studies on the effects on health of such magnetic fields do not exist. In 2002, however, the International Agency for Research on Cancer (IARC) classified static and low-frequency electromagnetic fields as possibly carcinogenic (Group 2B) [22]. This is based on epidemiological studies that indicate that long-term and sustained exposure to magnetic fields in the low dose range of 1< 0.4 µT could increase the risk of suffering from leukaemia in children or from Alzheimer's disease [6]. It is not clear whether such a risk also exists with mobile phonesHochfrequente elektromagnetische Felder

High-frequency Electromagnetic Fields
In 2011, based on studies that showed a possible connection between telephoning with a mobile phone or a cordless telephone and the occurrence of brain tumours, the International Agency for Research on Cancer (IARC) classified high-frequency electromagnetic fields as possibly carcinogenic (Group 2B) [23]. However, the IARC found that the overall data and evidence were somewhat limited, as these studies had shortcomings in regard to the study design and the estimation of the length of exposure.

5.2 Other effects on health investigated in connection with mobile phones

Effects on brain activity

Electroencephalograms (EEG) are used to investigate the electrical activity of the brain. 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 showed indications to suggest that radiation from mobile telephony might reduce reaction times, in more recent studies this effect was found to occur only sporadically.

Microwave hearing

There is no evidence that radiation from mobile telephony causes people to hear non-existent noise.

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

From surveys it is known that some people ascribe non-specific symptoms, such as fatigue, dizziness, headaches, (symptoms that are not linked to an illness) to mobile phone radiation. However, in epidemiological studies [25-28] this connection was not consistently confirmed. Possible long-term effects such as these have not yet been adequately investigated; accordingly, the effects of radiation from mobile telephony on the general well-being have not been assessed [29].

Effects on sleep

Several studies have investigated the impact of mobile phone radiation on sleeping patterns. In some of these studies persons, who were exposed to mobile phone radiation before going to sleep, exhibited a shorter time to fall sleep [30] as well as a change in the electrical activity of the brain during sleep [31]. However, in the majority of these studies no correlation was identified between mobile telephony radiation and sleep. In epidemiological studies, a consistent relation between the self-reported quality of sleep and exposure to high frequency radiation was not found [25, 27]. It is often the case that mobile phones are not switched off at night and can influence sleep quality. A study with 439 people showed that being woken up at night by mobile phones was associated with increased fatigue, headaches and becoming tired more rapidly; there was no impact on cognitive abilities (e.g. power of concentration) [32].

Children and attention deficit disorders

Few studies have investigated the correlation between attention deficit disorders in children and mobile telephony [33]. Although indications were found that high-frequency radiation had an influence on behavioural disorders in children and adolescents [33], these results have neither been satisfactorily confirmed nor can it be excluded that other factors are responsible for these behavioural disorders.

Fertility

Owing to the paucity of studies it is not possible to make a conclusive assessment of the extent to which fertility is influenced by mobile phone radiation. The majority of studies investigated the effects of mobile phone radiation on the mobility, respectively concentration [34] of sperm. In these studies however, the estimation of exposure to the mobile phone radiation was mostly unsatisfactory, such that no conclusions may be drawn.

Interference with implants

Mobile phones can interfere with pacemakers (inhibition, stimulation with a false signal, asynchronous pacing) [35-37]. More recent pacemakers [38, 39], implanted defibrillators [35] and brain stimulators [40] are less susceptible to interference. It is nevertheless advisable to keep the mobile phone at least 30 cm away from the implant. People that have implants should therefore not carry the mobile phone in their breast pocket and should hold the phone on the side opposite the implant when making calls [35].

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 [40-42]. The adverse impact of mobile-phone use on driving behaviour can be likened to driving with too much alcohol (0.08‰) in the blood [43]. The risk not only increases during the call but also for some time afterwards. The use of a hands-free kit does not reduce this risk.

6 Regulation in Law

Mobile phones must comply with the European product standard EN SN 50360 [44]. When measured in accordance with EN50361 [45], the SAR must not exceed the ICNIRP limit value [14] of 2 W/kg. For devices that offer a plurality of 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 SAR caused by the other services is less than 5%, then only the SAR of the service with the highest value is counted [46].

The radiation from mobile communication base stations is governed by the Ordinance relating to Protection from Non-Ionising Radiation (NIRO) [47].

7 References

1. gfs.Bern. Neues Nutzungsverhalten, deutliche Nutzensicht, verstärkte Sensibilität gegenüber gesundheitlichen Risiken – Schlussbericht. Studie im Auftrag von Forum Mobil, Januar 2015.
2. SEAWIND - Sound Exposure & Risk Assessment of Wireless Network Devices, FP7-Final Sumary Report 2012.
3. Roser et al., Development of an RF-EMF Exposure Surrogate for Epidemiologic Research, Int J Environ. Res. Public Health 2015.
4. http://www.handystrahlung.ch/sar.php
5. http://www.bafu.admin.ch/elektrosmog/01079/01086/index.html?lang=de
6. BAKOM, Faktenblatt GSM, Juni 2015 http://www.bakom.admin.ch/themen/technologie/01182/index.html?lang=de
7. BAKOM, Faktenblatt UMTS, 12. Juni 2015 http://www.bakom.admin.ch/themen/technologie/01178/index.html?lang=de
8. BAKOM, Faktenblatt LTE und LTE+, Juni 2015 http://www.bakom.admin.ch/themen/technologie/01397/03794/index.html?lang=de
9. Medienmitteilung Swisscom: https://www.swisscom.ch/de/about/medien/press-releases/2015/10/20151008-MM-Swisscom-ruestet-ihr-Mobilfunknetz-fuer-die-Zukunft.html
10. Ardoino L, Barbieri E, Vecchia P. Determinants of exposure to electromagnetic fields from mobile phones. Radiat Prot.Dosimetry 2004;111:403-6.
11. Lönn S et al. Output power levels from mobile phones in different geographical areas; implications for exposure assessment. Occupational and Environmental Medicine 2004;61:769-72.
12. Georg R. Bestimmung der spezifischen Absorptionsrate (SAR-Werte), die während der alltäglichen Nutzung von Handys auftritt. 2006
13. Report ITU-R M.2039-2: Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses (11/2010).
14. European commission. Health and electromagnetic fields EU-funded research into the impact of electromagnetic fields and mobile telephones on health. 2006.
15. ICNIRP. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys. 1998;494-521.
16. Bit-Babik G et al. Estimation of the SAR in the human head and body due to radiofrequency radiation exposure from handheld mobile phones with hands-free accessories. Radiat.Res. 2003;159:550-7.
17. Troulis SE, Scanlon WG, Evans NE. Effect of a hands-free wire on specific absorption rate for a waist-mounted 1.8 GHz cellular telephone handset. Phys Med Biol 2003;48:1675-84.
18. Kühn S et al. Bestimmung von SAR-Werten bei der Verwendung von Headsets für Mobilfunktelefone. 2008. Siehe "Weitere Informationen"
19. Kramer A et al. Development of Procedures for the Assessment of Human Exposure to EMF from Wireless Devices in Home and Office Environments. 2005.
20. Manning MI, Densley M. On the effectiveness of varous types of mobile phone radiations shields. SAR Test Report 0113. 2001
21. Oliver JP, Chou CK, Balzano Q. Testing the effectiveness of small radiation shields for mobile phones. Bioelectromagnetics 2003;24:66-9.
22. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 80, 2002, Non-Ionizing Radiation, Part 1: Static and Extremly Low-frequency Electric and Magnetic Fields.

23. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 102, 2012, Non-Ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields.
24. Sage C, Johansson O, Sage SA. Personal digital assistant (PDA) cell phone units produce elevated extremely-low frequency electromagnetic field emissions. Bioelectromagnetics. 2007; 28:386-92.
25. Berg-Beckhoff G, Blettner M, Kowall B, Breckenkamp J, Schlehofer B, Schmiedel S, Bornkessel C, Reis U, Potthoff P, Schüz J. Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. Occup Environ Med. 2009;66(2):124-30.
26. Blettner M, Schlehofer B, Breckenkamp J, Kowall B, Schmiedel S, Reis U, Potthoff P, Schüz J, Berg-Beckhoff G. Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany. Occup Environ Med. 2009;66(2):118-23.
27. Hutter HP, Moshammer H, Wallner P, Kundi M. Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup Environ Med. 2006;63(5):307-13
28. Thomas S, Kühnlein A, Heinrich S, Praml G, Nowak D, von Kries R, Radon K. Personal exposure to mobile phone frequencies and well-being in adults: a cross-sectional study based on dosimetry. Bioelectromagnetics. 2008;29(6):463-70.
29. Kundi M, Hutter HP. Mobile phone base stations-Effects on wellbeing and health. Pathophysiology. 2009 Aug;16(2-3):123-35.
30. Mann K, Röschke J. Sleep under exposure to high-frequency electromagnetic fields. Sleep Med Rev. 2004;8(2):95-107.
31. Huber R, Treyer V, Borbély AA, Schuderer J, Gottselig JM, Landolt HP, Werth E, Berthold T, Kuster N, Buck A, Achermann P. Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG. J Sleep Res. 2002;11(4):289-95
32. Schoeni A, Roser K, Röösli M (2015) Symptoms and Cognitive Functions in Adolescents in Relation to Mobile Phone Use during Night. PloS ONE 10(7).
33. Thomas S, Heinrich S, von Kries R, Radon K. Exposure to RF-EMF and behavioural problems in Bavarian children and adolescents. Eur J Epidemiol. 2010;25:135-41.
34. Zilberlich A. et al. Habits of cell phone usage and sperm quality – does it warrant attention? Reproductive BioMedicine Online, 2015, Volume 31, Issue 3, 421-426.
35. Kainz W et al. Electromagnetic compatibility of electronic implants - review of the literature 1. Wien.Klin.Wochenschr. 2001;113:903-14.
36. Tandogan I et al. Effects of mobile telephones on the function of implantable cardioverter defibrillators. Ann.Noninvasive.Electrocardiol. 2005;10:409-13.
37. Barbaro V et al. On the mechanisms of interference between mobile phones and pacemakers: parasitic demodulation of GSM signal by the sensing amplifier. Phys Med Biol 2003;48:1661-71.
38. Trigano A et al. Reliability of electromagnetic filters of cardiac pacemakers tested by cellular telephone ringing. Heart Rhythm. 2005;2:837-41.
39. Hekmat K et al. Interference by cellular phones with permanent implanted pacemakers: an update. Europace. 2004;6:363-9.
40. Kainz W, Alesch F, Chan DD. Electromagnetic interference of GSM mobile phones with the implantable deep brain stimulator, ITREL-III. Biomed.Eng Online. 2003;2:11.
41. McEvoy P et al. Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study. BMJ 2005.

42. Redelmeier DA, Tibshirani RJ. Association between cellular-telephone calls and motor vehicle collisions. N.Engl.J.Med. 1997;336:453-8.
43. Violanti JM. Cellular phones and fatal traffic collisions. Accid.Anal.Prev. 1998;30:519-24.
44. Strayer DL et al. A comparison of the cell phone driver and the drunk driver. Hum Factors. 2006 ;48:381-91.
45. CENELEC. EN SN 50360: 2013-01 Product standard to demonstrate the compliance of mobile telephones with basic restrictions related to human exposure to electromagnetic fields (300 MHz - 3 GHz). Deutsche Fassung EN 50360:2001 + Cor. :2006 + A1:2012.
46. DIN EN 62209-1:2007-03. Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz) (IEC 62209-1:2005); German version EN 62209-1:2006.
47. IEC. 62209-2:2010 Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz).
48. SR 814.710 Verordnung über den Schutz vor nichtionisierender Strahlung (Stand 1.7.2012).

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