Electrosmog in the environment

Swiss Agency for the Environment, Forests and Landscape SAEFL

Electricity supply systems, electrical appliances and a wide range of transmitters for various wireless applications generate non-ionising radiation (commonly referred to as "electrosmog") that can be harmful to our health, depending on its intensity. With its Ordinance relating to Protection from Non-Ionising Radiation, the Federal Council introduced a legal instrument to protect the population against the harmful effects of electrosmog.

This brochure describes the main sources of electrosmog, assesses the associated risks, identifies existing gaps in research and suggests ways in which we can reduce our own level of exposure.

Swiss Agency for the Environment, Forests and Landscape SAEFL, June 2005

Electrosmog in the environment

Swiss Agency for the Environment, Forests and Landscape SAEFL

Precautions in the interest of public health

The countless options that have been opened up to us through the development of modern information and communications technology have fundamentally altered our daily life in the course of the past ten years or so. The rapid growth of mobile telephony and the Internet are just two obvious examples.

We are now using ever more electrical appliances and wireless devices at home, in the office and when we are on the move, but there is a negative side to this trend too, namely the increasing pollution of our environment in the form of non-ionising radiation. In February 2000 the Federal Council issued its Ordinance relating to Protection from Non-Ionising Radiation as an instrument to protect the population against the harmful effects of electrosmog. It stipulates exposure limit values for supply installations such as power lines, mobile phone antennae and wireless transmitters in order to protect the population against scientifically acknowledged harmful effects. In addition it contains stringent regulations governing facilities installed close to locations occupied by people for lengthy periods of time. Here, in applying the precautionary principle, exposure is limited to even lower values.

The relative complexity of non-ionising radiation and its biological effects, our lack of the necessary sensory organs for perceiving radiation, the continued existence of gaps in research and uncertainties relating to health risks give rise to a variety of speculations and fears, and with this brochure the Swiss Agency for the Environment, Forests and Landscape wants to counter these by providing some factual information. For example, it presents up-to-date findings concerning the impacts of non-ionising radiation on our health in as objective a manner as possible. We have also attempted to give a visual form to the invisible radiation that is ever-present in our environment, and thus to render it more tangible.

But this brochure also addresses the aspect of personal responsibility – for electrosmog is often home-made. In many homes, the main sources of non-ionising radiation are not external supply systems, but rather our own electrical appliances. And here, state legislation has its limitations in protecting us. It is therefore up to each of us to act in our own interest and make careful use of the many options provided by modern-day technology.

Philippe Roch
Director of the Swiss Agency for the Environment, Forests and Landscape

Contents

The electromagnetic spectrum

An overview of the various types of electromagnetic radiation by frequency range is presented in diagram form. "Electrosmog" is a collective term encompassing artificially produced non-ionising radiation in the frequency range from 0 hertz to 300 gigahertz.

› Pages 4 – 5

Electrosmog and health

It has been scientifically established that intensive non-ionising radiation is harmful to our health, but certain biological effects also occur at exposure levels well below internationally recommended limits. Since scientists cannot at present indicate how harmful these effects are, it is advisable to take certain precautions.

› Pages 6 – 13

ONIR: Ordinance relating to Protection from Non-Ionising Radiation

The Ordinance relating to Protection from Non-Ionising Radiation, which entered into effect on 1 February 2000, stipulates limit values for short-term exposure to supply systems. In addition, precautionary installation limit values for a variety of radiation sources help reduce long-term exposure in residential areas.

› Pages 14 – 19

Contents

Power supply

Electric and magnetic fields are unavoidable by-products of electricity transmission and use. The highest levels of exposure occur in the immediate vicinity of high-voltage power lines and transformer stations.

> Pages 20 – 27

Electrical appliances in the home

In most residential dwellings, electrosmog is home-made. Here we ourselves are able to considerably reduce our level of exposure by taking basic measures. For example, we should avoid placing electrical appliances that run constantly, e.g. clock radios, in places where people spend lengthy periods of time.

> Pages 28 – 33

Railway lines

Magnetic fields along railway lines fluctuate considerably. Accelerating or braking locomotives increase the current and thus intensify the magnetic fields. Exposure levels are higher on heavily frequented stretches.

> Pages 34 – 37

Mobile telephony

Thousands of base stations in Switzerland secure the almost nation-wide availability of mobile phone services. On the other hand, the numerous antennae give rise to an increase in high-frequency radiation throughout the country.

> Pages 38 – 45

Broadcasting, point-to-point microwave links, amateur radio

High-power transmitters for radio and TV programmes are usually placed at elevated locations. Since there are normally no residential dwellings within the critical range, it is usually no problem for them to comply with the installation limit value.

> Pages 46 – 51

Wireless devices in buildings

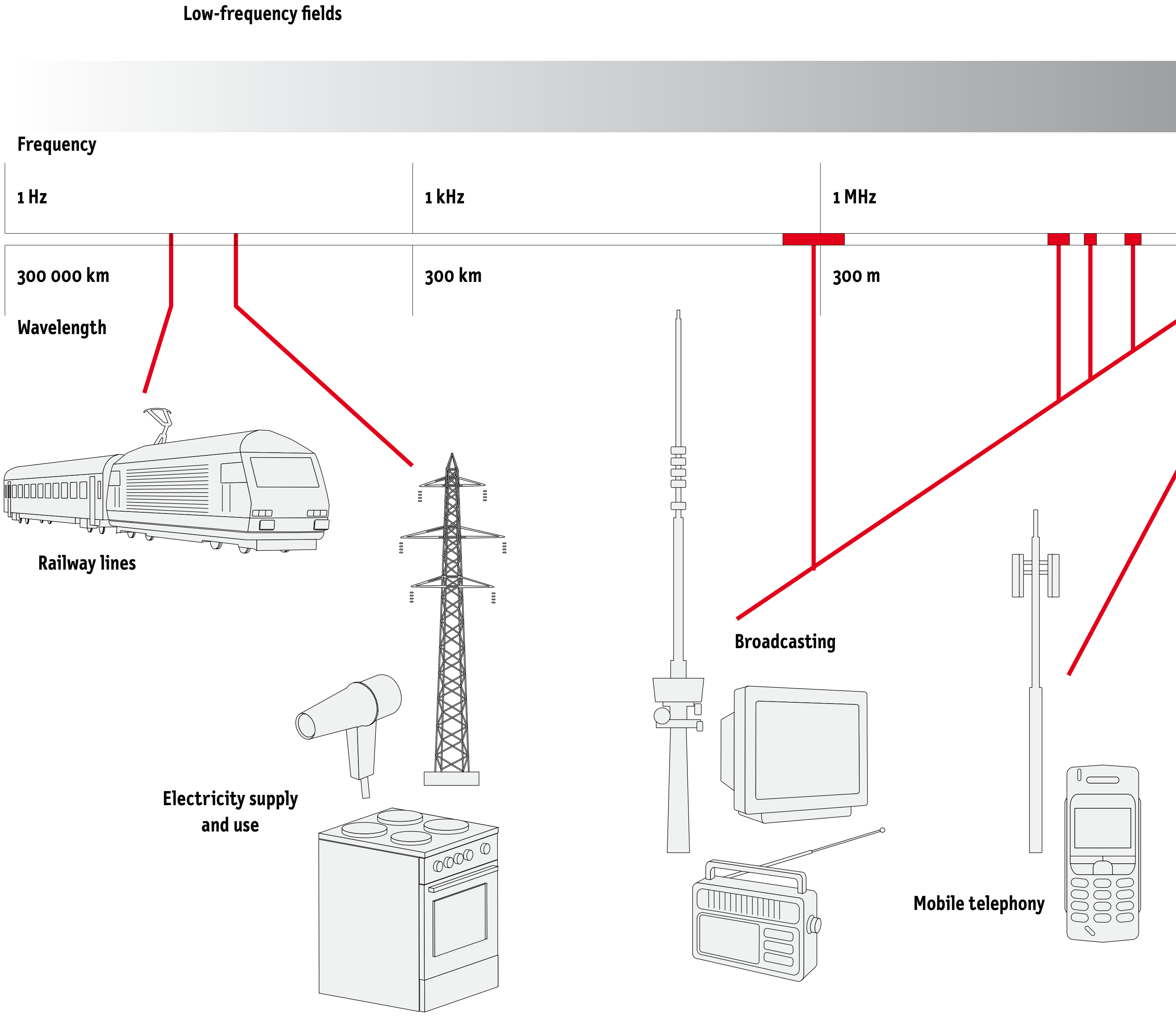
Wireless devices such as cordless phones, cordless headphones, baby monitors, WLAN stations, etc., are also being used in residential dwellings to an ever increasing extent. Although their transmitting power is often relatively low, these devices can dominate the indoor exposure to high-frequency radiation.

> Pages 52 – 55

Index, glossary, references, links, publication data

> Page 56

Electromagnetic spectrum



The diagram here shows an overview of the entire electromagnetic spectrum. Electromagnetic radiation occurs in our natural environment and is also generated artificially in a variety of forms, e.g. electric and magnetic fields from high-voltage power lines, radiation from mobile phone base stations and radio transmitters, visible light, x-rays. In physical terms, these types of radiation are distinguished by their frequency, i.e. the number of oscillations per second. Depending on their frequency they have different radiation properties and different effects on human beings.

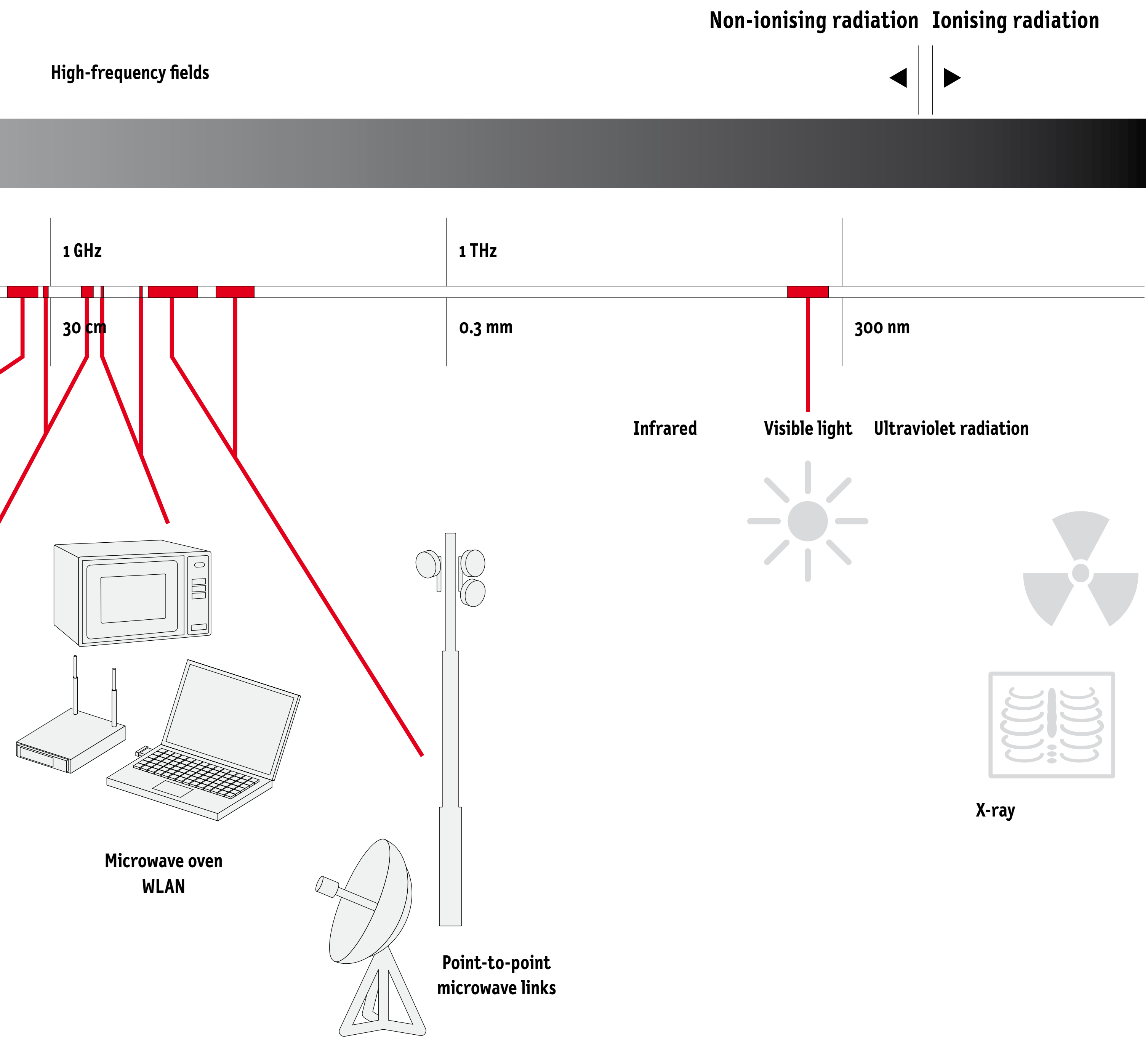
Division of frequency spectrum

The frequency spectrum of electromagnetic radiation is broadly divided into non-ionising and ionising radiation. Non-ionising radiation is divided into low-frequency and high-frequency radiation, infrared radiation, visible light and ultraviolet radiation. Artificially produced low-frequency and high-frequency radiation are also referred to as "electrosmog".

Low-frequency fields

The low-frequency range includes electric and magnetic fields from railway contact lines, high-voltage power lines and electrical household appliances. Since the railway power supply has a frequency of 16.7 oscillations per second, the fields it produces also have a frequency of 16.7 hertz (Hz). By comparison, the public power supply has a frequency of 50 Hz.

Electromagnetic spectrum



High-frequency radiation

We speak of high-frequency radiation when oscillations are 30,000 per second or more. Here, electric and magnetic fields are coupled and can propagate in the form of a wave. This is used for the wireless transmission of information. Specific examples include transmitters and receivers for radio and television, mobile telephony, point-to-point microwave links and radar. Such equipment uses frequencies ranging from several hundred kilohertz for medium-wave radio to several billion hertz (gigahertz) for point-to-point transmission, while heat radiation (infrared) and visible light have even higher frequencies. Although these are no longer described as "electrosmog", they nonetheless belong to the category of non-ionising radiation.

Ionising radiation

The transition to ionising radiation occurs in the ultraviolet radiation range. Ionising radiation includes x-rays and gamma radiation. By contrast with non-ionising radiation, ionising radiation possesses sufficient energy to directly alter the basic constituents of living organisms (atoms and molecules).

The negative impacts of intensive non-ionising radiation on our health have been scientifically established and are undisputed, but with the exception of workplace accidents, people are never exposed to such high levels of radiation. However, biological effects also occur at levels well below internationally recommended hazard thresholds. Since scientists are unable to indicate how harmful these effects are, it is advisable to take certain precautions.

Is electrosmog a health hazard?

Contents

Effects of low-frequency radiation > P 7

Nerve and muscle stimulation > P 7

Subliminal effects > P 7

Increased risk of leukaemia among children? > P 7

Effects of high-frequency radiation > P 10

Hazardous thermal effects > P 10

Numerous non-thermal effects > P 10

Phenomenon of electrosensibility > P 11

Electrosensitivity > P 11

Electrosensibility > P 11

Evaluation of effects of high-frequency radiation > P 12

Explanations > P 13

Effects of low-frequency radiation

Unlike many animals (such as birds and fish), human beings do not possess any sensory organs for electric or magnetic fields. The most we can do is perceive them indirectly. For example, some people experience a tingling sensation on their skin when standing directly beneath high-voltage power lines. Here the alternating electric field causes body hairs to vibrate, and this is perceived as a tingling sensation. While this effect may be perceived as an annoyance, it does not represent any danger to health.

Nerve and muscle stimulation

More intensive electric and magnetic fields are known to be harmful to our health, though we are not normally exposed to these in daily life. For example, extremely intensive magnetic fields over 10,000 microtesla (μT) can cause nerve and muscle cells to malfunction. Such powerful magnetic fields generate electric currents in the human organism that trigger undesirable nerve excitations and muscle contractions. And if the heart is exposed to extreme magnetic fields of more than 100,000 μT, this can cause cramping of the heart muscle – a condition that is life-threatening.
These effects on nerves and muscles are referred to as stimulation effects. They have been scientifically established and form the basis for defining international hazard thresholds. If these limits are not exceeded, no nerve or muscle cell malfunctions are triggered by low-frequency fields.

Subliminal effects

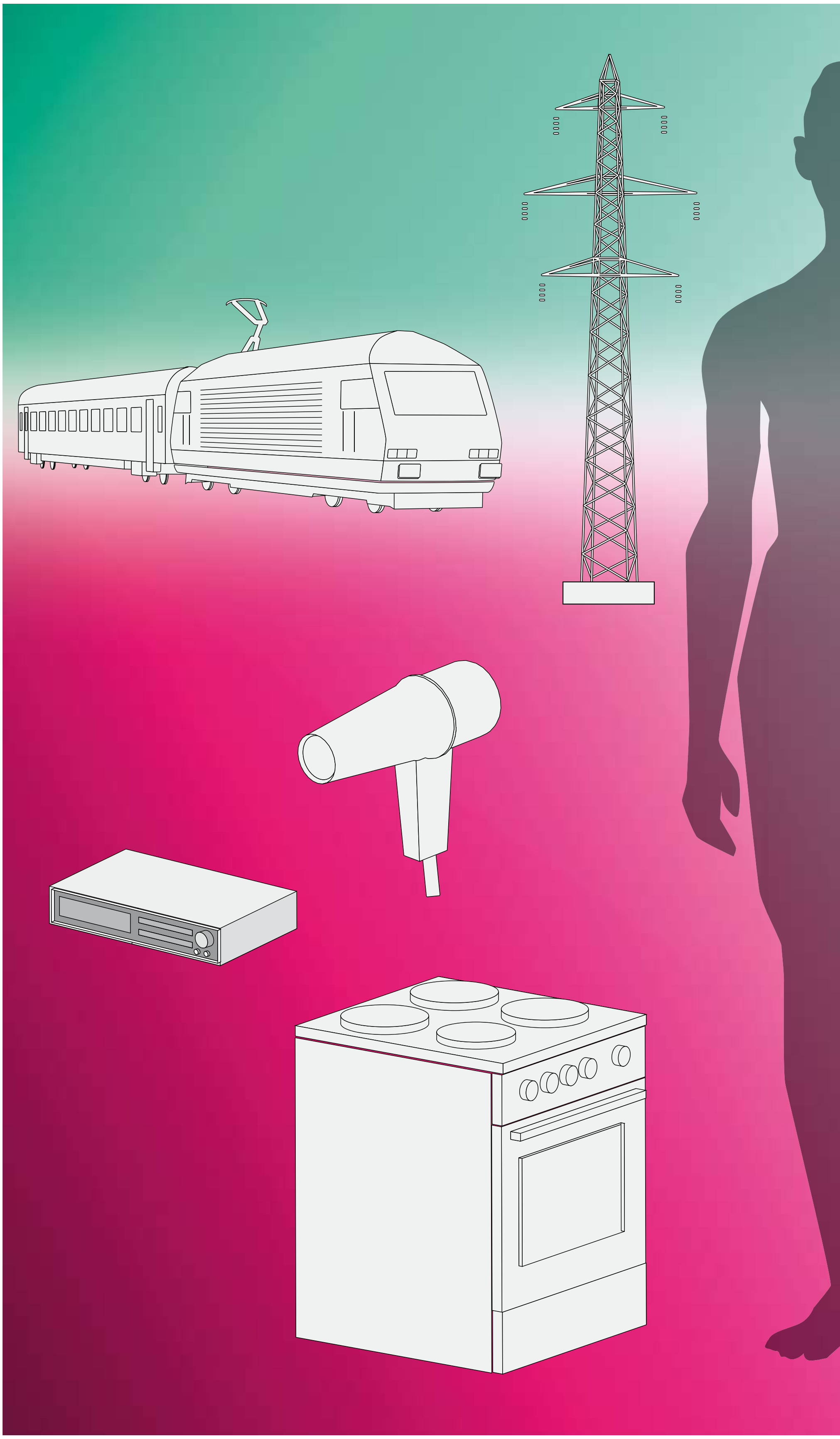
Various studies have revealed, however, that biological reactions may occur even if field strengths are well below the internationally defined thresholds. These reactions are referred to as subliminal effects.
Experiments conducted on both animals and human beings have identified changes in behaviour, interference with learning capacity and impacts on the hormone system. For example, it has been found that lower than usual levels of the hormone melatonin are produced. Melatonin controls the biological day/night cycle, has a stimulating effect on the immune system and inhibits the growth of tumours. Melatonin deficiencies are associated with sleep disorders, tiredness and depressive states. Research has also identified a variety of other impacts of low-frequency fields, including influences on growth and metabolism of cells and changes in genetic material.
The existence of subliminal effects is undisputed, but what we do not know is how they actually occur. Given the present-day status of knowledge, it is difficult to say whether these represent a health hazard, and if so under what circumstances.

Increased risk of leukaemia among children?

Epidemiological studies, which examine the frequency of occurrence of certain diseases among selected population groups, are a means of finding out more about any harmful effects that may be caused by non-ionising radiation. Studies of this sort have been carried out in a variety of countries since the early 1980s in order to determine whether low-frequency magnetic fields may cause or favour the development of cancer. For many years, the findings were varied and often contradictory, but as a result of more recent investigations and meta-analysis of earlier ones, researchers have meanwhile come to a uniform conclusion: the risk of contracting leukaemia is possibly twice as high among children who are exposed to magnetic fields over 0.4 μT for lengthy periods.
The International Agency for Research on Cancer (IARC) also came to the same conclusion, and in 2001 it classified low-frequency magnetic fields as potentially carcinogenic for human beings. It is of the opinion that weak magnetic fields represent a possible – though not probable or proven – leukaemia risk.
In Switzerland, around 60 children a year contract leukaemia. If long-term exposure to low-frequency magnetic fields of more than 0.4 μT really were to double the risk of children contracting leukaemia – which admittedly has not yet been definitively established – this means that about 1 new case a year would be attributable to magnetic fields, while the remaining 59 would be attributable to other causes.
The suspicion of a higher leukaemia risk is one reason to keep long-term exposure

Low-frequency fields

to low-frequency magnetic fields as low as possible as a precautionary measure. Insofar as electrical household appliances are the source, we ourselves are able to influence the level of exposure in our own homes. In contrast, electrical systems in our environment are subject to the provisions of the Ordinance relating to Protection from Non-Ionising Radiation, which entered into effect on 1 February 2000, and stipulates precautionary measures to reduce magnetic fields at locations occupied by people for lengthy periods of time, including residential dwellings, offices, schools, hospitals and playgrounds. At these locations, the installation limit value for all new high-voltage power lines and transformer stations at full load is 1 µT. However, long-term exposure is generally well below this level, since these systems seldom operate at full capacity.



In our daily life we are exposed to non-ionising radiation from a broad variety of sources. For example, railway catenaries, electricity supply systems and electrical household appliances all produce low-frequency electric and magnetic fields. If these are of high intensity, they can produce electric currents in the body that trigger undesirable nerve stimulations or muscle contractions.

High-frequency fields

TV and radio transmitters, mobile phone base stations, radar installations and microwave ovens all produce high-frequency radiation. This has different physical properties to low-frequency fields and its effects on human beings are also quite different. Intensive high-frequency radiation is converted in the body into heat, and this can harm sensitive organs. More research is required in order to clarify effects of low-level radiation.

Effects of high-frequency radiation

When we use a microwave oven, we are in fact utilising the heat produced by intensive high-frequency radiation. Here, biological tissue such as vegetables and meat absorbs the radiated energy and heats up. It is not only microwaves that heat up biological tissue, however: this process occurs as the result of high-frequency electromagnetic radiation from all sources – for example, radio and mobile phone transmitters – but it only occurs if the radiation is of sufficient intensity.
Many biochemical reactions in the human body only take place within a narrow temperature range. Diseases accompanied by high fever show us that these processes can already be severely disturbed if the body temperature rises by only a few degrees Celsius. For this reason, thermal impacts due to electromagnetic radiation have to be regarded as undesirable.

Hazardous thermal effects

In daily life we are normally not exposed to high-frequency radiation of such intensity that its thermal effects could harm our health.
A health risk arises if our body temperature increases by more than 1 to 2° C as a result of absorbed radiation. The resulting effects are similar to those experienced due to fever or overheating: memory disorders, interference with various bodily functions, including the reproductive organs. Organs that have poor blood flow and are therefore unable to cool quickly are especially at risk (e.g. the eyes, which can develop cataracts). If our body temperature increases even more, this can lead to internal burns or even death due to heat stroke.
Well-documented work accidents abroad, especially those involving radar equipment, demonstrate how dangerous high-frequency radiation can be. For example, a mechanic who inadvertently strayed very close to a radar transmitter suddenly felt very hot and suffered internal burns. He and two of his colleagues had to be taken to hospital with skin damage and severe coagulation problems. All three complained of tiredness, dizziness, headaches and pressure above the eyes. Scientists are well aware of these acute effects of intensive high-frequency radiation, which only occur above a certain level of radiation intensity. The corresponding threshold forms the basis for the definition of internationally recognised limits aimed at protecting the population against the harmful effects of short-term exposure.

Numerous non-thermal effects

Various studies have revealed, however, that biological effects may result even if radiation intensities are well below the internationally defined thresholds. Since they do not increase our body temperature, we refer to them as non-thermal effects.
Experiments on test subjects have demonstrated, for example, that radiation from mobile phones can influence brain waves and sleep patterns. In laboratory studies, behaviour changes among animals, and physiological changes in cell cultures, have been observed as the result of low-intensity, high-frequency radiation.
Epidemiological studies have also given rise to certain suspicions: studies carried out in the vicinity of TV and radio transmitters have yielded higher leukaemia and lymphoma rates than expected. However, findings are not uniform and some studies have methodological flaws.
To some extent, indicators of potential impacts on health come directly from the population. For example, an increasing number of people living in the vicinity of a now decommissioned short-wave radio transmitter in Schwarzenburg (canton of Bern) began to complain about nervousness, restlessness, insomnia, general weakness, tiredness and aching limbs, and a subsequent epidemiological study conducted on behalf of the federal government revealed a statistical correlation between sleep disorders and transmission patterns. However, the study was unable to definitively determine whether the various symptoms were in fact attributable to radiation from the transmitter, or whether confounding factors might have been involved.
Nonetheless, the fact that high-frequency radiation gives rise to non-thermal effects is undisputed. The problem is, we do not yet know how these effects come into being. Given the present-day status of knowledge, it is also difficult to say whether these effects represent a health hazard, and if so, under what circumstances. In view of the existence of contradictory findings and the fact that not all experiments can be successfully repeated, it is difficult to make a meaningful evaluation. This means that further research is essential if we are to gain an accurate picture of the impacts of low-intensity, high-frequency radiation on our health.

Intensive electromagnetic radiation can cause the body to heat up, and this results in symptoms similar to fevers. The limit values specified by the ONIR protect us against these undesirable thermal effects.

Phenomenon of electrosensitivity

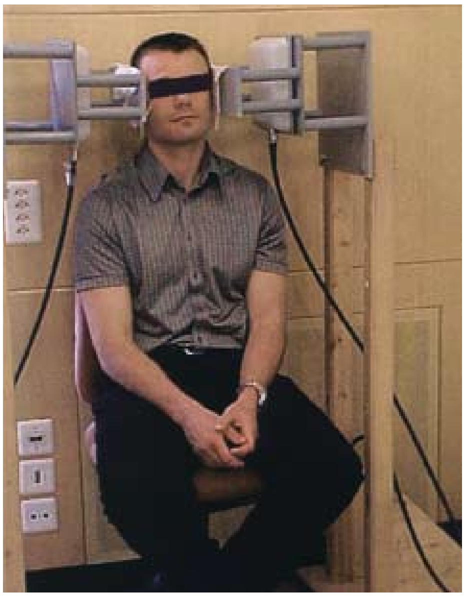
Human beings do not possess a sensory organ that enables them to directly perceive non-ionising radiation, but it appears that some especially sensitive people are able to perceive even very weak electromagnetic fields. Others feel certain that their health related symptoms are caused by electrosmog.

Perception of weak electromagnetic fields

Some people have the ability to consciously perceive weak electromagnetic radiation, which can be established in experimental arrangements and tests. Test subjects have to be able to tell the difference between a real and a sham exposure. Approximately 5 percent are able to accomplish this better than they could be expected to by chance. The ability to perceive weak electromagnetic fields does not mean, however, that the person concerned also suffers due to electrosmog.

Electrosensitivity

The term electrosensitivity (or electromagnetic hypersensitivity) is used when someone attributes his or her health problems to the effects of low-intensity non-ionising radiation. Here, people complain of frequent but non-specific symptoms such as sleep disturbances, headaches, nervousness, general tiredness, lapses of concentration, tinnitus (ringing in the ears), dizziness, aching limbs, heart pains.
As a rule, it is difficult to precisely determine the causes of these symptoms. In addition to electrosmog, a variety of other factors come into question, such as stress, noise, flickering light, chemicals, and physical or mental disorders. Furthermore, there are no generally acknowledged criteria for an objective diagnosis of electrosensitivity, and it also appears that ability to perceive weak fields and electrosensitivity exist independently of one another. This means that people with electrosensitivity do not necessarily have a higher perception of electromagnetic fields than average, and vice versa.
Many questions still need to be answered regarding these two phenomena, and therefore a great deal of research is still required.



In this scientific experiment, the subject's head is being exposed to electromagnetic fields similar to those produced by mobile phones. Exposure for only 30 minutes already alters our brain activity, but it is at present not possible to draw any clear conclusions from this with respect to potential harm to health.

People with electrosensitivity feel impaired by low intensity non-ionising radiation, even when the level is well below internationally recognised exposure limit values. The symptoms tend be non-specific, for example tinnitus (ringing in the ears).

Evaluation of effects of high-frequency radiation

Evidence	Effects		
	Serious	Reduced well-being	Relevance to health unknown
Established	Thermal effects (e.g. interference with memory and other functions, cataracts, internal burns)		
Probable		Non-specific symptoms (headaches, fatigue, problems of concentration, disquiet, burning skin, etc.)	
			Brain activity
			Sleep phases
Possible	Leukaemia/lymphomas		
	Brain tumours		
		Quality of sleep	
		Electromagnetic hypersensitivity	
			Cognitive functions, reaction times
Improbable	Mortality		
	Other types of tumour		
Not assessable	Stillbirth		
	Genotoxicity		
	Breast cancer		
	Eye tumours		
	Testicle tumours		
		Mental symptoms	
		Unspecific symptoms (insomnia, headaches, etc.)	
			Hormone system
			Immune system
			High blood pressure

Source of exposure
Various, above exposure limit values
Mobile phones
Mobile phones
Mobile phones
TV/radio transmitters
Mobile phones
Radio transmitters
Mobile phones
Mobile phones
Mobile phones
Various
Diathermy devices
Workplace exposure
Various
Mobile phones
Radar guns
Various
Mobile phone base stations
Various
Various
Radio transmitters

Explanations concerning the table on pages 12 and 13

The table on pages 12 and 13 is largely based on a study entitled "High frequency radiation and human health", published in 2003 and updated in 2004 (BUWAL UM-162-D), which was produced by the Institute for Social and Preventive Medicine, Basel, on behalf of the Swiss Agency for the Environment, Forests and Landscape. It presents a differentiated assessment of the findings from more than 200 studies.

The "evidence" column indicates the degree of certainty of each effect. For this purpose it has been divided into the following categories:

Established: The effect concerned is able to stand up to strict scientific examination.

Probable: The effect concerned has been established in a variety of studies, the quality of which is high enough to permit the exclusion of other influencing factors with a high degree of certainty, but a plausible causation mechanism is nonetheless lacking.

Possible: The effect concerned has been observed in various studies, but the findings are not consistent. Reports concerning individual cases support the scientific indicators.

Improbable: There are no indicators for the effect concerned, but multiple indicators of its absence.

Not assessable: The available data are insufficient for making a meaningful assessment.

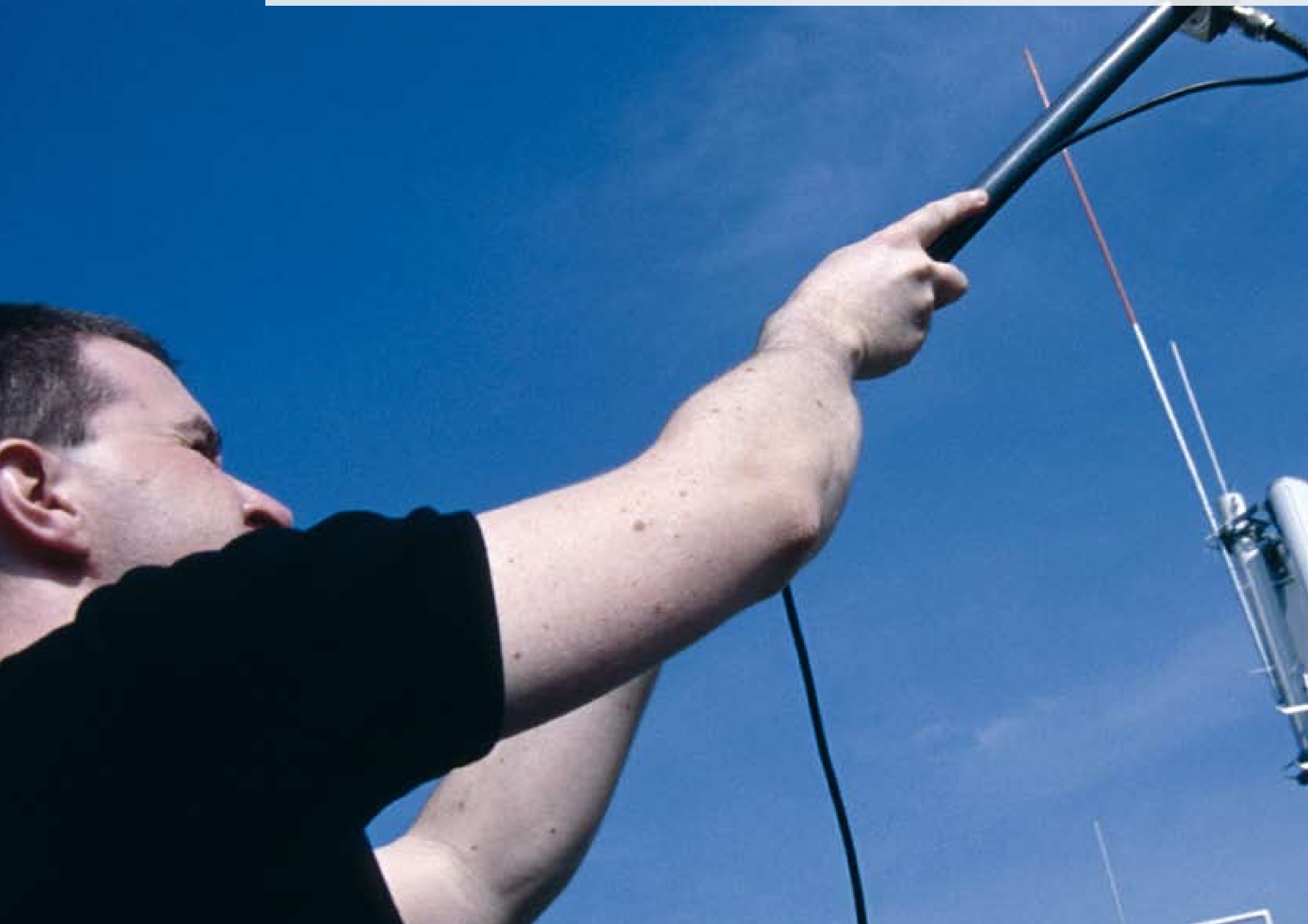
Secondly, the relevance of the effects to human health was evaluated, regardless of their indicated degree of certainty:

Serious: The effect concerned represents a drastic restriction of quality of life. It is life threatening and will shorten life expectancy.

Reduced well-being: The effect significantly restricts quality of life and well-being, but the symptoms are not directly life threatening.

Relevance to health unknown: The effect is physiologically measurable, but the observed changes are within the normal variability range of healthy individuals. Since it is normally not perceived, it does not represent an acute health risk, nor does it have an impact on quality of life. However, it is not clear whether it could lead to a health risk in the longer term.

The Ordinance relating to Protection from Non-Ionising Radiation (ONIR), which entered into effect on 1 February 2000, is intended to protect Switzerland's population against the effects of electrosmog. To provide protection against known and scientifically established risks, it specifies limit values for short-term exposure. In addition, precautionary installation limit values for a variety of radiation sources help reduce long-term exposure in residential areas.



Regulations to protect the population against the effects of electrosmog

Contents

Protection concept > P 15

Scope of application of the Ordinance > P 15

Limitation of short-term exposure > P 16

Exposure limit values > P 16

Precautionary limitation of long-term exposure > P 17

Installation limit values > P 17

Places of sensitive use > P 17

New building zones > P 18

Controls by means of calculations and measurements > P 18

Approval measurements > P 18

Control measurements > P 19

Measurement of radiation from mobile phone base stations > P 19

Protection concept

Wherever we may be, non-ionising radiation is all around us. It is produced by all electrical installations and appliances, and by transmitters of all kinds. As advances in technology continue to be made and use of these devices at the workplace and in the private sphere broadens, exposure to non-ionising radiation is likely to increase further. On 1 February 2000 the Federal Council enacted its Ordinance relating to Protection from Non-Ionising Radiation (ONIR) as an instrument to protect the population against the known and suspected harmful effects of electrosmog.
The scope of application of this Ordinance is limited to stationary sources of radiation such as power lines, transformer stations, railway catenaries and transmitters for mobile communication, broadcasting and radar. By contrast, it does not cover mobile phones, cordless phones, monitors, screens, microwave ovens and other electrical appliances. To limit radiation from the above appliances, internationally recognised regulations and standards are required that Switzerland cannot draw up unilaterally.
Non-ionising radiation must not be allowed to harm the health and well-being of the country's population, and the Ordinance pursues this objective in two ways:

- It limits short-term exposure in order to prevent scientifically accepted damage to health.
- As a precautionary measure, it also reduces long-term exposure in order to provide protection against potential (i.e. not yet scientifically established) health risks.

Scope of application of the ONIR

Systems covered by the ONIR:

- **High-voltage power lines (overhead and underground)**
- **Transformer stations**
- **Sub-stations and switchyards**
- **Domestic electrical installations**
- **Railways and tramways**
- **Mobile phone base stations**
- **Point-to point microwave links**
- **Wireless local loops (WLL)**
- **Broadcasting installations**
- **Professional mobile radio installations**
- **Amateur radio systems**
- **Radar installations**

Systems not covered by the ONIR:

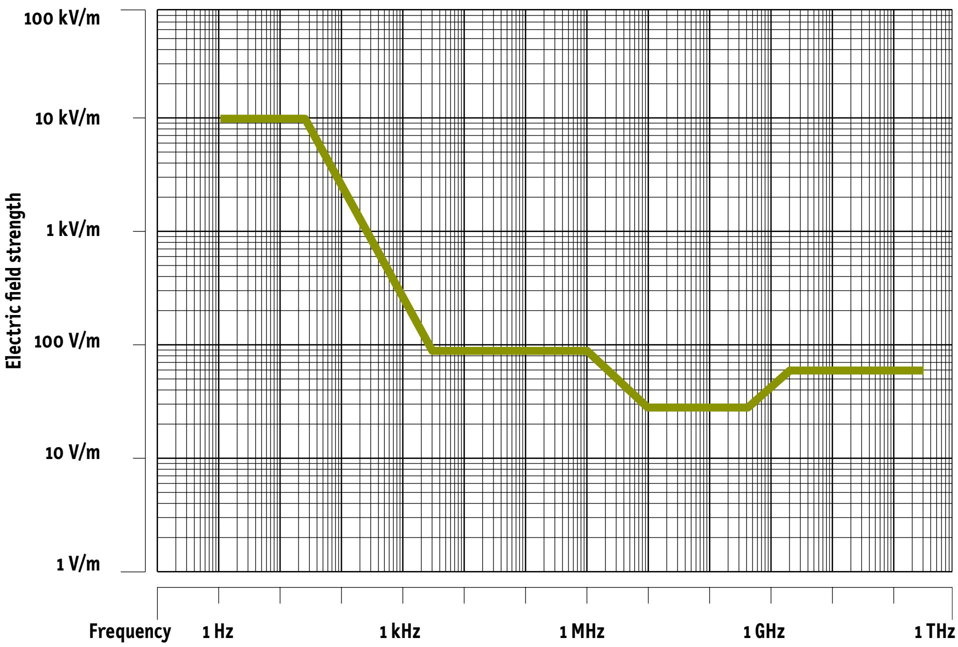
- **Mobile phones**
- **Cordless phones**
- **Bluetooth**
- **Microwave ovens**
- **Hotplates**
- **Electrical appliances (TV sets, computer monitors, clock radios, hairdryers, shavers, clothes irons, etc.)**
- **Medical devices**
- **Equipment at the workplace**

The ONIR contains regulations governing stationary installations that produce non-ionising radiation in the frequency range from 0 hertz to 300 gigahertz.

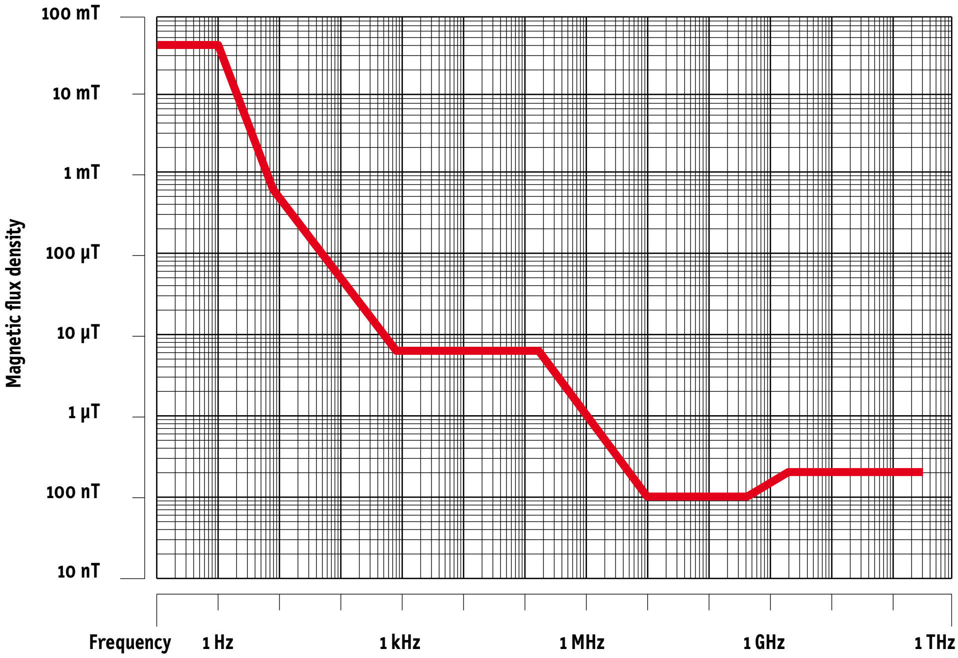
Stationary installations like the mobile phone antenna in the background have to comply with the limit values specified by the ONIR. Here the electromagnetic radiation is being measured with the aid of a calibrated hand-held antenna.

Limitation of short-term exposure

The Ordinance specifies exposure limit values aimed at limiting short-term exposure. These limits are based on the recommendations of the International Commission on Non-Ionising Radiation Protection (ICNIRP) that are used in many other countries. If these limits are complied with, none of the scientifically accepted negative effects on our health can occur. These include an increase in body temperature due to very high intensity radiation from transmitters, and triggering of undesirable nerve impulses or muscle contractions by intensive electric or magnetic fields. The exposure limit values must be complied with wherever people spend any length of time.



The exposure limit values for the electric field strength (green curve) specified in the ONIR vary according to the frequency of the radiation, since the effects on human beings occur at different intensities depending on frequency.



For the same reason, the exposure limit values for the magnetic flux density (red curve) are also frequency-dependent.

System	Frequency	Exposure limit value
Railway catenaries	16.7 Hz	300 µT and 10,000 V/m
High-voltage power lines	50 Hz	100 µT and 5,000 V/m
Radio/TV transmitters	10 - 400 MHz	28 V/m
Mobile phone	900 MHz	41 V/m
base stations	1,800 MHz	58 V/m
UMTS transmitters	2,100 MHz	61 V/m

Examples of exposure limit values for various frequencies.

Exposure limit values

– The exposure limit values specified by the Ordinance are internationally co-ordinated.
– They protect against scientifically accepted damage to health.
– They take account of the overall low-frequency or high-frequency radiation at a given location.
– They must be complied with wherever people spend any length of time (including very short periods).

Precautionary limitation of long-term exposure

Exposure limit values ensure protection against recognised, acute effects, but they do not protect against suspected effects at lower radiation intensities, especially with long-term exposure. A great deal of research is still required in this area. When the Federal Council drew up the ONIR, it did not want to wait for further research findings, and for this reason it included precautionary measures to limit the long-term exposure.

The provisions concerned are based on the principle of precaution as established in the Federal Law relating to the Protection of the Environment. Article 1, paragraph 2 of this law states: "Early preventive measures shall be taken in order to limit effects which could become harmful or a nuisance". In other words, suspicion of harmful effects is sufficient, and it is therefore not necessary to provide scientific proof. In Article 11, the Environmental Protection Law also states that measures must be taken at the source to limit environmental pollution. Here the criteria are technical and operational feasibility, as well as economic acceptability.

The ONIR implements these principles by specifying thresholds for various categories of radiation sources. These so-called installation limit values apply to radiation from a single installation and are well below the exposure limit values. For mobile phone base stations they are around 10 times lower, and in the case of new high-voltage power lines they are as much as 100 times lower. Installation limit values must be complied with wherever people spend lengthy periods of time (at places of sensitive use). These provisions are among the most stringent regulations of their kind in the world.

However, in view of the unclear situation with respect to risks to health, even these stringent regulations do not provide 100-percent safety. It is not possible for authorities and medical experts to provide a guarantee of safety, either now or in the future. However, this holds not only for the radiation issue, but also for many other new technologies. It is not possible to exclude all potential health risks on a scientific basis, since life processes are too complex to allow every conceivable biological effect to be studied in advance. But since the installation limit values reduce long-term exposure, the risk of any consequences to our health that are not clearly recognisable today is also minimised.

Installation limit values

- The installation limit values specified by the ONIR are of a precautionary nature.
- They are much lower than the exposure limit values.
- They are based on the principle of precaution established in the Federal Law relating to the Protection of the Environment, and have been specified in accordance with technical, operational and economic criteria.
- They limit the level of radiation from a given installation.
- They must be complied with wherever people spend lengthy periods of time.
- They ensure that exposure to electrosmog is low at places of sensitive use, and in this way they also reduce the risk of suspected harmful effects on health.

Installation limit values are based on technical, operational and economic criteria, and not on medical or biological findings. This means they are not levels indicating harmlessness, and compliance with them cannot guarantee that all harmful effects can be excluded. However, this also does not mean that negative effects occur if installation limit values are exceeded.

Places of sensitive use

Precautionary protection provided by the installation limit values is limited to locations where people regularly spend lengthy periods of time. Here, long-term exposure shall be kept as low as possible. Places of sensitive use include apartments, schools, hospitals, offices and playgrounds, but do not include balconies and roof terraces, stairways, garages, storage and archive rooms, temporary workplaces, churches, concert halls and theatres, camp sites, sports and leisure-time facilities, passenger areas in railways, observation decks.

System	Frequency	Installation limit value
Railway catenaries	16.7 Hz	1 µT (24-hr average)
High-voltage power lines	50 Hz	1 µT
Radio/TV transmitters	10-860 MHz	3 V/m
Mobile phone	900 MHz	4 V/m
base stations	1,800 MHz	6 V/m
UMTS base stations	2,100 MHz	6 V/m

Examples of installation limit values. These have to be complied with in the reference operating mode. Please refer to the descriptions of the various installation categories for more detailed information.

In order to protect the population, the designation of new building zones will only be permitted in close proximity to existing or planned supply installations emitting non-ionising radiation if the installations concerned are able to comply with the installation limit values specified in the ONIR.

New building zones

In addition to measures at source, the ONIR also sets out to ensure the lowest possible long-term exposure by means of land use planning. It restricts the development zoning of new areas if they are in the close vicinity of existing or planned facilities that produce non-ionising radiation. In this way it ensures that no heavily exposed places of sensitive use will be created in the future. Since 1 February 2000, the definition of new building zones is only permitted if the installation limit values can be complied with.
The situation is different, however, in building zones that were approved before the above date and are located near a radiation source. Here, development is permitted without any restrictions, even if an installation limit value is exceeded. However the installation concerned has to be improved, and the ONIR specifies the required degree of improvement for each type of installation.
For example, mobile phone base stations must be improved in such a manner as to ensure that the installation limit value is fully complied with at all places of sensitive use, but no such requirements apply to power lines and railway catenaries. In the case of electricity transmission, the Ordinance merely calls for optimisation of the phasing arrangement, and in the case of catenaries a return conductor is required. Even though these measures do not suffice to bring the level of radiation below the installation limit value in developed areas, the Ordinance does not call for any other improvements. The Federal Council was of the opinion that a reduction of radiation levels to below the installation limit value would be disproportionate for existing power lines and catenaries. For the same reason it also rejected the idea of reversing zoning in areas that are already zoned.

Controls by means of calculations and measurements

The competent federal, cantonal or municipal authorities verify whether the limit values specified by the Ordinance are complied with. For this purpose they may carry out calculations or measurements.
For example, operators of mobile phone base stations are required to submit a site data sheet together with their application for a building permit. The radiation in the vicinity of the installation is calculated on the basis of the transmission capacity and directions. The cantonal or municipal authorities check the accuracy of these data and calculations. Similar calculations are also carried out on other installations such as high-voltage power lines and railway catenaries.
The radiation can be measured after the system has been put into operation. Here a distinction is made between approval and control measurements.

Approval measurements

Approval measurements are carried out in order to ascertain that the respective installation limit value is complied with in a given operating mode – in the case of mobile phone base stations, for example, at full utilisation capacity and maximum approved transmission power. These measurements are normally carried out if calculations indicate that radiation levels are likely to exceed 80 percent of the specified installation limit value. It is often the case that the proprietor of the facility entrusts a specialised company with the task of carrying out these measurements, since such companies possess the necessary know-how and experience. The associated costs have to be borne by the proprietor in accordance with the principle of "polluter pays".
Approval measurements can never be carried out fully independently of the proprietor, since the latter is required to provide the necessary data concerning the current operating mode during the measurement procedure. In the case of mobile phone base stations, the Ordinance stipulates that the installation limit value must be complied with at full operating capacity and maximum transmission power. This status seldom applies in practice, however,

since the base station normally operates at lower output levels. For this reason, the results have to be projected from the current to the maximum approved transmission power. It is only in this way that the authorities are able to judge whether the installation limit value has been complied with. These projections are based on data provided by the operator concerning the current operating mode.

Control measurements

Control measurements are carried out for a quite different purpose, namely to determine the radiation level when the installation concerned is in its actual state of operation. Control measurements are carried out independently of the operator.

Measurement of radiation from mobile phone base stations

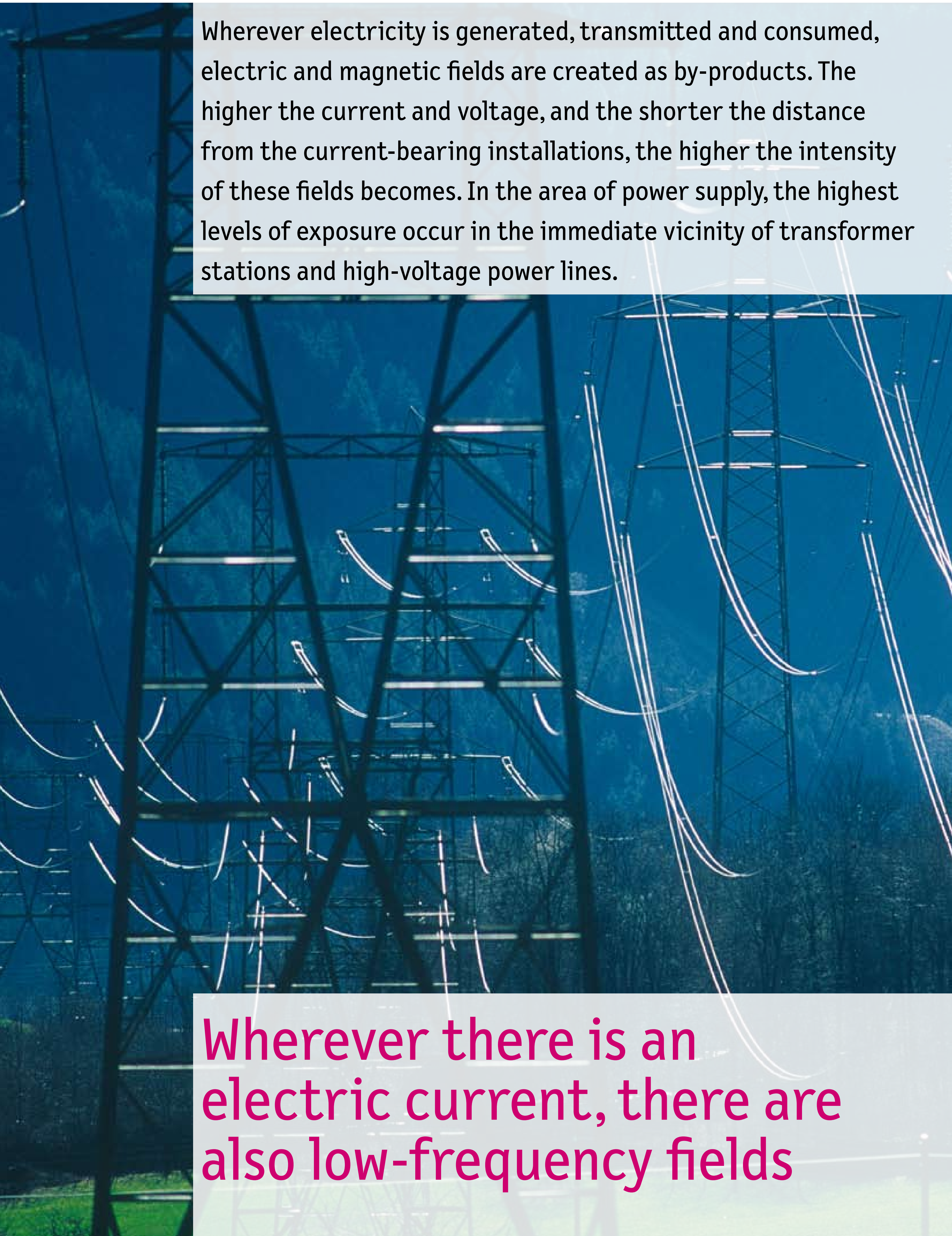
There are various methods for measuring radiation from mobile phone base stations:

Broadband measurement: With this method, a sensor is used which records the overall radiation in a broad frequency range. Alongside mobile phone base stations, other systems such as radio and TV transmitters also contribute towards these readings, but it is not possible to distinguish between the individual sources.

Frequency selective measurement: This method is used if, on the basis of a broadband measurement, it is not possible to judge with sufficient certainty whether a mobile phone base station complies with the installation limit value. Here it is only the radiation from the installation concerned that is measured. Selective frequency measurements are more demanding and time-consuming than broadband measurements, and require more complex measuring equipment.

Code selective measurement: This method is used for measuring UTMS radiation if the other two methods fail to yield conclusive results. Here, only the temporally constant proportion from the UMTS signal is recorded, and subsequently projected. In this way it is possible to clearly allocate the recorded signals to a specific transmitter.

This hand-held test antenna (above) can be used for detecting the maximum exposure level indoors. A spectrum analyser (below) depicts the results of the frequency selective measurement. Since each frequency is recorded separately, it is possible to specifically measure the level of radiation from a single mobile phone base station.



Wherever electricity is generated, transmitted and consumed, electric and magnetic fields are created as by-products. The higher the current and voltage, and the shorter the distance from the current-bearing installations, the higher the intensity of these fields becomes. In the area of power supply, the highest levels of exposure occur in the immediate vicinity of transformer stations and high-voltage power lines.

Wherever there is an electric current, there are also low-frequency fields

Contents

From power plant to mains socket > P 21

The three parameters of electricity > P 22

How fields are created > P 22

Three-phase alternating current > P 22

Magnetic fields from overhead power lines > P 23

Reduction of the magnetic field by phase optimisation > P 24

Temporal variation of the magnetic field near a high-voltage transmission line > P 25

Electric fields from overhead power lines > P 25

More localised magnetic fields from underground cables > P 26

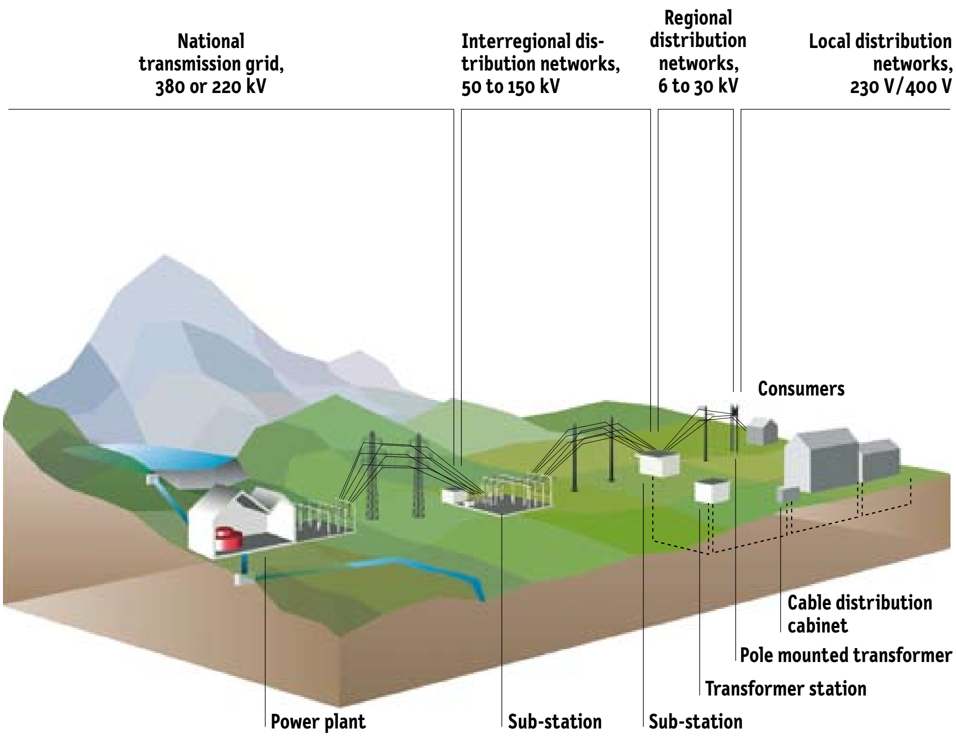
Precautionary regulations of the ONIR > P 26

Magnetic field from a transformer station > P 27

From power plant to mains socket

In Switzerland, a large proportion of electricity is produced from hydropower plants that are often located well away from places where it is subsequently consumed. This means that much of the energy we consume has already travelled a considerable distance. Generators in the various types of power plants generate electricity with a frequency of 50 Hz and a voltage of 6 to 27 kilovolts (kV).
High voltages reduce transmission losses, and in view of this, the voltage is increased in the respective power plant by means of transformers before the electricity is fed into the transmission grid. As a rule, levels of 220 or 380 kV are used for long-distance transport. This overland network mainly comprises overhead lines supported by pylons.

For shorter distances (e.g. region to region), the voltage is reduced to between 50 and 150 kV and the energy is usually transported via overhead lines supported by concrete masts.
And at the local level, the voltage is reduced to between 6 and 30 kV and the energy is transported either by underground cables or via overhead lines supported by wooden poles.
In residential areas, villages, etc., transformer stations finally reduce the voltage to the levels normally used in households (i.e. 230 and 400 volts).



On its way from power plant to end user, electricity first has to be converted to higher voltages, then brought back down to lower voltages. Electric and magnetic fields are produced both along power lines and in the vicinity of transformer stations.

The three parameters of electricity

There are three physical parameters which characterise electricity:

Current: This is measured in amperes (A) and indicates how much electricity is flowing through a conductor. If we use water supply as an analogy, the current would correspond to the throughput of water per time unit. The greater the throughput, the higher the current. In households, fuses in distribution boxes or panels limit the current to 10 or 16 A. The largest high-voltage power lines are designed for currents of up to 2,500 A.

Voltage: This is measured in volts (V). To stay with the water supply analogy, this is equivalent to water pressure, which is still present even if the tap is turned off and no water is flowing. In the same way, a plugged-in power cable, e.g. for a bedside table lamp, is "live", even if the light is switched off and no electricity is flowing. General purpose batteries range from 1.5 to 12 V. The mains supply in households is 230 V, while high-voltage power lines can be up to 420,000 V.

Frequency: This refers to the number of oscillations per second, and it is measured in hertz (Hz) (1 Hz = 1 oscillation per second). Frequency is only of importance for alternating current. With batteries, the positive and negative poles are fixed. They supply direct current that always flows in the same direction. By contrast, alternating current changes its flow direction: electricity in households has a frequency of 50 Hz. And this frequency is always the same, from the power plant to the mains socket, whereas voltage and current change according to network level.

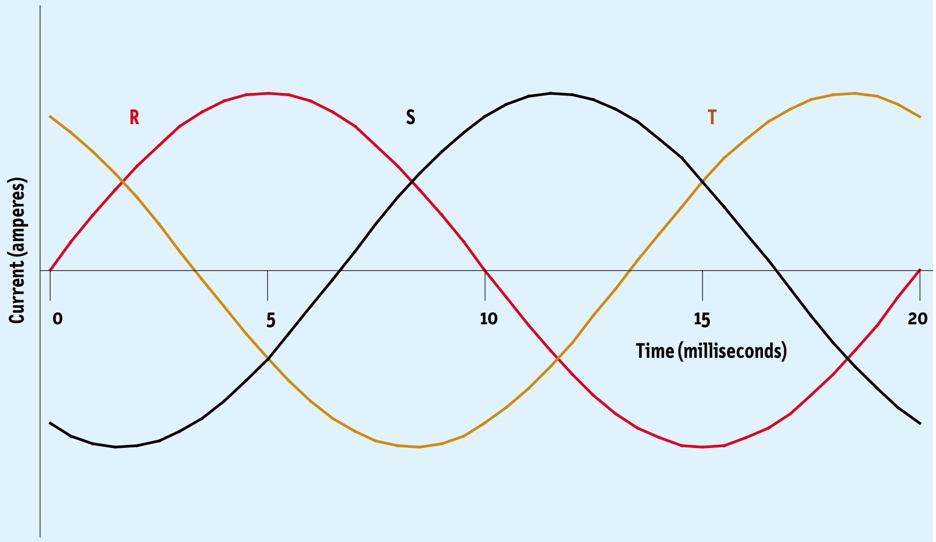
How fields are created

Everyday we use electrical appliances and devices at home, at work and in our leisure time. And wherever electricity is used, electric and magnetic fields are created – for example in close proximity to high-voltage power lines, sub-stations and transformer stations. But these fields are also created by electrical appliances in households, offices, factories, etc.
Electric fields occur as soon as an appliance is connected to the power supply via a cable and plug. As soon as it is switched on, current begins to flow, and this gives rise to a magnetic field in addition to the already existing electric field. Since our power supply is operated with alternating current with a frequency of 50 Hz, the electric and magnetic fields are also 50 Hz alternating fields.

Some of the properties of electric and magnetic fields are similar: for example, in both cases they weaken rapidly with increasing distance from the source. However, they differ greatly when it comes to screening: electric fields can be screened fairly easily, whereas magnetic fields freely penetrate practically all materials, and screening is therefore only possible with the aid of special metal alloys or thick aluminium sheets, and even then only to a limited extent.

Three-phase alternating current

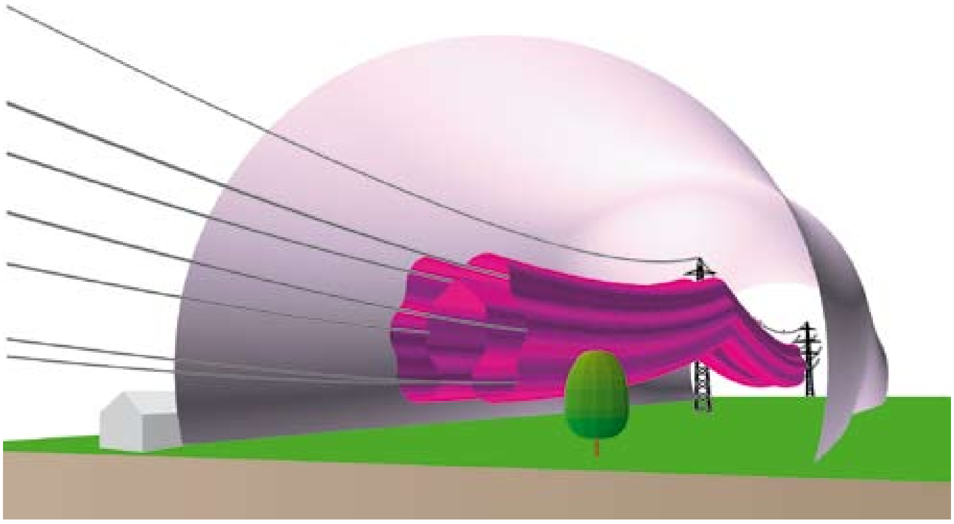
The 50 Hz electricity network is operated with three-phase alternating current. Here, three phase conductors form one line circuit. The alternating currents in each conductor are phase shifted by one-third of an oscillation period – they have differing phase angles. There are six different possible combinations for connecting the three phases (R, S and T) to the three phase conductors of a line circuit. As long as there is not a second circuit nearby, all six combinations generate an equally strong magnetic field. But as soon as two line circuits are brought close together, the magnetic fields of the individual circuits can be mutually strengthened or weakened. This depends on how the order of the phases of the second line circuit has been arranged in relation to the first one.



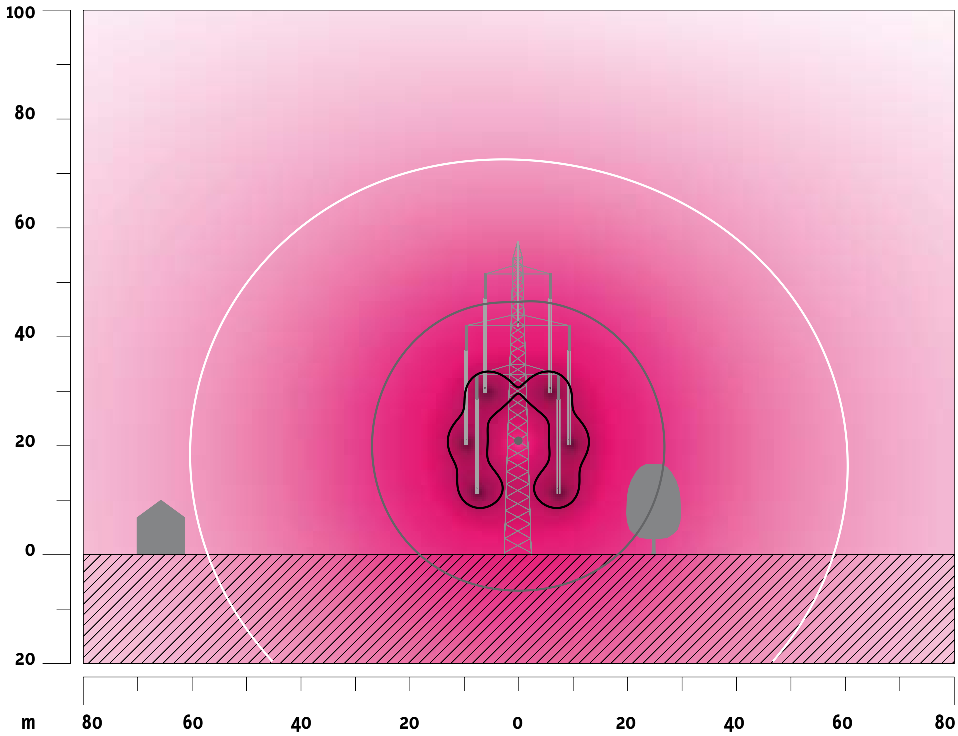
With the three-phase alternating current system, the currents in the three conductors are each phase shifted by one-third of an oscillation period. The three phases are designated R, S and T.

Magnetic fields from overhead lines

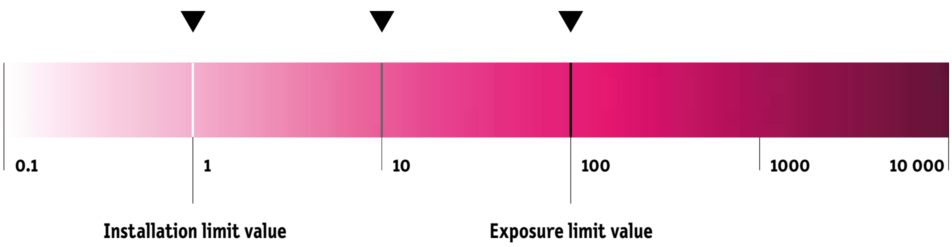
The intensity of a magnetic field is indicated in microtesla (µT). With high-voltage power lines, the higher the current, and the greater the distances between the power-bearing conductors, the greater the spatial bearing of the magnetic field. The most intensive exposure occurs at mid-span between two pylons, where the conductors are closest to the ground. The level varies, however, according to the design of the power line and the current. The magnetic field weakens with increasing distance from the power line. This means that the higher the conductors are above the ground, the weaker the field. In the case of transmission lines with several line circuits, or power lines running parallel to one another, the magnetic fields of the individual circuits can be mutually weakened or strengthened. Therefore it is possible to reduce the intensity of the magnetic field by optimising the order of the phases.
The walls of buildings cannot screen magnetic fields effectively. 380 kV overhead power lines can increase exposure to magnetic fields in neighbouring houses located up to a distance of 150 to 200 metres. Further away, exposure approaches the normal background level of approximately 0.02 to 0.04 µT which is usually encountered in residential dwellings connected to the electricity mains. However, the intensity can be much higher in the close vicinity of electrical appliances.



View (in perspective) of the magnetic field of a typical 380-kV high-voltage transmission line with two line circuits at full load (1,920 A). The highest exposure occurs around the six current-bearing conductors: within the red tubes the level is more than 100 microtesla (µT), and at the perimeter of the large tunnel it has fallen to 1 µT.



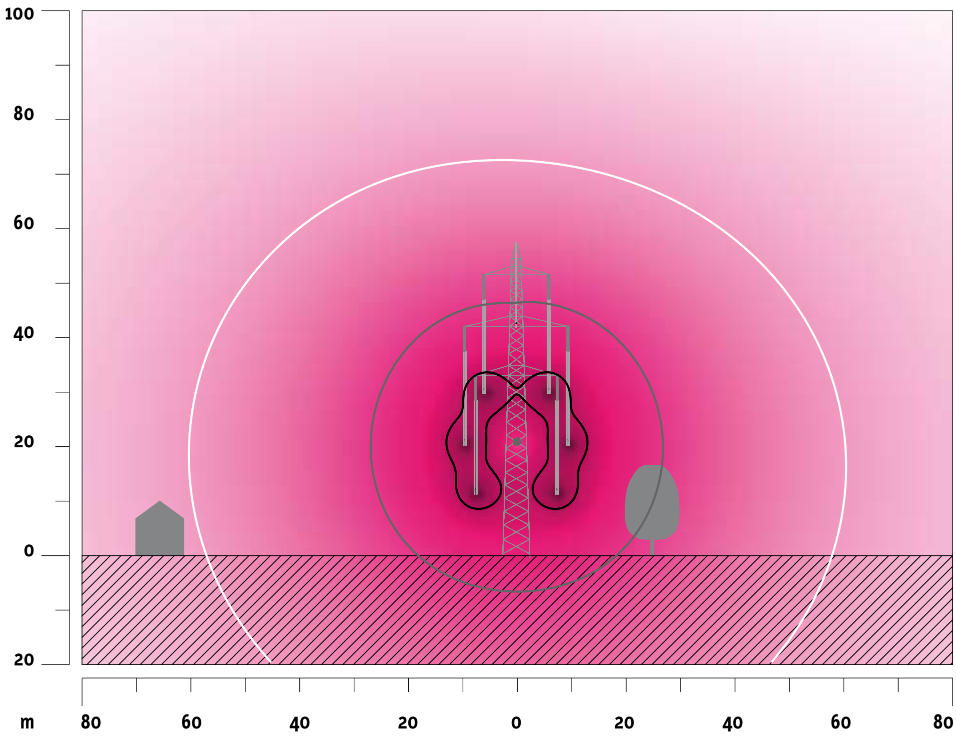
Cross-section of the magnetic field of the high-voltage transmission line depicted above, at mid-span between two pylons where the conductors are closest to the ground. The exposure diminishes with increasing distance from the power line, and is not influenced by walls, trees or the ground. The significance of the concentric lines is indicated in the colour scale below.



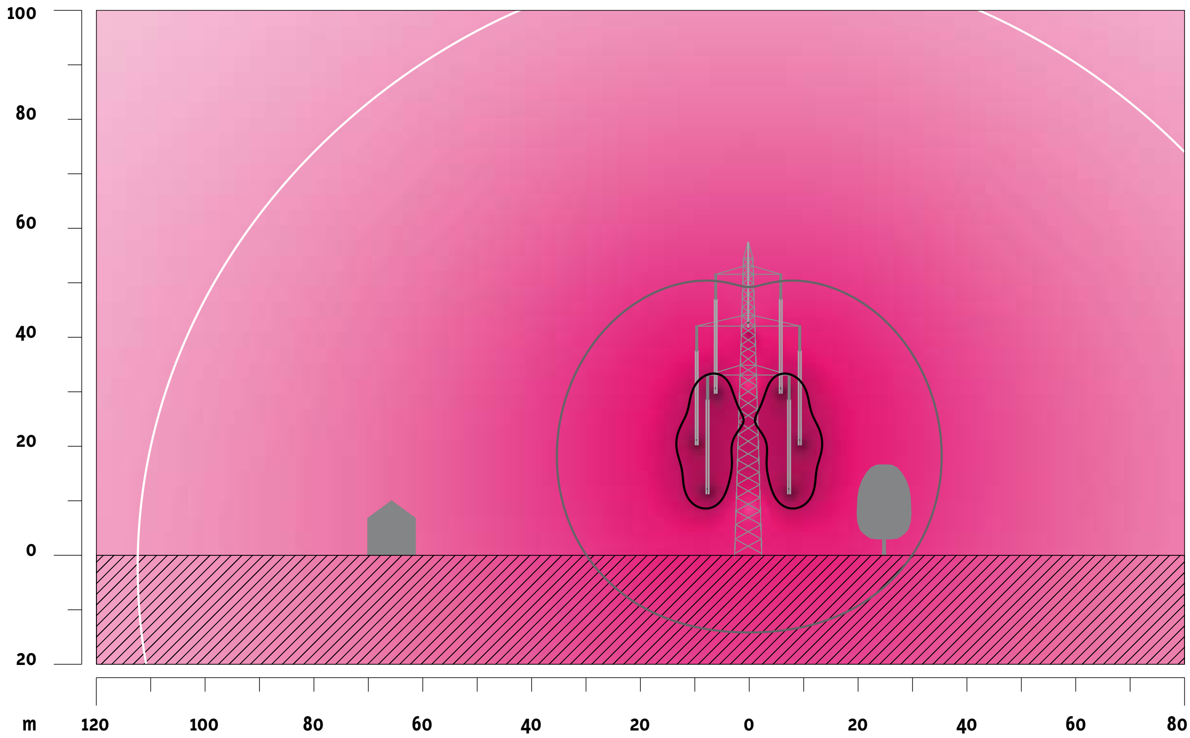
Scale of magnetic flux density in microtesla (µT).

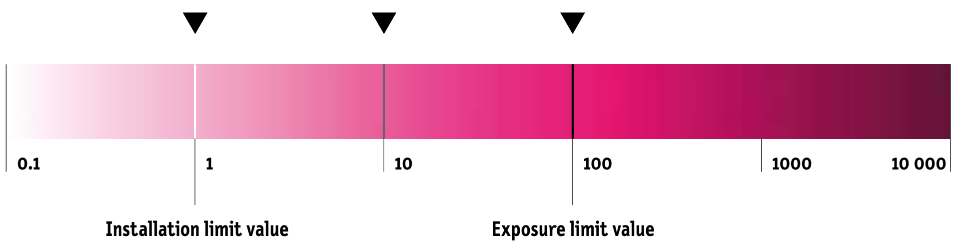
Reduction of the magnetic field by phase optimisation

By contrast with electric fields, it is very difficult to screen magnetic fields. Careful arrangement of the conductors and optimisation of the order of the phases are the best options for limiting their reach. The alternating currents in each conductor are shifted in time with respect to each other – they are said to have different phase angles. Depending on the way in which the three phases are connected to the conductors at the ends of the transmission line, the magnetic field will be of smaller or larger spatial extension. Optimisation of the order of the phases means connecting the conductors in such a manner that the spatial extension of the magnetic field is minimised. For this purpose, simulation programs are used that calculate the most suitable order of the phases based on the given conductor arrangement and predominant power flow directions.



With a favourable arrangement of the conductors and by optimising the order of the phases, it is possible to significantly reduce the spatial extension of the magnetic field. The illustration above depicts the magnetic field of a double-circuit 380-kV high-voltage transmission line with optimised phase order. The illustration below shows the same system with unfavourable phase order. The significance of the concentric lines is indicated in the colour scale.

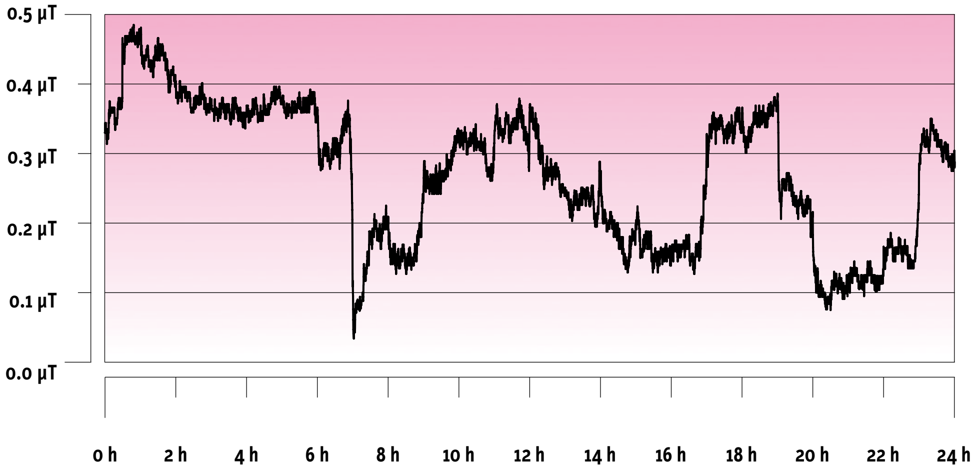




Scale of magnetic flux density in microtesla (μT).

Temporal variation of the magnetic field near a high-voltage transmission line

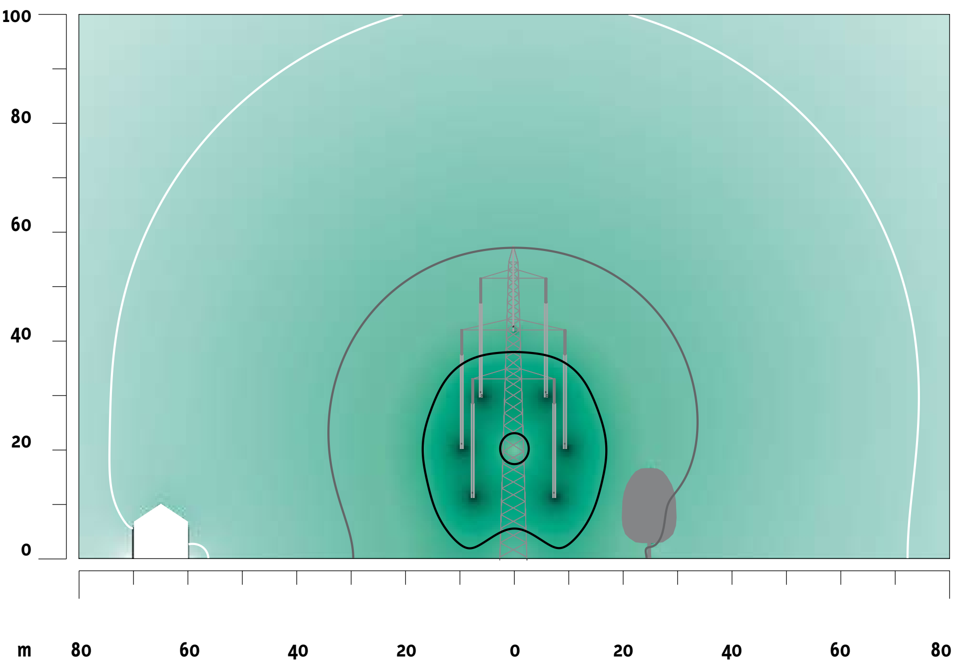
The magnetic field depends on the current, and thus on the corresponding electricity consumption in households, industry, etc. The time profile of magnetic field exposure in the vicinity of high-voltage power lines thus reflects the fluctuating electricity consumption, depending on time of day and season.
Unlike current, the voltage remains practically constant, and this also applies to the electric field of high-voltage power lines, which stays proportional to the voltage.



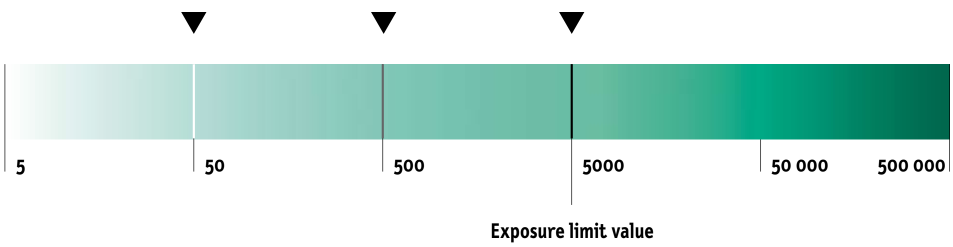
Example of a 24-hour profile of the magnetic field near a 220 kV high-voltage transmission line on a weekday in January. The magnetic field fluctuates depending on the currents flowing through the two line circuits

Electric fields from overhead power lines

The strength of electric fields is measured in volts per metre (V/m). It largely depends on the voltage and the distance from the conductor. Directly beneath a 380-kV high-voltage power line, the electric field strength close to the ground can reach 5,000 V/m. The lower the voltage, the less intense the electric field. For example, beneath a 220-kV line the strength is up to 3,000 V/m, for 110-kV lines it is a maximum of 700 V/m and for lines below 50-kV it is up to 400 V/m. As the diagram shows, the field strength weakens with increasing distance from the conductors.
Electric fields can be distorted and weakened by low-conductive materials such as trees, bushes and buildings. The conductivity of building materials usually suffices to reduce an external electric field by 90 percent or more inside the building.



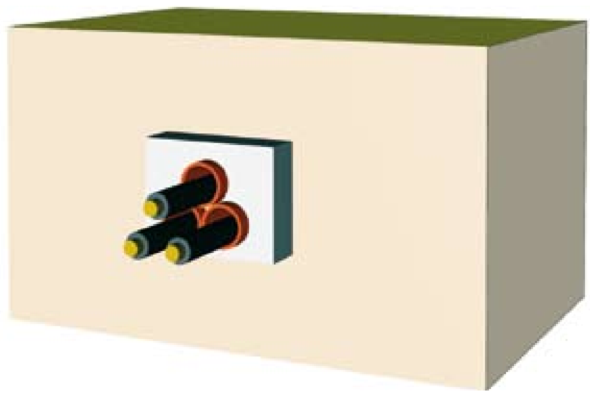
Cross-section of the electric field of a 380 kV high-voltage transmission line with two circuits, at mid-span between two pylons where the conductors are closest to the ground (minimum permissible distance from the ground). Directly below the power line, the exposure limit value of 5,000 volts per metre is almost reached. Buildings, trees and the ground distort electric fields and attenuate them. This means that exposure inside buildings from overhead power lines can be more or less ignored. The significance of the concentric lines is indicated in the colour scale below.



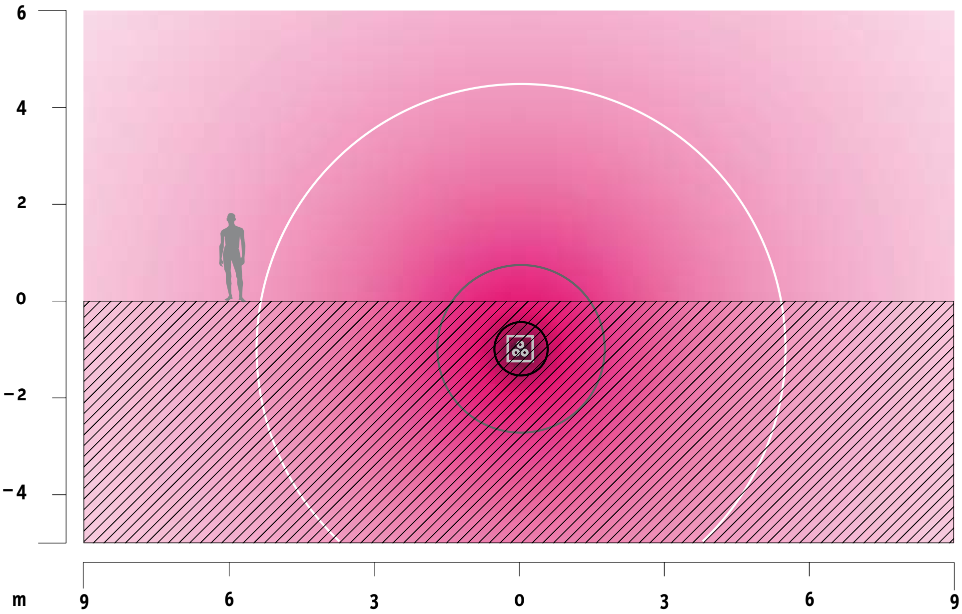
Scale of electric field strength in volts per metre (V/m).

More localised magnetic fields from underground cables

Whereas long-distance electricity transmission is primarily effected via overhead power lines, most local distribution is now carried out using underground cables.
With overhead lines, the air between the conductors acts as an insulator. The conductors have to be a certain distance apart in order to prevent arcing. But with underground cables, the conductors are very well insulated and can therefore be placed closer together, as a result of which the reach of the magnetic fields is reduced.
This means that, compared with overhead power lines carrying the same current, the magnetic field of an underground cable system has a much smaller spatial extension. Although the exposure may be just as high directly above an underground cable system as it is immediately beneath an overhead power line, it decreases more quickly on departing laterally than is the case with overhead lines.
Unlike the magnetic field, the electric field is completely shielded by the cable sheath and the soil. This means that no electric field is detectable even if we are standing directly above the underground cables.
Today it would be technically feasible to also lay high-voltage power lines (over 50 kV) underground, but the associated costs would be much higher, and repair work would be more costly and time-consuming. In view of this, electricity supply companies prefer to use overhead systems.



View (in perspective) of an underground cable line with three conductors in separated plastic tubes embedded in concrete.



Cross-section of the magnetic field of an underground cable line. Here the conduit is 0.8 metres below the surface. Since the current-bearing conductors (745 A each) are close together, the spatial extension of the magnetic field is significantly smaller than is the case with overhead transmission lines, and the exposure also diminishes more quickly with increasing distance.

Precautionary regulations of the ONIR

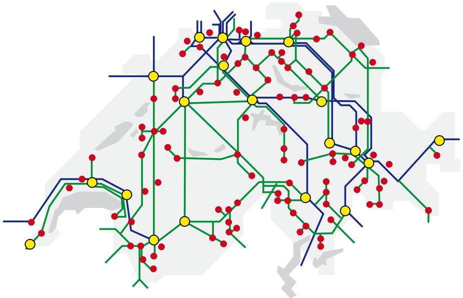
The precautionary emission limitations for high-voltage transmission lines specified in the ONIR vary according to whether the installation is new, to be modified or old.
New installations: At places of sensitive use such as residential dwellings, the installation limit value for new high voltage power lines or upon replacement of existing ones is 1 microtesla (µT). This limit applies to operation of the power line at full capacity. Since current varies according to time of day and season, and only rarely reaches full load, the average magnetic field exposure when the installation limit value is complied with is well below 1 µT. In certain exceptional circumstances, the relevant authorities may allow this limit value to be exceeded.
Installations to be modified: The term "modified" refers to all changes concerning conductor arrangement, phase order or operating status of an existing high-voltage power line. At places of sensitive use at which the installation limit value of 1 µT was already exceeded prior to the implemented changes, the magnetic field intensity may not be increased. At all other places of sensitive use, the installation limit value must be complied with. As with new installations, exceptions may be granted under certain circumstances.

220 kV overhead transmission line near Laax (canton of Grisons).

Old installations: If old power lines exceed the installation limit value at places of sensitive use, the phasing has to be optimised. Beyond this the Ordinance does not specify any additional requirements. If the power line concerned does not comply with the installation limit value even after optimisation of phasing, this is tolerated.

Type of power line	Distance for compliance with installation limit value of 1 µT
380 kV overhead lines	60 to 80 metres
220 kV overhead lines	40 to 55 metres
110 kV overhead lines	20 to 30 metres
50 kV overhead lines	15 to 25 metres
110 kV underground cables	3 to 6 metres

The cited direct distances from the conductors apply when phasing is optimised. The higher the conductors are suspended, the shorter the minimum lateral distance for compliance with the installation limit value.

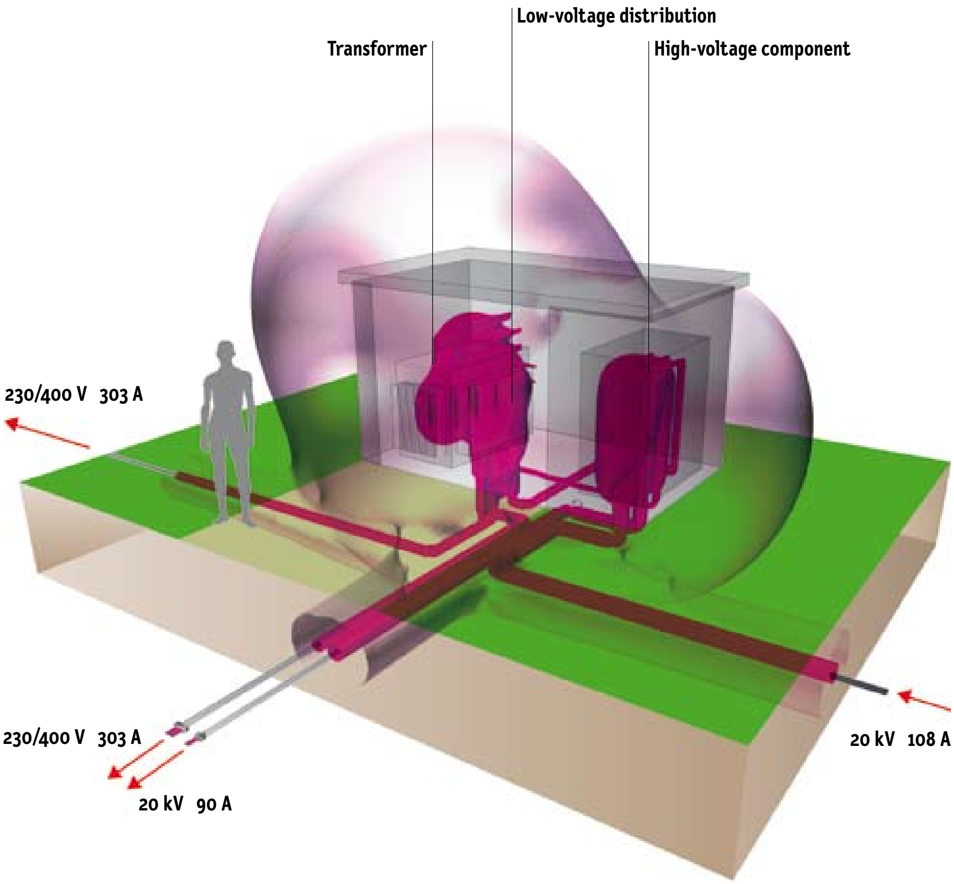


The transmission grid in Switzerland (blue = 380 kV, green = 220 kV).

Magnetic field from a transformer station

Transformers increase or decrease voltages. They are used in power plants, substations, residential areas and industrial zones. Transformer stations in residential areas are fed via the regional electricity distribution network. They change the supply voltage (which ranges from 6,000 up to 30,000 V) to the levels required for use in households (230 and 400 V). A basic transformer station comprises a high-voltage component, a transformer and a low-voltage distributor. Both the low-voltage distributor itself and its connection to the transformer generate the strongest magnetic fields. This is partly because the current is much higher here than it is on the high-voltage side, but also because the spatial separation between the individual conductors in the low-voltage distributor increases the magnetic fields still further.
Since there are numerous types of transformer stations, it is very difficult to make generally applicable indications of the magnetic fields they cause.

In addition to high-voltage power lines, sub-stations, too, produce relatively intensive magnetic fields within their fenced-in area.

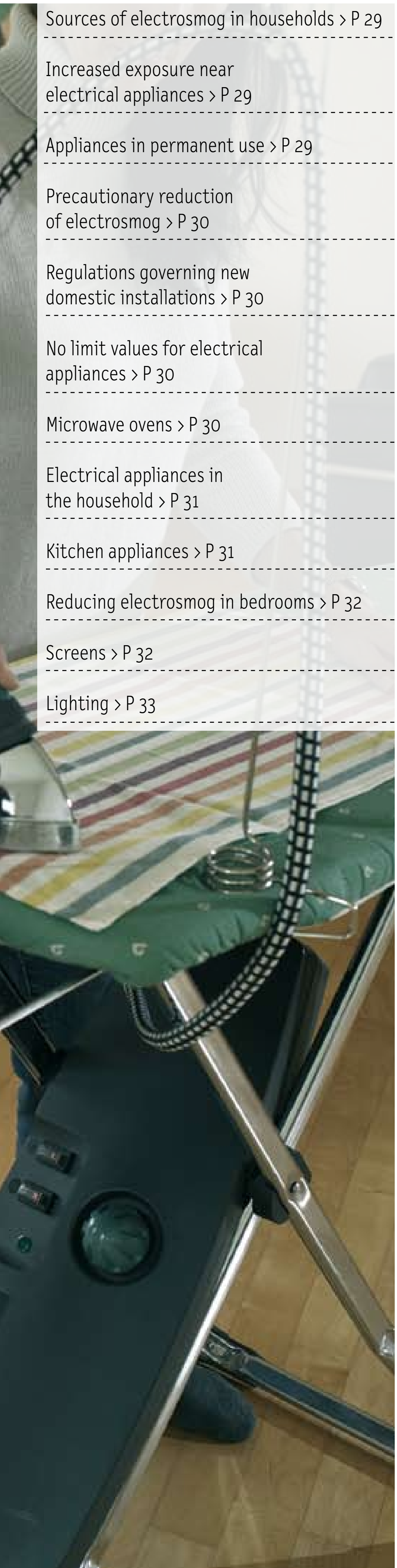


Depiction (in perspective) of the magnetic field of a walk-in transformer station at full load (630 kVA). In the dark-red sections, the magnetic field exceeds 100 µT, and at the perimeter of the lighter zone it is 1 µT. This is a well-designed transformer station with optimised components. The magnetic field of transformer stations that are not so well designed can have a much wider extension.

In most homes, field exposure is not dominated by external sources, it is mostly caused by electrical appliances we use indoors. Here we ourselves are able to exercise precaution and reduce our level of exposure by taking basic measures. For example, we should avoid placing permanently operated electrical appliances in locations where people spend lengthy periods of time.

Electrical appliances in the home are usually the main source of exposure

Contents



Sources of electrosmog in households > P 29
Increased exposure near electrical appliances > P 29
Appliances in permanent use > P 29
Precautionary reduction of electrosmog > P 30
Regulations governing new domestic installations > P 30
No limit values for electrical appliances > P 30
Microwave ovens > P 30
Electrical appliances in the household > P 31
Kitchen appliances > P 31
Reducing electrosmog in bedrooms > P 32
Screens > P 32
Lighting > P 33

Sources of electrosmog in households

In our own home we can also be exposed to electrosmog from external sources such as nearby high-voltage power lines, railway catenaries, mobile phone base stations, etc., but in most cases a large proportion is in fact home-made. Electrosmog in households is made up of the following emissions:

- Low-frequency electric and magnetic fields from domestic installations, i.e. fixed distribution and fuse boxes/panels, electricity cables, mains sockets, as well as extension cables
- Low-frequency fields from lighting and electrical appliances
- High-frequency electromagnetic radiation produced by cordless phones or wireless networks for computers (see page 52).

Increased exposure near electrical appliances

In houses connected to the electricity mains, the typical background level of the magnetic field from the power supply is between 0.02 and 0.04 microtesla (μT). This applies to the vast majority of buildings that are located outside the area of direct exposure to sources such as high-voltage transmission lines, railway catenaries and transformer stations.

These exposures are normally superimposed by magnetic fields from electrical appliances inside the building. Exposure can be significantly higher in the immediate vicinity of appliances that produce strong magnetic fields:

- High consumption appliances that generate heat, e.g. cookers, boilers, hairdryers, clothes irons
- Appliances with magnetic coils or transformers, e.g. TV sets, low-voltage halogen lamps, clock radios
- Appliances equipped with an electric motor, e.g. drills, food mixers, vacuum cleaners.

In the case of hairdryers, for example, magnetic fields of more than 100 μT can occur directly on the casing surface, but their level diminishes quickly with increasing distance. Depending on the type of hair-

dryer, the magnetic field falls to between 0.01 and 7 μT at a distance of 30 centimetres, and to between 0.01 and 0.3 μT at a distance of 1 metre. A similar situation applies to electric cooker tops: in the immediate vicinity, their magnetic field is between 1 and 50 μT, but this weakens to 0.15 to 8 μT at a distance of 30 centimetres, and falls to between 0.01 and 0.04 μT at a distance of 1 metre.

Appliances in permanent use

As a rule, our exposure to magnetic fields from appliances like those cited above is only short term because they are not in permanent use. However, the situation is different when it comes to appliances that are in use all the time, e.g. clock radios. If such devices are used in places where people spend several hours a day (e.g. bedrooms, living rooms), this can lead to long-term exposure. It is possible to significantly reduce the level of exposure by maintaining an adequate distance from appliances that are permanently in use. In the case of a clock radio, for example, at a distance of around 1 metre the magnetic field is no greater than the background level in the building. Since magnetic fields are able to penetrate even solidly constructed walls at virtually full strength, it is important to also pay attention to the situation in neighbouring rooms when deciding where to place permanently operated appliances.

Precautionary reduction of electrosmog

There are several simple precautionary measures we can take to reduce the level of exposure to non-ionising radiation at home:

– Switching off and unplugging appliances. Appliances continue to consume electricity even in standby mode, and they therefore produce a magnetic field. If we switch them off when we no longer need them, the magnetic field also disappears. And if we even unplug such devices when we do not need to use them for longer periods, we can also eliminate the electric field.
– Maintaining adequate distance from electrical appliances. Since field intensity diminishes with increasing distance from the source, we should maintain an adequate distance between electrical appliances and our preferred spots of stay. The recommended minimum distance from clock radios is 1 metre, and from TV sets it is 2 metres. And since magnetic fields are able to pass through walls without obstruction, these distances also apply to appliances in neighbouring rooms.
– Avoiding the long term use of electrical appliances close to the body. Electrical installations and appliances that are in use for lengthy periods of time (e.g. electric floor heating systems) can cause high levels of exposure. This applies especially if appliances are used close to the body, as is the case with electric blankets and electric water beds. Here, too, switching off such appliances and unplugging them during the night reduces the level of exposure.

Regulations governing new domestic installations

The ONIR does not specify any installation limit value as a precautionary emission limitation for domestic electrical installations, but it does contain technical requirements concerning the arrangement of cables and distribution systems in order to reduce field intensities. All new installations have to correspond to the recognised status of technology. This includes star-shaped arrangements of power feeds (wherever possible), avoidance of loops in power feeds, and installation of main distribution systems at a sufficient distance from bedrooms.

The ONIR applies to stationary installations and does not specify limit values for electrical appliances. But intensive magnetic fields also occur in the immediate vicinity of household appliances.

No limit values for electrical appliances

In Switzerland, there are no legally binding limit values concerning non-ionising radiation from electrical appliances. Technical measures to reduce electric and magnetic fields are certainly desirable, but in order to avoid trade barriers, these need to be defined at an international level. Corresponding standards currently exist for computer monitors (e.g. TCO label).
The intensity of fields produced by electrical appliances must not be compared with the limit values specified by the ONIR for installations such as high-voltage transmission lines or transformer stations. Electrical appliances produce localised, non-homogeneous fields, whereas the limit values specified by the Ordinance apply to more extensive fields.

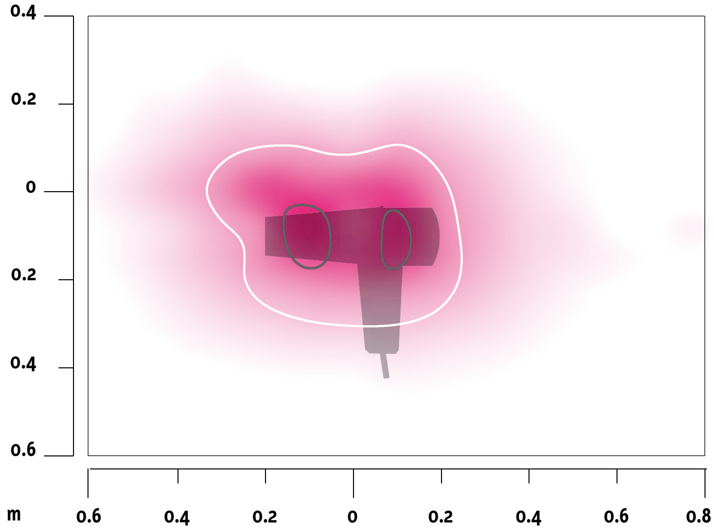
Microwave ovens

To cook foodstuffs, microwave ovens use the heat produced by high-frequency radiation with a frequency of 2.45 gigahertz (GHz). Thanks to screening and other protective measures, almost no radiation escapes from microwave ovens.
It is not possible to screen out radiation altogether, but as long as the microwave oven is intact, the amount of radiation that is able to escape through the door and seals is so low that it does not represent a health hazard. However, if the door seal should be heavily soiled or damaged, higher levels of radiation may escape under certain circumstances. The following measures can be taken to reduce radiation from microwave ovens:

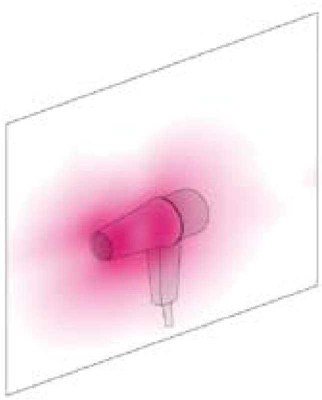
– The door seal and casing should be checked periodically to make sure they have not been damaged. Microwave ovens that have been damaged or have been in use for several years should be checked by specialists, and replaced if necessary.
– Keep the eyes sufficiently away from the door while the microwave oven is in operation.
– A distance of at least 1 metre should be maintained from a microwave oven if it is used for a lengthy period of time.

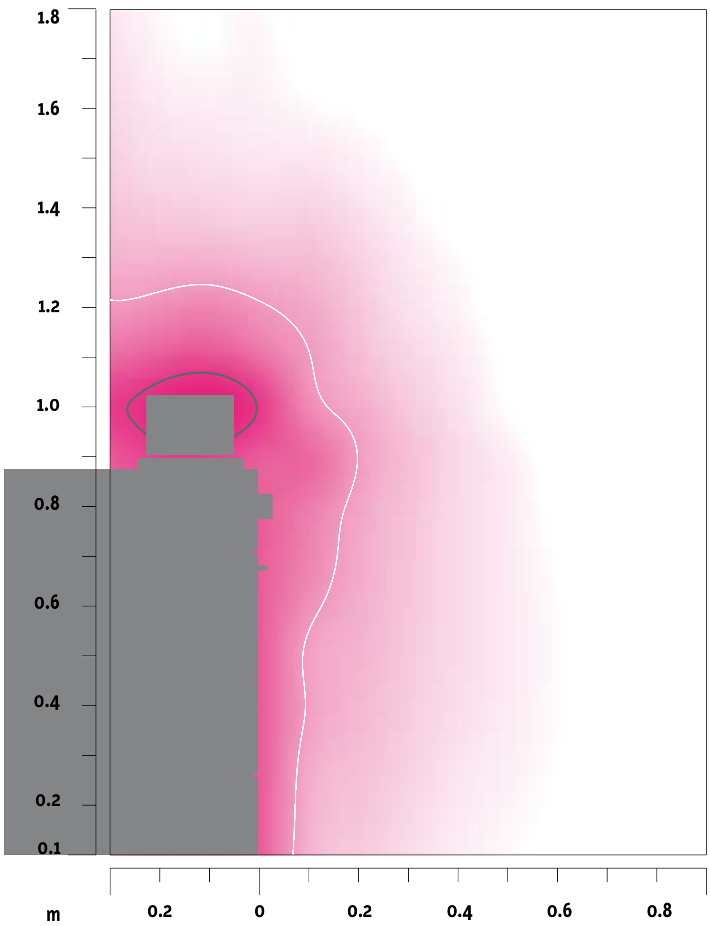
Electrical appliances in the household			
Appliance	Magnetic field (µT)		
	Distance of 3 centimetres	Distance of 30 centimetres	Distance of 1 metre
Hairdryer	6 – 2000	0.01 – 7	0.01 – 0.3
Electric shaver	15 – 1500	0.08 – 9	0.01 – 0.3
Drill	400 – 800	2 – 3.5	0.08 – 0.2
Electric saw	250 – 1000	1 – 25	0.01 – 1
Vacuum cleaner	200 – 800	2 – 20	0.1 – 2
Washing machine	0.08 – 50	0.15 – 3	0.01 – 0.15
Clothes dryer	0.3 – 8	0.1 – 2	0.02 – 0.1
Clothes iron	8 – 30	0.1 – 0.3	0.01 – 0.03

Kitchen appliances			
Appliance	Magnetic field (µT)		
	Distance of 3 centimetres	Distance of 30 centimetres	Distance of 1 metre
Electric cooker top	1 – 50	0.15 – 8	0.01 – 0.04
Microwave oven	40 – 200	4 – 8	0.25 – 0.6
Refrigerator	0.5 – 2	0.01 – 0.3	0.01 – 0.04
Coffee machine	1 – 10	0.1 – 0.2	0.01 – 0.02
Hand-held mixer	60 – 700	0.6 – 10	0.02 – 0.25
Toaster	7 – 20	0.06 – 1	0.01 – 0.02

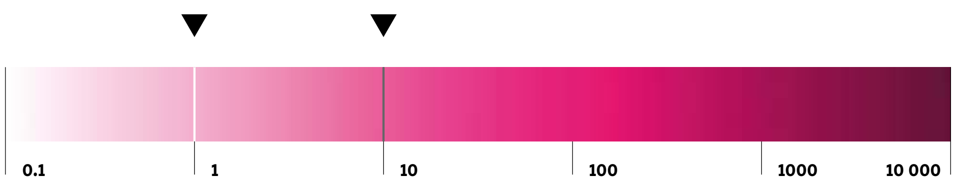


Magnetic field of a hairdryer. The most intensive fields occur close to the casing. The significance of the solid lines is indicated in the colour scale below.

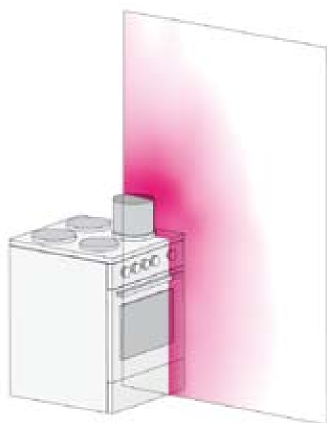




Like all appliances that consume high levels of electricity to produce heat, electric cookers (hotplates) generate intensive magnetic fields. However, the exposure quickly diminishes with increasing distance.



Scale of magnetic flux density in microtesla (µT).



Reducing electrosmog in bedrooms

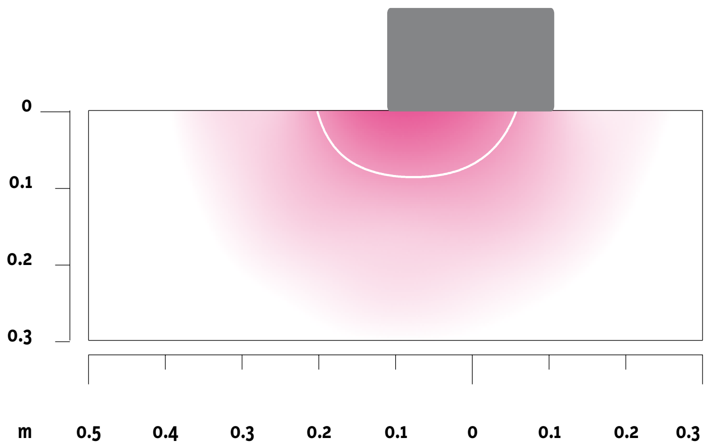
We spend about a third of our life in bed. In view of this, the situation in bedrooms is of particular importance. If we place electrical appliances in the wrong locations, we risk lengthy exposure to their electric and magnetic fields. For example, the magnetic field of a clock radio placed near the head of the bed can extend well into the bed, but at distance of 1 metre it is practically no longer detectable.
To reduce exposure to non-ionising radiation while we sleep, the following recommendations should be observed:
- Appliances such as computers and TV sets in the bedroom and in neighbouring rooms should be placed at a minimum distance of 2 metres from the bed. During the night, appliances should be switched off completely (not left in standby mode).
- Electrical appliances for monitoring babies and small children should also be kept at least 2 metres away from their bed.
- Mains powered clock radios should never be kept close to the head (minimum distance, 1 metre).
- Never sleep on electric cushions or electric blankets for lengthy periods if they are switched on.
- No extension cables should be placed beneath the bed.
- Beds should not be placed near electric risers or fuse boxes/panels.

Screens

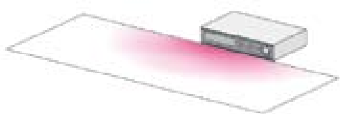
Cathode ray monitors for computers and TV sets generate different types of fields and radiation: electrostatic fields, low-frequency electric and magnetic fields, high-frequency non-ionising radiation and weak X-rays. To reduce exposure from screens and monitors, the following recommendations should be observed:
- **TCO label:** when buying a new screen, look for the TCO label (originally from Sweden). Labels like TCO 99 or TCO 03 indicate low-radiation computer screens.

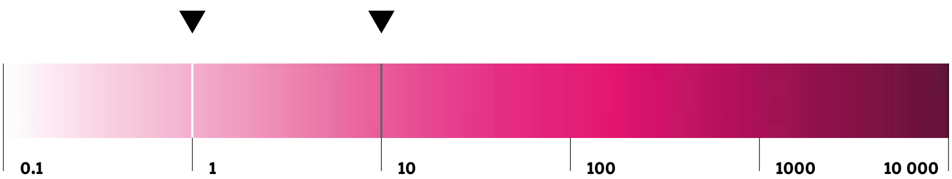
- Maintain an adequate distance: maintain a distance of at least 50 centimetres from computer monitors, and a minimum distance of 2 metres from TV screens (also applies in adjacent rooms).
- **Flat screens produce less electrosmog:** since they consume electricity, flat screens also generate low-frequency electric and magnetic fields, but otherwise they are free of radiation.

Appliance	Magnetic field (μT) Distance of 3 centimetres	Distance of 30 centimetres	Distance of 1 metre
Clock radio	3–60	0.1–1	0.01–0.02
Electric blanket	Up to 30		
TV set	2.5–50	0.04–2	0.01–0.15
Monitor with TCO label		0.2 (50 cm)	
Electric floor heating		0.1–8	
Stove	10–180	0.15–5	0.01–0.25



Magnetic field of a clock radio. To avoid long-term exposure while asleep, permanently operated electrical appliances like clock radios should be kept at least one metre away from the bed. The significance of the solid lines is indicated in the colour scale below.





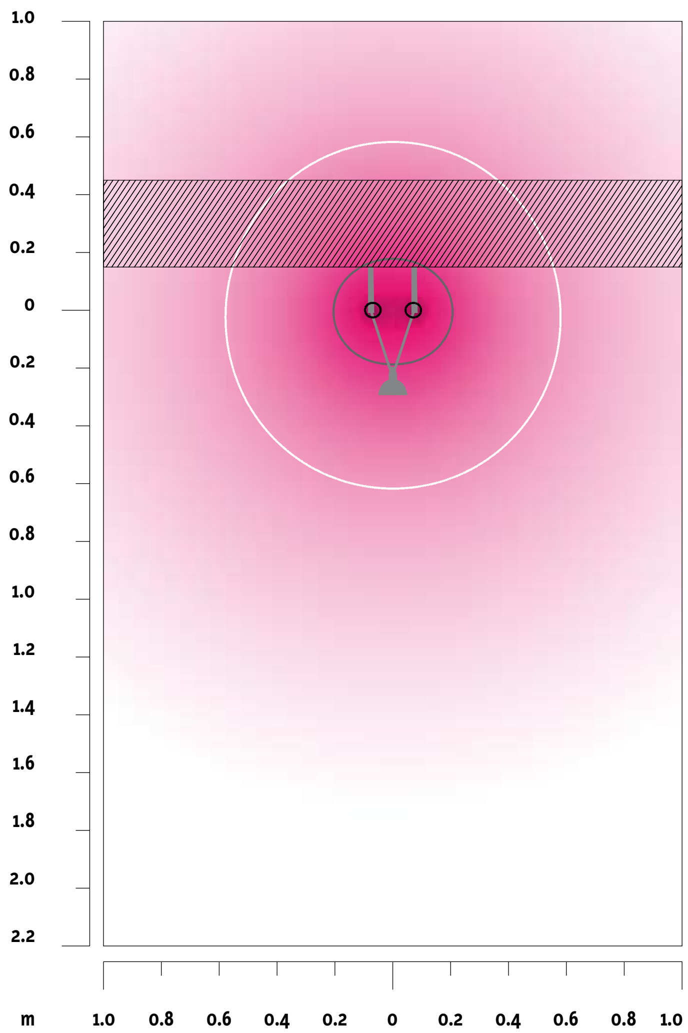
Scale of magnetic flux density in microtesla (μT).

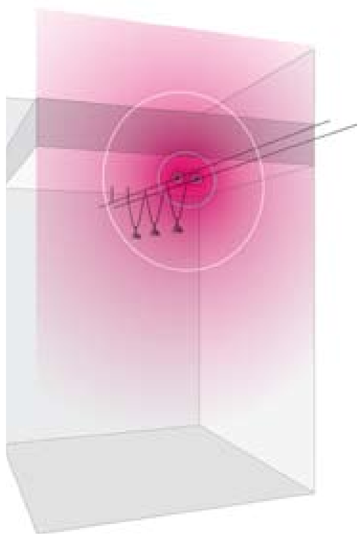
Lighting

Lighting systems such as low-voltage halogen lamps produce relatively intensive magnetic fields. These originate partly from the transformers that reduce the normal voltage in the household from 230 to 12 V, and partly from the current-bearing wires. In order to yield the same light output, the current in the cables of lamps operated with low voltage has to be higher than is the case in conventional lighting systems, and this means that the magnetic fields are also stronger. In addition, if the current conductors are not close together, the field intensifies and can also be measured on the floor above.
To reduce exposure, the following points should be observed when buying lighting equipment:

- **Filament bulbs.** These produce the lowest magnetic fields of all forms of lighting, but in view of their poor light efficiency they require significantly more electricity than energy-efficient lamps.
- **Energy-efficient lamps.** These produce slightly stronger fields than filament lamps due to the choke in the base, but the fields disappear already at a distance of around 50 centimetres. Thanks to their lower electricity consumption and longer service life, these lamps are more ecological than filament bulbs.
- **Fluorescent tubes.** Since their fields are more intense than those from energy-efficient lamps, a distance of at least 1 metre is recommended.
- **Low-voltage halogen systems.** These produce the strongest magnetic fields of all forms of lighting. It is recommended to install transformers and conductors at a distance of at least 2 metres from frequently occupied areas.

Appliance	Magnetic field (µT) Distance of 3 centimetres	Distance of 30 centimetres	Distance of 1 metre
Filament bulb (60 W)	0.1–0.2		
15-watt energy-efficient lamp (with electronic choke)	1	0.1	
Halogen table lamp	25–80	0.5–2	Up to 0.15
Low-voltage halogen lighting			Up to 0.3





Low-voltage halogen lighting systems produce the strongest magnetic fields of all forms of electric lighting. If they are installed on the ceiling, they can also cause considerable levels of exposure in rooms located directly above.

The magnetic fields from the catenary system (railway contact and feeder lines) fluctuate considerably. When locomotives accelerate or brake, they increase the flow of current and this intensifies the magnetic field. The busier the route, the higher the exposure levels.

Contents

Electric fields from catenaries > P 35

Large fluctuations of the magnetic field > P 35

Special characteristics of the railway power supply > P 35

Focusing the reverse current > P 36

Precautionary regulations of the ONIR > P 36

Exposure inside trains > P 37

Motor cars are not an alternative > P 37

Direct current (DC) transport systems > P 37

Highly fluctuating magnetic fields along railway lines

Electric fields from catenaries

Most railway services in Switzerland are operated with alternating current with a frequency of 16.7 Hz. This means that electric and magnetic fields occurring alongside railway lines also have this frequency.
The strength of the electric field directly beneath the catenary (e.g. at a level crossing) is around 1,500 volts per metre (V/m), and it decreases with increasing distance. The applicable exposure limit value in Switzerland for 16.7 Hz electric fields – 10,000 V/m – is therefore easily complied with. And since the voltage in the catenary remains fairly constant, independently of the level of operation, the electric field also does not vary – unlike the magnetic field.

Large fluctuations of the magnetic field

Since the catenaries do not always carry the same current, the magnetic fields in the vicinity of railway lines can fluctuate considerably. Whenever locomotives and railcars accelerate or feed electricity back into the network when braking, the current increases, and so does the magnetic field. And locomotives also require more electricity when they are travelling uphill or pulling heavy goods trains.
Typically, current is fed into the contact line at points 25 to 30 kilometres apart. If there is no train travelling along a section between two feed points, no current is flowing and therefore no magnetic field is created. In the example depicted here, this is the case between 1 a.m. and 4.30 a.m. But if there are trains in operation, the magnetic field exists along the entire section in which the locomotives are being supplied with electricity. The exposure alongside the railway line varies according to the amount of traffic along each supply section, the current location of each train and the fluctuating electricity demand of the locomotives.
Since the magnetic fields of the public electricity network and the railway supply network have different frequencies, their intensities cannot be directly compared. Depending on the frequency, the threshold of the magnetic field strength for eliciting health effects is different. The exposure limit values specified in the ONIR and aimed at protecting against short-term effects are 100 microtesla (µT) for 50 Hz magnetic fields, but 300 µT for 16.7 Hz fields.

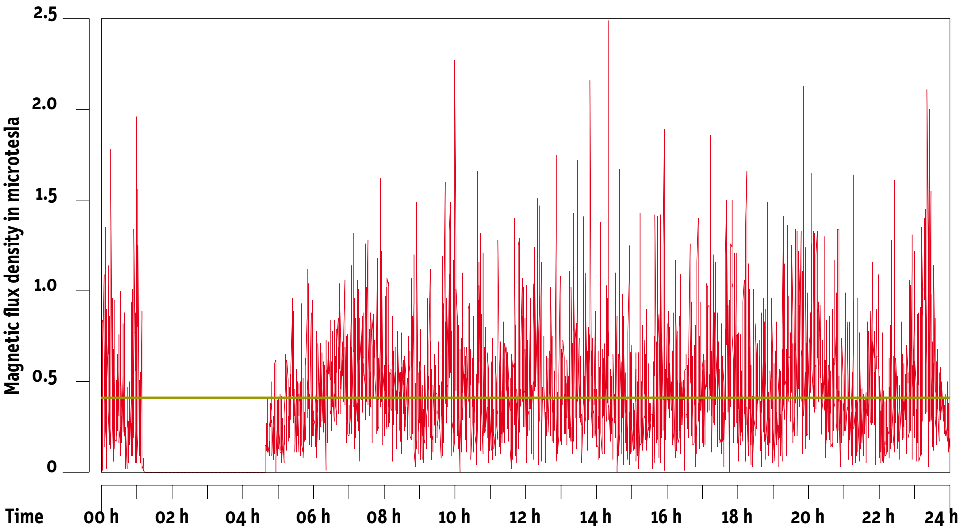
Special characteristics of the railway power supply

Like the public electricity supply network, most railway lines in Switzerland are operated with alternating current. Despite this common factor, however, there are certain significant differences that also affect magnetic fields in the vicinity of railway power supply systems:

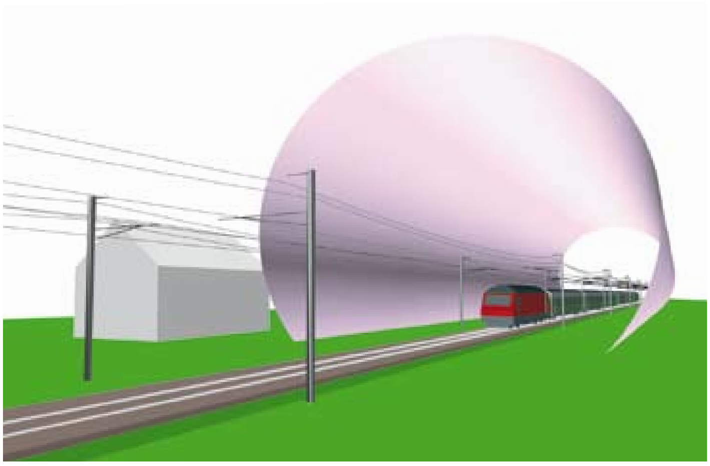
Lower frequency: The railway power supply has a frequency of 16.7 hertz (Hz), whereas the frequency of the public electricity supply is 50 Hz. This difference can be attributed to the fact that the earliest electric motors for trains required the lowest possible frequency in order to function reliably. In view of this, at the beginning of the 20th century a number of European countries (including Switzerland) agreed, after various trials, to adhere to the frequency of 16.7 Hz, which is still used today. This decision called for the construction and operation of a separate electricity supply network for railways, and as a result, major railway operators like the SBB (Swiss Federal Railways) possess their own power plants and own transmission lines. But in addition, they also use 50 Hz alternating current from the public grid, which has to be converted to 16.7 Hz by means of frequency changers. Electricity generated in power plants is fed to the railway sub-stations via separate high-voltage transmission lines at 132 kilovolts (kV). The voltage is then reduced to 15 kV, the level required by locomotives.

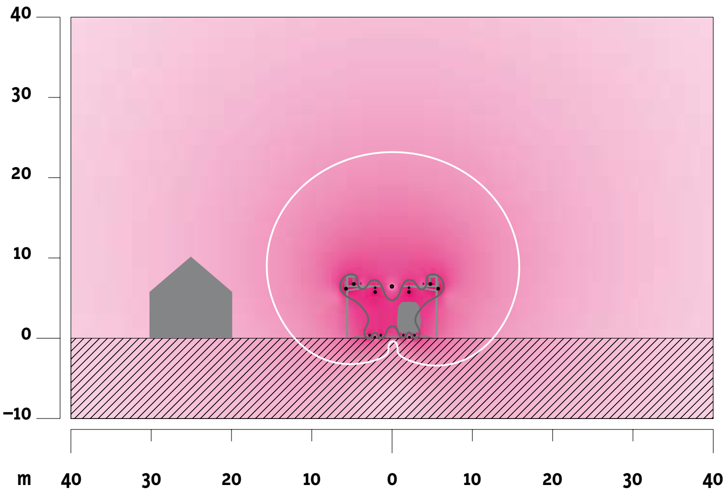
Fewer current conductors: The public electricity supply is a three phase system – here the circuit comprises three phase conductors. By contrast, the transmission network for the railway electricity supply uses only a feed and a reverse conductor, both of which are live. Along the railway line itself, the power required by locomotives is fed only via the contact line, while the reverse current passes through the rails, the return wire and the soil.

Mobile power consumers: As a rule, electrical appliances and machines are used at a fixed location, but locomotives fed by the railway supply network are constantly on the move. They can even generate current themselves when applying electric brakes: here the engine becomes a generator that converts brake energy into electricity which it feeds back into the supply network.

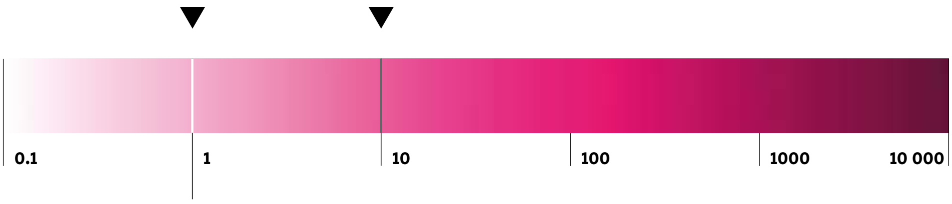


16.7 Hz magnetic field on the double track railway line between Lucerne and Basel near Nottwil, measured at a distance of 10 metres from the centre of the rails: the exposure level fluctuates depending on traffic volume. If there are no trains on this stretch, there is no exposure. The 24-hour average level (green line) is 0.41 microtesla. This is of relevance for comparison with the installation limit value, which (again averaged over a 24-hour period) is 1 microtesla, and is therefore complied with in this example.

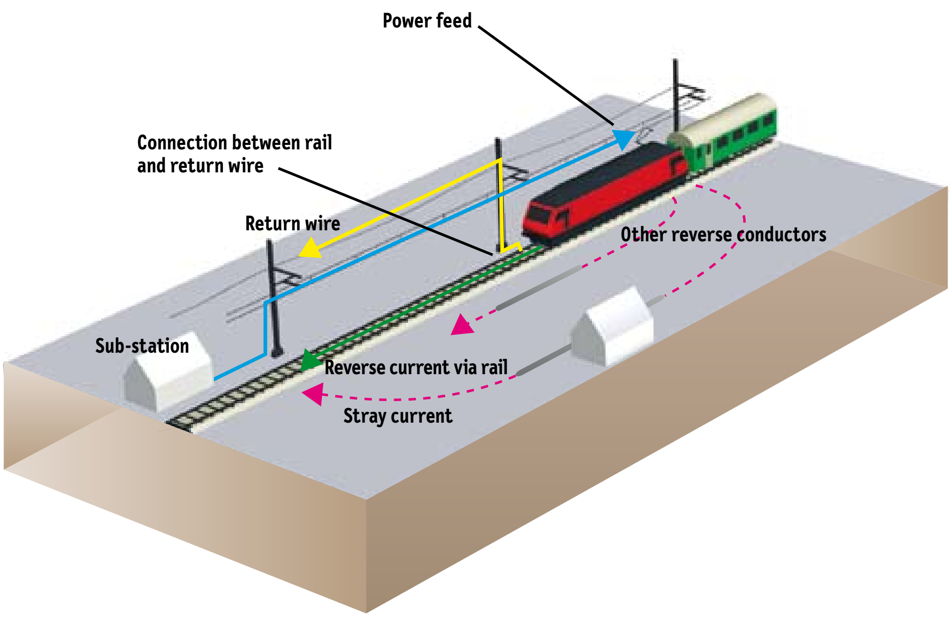




Magnetic field on a typical double track railway line. The magnetic flux density at the perimeter of the tunnel-like area (perspective view, left) is 1 microtesla (average over a 24-hour period). The cross-section of the magnetic field vertical to the railway line (right) shows how exposure diminishes with increasing distance from the contact line. The grey line represents a 24-hour average level of 10 µT, and the white line depicts a reading of 1 µT.



Scale of magnetic flux density in microtesla (µT).



Power is fed from the sub-station to the locomotive via the contact line (blue arrow). The current then flows back to the sub-station via the rails (green arrow), the return wire (yellow arrow), the soil and other reverse conductors in the ground (red arrows). The spatial extension of the magnetic field of a railway catenary is relatively broad due to the distance between the power feed and reverse currents.

Focusing the reverse current

The fact that the feeds and reverse currents are fairly far apart is another factor that is of significance with respect to the intensity of magnetic fields from railway catenary systems. Electricity is fed via the contact line, whereas the reverse current flows via the rails and the return wire. Due to the contact between the rails and the ground, however, some of the reverse current flows through the soil or via underground metal pipes (e.g. those used for gas or water supply). Stray currents of this sort can propagate over considerable distances and only return to the railway line in the vicinity of the sub-station.
The further apart the feed and reverse currents are, the greater the reach of the magnetic field (at the same current). To reduce this, the best solution is for the largest possible fraction of reverse current to flow via the return wire, since this is closest to the contact line.

Precautionary regulations of the ONIR

The precautionary emission limitations for catenary systems specified in the ONIR vary according to whether the installation is new, to be modified or old.

– **New installations:** These include catenary systems for new railway lines and for lines that are to be re-routed. At places of sensitive use they are required to comply with the installation limit value of 1 microtesla (µT). This is measured as a 24-hour average. On a double track line, for example, the specified installation limit value is normally complied with from a distance of between 10 and 25 metres from the contact line, depending on the traffic volume. In certain exceptional circumstances, the relevant authorities may allow the installation limit value to be exceeded.

– **Installations to be modified:** In the ONIR the term "modified" refers to the addition of tracks to an existing railway line. At places of sensitive use at which the installation limit value was already exceeded prior to the implemented changes, the magnetic field intensity must not be increased. At all other places of sensitive use, the installation limit value must be complied with. As with new installations the specified requirements may be eased in certain circumstances.

– **Old installations:** This term refers to catenary systems that are not being modified or that are renewed on existing lines. If the installation limit value is exceeded at places of sensitive use, these systems have to be equipped with a return conductor (earth wire) placed as close to the contact line as possible. This is already the case on most railway stretches today. The ONIR does not require any further measures for old installations.

Exposure inside trains

We are also exposed to magnetic fields when we are inside a train. These fields are produced partly by the currents in the catenary system and the rails, but also by the on-board power supply that is required for lighting, heating and air-conditioning purposes. This internal power supply consists of a special cable that is fed by the locomotive and runs beneath each coach right along the entire length of the train.

Measurements carried out in a double-decker train on the stretch between Bern and Zurich have shown that the magnetic fields fluctuate considerably throughout the journey, and can also vary greatly in different parts of the train. The magnetic field was found to be at its strongest on the lower level near the locomotive. At seat level, the mean reading for the journey was 4 μT, and short-term peak levels of up to 10 μT were recorded. At this position the main source of the magnetic fields is the supply cable running beneath each coach, whose importance diminishes with increasing distance from the locomotive. On the upper level of the first coach behind the locomotive, and on both levels at the other end of the train, the magnetic field intensity was approximately the same (average level for the full journey, around 0.7 μT, with short-term peaks of up to 3.5 μT).

Since trains are not included in the definition of places of sensitive use, no precautionary limitation applies inside railway coaches for the magnetic field.

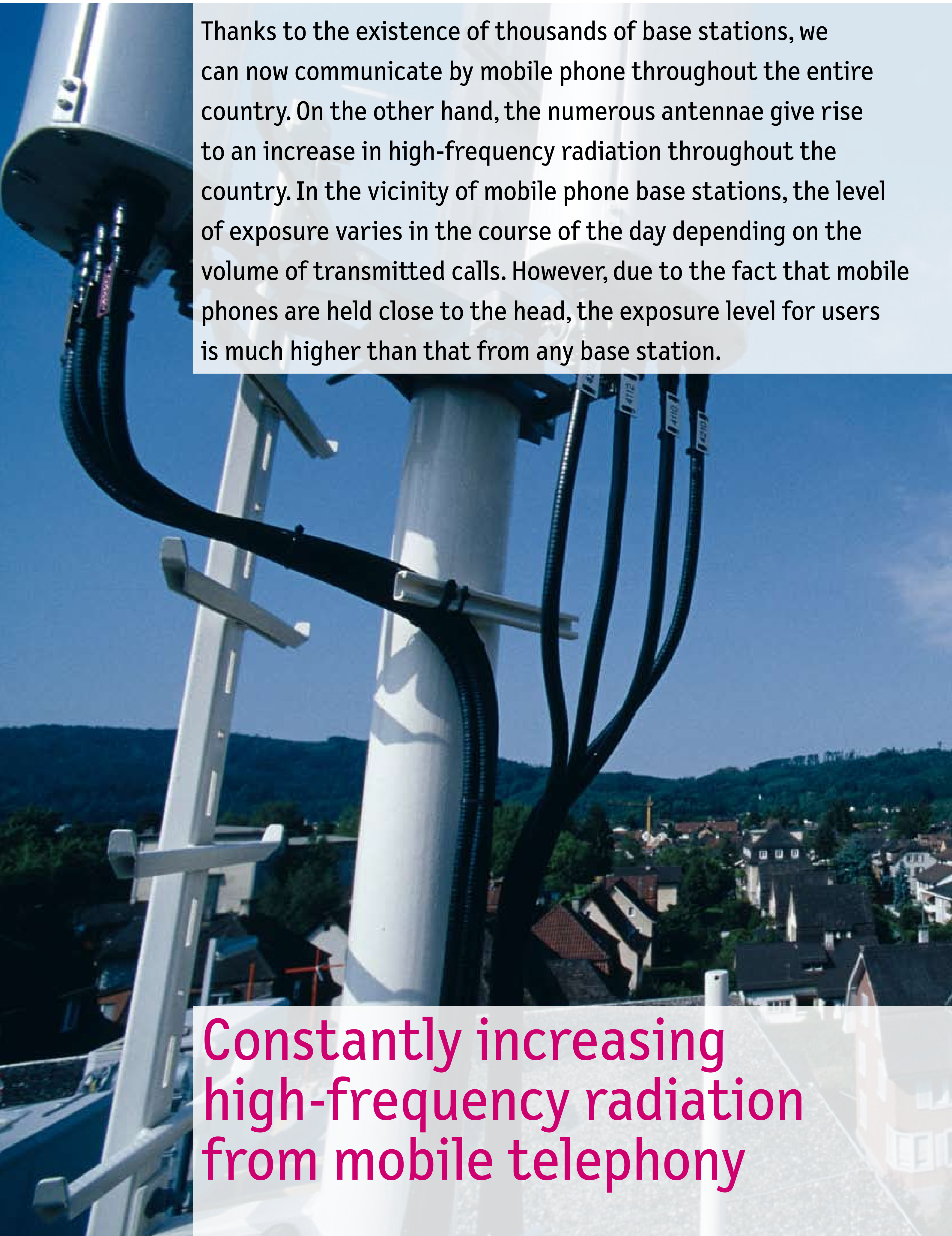
We are also exposed to magnetic fields when we are inside a train. The level of exposure varies according to the part of the train we are in.

Motor cars are not an alternative

The presence of magnetic fields inside trains is not a reason for changing the means of transport, however: magnetic fields also occur in motor cars. These are partly attributable to on-board electrical systems, but can also be produced from magnetised wheel rims and steel belts in tyres. Measurements carried out inside moving cars showed that the highest exposure occurs in the area around the passenger's feet and on the rear seat. Readings varied greatly from model to model, and covered the same range as fields inside trains.

Direct current (DC) transport systems

Trams, trolley buses and some narrow-gauge railways are operated with direct current, and these systems produce static (DC) electric and magnetic fields. For DC magnetic fields, the ONIR specifies an exposure limit value of 40,000 μT, and this level is always complied with by a very large margin. Research has not yielded any indications of potential health risks associated with DC fields encountered in everyday life, and for this reason the Ordinance does not specify any installation limit value for DC transport systems.

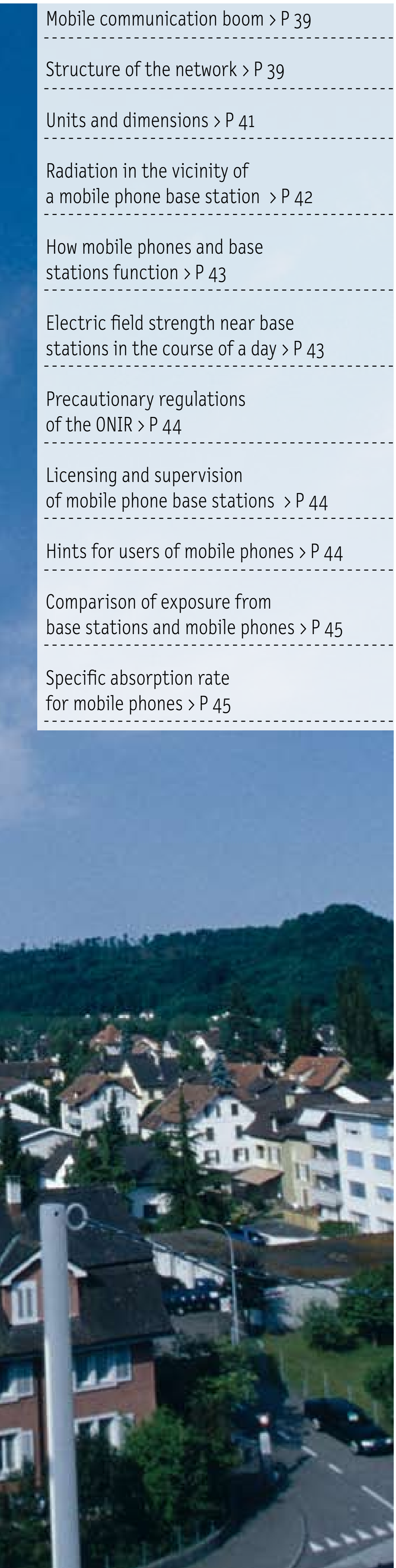


Thanks to the existence of thousands of base stations, we can now communicate by mobile phone throughout the entire country. On the other hand, the numerous antennae give rise to an increase in high-frequency radiation throughout the country. In the vicinity of mobile phone base stations, the level of exposure varies in the course of the day depending on the volume of transmitted calls. However, due to the fact that mobile phones are held close to the head, the exposure level for users is much higher than that from any base station.

Constantly increasing high-frequency radiation from mobile telephony

Contents

Mobile communication boom > P 39
Structure of the network > P 39
Units and dimensions > P 41
Radiation in the vicinity of a mobile phone base station > P 42
How mobile phones and base stations function > P 43
Electric field strength near base stations in the course of a day > P 43
Precautionary regulations of the ONIR > P 44
Licensing and supervision of mobile phone base stations > P 44
Hints for users of mobile phones > P 44
Comparison of exposure from base stations and mobile phones > P 45
Specific absorption rate for mobile phones > P 45



The fact that we hold a mobile phone so close to our head when calling means that the level of exposure is much higher than that from a base station antenna.

Mobile communication boom

The majority of the population of Switzerland now own a mobile phone, and more than 9,000 base stations ensure that we can make calls with them from almost anywhere in the country. After 1993, the GSM mobile communication standard gradually replaced the existing Natel C network and thus contributed towards the boom in mobile telephony. In 2002 the implementation of UMTS—a third generation network—was initiated. But the constantly expanding range of services and growing demand in the area of mobile communication are also resulting in increasing exposure to high-frequency electromagnetic waves. By contrast with electricity supply, in which radiation is an undesirable by-product, in the area of mobile communication it is used deliberately as a means of transmitting data without wire.

Structure of the network

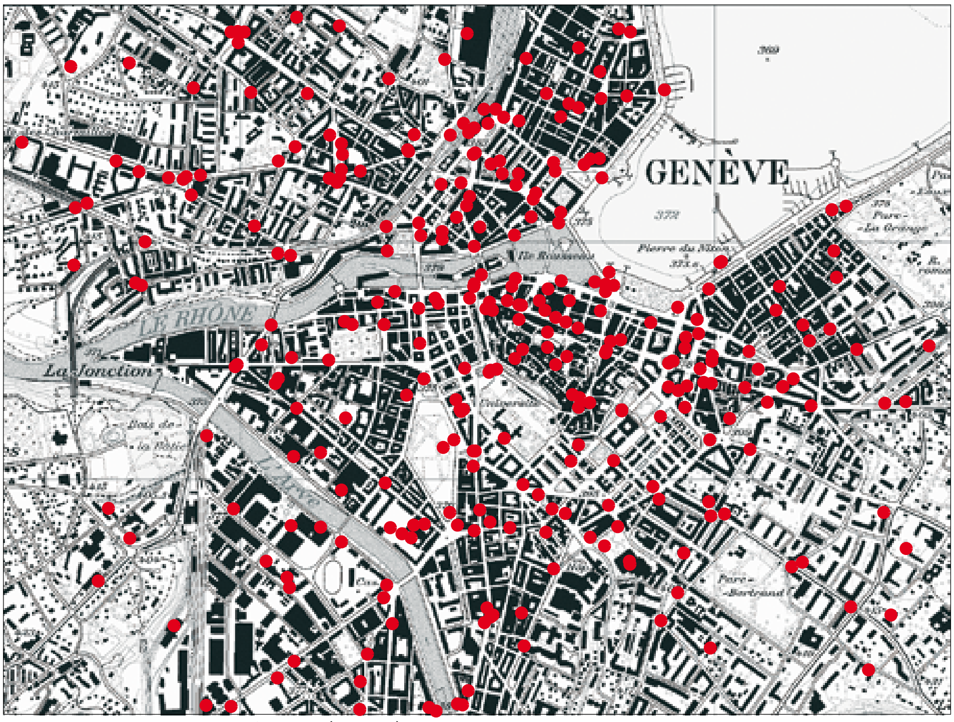
A mobile communication network comprises multiple cells. Each cell has an antenna that establishes a wireless connection to the mobile phones in its vicinity. Normally a number of cells are supplied from a given location, and all the antennae at this location form a base station.
Base stations are linked to a network switching centre via standard cable connections or via point-to-point microwave links. From here they receive calls that they have to pass on to mobile phones in their cells. And vice versa, they also transmit calls to this switching centre that are being made with a mobile phone in their supply area.
Each base station can only transmit a limited number of calls. The range of each cell is thus determined by the intensity of utilisation. In rural areas with low mobile phone density, cells can have a radius of several kilometres, whereas in urban centres they only have a range of a few hundred metres. And the micro-cells frequently used in town centres are even

GSM: the GSM (Global System for Mobile Communications) standard has been in use in Switzerland since 1993. GSM networks operate in two frequency ranges: 900 MHz (GSM900) and 1,800 MHz (GSM1800).

UMTS: UMTS (Universal Mobile Telecommunications System) is the standard for the third generation of mobile communication. The UTMS network, for which implementation began in 2002, operates in the 2 gigahertz frequency range (1,900 to 2,200 MHz). It is able to transmit much higher volumes of data than GSM, and thus enables the transmission of moving images.

smaller. These are used in areas where call volumes are particularly high, or coverage is difficult due to building density. Finally there are also pico-cells, which have a radius of only a few dozen metres and are used for providing connections within buildings.

The transmitting power of an antenna has to be so high that the signals to be transmitted also reach the mobile phones at the perimeter of the cell. On the other hand, they must not be too intensive, otherwise they would interfere with signals in other cells. Since antennae in small cells operate with a lower transmitting power, they produce a lower level of radiation exposure. Although more antennae are required, the overall power radiated by all base stations is lower, not higher – at least in urban areas. A fine-meshed network can even transmit more calls with an overall lower transmitting power.



Reproduced with the kind permission of swisstopo (BA056863)

Reproduced with the kind permission of swisstopo (BA056863)

The higher the demand for phone services, the greater the density of the mobile communications network, as we can see from a comparison between the city of Geneva and the small country town of Bière (canton of Vaud). Each red dot represents a mobile phone base station. The two maps depict the situation as of 1 June 2004. The locations of all transmitters in Switzerland can be viewed at www.funksender.ch.

Mast with mobile communication antennae (top) and antennae for point-to-point transmission (round). The latter link base stations to the switching centres.

Units and dimensions

Mobile phone antennae transmit high-frequency electromagnetic waves or radiation – also referred to as high-frequency non-ionising radiation.

Frequency: This refers to the number of oscillations of an electromagnetic wave per second, and it is measured in hertz (Hz), megahertz (MHz) or gigahertz (GHz).
1 Hz = 1 oscillation per second
1 kHz = 1,000 Hz
1 MHz = 1,000,000 Hz
1 GHz = 1,000,000,000 Hz
Mobile communication networks in Switzerland operate at 900 MHz (GSM900), 1,800 MHz (GSM1800) and between 1,900 and 2,200 MHz (UMTS).

Transmitting power in watts (W): This indicates how much energy is supplied to an antenna per time unit. Typical levels per direction are between a few thousandths of a watt and 40 to 50 watts. Fluctuations occur in the course of each day due to variable loads of mobile communication systems.

Equivalent radiated power (ERP) in watts: ERP is another means of indicating transmitting power, and is also expressed in watts. It is used for calculating exposure and in Switzerland it is also of relevance for the licensing of mobile phone base stations. ERP levels are significantly higher than those of the transmitting power. For a typical base station antenna, they may be around 30 times higher. They take account of the fact that the radiation from an antenna is not emitted uniformly all round, but rather is focused within a sector. By contrast with the transmitting power, ERP describes the conditions within the main radiation cone. Here the situation may be compared to that of a spotlight. Due to its directional nature, its light is much brighter than that of a normal filament bulb with the same output. In this example, the ERP would correspond to the power required to be fed into a conventional light bulb in order for it to produce the same brightness as the spotlight in its radiation cone.

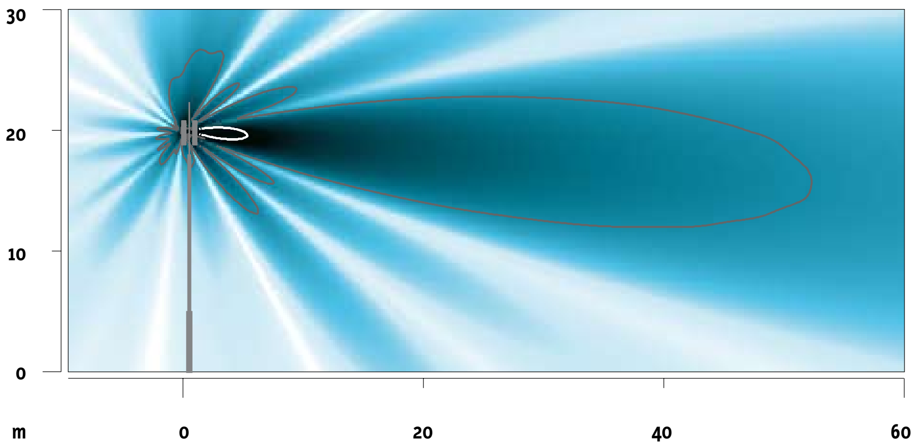
Electric field strength: This indicates the radiation intensity and is measured in volts per metre (V/m).

The antennae installed at base stations establish contact with mobile phones within their range.

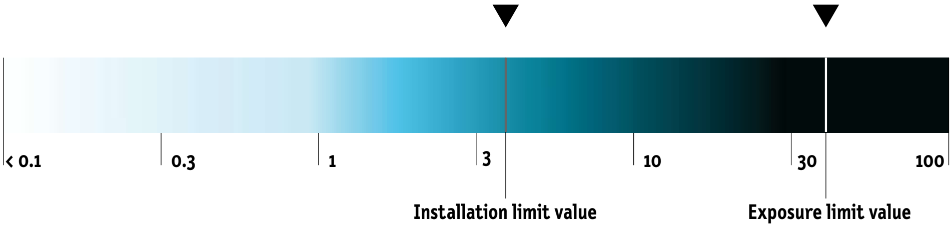
Power flux density: This, too, indicates radiation intensity. It measures the energy flux per unit time through a perpendicular reference area, and is indicated in watts per square metre (W/m^2) or microwatts per square centimetre ($\mu W/cm^2$).
The power flux density can be calculated from the electric field strength, and vice versa. The power flux density is proportional to the square of the electric field strength. Both field parameters are in direct correlation with the transmitting power of an antenna:

- The power flux density is directly proportional to the transmitting power. If the transmitting power is doubled, this means that the power flux density is also doubled.
- By contrast, the field strength only increases by the square root of the transmitting power. If the transmitting power is doubled, the electric field strength therefore only increases by the factor $\sqrt{2}$, which is equivalent to an increase by 41 percent. This physical law is also of significance if two antennae radiate towards the same location from different locations with the same transmitting power. Here, too, the overall field strength is not doubled, but merely increases by 41 percent. In order for the field strength to double, four antennae of the same power would have to transmit to a given location, and 100 antennae would be required for the field strength to increase tenfold.

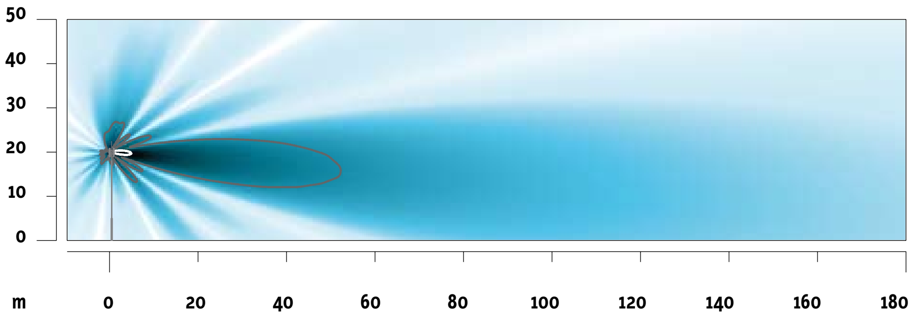
Electric field strength	Power flux density	
(V/m)	W/m²	µW/cm²
61.4	10	1000
33.6	3	300
19.4	1	100
10.6	0.3	30
6.1	0.1	10
3.4	0.03	3
1.9	0.01	1
1.1	0.003	0.3
0.6	0.001	0.1
0.3	0.0003	0.03
0.2	0.0001	0.01



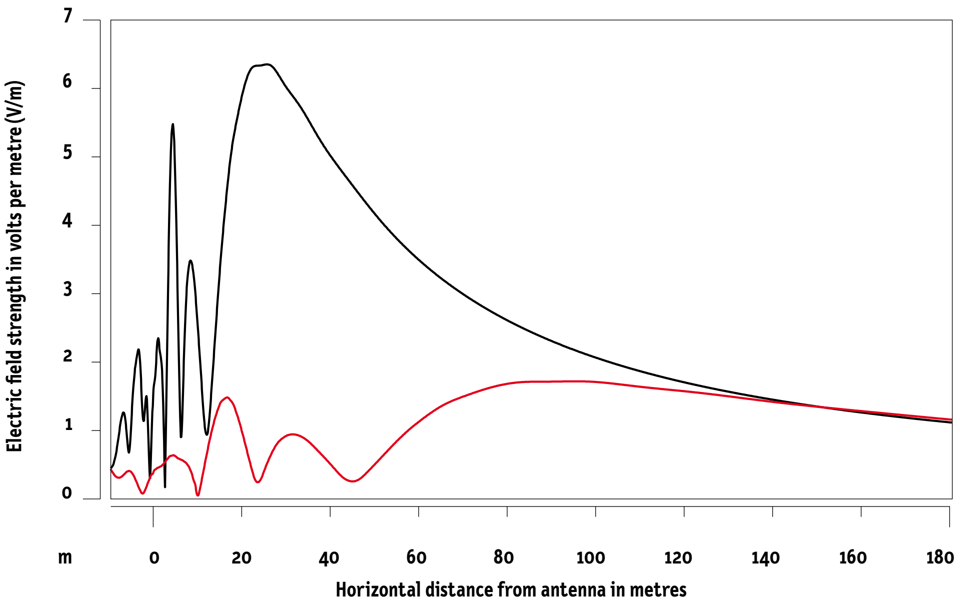
Radiation in the vicinity of a base station antenna with an equivalent radiated power of 1,000 watts in the 900 MHz frequency range (GSM900). The antenna is located on a 20-metre mast and has a slight downward orientation. The significance of the solid lines is indicated in the colour scale below.



Scale of electric field strength in volts per metre (V/m).



Close-up of the radiation pattern of the same antenna as above.



Radiation in the vicinity of a mobile phone base station

The intensity of radiation in the vicinity of a mobile phone base station depends on a variety of factors. All these parameters are taken into account by the licensing authorities for the purpose of calculating exposure due to a planned facility:

- **Equivalent radiated power (ERP):** The higher the radiated power of an installation, the higher the radiation intensity in the vicinity.
- **Spatial radiation pattern of the antenna:** Antennae at base stations do not radiate uniformly in all directions. Instead they focus their radiation – rather like a spotlight – and steer it in the desired main direction. Outside this cone, radiation is still present, but it is greatly reduced. Besides the main direction, we can also identify side lobes.
- **Distance from the antenna:** The electric field strength is halved at twice the distance from the antenna. This applies especially along the main beam. On the ground, however, the situation is more complicated. Exposure in the immediate vicinity of the antenna mainly originates from the side lobes. Outside their range of influence, the field strength gradually increases with increasing distance, since here it is the radiation from the main beam that predominates. In the above example, it reaches its peak at around 90 metres, and only then does it gradually diminish.
- **Attenuation thanks to walls and roofs:** Walls and roofs attenuate radiation that reaches a building from the exterior. This also applies to a building on which an antenna is located. If there are no skylights in a concrete roof, most of the radiation is shielded. However, radiation easily passes through tile and timber roofs and through windows with uncoated panes.

Electric field strength at increasing distance from the antenna depicted above, shown at two different heights above the ground. The black curve shows the exposure along the direction of the main beam at 15 metres above the ground, while the red curve shows exposure 1.5 metres from the ground.

How mobile phones and base stations function

In order to allow a number of people to make phone calls at the same time in a given cell, with GMS up to eight users share the same frequency channel. Each of them is allocated an eighth of the time (time slot) for the transmission. The data are partitioned in separate packages with a duration of 577 microseconds (µs) that are sent at intervals of 4.6 milliseconds (ms) – see Fig. 1. For this reason, mobile phones emit a pulsed radiation with a repetition rate of 217 pulses per second.
GSM mobile phones are equipped with a dynamic output control. When a connection is being established, the phone transmits at maximum output. This level is then reduced until it is just sufficient to maintain an adequate connection with the base station.
In its turn, the base station transmits on a broadcast control channel and on traffic channels.
The broadcast control channel transmits all eight time slots with full transmitting power (Fig. 2). A brief blank out takes place between each time slot. In one time slot, technical data are transmitted that, for example, are required for establishing or maintaining connection. The other time slots on the broadcast control channel are used for transmitting calls or are artificially filled with blank data.
If the capacity of the broadcast control channel no longer suffices to handle all calls, the traffic channels are activated. These only emit radiation in the actually required time slots and are adjusted so that their power output is kept as low as possible (Fig. 3). The temporal transmission pattern of a traffic channel varies according to the number of transmitted calls and the quality of the connections. In the example shown here, time slots 2 to 4 each operate at a different transmitting power, and time slots 1 and 5 to 8 are not activated.

Fig. 1: Mobile phone

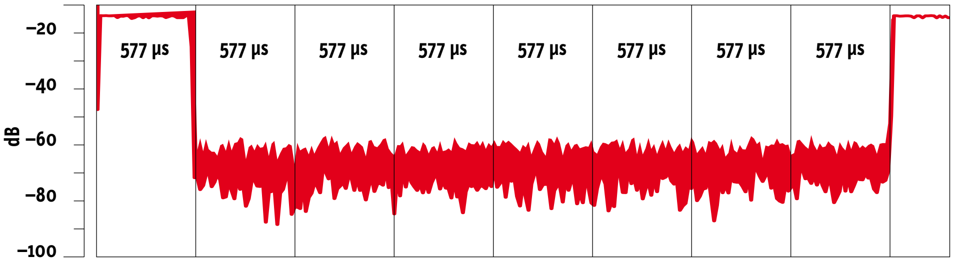


Fig. 2: Base station: broadcast control channel

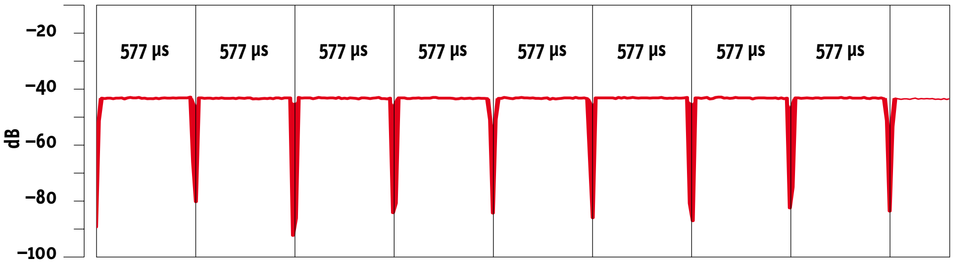
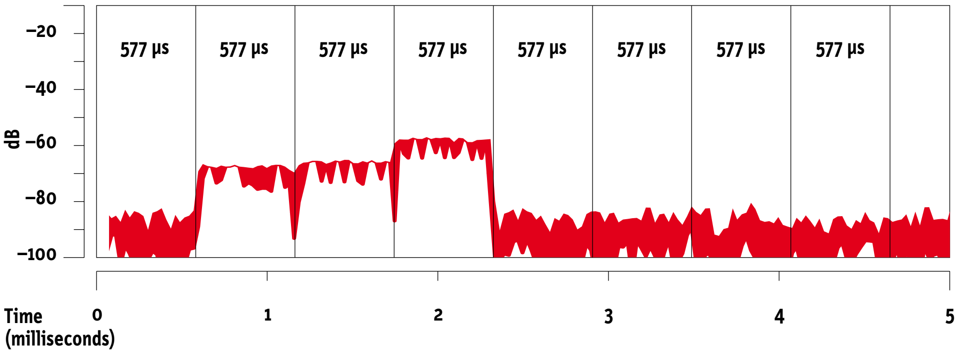
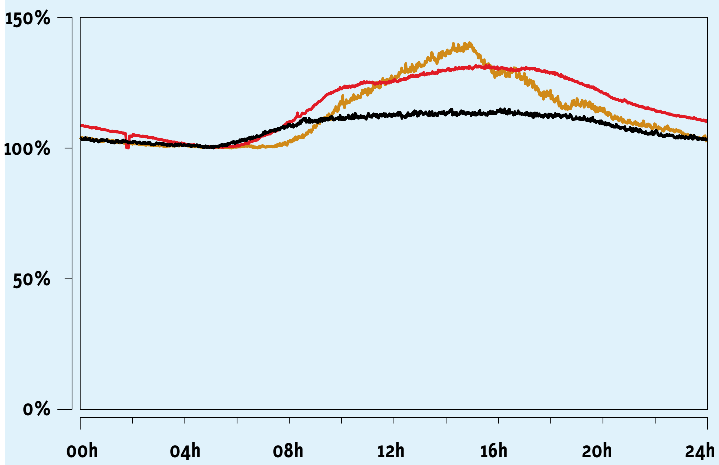


Fig. 3: Base station: traffic channel



Temporal transmission patterns of a mobile phone (top) and base station (middle: broadcast control channel; bottom: traffic channel). The levels in dB are given in logarithmic units: a difference of 20 means factor 100 in the transmitting power and factor 10 in the field strength.

Electric field strength near base stations in the course of a day



24-hour profile of radiation exposure from three different base stations. The graph shows the electric field strength during a 24-hour period in percentage of the minimum level. At the minimum level of 100 percent, only control channels are transmitting.

In the vicinity of a mobile phone base station, the level of exposure varies in the course of the day depending on the volume of transmitted calls. During the night, exposure practically comes from the control channel only. Then in the course of the morning the level increases with the volume of calls and activated traffic channels, and reaches its peak in the course of the afternoon or towards evening.
When averaged over time, and especially during the night, the actual level of radiation exposure is lower than indicated with mathematical predictions and approval measurements, since these are based on the maximum possible load, which seldom occurs.

Precautionary regulations of the ONIR

At places of sensitive use, mobile phone base stations are required to comply with the installation limit value specified by the ONIR. This applies to residential dwellings, schools, hospitals, offices and playgrounds. An installation comprises all mobile phone antennae on the same mast, on the same building or those that are otherwise located closely together. The specified installation limit value must be complied with at full capacity – i.e. at maximum call and data volume with maximum transmitting power. The following installation limit values apply:

- 4 V/m for GSM900 installations
- 6 V/m for GSM1,800 and UMTS installations
- 5 V/m for a combination of GSM900 and GSM1,800/UMTS installations

In the main transmission direction and without attenuation by building structures, these requirements call for the following distances from an antenna:

ERP per direction	Distance for compliance with the installation limit value (in main transmission direction)	
	GSM 900	GSM 1800 UMTS
10 W ERP	5.5 m	3.7 m
100 W ERP	18 m	12 m
300 W ERP	30 m	20 m
700 W ERP	46 m	31 m
1000 W ERP	55 m	37 m
2000 W ERP	78 m	52 m

Outside the main beam or if the radiation is attenuated by a building shell, these distances are significantly shorter – in the mathematical prediction in the site data sheet down to one-thirtieth.

Licensing and supervision of mobile phone base stations

A building permit is required for most mobile phone base stations. This procedure may vary in terms of content or implementation, depending on the canton, but the basic principles are the same everywhere.

- **Application for building permit, submission of site data sheet:** Operators of mobile phone base stations are obliged to submit an application for a building permit to the authorities of the municipality concerned. The required documentation includes a site data sheet in which the operator provides details such as transmitting power and main transmission directions of the antennae, and calculates the anticipated radiation in the vicinity of the facility. The building legislation of the canton concerned also specifies whether a structure profile of the planned antenna mast has to be erected at the intended location.
- **Publication of application, objection options:** The municipality concerned is obliged to publicly disclose the application for a building permit. In most cantons, residents have the opportunity to examine the application and raise objections. The site data sheet indicates up to which distance between place of residence and site of the facility the residents concerned are entitled to object.
- **Material examination of application and objections:** The relevant authorities examine the application and if necessary call on the assistance of the cantonal consulting office for non-ionising radiation. All calculations and details contained in the site data sheet are examined, and this sometimes requires on-site inspection. Objections also have to be evaluated, and a decision is taken concerning the building permit after hearings have been completed.
- **Building permit and appeal options:** If a planned mobile phone base station complies with the limit values specified by the ONIR and meets the applicable building regulations, it then has to be approved by the relevant authorities. The decision regarding the building permit is then communicated to the applicant and to any residents who may have raised objections. The latter then have the option of lodging an appeal against this decision with the relevant cantonal courts, up to the Federal Tribunal as final instance.
  In the event that 80 percent of the installation limit value is reached or exceeded, the relevant authorities require an approval measurement of the radiation level of the facility after start-up. In this way the authorities examine whether the facility complies with the installation limit value both on paper and in practice.

Hints for users of mobile phones

Mobile phone users can reduce their exposure to radiation by observing the following recommendations:

- **Low-radiation mobile phones:** Use a low-radiation device where possible. The lower the specific absorption rate (SAR), the lower the radiation that is absorbed by the head during a call. Details concerning the specific absorption rate of mobile phones can be found in the related operating instructions or at **www.topten.ch** and **www.handywerte.de** (in German).
- **Hands-free device:** With a hands-free device, the distance from the antenna of the mobile phone is increased, and this reduces the level of radiation that can enter the head. To protect other sensitive parts of the body, when using a hands-free device the mobile phone should not be kept in a pocket near the heart or in a front trouser pocket.

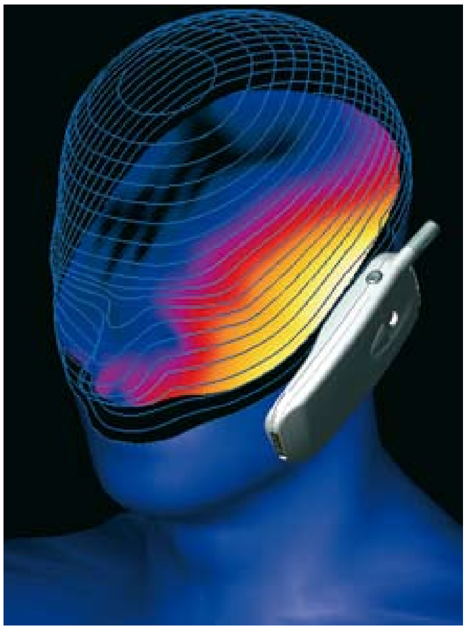
Comparison of exposure from base stations and mobile phones

Mobile phones have a considerably lower transmitting power than antenna systems, but exposure to radiation from a mobile phone when making a call is much higher than that from the most powerful base station. The reason for this is that we hold a mobile phone very close to our head, whereas we hardly ever come within a few metres of an antenna of a base station.
In view of the large distance from the base station, our entire body is uniformly exposed to an equal level of radiation, whereas with a mobile phone, the radiation is concentrated primarily on the head.
Another difference here is that a base station radiates permanently, whereas a mobile phone only does so during a call. If no call is being made – i.e. the device is in ready or standby mode – a mobile phone that is switched on receives control signals from the nearest base station, but it only sends a short signal every few minutes in order to report its whereabouts.
In the case of GSM, there are also different forms of signals. The radiation from a mobile phone is pulsed at a repetition rate of 217 Hz. The broadcast control channel of the base station transmits continuously with only short blank outs. If traffic channels are also activated, this results in a complicated and varying overall signal of the base station, since the signals of traffic channels vary according to the number of calls.

Base station	Mobile phone
Stronger transmitters	Weaker transmitters
Considerable distance away from people	Very close to head
Uniform exposure of entire body	Local exposure of head
Low absorbed power	High absorbed power in head region
Radiation permanently present	Radiation only present during calls
Radiation has a complicated signal form (applies to GSM)	Radiation regularly pulsed at 217 Hz repetition rate (applies to GSM)

Specific absorption rate for mobile phones

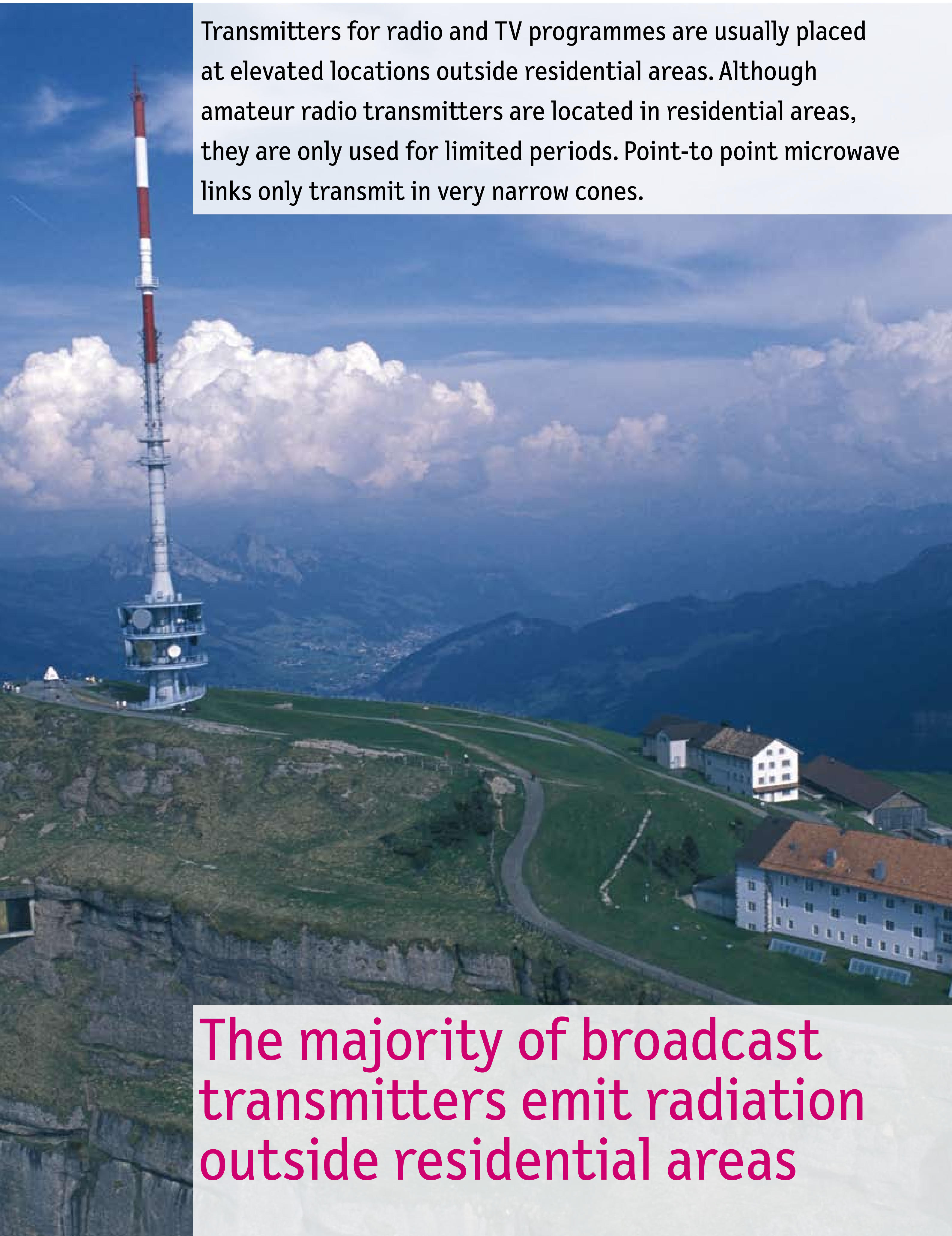
An international guideline applies in Switzerland for mobile phones, recommending a limit value for the specific absorption rate (SAR) of 2 watts per kilogram of body weight. The specific absorption rate indicates how much radiation the body absorbs and converts into heat during a call. The lower the SAR, the weaker the level of radiation.



Example of the calculation of radiation exposure of the head when using a mobile phone: the model concerned has an SAR of 0.61 W/kg. The highest exposure is in the white/yellow zone in the outer layers. The exposure diminishes rapidly towards the interior. In the black zone it is 100,000 times weaker than in the outer layers.
(Original image from IT'IS Foundation, Federal Institute of Technology, Zurich)

- **Quality of reception:** If the quality of the connection to the base station is good, the mobile phone transmits at low power. The level of exposure can therefore be reduced by making calls from locations where the level of reception is good (i.e. sealed rooms, cellars, etc. should be avoided).
- **Avoid phoning from a car:** Reception inside a car is poor, since the vehicle body strongly attenuates the radiation. Mobile phones should - if at all - only be used inside a car if the vehicle is equipped with an external antenna. Various studies have demonstrated that the use of a mobile phone when driving increases the risk of an accident because the driver no longer concentrates fully on the road. For safety reasons, making calls in a moving car is only permitted with the aid of a hands-free device.
- **Establishing a connection:** A mobile phone transmits at the highest power when establishing a connection. After dialling, the mobile phone should be kept away from the head until the connection has been made. In this way, exposure can be reduced.
- **Keeping calls short:** The shorter the call using a mobile phone, the lower the exposure.

Transmitters for radio and TV programmes are usually placed at elevated locations outside residential areas. Although amateur radio transmitters are located in residential areas, they are only used for limited periods. Point-to point microwave links only transmit in very narrow cones.



The majority of broadcast transmitters emit radiation outside residential areas

Contents

Broadcasting > P 47

Transmitting power > P 47

Radio > P 47

Precautionary regulations of the ONIR > P 49

Television > P 49

Point-to-point microwave links > P 50

Point-to-point microwave links in Switzerland > P 50

Strongly focused radiation > P 50

Limit values for point-to-point microwave transmitters > P 50

Amateur radio > P 51

Limit values for amateur radio installations > P 51

Broadcasting

Broadcasting transmission installations serve the purpose of transmitting radio and TV programmes through the air. They are usually placed at elevated locations, e.g. on hilltops or in the mountains. Some large-scale facilities are named after the mountain peak they are situated on, e.g. La Dôle, Chasseral, Rigi, Säntis, Monte San Salvatore, and in addition there are numerous smaller installations. In Switzerland, approximately 400 radio and 600 TV stations broadcast programmes. Their locations and details concerning their transmitting power and programmes broadcast can be found at www.funksender.ch.

Transmitting power

Broadcasting installations that cover a large area use high transmitting power. Due to Switzerland's topography, most of these high-output systems are installed at elevated locations, and this means that there are usually no residential buildings in their immediate vicinity. The radiation from these transmitters is narrowly focused vertically and directed slightly downwards while it is omnidirectional hor-

Broadcasting stations on the Rigi, canton of Schwyz (left) and Bantiger, canton of Bern (above). The directional dishes in the lower section of the towers link the station with other transmitters. The antennae for broadcasting TV and radio programmes are at the top.

Radio

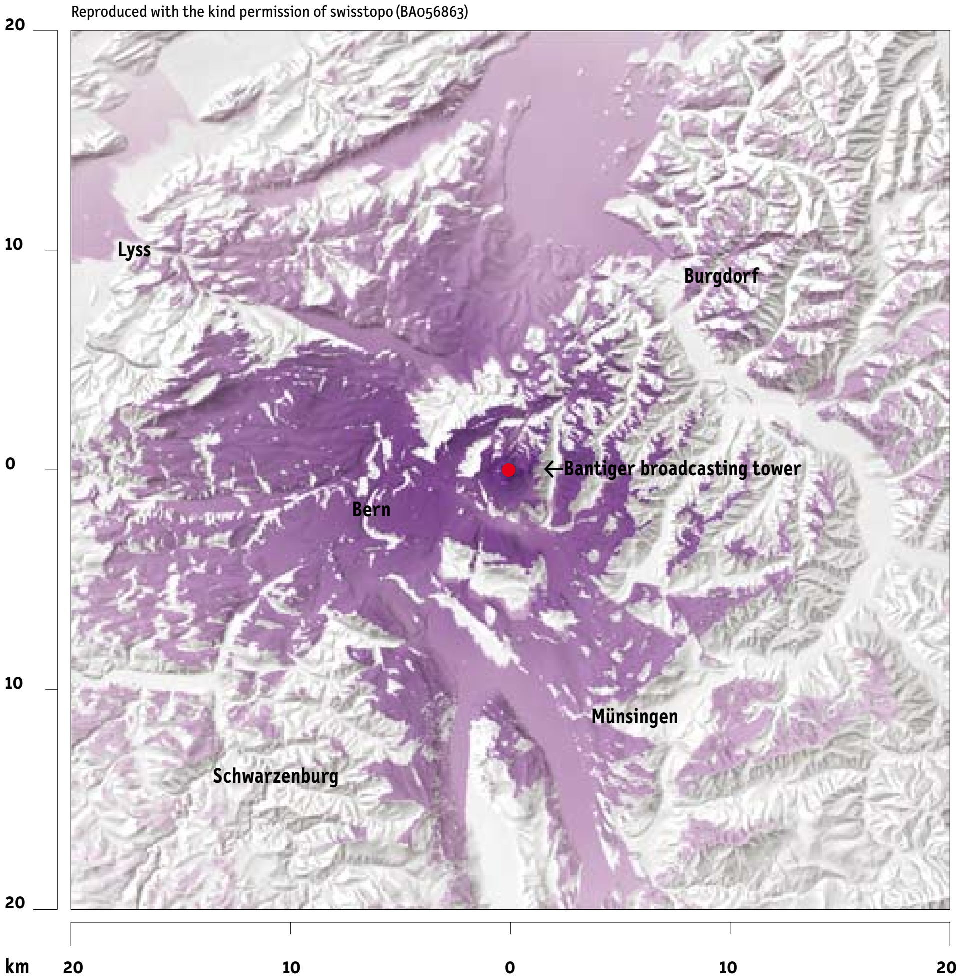
Radio programmes are broadcast at a variety of frequencies. Each frequency range is named after the corresponding wavelength.

Medium wave (MW): Medium wave is the name given to the range from 300 kHz to 3 MHz. It was this frequency range that was used to broadcast the first radio programmes in Switzerland in the 1920s, and was later also used by national stations such as Beromünster, Sottens and Monte Ceneri. After the introduction of VHF (very high frequency), medium wave began to lose ground due to its inferior sound quality. Since the mid-1990s, only two stations have continued to use medium wave ("Option musique" and "Musigwälle 531").

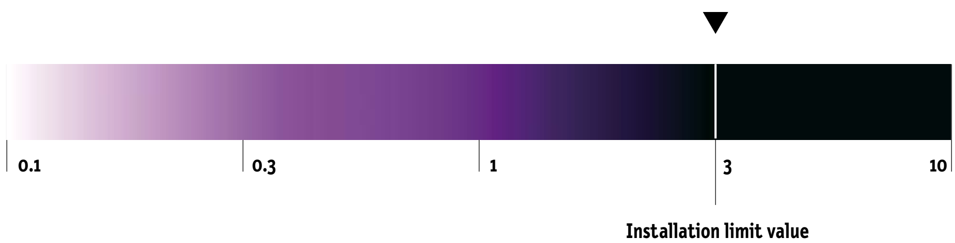
Very high frequency (VHF): Nowadays, most radio programmes are broadcast on VHF. This frequency range is between 30 and 300 MHz, and within this range the band from 87.5 to 108 Hz is reserved for radio programmes. VHF has been in use in Switzerland since the 1950s. Its sound quality is better than that of medium wave, and it is possible to broadcast in stereo.

T-DAB digital radio: This is intended as a medium-term extension of VHF. T-DAB stands for terrestrial digital audio broadcasting. It was introduced in Switzerland in 1999. In addition, digital radio programmes are also broadcast via cable and satellite.
With DAB, the sound signal is digitised before it is broadcast, i.e. it is converted to a numerical sequence based on 1 and 0 similar to the method of storing data on a music CD. The receiver then converts the digital data back into words and music. Thanks to this technology it is now possible to listen to the radio while driving, without the problem of interference. DAB is primarily used in the VHF range between 223 and 230 MHz.

izontally. There are also fill-in transmitters that supply valleys via antennae with low transmitting power.
Outside of cities and urban centres, broadcasting transmitters usually account for the largest proportion of high-frequency background radiation. But in densely populated areas, it is often signals from base station antennae that predominate.
At present it is difficult to assess the impact of the changeover from analogue to digital transmission technology on radiation exposure. Although digital technology requires fewer frequencies for transmitting a certain number of TV programmes than analogue technology, this advantage would be lost again if more programmes were to be transmitted using wireless technology in the future.
Digital transmission requires lower transmission power than analogue technology for the same reception quality, but this advantage, too, would be lost again if TV signals were also to be designed for reception by mobile (portable indoor) TV sets equipped with a smaller antenna, instead of for fixed outdoor reception (i.e. via an aerial on the roof). In this case, the attenuation of the building shell would have to be offset by using a correspondingly higher transmitting power. Whether digital TV (DVB-T) will lead to lower transmission power, and thus to lower radiation exposure, therefore depends on the number of programmes to be transmitted in the future, and on requirements relating to reception quality.



Depiction of electric field strength in the surroundings of the Bantiger broadcasting tower (canton of Bern). The calculations are based on simplified assumptions that do not take diffraction and reflection into account. Due to the topography of the region, there is no visual contact with the transmitter in the areas shown in white. Although the electric field strength here is very low (less than 0.1 V/m), it is usually still possible to receive radio and TV signals.



Scale of electric field strength in volts per metre (V/m).

Designation	Wavelength	Frequency	Frequencies used in Switzerland
Long wave (LW)	1–10 km	30–300 kHz	Not used
Medium wave (MW)	100–1000 m	300 kHz–3 MHz	531 kHz–1.5 MHz (MW radio)
Short wave (SW)	10–100 m	3–30 MHz	Discontinued as of the end of 2004
Very high frequency (VHF)	1–10 m	30–300 MHz	47–68 MHz (analogue TV) 87.5 - 108 MHz (VHF radio) 174 - 230 MHz To date: analogue TV and digital radio In future: digital radio and TV
Microwaves	1 mm–1 m	300 MHz–300 GHz	470–862 MHz To date: analogue TV, in future digital TV 1452 - 1492 MHz In future: to be considered for transmission of local digital radio programmes

Precautionary regulations of the ONIR

At places of sensitive use, broadcasting transmission installations are required to comply with the installation limit value specified by the ONIR. An installation comprises all broadcasting antennae on the same mast or otherwise located closely together.
The installation limit value must be complied with at maximum transmitting power, and is as follows:
- 8.5 volts per metre (V/m) for medium wave transmitters
- 3.0 V/m for all other transmitting installations

Since most broadcasting installations are located outside of residential areas, they can usually comply with the installation limit value without difficulty. The only exception here concerns some mountain restaurants or cable car/railway stations located close to a transmitter. Here it is possible that the limit value may be exceeded. Unlike mobile phone base stations for which compliance with the installation limit value is compulsory, in certain exceptional cases the authorities may allow broadcasting installations to exceed their installation limit value.

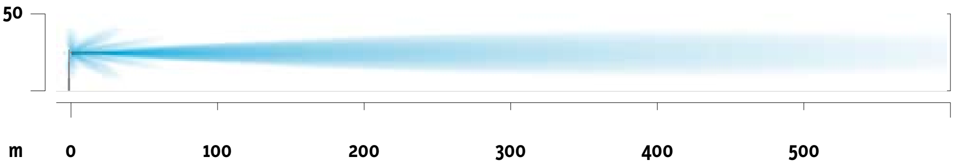
Television

Nowadays we receive most TV programmes viacable or satellite. However, the programmes of Swiss TV are also broadcast via terrestrial transmitters using frequencies in the VHF range (47 to 68 MHz and 174 to 230 MHz) as well as higher frequencies (470 to 862 MHz).

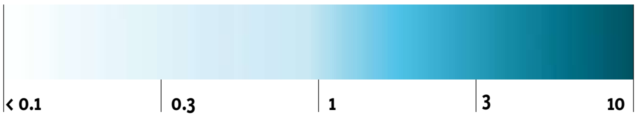
DVB-T: At the end of 2001, TV also began converting from conventional analogue technology to DVB-T (which stands for digital video broadcasting terrestrial). This new technology offers higher sound and picture quality as well as the advantage of broadcasting additional data. It also uses frequencies more efficiently. For example, with DVB-T it is possible to simultaneously transmit two to six digital programmes (depending on the desired quality) on one conventional analogue channel.

The city of Zurich is served by the broadcasting tower at nearby Üetliberg. Since the majority of broadcasting transmitters are located in mountains or on hilltops, residential areas are seldom exposed to intensive radiation.

Point-to-point microwave links



Depiction of the radiation of a point-to-point microwave link. The significance of the colours is indicated in the colour scale below.



Scale of electric field strength in volts per metre (V/m).

These directional antennae on the Jakobshorn (canton of Grisons) link mobile phone base stations and switching centres over relatively short distances.

Point-to-point microwave links in Switzerland

In Switzerland there is a nation-wide point-to-point microwave network with typical distances of 50 to 70 kilometres between the transmission and reception antennae. These distances are bridged with frequencies of 4 to 13 gigahertz (GHz). The required parabolic antennae have a diameter of up to several metres and are usually installed on high towers in exposed locations (e.g. on hilltops).
In addition to the national network, point-to-point microwave links over shorter distances are being used to an increasing extent. These can be used to connect mobile phone base stations with their switching centre. To cover shorter distances of a few hundred metres up to a few kilometres, frequencies in the range from 18 to 38 GHz are used. The respective parabolic antennae have a correspondingly smaller diameter of several dozen centimetres.

Strongly focused radiation

Parabolic antennae focus the radiation to such an extent that it is confined within a narrow beam propagating linearly between the transmitting and receiving stations. Thanks to this property, point-to-point transmitters can work with very low transmitting power compared with broadcasting transmitters. For longer distances, all they require is a few hundred milliwatts per frequency, and for shorter distances this falls to 10 to 100 mW. As a rule, point-to-point microwave installations do not transmit pulsed signals, but rather continually and with constant output power.
Despite the initial narrow focusing of the signal, it nonetheless widens somewhat on its way to the reception antenna. This means that it covers a considerably wider area than that of the targeted parabolic antenna. The further the two stations are apart, the wider the covered area.
Apart from the main beam, parabolic antennae also produce a variety of significantly weaker secondary beams, referred to as side lobes. Since these leave the transmitter at a different angle than the main beam, they can also reach the ground beside and beneath the antenna. Measurements carried out near a powerful transmitter within the national network have yielded scattered radiation readings of between 0.03 and 0.15 volts per metre (V/m). If any exposure is measured in the vicinity of point-to-point transmitting antennae, this can be attributed to side lobes.

Limit values for point-to-point microwave transmitters

Stationary point-to-point transmitting installations are covered by the ONIR. They have to comply with the exposure limit values, and are usually able to do so without difficulty. The only exception that might arise here is if someone stands close to the antenna directly in the main beam. In such cases the human body would considerably attenuate or even interrupt the signal, and for this reason, such situations are of course undesirable for operational reasons. Point-to-point microwave link antennae are therefore installed at elevated locations and if necessary are fenced in so that no one is likely to block the signal. This also ensures that the exposure limit values are complied with. The Ordinance does not specify any installation limit values for point-to-point transmitting facilities.

Point-to-point microwave links

Point-to-point microwave links are used for wireless transmission of phone calls, data and radio and TV programmes between two points with direct visual contact. They support and complement data transmission via the cable network. In difficult terrain they are easier to install and more economical to operate than cable systems. Point-to-point microwave systems comprise a parabolic antenna at both locations (transmission and reception).

Amateur radio

In Switzerland there are approximately 5,000 amateur radio users, and throughout the world there are more than a million. In most cases, the required equipment is installed in private homes, though it is also possible to operate amateur radio from a car, ship or aircraft. For amateur radio, numerous frequencies are available, ranging from long wave to microwave.
The necessary antennae are often installed on the roof or in the immediate vicinity. Since do-it-yourself and experimentation are an important aspect of this hobby, there are numerous different constructions. For low frequencies, fixed wire antennae are usually used, and for shortwave frequencies, many people use vertical aerials and directional antennae, while in the VHF and microwave ranges, directional antennae, vertical aerials and parabolic antennae are common.
By contrast with mobile communication or broadcasting, amateur radio systems are not permanently in use and therefore do not generate permanent radiation, since they only do so when they are actually transmitting. An amateur radio licence permits a maximum transmitting power of 1,000 watts, but in practice, many systems only have an output of up to 100 watts.
Since the antennae are often located in residential areas, their distance from other residential buildings is relatively short. For this reason, amateur radio equipment can account for the main proportion of exposure to high-frequency radiation in their immediate vicinity when they are in use. All stationary installations are subject to the ONIR and must comply with the defined limit values.

Amateur radio aerials can take very different forms. The one shown here is a Yagi roof aerial.

Limit values for amateur radio installations

Amateur radio installations have to comply with the exposure limit values specified by the ONIR. These are between 28 and 87 volts per metre, depending on the frequency used. Otherwise no installation limit value has to be complied with as long as the system is not in operation for more than 800 hours a year. This is almost always the case with hobby users. However, if a system exceeds the above threshold, it has to comply with the applicable installation limit value at places of sensitive use. This limit value is 8.5 V/m for long wave and medium wave transmitters and 3.0 V/m for all other frequency bands. The cantons or municipalities are responsible for the enforcement of the ONIR in the area of amateur radio.

Amateur radio equipment

Amateur radio frequencies

Frequency range	Frequencies used in Switzerland for amateur radio
Long wave	135.7 - 137.8 kHz
Medium wave	1.81 - 2 MHz
Short wave	Several bands between 3.5 and 29.7 MHz
VHF	50 - 52 MHz 144 - 146 MHz
Microwave	Several bands between 430 MHz and 250 GHz

More miniature transmitters also in private households

More and more wireless applications are now also being used indoors, e.g. cordless phones, wireless headphones, baby monitors and WLAN stations for wireless connection to the Internet. Although their transmission power is often relatively low, these devices can dominate the indoor exposure to high-frequency radiation. To keep exposure as low as possible, these devices should be used at a due distance from places where people spend lengthy periods of time, including bedrooms, living rooms, home offices and children's rooms.

Contents

Wireless devices in buildings > P 53

Cordless phones > P 53

Technical data of cordless phones > P 53

Calculated exposure from DECT base stations > P 53

Wireless networks – WLAN > P 54

Transmitting power > P 54

WLAN: technical data > P 54

WLAN: measured exposure > P 54

Bluetooth > P 55

Bluetooth: technical data > P 55

Bluetooth: calculated exposure > P 55

Baby monitors > P 55

Technical data of wireless baby monitors > P 55

Wireless devices in buildings

Mobile phone base stations, broadcasting transmitters and other wireless systems operated outdoors are not the only sources of high-frequency radiation. An increasing variety of wireless devices are now being used indoors, too, e.g. wireless networks (WLAN), cordless phones and baby monitors. Some of these technologies use similar frequencies to those used by mobile communication systems, others make use of higher frequencies. They operate with relatively low transmitting power, but because they are used indoors, they are often located very close to spots frequently occupied by the inhabitants.
Most of these technologies work with pulsed transmission, though the pulse patterns vary considerably.

Cordless phones

Cordless phones comprise a base station connected to the fixed phone network, plus one or more handsets for cordless phoning. Most devices in use today are based on the DECT standard and operate in a frequency range from 1,880 to 1,900 MHz. DECT stands for digital enhanced cordless telecommunications.

The signal pulses at 100 Hz. The transmitting power during a single pulse is 250 milliwatts (mW), and the time averaged level is 10 mW. This means it is lower than that of a GSM mobile phone operating under poor reception conditions, which in this case transmits with a pulse power of 1,000 or 2,000 mW, corresponding to a time averaged output of 125 or 250 mW. But unlike a cordless phone, a mobile phone adjusts its transmitting power to the reception conditions, and in ideal circumstances can reduce it thousandfold.
The transmitting power from DECT base stations is also 250 mW in the pulse and the average level is 10 mW for each handset served by the base station. DECT base stations are available on the market with up to six handsets.
While the latter only transmit during a call, the DECT base station transmits permanently, i.e. even when no call is in progress (in which case the average transmitting power is 2.5 mW). To minimise exposure, the base station should be kept as far away as possible from places where people spend lengthy periods of time, e.g. beds, armchairs, workdesks.
As an alternative to DECT phones, there are some cordless phones on the market that are based on the CT1+ standard. Here the base station only transmits during a call, and the signal is not pulsed. However, the frequency bands used by such models will be attributed to mobile telephony as of the end of 2005. This means that, under unfavourable circumstances, interference-free operation will no longer be possible. CT1+ phones, which in turn interfere with mobile phone communications, have to be put out of operation.

Calculated exposure from DECT base stations

Distance from DECT base station	Calculated electric field strength (time averaged) (source: Federal Office of Communications)
0.5 m	0.7 – 4.9 V/m
1.5 m	0.2 – 1.6 V/m
3 m	0.1 – 0.8 V/m
7 m	0.05 – 0.4 V/m

Technical data of cordless phones

	DECT Base station	DECT Handset	CT1+ Base station	CT1+ Handset
Frequency	1880 – 1900 MHz	1880 – 1900 MHz	930 – 932 MHz	885 – 887 MHz
Pulse	100 Hz	100 Hz	none	none
Maximum transmitting power	250 mW	250 mW	10 mW	10 mW
Mean transmitting power during call	10 mW (per handset)	10 mW	10 mW	10 mW
Mean transmitting power without call	2.5 mW (per handset)	0 mW	0 mW	0 mW
Transmission status	Transmits permanently	Only transmits during a call	Only transmits during a call	Only transmits during a call
Range	Approx. 50 m indoors, approx. 300 m outdoors			

Unlike conventional telephones with cords, DECT cordless phones and their base stations emit pulsed radiation.

Wireless networks – WLAN

WLAN stands for Wireless Local Area Network. This technology is used for connecting several computers to one another without the need for cables. It can also be used for transferring data to peripheral devices such as printers, scanners and beamers. It enables connections both inside buildings and in the public zone, and also permits wireless access to the Internet or a company intranet.
Hot spots: One example of use of WLAN in the public zone is wireless broadband Internet access from highly frequented locations such as railway stations, airports, restaurants, universities, etc. At a hot spot, the laptop establishes contact by means of its wireless card with a fixed transmission and reception station that is connected to the Internet via a server. These WLAN base stations are called access points. A fee may or may not be charged for Internet access, depending on the hot spot.

WLAN at home and in the office: Wireless Internet access can also be set up at home. Here the WLAN base station is connected via the phone line or TV cable. Within companies, computers and peripheral devices can be connected both to the Internet and to an intranet via access points.
WLAN applications operated via an access point are referred to as infrastructure networks. If no access point is available, end devices can communicate directly with one another, thus forming an ad hoc network.

Transmitting power

In Switzerland, WLAN applications operate in the frequency bands of 2.4 or 5.2 to 5.7 gigahertz, depending on the relevant standard.
Access points transmit not only during data transfer, but also in standby mode. The corresponding control signal is pulsed with a frequency of 10 to 100 hertz (Hz). During data transfer, both the access point and the communication card of the computer transmit signals that have a higher pulse frequency – up to 250 Hz, depending on the quality of the wireless connection and the number of involved stations.
With 100 mW, 200 mW or 1 W, the maximum WLAN transmitting power is often higher than that of DECT base stations and phones. Compared with the WLAN base station (access point), the radiation exposure caused by the WLAN wireless card of the computer is usually higher, since the latter is normally located closer to the user.

WLAN: technical data

Standard	IEEE 802.11b	IEEE 802.11h
Frequency	2.4 - 2.4835 GHz	5.15 - 5.35 GHz, 5.47 - 5.725 GHz
Maximum transmitting power	100 mW	200 mW - 1 W (power control as required)
Pulse in standby mode	10 - 100 Hz	10 - 100 Hz
Pulse during data transfer	10 - 250 Hz	10 - 250 Hz
Range	~30 m indoors ~300 m outdoors	~30 m indoors ~300 m outdoors

WLAN: measured exposure

Access points in public areas (100 mW/200 mW)	
Distance to access point	Measured maximum electric field strength
1 m	0.7 – 3 V/m
2 m	0.4 – 1.5 V/m
5 m	0.1 – 0.7 V/m
10 m	0.05 – 0.4 V/m

Access points at home (100 mW/200 mW)	
Distance to access point	Measured maximum electric field strength
1 m	0.7 – 1.3 V/m
5 m	0.1 – 0.3 V/m

WLAN wireless cards for computers (100 mW/200 mW)	
Distance to WLAN card	Measured maximum electric field strength
50 cm	1.1 – 4.9 V/m
1 m	0.7 – 2.8 V/m

Stationary WLAN installations in areas accessible to the public have to comply with the exposure limit values specified by the ONIR. Due to the low transmitting power, this is generally the case already. By contrast with mobile phone base stations, the Ordinance does not specify any precautionary limit values for WLAN.

Bluetooth

Bluetooth devices operate at relatively low levels of transmitting power, and this means that radiation exposure is also low.

Bluetooth is a standard for wireless data transfer over short distances, e.g. between a computer and a printer, or between headphones and a mobile phone. It differs from WLAN technology in that the range is shorter and it uses a different transmission protocol. For data transfer, Bluetooth uses 79 different frequency channels around 2.4 GHz. The frequencies are changed 1,600 times a second (and the signal therefore is pulsed at a frequency of 1,600 hertz).

Three performance categories exist for Bluetooth devices, with maximum transmitting power of 1 mW, 2.5 mW or 100 mW (i.e. lower than those for DECT and WLAN).

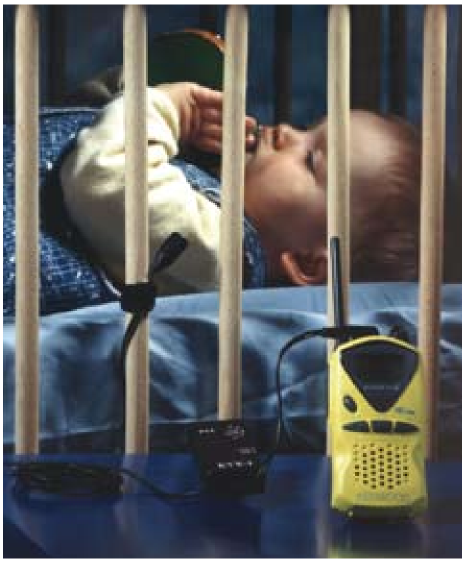
Bluetooth: technical data

Frequency	Transmitting power	Pulse frequency	Range
2.4 - 2.4835 GHz	1 mW	1,600 Hz	approx. 10 m
2.4 - 2.4835 GHz	2.5 mW	1,600 Hz	approx. 15 m
2.4 - 2.4835 GHz	100 mW	1,600 Hz	approx. 100 m

Bluetooth: calculated exposure

Transmitting power (power control as required)	Maximum electric field strength at a distance of 50 cm	Maximum electric field strength at a distance of 1 m
1 mW	approx. 0.4 V/m	approx. 0.2 V/m
2.5 mW	approx. 0.6 V/m	approx. 0.3 V/m
100 mW	approx. 3.5 V/m	approx. 2 V/m

Baby monitors



Baby monitors are devices for acoustic monitoring of babies and small children. The transmitter picks up sounds via a microphone and transmits them to a receiver that plays back the sounds via a loudspeaker. The two devices can be connected via a dedicated cable, the electricity supply in the house or via a wireless system. Wireless baby monitors are operated at 27.8 or 40.7 MHz. Some models transmit permanently and therefore also generate radiation continuously, while others only transmit when a sound is emitted. Electrosmog exposure can be reduced by choosing the right device:

- Baby monitors that transfer sounds via the power supply do not generate any significant electrosmog exposure.
- The wireless monitors that generate the lowest radiation exposure are those that only transmit when a sound is made.
- Regardless of the type of device, wireless monitors should be kept at a minimum distance of 1.5 to 2 metres from the baby.

Technical data of wireless baby monitors

Frequency	Transmitting power	Range
27.8 MHz	100 mW	approx. 400 metres
40.7 MHz	10 mW	approx. 400 metres

Index

Amateur radio	51
Baby monitors	55
Base station antenna	42
Bluetooth	55
Cable lines	26
Clock radios	32
Computer monitors	32
Cordless phones	53
Current	22
Direct current (DC) transport systems	37
Domestic installations	30
Electric field strength	41
Electrical appliances	28
Electromagnetic spectrum	4
Electrosensitivity	11
Equivalent radiated power	41
Exposure limit values	16
Frequency	22, 41
GSM	39
Hairdryers	31
Halogen lighting systems	33
Health impacts	6
High-frequency radiation	5
High-voltage power lines	23
Hotplates	31
Household appliances	28
Installation limit values	17
Ionising radiation	5
Leukaemia	7
Lighting	33
Limit values	16
Low-frequency fields	4
Measurements	18
Microtesla	23
Microwave oven	30
Mobile phone base station	39
Mobile phones	45
Mobile telephony	38
Non-ionising radiation	4
Non-thermal effects	10
ONIR Ordinance	14
Phase optimisation	24
Places of sensitive use	17
Point-to-point microwave links	50
Power flux density	41
Power supply	21
Radio broadcast transmitters	47
Radio/TV transmitters	47
Railways	34
Screens	32
Thermal effects	10
Trams	37
Transformer stations	27
Trolley buses	37
TV transmitters	49
UMTS	39
Voltage	22
Watts	41
WLAN (wireless networks)	54

Glossary

Frequency: Frequency refers to the number of oscillations per second, and it is measured in hertz (Hz) (1 Hz = 1 oscillation per second). In the field of wireless communication, kilohertz (1,000 Hz), megahertz (1,000,000 Hz) and gigahertz (1,000,000,000 Hz) are widely used units.

High-frequency radiation: Non-ionising radiation with a frequency of 30 kilohertz to 300 gigahertz is referred to as high-frequency radiation. Here, the electric and magnetic field are coupled and can propagate in the form of a wave. Mobile telephony, various wireless applications, radar systems and radio and TV use this property for wireless transmission of data.

Ionising radiation: Ionising radiation refers to electromagnetic radiation in the highest frequency range. It possesses enough energy to release electrons from atoms and molecules, and thus to alter the basic constituents of living organisms. Well-known examples of this include gamma radiation and x-rays.

Low-frequency fields: By contrast with high-frequency radiation, the electric and magnetic fields in the frequency range from 0 Hz to 30 kHz are decoupled. This is why we tend to speak of fields rather than radiation. The sources of these fields include contact lines of railways (catenaries), high-voltage transmission lines, other systems used in electricity distribution (e.g. transformer stations and sub-stations), and electrical appliances.

Non-ionising radiation: Non-ionising radiation does not possess enough energy to alter the constituents of living organisms. It encompasses ultraviolet radiation, visible light, heat radiation, high-frequency radiation and all low-frequency electric and magnetic fields. Artificially produced low-frequency and high-frequency radiation are also widely referred to as "electrosmog".

ONIR: Ordinance relating to Protection from Non-Ionising Radiation: The Ordinance entered into effect on 1 February 2000. Its legal basis is the Swiss Federal Law relating to the Protection of the Environment. The federal government issued this Ordinance in order to protect the population against harmful and annoying effects of non-ionising radiation.

Published by:
Swiss Agency for the Environment, Forests and Landscape SAEFL
The SAEFL belongs to the Federal Department of the Environment, Transport, Energy and Communications (DETEC).

Concept and text:
Alexander Reichenbach, Non-Ionising Radiation Section, SAEFL
Assistance:
Jürg Baumann, Stefan Joss, Andreas Siegenthaler (all from the Non-Ionising Radiation Section); Georg Ledergerber (Communication section)

Concept, editing, production:
Beat Jordi, Biel
Translation:
Keith Hewlett, Zug
Design, illustrations, layout:
Beat Trummer, Biel

Sources of illustrations:
SAEFL/AURA: Cover, 2 (bottom left), 2 (bottom right), 3 (bottom left), 3 middle, 3 (bottom right), 11 (bottom), 13 (top), 14, 18, 19 (middle), 19 (bottom), 28, 29, 30, 38, 40, 41, 52, 53, 54; Archiv Fotoagentur AURA, Lucerne: Cover, 2 (top), 3 (top left), 3 (middle), 3 (top right), 6, 13 (bottom), 17, 20, 26, 27 32 (top), 34, 37, 39, 46, 47, 49, 50; Beat Trummer, Biel: 10, 55 (left); Institute for Pharmacology and Toxicology, University of Zurich: 11 (top); Non-Ionising Radiation Section, SAEFL: 19 (top), 32 (bottom), 51 (top); www.dj4uf.de: 51 (bottom); www.kenwood.de, Pressefoto: 55 (right).
Ordering details:
Copies of this brochure may be ordered free of charge from the Swiss Agency for the Environment, Forests and Landscape, Documentation, CH 3003 Bern
Fax +41 31 324 02 16,
e-mail: docu@bafu.admin.ch
Internet: www.buwalshop.ch.
Order no.: DIV- 5801-E
This brochure may also be downloaded from the Internet in PDF format: www.buwalshop.ch
Order code: DIV-5801-E
NB:
This brochure is also available in French (DIV-5801-F), Italian (DIV-5801–I) and German (DIV-5801-D).

Further Reading

- www.environment-switzerland.ch > Publications > Electrosmog

Links

- www.environment-switzerland.ch/electrosmog
- www.bag.admin.ch/themen/strahlung/00053/index.html (in German and French)
- www.bakom.ch > Topics > Technology
- www.mobile-research.ethz.ch
- www.aefu.ch > Themen > Elektrosmog (in German)
- www.icnirp.de
- www.who.int/peh-emf/en

For further information, please contact:
Swiss Federal Office for the Environment
Non-Ionising Radiation Section
CH 3003 Bern
Switzerland

Phone +41 31 322 93 12
Fax +41 31 324 01 37
E-Mail: nis@bafu.admin.ch
Internet:
www.environment-switzerland.ch/electrosmog

Swiss Agency for the Environment, Forests and Landscape SAEFL