

Mobile communications and health

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Mobile telephony has become one of the most successful and widely spread applications of radio communications. A majority of the population in many countries has a mobile phone, and the number of radio base stations is growing as operators strive to provide greater coverage and better quality of service. However, many people do not know how radio technology works and some wonder if it is safe. Their main concerns regard the possible effects on health from radio waves that mobile phones and base stations transmit in order to communicate with each other.

Ericsson takes these health concerns seriously, addressing them in a number of different ways. For instance, Ericsson employs rigid product design, testing, and installation procedures to ensure that radio wave exposure levels from products and network solutions are below established safety limits. Ericsson also supports independent research to further knowledge in this important area. Finally, Ericsson describes how mobile communications work and provides information on health and safety issues.

In this article, the authors describe what is known about radio waves and health, which safety limits and standards apply to mobile communications, what research activities Ericsson is contributing to, how Ericsson ensures that its products comply with set limits, and how it addresses needs for information.

Introduction

The growth of mobile communications during the past 15 years has been tremendous. Today, in many parts of the world, practically everyone has a mobile phone. This development has come about thanks to the continuous evolution of mobile products, networks and services, allowing more and more people to benefit from wireless voice and data communications anywhere and anytime. However, as with many other new and rapidly growing technologies, a lot of people are unaware of how mobile commu-

nications really work. This, and articles in the media that speculate about the risks to health from mobile phones and base stations, have given rise to questions about the safety of mobile communications.

Most health concerns center around "radiation" or the radio waves (radio signals) transmitted by mobile phones and base station antennas. These radio waves are necessary for mobile communications. Radio waves are radio frequency (RF) electromagnetic fields (EMF). Examples of natural sources of electromagnetic fields are the earth and sun. Mobile communications use a variety of frequency bands between 400 and 2500 MHz in the electromagnetic spectrum.

Knowledge from 60 years of research

Occasionally, mobile telephony is described as a new technology whose effects on health cannot be understood until it has been in use for several years. In truth, however, radio waves have been used for more than 100 years in various sorts of applications. Guglielmo Marconi demonstrated the first radio transmitter in 1895, and in the 1920s, radio broadcasting spread in earnest around the world. It was then that Ericsson began manufacturing radio transmitters.

Early on, scientists took an interest in the health effects of radio waves. In the late 1800s, French scientist D'Arsonval studied the physiological effects of RF fields; in the early 1900s, studies were made of the heating effects of radio waves. The development of radar and medical applications, such as diathermy, gradually improved understanding of the interaction between RF fields and the human body. Given the long use of radio waves, there have, in fact, been thousands of studies investigating the possible health effects of RF fields. From this extensive corpus of research, every established effect on health has been related to the well-known heating effects of radio waves. At very high RF exposure, the heating of body tissues can be significant, which ultimately might have adverse effects on health. Considerable research has been conducted on possible non-thermal health effects. No such effects have been established.

During the past fifteen years, several hundred studies have been conducted using mobile phone signals specifically. The

BOX A, TERMS AND ABBREVIATIONS

CAD	Computer-aided design	ICNIRP	International Commission on Non-ionizing Radiation Protection
CENELEC	European Committee for Electrotechnical Standardization (Comité Européen de Normalisation Electrotechnique)	IEC	International Electrotechnical Commission
DECT	Digital enhanced cordless telecommunications	IEEE	Institute of Electrical and Electronics Engineers
EC	European Community	MMF	Mobile Manufacturers Forum
EMF	Electromagnetic field	RTTED	Radio and telecommunications terminal equipment directive
EU	European Union	RF	Radio frequency
GSM	Global system for mobile communication	SAR	Specific absorption rate
GSMA	GSM Association	SWEDAC	Swedish Board for Accreditation and Conformity Assessment
IARC	International Agency for Research on Cancer (WHO agency located in Lyon, France)	UMTS	Universal mobile telecommunications system
		WHO	World Health Organization

great majority of these studies has not indicated any adverse health effects linked to mobile telephony. Several expert groups and health authorities have reviewed these studies (Figure 1). The World Health Organization (WHO), for example, summarizes the current status as follows: “None of the recent reviews have concluded that exposure to RF fields from mobile phones or their base stations causes any adverse health consequence.”

Increasing the knowledge

Research sponsoring

WHO and several other health authorities and expert groups have clearly stated that no adverse health effects can be attributed to mobile telephony. However, a consistent message has also been that more research is needed to increase the knowledge and to ensure the best possible assessment of health risks. To facilitate a focused research effort, WHO has established the International EMF Project, in which an agenda of recommended research has been developed. While it is never possible to fully guarantee the absence of adverse health effects, additional research increases the possibility of discovering any effect, even if it is very subtle. Ericsson acknowledges the expertise of WHO, and sponsors EMF research according to its recommendations. This sponsoring, which is coordinated by the EMF Health and Safety department at Ericsson Research, mainly occurs in collaboration with the Mobile Manufacturers Forum (MMF), but also within other organizations. The MMF is an international association of radio equipment manufacturers whose members include Alcatel-Lucent, Ericsson, Mitsubishi, Motorola, Nokia, Nokia-Siemens, Panasonic, Philips, Sagem, Samsung and Sony Ericsson. The MMF was formed in 1998 to jointly

- fund key research projects, and
- cooperate on standards, regulatory issues and communications activities concerning health and mobile phone technology.

In supporting this research, Ericsson recommends that projects should be funded jointly with independent national or international research-funding sources. It also encourages the publication of research findings in peer-reviewed scientific journals, to ensure high quality, openness and trans-

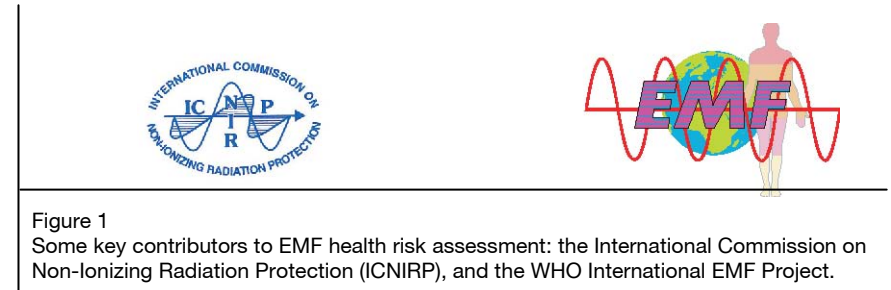


Figure 1
Some key contributors to EMF health risk assessment: the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the WHO International EMF Project.

research projects related to EMF and health, and has since 1996 been involved in co-funding of more than 80 studies with a total cost of more than EUR 40 million.

A major project sponsored by Ericsson is a multinational epidemiological study on mobile phone use and possible links to tumors in the head and neck. This study, entitled INTERPHONE (International case control study of cancer in relation to mobile phone use), is coordinated by IARC, which is a WHO agency located in Lyon, France. In all, this project involves several thousand people. The exposure information will rely on questionnaires that cover any previous mobile phone use. Some validation will also be performed to guarantee the reliability of the information. For this study, Ericsson has supplied several mobile phones whose software has been modified to register output power distribution and timing information. The project is part of the EC 5th framework program. Nine countries—Sweden, Denmark, Finland, Norway, the UK, Germany, France, Italy and Israel—make up the core of the project, which receives financial support from the EC, MMF and GSM Association (GSMA) and various governments. Canada, Japan, Australia and New Zealand are also participating in the project. Some national results have been published and overall these have not shown any link between mobile phone use and tumors. IARC coordinates the analysis of the pooled data from all the participating countries, and the results are expected to be published in 2008.

Another major project sponsored by Ericsson through the MMF, called PERFORM-A (In vivo research on possible health effects related to mobile telephones and base stations), was also part of the EU 5th framework program. The aim was to determine whether GSM 900 and 1800



Figure 2
Radio frequency exposure facilities at the Fraunhofer Institute in Germany used in the PERFORM-A project sponsored by Ericsson.

MHz RF fields can cause or affect the development of cancer. This project, composed of six animal studies in three countries, was coordinated by the Fraunhofer Institute in Hannover, Germany (Figure 2). Additional funding was provided by the GSMA, the EC, and the Swiss and Austrian governments. The project has been completed and most of the results have been published. These do not provide any evidence of a link between exposure to GSM signals and cancer.

Health research concepts

There are several ways of studying whether or not radio waves from mobile telephony might cause adverse health effects. Epidemiological studies examine any association between mobile phone use and disease. To establish such possible links, extensive information on mobile phone usage must be collected. Likewise, relevant background information, such as physical or chemical exposures and life-style factors, must be obtained. Obviously, obtaining this information is difficult, in particular because historical data covering a span of many years is often needed. This is why animal experiments are used as a complement to epidemiology — since the exposure in these experiments can be carefully controlled. One cannot directly extrapolate any findings of animal experiments to humans, but in the area of cancer research, at least, there is extensive experience of comparing animal and human data. As a further complement, experiments are conducted exposing cells sep-

arated from the living body. In general, these kinds of study can provide additional supportive information to animal and human studies.

Please note that one needs to distinguish a biological effect from an adverse health effect. For example, staying in the sun for an extended time might slightly increase the body temperature. This is an example of a biological effect that is completely harmless at moderate levels of exposure. WHO describes the distinction between a biological effect and an adverse health effect as follows: “A health hazard is a biological effect outside the normal range of physiological compensation that is detrimental to health or well-being.”

New scientific findings are commonly confirmed or refuted through replication in independent labs. This practice increases the possibility of discovering chance findings or artifacts in experiments. The careful work of independent scientific review bodies makes it possible to compile all available information, giving weight to each study according to its quality, and to provide overall conclusions and recommendations.

Limits and standards for safety

The most important organization to give guidance regarding EMF exposure is the International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP, whose members are independent experts from various countries, is formally recognized by WHO as the non-governmental organization for EMF protection. In 1998, ICNIRP published guidelines for limiting exposure to electromagnetic fields in the frequency range 0 Hz to 300 GHz. The recommended limitations are a result of an extensive review and analysis of several thousand scientific papers related to effects to human health from exposure to electromagnetic fields. The limits have been set with wide margins and protect all persons from established adverse effects from short- and long-term exposure. It is the conclusion of ICNIRP and several other expert groups and authorities that there are no established health effects below the recommended limits.

The ICNIRP guidelines have been adopted in national standards and regulations in many countries worldwide, and in an EU Council Recommendation on EMF from 1999. Ericsson is not in any way involved in setting limits for EMF protection, but it

TABLE 1, ICNIRP BASIC RESTRICTIONS FOR THE GENERAL PUBLIC (10 MHz – 10 GHz)

Average mass	SAR (W/kg)
Whole-body	0.08
10g, head and trunk	2
10g, limbs	4

does support the global harmonization of safety standards based on the ICNIRP guidelines. Basic restrictions expressed as specific absorption rate (SAR) levels are specified in the frequency range 10 MHz to 10 GHz, which includes the frequency bands used by wireless communications. SAR, which has the unit W/kg, is a measure of the rate of energy absorption in the body of a person exposed to RF fields. The SAR limits are set to ensure that the whole-body or localized adverse heating effects do not occur due to exposure. Table 1 lists the basic SAR restrictions recommended by ICNIRP for the general public. These limits have been set 50 times below the levels at which adverse health effects have been established. The wide safety margin ensures that any increase in body tissue temperature is negligible.

For workers, the limits are five times higher. The rationale for having lower limits for the general public is that this group includes children, the elderly, and other persons of varying health status or susceptibility, and exposure might be continuous, 24 hours a day. The SAR values are to be averaged over any six-minute period of exposure. This period reflects the fact that it takes time for body temperature to rise during exposure to RF fields. This means that exposure levels exceeding the SAR limits may be accepted for short periods as long as the time-averaged SAR levels during any six-minute period are below the basic restrictions. 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.

Since it is difficult to measure or calculate SAR in many real exposure situations, the ICNIRP guidelines also specify reference levels. In the frequency range of wireless communications, these are given as levels of frequency-dependent

- electric field strength (E), measured in terms of volts per meter (V/m);
- magnetic field strength (H), measured in terms of amperes per meter (A/m); and
- power density (S), measured in terms of watts per square meter (W/m²).

These levels should be assessed in air without the presence of the exposed person. Table 2 lists the reference levels for the GSM and UMTS frequency bands. The reference levels have been derived from the basic restrictions and include extra margins. This means that compliance with the

reference levels ensures compliance with SAR limits. However, exceeding the reference levels does not necessarily mean that the basic restrictions have been exceeded. For example, whereas the field strength levels close to a mobile phone can exceed the reference levels, the maximum localized SAR in the head tissue of the user is still in compliance with the basic restriction. Ordinarily, the reference levels are used to assess RF exposure compliance of macro-cell radio base stations, and the mass-averaged SAR limits are applied to mobile phones and other wireless terminals used in close proximity to the body. The SAR limits are also used for low-power base stations.

Ensuring compliance with safety limits

RF safety limits are meaningless without standardized methods and procedures for determining exposure levels and for assessing compliance. The main international organization that develops such methods and standards is the International Electrotechnical Commission (IEC). Other important organizations active in this area are the European Committee for Electrotechnical Standardization (CENELEC) and the Institute of Electrical and Electronics Engineers (IEEE). Ericsson actively participates in the working groups of the IEC, CENELEC and IEEE that are developing EMF test standards for mobile communication equipment. Several important standards have already been finalized and published.

Mobile phones

CENELEC developed a SAR test procedure for handheld mobile telephones that was published as a European standard (EN 50361) in 2001. Similarly, another standard (EN 50360), which specifies the criteria for evaluating compliance, has been listed as a harmonized standard under the EU directive for radio and telecommunications terminal equipment (RTTED). Testing is mandatory for mobile phone products with an average emitted power of 20 mW or more.

IEEE published in 2003 a SAR test standard (Std1528) for mobile phones that was well in line with the CENELEC specifications. Based on the CENELEC and IEEE specification, IEC has developed an international standard that was published in 2005 (62209-1) and has been adopted in many countries worldwide. In Europe, it has replaced the CENELEC standard from

TABLE 2, ICNIRP REFERENCE LEVELS FOR THE GENERAL PUBLIC (GSM AND UMTS FREQUENCY BANDS)

Frequency (MHz)	E (V/m)	H (A/m)	S (W/m ²)
900	41	0.11	4.5
1800	58	0.16	9.0
2100	61	0.16	10

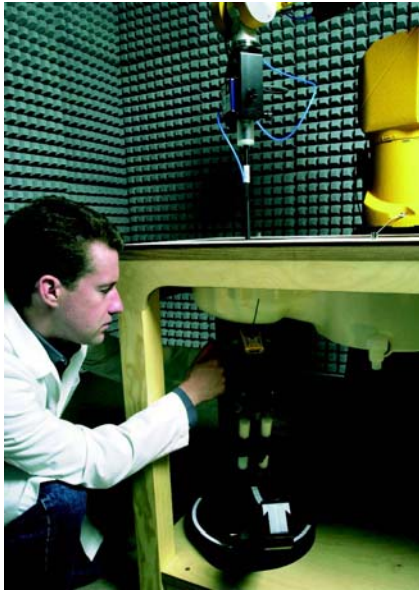


Figure 3
Setup for SAR measurements of mobile phones at Ericsson Research. A miniature probe is used for measuring the electric field induced in a head phantom.

2001. IEC is in the process of extending the standard to include body-mounted devices, desktop terminals, and products with multiple radio transmitters.

The SAR test standards for mobile terminals specify the measurement system, the SAR test protocol, and the uncertainty assessment procedures. The measurement system consists of a phantom model that represents a human head or body, a device holder, SAR measurement equipment and a scanning system. The holder is used to position the device being tested. The scanning system is needed to move a miniature electric field probe inside the phantom, which is a thin, low-loss shell filled with a liquid that simulates head or body tissue. From the obtained electric field strength distribution, the localized SAR is calculated as follows:

$$SAR = \frac{\sigma E^2}{\rho}$$

where σ (S/m) is the electrical conductivity of the tissue, E (V/m) is the measured internal electric field strength, and ρ (kg/m³) is the mass density of the tissue.

Measurements are performed at maximum output power levels and for all frequency bands. The highest measured SAR value must be below the limit. Figure 3 shows the system Ericsson Research uses for SAR measurements of mobile phones.

Ericsson's SAR test laboratory

- meets the specifications in the standards;
- meets the ISO 17025 quality standard; and
- is accredited by the Swedish Board for Accreditation and Conformity Assessment (SWEDAC).

Sony Ericsson has several systems of the same type that it uses to test compliance of new mobile phone models and prototypes.

Ericsson Research also uses advanced numerical methods for electromagnetic computations to calculate RF exposure from mobile terminals. Detailed CAD models of mobile phones and human body phantoms enable accurate estimations of SAR levels. Compared to measurements, the main advantage of numerical assessments is that RF exposure can be evaluated during an early stage of the development process of new wireless products without need of a hardware prototype. Numerical computations are also less costly and time-consuming than measurements. Figure 4 shows a CAD model of a mobile phone prototype and a head phantom for SAR evaluations.

Radio base stations

IEC and CENELEC are also developing procedures for determining the RF exposure from radio base stations. European standards

Figure 4
CAD-based model of head phantom and mobile phone prototype used for calculations of SAR and electromagnetic field strength. The figure shows the RF magnetic field strength distribution at the surface of the phone.



for assessing compliance were published in 2002 (EN 50383, EN 50384, EN 50385). These standards specify requirements and methods of calculating and measuring RF exposure levels and compliance boundaries for typical configurations of radio base station products. A compliance boundary is the surface surrounding the base station antenna outside of which RF exposure does not exceed the basic restrictions or the reference levels of the RF safety standards. For low-power (≤ 1 W) base stations with small antennas, SAR measurements are conducted in a body model. For other base stations with higher output power or larger antennas, the standards specify experimental, analytical and numerical procedures for determining three-dimensional field-strength distributions around the antenna. Ericsson Research has developed and implemented procedures and test methods for assessing RF exposure from base station products. These conform with the requirements in the CENELEC standards. Figure 5 shows a SAR measurement setup for testing pico-cell, DECT, and other low-power base stations. Figure 6 shows an example of a numerical calculation of the field-strength distribution around a typical antenna recommended for use with the Ericsson RBS 3202 UMTS base station; and Figure 7 illustrates a typical compliance boundary (in the shape of a cylinder) that has been determined from the field-strength distributions.

The size of a compliance boundary varies from a few centimeters for low-power indoor base station antennas, to a few meters for macro-cell antennas installed on roof-tops and masts. Base station antennas must be installed in such a way that people cannot enter the area enclosed by the compliance boundary. Ericsson GSM and UMTS product documentation contains information on RF safety and compliance boundaries for typical base station configurations. Guidelines for calculating RF exposure levels from base stations and for installing antennas are also available.

Addressing information needs

Although the RF exposure levels from mobile phones and base stations are below appropriate safety limits, and several expert groups have consistently concluded that RF exposure from mobile communications is not known to cause any health effects, some

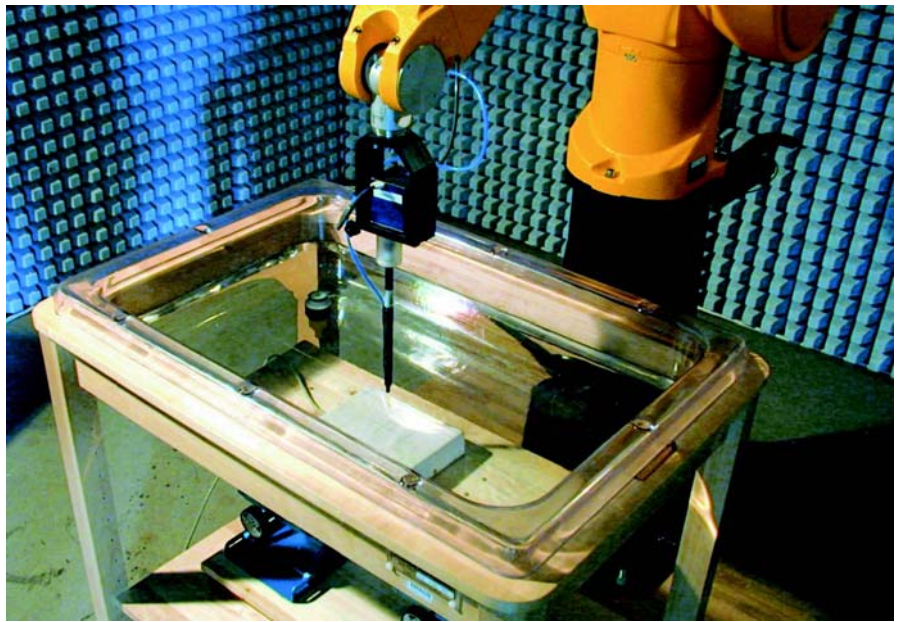


Figure 5
Setup used at Ericsson for SAR measurements of low-power base station products.

people still feel concern. One complaint is that it is difficult to find information that answers their questions. To address these concerns and information needs, Ericsson has produced several brochures and fact sheets that

- explain how mobile communications work;

Figure 6
Calculated RF electric field strength distribution close to a UMTS base station antenna with 20 watt input power. The circle, having a diameter of 3 m, indicates the exposure limit compliance boundary.

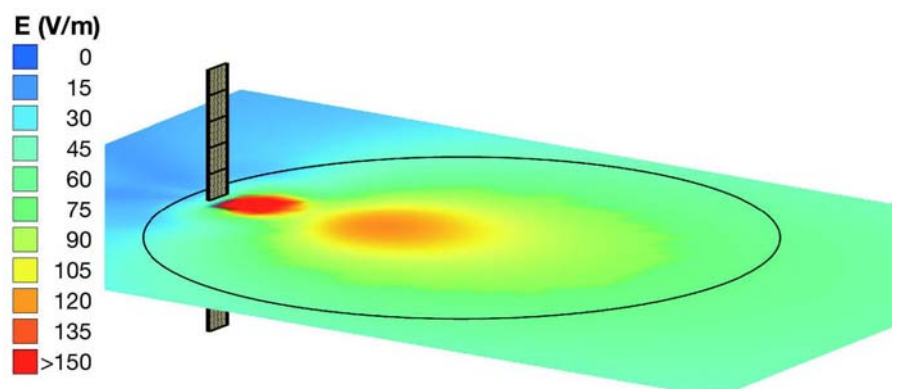




Figure 7
RF exposure compliance boundary for an antenna connected to an Ericsson RBS 3202 (UMTS) base station.

- answer questions related to radio waves, safety and health; and
- give references to relevant sources of information.

This information is also available on a special Ericsson website dedicated to radio waves and health. The MMF has also produced a set of information materials that addresses questions from consumers and the general public. Likewise, mobile phone user manuals contain information on RF exposure and health. Since 2001, when the first SAR measurement standard was published, extensive information on SAR has been provided with all new products. This information, which is also available on the Sony Ericsson web-site, explains what SAR is, and states the maximum measured value for each given model. These values are provided to show consumers that the products comply with the SAR safety limits. They should not, however, be used to compare different models, since a difference in maximum SAR does not indicate a difference in safety. Moreover, due to power regulation and other factors, the average SAR during use is often much lower than the maximum value. This is explained in greater detail in a fact sheet from Ericsson.

In recent years, given the rapid rollout of second- and third-generation networks, public concern about base stations has increased. Many people are requesting more

information on, and asking questions about, the RF exposure levels in their homes or workplace. Local authorities, landlords and tenant associations sometimes have similar questions when operators request building permits. These questions are understandable and relevant—but the fact remains that antenna installation procedures ensure that RF exposure levels are safe where people live and work. What is more, since the intensity of the radio waves decreases very quickly with distance, typical levels from base station antennas are 100 times below the ICNIRP reference levels, and comparable to levels from commercial radio, TV and other communication transmitters.

As mentioned above, Ericsson provides information and fact sheets that address concerns about base stations. Furthermore, Ericsson Research employs advanced methods of calculating and measuring RF exposure levels associated with base stations in existing, new and planned installations. These assessments are conducted on a regular basis to help network operators respond to queries. Figure 8 shows the calculated RF power density levels around third-generation antennas installed on a roof-top. When just a few meters from the antenna, the levels drop below the limits. Within the building and on the ground, the maximum RF exposure level is less than 1% of the ICNIRP reference level.

Conclusion

Radio waves have been used for more than 100 years, and thousands of studies have been made to investigate the possible health effects of RF fields. Of these, several hundred specifically used mobile communication signals. Numerous health authorities and expert groups have consistently concluded that no adverse health effects are caused by the RF exposure from mobile phones or base stations. Notwithstanding, Ericsson supports additional research, as advised by WHO, to increase knowledge.

Ericsson is not in any way involved in setting limits for EMF protection, but it does support the global harmonization of safety standards based on the exposure limits recommended by ICNIRP. These science-based limits have been set 50 times below the levels at which adverse health effects have been established. By means of design, testing and installation procedures, Ericsson ensures that its mobile communication products fulfill all relevant RF safety requirements.

In recent years, public concern about base stations has increased. Many people are requesting more information on, and asking questions about, the RF exposure levels in their homes and workplace. These questions are understandable and relevant, although the RF exposure levels typically are far

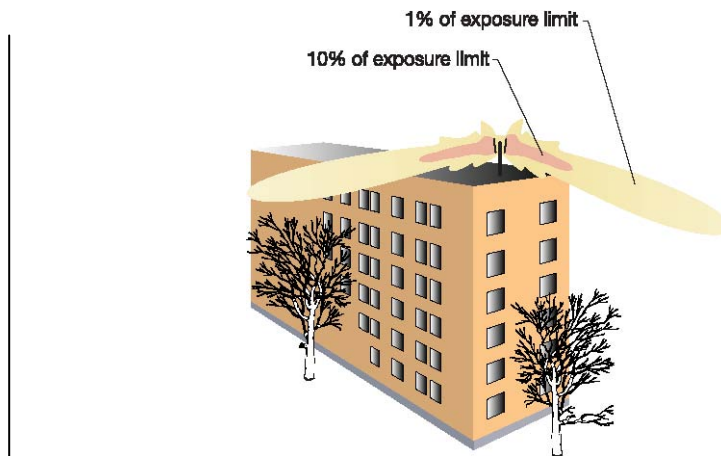


Figure 8

Calculated electromagnetic field distribution around UMTS antennas installed on a rooftop. The border of the red area corresponds to 10% of the ICNIRP exposure limit, and the border of the yellow area, to 1% of the limit. Within the building and on the ground, the maximum level is below 1% of the ICNIRP limit.

below safety limits. Ericsson provides information and fact sheets that address these concerns. Furthermore, Ericsson employs advanced methods of calculating and measuring RF exposure levels associated with base stations in existing, new and planned installations. These assessments are conducted on a regular basis to help network operators respond to queries.

BOX B, LINKS TO ADDITIONAL INFORMATION

WHO International EMF Project
www.who.int/peh-emf

ICNIRP
www.icnirp.org

Ericsson

www.ericsson.com/health

Mobile Manufacturers Forum (MMF)
www.mmfai.org