

# Radio Waves & Health

In-building solutions



# In-building mobile

*Ericsson provides solutions and technologies for high-quality mobile communications in indoor environments, such as offices, shopping malls, hospitals and airports. Sometimes people ask questions about the safety of these in-building radio communication systems. The aim of this report is to answer these questions and to provide facts and information that is easy to understand.*

## Exposure to radio waves



In all mobile communication systems, the terminals communicate with fixed base stations by exchanging low-power radio signals. These radio signals, or radio waves, are radio frequency (RF) electromagnetic fields (EMF) of the same type as those used for television and radio broadcasting. Mobile communications use radio waves in the frequency range between 400 and 2500 MHz. A well-known property of all radio waves is that part of the carried energy may be absorbed in an exposed body.

To ensure that such RF energy absorption is kept far below the level where potentially adverse heating effects might occur, national and international health authorities have specified exposure limits. The radio wave exposure from mobile communications equipment is below these limits.

### Science and research

Radio waves have been used for more than one hundred years in different kinds of applications, including wireless communications. The increasing use of radio triggered the interest to investigate whether radio waves can cause adverse health effects. Over the past sixty years numerous studies have been conducted. Based on this research, limits for human exposure to RF fields have been set by scientific organizations.

The World Health Organization (WHO) and several national and international expert groups have reviewed the research on radio waves, mobile telephony and health. The overall conclusion of these reviews has consistently been that RF fields from mobile phones and base stations have not been shown to cause any adverse health effects.

“None of the recent reviews have concluded that exposure to the RF fields from mobile phones or their base stations causes any adverse health consequence.”  
WHO fact sheet 193, June 2000 (1)

# communications safety

However, WHO and others still recommend additional research concerning RF exposure and health to further improve the basis for health risk assessment. At present, several ongoing research projects comply with the WHO recommendations. Ericsson co-sponsors many of these.

## Guidelines and limits

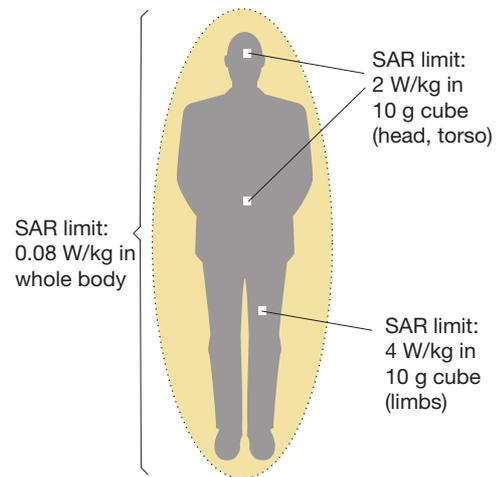
The most widely adopted RF exposure guidelines are those developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These are endorsed by the World Health Organization (WHO) and have been adopted in the European Council Recommendation, 1999/519/EC [2]–[3].

*Specific Absorption Rate (SAR)* is the quantity used to specify basic restrictions for both general public and occupational exposure in the frequency range between 10 MHz and 10 GHz. SAR is a measure of the rate of RF energy absorption in the body expressed in units of watts per kilogram (W/kg). The ICNIRP guidelines specify both whole-body and localized SAR values (averaged in any 10 g of tissue).

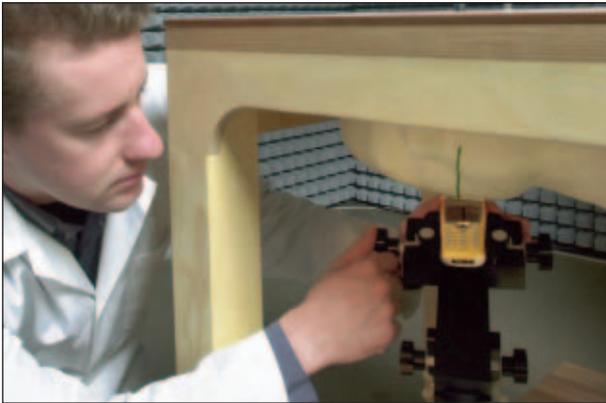
The values specified in the figure to the right are valid for exposure of the general public. For occupational exposure, the allowed values are five times higher.

The SAR values are to be averaged over any six-minute period of exposure. This reflects the fact that it takes some time for the body temperature to rise when exposed to RF fields. Radio transmitters with maximum output power levels of less than 20 mW, such as low-power Bluetooth devices, cannot in any situation cause RF exposure levels that exceed the basic restrictions.

Because SAR is normally difficult to determine, reference levels expressed in terms of power density ( $W/m^2$ ) – and the corresponding electric field strength (V/m) and magnetic field strength (A/m) values – have been developed for



Radio transmitters with maximum output power levels less than 20 mW cannot in any situation cause RF exposure levels that exceed the ICNIRP basic restrictions.

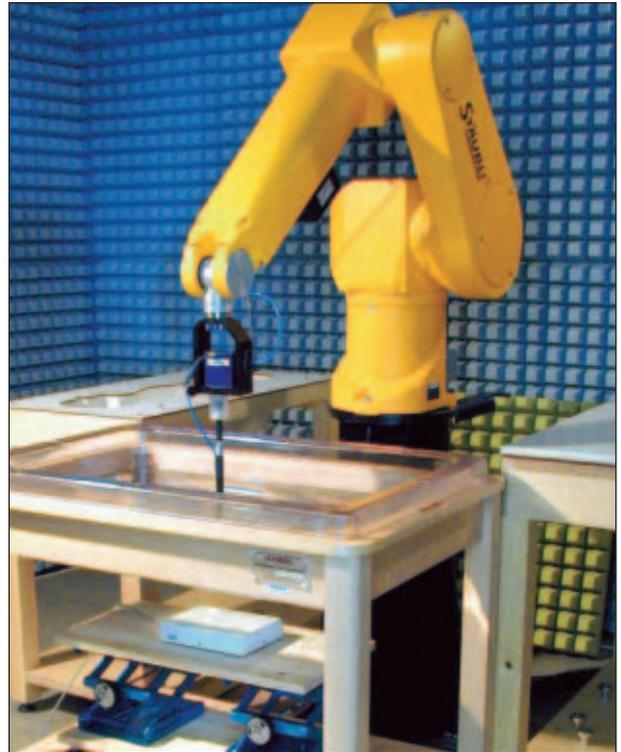
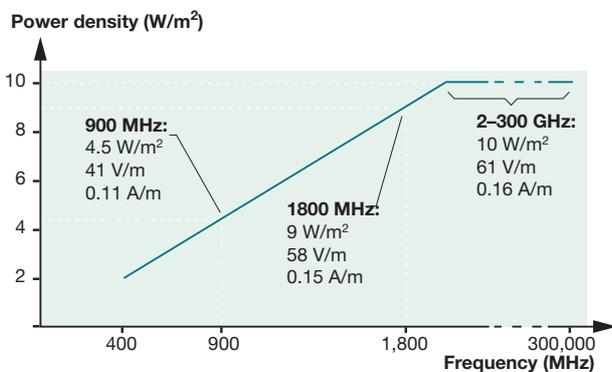


SAR measurements of a mobile phone and an in-building base station antenna.

comparison with exposure quantities in air. The reference levels, which are frequency dependent, have been chosen to ensure that the basic SAR restrictions cannot be exceeded in any exposure situation. This means that additional safety margins have been introduced. The reference levels are primarily applicable in the far field from a radio transmitter.

For partial-body near-field exposures, the reference levels are very conservative. In fact, the reference levels may be exceeded in near-field exposure situations, even though the exposure is in compliance with the basic restrictions. The figure below shows the ICNIRP reference levels for general public exposure. The corresponding power density reference levels for occupational exposure are five times higher.

The ICNIRP reference levels for general public exposure



## Product compliance

Mobile phone products are designed and tested to be in compliance with the SAR limits specified in the internationally accepted RF safety standards. The SAR measurements are performed at maximum output power levels and using standardized methods. Sony Ericsson provides information about SAR, including the measured maximum values for new phone models, in its user manuals and on the web.

For radio base stations, measurements or calculations are made to determine the compliance boundary, which is defined as the boundary, enclosing the antenna, outside of which RF exposure is below the appropriate limits.

SAR measurements are conducted for base stations with output power levels below 1 watt. For large antenna structures with higher output power levels, field strength assessments are used to determine the compliance boundary. Ericsson performs compliance boundary assessments according to standardized procedures and provides information for typical base station configurations.

The installation of base station antennas should ensure that people remain outside of the area enclosed by the compliance boundary.

## Electromagnetic interference

A wide variety of wireless applications uses radio waves of different frequencies, output power levels and modulation schemes. Electromagnetic fields from these applications can interfere with the functions of other electronic devices.

The three most important factors affecting the risk of electromagnetic interference are the transmitted power level, immunity of the electronic device and distance to the transmitter. The risk of interference increases with transmitted power and decreases with distance and improved immunity.

The radio signal's frequency and characteristics might also affect the risk of interference. Generally, equipment is more immune to high-frequency signals than to low-frequency signals and less immune to pulsed signals than continuous signals.

Digital mobile phones (for instance GSM and UMTS) automatically reduce their power when used in environments with good coverage, thereby reducing the risk of interference. The table at the end of this brochure contains information about frequency, pulse repetition rate, and terminal output power levels for the most common mobile phone systems.

## Medical devices, pacemakers and hearing aids

Telecommunication products have to meet electromagnetic compatibility (EMC) requirements that limit the emission outside the specified frequency range of operation.

Likewise, EMC requirements for medical equipment specify immunity limits below which the product should work satisfactorily. The International Electrotechnical Commission (IEC) issued a revised standard for medical equipment in 2001, specifying an immunity level of 3 V/m for non-life-supporting equipment. Life-supporting equipment should be able to work satisfactorily in environments with electric field strength levels of up to 10 V/m.

Cardiac pacemakers and hearing aids can be susceptible to wireless equipment such as mobile phones. However, the immunity of these products has increased immensely in recent years. Pacemakers sense electrical signals in the heart and are activated when anomalies occur. It has been shown that strong electromagnetic fields can affect pacemakers.

At very short distances between a mobile phone and a pacemaker, there is a risk that radio signals might interfere with the operation of the pacemaker. This risk is very low and no case of injury has been reported due to such interference. Ericsson and other manufacturers recommend that

pacemaker patients should always maintain a distance of at least fifteen centimeters between an activated mobile phone and the pacemaker.

Modern hearing aids have good immunity, and sounds from interference solely occur at very close distances to a digital mobile phone in use. Nowadays, there is virtually no risk of interference when other people use mobile phones.

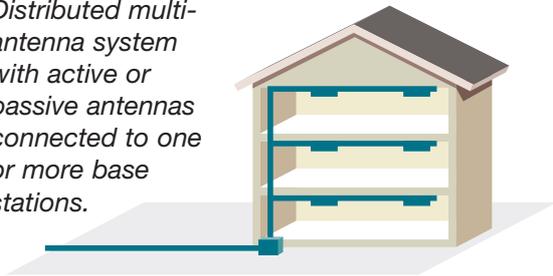
Interference from one's own phone can occur, however. These problems can be avoided by using handsfree equipment, which increases the distance to the transmitter. Large hearing aids used behind the ear are usually more sensitive than small devices worn in the ear or ear canal.

### Factors affecting the risk of interference:

- Transmitted power
- Distance to source
- Immunity
- Frequency
- Signal characteristics

In the frequency range 80 MHz to 2.5 GHz the specified immunity levels for electric field strength are 10 V/m for life-supporting equipment and 3 V/m for non-life-supporting equipment.  
(IEC 60601-1-2, 2001)

*Distributed multi-antenna system with active or passive antennas connected to one or more base stations.*



*Single cell in-building radio base station.*



## In-building systems

There are many ways to build a mobile communications network to obtain good coverage and capacity in an indoor environment. One possibility is a dedicated in-building network with antennas placed inside the building. Another alternative is to use pico cell base stations with integrated antennas. Still other solutions are to put outdoor antennas nearby or to extend an existing network using a repeater. Each alternative has different advantages regarding coverage, capacity and cost. Four different approaches are shown to the left.

*Outdoor antennas connected to macro or micro radio base stations, installed for instance on a mast or on a nearby building.*



*Repeater used to provide in-building coverage from a surrounding macro cell.*

### Radio wave exposure from antennas

In-building systems with distributed antennas can be planned in various ways. The more antennas used the lower the output power level needed for good coverage and capacity. The antennas can transmit in one (directional), two (bi-directional) or all directions (omni-directional). The maximum input power for in-building antennas, and pico radio base stations with integrated antennas, is usually less than 30 dBm (1 W). Another antenna solution makes use of leaky cables. This solution is mainly used in basements and culverts.

The *Effective Isotropic Radiated Power* (EIRP) is typically between 0 dBm and 20 dBm (1 mW–100 mW) in a distributed in-building antenna system. The EIRP can be higher (up to one or a few watts) for solutions with few antennas. Usually the systems are balanced in such a way that all antenna output power levels are more or less the same.

For distributed antenna configurations with 1 W input



*Directional panel antenna  
Gain: 7 dBi*



*Bi-directional antenna  
Gain: 5 dBi*



*Omni-directional antenna  
Gain: 2 dBi*

power, the RF exposure compliance distance for the general public is less than 10 cm. For the typical output power levels mentioned above, the basic restrictions will not be exceeded even at the surface of the antenna cover. The compliance distances for occupational exposure are even shorter than those for the general public.

Due to the very short compliance distances, these antennas do not require any special RF exposure safety instructions. Installation and maintenance personnel can work close to antennas in operation without being exposed to levels exceeding the basic restrictions. Touching an antenna for short times will not lead to exposure levels that exceed the SAR limits. However, it is advisable that the antenna should be placed where it cannot be easily reached by the general public.

### Real-life example

Taking an example from the real world, Ericsson has measured the output power levels in a modern office building in Gothenburg, Sweden, with a typical in-building network consisting of more than 100 distributed antennas of the three types mentioned above. In the GSM 1800 MHz frequency band the average output power level for the mobile phones was reduced considerably from the maximum to about 15 mW, and the base station antennas transmitted with an average EIRP level of 10 mW and a maximum level of 50 mW.

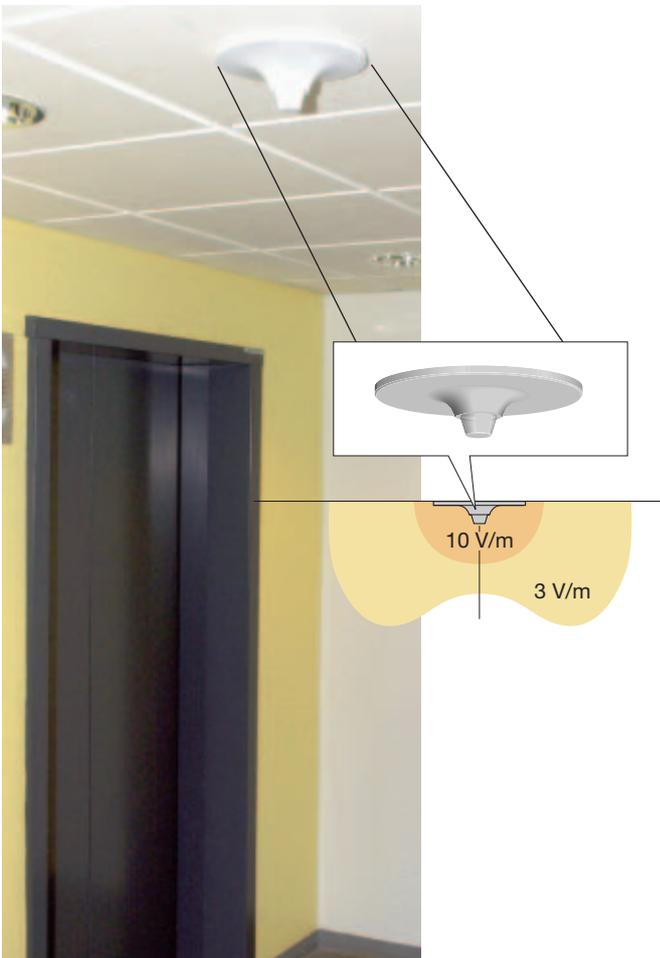
At a distance of less than 10 cm the maximum RF exposure levels of typical in-building network antennas with 1 W input power or less, are below the ICNIRP basic restrictions.

### Example from office building in Sweden

Mobile phone output peak power at 1800 MHz  
 Min 1 mW  
 Max 1 W  
 Average 15 mW

Base station antenna EIRP at 1800 MHz  
 Min 1 mW  
 Max 50 mW  
 Average 10 mW





*At a distance of 20 cm, the electric field strength of a typical omni-directional in-building antenna (GSM 1800 MHz, EIRP 100 mW) is 10 V/m (immunity level for life-supporting equipment). The immunity level for non-life supporting equipment, 3 V/m, is met at 40 cm.*

### Electromagnetic interference issues

With in-building wireless solutions, the phones generally transmit at a highly reduced output power due to the close vicinity of the base station antennas. Therefore, the risk of electromagnetic interference to sensitive electrical devices is low.

In extremely sensitive environments it is sometimes possible to limit the maximum power transmitted from phones to less-than-normal levels. This can be done by setting base station network parameters.

The electric field strength around an in-building system antenna with 100 mW EIRP (about 20–60 mW antenna input power) is below the immunity levels for medical equipment at a distance of less than one meter in the main beam direction and at shorter distances in all other directions.

For the GSM 1800 MHz omni-directional antenna (100 mW EIRP) shown left, the electric field strength levels are 3 V/m and 10 V/m at 40 and 20 centimeters, respectively. Consequently, there is very little risk that the fields from the in-building antennas can cause electromagnetic interference in sensitive equipment.

# Summary

- The radio frequency exposure from typical in-building network antennas is below established safety limits at a distance of 10 centimeters.
- Mobile phones used in indoor environments transmit with highly reduced output power; therefore the risk of electromagnetic interference to sensitive electrical equipment is low.
- Due to the low output power from in-building base station antennas, the field strength level at a distance of one meter is below the immunity levels of medical and other sensitive equipment, which means that the risk of electromagnetic interference is low.

## Q&A

### What about “radiation” from mobile phones and base stations?

Mobile phones and base stations use radio waves (electromagnetic fields or non-ionizing radiation) to send and receive voice, text messages, pictures and other data. Radio waves have long been used for different types of wireless communication, such as radio and TV broadcasting. Do not confuse radio waves with radioactive radiation.

### Is it true that using a mobile phone causes cancer or other health effects?

Extensive research over the course of many years has not established any conclusive evidence of a link between adverse health effects and the use of mobile phones.

### Are there any safety limits on human exposure to radio waves?

Yes. International and national health authorities, such as WHO, have adopted science-based safety guidelines specifying radio wave exposure limits. The limits have been set with wide margins to provide protection from established adverse effects on health.

### Is it all right to be close to base station antennas?

Yes. There is only a small area in front of the antennas where exposure can exceed the safety limits. The size of this area varies from a few centimeters for in-building antennas to a few meters for outdoor antennas. The antennas are to be installed in a way that restricts people from entering this area.

### Will an in-building mobile communication system cause electromagnetic interference to other electronic equipment?

Due to the low output power from in-building antennas and mobile terminals, the risk of electromagnetic interference is low and can be avoided with proper system design.

## References

- 1 WHO, "Electromagnetic fields and public health: mobile telephones and their base stations", World Health Organization, Fact sheet 193, revised in June 2000.  
[www.who.org/emf](http://www.who.org/emf)
- 2 ICNIRP, "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)", International Commission on Non-Ionizing Radiation Protection (ICNIRP), *Health Physics*, vol. 74, pp 494–522, April 1998.  
[www.icnirp.org](http://www.icnirp.org)
- 3 1999/519/EC, EU "Council Recommendation of the 12 July 1999 on the limitation of exposure to the general public to electromagnetic fields 0 Hz to 300 GHz", *Official Journal of the European Communities*, July 30, 1999.  
[europa.eu.int/comm/health/](http://europa.eu.int/comm/health/)

## Additional information sources

Ericsson's Internet health and safety site provides information and statements from Ericsson.  
[www.ericsson.com/health](http://www.ericsson.com/health)

Sony Ericsson's website provides SAR information for different mobile phone models.  
[www.sonyericsson.com](http://www.sonyericsson.com)

Mobile Manufacturers Forum (MMF) is an international association of radio communication equipment manufacturers. It provides information related to mobile communications and health.  
[www.mmfai.org](http://www.mmfai.org)

World Health Organization (WHO) International EMF Project is pooling resources and knowledge concerning electromagnetic fields and health.  
[www.who.org/emf](http://www.who.org/emf)

National Radiological Protection Board (NRPB) gives advice and information on radiation protection in the UK.  
[www.nrpb.org](http://www.nrpb.org)

Swedish Radiation Protection Authority (SSI) is a government authority that provides advice and information on radiation issues.  
[www.ssi.se](http://www.ssi.se)

Federal Communications Commission (FCC) is an independent United States government agency that oversees cellular phones and regulates the use of the radio spectrum.  
[www.fcc.gov/oet/rfsafety](http://www.fcc.gov/oet/rfsafety)

COST 281 is a European framework for research cooperation on potential health implications from mobile communication systems.  
[www.cost281.org](http://www.cost281.org)

ITIS, Foundation for Research and Information Technologies in Society  
[www.itis.ethz.ch](http://www.itis.ethz.ch)

EMF information from Professor John Moulder at the Medical College of Wisconsin on Cellular Phone Antennas and Human Health.  
[www.mcw.edu/gcrc/cop/cell-phone-health-FAQ/toc.html](http://www.mcw.edu/gcrc/cop/cell-phone-health-FAQ/toc.html)

Mobile communication system data

Technology	Frequency (MHz)	Maximum output power from terminal (W)		Pulse repetition rate, etc.
		Peak	Average	
CDMA	800	0.2	0.2	Between 50 Hz and 800 Hz (full rate) <sup>1</sup>
	1900	0.2	0.2	
CDMA 2000 (3G)	2000	0.25	0.25	Between 50 Hz and 800 Hz (full rate) <sup>1</sup>
GSM	800	2	0.25 <sup>2</sup>	217 Hz, Low-frequency components, 8 Hz, 2 Hz (DTX mode)
	900	2	0.25 <sup>2</sup>	
	1800	1	0.125 <sup>2</sup>	
	1900	1	0.125 <sup>2</sup>	
WCDMA (3G)	2000	0.25	0.25	Continuous transmission <sup>3</sup>
		0.125	0.125	
DECT	1900	0.25	0.01	100 Hz
Bluetooth	2450	0.001 <sup>4</sup>	0.001 <sup>4</sup>	Frequency-hopping technology
WLAN (IEEE 802.11b)	2450	0.1 <sup>4</sup>	0.1 <sup>4</sup>	Frequency-hopping or direct sequence technology

<sup>1)</sup> Additional low-frequency components might exist due to fast power regulation

<sup>2)</sup> Higher average output power levels are possible when using GPRS multislot transmission

<sup>3)</sup> Low-frequency components might exist due to fast power regulation

<sup>4)</sup> Other power levels are also specified

Ericsson is shaping the future of Mobile and Broadband Internet communications through its continuous technology leadership.

Providing innovative solutions in more than 140 countries, Ericsson is helping to create the most powerful communication companies in the world.