Dedicated to Ulf Bergqvist

Mobile telecommunication base stations – exposure to electromagnetic fields

Report of a Short Term Mission within COST 244bis

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Introduction

In Europe, the use of commercial land based cellular mobile telephony has increased dramatically since the first services appeared in the beginning of the 1980’s, especially with the introduction of the digital GSM 900/1800 systems in the 1990’s. This increased use of mobile phones has led to an increased deployment of base stations and antennas.

As a reaction to this development, public debates and, in several situations, concerns and worries about the possibility of adverse health consequences due to exposure to radiofrequency fields from mobile telephony components have also increased. Although the intensity and focus of this discussion differs substantially between European countries, the discussion is, in many countries, concentrated on the exposure found in the vicinity of base station antennas. In some countries, this has led to demands for “mobile phone free zones”, where no base stations should be permitted, and also to requests for reduced exposure limits or other precautionary approaches.

The focus of risk perception among some parts of the public towards base station antenna rather than mobile phones is somewhat contrary to a technical based risk assessment – since the use of handsets entails substantially higher exposure levels than the public receives from base stations. It can, however, be explained by several factors that are known to enhance the perception of risk: such as lack of control by the individual, lack of perceived benefit and high media attention.

In relation to this public perception, some relevant issues and questions related to exposure to electromagnetic fields from base station antennas are:

- What levels of exposure to radiofrequency fields are found in the general environment or in the vicinity of base stations?
- How does the increased deployment of antennas relate to exposure levels?
- Do these exposures to electromagnetic fields from base station antenna comply with standards and regulations?

The European Council Recommendation of July 12, 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz – 300 GHz) does not only recommend that Member States should aim to achieve restrictions for public exposure based on this recommendation. It also requires them to provide information on exposure to electromagnetic fields to the public and report to the Commission about the measures they take and the experiences they have.

Thus, throughout the European community, there is a need for data on the exposure to radio frequency fields due to base station antennas in order to evaluate compliance with European and national recommendations and regulations, and for use in risk communication. In many European nations, data exist that might respond to this need for information, but their use would be strongly enhanced if there was a common base for the interpretation of such data.

It was therefore decided, within the COST 244bis Action "Biomedical Effects of Electromagnetic Fields", that a Short Term Mission addressing some of these aspects should be valuable. The aim of this Short Term Mission was to:

- compile data from some European nations on the exposure levels from base stations and, if possible, to draw conclusions with regard to:
  - comparability of the data from different sources and countries,
  - usability of the data as a source for information of the public,
  - the establishment of a future common data-base, and
  - identification of gaps of knowledge concerning the data and the procedure by which they are obtained so that a basis for further action by responsible bodies may be provided.

The Short Term Mission was initiated at the COST 244bis meeting in Zurich, Switzerland in February 1999, and concluded in November 2000. This report contains the findings of the Short Term Mission.

The data provided and the evaluations performed within this Short Term Mission are relevant for outdoor base station antenna of current technology (the 2nd generation "digital, GSM", system), and the exposure to radiofrequency fields from these antenna found in places where the public normally have access. The report does neither address occupational exposure of service personnel, nor exposure due to the use of mobile phones. Exposures due to indoor systems such as DECT in homes or office are not explicitly discussed in this report. It is also important to note that the report deals primarily with fields emitted by mobile phone base stations. Other sources of radiofrequency fields are not covered in this report.

The main report first gives a brief description of GSM mobile telephone systems and base stations, emphasising some properties of these systems that may have an influence on the outcome of measurement activities. The rationale, design and reporting of measurements are then discussed. The existence and variations in different regulations, standards and recommendations are described, followed by an evaluation of measurement data in terms of science based standards. The report ends with some conclusions and recommendations for further activities. Closer descriptions of the situation in some of the participating countries (Austria, Germany, France, Hungary and Sweden) are found in the Appendices.

Background

Use of radiofrequency radiation

The electromagnetic spectrum can be subdivided into several ranges, classified according to the frequencies of the fields, see figure 1 for an overview. At sufficiently high frequencies (energies), the radiation is capable of breaking the bonds between atoms and electrons, hence such radiation is named ionizing radiation. Non-ionizing radiation (with energies too small to ionise atoms) comprises electric, magnetic and electromagnetic fields, as well as optical radiation (infrared radiation, visible light and ultraviolet radiation).

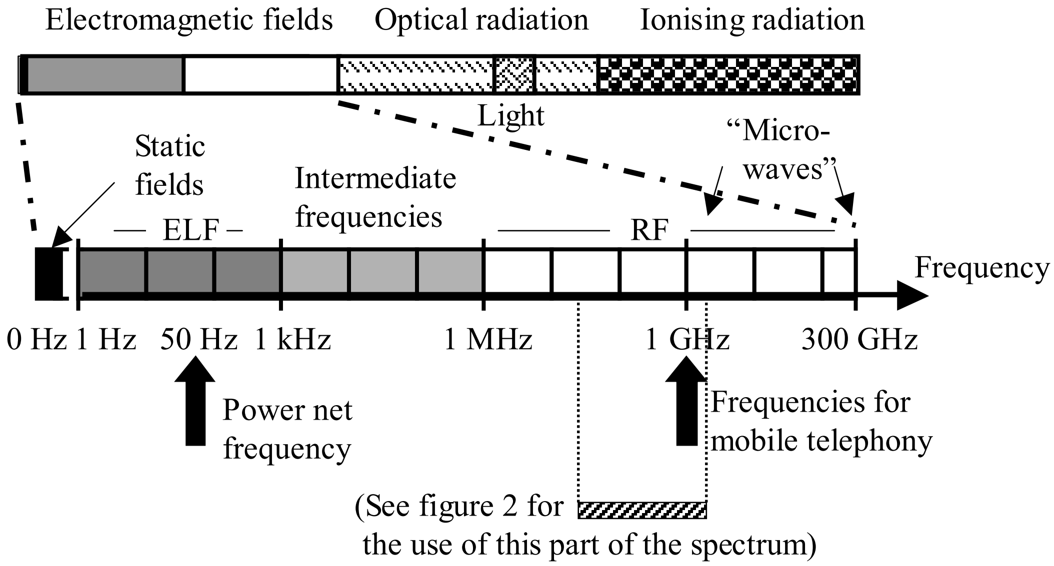


Figure 1. The electromagnetic spectrum. ELF = extremely low frequency, RF = radiofrequency.

For telecommunication purposes, radiofrequency fields between a few MHz to some GHz are of particular interest. Within this range, numerous broadcasting sources in addition to mobile telephony can be found, such as radio and television systems and commercial (communication) radio systems. FM radio transmitters at some 100 MHz and television (UHF) broadcasts at around 800 MHz are examples of high-power sources in this range. Other frequencies may be used for industrial purposes (e.g. at 27 MHz and 2.45 GHz), which sometimes may cause a substantial local exposure to workers. The allocation of different frequencies is strictly controlled, internationally by the ITU (International Telecommunication Union), and nationally by various agencies. An example of the frequency allocation between 30 MHz and 2 GHz is given in figure 2.

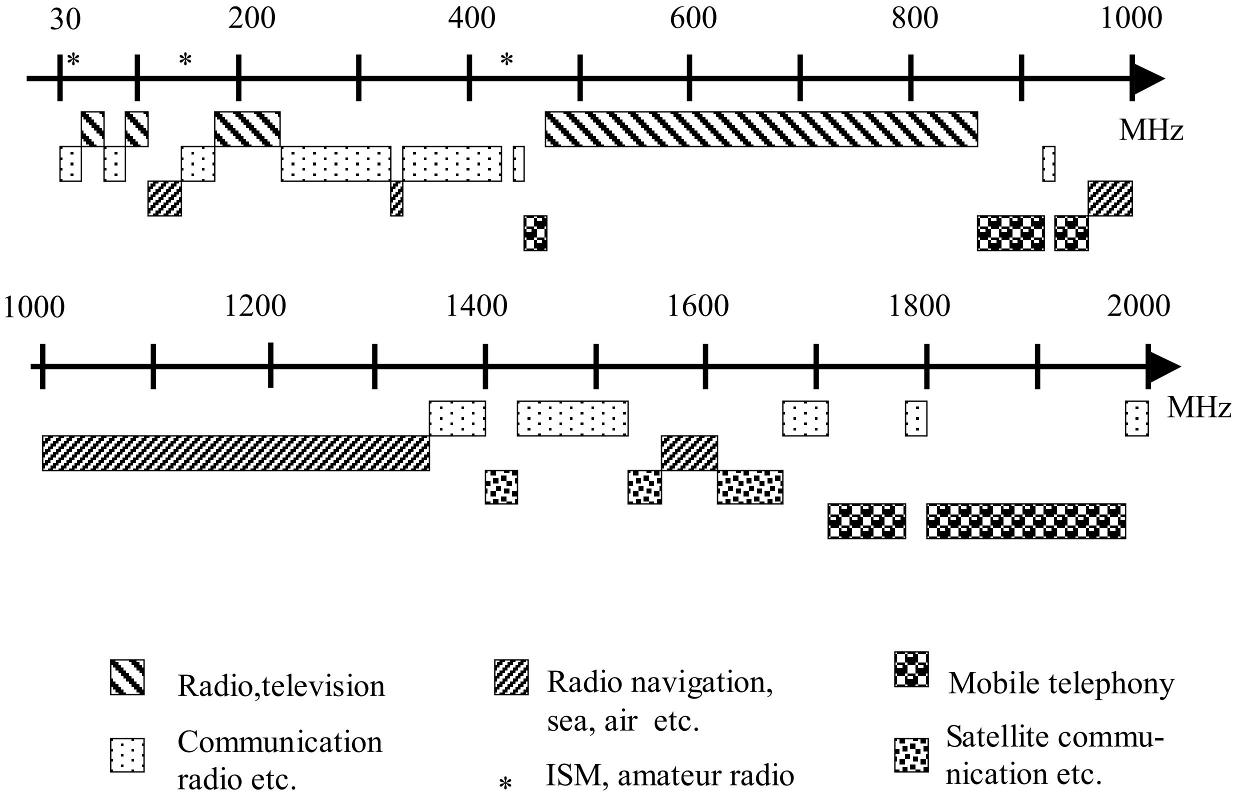


Figure 2. Allocation of frequencies between 30 MHz and 2 GHz (Swedish data, from www.pts.se). Some emerging telecommunication systems such as UMTS will also utilise frequencies above 2 GHz (not shown in figure).

Mobile telephony specific emissions are limited to bands around 450 MHz (analog system), 900 MHz (a second analog system now being phased out, and digital systems/GSM), 1800 MHz (further GSM services) as well as 1900-2200 MHz (the coming UMTS). (GMS = Global System for Mobile Telecommunication, UMTS = Universal Mobile Communications System.)

As indicated in figure 2, and verified by measurements in several European countries, emissions from mobile telephony systems corresponds to only a part of the total radiofrequency exposure (see further discussion below on broadband vs. frequency specific measurements).

Description of the mobile telephone system

The mobile (cellular) phone system works as a network containing base stations. Within each cell, a base station (with an antenna) can link with a number of handsets (mobile phones). The mobile phones and the base stations communicate with each other, sharing a number of operation frequencies. Other transmission links connect this base station with switches connecting to base stations in other cells, or with switches connected to conventional phones. The cell exists in order to permit re-use of frequencies – the same frequency can be used in different cells (given a sufficient distance). The links (uplink from handset to base station, downlink from base station to handset) employ high frequency electromagnetic fields. Figure 3 outlines this structure.

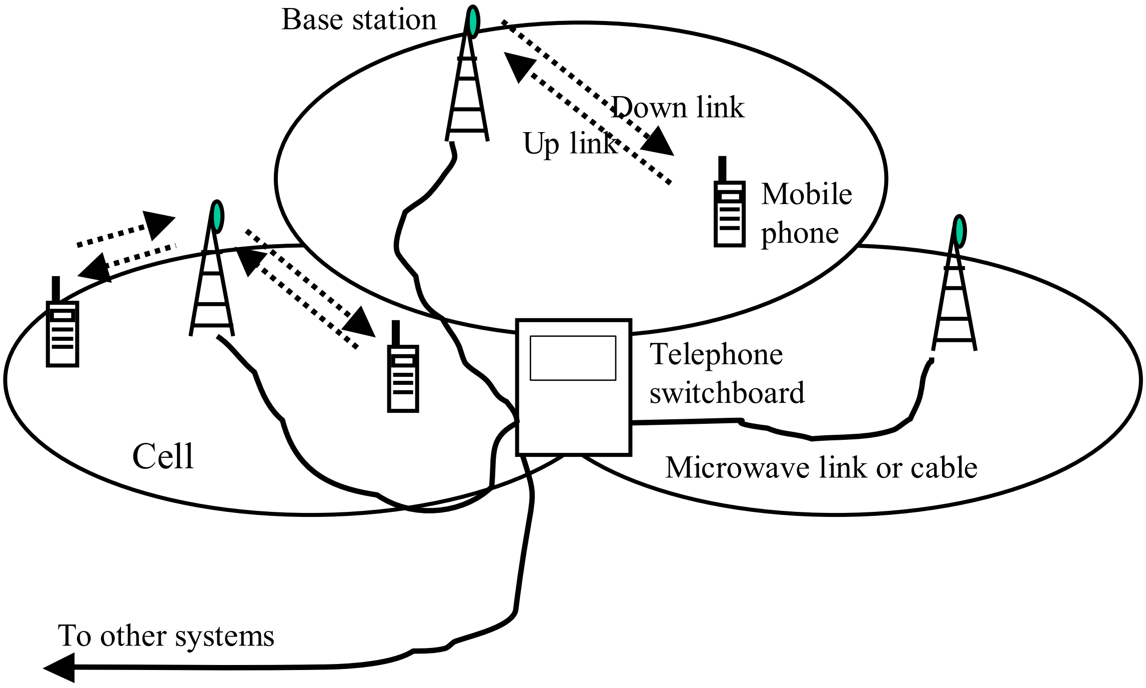


Figure 3. The structure of the mobile telephone system (here with three cells).

The outdoor base station antennas may be mounted on the roof or walls of buildings or on free standing masts. The size of the cells may vary, from several kilometres (in rural areas with low traffic density) down to some 10-100 meters (in high traffic density areas in cities). Small indoor cells occur, using either normal mobile telephone systems such as GSM, or systems for cordless telephony (e.g. DECT).

A particular base station may operate several channels (typically 2 or 3), where each channel uses a specific set of frequencies, one for the uplink and one for the downlink. Depending on technique, each channel can (at the same time) handle communication from one or several active handsets. In an analogue system such as the NMT or the TACS, one call is handled in each channel, which – with the fast increase in traffic – has been found incapable of sufficient capacity. In order to increase the capacity, digital systems such as the GSM 900 and GSM 1800 were introduced in 1992 and 1993, respectively. In these systems, several users can use the same frequency, since each transmission is digitalised and compressed to fit into one of 8 time slots. A new system, the UMTS, is currently being introduced, and will use codes to separate the calls.

The typical power emitted from outdoor antennas is between 5 and 10 W per channel, which means that the total power from a base station could amount to some 50 W depending on the number of channels and varying with time (see further below).

Electromagnetic field emissions from base station

Frequencies used

The GSM 900 system has been allotted two frequency bands, 890-915 MHz for the uplink (mobile phone to base station) and 935-960 MHz for the downlink (base station to phone). The downlink of a particular channel is 45 MHz higher than the uplink (duplex operation). The GSM 1800 system uses bands of 1710-1785 and 1805-1880 MHz, respectively. (The 1st generation (analog) systems use frequency bands around 450 and 900 MHz, while the coming UMTS is allocated bands of 1900-2025 and 2110-2200 MHz. Emissions from these systems are not included in this evaluation, however.)

In the GSM systems, each link is allocated a bandwidth of 200 kHz (0.2 MHz). Thus, the allocated spectrum could theoretically encompass 124 (GSM 900) or 374 (GSM 1800) different channels (pairs of links). However, the need to have a few cell's separation between re-use of the same frequency, and the fact that a single operator is usually only allocated a part of the frequency band, limit the number of possible channels to be used in each cell, and thus also the total emitted power.

Emission variations with time

One channel (the control channel) from each base station is always transmitting with essentially a constant power, regardless of the traffic intensity. Other channels (traffic channels) do only send when the traffic requires, and may also use a power regulation system. Accordingly, the emitted power from a base station may vary over the day and week from a minimal power of e.g. 10 W during times with low to modest traffic, to perhaps up to 5 times that level at peak traffic (if there are four traffic channels in addition to the control channel). An example with one control and two traffic channels is shown in figure 4.

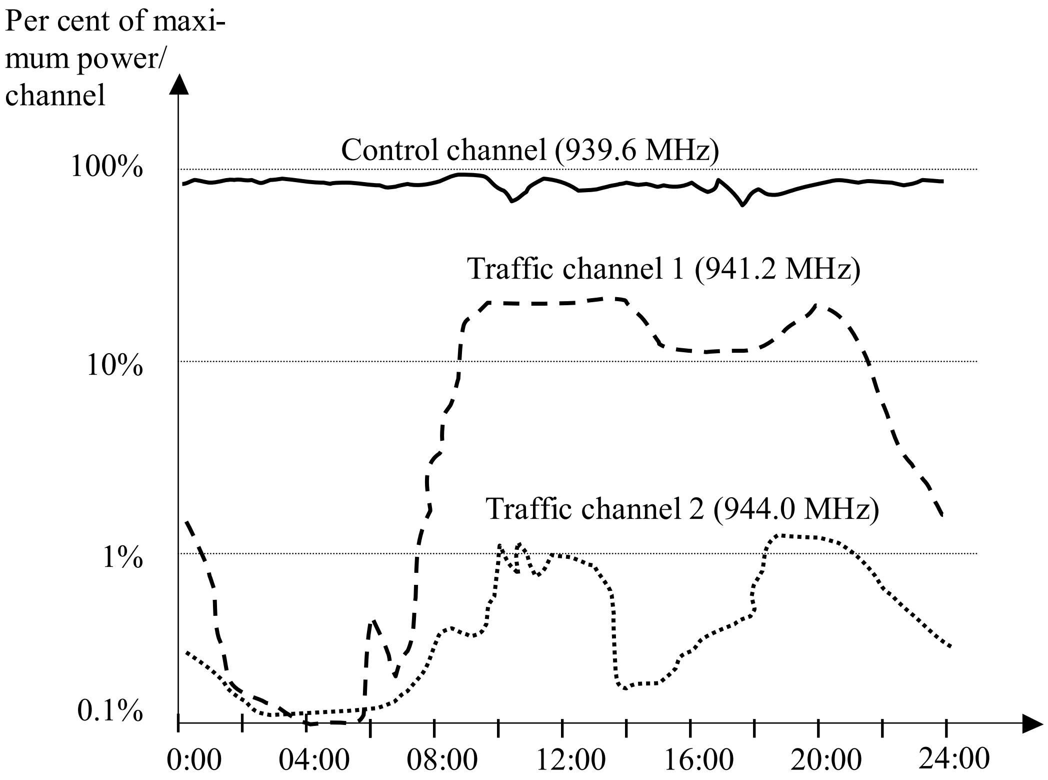


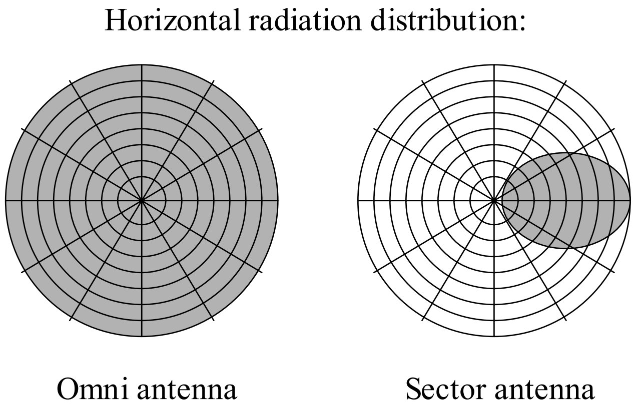
Figure 4. Example of 24-hour variation in emitted power from a 3-channel base station (data from Wiart 2001).

From a GSM base station with more than one channel, there are thus a variety of reasons for variations in the transmitted power at any given time: how many channels are in use, how many of the time slots in the traffic channels are used, and whether DTX is used or not. (DTX is a function that inactivates the transmission if there is no voice detected – then only a sample of the background noise is transmitted. If DTX is used, it effectively reduces the average power by approximately a factor two.) Any attempt to characterise the exposure around a base station should take this traffic-dependent time-variation into account. Information from the operator of the base station on traffic statistics could provide a basis on how this should be done. Options could include sampling (for average situation) and/or choosing a probable maximum traffic time (for worst case situation).

Exposure variations with distance from the base station

An antenna does generally have some directionality. Omni antennas radiate in every direction (seen horizontally), while sector antennas effectively only radiate in a (horizontal) sector, see figure 5. This will permit increased re-use of frequencies, as it will reduce interference – accordingly, most base stations in high traffic density areas such as cities are of the sector type. The preferred sector antenna gain is between 10 and 20 dBi – this means that the emitted power may be between 10-100 times stronger in the intended directions compared to an omni antenna, while it will be correspondingly weaker in other directions. For example, the exposure behind a sector antenna could be 300 times weaker than in the main lobe (Ramsdale and Wiener, 1999).

In addition to this horizontal directionality, the antenna lobe will also have a strong vertical directionality, with a fairly narrow beam, which is often tilted slightly downward (see figure 5).


Horizontal radiation distribution:

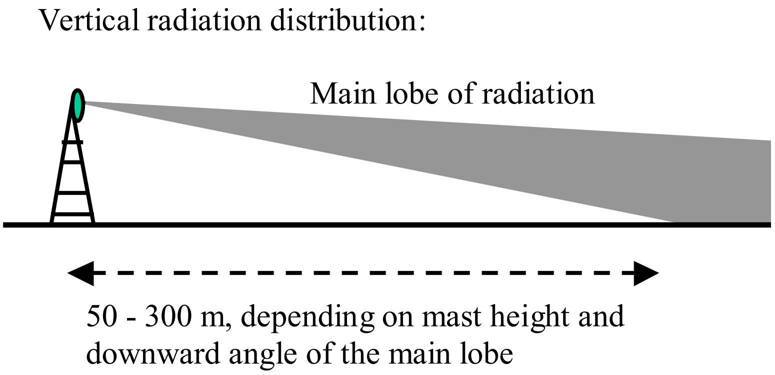

Vertical radiation distribution:

Figure 5. The direction of main radiation (main lobe) from base station antennas, both in the horizontal direction (above) and in the vertical direction (below).

At a sufficient distance from the antenna (of at least 10-15 meters) the EMF exposure levels can be characterised by the power density in W/m^2. In the main lobe, and disregarding attenuation by other objects (“free space”), this power density will decrease with the square of the distance. On the ground, however, this distance variation will be more complex, as the highest level will be found at a distance from the antenna where the main lobe reaches the ground, see figure 5. Closer to the antenna, the ground level will be substantially lower than in the main lobe. Due to the existence of side lobes, the actual variation with distance could be rather complicated. Similarly complicated variations can also be found indoors, on terraces etc.

At larger distances, where (often) buildings or hills will interfere, attenuation and/or reflections will cause an even faster overall decrease in the power density, but also cause substantial variation (see further below). A decrease of power density with distance as $1/r^{3.5}$ has been found to be useful for e.g. base station power calculation (ETSI, 1996).

Rationale for measurements

Whenever measurements of exposure levels in the vicinity of base stations are made, the design of the measurement campaign will be closely related to the ultimate use of the data. Therefore the motivation should be clarified in advance and, on the other hand, when interpreting data, the initial reasoning for the data collection has to be taken into account. The importance of this stems from the fact that measurements made for different purposes may not be fully comparable – see the discussion below.

Basically, some different rationales for measurements can be discerned:

- Measurements made for compliance evaluation. Such compliance testing may be required by national legislation, or may be called for in order to provide a basis for risk communication. When assessing either public or occupational exposure, worst case scenarios are – in principle – considered. Specifications on the measurement design should be found in the standard or regulation text for which compliance is tested. Usually, the relevant source or sources will be identified and the maximum exposure scenario will be identified and subject to measurements. Often the assessment is repeated or at least samples of a series of such measurements are repeated in order to evaluate reliability of the data.
- Measurements made in response to demands or requests. The general public and activist groups, authorities or providers may ask for measurements at a specific location. Then the exposure at this specific location is measured, even if this may not represent the worst case scenario. Depending on the frequency band used, all relevant other high-frequency sources may not always be identified.
- Measurements made for comparison purposes. The emission or exposure at a particular location may be compared with that of other locations or background levels. The results may e.g. be expressed as the "added burden" of an existing (or proposed) source.
- Measurements made for scientific reasons. The scientific reasons for doing measurements may comprise risk assessment in general, monitoring of the general population's exposure over time, or measurements for exposure assessments in an epidemiological study. Here, averages are usually used and representative rather than worst case scenarios are chosen. The sources will not always all be identified.

Of course there may be overlaps between these scenarios, e.g. requests on local exposure data may be answered by existing data from compliance measurements.

Table 1 summarises the different rationales and choices.

Table 1: Common measurement design decisions for various measurement aims

Main aim of the measurements	Type of scenario needed [a/]	Measurement location	Source identification needed
Compliance testing	Worst case	Specified	Yes [c/]
Fulfil a local request for data	Varies	Specified	Usually inherent in the request
Comparisons	Varies [b/]	Specified	Yes, normally
Scientific reasons: epidemiological study or monitoring	Representative or average	Random or grid	No

Note: [a/] Choice of measurement situation in relation to spatial or temporal variations. [b/] As long as similar situations are examined in the comparison sites. [c/] See discussion below.

Since most regulations and recommendations specify the maximum exposure and not the maximum emission from a particular source, then compliance testing also requires knowledge about the exposure due to other sources of radiofrequency fields. Restricting the exposure assessments to the frequencies of base station antenna could be justified only insofar as it can be assumed that this source dominates other sources. This assumption is, however, generally not correct, since substantial contributions to the public exposure within the radiofrequency range also comes from other sources, such as radio and television broadcasts (see further broadband vs. frequency specific measurements below). For other aims, the restriction to base station frequencies may often be justified. (In e.g. Switzerland, so-called immission levels have also been formulated, restricting the exposure contribution from single installations, in addition to the exposure restrictions.)

Most of the data represented within this Short Term Mission are due to measurements done on request, with two exceptions. The Swedish data were obtained in order to give a representative overview of the exposure of the general population (“scientific monitoring”), while some of the Austrian (and the Swedish) data were also obtained in order to make comparisons between sites and to look at variations.

Measurement procedures and methods

Measurement requirements

Near field and far field situations

The physics of electromagnetic emission from an antenna produces different circumstances for measurements depending on the distance r from the source. For practical purposes, this is commonly described as the existence of three zones (see figure 6).

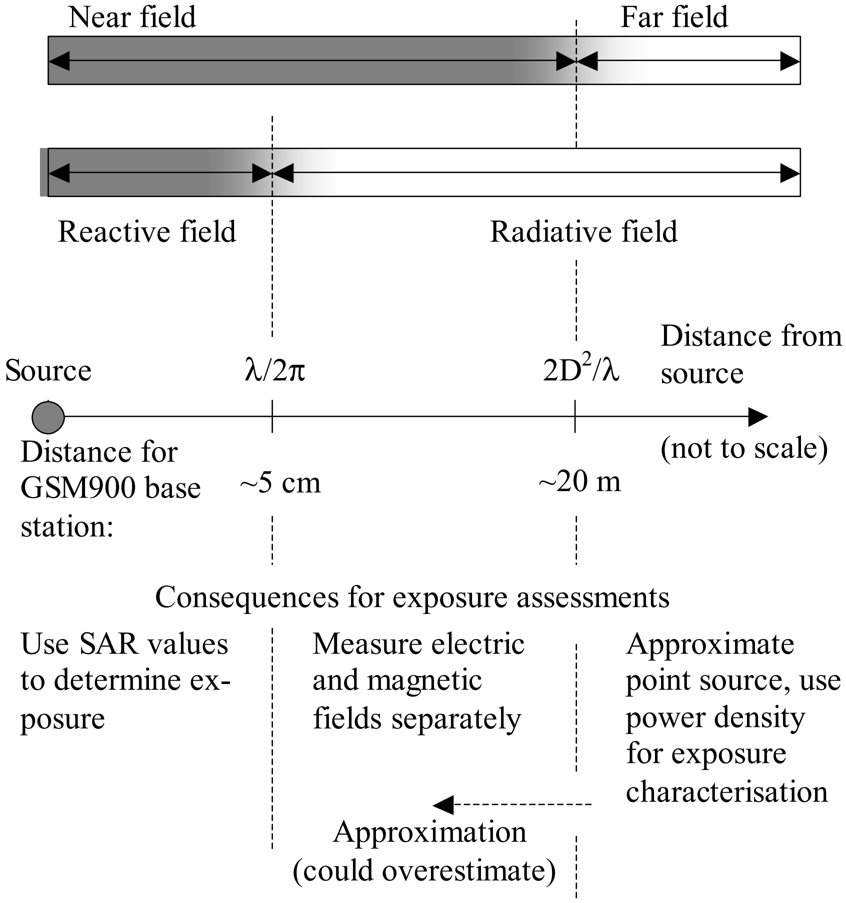


Figure 6. Illustration of three zones: reactive near field, radiative near field and (radiative) far field, and its consequences for exposure assessments. D = largest dimension of source (see comments in text). λ = wavelength (33 cm for 900 MHz). SAR = Specific Absorption Rate.

At a sufficiently large distance from the source, in the so-called far-field region, the electric and magnetic field components are closely related, and it is sufficient to evaluate only one of them. This region can be expected at a distance larger than about $2D^2/\lambda$, where D is the largest dimension of the antenna, and λ is the wavelength. Considering the wavelength λ of 33 cm for 900 MHz and 17 cm for 1800 MHz, and assuming an antenna dimension D of 1.8 m suggests that this far-field zone boundary should be as far as 20 to 40 meters from a large base station antenna. (The critical value is the dimension D of the antenna. It is, however, not clear whether the value of the total panel dimension should be used, or whether a smaller size is relevant. As a result, the far-field boundary might be expected at somewhat shorter distances). As this situation can be described as radiating, it is frequently found useful to characterise the exposure in terms of the incident power density in W/m^2. Since the electric and magnetic fields have a simple relationship, then the power density can be calculated based only on measurements of the electric field, according to the formulae $P = E^2/377$, where E is the electric field in V/m and P is the power density in W/m^2. In this far field region, the source can be approximated as a point, suggesting that the power density for an isotropic antenna, and in the absence of any interfering objects, will decrease as $1/r^2$. As already indicated, the actual decrease may be even faster due to objects interfering with the path.

In the close vicinity of base stations, measurements and calculations are more difficult because of the so-called near field conditions. In the radiative near field, the relationships between the electric and the magnetic fields are much more complex, and separate evaluation of them should be performed. Measuring the electric fields and using the far-field assumptions (above) in this zone would often lead to overestimating the exposure. Calculations by the NRPB (Mann et. al., 2000) has indicated that using the far-field approximation (above) at e.g. 10 m from a large base station antenna would overestimate the exposure by a few percent, while at 1 m the overestimate would be some 10-20 times.

In the reactive near field, at distances somewhat smaller than one wavelength (e.g. <10 cm from a mobile telephony source), there is a dynamic energy interaction between the source and the human body. As a consequence, the external field strengths are not good indicators of the actual exposure, and other methods of evaluations must be used – primarily the determination of the exposure directly into SAR levels (SAR = Specific Absorption Rate).

From a practical point of view, beyond a distance of about 10 metres from the base station antenna, far-field-based calculations are suitable for determining and surveying the exposures. This is especially true for compliance evaluation, where a limited overestimate would normally not be crucial. Most measurements reported in this document are expected to fulfil this requirement, although some measurements have been made within the radiating near-field zone.

Frequency selective versus broadband measurements

As already described above, the radiofrequency spectrum between a few MHz to some GHz is allocated to a large number of different communication services. In terms of the frequencies involved, two kinds of measurement requirements can be formulated for measurements of this exposure to radiofrequency fields: broadband and frequency selective measurements.

The broadband measurements integrate the detected exposure over a specified frequency range, and would therefore include all sources (including all radio systems) in the specified part of the spectrum. Frequency selective measurements means that only a narrow part of the spectrum is measured at each time – the bandwidth describes the width of the selected part of the spectrum. By varying the selected frequency (either manually or automatically), the exposure over a larger frequency range can be sequentially evaluated.

If one wishes to evaluate the contribution to the radiofrequency field exposure from base station antennas, frequency-selective measurements must be performed. Thanks to the frequency multiplexing scheme (different frequencies for uplink and downlink), the contributions of GSM antennas as distinct from the contribution of GSM phones can be identified in the measured spectrum. A second advantage when performing frequency selective measurements is that a precise compliance evaluation requires frequency-specific data, in order to weight the contribution at different frequencies before summing them (see further below).

As a consequence, frequency selective measurements are normally required for most measurement purposes (precise compliance testing, fulfilling a request or for comparison purposes, see e.g. table 1). Broadband measurements could be sufficient primarily in some monitoring schemes. Broadband measurements are often performed for a rough survey evaluation of compliance. As such, they can in many situations verify that the radiofrequency field exposure is low and below the limits of the EU recommendations. Within this STM, only frequency selective measurement data were considered. The frequency ranges covered by the various measurements generally encompassed GSM 900 and GSM 1800 downlink frequencies (see table 2).

Bandwidth and measuring time

An important measurement design decision concerning frequency selective measurements is the selection of the resolution bandwidth (RBW) for frequency-selective measurements. These parameters of the spectrum analyser can strongly influence the accuracy of the measurements. The resolution bandwidth must be substantially smaller than the actual bandwidth of a signal, which is 200 kHz for a GSM base station channel. In the data obtained in the STM, the bandwidths varied between 100 and 120 kHz

Depending on the degree of automation, the selected bandwidth, and the frequency range to be spanned, the time to measure the fields in one point can vary considerably. For GSM-specific measurements, this can vary e.g. from one to 10 minutes. A complete evaluation of the radiofrequency spectrum between e.g. 30 MHz to 2 GHz may take up to an hour.

The sensitivity of measurements

The sensitivity of the measurement is a very important issue, and must be adequate to meet the purpose of the measurement.

For compliance purposes, the electric field measurement sensitivity should in general be below some 1 V/m, and equivalently below some 3 mA/m for the magnetic field. For other purposes, e.g. detailed comparisons between GSM base station-related exposures at different sites as presented here, the frequency specific measurements need to be very sensitive, in light of the very low levels usually found. A measurement sensitivity of 0.01 V/m or lower appears warranted in order to permit detailed comparisons. (Out of 371 measurements reported here, the lowest exposure level reported within the STM corresponds to detecting an electric field of about 0.01 V/m.)

Measurement methods

As discussed above, in the current STM project, some data from frequency selective measurements were obtained in order to discuss comparability of results from the different participating countries. It should be kept in mind that the measurement designs were – in themselves – not specifically done for this project. The authors collected data already available in their countries; some presented examples of such data, while other included more extensive data – see the Appendices.

The selected frequencies varied slightly between the countries, but effectively covered the frequencies used for GSM 900 and GSM 1800 downlink. For all measurement data obtained from Austria, France, Germany, Hungary and Sweden, the assumption was made that far field conditions applied. Therefore the measured electric fields could be converted to power densities.

Measurements were performed using wide band antennas connected to a spectrum analyser. A schematic presentation is shown in figure 7. The details of the methods (frequency span, bandwidth, antenna, data storage etc.) used by different measurement series are shown in table 2 and discussed in the text.

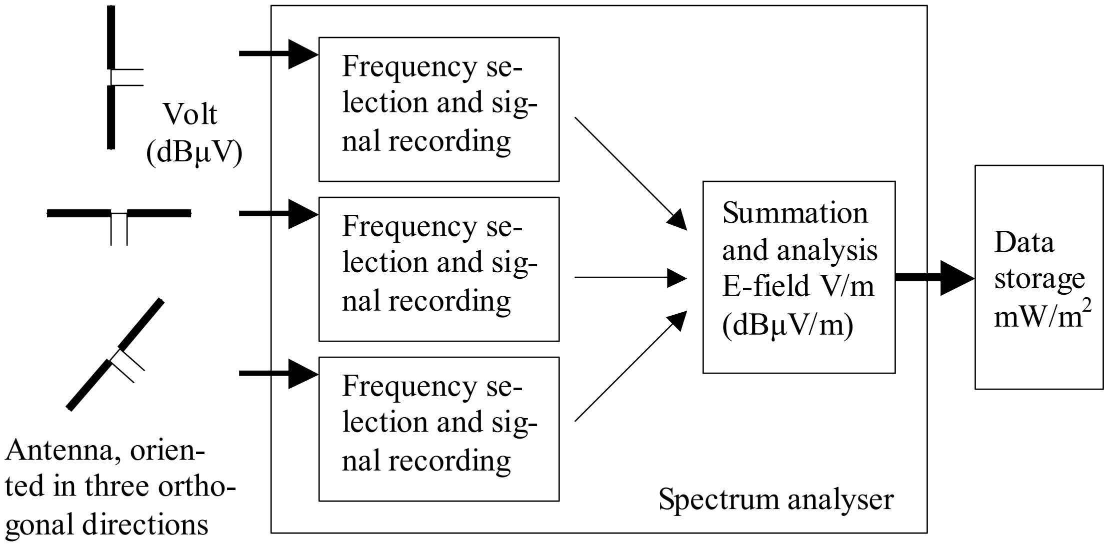


Figure 7. General outline of frequency specific measurements, comprising an antenna, a spectrum analyser and data storage facilities. See text for details.

A specially designed biconical antenna developed by the Austrian Research Centre (ARCS) was used by three groups (in Austria, Hungary and Sweden), while different antennas were used for the Belgian, and German. The antennas were always mounted on a tripod at slightly varied heights.

The signal to the spectrum analyser is expressed in volt and can be converted into electric field strengths (in V/m) using instrument design parameters such as antenna factor and cable loss. (For practical purposes, the results are often given in decibels, where e.g. $\mathrm{dB\mu V/m} = 10 \cdot \log \mu\mathrm{V/m}$.) The effective power density was obtained by the vectorial summation of the orthogonal field components. Alternatively, in some cases the direction of the maximum field strength was found by turning the antenna around its centre point. Using the formulae $P = E^2/377$, the result is expressed as the effective power density in $\mathrm{W/m^2}$.

All measurements were spot measurements, and in most cases no information concerning the variations of the field strengths versus time was available. During the sample (scanning) time, the maximum field strength in each direction could be obtained by using the "peak hold" function of the analyser – this procedure was performed for measurements in Germany, Hungary and Sweden.

The data analysis was generally performed off-line. The measured exposures were expressed in $\mathrm{mW/m^2}$.

Table 2. Comparison of measurement methods

Country	Frequency bands (MHz)	Antenna type	Peak hold or average	Sample time	RBW kHz [1)]	Antenna height	Antenna directions
Austria	943-960 1805-1880	ARCS PBA 10200	Scan [2)]	??	120	1.7 m	3 [3)]
Germany	935-960 1805-1880	Schwarz-beck USLP 9142	Peak hold	60 s	100	1.3 m	2 [4)]
Hungary	925-965 1790-1830	ARCS PBA 10200	Peak hold	60s	100	1.3 m	2 or 3
Sweden	935-959 1805-1880	ARCS PBA 10200	Peak hold	50 s	100	1.5 m	3

Data on the French measurements have not been received. [1)] The video bandwidth was in all cases the same as the resolution bandwidth (RBW). [2)] The measurements were mainly performed using a software scanning over the frequency range, the sample rate was typically 5 ms. [3)] Some measurements performed a maximum search. [4)] The German measurements were performed with a 360° azimuth rotation of the antenna (maximum search) for each of the two directions.

Variation and uncertainty

The data collected within the STM on different public exposure measurements show a very large variation covering eight orders of magnitude (see below). There are a number of different causes of such variation that must be evaluated before performing comparisons of these data. Basically there are three different sources of such variations and uncertainty:

- Uncertainty in measurement results due to differences in the measurement technique used.
- Spatial variations in signal strengths induced by various propagation path and technology, as well as large scale variations because of selection of different geographical sites.
- Temporal variations in traffic density at a given location.

The first source ("measurement uncertainty") reflects the degree by which the measured data correspond to the exposure at the selected position at the time when measurements were taken. In contrast, the spatial and temporal variations describe actual variations in exposures between different places and times.

Ideally, the procedures and methods of the measurements should be performed so that uncertainties are minimised and variations are adequately described, with both processes adjusted according to the aim of the measurements. In practice, there are several limitations to these processes, and an alternative that is relevant for decision processes that can accept some overestimation (e.g. compliance testing) is that of measuring a "worst case" situation.

Measurement uncertainty

Some basic sources of measurement uncertainty are due to the limitation of the instrumentation (the antenna, frequency analyser and signal recorder). Measurement methods should be harmonised, which is one of the tasks of standardisation organisations such as CENELEC (e.g. EN 50361, EN 50361). This uncertainty of the frequency selective spot measurements used within the current project – excluding the signal variation which is independent from the measurement setup – should be within ±30% or less. In principle, repeating a large number of measurements (under identical/similar situations) is expected to decrease this type of variation in data.

The "peak hold" procedure described above may, however, introduce some additional sources of variation in the data. Noise in the signal input will cause an overestimate which can however be corrected for, as e.g. described for the Swedish data series (Uddmar 1999). Another problem is that if a signal is discontinuous, it may only contribute to one or two of the three different antenna directions (because it may be "gone" when the last direction is measured), and may thus be underestimated. (Of course, a sporadic signal may be altogether missed – but can then not be identified. See further discussion below on temporal variations.)

Signal variations caused by propagation path, technology and distance

Variations in the distance from a single source have – in principle – a strong influence on the signal strength, which however also depends on the directionality of the antenna beam. When a measuring site is in the main beam (see figure 5), and neglecting interference from other objects, the signal strength (expressed in mW/m^2) is expected to decline with the square of the distance. Outside of the main beam, the signal strength is greatly reduced, and the variations with distance may become more complicated. At ground level very close to a base station antenna on a mast, the exposure level will be very low, but may often increase gradually with distance in the direction of the main lobe because various side lobes from the antenna will be encountered. At a certain distance of e.g. between 50 and 300 m, the main lobe will be entered, after which a $1/r^2$ decrease may occur. For a sector antenna, the exposure levels in other directions may generally be a few orders of magnitude lower than in the intended sector.

When measuring the field emitted by a single source in a real environment, large variations may be observed in the resulting exposure levels even within small variations in distance (e.g. within a meter). This is due to the existence of various propagation paths (reflections, diffractions and line of sight propagation). The resulting variations, which in principle are due to the presence of other objects (houses etc.) can be described by fast fading and shadowing.

The fast fading characterises quickly changing variations from the mean value of the field strength, brought about by summation of contribution of field strengths having different propagation paths from the source, and as a consequence may have different magnitude, polarisation and phase. As a result, the sum of all these contributions would show large variations. Such multipath fading effects may lead to variations of about ±3 dB (a factor 2-3 in each direction) in measurements in the GSM frequency bands within small areas. The shadowing effects characterise the blocking of the propagation by various objects such as terrain, houses, walls etc. As one important example, lower levels are generally found indoors compared to outdoors, depending on the wall material, closeness to windows etc.

In high traffic areas such as an inner city, the average distance to base stations is much smaller than in e.g. rural areas, and the number of base station (and channels) contributing to the exposure is likely much greater. As a general result, measurements made in such different areas should not be expected to be similar. These variations in measurement results due to the selection criteria (”where to do measurements”) should not be harmonised, given that measurements are made for different reasons, but some major sources of variation should be categorised.

The variations in selection of sites may be responsible for differences of several orders of magnitude in the measured field strengths. This may be one of the biggest sources of variation.

Temporal variations in traffic

As discussed above, the signals from the different channels from a base station may vary in time. Compared to spatial variations, however, these variations are somewhat limited due to the fact that one channel is always transmitting at full strength. Accordingly, the variations should not exceed the number of channels, and will thus normally be less than one order of magnitude.

Categories for measurement reporting

Categorisation that will in part handle these different sources of variation will provide more information as regard to the evaluation of the measured exposures levels. This report includes some suggestion on categories to be considered, such as whether the measurements were made:

- at ground level or higher up on roofs, terraces etc., which could be relevant to the likelihood of being in the main lobe or not,
- indoor or outdoor, and if indoor, whether close to windows or not, which would be relevant to some shadowing effects, and
- in urban or rural areas, which should be relevant to distances and density of base stations and traffic levels.

Such categories are expanded in the standard spreadsheet used within the STM project, see below.

Further refinement should include the time of measurement, in order to partially handle variations across the day (see e.g. figure 7). In the current data, such information was generally lacking. Another refinement, which is not traceable for data presented here (except in general terms or in some national series) would be the purpose of the measurement and/or the site selection process.

Standardized reporting of the measuring results

In order to provide information on some major causes of variations (as described above), a common spreadsheet has been developed to present the data obtained by the different participants. The tables should consist of harmonised and comparable information about the measurement site and results of importance for further interpretation of the data (see the next chapter). The data sheets presented in the appendices note the respective country and an indication of the type of area where the measurement took place. (Underscored terms are used in table headings.) Type of area is coded as:

- Inner city (IC)
- Outer city (OC)
- Industrial area (IR)
- Small town (ST)
- Rural or country-side area (R)

Details of the measurement site characteristics were further categorised in the following types. This description of the local environment is categorised as:

- Outdoors on the ground (0)
- Outdoors on roof, terrace, balcony (1)
- Indoors, close to windows, 1.5 m or less (2)
- Indoors, not close to the windows (3)

More detailed information about the exposure situation is categorised as

- Places where children spend part of the day outside their home, i.e. kindergarten, schools, playgrounds (1)

- Workplaces in general (2)
- Hospitals, old people's home (3)
- Houses (4)
- On the street (5)
- Leisure places, parks, gardens (6)
- Woods or fields (7)
- Places where the public normally does not have access (9)

The data spreadsheet used by the participants then provides information on the highest power density (S_i, mW/m^2) and the respective frequency (Frequency, MHz) as well as the sum of all power densities (S_{sum}, mW/m^2) within the GSM bands (GSM900 and/or GSM1800). The distance between the measurement site and the base station (when a particular station was identified) was also reported when information was available. (The availability of distance data may depend on the purpose of the measurements – no such distances are reported for e.g. Swedish data, where site selections were not made because of a particular base station.)

Detailed national results from project participants presented in this format are available in the Appendices of this COST 244bis STM report.

Overview of recommendation for exposure limits

In this chapter, the derived limits and reference levels of different national and international regulations, laws, standards, guidelines and other documents are compared. The main focus is set on the limits in the frequency range around 900 MHz and 1800 MHz to cover exposure next to GSM 900 and DCS 1800 base stations.

Different documents for exposure limits

Health based documents

The International Commission for Non-Ionising Radiation Protection (ICNIRP) after reviewing the scientific literature, formulated in 1998 guidelines on exposure limits for electromagnetic fields in the frequency range from 0 Hz up to 300 GHz. These guidelines are based on acute health effects such as elevation of tissue temperatures resulting from absorption of energy during exposure to electromagnetic fields between 100 kHz and 300 GHz (ICNIRP, 1998). The results of studies on possible long-term effects such as cancer were not considered to be adequate for setting limits on a scientific basis.

In 1999 the European Union published recommendations to limit the exposure of the general public in electromagnetic fields (EU, 1999). These recommendations rely on the ICNIRP guidelines of 1998 and are therefore based on scientific appraisal of risk-related data. Some countries have established similar national laws, regulations, guidelines or standards for exposure to radio-frequency fields, while others have adopted or are in the process of adopting the ICNIRP guidelines, in Europe in response to the EU recommendations. Accordingly, most national and international documents are based on the concept of avoiding the established short term health effects of exposure. Of the reviewed guidelines in this report, documents of this type are those of ICNIRP (1998), IEEE (1999) and CENELEC (1995) as well as national guidelines from Australia (AS/NZS, 1998), Austria (ÖNORM 1992), the Netherlands (NEL, 1997) and the UK (NRPB, 1993).

Documents based on different approaches

Several countries of the former East Block States also use risk related data, however, their way of evaluating scientific data traditionally rely on different parameters and thus led to different recommendations. The main differences are that they integrate the exposure over time and have different criteria for the definition of damage and adverse health effects. The Hungarian guidelines (Hungary, 1986) is an example of this type of document.

However, in some countries regulations were adopted containing exposure limits far below the ICNIRP recommendations. These limits are generally based on precautionary concepts that strongly depend on social and political arguments in addition to or as alternative to scientific considerations. Of the reviewed documents, regulations from Italy (Italy, 1998) and local proposals from Salzburg in Austria (SvorGW, 1998) are based on this approach. It should be noted that the precautionary approaches used in these documents appear to be different from the Precautionary Principle recently forwarded by the European Commission (CEC, 2000). In Switzerland (NISV, 1999), exposure limits are based on the ICNIRP recommendations, but in addition, the exposure contribution from base stations ("immission") is also limited, based on a precautionary approach.

Table 3 lists the considered documents reviewed in this report. In figures 8 and 9 the general public limits given in these 11 documents for the electric field strengths in the frequency range from 0.1 MHz up to 3000 GHz are shown.

Table 3. List of guidelines for general public exposure reviewed in this report

Country or organisation	Type	Reference
International / International Commission of Non Ionising Radiation Protection	Guidelines	ICNIRP 1998
International / IEEE	Standard	IEEE 1999
European / CENELEC / Technical Committee 211	Prestandard (withdrawn)	CENELEC 1995
Australia / Standard Association of Australia	Standard	AS/NSZ 1998
Austria - national / Österreichisches Normungsinstitut	Prestandard	ÖNORM 1992
Austria - local / Salzburger Sanitätsrat	Report	S vorGW 1998
Hungary / Hungarian Standard Institution	Standard	Hungary, 1986
Italy / Ministry of Environment	Decree	Italy 1998
Netherlands / Health Council of the Netherlands	Report	NEL 1997
Switzerland / Schweizer Bundesrat	Regulation	NISV 1999
United Kingdom / National Radiation Protection Board [a/]	Report	NRPB 1993

[a/] The UK has recently decided to adopt the ICNIRP/EU recommended limits.

Several international and national documents are not explicitly reviewed in the tables or figures of this section because they contain the same limits as one of the listed documents. This is e.g. the case for limits from the EU, Germany, New Zealand or South Africa (similar to the ICNIRP 1998 limits), limits from France (similar to the CENELEC 1995 limits), or limits from Japan (similar to Austrian national limits, ÖNORM 1992). In Sweden, work is currently ongoing to adopt the ICNIRP 1998 and EU 1999) guidelines into national recommendations for the general public.

Basic restrictions and reference levels

In many documents, the basic limits ("basic restrictions") are expressed in quantities such as the specific absorption rates (SAR), since these are intended to be closely related to the biological impact. In order to simplify compliance testing, these biologically effective quantities are converted into external field levels and power densities ("reference levels"), based on dosimetry and worst case situations. Thus, compliance with these reference levels ensures that also the basic restrictions are complied with. Failure to comply with the reference levels, on the other hand, does not necessarily mean that the basic restrictions are not complied with - this must then be investigated. Having in mind the distances involved (compare figure 6), only reference levels will be discussed here. In some documents (e.g. from Italy), limits are only expressed in external field levels.

Comparison of limits for radiofrequency fields

Figure 8 describes graphically the general public limits of the reviewed documents for the electric field strengths between 0.1 MHz and 300 GHz. To have the possibility to better compare the limits in the frequency bands of GSM 900 and GSM 1800 a more detailed overview on the limits of the mentioned documents is given for the frequency range 100 MHz to 10 GHz in figure 9.

As seen in figures 8 and 9, there is a substantial frequency variation in these levels in some guidelines – essentially those that are primarily based on restriction the SAR levels. Across the frequency range between 100 kHz and 10 GHz, this basic restriction in SAR is the same (e.g. 0.08 W/kg fore general public exposure according to ICNIRP, 1998), but the coupling of the external field (=the ability for a field level to cause a certain SAR level) is at its maximum between some 20 MHz and some few hundred MHz – the so-called resonance range. Accordingly, most reference levels shown in figures 8 and 9 are at a minimum at these frequencies, and do increase at lower and higher frequencies, where the ability of the external fields to pass into the body diminishes.

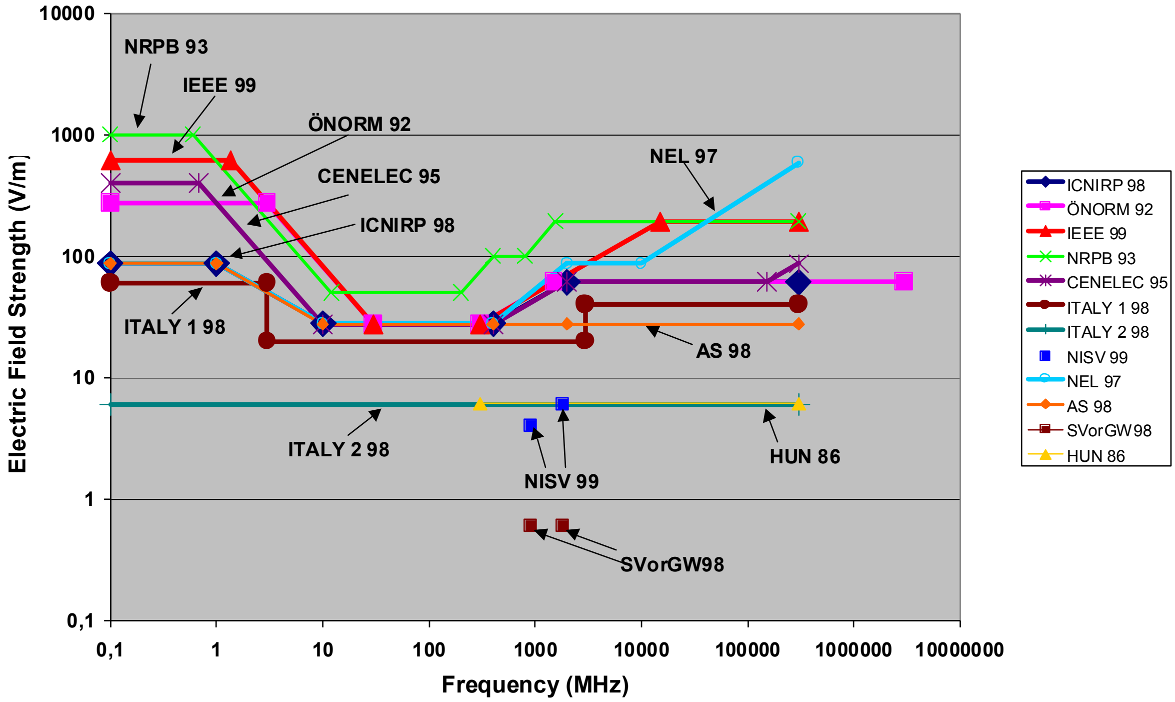


Figure 8: Overview on limits of the electric field strength reference levels for the general public from 0.1 MHz up to 300 GHz. In Italy, two limits for the general public are in force: in addition to the general limits (Italy 1 98), additional precautionary measures have to be applied in buildings used for periods of more than four hours (Italy 2 98). (Abbreviation: AS 98 = AS/NSZ 1998, HUN 86 = Hungary 1986. For others see reference list.)

Comparing in figure 8 the electric field strength limits of different document in the intermediate frequency range from 0.1 to 1 MHz, differences of up to three orders of magnitude can be found. This is mainly caused by different protection concepts applied by the different national authorities or committees. A central distinction is that between exposure limits based on scientific evaluation of health based data, and other documents such as the ones issued by the Italian Ministry of Environment (Italy 1 98 and Italy 2 98), which applied another protection concept largely based on social and political considerations resulting in much lower limits. A second distinction is that between those guidelines intended to restrict a biologically relevant exposure parameter (e.g. SAR levels) – and where as a consequence the reference levels vary with frequency (see above), and those guidelines where the primary objective is to restrict the external field levels.

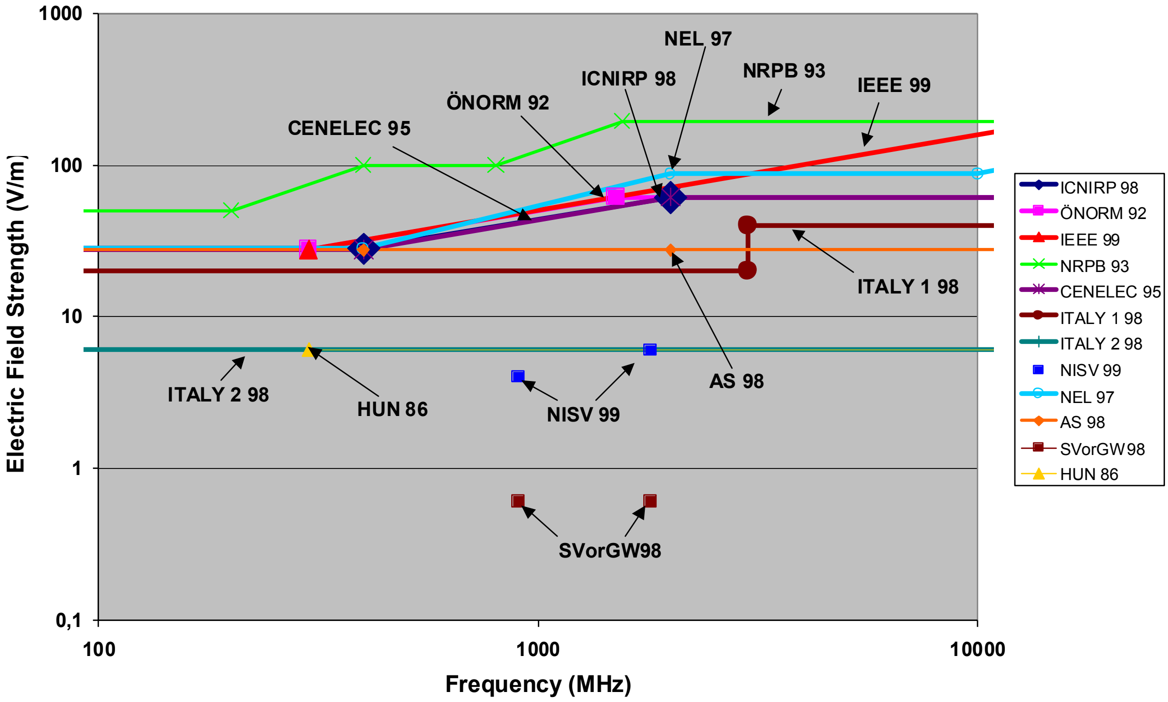


Figure 9: Overview on limits of the electric field strength reference levels for the general public from 100 MHz up to 10 GHz.

In some contrast, in the resonant range from about 20 MHz to some hundred MHz, the variation of limits is approximately restricted to about one order of magnitude, which could reflect a better understanding of dosimetry (e.g. in terms of absorption) in this frequency range. At higher frequencies (above some 300-400 MHz) there are again increased differences between different documents largely for the same reasons as in the 0,1 – 1 MHz frequency range and motivated on the reduced coupling of the external fields, as discussed above.

In addition, in the document with the highest limits, the National Radiation Protection Board (NRPB, 1993) took short term effects as a basis for his limits but have not, in contrast to e.g. ICNIRP (1998) limits, introduced additional reduction factors for general public exposure, but uses the same levels as for occupational exposure – which in principle are a factor 5 higher in power density (and a factor of $\sqrt{5} \approx 2.2$ higher for electric fields). (Note, however, that the UK has recently adopted guidelines based on the ICNIRP (1998) recommendations.) The large variations of the limits in this frequency range also reflect considerable uncertainty as to the details and numerical scientific basis for establishing limits.

Comparison of limits for mobile telephony frequencies

Numerical values of the limits of the electric field strength and power density limits for the general public at 900 MHz and 1800 MHz are given in table 4.

At 900 MHz, the limits of the electric field strength of all considered documents vary between 0.6 and 112.5 V/m (corresponding to a range of 0.001 to 33 W/m^2 for power density limits), while at 1800 MHz, the range is from 0.6 to 194 V/m (0.001 to 100 W/m^2). As the data in this document are later presented in terms of power density, the discussion below will focus on this parameter – but it is equally valid for the electric field levels.

Table 4: Reference levels for the general public at 900 and 1800 MHz.

Document	900 MHz limits		1800 MHz limits	
	Electric field V/m	Power density W/m^2	Electric field V/m	Power density W/m^2
International health based guidelines				
ICNIRP, 1998	41.25	4.5	58.3	9.0
IEEE, 1999	47.6	6.0	67.3	12
CENELEC, 1995	41.1	4.5	58.1	9.0
National health based guidelines				
AS/NSZ, 1998	27.5	2.0	27.5	2.0
ÖNORM, 1992	47.6	6.0	61.4	10.0
NEL, 1997	49.1	6.4	80.9	17.4
NRPB, 1993	112.5	33.2	194	100
East European health based guidelines				
Hungary, 1986	6.1	0.1	6.1	0.1
National guidelines based on precautionary approaches				
Belgium [a/]	20.6	1.1	30	2.4
Italy 1, 1998 [b/]	20	1.0	20	1.0
Italy 2, 1998 [b/]	6	0.1	6	0.1
NISV, 1999	4	0.04	6	0.1
Local recommendations, based on precautionary approaches				
S vorGW, 1998	0.6	0.001	0.6	0.001

The power density values are obtained by the formula $E^2/377$, and somewhat rounded.

[a/] Belgium has recently adopted some federal standards, apparently based on precautionary approaches. [b/] In Italy, two limits for the general public are in force: in addition to the general limits (Italy 1 98), additional precautionary measures have to be applied in buildings used for periods of more than four hours (Italy 2 98).

The levels of the first seven "health based" documents listed in table 4 are somewhat similar, with power density levels ranging from 2.0 to 33.2 W/m^2 (900 MHz) and 2.0 to 100 W/m^2 (1800 MHz). Two of these documents are somewhat different than the others though: NRPB does not apply an additional safety factor for the general public, and thus the level is generally higher. In the Australian document the derived limits are not increased after the end of the resonance range, but uses the same reference levels also at higher frequencies and thus results in somewhat lower levels. (See above for a general discussion on these variations). Apart from these two modifications there is a variation between 4.5 and 6.4 W/m^2 at 900 MHz and between 9.0 and 17.4 W/m^2 in the limits of these documents. It should be noted that the numerical values presented in table 4 are based on 900 MHz and 1800 MHz frequencies. At the actual downlink frequencies (emitted from base station antennas) of 935-960 MHz and 1805-1880 MHz, the limits are somewhat higher than those presented in table 4. The ICNIRP levels are between 4.675 and 4.8 W/m^2 for GSM900 downlink frequencies and between 9.025 and 9.4 /m^2 for GSM1800 downlink frequencies. For simplicity, the comparisons made in this document will use the slightly lower (more restrictive) limits at 900 and 1800 MHz.

The other five documents have substantially lower limits, basically because of the application of different protection concepts and the lack of variation with frequency (except for the Swiss document) – see above for further discussion. The limits for the general public of these five documents vary between 0.001 and 1.1 W/m^2.

In conclusion, it can be stated that there are large variations between the field limits (derived levels, reference levels) given in different international documents. The main reasons for this large variation appear to be differences in the protection concepts used in different countries. Documents applying similar scientifically evaluated health data (“health based guidelines”) and existing knowledge about dosimetry are, on the other hand, fairly similar. In terms of electric field levels, the variation is about 20-30% (and 30-50% in terms of power density levels). Five such documents were reviewed here (ICNIRP 1998, CENELEC 1995, ÖNORM 1992, NEL 1997 and IEEE 1999), but a number of other countries have adopted or are in the process of adopting such limits, and the ICNIRP (1998) limits have also been recommended for member countries by the European Union (EU 1999). For these reasons, evaluation of data in this report is primarily based on the ICNIRP (1998) limits.

Comparison will, however, also be made in terms of some limits based on other approaches (as forwarded in Hungary, Italy, Switzerland and Salzburg). This is done for information purposes, and should not be taken as a recommendation concerning the use of those limits. A decision to use precautionary approaches or not is a risk management and a political decision, which the authors consider to be beyond the scope of this report.

Presentation and interpretation of data

The purpose of the Short Term Mission was to compile some available data and to discuss comparability and usability of these data as source of information to the public. As already stated above, the data were originally not obtained with such comparability in mind, which in the view of the STM group clearly limits the comparability of data from different measurement series.

In this section, some limited comparisons are presented, with the aim to exemplify what type of comparisons may be possible, and what improvement in data records are needed in order to improve the comparability. Despite these shortcomings in comparability, a few conclusions can – in our opinion – be drawn from the collected data, and are therefore given below.

Number of measurements

The database collected within this Short Term Mission contains 371 measurements on RF exposures from GSM base stations, 233 from Austria, 10 from France, 17 from Germany, 80 from Hungary and 31 from Sweden. Thus, the number of measurements available for this report varied considerable between the different countries. This is caused by several facts, e.g. that some members joint the Short Term Mission at a late date, and by the primary purpose of the Short Term Mission – to discuss comparability of data that have been obtained for different purposes. Thus, the presented data do not represent all data available from these countries – but were those collected by the group in order to investigate what conclusions could be drawn from such data, and to develop a common reporting protocol. For example, a number of broadband measurements have also been performed, taking into account contributions also from other radiofrequency field sources, such as radio and television broadcasts. However, these measurements are not included here, as the specific contribution from GSM base stations could not be discerned. Of these 371 measurements, 25 outdoor measurements were made in places where the public normally would not have access. Thus, the results below are based on the remaining 346 measurements.

Out of these 346 measurements, 181 (52%) were performed indoors and 165 (48%) outdoors. 85 of the indoor measurements were performed at distances of 1.5 m or less from the closest window, while 96 were done at distances larger than 1.5 m. 135 measurements were performed outdoor on the ground (on street level) and 30 outdoor on terraces, balconies or roofs. It is noteworthy that the distribution of the types and characteristics of measurement locations varies considerable in the data available from the different countries. For example, apart from Germany and Austria the number of reported indoor measurements is low compared to the number of outdoor measurements. Most of the outdoor measurements were performed on the ground, while higher levels are expected on roofs, terraces or balconies. These choices are presumably based on the varying purpose of the measurements (see above), but – as will be discussed below – presents some obstacles for the comparability of the data.

Summation of exposure from the total GSM bands

In the majority of the Austrian data (n=193), information was available only from the GSM frequency causing the maximum GSM-derived exposure. For 31 Austrian data, and from the data from the other countries, information on the total exposure in the GSM 900 band was available. In the French and some of the German data, this summation included also the GSM 1800 band, as indicated in the respective tables. Some care must therefore be exercised when summing data from different countries or data series in this respect. Measurements performed in Sweden resulted in higher contributions from GSM 900 base station than from GSM 1800 base stations, presumably because the number of GSM 1800 base stations is small compared to the number of GSM 900 base stations, and thus the average distance to a GSM 1800 station may be much longer and thus the signal weaker. In total, the data base contains 152 exposure measurements of GSM 900/GSM 1800 base station exposures.

The distributions of these 152 data according to the type of site (city, rural etc.) and the immediate environmental characteristics (outdoor, indoor etc.) are shown in tables 5 and 6, respectively.

Table 5. Number of measurements (with GSM exposure summation) in this report from different countries separated according to type of site

Country	Total	Inner city (IC)	Outer city (OC)	Industrial area (IR)	Small Town (ST)	Rural area (R)
Austria	31	6	9	2	0	14
France	9	9	0	0	0	0
Germany	17	3	3	3	3	5
Hungary	64	41	10	0	0	13
Sweden	31	11	7	0	6	7
Total	152	70	29	5	9	39

Table 6. Number of measurements (with GSM exposure summation) in this report separated according to site characteristics.

Characteristic	Total	Inner city (IC)	Outer city (OC)	Industrial area (IR)	Small Town (ST)	Rural area (R)
Outdoors, ground levels (0)	74	31	15	4	5	19
Outdoors, roof or terrace (1)	11	8	3	0	0	0
Indoor, close to windows (2)	39	17	7	1	3	11
Other indoor measurements (3)	28	14	4	0	1	9
Total	152	70	29	5	9	39

Descriptions of these data are made according to the following:

- All 346 measurements, describing the strongest GSM source.
- The 152 GSM summary measurements, also separated according to:
  - type of site, and
  - site characteristics, but only for inner city and rural measurement because of limited data in other types of areas.

The comparability between data series from different countries is also discussed, with some limited examples. Apart from the exclusion of the “non public access sites”, no further descriptions were made for the exposure situations.

In principle, measurement uncertainties must be taken into account when interpreting available data, this problem is discussed in detail in the chapter on measurement procedures and methods. It must be pointed out, however, that the large variation in the exposure levels presented here (up to eight orders of magnitude) is not explainable by variations in the quality of the measurements, but is more likely the results of real variations in exposures. All results used in the frame of this report are obtained from high qualitative measurements based on state of the art measurement procedures.

Summary of measurement results

Exposure at single frequencies

The highest measured power density among the 346 measurements at a single frequency in the GSM 900 and GSM 1800 band was 13.4 mW/m^2 at a frequency of 952.4 MHz, corresponding to 0.28% of the ICNIRP exposure limit for the general public. The maximum power density at single frequencies varied between <0.000001 and 13.4 mW/m^2, thus with a variation of at least seven orders of magnitude. The median value was 0.01 mW/m^2 (or 0.0002% of the ICNIRP 1998 guidelines), and eleven of the 346 measurements (3.2%) exceeded

1 mW/m^2. These 11 higher measurements were found in cities or industrial areas.

Total exposure from GSM base stations

The maximum sum of all the levels in the GSM 900 and GSM 1800 band was 47.6 mW/m^2 or about 1% of the ICNIRP exposure limits for the general public. The exposure levels for the 152 measurements varied between <0.000001 and 47.6 mW/m^2 (eight orders of magnitude) with a median level of 0.2 mW/m^2, corresponding to about 0.004% of the ICNIRP 1998 levels. In table 7, a comparison is made between these measured exposure levels and various recommendations.

Table 7. Comparison of GSM base station exposure with international and national recommendations

Recommendation		Exposure or immission limit at 900 MHz , mW/m^2	Number of measurements exceeding limit	Maximum exposure, % of limit
International	ICNIRP, 1998 [a/]	4 500	0 of 152	1%
Hungary	Hungary, 1986 [b/]	100	0 of 152	48%
Italy	Italy 1, 1998	1000	0 of 152	5%
	Italy 2, 1998	100	0 of 152	48%
Switzerland	NISV, 1999	42	1 of 346	113%
(Salzburg	S vorGW, 1998 [c/]	1	37 of 152	48 times)

[a/] and other science health based guidelines. Such guidelines exist or are being introduced in Austria, France, Germany and Sweden. [b/] Thus directly relevant for Hungarian measurements. [c/] Local report, not national or international guideline.

It can be seen from the results that all measured exposure levels are at least two orders of magnitude below the limits of the ICNIRP 1998 guidelines. Apart from this, exposure levels vary by about eight orders of magnitude in the different examined locations. The exposure level depends on several factors like the input power of the antenna, the type of the antenna, the location of the examined position in respect to the antenna and several environmental factors. It must be pointed out that the knowledge of the distance to a base station alone is not sufficient to make reliable estimations on exposure levels.

It is important to note that all measurements presented in table 7 were spot measurements and that worst case exposure situations – e.g. in terms of time of day – were not identified. As discussed above, the time variation may, at most, amount to a factor that is not likely to exceed 5. Thus, time variations in these data will not affect compliance with ICNIRP guidelines.

Substantial variations could occur due to distance to base station antenna, in that very close approach to a base station antenna in the direction of the main radiation lobe would result in exposures much higher than those presented here.

Thus, much higher exposure levels can be expected for service personnel having very close access to base station antenna in the main beam. The data in this report should, however, be relevant for various positions where members of the public can be expected to have access.

A further complication is that e.g. the ICNIRP guidelines require summation of all contributions between 0.1 MHz and 300 GHz. In practice, this means that the exposure from base station antenna (as recorded here) should be added to the exposure from sources such as radio and television broadcasts etc. The Short Term Mission reviewed also some broadband measurements, which included a number of these sources. The highest level found in these measurements corresponds to about 3.3% of the ICNIRP general public exposure limit.

Measurements from specific types of site

The results of these measurements were separated according to type of site where the measurements were performed. The results suggest that while inner and outer city levels were reasonably similar (median values of 0.40 and 0.31 mW/m^2, respectively) there is a considerable difference between those and rural area exposures (median values of 0.007 mW/m^2). While this difference is statistically quite apparent, the large variation (5 to 7 orders of magnitude) in the inner city, outer city and rural data should also be noted. (For industrial areas and small towns, the numbers of data are too small for any deliberations.)

This comparison between inner city and rural data was also evaluated when controlling for the character of the measurement site (indoor, outdoor etc.). The difference between inner city and rural exposure levels, by at least 1 order of magnitude, was confirmed both for outdoor ground levels (median 0.66 mW/m^2 in inner city, 0.01 mW/m^2 in rural areas) and for indoor levels close to windows (0.17 and 0.02 mW/m^2, respectively.) In both inner city and rural areas, there was also a modest expected decrease in indoor levels compared to outdoor levels. Likewise, in inner city areas, roof or terrace levels appear somewhat higher than ground (outdoor) levels, but the small number of comparable measurements makes it difficult to ascertain this difference with any certainty.

Comparison between countries

Apart from possible real differences between countries, differences in data from different measurement series could arise due to the various methods of data collection.

- The measurement methods were not always the same in the different countries. In Austria, Sweden and Hungary the same type of antenna was used to perform measurements. In Austria and Sweden, measurements were generally performed in three orthogonal directions at a measuring position and the effective field strength was derived from these three measurements. In Hungary, measurements were performed in horizontal and vertical polarisation of the antenna alone and not in the direction of the x-, y- and z-axes. Such differences in the measurement protocol have to be taken into account while trying to compare results obtained by different measuring institutions. On the other hand, such differences would not be expected to cause differences of orders of magnitude.

- In addition, one has to consider that the selection criteria of the measurement location were not always the same in different countries, e.g., measurement positions in Austria were often selected in the living environment of concerned people. The information available from Austria is mainly representative for such places, but this does not have to imply that these data are representative for Austria in general. In Sweden, measurement locations were chosen to give an overview of different environments, e.g. rural areas, cities, small towns. The selection criteria could have considerable influence on the results and make reasonable comparisons difficult.

Thus, a direct comparison of these results obtained in different countries by different methods and for different reasons can lead to wrong conclusions.

As an example, a comparison was made between Swedish and Hungarian data from inner city and in rural areas (both at outdoor, ground level):

- For inner city, Hungary median was 0.7 mW/m^2 (range 0.008-5.0 mW/m^2, n=15), while Swedish median was 0.6 mW/m^2 (range 0.03-2.7 mW/m^2, n=6).
- For rural areas, Hungary median was 0.06 mW/m^2 (range 0.01-0.45 mW/m^2, n=9), while Swedish median was 0.0003 mW/m^2 (range <0.000001-0.006 mW/m^2, n=7).

Possible explanations for the observed difference in rural data could be differences in the population density (modified by different mobile telephony penetration rates), and the selection of site and thus distance to base station. (These Hungarian rural measurements were obtained at distances between 50 and 192 m from a base station, while Swedish sites were not chosen because of vicinity of base stations.) While the first would constitute a basis for a "real" difference, the second could be seen as a result of the measurement design. (Both types of influences would be expected to have a lower influence in city areas, which agrees with the lack of observed differences in inner city data.) In the opinion of the authors, while both types of influences are likely operative in rural areas, it is not possible to determine the relative importance of them. As a consequence, it is not possible to deduce whether the observed rural differences between Hungarian and Swedish data indicate a real difference or not.

Final comments

The data analysed in the frame of this Short Term Mission allow the following conclusions:

- Exposure levels in areas accessible to the public in the vicinity of base stations are varying by several orders of magnitudes. This is likely due to differences in the input power of the antenna, different types of antennas, variation of location of the measuring position in respect to the antenna and different environmental or shadowing factors.
- Detailed comparison of different sets of data is only possible if type and characteristics of the site as well as site selection criteria are matched.
- Variations in measuring methods and measuring uncertainties should be taken into consideration, but are not likely to explain the very large variations found.
- Exposure levels appear often to be lower in rural than in urban areas.
- Despite these variations and uncertainties, it remains clear that exposure levels were well below the reference levels of the ICNIRP guidelines in all these measurements, performed in areas accessible to the public.

Summary and conclusions

Main findings of the Short Term Mission

Background and purpose of the Short Term Mission

In response to the increased deployment of mobile telephony base stations, concerns about the resultant exposure to electromagnetic fields and the possibility of adverse health consequences have arisen. Compilation of exposure data should enable some evaluations: e.g. what levels are to be expected and whether these levels comply with health based exposure recommendations. This Short Term Mission (STM) within the COST 244bis Action “Biomedical Effects of Electromagnetic Fields” was therefore launched with the objective of compiling existing exposure data from different European nations, evaluating the comparability of such data, and outlining the requirement for a future common data-base.

In this compilation, exposure data were restricted to the contributions from mobile telephony base stations of the 2nd generation (GSM), as they appear in areas where the public would normally be expected to have access. All available data in the participating countries were not obtained, since the aim was to compile sufficient data in order to evaluate the comparability and usefulness of such data, that have originally been obtained without consideration of such comparability.

A large number of different applications have been given licence to use the radiofrequency part of the electromagnetic spectrum. Mobile telephony systems utilise only a small part of this range, with emissions from GSM base stations occurring between 935 and 960 MHz, and between 1805 and 1880 MHz. The resultant exposures vary in space depending on the direction of the main beam, on the distance from the antenna, and on the occurrence of interfering objects, and in time depending on the traffic volume.

Rationales for measurements

Most of the data compiled within the STM were originally obtained following requests for information or complaints at particular sites. Other reasons for measurements were the need to evaluate compliance with national or international reference levels, or scientific interest such as monitoring the normal exposure of the public. These different purposes often necessitated different measurement designs, especially in terms of how measurement sites were selected. For example, monitoring would normally require representative measurements or random site selection, whereas compliance testing has to take into account worst case situations. Because of the large variations between different sites, such variations in design can therefore be expected to result in substantial differences in exposure measurements.

Measurement methods

The data reported here have generally been obtained at a sufficient distance (10 metres or more) to allow far-field calculations. Thus, exposures can be measured as electric field strength (in V/m), and expressed as the power density in W/m^2. In several countries, a substantial number of data was collected by broadband measurements in the high frequency range. However, the STM did not include such broad band data since the information specific to mobile phone frequency bands could not be extracted. All compiled data were obtained by frequency specific measurements.

The measurement methodology by which data were obtained has varied somewhat between different investigations and in different European nations. For example, one difference was that the field measurements were made either in three orthogonal directions or only in two. The measurement equipments used, e.g. antennas or analysers, have also varied. It should be acknowledged, however, that these different methods result in high-quality data for the specific aim of each investigation, and was based on best technical know-how. Furthermore, these variations in measurement methods and measurement uncertainties are not expected to cause order of magnitude differences in the data.

Recommendations for exposure limits

The use of basic restrictions and reference levels to facilitate protection as recommended by the European Council rely on the guidelines issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These recommendations are based on scientific appraisal of risk-related data. Many nations in Europe and elsewhere have adopted these or similar recommendations or are in the process of adopting them. In these recommendations or regulations, basic restrictions (e.g. expressed in levels of Specific Absorption Rates /SAR/ in W/kg body weight) constitute the real requirements, whereas reference levels (e.g. in W/m^2) is a practical way of asserting compliance. The reference levels for 900 and 1800 MHz recommended by ICNIRP (and adopted by the EU) are 4.5 and 9.0 W/m^2, respectively. Most other Western health-based recommendations are similar or somewhat higher.

Countries of the former East Block also use risk related data, however, their way of evaluating scientific data traditionally rely on different parameters and have thus led to different regulations. Some European countries have incorporated additional precautionary measures into their regulations due to socio-political considerations. Some of these latter regulations do not specify basic restrictions, and thus use external field levels (e.g. electric fields in V/m) as the primary restrictions. As a consequence, they do not always show a variation of reference levels with frequency. Levels are generally about 2 orders of magnitude lower than the ICNIRP reference levels.

Results and interpretation of data

In all, 371 frequency specific exposure measurements from Austria, France, Germany, Hungary and Sweden were collected within the STM, about half from outdoor situations, with most of those at ground levels. For 152 measurements carried out in places where the public would normally have access, data on the total contribution of all GSM frequencies were available, and were mainly obtained in larger cities (65%) or rural areas (26%).

Exposure levels due to GSM base stations varied by eight orders of magnitudes in different locations, ranging from <0.000001 to 48 mW/m^2, with a median of 0.2 mW/m^2. This large variation is presumably due to differences in physical parameters, e.g. input power of the base station, in measurement protocol, e.g. position of the measurement antenna in relation to the base station antenna and its main lobe, and in the type and characteristics of the measurement site, e.g. indoors/outdoors. As a consequence, even though all data included in this report represent a certain site and situation in a country very well, a comparison between different sets of data is only possible if site selection criteria are matched.

Despite these large variations, compliance with the European Council Recommendation (based on ICNIRP 1998) in places where the public would normally have access can be safely confirmed. In all data sets examined, the measured exposure levels were well below the reference levels. The highest encountered exposure was at about 1% of the ICNIRP reference level.

Final Conclusions

A large number of measurements from different countries was compiled for this report and presented in data sheets with the same layout. The data cover a broad range of situations, site selections and measurement methods. All measured levels were well below the recommendations of the European Council.

Nevertheless, even at levels substantially below the recommendations, measured levels due to base station emissions vary by several orders of magnitude, due to different factors. Having analysed sources of these differences, the Short Term Mission group concludes that comparisons of different exposure data sets are only possible if selection criteria are matched.

These conclusions are especially relevant for decision makers seeking advice in data bases for risk management decisions and for the preparation of information material.

Recommendation for the future

The Short Term Mission recommends that future national and international activities concerning measurements of exposure levels around base stations should address the improvement of comparability between different measurement series.

One important step in this direction is the harmonisation of measurement techniques. European and international standardisation bodies are the appropriate agencies for such a harmonisation. As a minimum, specification of the methods used should be reported, e.g. giving details about frequency range, resolution bandwidth, sample time, method of averaging, antenna type, antenna direction and antenna height over ground.

The other step is appropriate recording of circumstances under which the measurements were obtained, this includes specification of physical factors such as parameters of the base stations in question as well as type of surroundings such as inner city first floor balcony. The STM suggests a standardised reporting of measurement data with the following details (describing “why”, “where”, “when” and “what”):

- Purpose of the measurement (compliance, local request, comparison or scientific), and site selection method (random, close vicinity of a specified base station, etc.).
- Country, type of area (inner city, rural area etc.), site characteristics (indoor or outdoor, ground level or on roof/terrace/balcony), and pertinent further details of the exposure situation. If a particular base station is identified or evaluated, the distance in metres should be included.
- The time of measurement (year, weekday/weekend, time of day).
- The measurement results: the highest power density and respective frequency, and the sum of all power densities in the appropriate (and specified) frequency bands.

For data compiled in this report, only the 2nd and 4th descriptions (“where” and “what”) were generally available.

The Short Term Mission group also recommends that measurement data should be used more widely in information campaigns for the public. Further co-ordination of these activities should be important objectives of a future COST Action within this field.

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Appendices - National reports

In appendices 1 – 5, additional descriptions are given from five of the participating countries (Austria, France, Germany, Hungary and Sweden). The reports are structured in a similar way, presenting regulations and standards, the mobile telephone network in each country, measurement rationale and methods used for the data compiled by STM from each country, evaluation of the national data and some added discussion points.

In subsequent tables, all data from that country included in this report are presented in a standardised spread-sheet, with the following headings and explanations:

- Country: The country where measurements were performed.
- City/place: The city and localisation where measurements were performed (optional).
- Type of area: Coded as inner city (IC), outer city (OC), industrial area (IR), small town (ST) or rural area (R).
- Site characteristics: Categorised as outdoors on the ground (0), outdoors on roof/terrace/balcony (1), indoors close to windows (1.5 m or less) (2) or indoors not close to the windows (3).
- Exposure situation: Coded as places where children spend part of the day outside their home, i.e. kindergarten, schools, playgrounds (1), workplaces in general (2), hospitals, old people's home (3), houses (4), on the street (5), leisure places, parks, gardens (6), woods or fields (7), or places where the public normally does not have access (9).
- Frequency band: Frequency of the highest single frequency in the GSM band.
- Highest power density measured at a single frequency (S_i, mW/m^2).
- Power density sum over all GSM frequencies bands (GSM900 and/or GSM1800). (Not evaluated for part of the Austrian data.)
- Distance to the nearest base station antenna (when a particular station was identified).

In some of these countries, further data exist. However, as the designs of the underlying measurements were not done with the objective of comparability, it was decided by the STM to collect only sufficient data to enable an evaluation of the comparability. Additional data also exist in other European nations. For example, a substantial data set has been published by the National Radiological Protection Board in the UK (Mann et. al., 2000).

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Appendix 1 – National report Austria

Introduction

Data of frequency selective measurements of power density from 233 positions distributed over Austria were analysed. Measurements were performed from 1997 to 2000 by three independent measurement institutions in Austria (ARCS, TGM, TÜV). In the first two years, measurements were mainly executed in the frequency range from 30 MHz to 1 GHz. At this time the net DCS 1800 (GSM 1800) had not been installed. Since 1998 the measurement range has been extended up to 1.9 GHz to include the exposure due to GSM 1800.

Regulations in Austria

Pre-standard ÖNORM S1120

Since July 1992 the pre-standard ÖNORM S1120 is in force. This pre-standard covers the frequency range from 30 kHz to 3,000 GHz and gives limits for the general population and workers. For the frequency range of interest for GSM base stations the pre-standard gives the following derived limits for the general public averaged over any six minute interval:

Table App 1A Derived limits of the prestandard ÖNORM S1120 between 300 MHz and 3000 GHz.

Frequency (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m²)
300 – 1 500	$1.596*f^{(0.49907)}$	$3.97876*10^{(-3)}*f^{(0.50768)}$	$6.66666*10^{(-3)}*f$
e.g. 950	48.9	0.129	6.33
1 500 – 3 000 000	61.4	0.16	10

Telecommunication Law

Since August 1997 the law of telecommunication has been in force in Austria (Telekommunikationsgesetz BGBl. 100/1997). The purpose of this law is to guarantee provision of reliable, high-grade and innovative telecommunication services to the population, trade and industry. It also states that protection of life and health of the population must be warranted during the use of transmitting facilities.

Mobile telephone networks in Austria

In Austria 4 mobile net providers run 4 independent mobile phone networks. The only analogue one is the D-Net. An overview of the existing networks is given in table App 1B. In November 2000 UMTS licenses were auctioned.

Table App 1B Existing network in Austria (pre-UMTS)

Net	Frequency (approx. in MHz)	Standard	Network provider	In operation since
D	900	analogue	Mobilkom	1990
A1	900 + 1 800	digital (GSM)	Mobilkom	1996
max	900 + 1 800	digital (GSM)	maxmobil	1996
one	1 800	digital (GSM 1800)	Connect	1998
telering	1 800	digital (GSM 1800)	Telering	2000

When the licenses for these existing nets were sold, the contracts contained stipulations regulating the minimum quality the net provider has to guarantee and the coverage (typically more than 90 % after some years).

Rationale for measurements

The legal situation in Austria does not require measurements in the locations next to each transmitter to prove compliance with the limits. However, public reactions in recent years have led to an increasing number of measurements next to base stations due to different reasons. The motivation for these measurements were fears of people living next to such installations and also lack of information of the people concerned. Network providers are using such measurements to show that the field levels are well below the limits, to calm people and to give some information on the respective exposure situation. In some cases measurements were used to get an idea about the variations of the exposure levels at different measurement locations.

Measurement methods

Measurements were most times performed using spectrum analysers with a bandwidth of 120 kHz, if not otherwise indicated, measurements were performed 1.5 to 1.7 m above ground. The measurement antennas used by the three institutions were not the same: the ARCS used a special designed biconical antenna enabling direction independent measurements of the maximum levels of all sources for almost all its measurements. The effective power density is obtained by the vectorial summation of the three orthogonal field components.

The other two institutions used logarithmic periodical antennas. In these cases no effective power densities were evaluated, but it was tried to find the direction where the maximum field strength occurred by turning the antenna around its centre point. Summation of field strengths or power densities was always done according to the Austrian pre-standard. All measurements were spot measurements, in most cases no information of the variations of the field strengths versus time is available. All measurements were performed at ambient temperatures above 10°C (the temperature of the location where the spectrum analyser stood was never below 10°C). The antenna was never exposed to rain. Antennas were always mounted on a tripod.

In some cases measurements were performed using broad band field probes. However, these results will not be discussed in this report, therefore the measurement methods for handling such probes are also not discussed here.

Interpretation of data

The existing data show that the exposure levels were well below the limits in all examined cases. The highest power density at a single frequency in the GSM band was 13.43 mW/m^2 or 0.3 % of the limit for the general public of the ICNIRP guidelines. The maximum sum of all the levels in the GSM 900 band was 47.62 mW/m^2 or 1.06 % of the ICNIRP limits. As mentioned in the previous chapters, also broadband measurements taking into account the levels from other sources were also performed. The highest level found during these measurements corresponded to 3.3 % of the limit. However, these measurements are not in the scope of this report.

Variations of eight orders of magnitude are found in the level of the highest power density at single frequencies in the GSM bands measured at different locations. In fact, the maximum power densities at single frequencies are between 13.43 and 0.00000016 mW/m^2. The average value is 0.257 mW/m^2, the median 0.0095 mW/m^2.

Of the 233 measurements, 137 (58.8%) were performed indoor and 96 (41.2%) outdoor. 61 (26.2 %) of the indoor measurements were performed at distances of or less than 1.5 m to the closest window, 76 (32.6 %) at distances above 1.5 m. 66 (28.3 %) measurements were performed outdoor on the ground (on street level) and 30 (12.9 %) outdoor on terraces, balconies or roofs. The average value of all indoor measurements was 0.1919 mW/m^2, of all outdoor measurements 0.3496 mW/m^2.

Measurements performed outdoor on the ground ranged between 0.95 to 0.00000016 mW/m^2, the average value was 0.10025 mW/m^2, the median 0.00688 mW/m^2. Measurements performed outdoor on roofs, terraces or balconies were between 13.43 to 0.000076 mW/m^2, the average value was

0.89813 mW/m^2, the median 0.09103 mW/m^2. The measurement results obtained indoor close to windows ranged between 9.275 to 0.0000282 mW/m^2, the average value was 0.35918 mW/m^2, the median 0.001988 mW/m^2. Measurements performed indoor not close to windows ranged between 1.3475 to 0.0000234 mW/m^2, the average value was 0.05767 mW/m^2, the median 0.003075 mW/m^2.

The sum of all levels in the GSM 900 band is varying between 47.62 and 0.00343 mW/m^2. Information of the sum of all power densities was available in 33 (14.16 %) cases. The average value is 3.43 mW/m^2 and the median value 0.35 mW/m^2. It is important to notice that all measurements were spot measurements and worst case exposure was not examined. The sum of the GSM signals is restricted to the GSM 900 band and does not include GSM 1800 signals. Under these conditions the sum was above 1 mW/m^2 in 10 locations out of 33.

It can be seen that the average of the results from the outdoor measurements on roofs, balconies or terraces are about one order of magnitude higher compared to the outdoor measurements on the ground. Similar results can be obtained by comparing the average of the results measured close to windows with those obtained not close to windows. However, variations between indoor and outdoor measurements are not very high.

It can be seen from the results that the exposure levels are well below the limits of the ICNIRP guidelines in the examined cases. Apart from this, exposure levels are varying by orders of magnitude in different locations examined. The exposure level depends on several factors like the input power of the antenna, the type of the antenna, the location of the examined position in respect to the antenna and several environmental factors. It must be pointed out that the knowledge of the distance to a base station alone is not sufficient to make reliable estimations on exposure levels.

Discussion

In most cases measurement positions were located in the living area of people concerned about possible health consequences due to the exposure next to mobile phone base stations.

The selection of the measurement position is biased because the positions were in most cases chosen on the basis of the specific request of concerned people. Such requests were often motivated by the construction of new base station in the vicinity of the living environment of the respective persons. Several aspects may have been of importance for these people: the awareness of the exposure due to a new source and concern about possible health consequences, subjective symptoms that have been related to new sources and the request for information. However, concerns of the public are not directly related to rather elevated exposure conditions. This suggests that vicinity to new sources may have some impact on the risk perception. If a base station is erected on a house, people living in such a house are often more concerned about the exposure than people living in neighboured houses. But due to the radiation characteristics of base stations rooms in adjacent buildings often have a higher exposure than rooms in the house with the antenna. Analysis of the data shows that there was a rather balanced distribution between measurement positions where rather high exposure was to be expected and between positions where exposure was estimated to be rather low.

Tables of measurement data

Table App 1C. Data from Austria compiled for this STM, for which the sum of all GSM contributions were available.

Country	City/place	Type of area	Site characteristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Austria	Salzburg	IC	2	2	952.8	4.068	8.3129	20
Austria	Salzburg	OC	2	4	950.2	3.204	5.6674	69
Austria	Salzburg	IC	1	6	952.4	13.433	47.6203	14
Austria	Salzburg	IC	2	4	953.4	9.275	24.0343	30
Austria	Salzburg	OC	0	1	954.2	0.932	2.7282	82
Austria	Salzburg	IR	0	5	949.4	0.857	2.6106	23
Austria	Salzburg	OC	1	9	949	0.773	2.1689	97
Austria	Salzburg	OC	1	4	956	4.551	11.5376	46
Austria	Salzburg	OC	3	4	949.6	0.7103	1.9638	68
Austria	Salzburg	IR	2	4	944	0.799	1.4204	45
Austria	Salzburg	OC	1	4	948.8	0.306	0.993	65
Austria	Schardenberg	R	2	4	947.6	0.2758	0.6618	-
Austria	Kitzbühel	R	3	4	944.4	0.24297	0.55842	52
Austria	Thalgau	R	2	4	949.2	0.1877	0.5491	25
Austria	Salzburg	IR	1	9	954.6	0.276	0.5289	48
Austria	Salzburg	OC	2	4	951.2	0.252	0.5113	28
Austria	Salzburg	IC	2	2	953.8	0.181	0.35027	-
Austria	Salzburg	OC	1	6	949.4	0.132	0.3405	35
Austria	Salzburg	IC	1	4	948.2	0.105	0.3268	149
Austria	Salzburg	OC	3	1	950.2	0.0857	0.1625	-
Austria	Salzburg	IC	2	1	946.6	0.032	0.086	28
Austria	Kitzbühel	R	2	4	945.8	0.0491	0.0847	27
Austria	Salzburg	OC	0	1	950.8	0.0023	0.01893	68
Austria	Göfis	R	3	4	950.8	0.003704	0.0074	490
Austria	Schardenberg	R	2	4	947.6	0.002196	0.00661	-
Austria	Göfis	R	3	4	950.8	0.00206	0.00452	85
Austria	Thalgau	R	3	4	949.2	0.0012	0.00397	-
Austria	Thalgau	R	2	4	949.2	0.00099	0.00342	42
Austria	Mantscha	R	2	4	953.8	0.001184	0.003049	-
Austria	Göfis	R	3	3	950.8	0.000355	0.001984	330
Austria	Mantscha	R	2	4	953.8	0.000075	0.00126	-
Austria	Mantscha	R	2	4	953.8	0.0000315	0.0011986	-
Austria	Mantscha	R	3	4	953.8	0.0000204	0.0011746	-

Table App 1D. Data from Austria compiled for this STM, for which the sums of all GSM contributions were not available.

Country	City/place	Type of area	Site charac-teristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Austria	Bischofshofen	IC	1	9	954.8	1.988521	-	-
Austria	Wien	IC	1	6	954.6	1.849843	-	-
Austria	Salzburg	IC	3	4	1867	1.3475	-	53
Austria	Wien	IC	1	4	952.2	1.027	-	-
Austria	Süßenbrunn	OC	0	5	948.1	0.95449	-	-
Austria	Salzburg	OC	0	9	949.6	0.838	-	-
Austria	Salzburg	OC	1	6	954	0.838	-	-
Austria	Süßenbrunn	OC	0	5	948.1	0.616	-	-
Austria	Bischofshofen	IC	1	9	954.8	0.5416	-	-
Austria	Wien	OC	2	4	957.2	0.487388	-	-
Austria	Salzburg	OC	3	4	954	0.4204	-	-
Austria	Wien	OC	2	4	1829.3	0.417138	-	-
Austria	Salzburg	IC	1	6	1851.4	0.4045574	-	-
Austria	St. Georgen	R	0	5	954.4	0.3853	-	-
Austria	Strengberg	R	2	4	952.6	0.3746784	-	-
Austria	Wien	OC	3	4	953.8	0.369686	-	-
Austria	Salzburg	OC	2	4	1866.75	0.33691	-	80
Austria	Salzburg	OC	1	9	943.2	0.334	-	-
Austria	Salzburg	IC	2	4	1851.8	0.2959647	-	-
Austria	Wien	OC	2	4	942.8	0.2908	-	-
Austria	Korneuburg	OC	2	4	946.1	0.2592609	-	-
Austria	GroßEbersdorf	R	0	5	953.4	0.228739	-	-
Austria	Salzburg	IC	0	5	950	0.21947	-	-
Austria	Wien	OC	2	4	954.4	0.2039	-	-
Austria	Wattens	OC	3	4	958	0.18934	-	-
Austria	Bischofshofen	IC	3	1	954.8	0.185495	-	-
Austria	Garsten	R	0	4	1855.85	0.1762044	-	-
Austria	Süßenbrunn	OC	0	5	948.1	0.1427	-	-
Austria	St. Georgen	R	0	5	954.4	0.140932	-	-
Austria	Berg im Attergau	R	0	2	951	0.128002	-	53
Austria	Salzburg	OC	2	4	1837.4	0.1217715	-	-
Austria	Untergaisbach	R	0	5	954.4	0.12143	-	-
Austria	St. Georgen	R	0	5	954.4	0.119023	-	-
Austria	Wien	OC	3	4	958.8	0.117277	-	-
Austria	GroßEbersdorf	R	0	1	953.4	0.113074	-	-
Austria	Zürs	IR	1	2	945.7	0.11258456	-	-
Austria	Schwechat	IR	3	2	952	0.110563	-	-
Austria	Korneuburg	OC	2	4	945.1	0.1088205	-	-
Austria	Loschberg	R	0	7	948.4	0.1052531	-	-
Austria	Klosterneuburg	-	2	3	940.6	0.09630718	-	-
Austria	Bischofshofen	IC	3	1	954.8	0.0897	-	-
Austria	Strengberg	R	2	4	958.2	0.085243	-	-
Austria	Korneuburg	OC	2	4	946.1	0.0840998	-	-
Austria	Wildermieming	R	1	4	950.7	0.077058	-	-
Austria	GroßEbersdorf	R	0	5	953.4	0.075729	-	-
Austria	Wien	OC	2	4	953.8	0.065972	-	-
Austria	Wildermieming	R	0	4	950.7	0.056316	-	-
Austria	Wien	OC	3	4	958.8	0.055777	-	-
Austria	Sollenau	R	0	6	945.8	0.05292	-	-
Austria	Bischofshofen	IC	3	4	954.8	0.052	-	-
Austria	Neubau	R	0	5	956	0.04688	-	-
Austria	Wien	IR	2	2		0.046	-	-
Austria	Salzburg	OC	2	4	1869.8	0.04584	-	34
Austria	Walding	R	0	6	1869.5	0.044391	-	-
Austria	Viktring	R	0	6	1884.3	0.0425677	-	-
Austria	Sollenau	R	0	5	947.4	0.04204	-	-
Austria	Klosterneuburg	R	1	9	957.4	0.03586	-	200
Austria	Wien	IC	3	2	957.2	0.0338	-	-
Austria	Wr. Neustadt	IR	0	9	1855.4	0.0326578	-	-

(Continued)

Table App 1D (cont´d)

Country	City/place	Type of area	Site characteristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Austria	Salzburg	IC	3	4	1866.75	0.03131	-	90
Austria	Wien	OC	3	4	1858.6	0.0313	-	-
Austria	Korneuburg	OC	1	6	952.8	0.03105	-	-
Austria	Tragwein	R	3	4	950.8	0.028837	-	-
Austria	Wien	OC	3	4	953.8	0.02842	-	-
Austria	Wattens	OC	2	4	956.8	0.02834	-	-
Austria	Saalfelden	IC	1	6	944.4	0.0275	-	-
Austria	Seelach	R	3	4	945.4	0.026525	-	-
Austria	Tulln	OC	2	4	1863.8	0.0250414	-	63
Austria	Salzburg	IC	3	4	1866.3	0.02345	-	-
Austria	Salzburg	OC	2	4	1854.88	0.0224	-	64
Austria	Salzburg	OC	2	4	950.2	0.0211	-	-
Austria	Seelach	R	1	6	949.4	0.02107	-	-
Austria	Salzburg	OC	3	4	954	0.021	-	-
Austria	Taxenbach	R	3	4	944.8	0.0205922	-	-
Austria	Wien	OC	3	4	953.8	0.02046	-	-
Austria	Korneuburg	OC	2	4	946.1	0.01988	-	-
Austria	Strengberg	R	2	4	952.6	0.019799	-	-
Austria	St. Georgen	R	0	5	958.6	0.019024	-	-
Austria	Innsbruck	-	1	4	958.4	0.017897	-	-
Austria	St. Leonhard	R	1	4	956.2	0.017422	-	-
Austria	Berg im Attergau	R	1	6	951	0.017241	-	136
Austria	Salzburg	OC	2	4	950.2	0.0167	-	-
Austria	Walding	R	0	5	958.8	0.016627	-	-
Austria	Korneuburg	OC	2	4	952.7	0.0157	-	-
Austria	Saalfelden	IC	1	2	957.8	0.0147	-	-
Austria	Wien	IC	2	2	957.2	0.0144711	-	-
Austria	Feldkirch	OC	3	1	950.8	0.014387	-	-
Austria	Lainz	OC	2	3	1866.9	0.0113935	-	-
Austria	St. Leonhard	R	0	5	956.2	0.010576	-	-
Austria	Salzburg	OC	3	4	954	0.01056	-	-
Austria	Salzburg	OC	3	4	954	0.01056	-	-
Austria	Tragwein	R	2	4	950.8	0.0098295	-	-
Austria	Schwechat	IR	3	2	952	0.00973	-	-
Austria	Wien	OC	3	4	953.8	0.0096959	-	-
Austria	Hausmannsstätten	R	0	1	956.2	0.00947612	-	-
Austria	St. Gotthard	R	0	5	958.8	0.009451	-	-
Austria	Innsbruck	R	3	1	1855	0.00864	-	-
Austria	St. Leonhard	R	0	5	956.2	0.008325	-	-
Austria	Wien	IR	2	2	958.8	0.00813	-	-
Austria	Hausmannsstätten	R	0	5	956.2	0.00767174	-	-
Austria	Bischofshofen	IC	0	5	954.8	0.0075	-	-
Austria	Walding	R	0	5	1869.5	0.007125	-	-
Austria	Mistelbach	IR	0	5	952.2	0.00665	-	-
Austria	Innsbruck	R	3	4	958.8	0.006545	-	-
Austria	Salzburg	OC	2	1	948.6	0.0064071	-	-
Austria	Viktring	R	0	5	1866.5	0.0061166	-	-
Austria	Salzburg	OC	2	4	1854.88	0.006091	-	64
Austria	Stockerau	OC	3	4	957.6	0.005796	-	-
Austria	Wr. Neustadt	IR	0	9	1858.4	0.0054893	-	-
Austria	Salzburg	OC	2	4	950.2	0.0053	-	-
Austria	Seelach	R	3	4	945.4	0.005292	-	-
Austria	Wildermieming	R	0	4	950.7	0.005174	-	-
Austria	Taxenbach	R	0	6	944.8	0.0050865	-	-
Austria	Schwechat	IR	3	2	952	0.00484177	-	-
Austria	Wattens	IR	2	2	958.6	0.004801	-	-
Austria	Garsten	R	2	1	1859.75	0.004687	-	-
Austria	Korneuburg	OC	3	4	954.4	0.00458	-	-
Austria	Seelach	R	3	4	949.4	0.004204	-	-
Austria	Lainz	OC	2	3	1866.9	0.0038429	-	-
Austria	Elixhausen	R	3	4	949.8	0.0033936	-	-

(Continued)

Table App 1D (cont´d)

Country	City/place	Type of area	Site charac-teristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Austria	Bischofshofen	IC	1	6	954.8	0.0032	-	-
Austria	Neulengbach	OC	2	4	1861.8	0.0032	-	-
Austria	Korneuburg	OC	3	4	953.4	0.0031	-	-
Austria	Stockerau	OC	3	4	952	0.00305	-	-
Austria	Innsbruck	R	3	1	950	0.002977	-	-
Austria	Korneuburg	OC	2	4	952.7	0.0028068	-	-
Austria	Untergaisbach	R	0	5	958.8	0.002755	-	-
Austria	Elixhausen	R	1	6	949.8	0.00267	-	-
Austria	Saalfelden	IC	3	2	948	0.0026	-	-
Austria	Innsbruck	R	3	4	948.4	0.002588	-	-
Austria	BadMitterndorf	R	2	2	1863.4	0.00252	-	-
Austria	Salzburg	IC	0	5	950	0.002493	-	-
Austria	Schrems	R	1	6	951.6	0.00226	-	-
Austria	Mollersdorf	R	1	4	1861.8	0.0021216	-	179
Austria	Reggau	R	2	1	949.6	0.002034	-	-
Austria	Wien	OC	3	4	958.8	0.001906	-	-
Austria	St. Pölten	OC	0	5	1859.3	0.0018264	-	-
Austria	Wien	OC	3	4	954.6	0.00174657	-	-
Austria	Wien	OC	2	4	950	0.001741	-	-
Austria	Hausmannsstätten	R	0	5	956.2	0.00172858	-	-
Austria	Bad Mitterndorf	R	2	4	957	0.00169	-	-
Austria	Seelach	R	1	6	949.4	0.001673	-	-
Austria	Wildermieming	R	2	4	950.7	0.001673	-	-
Austria	Taxenbach	R	3	4	944.8	0.001617	-	-
Austria	Innsbruck	R	3	4	950.8	0.001529	-	-
Austria	Walding	R	0	6	958.8	0.001499	-	-
Austria	Viktring	R	0	6	944.36	0.0013875	-	-
Austria	Schrems	R	3	4	951.6	0.00137	-	-
Austria	Wattens	OC	2	4	956.8	0.001352	-	-
Austria	Sollenau	R	0	6	951.6	0.00133	-	-
Austria	Schrems	R	3	4	951.6	0.00133	-	-
Austria	Bischofshofen	R	3	4	954.8	0.0011	-	-
Austria	Walding	R	0	5	958.8	0.001071	-	-
Austria	Wien	IR	3	2	950	0.00106	-	-
Austria	Seelach	R	3	4	949.4	0.001056	-	-
Austria	Innsbruck	R	3	4	958	0.000962	-	-
Austria	Viktring	R	0	6	1869.8	0.000945	-	-
Austria	BadMitterndorf	-	3	4	946	0.000929	-	-
Austria	Seelach	R	3	4	945.4	0.000839	-	-
Austria	Seelach	R	3	4	949.4	0.000839	-	-
Austria	Viktring	R	0	5	1866.3	0.0007609	-	-
Austria	Walding	R	2	4	958.8	0.000707	-	-
Austria	Salzburg	C	0	5	950	0.000672	-	-
Austria	Walding	R	0	5	958.8	0.000667	-	-
Austria	Seelach	R	3	4	949.4	0.0006663	-	-
Austria	Tulln	OC	3	4	1863.8	0.000632	-	63
Austria	Mollersdorf	R	0	1	1861.8	0.0005658	-	250
Austria	Seelach	R	3	4	949.4	0.0005292	-	-
Austria	Seelach	R	3	4	949.4	0.0004204	-	-
Austria	Hausmannsstätten	R	3	4	956.2	0.0004138	-	-
Austria	Hausmannsstätten	R	3	4	956.2	0.00037525	-	-
Austria	Bischofshofen	R	3	4	954.8	0.0003	-	-
Austria	Bischofshofen	R	3	4	954.8	0.0003	-	-
Austria	Lainz	OC	2	3	1886	0.0002862	-	-
Austria	Bad Kreuzen	R	0	5	949.4	0.000214	-	-

(Continued)

Table App 1D (cont´d)

Country	City/place	Type of area	Site characteristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Austria	Wien	IC	3	2	948	0.0001807	-	-
Austria	Schrems	R	3	4	951.6	0.00018	-	-
Austria	DeutschWagram	OC	3	4	943.2	0.0001616	-	-
Austria	Hausmannsstätten	R	0	1	956.2	0.00014211	-	-
Austria	Seelach	R	3	4	949.4	0.0001329	-	-
Austria	Innsbruck	R	3	4	944.6	0.000119	-	-
Austria	GroßSchönau	R	0	1	947	0.000105	-	150
Austria	Hausmannsstätten	R	3	1	956.2	0.00009467	-	-
Austria	Bad Kreuzen	R	0	5	949.4	0.000083	-	-
Austria	GroßEnzersdorf	R	2	4	946	0.0000776	-	-
Austria	Grammastetten	R	1	6	1869.2	0.000076	-	-
Austria	Bad Kreuzen	R	0	1	949.4	0.000054	-	-
Austria	Mollersdorf	R	0	5	1861.8	0.0000496	-	500
Austria	Wien	OC	3	4	958.8	0.000046	-	-
Austria	Walding	R	0	6	1869.2	0.000043	-	-
Austria	Haibach	R	0	1	944	0.000042	-	-
Austria	Bad Kreuzen	R	0	6	949.4	0.000042	-	-
Austria	Salzburg	R	0	6	952	0.000033	-	-
Austria	GroßEnzersdorf	R	2	4	946	0.0000262	-	-
Austria	GroßSchönau	R	3	4	947	0.000024	-	500
Austria	Bad Kreuzen	R	0	6	949.4	0.000024	-	-
Austria	Elixhausen	R	3	4	949.8	0.00002165	-	-
Austria	Klosterneuburg	OC	0	6	940.6	0.000008	-	-
Austria	Haibach	R	0	1	944	0.0000066	-	-
Austria	Haibach	R	0	6	944	0.00000016	-	-

(end of table)

Appendix 2 – National report Belgium

Introduction

In Belgium we have about 4,5 million GSM subscribers (at the end of the year a penetration of 50% is expected). Due to the dense population in Belgium, the network of base station antennas is really visible and therefore there is a big concern about safety of EM-fields. This is for a great part due to the bad communication of the operators and the government to the public.

Regulations in Belgium

Under pressure from the public, the government is forced to make norms before the end of the year 2000. 3 experts (2 of which were involved in COST244) have made a summary of the state of the art about health effects of EM-fields before summer holidays 2000. Since September 2000, a long discussion is going on in the government.

Mobile telephone network in Belgium

In Belgium 3 mobile net providers (Proximus, Mobistar, Orange) run 3 independent mobile phone GSM networks.

Measurements

Many measurements are on-going. E.g. the department of Information Technology of Ghent University (group of Prof. L. Martens) executes on average measurements on two sites per week. No standard measurement procedure is available. The group of Prof. Martens is developing a standard procedure.

Once a norm will be available, a discussion on control and measurement procedure will be started.

Appendix 3 – National report France

Introduction

In France, there was about 34 million mobile telephone subscriber in September 2001, and local authorities as well as network operator have to respond to more and more questions from the general public. In 2000, The French government commissioned an expert group lead but Professor Zmirou, with the mandate to review the scientific literature and to produce recommendation on the situation. The report was published in January 2001. In the conclusions, the expert group states that:

> “Experimental and epidemiological research into a range of health problems, including brain cancers and headaches, is currently in progress; the role of exposure to RF in these symptoms or diseases has not yet been clarified. However, in view of the exposure levels observed, the group of experts does not back the hypothesis that there is a health risk for populations living in the vicinity of base stations”.

Since there is a large public concern about base station, so even if “in view of the exposure levels observed, the group of experts does not back the hypothesis that there is a health risk for populations living in the vicinity of base stations”, the expert group “recommend that ‘sensitive’ buildings (hospitals, day care centres, and schools), located less than 100 metres from a base station, should not be directly in the path of the transmission beam 1). This recommendation is not incompatible with the installation of a base station antenna on the roofs of buildings in this category, as the incident beam has little or no effect on the area immediately below it ("fountain" effect). The group of experts feel that, if operators apply these measures, public fears, especially those of parents concerned by their children's exposure in school, will be allayed, especially keeping in mind that, in view of the exposure levels observed, the group of experts does not back the hypothesis that there is a health risk for populations living in the vicinity of base stations”.

In line with the expert recommendations, the French government asked ANFR (Agence Nationale des frequences – the French regulatory agency) to carry out measurements. A hundred sites including radar, broadcast, FM and base station will be measured and the results will be published.

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1) The limit of the beam is reached when the field power has decreased by a factor of two. This beam is defined in the horizontal axis and in the vertical axis.

In June 2001 the French parliament asked the new French environmental agency to write by June 2002 a report on the EMF impact of base stations.

Regulations in France

The French standard are in line with the previous CENELEC 50166-1 and 50166-2, these have been translated in AFNOR C600 and C610 and are still applicable even after the withdrawn of the previous CENELEC guidelines. The exposure limits are those described in the ICNIRP guidelines.

The volume, in which the field emitted by mobile base station is above the ICNIRP limits, is a cubic volume with a maximum distance of a few meter just in front of the antenna. Even if there is no specific regulation concerning this, French mobile operators put chains and signs to visualize the compliance distances.

In July 2001, the Frenchgovernment modified the “code des PTT” and included health protection and the compliance of limits. These limits will be set up using a “decret”. Since the expert group recommended the use of the ICNIRP limits, these limit should be the limits recommend by the European council. By this way the French government have transferred into French law the European recommendation of July 1999.

Mobile telephone network in France

In France, three mobile net providers run independent mobile phone GSM networks (Orange France, SFR and Bouygues Telecom). Concerning the third generation mobile telephony systems, two licences have been issued.

Measurement methods

In France, there is no in situ measurement standard, but a measurement protocol has been issued under the umbrella of the ANFR. This protocol describes in detail the manner in which “in situ” measurements should be carried out, and the estimation of the uncertainties. To carry out such measurements, broadband probes or frequency selective and isotropic probes can be used depending on the situation.

The measurement performed in France have to be in compliance with this ANFR protocol. For details see (www.anfr.fr).

Some measurements have been carried out using an isotropic and selective probe (the probe is a "meloppée" probe developed by Thales Compagny) in various locations of Paris, see the table below.

Table of measurement data

Table App 3. Data from France compiled for this STM

Country	City/place	Type of area	Site characteristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
France	Paris	IC	0	5	GSM900	0.72	6.8	-
France	Paris	IC	0	5	GSM900	0.54	3.0	-
France	Paris	IC	0	5	GSM900	0.12	2.3	-
France	Paris	IC	0	5	GSM1800	0.26	2.1	-
France	Paris	IC	0	5	GSM900	0.12	1.8	-
France	LaDefence	IC	0	5	GSM900	0.087	1.5	-
France	Paris	IC	0	5	GSM1800	0.035	0.66	-
France	Paris	IC	0	5	GSM1800	0.046	0.50	-
France	Paris	IC	0	5	GSM1800	0.022	0.43	-
France	Paris	IC	0	5	-	-	-	-

Appendix 4 – National report Germany

Regulations

Ordinance

Since 1 January 1999, an ordinance limiting immissions of non-ionizing radiation, based on the ICNIRP recommendations, is in effect (26. Verordnung zum Bundes-Immissionschutzgesetz). However, not all frequencies are covered and the ordinance gives only health limits for the public, not for the occupational settings. It applies to commercially run low and high frequency facilities at fixed sites.

For the frequency range of interest for mobile communication the ordinance gives the following health limits in terms of effective electric and magnetic fields (averaged over 6 minute intervals):

Table App 4A. Limits in German ordinance for mobile telephony frequencies

Frequency in MHz	Electric field in V/m	Magnetic field in A/m
400-2000	$1.37\ f^{1/2}$	$0.0037\ f^{1/2}$ A/m

The ordinance requires that measurements and calculations of field strengths are done according to best technical standards; the technical norm described in DIN VDE 0848, part 1, from May 1995, is to be used.

The missing frequencies (below 10 MHz no frequency except for 50 Hz and 16 2/3 Hz is included in the ordinance) will be taken into account in the new version of the ordinance, a draft is presently in preparation.

Notification of new or newly changed base stations

Historically the general regulation of telecommunication and the allocation of frequencies in the high frequency range has been one of the tasks of the Bundesamt für Post und Telekommunication (BAPT, Federal Office for Telecommunication and Post) which has evolved into the Regulierungsbehörde für Telekommunikation und Post (RegTP, Regulatory Authority or Telecommunications and Post). Therefore the above mentioned ordinance refers to the contents of the Telecommunication Law in the high frequency range. Accordingly, two weeks prior to use any operator of a high frequency emitter (power above 10 Watts EIRP) has to give notice about this emitter via a form, the so-called „Standortbescheinigung“. This form has to be ordered from the regional RegTP and contains the technical data of the emitter as well as the safety distance, i.e. the distance where the safety limits given in the ordinance are met. The RegTP usually calculates this safety distance under worst case conditions. All immissions from other emitters have to be taken into account.

Building laws

The only reference of the German Building Law possibly concerning mobile phone antennas are building permits. Accordingly any facility located in a housing area, but serving transregional needs, requires a building permit. As the law does not specify „facility“ there is an unsolved dispute if this law really does include mobile phone antennas.

Beside the German Building Laws, different districts of Germany (Länder) have their own additional Building Laws, usually referring directly to mobile phone antennas. For example the Bavarian Building Law regulates that antennas measuring less than 10 m with a supply unit of less than $10m^3$ do not need a building permit, which at the moment does raise some questions considering the above mentioned German Building Law.

Examples for juridical rulings concerning base stations

Although the passing of the above cited ordinance allowed for more security in planning new facilities and stopped many law suits concerning the health limits to be applied there are still some law suits around.

In several cases tenants of flats lying directly under roof antennas went to court and claimed they wanted to pay less rent because of this „flaw“ or they wanted the antenna to be removed. In one case a municipal court decided (April 1998, Munich) that fear of possible health effects was enough to pay a rent reduced by 20%. Up to now this decision stands out quite singularly and in many subsequent cases similar claims were dismissed.

Due to the above mentioned lack of clarity of the German Building Law, some cases were brought to court about antennas built without building permit according to the building law of a federal state but being located in a housing area. Up to now, the decisions of the courts have varied in this respect and some clarification of the applicability of the German Building Law is necessary.

Mobile telephone network in Germany

In Germany, up to now, four mobile net providers run five independent mobile phone networks. The only analogue one is the C-Net, which will be dismantled at the end of the year 2000. In August 2000, six UMTS licenses were auctioned. As the UMTS network will only be built up in the next few years, UMTS is not included in this review.

Table App 4B. German mobile phone systems

Net	Frequency (approximately in MHz)	Standard	Operator	In operation since
C	450	analogue (C-450)	Telekom	1984
D1	900	digital (GSM 900)	Telekom	1992
D2	900	digital (GSM 900)	Mannesmann	1992
E1	1800	digital (GSM 900)	E-Plus	1994
E2	1800	digital (GSM 900)	Viag Interkom	1998

Usually, sector antennas are used, with horizontal opening angle between 30 to 120 degrees. Depending on the range needed, a base station emits between several Watts up to 50-100 Watts. When the licenses for these existing nets were sold, the contracts contained stipulations regulating the minimum quality the net provider has to guarantee and the coverage (required coverage is typically more than 90 % after some years).

Rationale for measurements

Due to the legal situation in Germany, calculations or measurements are obligatory to prove the compliance of emitters with the limit values. The Regulatory Authority usually calculates the safety radius and only in very few cases the RegTP does make additional measurements. High frequency emitters may only be operated when the safety radius is secured and cannot be transgressed by the public. For base stations this usually does not pose a problem.

However due to its role in regulation of telecommunication, the RegTP is running measurement programs every few years: The results of the programs of 1992, 1996/97, 1999/2000 are published on the internet. Each of the last two programs contains short time spot measurements at more than 1200 locations in Germany. Of course places in the vicinity of strong emitters such as Radio or TV towers are included as well as locations around base stations. Due to changes in the legal situation the data presentation of the three programs differ. The 1999/2000 campaign covered the frequency range from 9 kHz up to 2.9 GHz. The ICNIRP sum rules for exposure to multiple frequency sources were used in order toto find for each location the factor below the limit. As induced currents and electrical stimulation are possible up to 10 MHz and thermal effects start at 100 kHz both sum values appear. (For more details check www.regtp.de/reg_tele/start/fs_05.html). Due to these sum values the exposure due to base stations cannot be separated.

Despite existing regulations, the fast expansion of the mobile phone networks has intensified the public reactions. The reasons for concern may differ: fears of health effects, wish for public participation in the siting (people want to be asked) and envy about those getting monthly payments from the mobile phone company for having a mobile phone antenna on their roof. Sometimes these reasons are interchanged when people are complaining, depending on how more public interest might be gained.

Due to this increasing public concern, demands for more measurements has grown on the side of: communities, activist groups, neighbors, neighboring schools or kindergartens or home owners who think about having an antenna installed.

Therefore, beside the Regulatory Authority for Telecommunication and Post, also some federal offices or offices of the federal states in the environmental/ radiation sector, such as the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz) or the Lower Saxonian Office for Ecology (Niedersächsisches Landesamt für Ökologie), started to perform measurements. Several official entities decided not to do measurements themselves, but to contract e.g technical institutions, universities or private companies.

Methods for measurements

For professional measurements of radio frequency fields a spectrum analyzer is used with calibrated antennas (log-periodic or bi-conical) mounted on a tripod. The measurements are spot measurements, mostly short time only. The effective field strengths of either E or H are obtained by vectorial summation of the respective 3 orthogonal field components. In the far field of a base station (>10 meters), it is possible to measure only either the H-field or the E-field components and calculate the other field as well as the power density. The summation of multiple sources is done according to ICNIRP recommendations.

Due to reflections, the polarization of the original signal can be changed, this is the reason for measuring 3 orthogonal components. Multipath propagation may cause interferences which lead to inhomogeneities. Therefore field strengths may vary by up to 30 dB within distances of only 50 cm. Great care has to be taken to find representative field strengths or rather even the worst case field strengths by looking for an optimum location.

The norms which ought to be observed are: the DIN VDE 0848 (latest issue: 8/2000) and a guide for measurements issued by the BAPT, called MV20-22.

Interpretation

The data given in the appendix represent a very small sample of the huge amount of existing measurements. As detailed in 4), the Regulatory Authority for Telecommunications and Post has published on the internet several thousand data points on radio frequency measurements taken in Germany. However they are not in the format used for this review paper. Also lots of measurements have been done by different institutions and companies, but only a small fraction of these data is made available to the general public. The data in the appendix were chosen to show the typical features of measurements in Germany.

Existing data in Germany for measurements of mobile phone signals come from all kinds of areas, that is from inner cities, outer cities, industrial areas, small towns, country side and rural areas. Measurements are taken outdoors on the ground, on elevated places, such as roofs or balconies as well as indoors, close to windows and further away from windows. The more detailed information about the place of the measurement for the data presented (in column ENV B) shows that measurements locations exist for sites with no direct access for the people, for occupational settings and of course for exposure of the public, including housing, leisure places, streets, kindergartens and hospitals. The distances between the base station and the measurement site varied according to the requests, they were not always measured.

For distances of more than 50 m from a base station, the power densities measured typically are much lower than 1 per mille of the limit values.

Table of measurement data

Table App 4C. Data from Germany compiled for this STM

Country	City/place	Type of area	Site characteristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Germany	-	IC	3	4	GSM1800	9.6	10.2	5
Germany	-	IR	0	5	GSM900/1800	1	1.1	400
Germany	-	R	2	4	GSM900	0.58	0.58	150
Germany	-	IR	0	5	GSM900	0.2	0.5	20
Germany	-	ST	2	1	GSM900	0.2	0.35	50
Germany	-	IC	0	5	GSM900/1800	0.06	0.2	200
Germany	-	IC	1	6	GSM900/1800	0.08	0.2	10
Germany	-	ST	2	2	GSM900	0.08	0.1	400
Germany	-	IR	0	5	GSM900	0.02	0.03	500
Germany	-	R	2	4	GSM900/1800	0.013	0.022	400
Germany	-	OC	0	5	GSM900	0.002	0.003	800
Germany	-	R	0	1	GSM1800	0.003	0.003	200
Germany	-	R	0	7	GSM900/1800	0.0001	0.0006	-
Germany	-	OC	2	3	GSM900	0.0002	0.0003	-
Germany	-	ST	2	4	GSM900	0.00001	0.000027	-
Germany	-	R	0	7	GSM900	0.0000026	0.000005	-
Germany	-	OC	2	4	GSM900/1800	0.000001	0.00000385	1000

Appendix 5 – National report Hungary

Regulations and standards

In Hungary the first standard relevant to electromagnetic field and human exposure was released in 1985 by the governmental Hungarian Standards Institution (HSI). The standard covers the frequency range of 30 kHz-300 GHz. The title of standard is "Safety levels of high frequency electromagnetic fields" and issued as MSZ 16260-86 Standard. The standard separated in permissible levels for general public and workers, as defined the controlled and uncontrolled area A third area also was defined which is not allowed to access for humans (only with safety shielded clothes). In the range of 30 kHz-300 MHz the standard defines a fourth tier as called harmless area. (see Table I). The values of permissible levels are close to the reference levels, generally used Eastern European countries.

Below 30 kHz no National Standard was released to the human exposure. Although a National Standard has been issued in 1986 (MSZ 151/5-86) titled "Overhead lines for power transmission. Approaches and crossing" in which one item deals with the exposure limits to humans but only for electric field and not magnetic. The permissible level of electric field at 50 Hz frequency for the area that is accessible to public is 5 kV/m. No permissible level for exposure to magnetic field. Therefore in Hungary we use in the practice the ICNIRP Guidelines for the frequency range below 30 kHz both for electric and magnetic field.

Table 5A. Hungarian MSZ 16260-86 Standard: "Safety levels of high frequency electromagnetic fields" in the frequency range 300 MHz-300 GHz

Area	Power density (mW/cm^2). 300 MHz-300 GHz Standing source	 Rotating source
Uncontrolled (general public)	0.01	0.1
Controlled (occupational)	0.1	1.0
Restricted in time (occupational)	$\sqrt{\frac{0.08}{hour}}$	$\sqrt{\frac{8}{hour}}$
Harmful (not allowed)	10	100

In 1997 the HSI released the European Prestandard (ENV 50166-1/2) as the Hungarian Prestandard as MSZ ENV 50166-1/2. The Prestandard has an *Endorsement Notice:* "The European Prestandard ENV 50166-1/2:1995 "Human Exposure to Electromagnetic Fields. Low Frequency (0 Hz to 10 kHz)/High Frequency (10 kHz-300 GHz)" has been endorsed by the Hungarian Standard Institution as a Hungarian National Prestandard. The English version of the European Prestandard shall bee considered as the Hungarian National

Prestandard.”. The Prestandard also introduced a *National Foreword:* “The relevant Hungarian standard that is valid (is in operation) is the MSZ 151/5-86 for low frequency range and the MSZ 16260-85 for high frequency range”.

Ordinance and process

There is a mandatory Hungarian Standard (the limits are well below the ICNIRP above 300 MHz). According to the departmental order by the Minister of Transportation and Telecommunications issued in May 1 2000., a Report of Radiohygiene (Report) is requested within the authorization process of installation of base stations (BS). The process of the order includes a request of the following technical details of the planned BS from the operators:

1. site of the antennas (address, tower, rooftop, wall-mounted)
2. number of antennas
3. in case of rooftop BS, a planning draw about the site
4. existing RF sources at the site
5. RF frequency
6. direction (Azimuth) of each antenna
7. tilting of each antenna
8. antenna type
9. antenna gain
10. output power (nominal and/or EIRP)
11. height of the antenna from the ground/rooftop
12. height of buildings are nearby within 200 m
13. characterization of the terrain around the site
14. information about schools, children’s institution or hospital within 200 m from the site

The Report issued by the Natl. Res. Inst. for Radiobiology and Radiohygiene (NIRR) before the installation. In case of rooftop installation, when the antenna sited below 4 m high from the roof level - because of other existing building laws - the BS is excluded from any authorization process (in this case many times the operators apply for the Report voluntary). Depending on the site and technical data of BS, RF radiation monitoring is requested by NIRR after the installation.

Mobile telephone network in Hungary

In Hungary works four networks provider. The penetration of users within the whole population is 24% (2,4 million, 2000. October). The operation of GSM 1800 has been started in 1999. The UMTS network will be probably auctioned the next year (2001).

Table App 5B. Hungarian mobile phone systems

Standard	Operator	In operation since
Analogue, NMT-450	Westel Radiotelephone Ltd	1990
GSM 900	Westel Mobile Telecom Company Ltd	1994
GSM 900	Pannon GSM Ltd	1994
GSM 1800	Vodafone	1999

From the beginning of 2001 all three digital GSM provider will be licensed in operation on both GSM bands. The number of base station is continuously growing especially in the downtown and heavy traffic areas. The cell radius in these areas is commonly 500 m or less. The main figures showed that every 500-1000 new subscribers need a new base station. The trend is characterised by the following numbers in Hungary: since the GSM system has been introduced, takes 6.5 years, that means approximately 2000 days. Now the number of base stations are 2000 approximately provided by two operators, that means, since the start of the GSM system one new base station were built per day. Meantime the last period the number of mobile users increased 40-50 % per year and this trend is going on nowadays. The typical transmitter power is between 5-50 W, the preferred sector antenna gain is between 10-20 dB.

Measurement methods

The measurements were made by portable spectrum analyzer Advantest U4941, using wide band (80 MHz-2200 MHz) biconical antenna developed by Austrian Research Center (ARC) PBA 10200 and a Rhode-Schwarz HL 040 400 MHz-3000 MHz log-per antenna.

In the measurement the frequency sweep was: 40 MHz, (925-965 MHz), RBW: 100 kHz, VBW: 100 kHz. All data were storage on SRAM memory (700 points, all row data are archived) for further analysis. The distance between the base station and the measurement point were measured by laser meter. The measurements were spot measurements, using peak-hold mode in two (vertical, horizontal) or three axis. In the evaluation Excel tables was used: dbµV/m, V/m, mW/m2, µW/cm2, were calculated in all axis and the resultant according to the sum of E-field strength vector components. The area and type of the measurement site were identified according to COST 244bis STM.

Although the broadband measurement is out of interest in the present report, during the last years the radiofrequency radiation was measured in the environment of more than hundred base (GSM) stations in Hungary. In the survey measurement three type of commercially broadband RF monitors were used: Narda 8616 series, Wandel & Goltermann EMR 300 and Chauvin Arnoux C.A 43 field meter. It is well known that the broadband in-situ measurements generally overestimate the real RF exposure emitted from the GSM base station.

Discussion

Summary of results: The RF exposure levels, at the living area of general public were collected and evaluated according to the ICNIRP reference levels and the Hungarian Exposure Standard (MSZ). According to the results of the spectral measurements at more than 40 sites, and the broadband measurements more than 300 sites, it was found, that in most cases the exposure levels from the base stations were many times below the strict Hungarian permissible RF exposure level for the general public (0.01 mW/cm^2). The exposure did not exceed a few microwatt/cm^2 , at location accessible to public except in special cases where the exposure was in the order of the Hungarian permissible level (by MSZ) but below the relevant ICNIRP guidelines (0.45-0.9 mW/cm^2).

Many difficulties are coming in the communications between the industry, authorities and general public related to the base station installation and mobile network development. The main reason of the mentioned debate, that people and local authorities not having adequate input into siting decisions. They feel that industry does not consult about the siting facilities before the installation. There are insufficient monitoring of exposure, not having enough information on emission levels from existing sites The general people and local authorities have insufficient information about the technology, details about the planned devices (power, antenna gain, no. of channels, tilting -electronically/mechanically-, etc.). Many confusions are about the exposure levels and emission from the base station (ERP, EIRP, W, dBm, W/m^2, mW/cm^2, mW/m^2, V/m, dBμV/m, mW/g, W/kg, etc.). Moreover many cases appear conflicting opinions amongst scientific (even non-scientific) experts on weather or not there are health effects. These scientific and non-scientific debates are interpreted by the media via a very oriented way.

Table of measurement data

Table App 5C. Data from Hungary compiled for this STM

Country	City/place	Type of area	Site characteristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Hungary	Bp. Orczy út 11-15	IC	1	4	949.91	0.710912	12.8100961852	-
Hungary	Bp. Gutenberg tér	IC	3	4	937.29	0.722533	9.0184924132	-
Hungary	Bp. Dessewffy u.	IC	3	4	944.66	0.931813	7.83369782	-
Hungary	Bp. Desswffy u.	IC	2	4	946.77	0.488129	5.393455004	-
Hungary	Budapest	IC	0	5	957.74	0.23754	4.98553	-
Hungary	Eger	OC	0	5	951.17	0.2065	3.698	185
Hungary	Veszprem	IC	1	7	954.83	0.112798	3.191081	100
Hungary	Balatonföldvár	R	3	3	956.49	0.400657	2.5484037044	189
Hungary	Eger	OC	0	5	951.8	0.117	2.217	163
Hungary	Eger	OC	2	4	957.17	0.1247	2.125	197
Hungary	Budapest	IC	1	9	956.6	0.1012	2.016	15
Hungary	Budapest	IC	0	5	944.54	0.1588	1.904	-
Hungary	Budapest	IC	0	5	943.06	0.13263	1.68987	126
Hungary	Veszprem	IC	1	7	957.11	0.078643	1.506055	112
Hungary	Eger	OC	0	5	957.17	0.0731	1.43	239
Hungary	Bp. Nyirpalota u.	IC	1	4	954.14	0.076877	1.3470203512	-
Hungary	Tatabanya	IC	0	5	1809.77	0.172425	1.30698	181
Hungary	Mezonyarad	R	0	9	955.29	0.072192	1.29225	128
Hungary	Budapest	IC	0	5	1808.00	0.084124	1.13413	-
Hungary	Budapest	IC	0	5	957.23	0.108181	1.093102	65
Hungary	Balatonföldvár	R	3	3	925.00	0.000035	0.8197984092	141
Hungary	Eger	OC	2	4	957.17	0.0436	0.815	185
Hungary	Budapest	IC	0	5	951.29	0.027609	0.76606	-
Hungary	Kunszentmarton	R	0	9	955.57	0.039567	0.665566	116
Hungary	Gyongyosfalu	R	0	9	958.6	0.06736	0.63774	168
Hungary	Szombathely	IC	0	5	953.29	0.03346	0.63723	-
Hungary	Felnemet	R	0	9	955.86	0.038342	0.572305	118
Hungary	Veszprem	IC	0	5	947.00	0.055623	0.543607	82
Hungary	Bp. Vándor S.u. 3	IC	2	4	945.00	0.044943	0.5295921788	-
Hungary	Eger	OC	0	5	955.4	0.0388	0.472	183
Hungary	Mikepecs	R	0	9	954.43	0.05931	0.46414	192
Hungary	Orgovány	R	0	7	958.09	0.06613	0.452833306	100
Hungary	Debrecen	OC	0	5	958.26	0.018871	0.39809	150
Hungary	Bp Hotel Hélia	IC	3	4	955.63	0.027912	0.3795761828	-
Hungary	Budapest	IC	1	9	955.29	0.0167	0.3608	54
Hungary	Hajduszoboszló	IC	2	4	1814.74	0.057081	0.338762038	-
Hungary	Budapest	IC	0	5	957.69	0.018625	0.33564	-
Hungary	Gyal	OC	0	5	950.77	0.010713	0.279205	-
Hungary	Ostyassz	R	0	9	958.6	0.028074	0.2783	83
Hungary	Bp. Nyirpalota u.	IC	1	4	957.34	0.003033	0.2500172428	-
Hungary	Hajduszoboszló	IC	3	4	1814.8	0.032911	0.2349794232	-
Hungary	Budapest	IC	2	4	946.31	0.0227	0.229	-
Hungary	Budapest	IC	0	5	1807.2	0.009094	0.209025	126
Hungary	Salgotarjan	IC	0	5	953.51	0.033318	0.19799	119
Hungary	Budapest	IC	0	5	940.43	0.013381	0.187655	-
Hungary	Mezonyarad	R	0	9	1817.43	0.004478	0.18695	128
Hungary	Nagykapornak	R	0	7	953.8	0.0123	0.1456044	50
Hungary	Bp. Desswffy u.	IC	3	4	1808.4	0.006129	0.1314235456	-
Hungary	Bp. Dessewffy u.	IC	2	4	1808.4	0.001674	0.1188457884	-
Hungary	Madras	R	0	5	957.23	0.016543	0.117925	138
Hungary	Lajoskomárom	R	3	3	951.69	0.013805	0.1149470676	164
Hungary	Hajduszoboszló	IC	2	4	1814.74	0.00117	0.10820725	-
Hungary	Tatabanya	OC	0	5	958.71	0.001698	0.10342	119
Hungary	Hajduszoboszló	IC	2	4	956.49	0.006051	0.1026735584	-
Hungary	Bp. Vándor S.u. 3	IC	2	4	946.66	0.004271	0.0992507684	-
Hungary	Galambok	R	2	2	951.11	0.015072	0.0991334156	132

(Continued)

Table App 5C (cont´d)

Country	City/place	Type of area	Site charcteristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Hungary	Eger	IC	0	5	951.74	0.001688	0.09094	128
Hungary	Kunszentmarton	R	0	9	936.6	0.004366	0.0829	105
Hungary	Katymar	R	0	9	957.63	0.008447	0.072207	124
Hungary	Bp. Nyirpalota u.	IC	3	4	943.17	0.002182	0.0711599852	-
Hungary	Ostyassz	R	0	9	953.8	0.004206	0.06886	93
Hungary	Bp. Vándor S.u. 3	IC	2	4	948.77	0.004827	0.0659761788	-
Hungary	Dabrony	R	0	7	956.09	0.00499	0.06570308	100
Hungary	Gecseapati	R	0	5	943.06	0.003214	0.06387	135
Hungary	Bp. Vándor S.u. 3	IC	3	4	948.71	0.003761	0.0608401828	-
Hungary	Hajduszoboszló	IC	3	4	951.63	0.002628	0.0577948052	-
Hungary	Dabrony	R	0	7	951.7	0.00384	0.05193948	100
Hungary	Bp. Nyirpalota u.	IC	3	4	950.94	0.001101	0.0474815224	-
Hungary	Tatabanya	OC	0	5	951.06	0.000319	0.038009	181
Hungary	Budapest	IC	1	9	958.6	0.00247	0.0373	-
Hungary	Hajduszoboszló	IC	2	4	956.94	0.002091	0.03471687	-
Hungary	Varosfold	R	0	9	946.77	0.00238	0.0337	145
Hungary	Hajduszoboszló	IC	3	4	954.66	0.000439	0.0255466904	-
Hungary	Highway	R	0	5	945.29	0.000271	0.020989	95
Hungary	Orkeny	R	0	9	949.86	0.00215	0.0209	114
Hungary	Vasszecseny	R	0	9	935.57	0.000443	0.02048	102
Hungary	Ágfalva	R	0	7	957.46	0.000592	0.018838022	50
Hungary	Bp. Rózsa u. 8.	IC	3	4	957.97	0.00035	0.018827156	-
Hungary	Ágfalva	R	0	7	958.43	0.000362	0.018305588	50
Hungary	Budapest	IC	0	5	945.29	0.000078	0.0081	57

(End of table)

Appendix 6 – National report Sweden

Regulations and standards

In Sweden, occupational regulations limiting exposure to electromagnetic fields currently exist only for the radiofrequency part of the spectrum, over 3 MHz. The National Board of Occupational Safety and Health has decided that this ordinance needs to be updated in several respects, and has therefore initiated work to introduce new exposure limitations, based on the recommendations issued by ICNIRP (ICNIRP 1998).

There are currently no specific radiofrequency recommendations or regulations for the General Public in force in Sweden. The recommendations of the European Council made in 1999 are relevant for the public's exposure, which implies that the activity to introduce these in Sweden falls within the mandate of the Swedish Radiation Protection Institute. Work is currently ongoing to transform these recommendations of ICNIRP and the EU into general advice to the public.

In 1996, five national authorities jointly issued a Precautionary Strategy (NBOSH 1996), because of a scientifically supported suspicion of cancer risks in relation to low frequency magnetic fields. This precautionary strategy suggests that decisions should be made for reasonable actions to limit unnecessary exposure to low frequency magnetic fields. It has been argued whether this strategy should be extended also to radiofrequency fields and mobile telephony or not. So far, the authorities involved have not made such an extension, due to the evaluation that there is currently an absence of a scientific basis for suspicion about adverse health.

The process of building permits for base station antennas is currently debated because of the preparations for the 3rd generation mobile phone system, and the large number of new base stations required (estimated at about 10 000 or more). A building permit is required by local authorities for the erection of a mast, but not for the placement of an antenna on buildings (here the approval of the owner is sufficient). In the current absence of specific legal regulations on exposures of the general public, national authorities are able to refer to international recommendations such as ICNIRP. Calls for "base station free zones" have been voiced, and has led to appeals to refuse building permits, but such appeals have, so far, been rejected, on the grounds that the installations fulfil "current exposure limits" (implicitly referring to the EU and ICNIRP recommendations).

Mobile telephone networks in Sweden

Since the early 1960s, several mobile phone systems have been operated by the Swedish Telecommunications Administration (now Telia Mobile). In October 1981 the analogue NMT 450 (Nordic Mobile Telephone – 450 MHz) began in the Nordic countries. NMT 450 was followed by NMT 900 in 1986. In 1992 the digital system GSM 900 was taken in operation followed by GSM 1800. In addition to Telia Mobile, there are two other networks operators in Sweden, see table App 5A. The penetration of users within the whole population is around 65%.

Table 6A. Mobile phone network systems and operators in Sweden

Standard	Operator	Comment
Analogue, NMT-450 & NMT 900	Telia Mobile	NMT 900 ended 1 December 2000.
GSM 900 & 1800	Telia Mobile	
GSM 900 & 1800	Europolitan/Vodaphone	
GSM 900 & 1800	Comviq	

Recently, four operators (Europolitan, HI3G, Orange and Tele2) were given licenses for the UMTS (3rd generation) network, which should be fully operative with a stipulated coverage of the Swedish population by the end of 2003. Discussions about co-operation (concerning both masts and radio equipment) between various operators is currently (spring 2001) ongoing.

Rationale for measurements

The purpose of the measurements reported here was to estimate the radiofrequency exposure of the Swedish population due to base stations. Therefore, measurement positions were chosen in order to reflect public exposure in different environments, such as city, town, and rural area both outdoor and indoor. Positions that are normally used by people have been chosen with *no preference* to there being a base station in the vicinity or not. The individual measurement results will not reflect an average from these locations; each measurement is only a sample in time and location.

Methods for measurements

The measurements were made by a portable spectrum analyser, Hewlett Packard E4402B, using a wide band (80 MHz-2000 MHz) biconical antenna, developed by Austrian Research Center (ARC) PBA 10200. The antenna was mounted 1.5 m over ground on a non-conducting tripod.

In the measurement, the frequency sweep was 40 MHz, (925-965 MHz), RBW: 100 kHz. All data were stored on a floppy disk for further analysis. The measurements were spot measurements, using peak-hold mode, in three orthogonal directions in each measurement point. From the measured field strength values, in the three directions, the power density in mW/m^2, was calculated from the resultant of the E-field strength vector components, assuming far field conditions.

Discussion

The mean exposure for all locations, from GSM 900 base stations was 0.25 mW/m^2, and the median value was 0.02 mW/m^2. The reason for this difference is that the exposure levels in most city positions are much higher than in the rural areas. The mean outdoors exposure was in city area 0.5 mW/m^2, in town 0.018 mW/m^2 and in rural areas only 0.0006 mW/m^2. However as only 31 locations have been measured, generalisations from data should be made with caution. These measured radiofrequency exposure levels were evaluated according to the ICNIRP reference levels. It was found that the exposure levels due to the base stations, were in all cases many times below the reference levels.

Table of measurement data

Table App 6B. Data from Sweden compiled for this STM

Country	City/place	Type of area	Site charcteristics	Exposure situation	Frequency band MHz	Highest power density Si, mW/m^2	Power density sum Ssum, mW/m^2	Distance m
Sweden	Goteborg	IC	0	5	937,00	1.439	2.74	-
Sweden	Goteborg	IC	2	2	938.4	0.715	1.475	-
Sweden	Goteborg	IC	0	5	937.8	0.332	0.733	-
Sweden	Goteborg	IC	0	5	944.0	0.195	0.656	-
Sweden	Goteborg	IC	0	5	943.8	0.243	0.533	-
Sweden	Goteborg	IC	0	5	937.6	0.21	0.319	-
Sweden	Goteborg	IC	3	2	939.4	0.141	0.271	-
Sweden	Vaxjo	IC	2	4	GSM 900 band	0.061	0.076	-
Sweden	Kungalv	ST	0	1	943.4	0.015	0.043	-
Sweden	Hovsta	ST	0	5	GSM 900 band	0.042	0.043	-
Sweden	Karlskrona	ST	0	6	941.1	0.005	0.04	-
Sweden	Goteborg	IC	0	5	944.1	0.006	0.029	-
Sweden	Goteborg	OC	0	1	937.2	0.012	0.023	-
Sweden	Kungalv	ST	0	1	939.0	0.005	0.021	-
Sweden	Skaftö	R	0	6	954.5	0.0007	0.006	-
Sweden	Goteborg	OC	0	5	939.3	0.0008	0.004	-
Sweden	Goteborg	IC	2	4	944.1	0.0006	0.004	-
Sweden	Kungalv	ST	0	5	951.1	0.0005	0.002	-
Sweden	Karlskrona	ST	3	2	939.2	0.0011	0.002	-
Sweden	Goteborg	OC	3	1	941.6	0.0011	0.002	-
Sweden	Goteborg	OC	0	5	938.6	0.0006	0.001	-
Sweden	Goteborg	IC	3	4	950.6	0.0003	0.001	-
Sweden	Horby	R	0	6	957.4	0.0005	0.001	-
Sweden	Goteborg	OC	2	4	942.4	0.0001	0.0008	-
Sweden	Grundsund	R	0	6	947.8	0.0001	0.0004	-
Sweden	Kolhattan	R	0	6	943.4	0.0002	0.0003	-
Sweden	Goteborg	OC	3	4	953.2	0.00002	0.0001	-
Sweden	Vase	R	0	5	GSM 900 band	0.00002	0.00005	-
Sweden	Kungalv	R	0	6	956.6	0.000001	0.000004	-
Sweden	Tjorn	R	0	6	GSM 900 band	<0.000001	<0.000001	-
Sweden	Goteborg	OC	0	6	GSM 900 band	<0.000001	<0.000001	-