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WLAN

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A WLAN (wireless local area network) is a wireless network using radiofrequency electromagnetic radiation to transmit electronic data between connected devices. These devices usually communicate via a router – a central switching point connecting them to each other and to the internet.

The electromagnetic radiation emitted by WLAN devices depends in particular on the volume of data transmitted and the transmission and reception characteristics of the network. Even at maximum transmit power, the maximum radiation emitted by a WLAN device is low. It also decreases rapidly with increasing distance from the device. Laboratory measurements show that it is approx. 10 times lower than the exposure limit at a distance of 20 cm, and approx. 40 times lower at a distance of 1 metre. As a result of these characteristics, even a number of WLAN devices operating at the same location or adjacent wireless networks will not cause high levels of electromagnetic radiation.

Several studies show that, in everyday life, the exposure of children and adults to radiation emitted by WLAN devices is low. According to a Swiss study, it is on average around 1500 times lower than the exposure limit. The highest radiation levels measured are around 400 times lower than the exposure limit. The question whether such low levels of radiation can pose health risks has been investigated in numerous studies. No solid findings or plausible evidence of such risks have emerged from high-quality studies carried out in recent years.

Existing studies on radiofrequency radiation from WLANs do not provide either solid findings or plausible evidence of health risks. Measures to protect against electromagnetic radiation emitted by WLANs are thus not required for any population groups.

Accordingly, the following suggestions are addressed exclusively to individuals who wish to reduce their exposure to electromagnetic radiation from WLAN devices for personal reasons:

- Position the router centrally in the area to be served, so that all WLAN devices receive a strong signal.
- Switch off the router and the wireless function of connected devices if you are not using the network.
- Keep the router one metre away from places where you work, sit or rest.
- If your router’s output can be adjusted, you can reduce the power to the lowest level at which all devices can still connect to it.
- Use devices with the latest transmission technologies Wi-Fi 6, Wi-Fi 5 or Wi-Fi 4 (IEEE standards 802.11ax, 802.11ac or 802.11n), which transmit data highly efficiently.

Additional information

- A WLAN device displays all available wireless networks within connection range. Due to the technical specifications, connections between wireless devices are possible even at low radiation intensities. It is therefore not possible to draw any conclusions about exposure levels where your own device is located, based on the number and strength of nearby wireless networks displayed.
- Measurement of radiation emitted by wireless networks requires complex and extremely costly techniques. Commercially available handheld equipment is not suitable for measuring emissions from wireless devices.
- Wireless devices should only be operated with an antenna which is built-in or specified by the manufacturer. If an unsuitable antenna with excessive gain is used, the maximum permissible transmit power may be exceeded.

1 Structure and applications

A WLAN usually consists of a wireless router providing access to the internet. Its integrated access point connects wireless-capable devices to the internet or to each other via radio links. Products containing WLAN transmission and reception modules can currently be found in the following areas:

- computer networks: tablets, e-readers, smartphones, smartwatches, laptops, desktops, access points, wireless adapters, wireless repeaters, printers, scanners, wireless hard disks, etc.;
- household and leisure: radios and televisions, home cinema systems, audio equipment, video game consoles, action, web, photo and video cameras, surveillance and baby monitors, control systems for heating and domestic installations, smart lighting, certain domestic appliances;
- multimedia: radios and televisions, digital projectors;
- wireless telephony: WLAN telephones, IP telephones, smartphones with Wi-Fi calling.

Due to their limited transmit power and range, WLANs are mainly used to serve small areas such as apartments, detached houses, public transport or public spaces. Larger areas, such as large buildings, universities and schools or whole districts, can be served using repeaters (also known as extenders or boosters), or by larger networks containing a number of access points. Repeaters are either designed as standalone units or integrated into equipment such as lighting or base stations for WLAN telephones.

2 Technical information

2.1 Standards

Various standards for WLANs (the 802.11 family) have been published by the Institute of Electrical and Electronics Engineers (IEEE), an international professional association. The transmission characteristics specified are shown in Table 1. Modern products operate with the standards Wi-Fi 6, Wi-Fi 5 and Wi-Fi 4 (equivalent to the IEEE standards 802.11ax, 802.11ac and 802.11n).

IEEE Standard	Wi-Fi 6 802.11ax	Wi-Fi 5 802.11ac	Wi-Fi 4 802.11n	802.11a	802.11b	802.11g	802.11h
Frequency (MHz)	1. 2400 – 2483,5 2. 5150 – 5350 3. 5470 – 5725	1. 5150– 5350 2. 5470– 5725	1. 2400 – 2483,5 2. 5150– 5350 3. 5470– 5725	5150 – 5250	2400 – 2483,5	2400 – 2483,5	1. 5150 – 5350 2. 5470 – 5725
Max. transmit power (mW) [1]:	1. 100 2. 200 3. 1000	1. 200 2. 1000	1. 100 2. 200 3. 1000	200	100	100	1. 200 2. 1000
Max. transmit power (mW) without power control [1]	1. 100 2. 100 3. 500	1. 100 2. 500	3. 100 4. 100 1. 500				
Average beacon transmit power (mW)	1. 0.5 2. 1 3. 2.5	1. 1 2. 2.5	1. 0.5 2. 1 3. 2.5	1	0,5	0,5	0.5
Max. average transmit power (mW)	1. < 100 2. < 200 3. < 1000	1. < 100 2. < 500	1. < 100 2. < 200 3. < 1000	< 200	< 100	< 100	< 200
Power control	Yes	Yes	Yes	No	No	Yes, static	Yes, dynamic
Max. raw data rate (Mbit/s)	1201 per antenna (max. 8 antennas)	866.7 per antenna (max. 8 antennas)	150 per Antenna (max. 4 antennas)	54	11	54	54
Distribution	Current	Current	Current	Outdated	Outdated	Outdated	Outdated

Table 1: Characteristics specified in the various WLAN standards [see also 1]: frequency in megahertz (MHz), transmit power in milliwatts (mW), data rate in megabits/second (Mbit/s)

2.2 Data rates

Wi-Fi 6, Wi-Fi 5 and Wi-Fi 4 devices, in contrast to devices using older standards, operate with advanced modulation types, enabling high data rates. They are equipped with beamforming antennas, which direct the signals to connected devices. Using MIMO (multiple-input, multiple-output) technology, several of these antennas can be grouped together to increase data rates. If several devices use a connection to an access point at the same time (e.g. several computers in a classroom), transmission capacity is split up, with the data rate for each device decreasing accordingly.

2.3 Electromagnetic radiation

The electromagnetic radiation emitted by a WLAN is primarily determined by data traffic and thus fluctuates. If there is no data traffic, a beacon of approx. 0.5 ms duration will typically be transmitted at intervals of 100 ms by the access point to allow connected devices to synchronise with it. Access point beacons generate pulsed electromagnetic radiation, whose frequency depends on the interval between two beacons, with the usual default setting for access points being 10 Hz.

If a 100 mW access point is only transmitting beacons, the time-averaged radiated power is 0.5 mW. However, if large volumes of data are being transmitted, the average radiated power can be up to 70 mW.

WLAN devices are highly sensitive, which means that they can still connect to the network even if radiation levels are very low.

2.4 Distance dependence

The electromagnetic radiation emitted by WLAN devices decreases significantly with distance and also as a result of obstacles such as walls, ceilings or glass. Data rates may therefore be reduced when connected devices are at a considerable distance from the access point.

3 Electromagnetic radiation

3.1 SAR

The specific absorption rate (SAR), expressed in watts per kilogram (W/kg), indicates how much electromagnetic radiation (power expressed in watts) is absorbed by a particular mass of human tissue (kg). This absorption leads to an increase in body temperature. The restrictions recommended by the EU for the SAR and also used to assess product safety in Switzerland [2] limit this temperature rise to levels that do not pose a risk to human health. The restrictions vary, depending on whether exposure involves the whole body, the limbs, or the head and trunk. The restriction recommended for the head and trunk is the strictest, set at 2 W/kg, averaged over 10 g of tissue. This means that in the most exposed 10 g of tissue, the SAR must not exceed 0.02 W/kg. SAR values are employed in particular to assess devices which are normally used on or close to the surface of the body. The recommended exposure limits include a safety factor of 50, to ensure that sensitive population groups are also protected.

In two studies commissioned by the FOPH, SAR values were measured for a tablet, several access points, PC cards and a PDA [3, 4]. As the radiation emitted by WLAN devices depends on the transmit power and data transmission rate, all measurements were carried out at the maximum transmit power and data rate, in close proximity to the devices (Table 2).

maximum SAR values		
Standard	Device	SAR (W/kg)
802.11ax	No measurements available	
802.11ac	Access point 5 GHz	0.070
	Tablet 5 GHz	0.511
802.11 n	Access point 2.4 GHz	0.256
	Access point 5 GHz	0.096
	Tablet 2.4 GHz	0.398
	Tablet 5 GHz	0.697
802.11a	Access point	0.54
	PC card	0.07
802.11b	Access point	0.73
	PC card	0.43
	PDA	0.067
802.11g	Access point	0.27
	PC card	0.11

Table 2: Maximum SAR values measured in close proximity to the devices. SAR values were measured using a dosimetric phantom [3, 4].

Although the recent 802.11ac and 802.11n standards have a significantly higher data rate than the older 802.11a, b and g standards, the radiation measured at these access points tends to be lower than with the older standards. This is due to the use of beamforming and MIMO antennas, which can concentrate the radiation from a number of antennas and direct the signal towards connected devices.

3.2 Electric field

The electromagnetic radiation emitted by devices such as WLAN routers which are not worn on or used close to the body can be assessed on the basis of their radiofrequency electric (electromagnetic) fields. Electric fields are much easier to measure than SAR values. The recommended exposure limit for electric fields in the frequency range used by WLAN devices is 61 volts per metre (V/m). If a device’s electric field strength complies with this limit, then the SAR restriction will generally also be complied with.

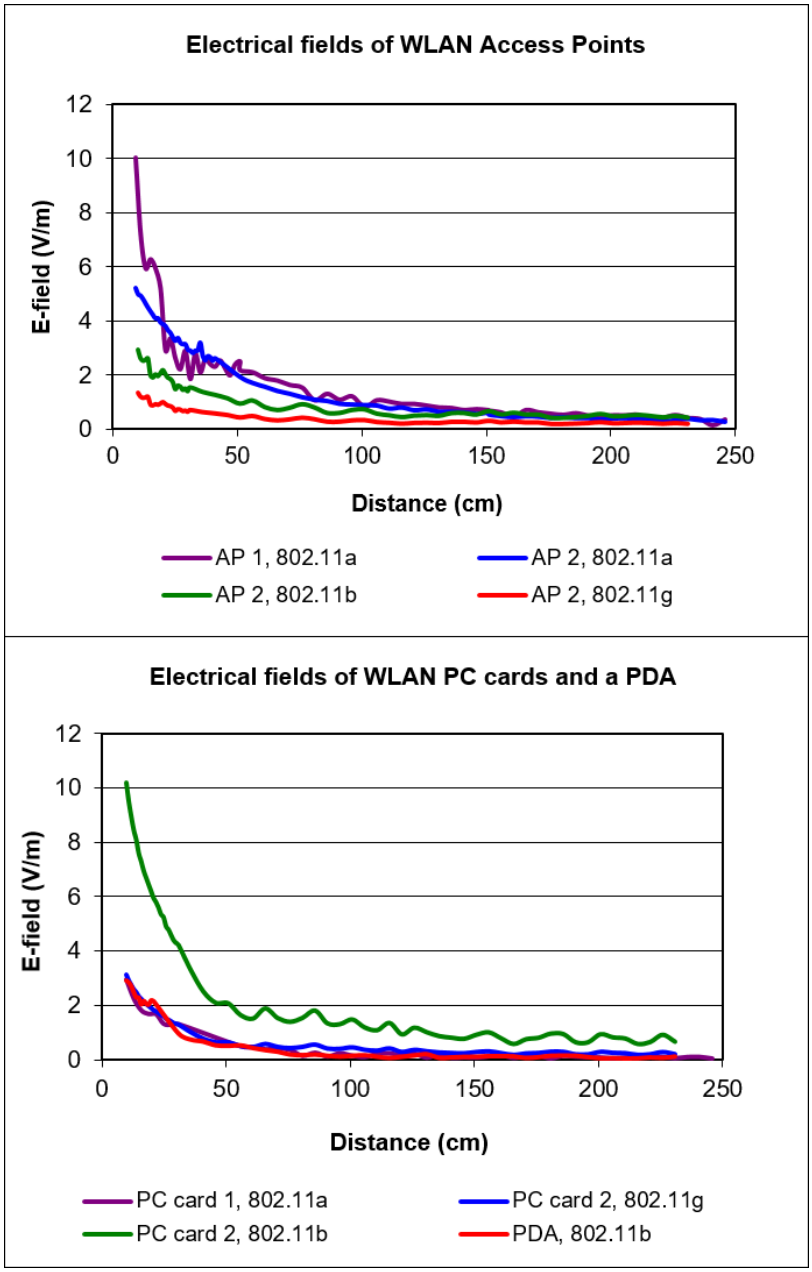

Figure 1: Electric field (E-field) strength as a function of distance (cm) for two different WLAN access points (AP), two different PC cards and a PDA. Access point 2 can be operated using the 802.11a, b or g standard, and PC card 2 using 802.11b or g.

The results of a study commissioned by the FOPH [3] show that the electric field strength decreases rapidly with increasing distance from the transmitter (Figure 1) and is below the recommended limit [2] at all distances. In all cases, it is less than 10% of the recommended limit at a distance of 20 cm and less than 2.5% at a distance of a metre. The results of these measurements cannot be generalised to all WLAN devices. However, as the transmit power of WLAN devices is regulated by law [1], it may be assumed that the electric fields of other WLAN devices are of similar strength.

3.3 Electromagnetic radiation from WLAN devices in everyday life

Comprehensive and continuous measurements of the population's exposure to electromagnetic radiation are not currently available. Useful evidence is provided by studies in which electromagnetic radiation was measured at specific locations or with the aid of persons wearing a dosimeter during their everyday activities. Such dosimeters provide continuous measurements at short intervals of the radiation originating from various wireless technologies. Based on the activities recorded in diaries by these individuals, the contributions of various everyday situations and wireless technologies to total exposure can be determined.

The results of high-quality studies analysing exposure levels in Europe between 2015 and 2018 were summarised in a systematic review [5]. The following information relates to this period. Most studies indicate the mean electromagnetic radiation values measured over time. The overview shows that everyday exposure to electromagnetic radiation is well below recommended limits. In most everyday situations, WLAN devices are the lowest contributors. In indoor environments, WLAN devices account for approx. 3% of total electromagnetic radiation. In schools, the proportion of electromagnetic radiation attributable to WLANs does not exceed 5% in most cases, although WLAN devices were found to account for 30% of total electromagnetic radiation in one study.

In some studies, the maximum values measured are indicated as well as mean values. Studies from Stockholm show that the maximum electromagnetic radiation values measured in the Old Town and at the Central Railway Station [6. 7] are at least 180 times lower than the recommended limit and even lower in most places. A study from Örebro (Sweden) measured electromagnetic radiation in schools [8]. The maximum exposure level due to WLAN devices was around 50 times and the mean value almost 1800 times lower than the recommended limit. A study from Slovenia [9] showed that, in children, exposure to electromagnetic radiation was on average 1000 times lower and the highest value measured 25 times lower than the recommended limit. In another study measuring exposure due to WLAN devices operating in the 5 GHz band in an indoor environment [10], the maximum electromagnetic radiation value was found to be around 30 times lower and the mean value almost 250 times lower than the recommended limit.

3.4 Studies from Switzerland

In Switzerland, several studies have investigated exposure to electromagnetic radiation in everyday situations. In a study from the canton of Zurich [11], where 115 subjects wore a dosimeter for 2–3 days, the mean total exposure to electromagnetic radiation over time was below the recommended limit. The main sources were, firstly, mobile phones and, secondly, mobile phone base stations. The electromagnetic radiation from WLAN devices accounted for 5% of mean total exposure. Exposure levels were 0.04 V/m in households with and 0.02 V/m in households without WLAN devices and were thus between 1500 and 3000 times lower than the recommended limit. The maximum value measured was approx. 400 times lower than the recommended limit.

Another Swiss study, involving 90 adolescents aged 13–17, obtained similar results [12]. WLAN devices accounted for 3.5% of total personal exposure to electromagnetic radiation. The highest value measured was around 600 times lower and mean exposure at least 2000 times lower than the recommended limit. The detailed analysis indicates that exposure to WLAN radiation depended only marginally on whether WLAN devices were used in school or at home. It also only marginally

depended on whether the adolescents' mobile phones were connected to the internet via WLAN, via mobile internet (mobile phone base stations) or not at all.

4 Health effects

According to current scientific knowledge, the electromagnetic radiation emitted by WLAN devices is not strong enough to cause – as a result of absorption – an increase in body temperature that would pose any acute health risks. Research on possible long-term effects associated with the use of this technology over long periods is not yet adequate to permit any firm conclusions. However, available studies on radiofrequency radiation from WLANs do not provide either solid findings or plausible evidence of health risks.

In recent years, numerous studies have investigated the biological and health effects of electromagnetic radiation at levels below recommended exposure limits. The results of a total of 23 selected studies on the health effects of WLAN radiation were analysed in a review commissioned by the FOPH and conducted by scientists at the University of Basel [13]. Studies in cells and animals were designed to elucidate biological mechanisms associated with WLAN radiation. Experimental human and epidemiological studies aimed to identify any risks arising from typical exposures in everyday life. Included in this review were studies investigating radiofrequency electromagnetic radiation with characteristics typical of WLAN devices (frequencies in the 2.4 GHz and 5 GHz band, not a continuous wave signal, WLAN-typical modulation, low pulse rate) and meeting the following minimal quality criteria: (a) cell and animal studies: adequate dosimetry; (b) cell, animal and experimental human studies: at least single-blinded, with exposure and control group(s) and measured or modelled exposure levels; (c) epidemiological studies: definition of inclusion and exclusion criteria and consideration of basic confounders. Excluded were any studies which did not meet these quality criteria, employed radiation not typical of WLAN devices, or involved plants, fungi or bacteria.

The results of the cell studies do not indicate either perturbed cellular processes or genotoxic properties of WLAN radiation.

The animal studies were mainly concerned with effects on reproduction and development in rodents. Several studies by one research group showed that, for most outcomes, no significant effects were associated with exposure to WLAN radiation. In female rats, a non-dose-dependent increase in food consumption was seen during the post-exposure lactation period, but no effects were observed on maternal body weight, number of implantation sites, fetal death rate, number of live births/stillbirths, litter size or macroscopic abnormalities. In the brains of young rats, no signs of neurotoxicity (altered gliosis or apoptosis) were found. The blood of newborns showed no evidence of exposure-related increased oxidative stress. Nor were any alterations observed in pups' body weight or anogenital distance (marker of reproductive health), or in the expression of stress markers such as heat shock proteins, and no macroscopic abnormalities were observed. Likewise, there was no evidence of exposure-related effects on physical and functional development or behaviour. A study investigating fertility in male rats showed that exposure to WLAN radiation was not associated with morphological defects or with alterations in sperm motility/concentration or spermatogenesis. Nor were testes or prostate weight affected. Exposed animals showed (a) an increased proportion of sperms with head defects, (b) decreased weight of epididymis and seminal vesicles, (c) reduced thickness of the tunica

albuginea (connective tissue) and (d) reduced diameter of seminiferous tubules. Several studies investigating the immune system showed essentially no alterations of immunological parameters in animals exposed pre- or postnatally to WLAN radiation. An exception to this was reduced interferon-gamma production in male mice, although this was observed at a high exposure level that would not typically occur with WLAN devices.

The experimental human studies included both cognitive and physiological investigations. In an EEG study, WLAN exposure was associated with gender-related alterations in neural activity associated with attention during cognitive testing. In another EEG study, no exposure-related changes were observed in waking EEG recordings or in a psychomotor vigilance test (reaction time, number of lapses, variability of responses); nor was self-reported fatigue affected. Two studies by one research group found no exposure-related effects on respiratory rate, heart rate variability, blood pressure or skin conductance in self-declared electrohypersensitive individuals; nor were any effects observed on salivary concentrations of alpha-amylase, cortisol or immunoglobulin A. A sleep study found no exposure-related effects on brain activity (EEG), with the exception of reduced global power in the alpha frequency band during non-REM sleep, which did not however affect the participants' subjective sleep quality or sleep structure. Another study found no exposure-related effects on subjects' reaction time, short-term memory or reasoning ability.

The epidemiological studies concerned both adolescents and adults. One study found that adolescents with a WLAN at home were significantly less likely to wake up during the night; in addition, no relationship was found between the presence of a WLAN at home and symptoms such as headaches, feeling down or depressed, tinnitus, trouble falling asleep, tiredness during school, painful texting thumb, or behavioural problems. In a larger study investigating sleep in children, no relationship was found between WLAN exposure and sleep onset delay, sleep duration, night awakenings, parasomnias or daytime sleepiness. Higher sleep anxiety was, however, observed in children with a WLAN at home. In a study on electrohypersensitivity, WLAN radiation was most frequently cited by participants as a cause of their complaints. In 1 of the 36 participants, a significant association was found between symptoms and WLAN exposure. In a study of pregnant women, no association was found between oxidative stress parameters in the blood and placenta collected immediately after birth and WLAN exposure at the workplace or at home.

5 Legal regulations

5.1 WLAN devices

WLAN devices are subject to the Ordinance on Telecommunications Installations (FAV) [14], which sets out basic requirements for protecting the health and safety of persons who use or are exposed to radiation from telecommunications installations. These requirements are elaborated in Swiss-European standards. The limits specified in these standards correspond to those given in the 1999/519/EC: Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) - Publications Office of the EU.

Manufacturers are responsible for ensuring that their appliances comply with the conformity criteria. In Switzerland, no authority checks whether WLAN devices meet these standards (23.4244 | Mobile phones emit more radiation than permitted. The time has come to check the NIR limits in Switzerland

too! | Item of business | The Swiss Parliament – available in German, French and Italian).

5.2 WLAN hotspots

WLAN hotspots are areas where internet access is available via a WLAN and which are either accessible to the public (stations, airports, etc.) or restricted to specific users (hotels, etc.). The access points of publicly accessible hotspots are stationary transmission installations and thus fall within the scope of the Ordinance on Protection against Non-Ionising Radiation (NISV) [15]. As the maximum permissible output of WLAN access points is below 6 watts of effective radiated power (ERP), they are exempt from precautionary emission limitation requirements, i.e. they are not subject to an additionally reduced installation limit value. However, hotspots are required to comply with the less strict ambient limit values specified in the NISV if the whole body is evenly exposed to radiation. In cases where people come so close to the antennas of a hotspot that their body is no longer evenly exposed, the ambient limit value specified in the NISV is not applicable; instead, the requirements of the FAV, or the exposure limit of 2 W/kg recommended for the specific absorption rate [2], must be complied with.

6 References

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