OCCUPATIONAL EXPOSURE RELATED TO RADIOFREQUENCY FIELDS FROM WIRELESS COMMUNICATION SYSTEMS

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INTRODUCTION

Along with the explosive growth of products and services utilized in modern information technology applications, wireless communication systems have become essential part of working life. Though majority of workers are exposed to radiofrequency (RF) fields from wireless systems, most telecommunication devices produce field strengths that can be considered harmless. However, there are certain work situations where safety limits may be exceeded, and determination of occupational exposure is needed.

MOBILE TELEPHONY

Cellular phones

Cellular phones are a specific group of RF sources, since they are used in close vicinity of the head: either on the ear or in front of the face. The exposure to RF fields emitted by mobile phone handsets is determined as values of the *specific absorption rate* (SAR). The SAR values of localized exposure of the head are determined as an average over 10 g of tissue during 6 minutes. Exposure evaluation can be based either on dedicated measurements or on numerical modelling.

The measurement equipment consists of an anatomical human head model. This head phantom is filled with liquid that imitates the electrical properties of the brain. The absorbed power is measured with a small electric field probe using a robot arm controlled by a computer. Due to the difficulty to measure the SAR values in various exposure situations, several different numerical techniques have been developed. The appropriate method for particular problem depends e.g. on the exposure conditions, the frequency, the size of the object and the required accuracy.

During normal use of GSM phones with maximum output powers of 1 to 2 W, the localized SAR is less than 2 W/kg (occupational limit value 10 W/kg) [1]. Similarly, the measurements with a head phantom have resulted in the average SARs of 0.9 W/kg (ear) and 0.24 W/kg (face) for 1 W hand-held TETRA phones [2]. Accordingly for 3W TETRA handsets, the SAR values are 2.9 W/kg and 0.5 W/kg, respectively. The RF emissions by UMTS handsets (*Universal mobile telecommunication system*), the 3rd generation network operating at frequencies 1900 - 2200 MHz, are similar to those from GSM phones. In general, new phone models with higher frequencies emit less power than older types, and since the year 2001 the mobile phone manufactures have been required to notify the SAR levels of their new phone models.

In general, new cellular phone models operate at higher frequencies but emit at a lower power than older types (Table 1). The mobile phones also control the transmitted power according to the network coverage. The better the network coverage, the less transmitted power of a cellular phone is needed to communicate with the base station. Using mobile phones to transmit data may increase power levels two to three times higher than those transmitted in speaking mode. In these cases the mobile phone is usually further away from the body. In addition, the use of a hands-free device and even a small distance between the body and the phone e.g. belt holder, reduces the exposure of the phone user.

Table 1. Frequency bands and power levels of common mobile phone systems.

	TETRA	GSM 900	GSM 1800	UMTS
Frequency (MHz)	400	900	1800	2000
Average output power (W)	0.25 - 7.5	0.25	0.125	0.125

Base Stations

Mobile phones communicate by radio signals passing between the phone and the base station antennas. Mobile telephones are connected to the base station by two separate radio links: the uplink from phone to base station and the downlink from the base station to phone. The coverage of a base station is called a cell. Cells may be divided to sectors, in which case the base station transmits different signals to different sectors. Cell sizes vary depending on the surrounding environment and phone users. The largest cells are known as macro-cells, while smaller ones are called micro- and pico-cells (Table 2). Macro cell antennas are usually situated on a roof or in masts, whereas micro- and pico-cells can be more easily approached. Occupational exposure is possible during maintenance of a base station, as well as during construction and similar tasks on the roof, in a close proximity of the transmitting antenna.

Table 2. A GSM cell classification [3,4].

	Macro cell	Micro cell	Pico cell
Power	tens of watts	few watts	less than 1 watt
Coverage	more than 500 m	300 -1000 m	up to 100 m
Mounted	rooftops	street level	street level
	ground-based masts	wall of structures	indoors/outdoors
		lamp posts	walls

The general approach to evaluate safe exposure distances in front of base station is to measure or calculate power densities around the antenna. As an example, a typical 900 MHz omnidirectional antenna with a total radiated power of 80 W produces power density of 100 W/m^2 at about 10 cm from the antenna, while for a similar 1800 MHz antenna power density at 10 cm is about 300 W/m^2. In Fig. 1 measurements from typical GSM 900 base station (?? W) are shown. The occupational exposure limit value is exceed at 0.5 m and at 1.5 m (?) for general public. The antennas are positioned so that RF energy is directed away from the buildings to provide the best coverage for telecommunication devices. This results in low RF fields directly below the antenna. The RF energy is also directed mainly to the bore sight, so RF fields on the sides and behind the antenna are generally low. From the RF exposure point of view, the UMTS base stations are quite similar to GSM base stations.

WIRELESS LOCAL AREA NETWORKS (WLANs)

By using wireless computer network, a user can access local area network through wireless radio connection. These wireless connections are becoming more common in offices and homes. In many public places, it is also possible to access the internet via so called 'hotspots', provided by WLANs. The WLAN systems operate at various frequencies, the lowest band being at 2.4 GHz, and the three other bands at 5.15 - 5.85 GHz. The technologies for WLANs are described in the standard IEEE 802.11 [5].

Computers using WLAN have either an integrated (inside) or a mounted (outside) antenna. Exposure to WLAN equipment depends on the position of the transmitting antenna, the peak transmitted power and duration of the transmission. In the office environment, the power density is much below occupational exposure limit values. Within few centimeters of the antenna (e.g. laptop on lap), the exposure situation is different and SAR measurements or calculations for exposure assessment may be needed.

BLUETOOTH

Bluetooth is an industry specification for short-range radio frequency based connectivity for portable personal devices. These devices include among others hands-free devices, PDAs, laptops, printers, digital cameras, PCs and hearing protectors that have Bluetooth connection. The Bluetooth technology operates on unlicensed frequency range of 2400 - 2480 MHz. The equipment is divided into three Power Classes from 1 to 3, with maximum output power of 100 mW, 2.5 mW and 1 mW, respectively [6]. The maximum operating range for Bluetooth devices is approximately 100 m for Class 1, 20 m for Class 2, and 10 m for Class 3. Devices belonging to the Class 1 transmit at power levels similar to cellular phones, and exposure assessment is needed if these devices are used near human body.

CONCLUSIONS

Personal wireless communication systems generally comply with the safety limits for electromagnetic fields. The head SARs of new mobile phone models are much less than the recommended value for occupational exposure (10 W/kg). Bluetooth devices ranging less than 20 m (Power Class 2-3), such as hands-free devices, can be considered safe. The safety limits can, however, be exceeded in the immediate vicinity of the mobile telecommunication base station antennas. The electric field is at highest value right in front of the antenna. Below, behind or on the side of the sector antenna the RF field is considerably lower. In addition to previously mentioned technologies, there exist several other wireless communication schemes, such as ultra wideband (UWB) and radiofrequency identification (RFID) systems. These technologies have their own RF emission characteristics, and hence also need dedicated assessment techniques to produce reliable exposure results.

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