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Eidgenössisches Departement des Innern EDI
Bundesamt für Gesundheit BAG

Bluetooth

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Bluetooth is a transmission technology which enables wireless data transfer between desktop computers and notebooks, PDAs, smartphones, printers, scanners, digital photo and video cameras as well as various electronic domestic appliances and personal devices.
Bluetooth devices are assigned to one of three power classes: 1, 2 and 3 (Table 1) and have correspondingly different transmission powers and transmission ranges.

Table 1: Power Classes of Bluetooth Transmitters

Power Class	Peak Transmission Power (mW)	Maximum Transmission Power (mW)	Minimum Transmission Power (mW)	Range (m)	SAR Limit (W/kg)
1	100	76	1	100	0,5
2	2,5	1,9	0,25	40	0,03
3	1	0.8		10	0,01

The radiation emitted from Bluetooth devices of power classes 2 and 3 is weak and limited in range. Most of the Bluetooth applications used close to the body belong to one of these two power classes. In the transmission mode, Bluetooth transmitters of the most powerful class 1 can cause exposure to radiation similar to that emitted by smartphones/mobile phones if they are operated in the immediate vicinity of the body.

The radiation exposure caused by Bluetooth devices in all three power classes is below the international recommended levels. Effects on health from long-term exposure to high-frequency electromagnetic fields remain uncertain. However, short-term effects from high-frequency radiation from Bluetooth devices are not expected.

Bluetooth hands-free headsets to minimise radiation from mobile phones
In order to minimise radiation from mobile phones we recommend Bluetooth hands-free headsets of power classes 2 and 3. Instead of the smartphone/mobile phone, a Bluetooth transmitter that emits a far lower level of radiation is held to the ear during phone calls, thus reducing exposure of the head considerably.

Bluetooth (IEEE 802.15.1) is the first standard to be introduced for voice and data transfer over short distances (known as WPAN, or wireless personal area network). As Bluetooth transmitters are very small and cheap and use little power, a large number of devices are already equipped with them. Bluetooth enables data transfers over short distances between computers, tablets, smartphones and their peripheral devices as well as electronic domestic appliances.

Typical applications are:

- Hands-free headsets for mobile or cordless phones
- Cordless telephones for Internet telephony (Voice over IP)
- Wireless connections for audio and video systems, MP3 players and headphones
- Wireless connections between computers, printers, mice, digital cameras etc.
- Connection to external car antennas for mobile phones
- Patient monitoring in hospitals
- Health and fitness sensors to smartphones

1 Technical data

Bluetooth uses the globally available and identical world-wide frequency band reserved for ISM (Industrial, Scientific & Medical) applications (Frequency: 2.4 – 2.4835 GHz; wavelength: approx. 12.5 cm). Consequently, devices equipped with Bluetooth can be used throughout the world. The frequency hopping technique (1600 frequency changes per second) ensures a robust, secure and trouble-free data transmission. [1]

Recent developments of Bluetooth have increased data rates and security and reduced power consumption. Bluetooth version 2.0 has increased throughput in spite of limited bandwidth, Bluetooth High Speed version 3.0 combines Bluetooth with WLAN technology. The major applications of Bluetooth version 4.0 are wearables (clothes with in-built sensors) and the Internet of Things (e.g. household management such as lighting, heating, security applications, smart meters or electronically communicating domestic appliances). The power consumption of this version is so low that tiny and light-weight health sensors and fitness trackers can be run for extremely long periods. Version 4.2 enables a secure and variable access to the Internet via packet standard IPv6 that strongly increases the number of connected devices. Version 4.2 enables correspondingly equipped devices to be remote controlled throughout the world.

Transmission power

There are three power classes for various Bluetooth applications, each with a different range. (Table 1).The effective transmission power is usually lower than the maximum power as transmission is only ever strong enough for the receiving device to pick up the signal. The receiving device can measure the transmission power and request the transmitter to increase or reduce it if possible. This power regulation prolongs battery life and avoids interference with other Bluetooth networks.

Table 1: Power Classes of Bluetooth Transmitters

Power Class	Peak transmission power (mW)	Maximum transmission power (mW)	Minimum Transmission Power (mW)	Range (m)	SAR Limit (W/kg)
1	100	76	1	100	0,5
2	2,5	1,9	0,25	40	0,03
3	1	0,8		10	0,01

This means that transmission power, and thus radiation exposure, are not constant. Power regulation is mandatory for power class 1 and optional for classes 2 and 3.

Operational architecture

Depending on the application, there are various communication profiles for Bluetooth devices. Each device only supports certain profiles: two devices can only communicate via a common profile, and are thus only compatible if this is the case.
When Bluetooth devices with the same communication profile are in range, they automatically communicate with each other. Up to eight devices can be actively linked in a network known as a piconet. One device (known as the master) takes the lead and organises data transfer within the piconet; all the other devices are known as slaves.

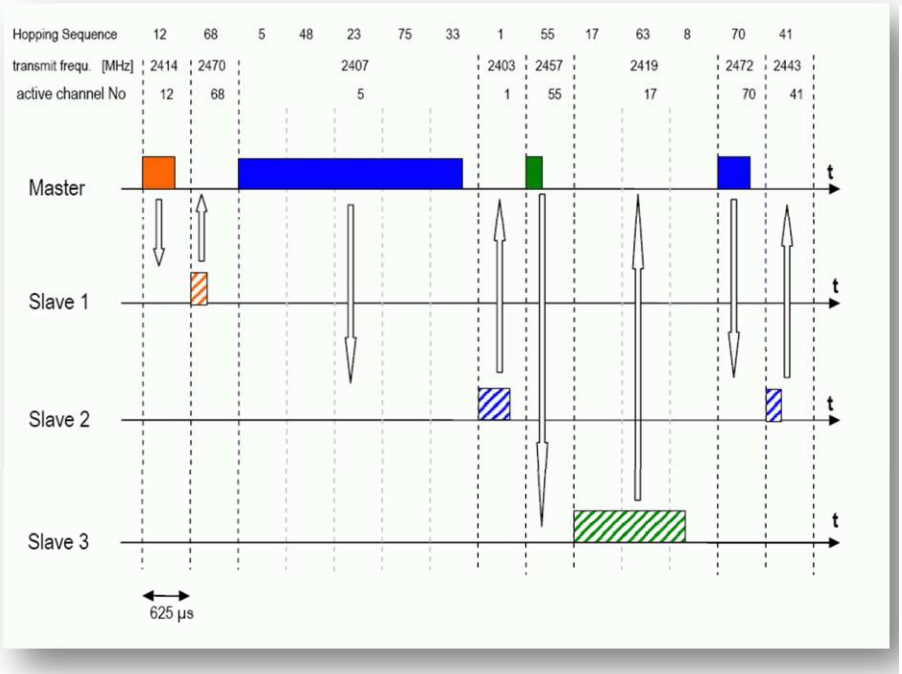

Figure 1 Example of a Bluetooth time slot structure: The master transmits on channels 12, 5, 55 and 70; the slaves transmit on channels 68, 1, 17 and 41. On channel 5, five time slots are combined to allow a larger volume of data to be transmitted; on channel 17, three time slots are combined. Individual time slots can be in use for different lengths of time depending on the volume of data being tran mitted. Image source [2]

If no data transmission is taking place, the slaves generally do not transmit, and receive only sporadically. The master sends a beacon even if no data are being transmitted (once a second, for example) 4 so that the slaves can synchronise with it.

Low-frequency fields emitted by Bluetooth devices:
Since a Bluetooth device only consumes power while it is transmitting and receiving, the battery is switched on and off repeatedly. This produces low-frequency magnetic fields from around 1 Hz (beacon) up to several thousand Hz.

2 Measuring exposure

The basic unit for measuring exposure to high-frequency radiation is absorbed energy per time interval and bodyweight, expressed as the specific absorption rate (SAR) in watts per kilogram (W/kg).

SAR is measured for Bluetooth devices operated in proximity to the body (up to 13 cm). For devices operated further away from the body, the electrical field is also an important parameter.

A study commissioned by the FOPH [3, 4] measured the SAR and the electrical field of the following applications:

- Two different Bluetooth USB plug-in antennas in power classes 1 and 2 at the maximum data
- A class 2 PDA (personal digital assistant)
- Two different hands-free headsets in class 3 (only SAR)

Figure 2: Measuring equipment to determine SAR values Left: Table with a container in the shape of a flat phantom body set into the surface, and a positioning robot with probe attached. Right: Phantom body with Bluetooth transmitter, seen from below. Image source [3]

SAR value

SAR values were measured in various parts of a phantom body (Figure 2). All SAR values measured were below the threshold of 2 W/kg recommended by the ICNIRP (International Commission on Non-Ionizing Radiation Protection) (Table 2) [5].

Table 2. SAR values of class 1, 2 and 3 Bluetooth devices

	Power Class	SAR (W/kg)
Plug-in antenna (USB)	1	0,466
Plug-in antenna (USB)	2	0,0092
PDA	2	0,01
Hands-free headset	3	0,00117 - 0,00319

Electrical field

Figure 3 shows the electrical field in the proximity of Bluetooth USB plug-in antennas operating at maximum transmission power. The field decreases rapidly with increasing distance from the device. The measured field strengths of the Bluetooth devices are more than 20 and 150 times lower than the threshold of 61 V/m recommended by the ICNIRP at a distance of as little as 20 cm [5].

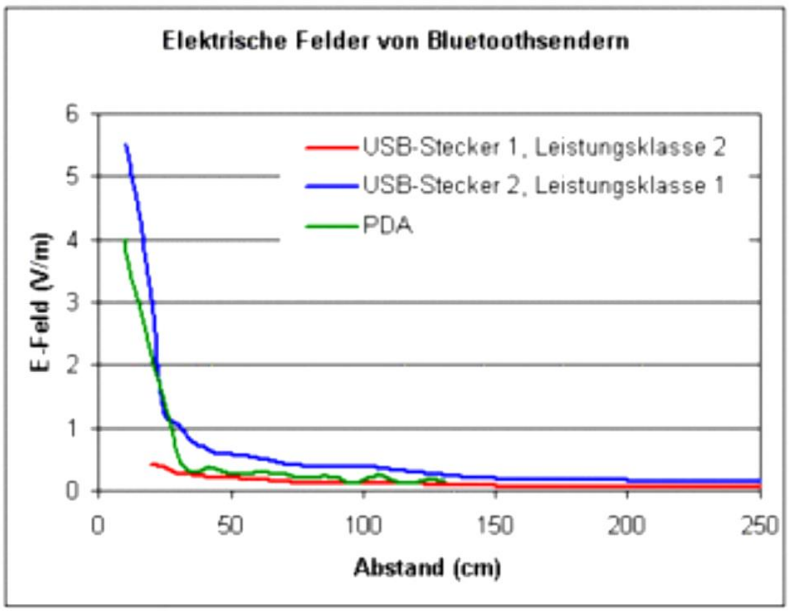

Figure 3: Maximum electrical field (E field) as a function of distance for two Bluetooth USB plugs in different power classes and a PDA. The electrical field decreases very rapidly with increasing distance. The measurements were carried out at maximum transmission power [3, 4]

In order to save energy and avoid interference with other devices Bluetooth normally reduces the transmission power if the connection between the devices is good. This produces an even smaller E field and lower SAR values.

3 Effects on Health

Based on the current state of knowledge and available exposure measurements, the high-frequency radiation emitted by Bluetooth networks is too weak to have an acute impact on health due to an increase in temperature following absorption.

High-frequency Electromagnetic Fields

In 2011 the International Agency for Research on Cancer (IARC) classified high-frequency electromagnetic fields as possibly carcinogenic (Group 2B) [6]. This, however, was based only on studies that saw a possible connection between telephoning with a mobile phone or a cordless telephone and the occurrence of brain tumours. The overall data was found to be limited by the IARC, as these studies on brain tumours and mobile phones and cordless phones have shortcomings in regard to the

study design and the estimation of the length of exposure. A connection between exposure to mobile and cordless phones and other illnesses or symptoms could not be determined. In addition, the IARC could not determine any connection between effects on health and high-frequency radiation emitted from other devices, such as for example Bluetooth. Short-term health effects are not to be expected as the present threshold values avoid acute damage.

Effects on the auditory nerve

Various studies on animal experimentation with electromagnetic radiation from Bluetooth transmitters showed no effect on the inner ear and had no impact on the basic hearing function. In tests with humans Bluetooth transmitters likewise showed no significant modifications to auditory nerve activity [7, 8].

4 Regulation in Law

Bluetooth devices are telecommunications terminal devices and as such regulated by the Swiss regulation on telecommunications systems [9]. This regulation lists technical standards which may be used to evaluate electromagnetic radiation. These standards are issued by the European Committee for Electrotechnical Standardization CENELEC [10 and 11-13] and describe the procedures for measuring the radiation emitted by specific devices.

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Specialist staff:
Federal Office of Public Health FOPH
emf@bag.admin.ch