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Report for XXXXX

Concerning UMTS and Exposure to Electromagnetic Fields.

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Concerning UMTS and Exposure to Electromagnetic Fields

1. Scope

XXXXX has requested advice on the following three questions concerning exposure to electromagnetic fields from public mobile telecommunications systems, in particular UMTS:

- What are the best legal practices in Europe?
- What is the relation between the field strength (V/m) and the number of emission sources?
- What are the elements that influence this relationship etc?

2. Background

Mobile phones and their base stations transmit and receive signals using electromagnetic waves (also referred to as electromagnetic radiation or fields, or radio waves). Electromagnetic radiation is emitted by many natural and man-made sources and plays a very important part in our lives. We are warmed by the radiation from the sun or from an electric fire and we see using that part of the visible electromagnetic spectrum that our eyes can detect. All electromagnetic radiation consists of oscillating electric and magnetic fields and the frequency, which is the number of times per second at which the waves oscillate, determines their properties and the use that can be made of them. Frequencies are measured in hertz or Hz where1 Hz is one oscillation per second, 1 kHz or kilohertz is a thousand Hz, 1 MHz or megahertz is a million Hz, and 1 GHz or gigahertz is a thousand million Hz. Frequencies between about 30 kHz and 300 GHz are widely used for telecommunication, including broadcast radio and television, and comprise the radio-frequency (RF) band.

Mobile telephone systems are increasingly planned, implemented and regulated on an international basis. UMTS is probably the most important element of the International Telecommunication Union's (ITU) IMT-2000 (International Mobile Telecommunications - 2000) global public mobile telecommunications project. In many countries including those in Europe UMTS is seen as the natural evolution from today's GSM voice and data systems towards a system globally available for today's services and in addition multi-media and higher speed data services. The frequencies have been identified globally by the ITU with the aim of achieving a large measure of harmonization in order to reduce costs. The ITU has also developed a broad framework for standardization whilst leaving the details to a body know as 3GPP (3rd Generation Partnership Project) whose organizational partners comprise the regional Standards Development Organizations from around the World. For the last two decades Europe has been the world leader in mobile telephone technology and has been at the forefront of both GSM and UMTS development. In Europe radio frequencies are coordinated by the European Conference of Postal and Telecommunications administrations (CEPT) whilst the European Union and the Commission has been very active in establishing a cohesive European policy for mobile telecommunications and has issued mandates to both CEPT and the European Telecommunications Standards Institute (ETSI) in the matter of UMTS. ETSI was a founder member of 3GPP in order to stimulate a global partnership to develop the standard for UMTS.

Market organizations such as the GSM Association and the UMTS Forum have their origins in Europe and have a driving principle to establish a regulatory and standards framework to facilitate, in principle, seamless global roaming to enable their customers to use their equipment in any country with a GSM/UMTS infrastructure.

Key points:

- UMTS/IMT-2000 will be planned and standardised on a global basis (ITU and 3GPP),
- In Europe CEPT, ETSI and the EU are involved,
- GSM Association and UMTS Forum will promote international roaming and circulation of terminals.

3. Technology of Cellular Mobile Phones

3.1 General

A mobile phone sends and receives information (voice messages, fax, computer data, etc) by radiocommunication. Radio frequency signals are transmitted from the phone to the nearest base station and incoming signals are sent from the base station to the phone at a slightly different frequency. Once the signal reaches a base station it can be transmitted to the main telephone network, either by telephone cables or by higher frequency radio links between an antenna (e.g. dish) at the base station and another at a terminal connected to the main telephone network. These microwave radio links operate at rather low power and with narrow beams in a direct line of sight between the antennas, so that any stray radiation from them is of much lower intensity than the lower frequency radiation transmitted to the phones.

Signals to and from mobile phones are usually confined to distances somewhat beyond the line of sight. They can reach into buildings and around corners due to various processes including reflection and diffraction, that allows the radiation to bend round corners to some degree, but the coverage area from a base station is partly governed by its distance to the antenna's horizon. In the current GSM system, a timing artefact in the signal processing within the receivers limits the maximum distance over which a mobile phone can be used to about 35 km. For such reasons an extensive network of base stations is needed to ensure sufficient geographical coverage. An ideal network may be envisaged as consisting of a mesh of hexagonal cells, each with a base station at its centre, but in practice the coverage of each cell will usually depart appreciably from this because of the topography of the ground and the availability of sites for the base stations. The sizes of the cells are usually less than the 35 km maximum because obstruction by hills, buildings and other ground features reduces the effective range. Furthermore, the modern GSM system recognises that the majority of terminal devices are hand-held units with relatively low power output; thus it is necessary to design cell sizes wherever possible to cater for these low power terminals. Frequencies are reused several cells away and the capacity of a network (the number of simultaneous phone calls which may be made) depends on the extent of the frequency spectrum available, the cell diameter and the ability of the system to work against a background of interference from other cells. To accommodate the steadily increasing volume of users, cell sizes have to be progressively reduced (for example, by using base station antennas of lower height and reduced power) so that the frequencies may be reused more often. Indeed in large cities, base stations may only be a few hundred metres apart and maybe installed in places such as railway stations where the density of users is particularly large ("microcells") and within buildings such as office blocks ("picocells"). Cellular systems also include technology that ensures that the frequency channels employed by a user in a vehicle change automatically as the vehicle moves from one cell to the next. Therefore the terminal generally determines the characteristics of the cellular network.

Key points:

- Hand held telecommunication terminals communicate with local base stations,
- Maximum cell size currently 35km,
- Most systems require smaller cell sizes to meet operational requirements,
- Smaller cell sizes cater for the lower power hand-held terminals which in turn require lower power levels from the base stations,

3.2 GSM

GSM, the acronym for Global System for Mobile Communications operate in Europe in either the 900 MHz or 1800 MHz band. The GSM standard is now widely used in many parts of the world. UMTS is considered the evolutionary path from GSM and will be launched in Europe in a band close-by the GSM1800 frequency band.

In the GSM system, each user requires a frequency channel of bandwidth 200 kHz; there is thus a maximum of 174 channels (175 minus one needed for technical reasons) within the maximum bandwidth of 35 MHz available for operators in the 900 MHz band. Concerning the 1800 MHz band, there are 374 channels available for allocation to network operators within the maximum possible bandwidth of 75 MHz. The channels are distributed across the cells in a way that allows neighbouring cells to operate at different frequencies to avoid interference. Cells are very often divided into three 120 degrees sectors with different frequencies for each. These considerations limit the number of frequency channels available to users in a particular sector. Since the wavelengths at 900 MHz are twice as long as those at 1800 MHz, they are better at reaching the shielded regions behind buildings, etc, as a result of diffraction (bending). So, to obtain the same coverage, fewer base stations and hence fewer channels are needed at 900 MHz than at 1800 MHz.

The maximum powers that GSM mobile phones are permitted to transmit by the present standards are 2 W (900 Hz) and 1 W (1800 Hz). However, because of the modulation technique used, the *average* powers transmitted by a phone are never more than one-eighth of these maximum values (0.25 W and 0.125 W, respectively) and are usually further reduced by a significant amount due to the effects of adaptive power control and discontinuous transmission. Adaptive power control (APC) means that the phone continually adjusts the power it transmits to the minimum needed for the base station to receive a clear signal. This can be less than the peak power by a factor of up to a thousand if the phone is near a base station, although the power is likely to be appreciably more than this in most situations. Discontinuous transmission (DTX) refers to the fact that the power is switched off when a user stops speaking either because he/she is listening or because neither user is speaking. So if each person in a conversation is speaking for about half the time, he/she is only exposed to fields from the phone for that half of the conversation. In summary, the largest output from a phone occurs if it is mainly used at large distances from the base station or shielded by buildings, etc. In this situation, the *peak* powers could approach the values of 2 W (900 MHz) and 1 W (1800 MHz) and the *average* powers could approach the values of 0.25 W (900 Hz) and 0.125 W (1800 Hz).

Specific Absorption Rate (SAR) is the basis of most safety standards. It is the rate of energy absorption per unit of body mass. The results of various published tests show that, on average, a GSM handset will sit at about 50% of the allowable SAR limit when tested for voice applications, i.e. one timeslot in use. It has been recognized that in the evolution towards UMTS, the soon to be introduced GPRS data service using multiple GSM time slots will provide an indicator for the UMTS situation. If multiple timeslots are used for calls there could be a potential for the SAR limit in some standards to be exceeded. While GPRS is intended primarily for data services and the user is unlikely to have the phone against their head, relevant exposure standards must however be observed and this will require careful monitoring by the industry.

Initial GPRS handsets are designed for single time slot transmission and multiple timeslot receive. For these handsets compliance requirements will be similar to those of non-GPRS handsets. There appears to be a need to monitor this situation and there may be a need to issue advice on how to use some GPRS terminals as they develop.

Key points:

- UMTS evolutionary path from GSM,
- UMTS operates at a similar frequency/wavelength to GSM1800,
- Average power of GSM1800 phone never more than 0.125 watts,
- SAR is basis of safety standards and currently GSM terminals sit at about 50% of limit,
- GPRS data terminals may approach the maximum SAR limit.

3.3 UMTS/IMT-2000

The third generation of mobile telecommunications technology has now been agreed and will be introduced in the next few years. The frequency bands identified for this system are 1885–2010 MHz and 2110–2200 MHz and are known as the ‘core’ UMTS band. The need for additional frequency spectrum to meet the future expected demand for capacity has also been recognised and was debated at the ITU World Radiocommunication Conference in May 2000 where additional frequencies were identified for implementation from the year 2005. These were the band 2500-2690 MHz and the existing GSM bands, which may be transferred from GSM to UMTS at some convenient time in the future. It should be noted that the core UMTS band is similar in frequency to GSM1800 and thus analogies can be made. The current round of licensing in Europe is only related to the licensing of IMT-2000 technologies in the ‘core’ UMTS bands.

The specifications allow some choice in the modulation to be used but it is expected that the main choice will be CDMA (Code Division Multiple Access). The frequency channels will have 5 MHz bandwidths and, as in GSM, each occurs at the same time, the changes in amplitude of the carrier wave are essentially random (noise-like).

Two types of CDMA are likely to be implemented: FDD (Frequency Division Duplex), where separate 5 MHz channels are used for the two directions (to and from the mobile phone), and TDD (Time Division Duplex) where the same channel is used but in different time slots. Both types lead to pulse modulation because of the need to send regular commands from the base station to change the power level. In FDD the pulse frequency is 1600 Hz, while for TDD it can vary between 100 Hz and 800 Hz.

In the hand-held terminal mode the terminal is, or can be, used as a handset or worn on the person (for example in the belt or in the pocket) and the antenna is an integral part of the terminal. Hand-held terminals may be used for voice and/or data communications. It is normally operated using its internal battery.
In order to minimize the battery power consumption, provide long operational time, enable small size devices and assure compliance with national and international electromagnetic exposure guidelines in all normal operational situations, terminals operating in the hand-held mode are likely to only support the lowest power class for terminals, i.e. 21 dBm (0.125 Watts). As noted above, in GSM1800 (operating close to the IMT-2000 band) the maximum average output power of 21dBm (0.125Watts) is used for handheld terminals. The market expectation for terminals in the new 3GPP UMTS system is that the maximum output power should not be higher than for GSM in the hand-held terminal mode.

The expected demand for the use of UMTS both for speech and for data and Internet services is such that systems may be expected to employ macrocells and microcells, and also short-range picocells, to meet the various requirements for mobility and wide bandwidth services – for example, in the office environment.

Key points:

- In terms of electromagnetic characteristics UMTS is similar to GSM1800,
- ‘Core’ UMTS frequencies are close-by GSM1800, in the future (from 2005) higher frequencies may be used,
- Hand held terminals are expected to be similar in power output to GSM1800 terminals,
- Base stations are also expected to operate similarly to a GSM1800 network.

4. Electromagnetic fields from Mobile Phone Systems

4.1 General

The considerations in this section are restricted to the fields produced by GSM1800 mobile phones and base station antennas since these form the large majority of those presently in use in the Europe and operate in a similar manner to UMTS.

4.2 Mobile handsets

The power from a phone is transmitted by the antenna and circuit elements inside the handset. The antenna is usually a metal helix or a metal rod extending from the top of the phone. At appoint 2.2 cm from an antenna the maximum peak value of the electric field would be 200 V/m for a 1 watt GSM1800 phone. For a 1 Watt, 1800 MHz phone the *maximum* intensity 2.2 cm from the antenna is very roughly about 200 Watts/m 2 (this is about one-quarter of the intensity of the Sun's radiation on a clear summer day, although the frequency of the emission from a phone is a million or so times smaller). These are the fields and intensities when the antenna is a long way from the head or body. When the antenna is near the body, the radiation penetrates it but the fields inside are significantly less, for the same antenna, than the values outside. For example, the largest *maximum* fields inside the head when its surface is 1.4 cm from the antenna are calculated to be about three times smaller than the values given above. (The *average* field values are all appreciably less than these *maximum* peak values).

Key points:

- Peak fields within the head from a terminal could be around 60 V/metre although maximum average fields would be 7.5 V/m. (The exposure to general public ICNIRP limit at 2000 MHz is 61 V/m)

4.3 Base stations

The base station antennas serving macrocells are either mounted on freestanding towers, typically 10–30 m high, on short towers on top of buildings, or attached to the side of buildings. In a typical arrangement, each tower supports three antennas, each transmitting to a 120 degrees sector. A large proportion of the power is focussed into an approximately horizontal beam typically about 6 degrees wide in the vertical direction and the rest of the power goes into a series of weak beams (called side lobes) either side of the main beam. The main beam is tilted slightly downwards but does not reach ground level until the distance from the tower is at least 50 m (usually 50–200 m).

The base station antennas transmit appreciably greater power than the phones. The limit to the power is normally set by the need to avoid radio interference in adjacent cells and defined by a licence issued by the radio regulatory administration (BIPT in Belgium). This does not directly limit the total power emitted but does so indirectly by fixing the maximum intensity of the antennas main beam. This is done by defining the maximum "equivalent isotropically radiated power" (EIRP) that can be emitted from the antennas. The EIRP is the power that would have to be emitted equally in all directions to produce a particular intensity. In fact, as already noted, the antennas used are very far from isotropic, with most of the power being concentrated into the main beam. The ratio of the EIRP to the total power output is called the gain of the antenna. For a 120 degrees sector antenna the gain is usually between about 40 and 60.

As an example if the licence sets the maximum EIRP at 1500 Watts per frequency channel, this corresponds to a maximum total radiated power of about 30 W per channel (= EIRP/gain). The licence may also limit the number of channels per antenna to 16 for 1800 MHz. However in practice typically less than 4 channels per antenna are utilised at 1800 MHz, which would correspond to maximum radiated powers of less than 120 Watts. Similarly, the total radiated power emitted from an antenna is generally limited by the characteristics of the equipment to somewhat less than 70 Watts and a figure of 60 Watts will be assumed in this report. It needs to be stressed that the number of channels used, and hence the total radiated power, is limited by technical rather than legal requirements, which would in fact permit significantly larger powers to be radiated. As with a handset the *average* power transmitted by a base station is normally less than the *maximum* power, although it could rise to the maximum at times (rather than to one-eighth of the peak power in the case of a phone). By the inverse square law, the *maximum* intensity in the main beam at a point on the ground 50 m from a 10 m tower carrying an antenna transmitting 60 Watts into a 120 degrees sector is about 100 mW/metre squared. This corresponds to an electric field of about 5 V/m and very roughly is about 50 to 100 times smaller than the field experienced 2.2 cm from the antenna of a handset.

The heating effects that these fields would produce will vary with the intensity and are about 5000 times smaller than he maximum value 2.2 cm from the antenna of a mobile phone.

The RF intensity on the ground is not zero outside the main beam, because of the power emitted into the side lobes. Its value will depend on the design of the antenna but it seems unlikely that it could ever be significantly more than that within the beam. So the values given above should be reasonable indications of the maximum intensity and fields that would be present on the ground around a base station. The intensity will, however, become appreciably larger as the antenna is approached, as it might be by maintenance workers.

In the UK tests have been made on the average intensities around base stations. Eight of these stations were mounted on the roofs of schools; four were on tower blocks and five on other buildings. Measurements were made at various points within the buildings, at ground level or at other locations of public access. The measured intensities were typically between 0.01 and 1 mW/metre squared and the maximum was never more than 10 mW/metre squared. These values are very much less than the calculated values in the main beam given above, although the sample was small. It is also of note that the calculations and most of the measurements were for towers used by one operator only. The average intensities would be expected to be larger near to a tower used by more than one operator.

Key points:

- Maximum electric field in the main beam at a point on the ground 50 m from a 10 m tower carrying an antenna transmitting 60 Watts into a 120 degrees sector antenna is about 5 V/m.
- Maximum measured field in the UK was 195 V/m. (The exposure to general public ICNIRP limit at 2000 MHz is 61 V/m)

5. Electromagnetic Human Exposure Standards

5.1 General

There are a number of national and international standards bodies that have developed electromagnetic human exposure guidelines. In many cases these guidelines do not have any legal status until referenced through other legislation, e.g., product safety or occupational health and safety. These committees are usually composed of persons with expertise in key areas and representatives of major stakeholder groups.

The majority of the standards in the western world are quite similar in their basic approach to limit setting, in that they determine the threshold dose for a biological hazard and then incorporate safety factors when establishing the allowable exposure level. The safety factors are intended to account for uncertainty in establishing the threshold level. Standards applied in some former Soviet Bloc countries take a different approach to setting of allowable exposure levels and in many cases appear substantially more conservative than western standards. However, the rationale for such standards is less well documented.

5.2 Western Standards

For transmissions in the frequency range used by mobile phone services, the dosimetric quantity underlying most modern standards is the *specific energy absorption rate (SAR)*. Also in this frequency range, the primary mechanism for biological interactions is heating. However, SAR is a fundamental dosimetric quantity not solely applicable to biological effects resulting from heating.
After more than 40 years of research it is generally agreed that the threshold for consistently observed biological effects at mobile phone system frequencies is an RF exposure that results in a whole body averaged SAR of 4 Watts/kg. The observed effects have been primarily behavioural and include reduced activity or avoidance of strong fields. Standards setting bodies usually then take a minimum safety factor of 10 so that the allowable SAR is 0.4 W/kg. Many standards include additional safety factors for the public resulting in an allowable whole body SAR limit of 0.08 W/kg. The primary differences among western standards are not in these basic SAR restrictions but in relation to the assumptions used in deriving easier to measure quantities such as *power density*. These types of SAR based restrictions are relevant to whole body exposure from a base station antenna

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In the case of localised exposures, such as a mobile phone handset in use, different considerations have been used to develop partial body exposure limits. By considering the non-uniform nature of RF energy deposition and practical measure volumes the United States standards committee established a limit of 1.6 W/kg in a 1 g cube of tissue. By comparison, based on the ability of small volumes of tissue to dissipate thermal loads, the UK National Radiological Protection Board (NRPB) and the International Commission on Non-Ionising Radiation Protection (ICNIRP) recommend a limit of 2 W/kg in a 10 g cube of tissue.

The European Commission has recommended adoption of the ICNIRP guidelines by Member States, see annex 1. Annex 2 provides information on the actual situation within Member States.

The ICNIRP public reference levels for the frequencies used by mobile phones are shown in the Table below. Reference levels for mobile telecommunications in the frequency range 800–1000 MHz are from 4 to 5 Watts /metre squared and for 1800–1900 MHz from 9 to 9.5 Watts /metre squared rising to 10 Watts / metre squared at 2000 MHz.

Table - ICNIRP reference levels for public exposure at mobile telecommunications frequencies

Frequency (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (Watts / metre squared)
400 - 2000	1.375f	0.0037f	f/200
2000 - 3000	61	0.16	10

f is the frequency in MHz.

Key points:

- Exposure limits have a built in safety factor of 10;
- Different values between the standards arise from interpretations necessary to make measurements of intensity and field;
- The European Commission has recommended adoption of the ICNIRP guidelines by Member States;
- Reference levels for mobile telecommunications in the frequency range 800–1000 MHz are from 4 to 5 Watts /metre squared and for 1800–1900 MHz from 9 to 9.5 Watts /metre squared rising to 10 Watts / metre squared at 2000 MHz.

5.3 Eastern European Standards

The RF exposure standards published in some former Soviet Bloc countries are based on reported 'neuraesthenic' effects at low levels of exposure. This is a general term referring to a range of reported subjective effects such as headaches, nausea, depression, etc. The rationale for the former Soviet standard is poorly documented and with the political changes in Eastern Europe, some former Soviet Bloc countries have adopted the ICNIRP guidelines.

Under the umbrella of the World Health Organization (WHO) International EMF Project, efforts are being made to achieve standards harmonization between east European and Western standards.

6. Specific XXXXX questions

6.1 What are the best legal practices in Europe?

There are a number of national and international standards bodies that have developed electromagnetic human exposure guidelines. In many cases these guidelines do not have any legal status until referenced through other legislation.

The European Commission has recommended adoption of the International Commission on Non-Ionising Protection (ICNIRP) guidelines by Member States, see Annex 1. Of the EU Member States plus Norway and Switzerland, 7 countries have adopted these limits. Italy and Switzerland have stricter limits whilst the UK has a slightly relaxed limit. 7 countries are studying the matter. For full details see Annex 2.

6.2 What is the relationship between the Electric Field (V/m) and the number of installations?

There is no direct relationship between the Electric Field and the number of installations. Exposure limits are normally derived from a parameter known as the Specific Absorption Rate (SAR). This is the time derivative of the incremental energy absorbed by (dissipated in) an incremental mass contained in a volume element of given density. SAR is expressed in units of watts per kilogram. From the SAR (with appropriate safety margins) values for maximum power density and maximum electric (and magnetic) fields can be derived.

From the foregoing text it can be seen that the device most likely to develop fields approaching the limit values are the handsets, which are held close to the head. This suggests the maximum order of power that should be developed by the terminals. This in turn has a bearing on the optimum size of the cell, as sufficient power must be generated in the terminal to be received at the base station. Other factors may however require the cell size to be reduced further, such as the need to reduce interference to neighbouring cells or to accommodate more terminals within the cell.

In general base stations develop smaller field strengths in public areas although the measurements in the UK suggest that on occasion fields may be developed which approach or even exceed the ICNIRP limits.

6.3 What are the elements which influence this relationship

These factors have been addressed in section 6.2 above. Moreover many of the preceding paragraphs have attempted to describe the detailed interactions and considerations involved with these issues.

There is probably little that can be done to reduce the electric field strength resulting from terminal equipment, especially as standards have been produced internationally in 3GPP that specify the various power output classes of user equipment. These will be transposed into European norms by ETSI. The significant momentum generated to allow for the free circulation of terminals will also mean that there will be a large number of users roaming into Belgium from other countries.

If base station emissions were thought to pose a threat operating at ICNIRP levels then the power output of transmitters could be reduced through the licensing process, however in the absence of similar measures for the terminals, the rationale for proceeding in this way would have to be developed with care.

7. Comment

In order to develop and implement a modern mobile telecommunications system such as UMTS it will be difficult and costly to reduce the power output of terminals much below current levels. This is because more base stations would have to be implemented which in turn would prove expensive and indeed have an environmental impact in turns of the increased number of visible equipment and structures.

On the other hand terminal manufacturers would be quite happy to reduce power levels (provided a compatible infrastructure was in place) as this would reduce the battery requirements (size and weight), which has a major impact on the overall size of terminals. In UMTS battery power will be at a premium in multi-media terminals.

As foregoing paragraphs have suggested electric fields generated by hand held terminals held close to the head are likely to produce higher fields than base stations, however in certain circumstances measurements have shown that the electric field from base stations at specific locations have approached or exceeded the ICNIRP recommended levels.

Major international study programmes are in progress to ascertain whether current limits based on SAR are adequate. Currently it is probably not possible to say that exposure to RF radiation, even at levels below ICNIRP guidelines, is totally without potential adverse health effects. Until much more detailed and scientifically robust information on any health effects becomes available gaps in the available knowledge base maybe sufficient to justify a precautionary approach to the use of mobile phone technologies for the time being. This might include published guidelines on how to use terminals as safely as possible and in the case of base stations ensure that antennas are sited sensitively and that the public (especially the most vulnerable groups i.e. children) is excluded from any area where the ICNIRP recommended limits are likely to be exceeded. Furthermore government, industry and other interested parties might work together to produce an appropriate code of practice.

ANNEXES HAVE NOT BEEN INCLUDED