



COMMISSION OF THE EUROPEAN COMMUNITIES

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Proposal for a

COUNCIL RECOMMENDATION

on the limitation of exposure of the general public
to electromagnetic fields
0 Hz-300 GHz

(presented by the Commission)

EXPLANATORY MEMORANDUM

INTRODUCTION

With the advent of modern telecommunications, the expansion on a massive scale of electrical and electronic equipment, and the proliferation of high-voltage electricity transmission lines, interest in, and concerns about, the effects of electromagnetic fields considerably increased over the recent years, and calls are constantly being made for measures and guidelines in this area.

Radiation from electromagnetic fields is quasi-ubiquitous. For health protection purposes it is usually distinguished between ionizing and non-ionizing. Community provisions with respect to the former have been laid down pursuant to the Euratom Treaty.

Electromagnetic non-ionising radiation includes ultraviolet radiation, visible radiation, infrared radiation (which together constitute optical radiation) and static and time-varying electromagnetic fields (EMFs). The manner in which these different radiations and fields interact with people is quite different and potential hazards have to be carefully assessed.

For members of the general public, optical radiation presents significant adverse health risks. There is convincing scientific evidence that exposure to the sun is a major risk factor in skin cancer and may play a role in the onset of cataract. Depending on individual circumstances, other exposure to ultraviolet radiation, such as from sunbeds and unshielded lamps, may also contribute to an individual's risk, but generally to a much lesser extent than sun exposure.

Concerning exposure of the general public to visible radiation (light), the most important with respect to potential for causing eye injury is laser radiation such as used for display and entertainment purposes.

Guidelines for limiting exposure to optical radiation and recommendations for health protection have been published by various international bodies, and are currently under consideration at Community level.

With respect to electromagnetic fields, concerns have been raised about possible health effects of exposure to artificially produced fields. While the acute effects of exposure to EMFs are generally well established, there is an ongoing debate as to the existence of long-term health effects, primarily cancer. In most Member States, authorities are constantly questioned about such effects. There is no convincing scientific evidence of EMFs causing cancer, however, and the concerns of the public can only be addressed through the results of focused research. There are however, health effects of EMFs that are well established, and these have been the object of various national regulations and international guidelines aimed at avoiding or limiting exposure which may give rise to them.

Regulations and guidelines in this area aim at establishing systems of health protection on the basis of scientifically derived principles and criteria, and comprise basic restrictions for exposure limitation and reference levels for taking appropriate action if the basic restrictions are not to be exceeded.

Underpinning the setting of basic restrictions and reference levels is information and scientific data concerning the sources and types of EMFs and health effects that may result from exposure to them. These are reviewed below.

SOURCES AND TYPES OF EMFs

People are exposed at work and in their living environment to different EMFs originating from many man-made sources.

Sources of static electric and magnetic fields

In addition to the environmental static electric and magnetic fields, new technologies such as visual display units (VDUs), and some public transportation systems, e.g. in underground trains and tramways, which utilize Direct Current (DC) supplies may involve exposure to static and slowly time varying fields.

Power lines and electric appliances

The principal artificial sources of extremely low frequency (ELF) fields are high voltage (HV) transmission lines, and devices containing current carrying wires. Inside buildings near HV transmission lines, electric fields are about 10 to 100 times lower than outside, depending on the structure of the building and the type of materials. Common building materials do not significantly attenuate magnetic fields. All electric appliances in homes and at workplaces are potential sources of power frequency (50/60 Hz) electric and magnetic fields. The magnetic fields vary from a few tenths of μT to a few mT close to appliances and drop off rapidly with distance.

Railway systems

Most of the European railway systems are electrified, using DC voltage or AC voltage with frequencies of $16\frac{2}{3}$ Hz or 50 Hz. For instance, the resulting electric field strength inside a train using AC voltage is only a few V/m, while on the platform field strengths may be much higher. The corresponding magnetic fields on the platform as well as inside the train are about a few tens of μT during acceleration of the train and are highly variable with time.

Broadcast transmitters

Broadcast transmitters use frequency bands from around 145 kHz to 110 MHz for LF, MF, HF and VHF radio broadcasting, and from 147 to 854 MHz for UHF television broadcasting. Measurements at an MF station with two 50 kW and two 75 kW

transmitters have indicated that at a distance of 30 m from a 75 kW mast radiator electric fields are about 275 V/m. Public access close to broadcast antennas is generally restricted.

Cellular radio

Mobile telecommunication systems can be divided into several categories, depending on the type of telecommunication network they use. Cellular mobile phone systems involve communication from hand-held radiotelephones or vehicle mounted transceivers to fixed base stations. Analogue cellular systems operate with frequency bands of 150, 200, 450 or 900 MHz. The European digital system, based on the harmonised European standard GSM, operates primarily at 900 MHz and has been used since 1992. A new system called DCS 1800 operates at 1800 MHz with characteristics very similar to GSM, and future systems will operate at even higher frequencies. Exposure to fields from hand-held mobile telephones is generally restricted only to small regions of the user's body, in the head and hand.

Mobile phone base stations

Base stations are usually mounted on separate towers or on the roofs of buildings, and access to the immediate vicinity of antennas should be restricted. The transmitting antennas are formed from vertical arrays of colinear dipoles which give a very narrow vertical beam width. The downward tilt of the antennas is less than 10° , and hence public exposure to the main beams is usually not possible at distances of less than about 60 m, and human exposure levels are very low in most cases.

Radar

Radar systems use microwave frequencies from 500 MHz up to around 15 GHz, although there are some systems operating up to 100 GHz. The signal produced differ from most of the sources in that they are pulsed and give average powers which are several orders of magnitude less than peak powers.

The antennas used for radars are moderately directive with main beams only a few degrees wide. Many of the systems feature antennas whose direction is continuously varied by rotating horizontally or nodding vertically.

Marine radar equipment ranges from large installations of super-tankers to the smaller mast mounted equipment used by yachts. Under normal operating conditions with the antenna rotating, the average power density of the higher power systems within a metre of the turning circle of the radar system can be calculated to be less of 10 W m^{-2} .

HEALTH EFFECTS OF ELECTROMAGNETIC FIELDS - A BASIS FOR EXPOSURE RESTRICTIONS

Health effects result from coupling between fields and the body. There are established basic coupling mechanisms through which static and time-varying electric and magnetic fields directly interact with living matter¹:

- coupling to static and ELF electric fields leads to surface charges on an exposed body which can be perceived;
- coupling to static magnetic fields by magnetic induction resulting in the flow of electric current and electric potentials across blood vessels; magnetomechanic interactions, resulting in forces on ferromagnetic molecules, magnetic particles and ferromagnetic implants; and electronic interaction processes which may affect chemical reactions;
- coupling to low-frequency electric fields results in the flow of electric charges (electric current), the polarisation of bound charge (formation of electrical dipoles), and the reorientation of electric dipoles already present in tissue;
- coupling to low-frequency magnetic fields results in induced electric fields and circulating electric currents that can lead to electrical stimulation effects;
- absorption of energy from electromagnetic fields of frequencies greater than 100 kHz or so, can lead to significant heating.

In addition, there are two indirect coupling mechanisms:

- contact currents or transient discharges that result when the human body touches an object at a different electrical potential (i.e., when either the object or the human body is charged by an electromagnetic field);
- coupling of electromagnetic fields to medical devices worn by a human.

The evidence concerning health effects on which limitations of exposure are based can be summarized separately for different frequency ranges.

Health effects of static fields

The few experimental studies that have been carried out on the biological effects of static electric fields provide no evidence to suggest the existence of any adverse effects on human health. For most people, the annoying perception of surface electric charges, acting directly on the surface of the body, will not occur during exposure to static electric field strengths of less than about 25 kV/m.

¹ United Nations Environment Programme/World Health Organization/International Radiation Protection Association. Electromagnetic fields (300 Hz to 300 GHz). Geneva, World Health Organization; Environmental Health Criteria 137; 1993

There is no direct experimental evidence of any acute adverse effect on human health from exposure to static magnetic fields up to 2 T. From the analysis of established mechanisms of interaction, long-term exposure to magnetic flux densities of 200 mT should not have any adverse consequences on health.

Health effects of time varying fields at frequencies below 100 kHz

Laboratory studies on cellular and animal systems have found no established effects of low-frequency fields that are indicative of adverse health effects when induced current density is at or below 10 mA/m². At higher levels of induced current density (10–100 mA/m²), more significant tissue effects have been consistently observed, such as functional changes in the nervous system.

Measurement of biological responses in laboratory studies and in volunteers has provided little indication of adverse effects of low-frequency fields at levels to which people are commonly exposed. A threshold current density of 10 mA/m² at frequencies up to 1 kHz has been estimated for minor effects on nervous system functions. Among volunteers, the most consistent effects of exposure are the appearance of visual phosphenes (faint flickering visual sensation) and a minor reduction in heart rate during or immediately after exposure to ELF fields, but there is no evidence that these transient effects are associated with any long-term health risk. A reduction in nocturnal pineal melatonin synthesis has been observed in several rodent species following exposure to weak ELF electric and magnetic fields, but no consistent effect has been reported in humans exposed to ELF fields under controlled conditions.

There is no convincing experimental evidence that ELF electromagnetic fields cause genetic damage and it is therefore extremely unlikely that they could have any effect on the initiation of cancer. There is little evidence from laboratory studies that power-frequency magnetic fields have a tumor-promoting effect. Although further animal studies are needed to clarify the possible effects of ELF fields on signals produced in cells and on endocrine regulation — both of which could influence the development of tumors by promoting the proliferation of initiated cells — it can only be concluded that there is currently no convincing evidence for carcinogenic effects of these fields and that these data cannot be used as a basis for developing exposure guidelines.

Epidemiological data on cancer risk associated with exposure to extremely low frequency (ELF) fields among individuals living close to power lines seem to indicate a slightly higher risk of leukaemia among children. The studies do not, however, indicate a similarly elevated risk of any other type of childhood cancer or of any form of adult cancer. The basis for the hypothetical link between childhood leukemia and residence in close proximity to power lines is unknown. In the absence of support from laboratory studies, the epidemiological data are insufficient to allow the recommendation of an exposure limit.

There have been reports of an increased risk of certain types of cancer, such as leukemia, nervous tissue tumors, and, to a limited extent, breast cancer, among electrical workers. In most studies, job titles were used to classify subjects according to presumed levels of

magnetic field exposure. A few more recent studies, however, have used more sophisticated methods of exposure assessment; overall, these studies suggested an increased risk of leukemia or brain tumors but were largely inconsistent with regard to the type of cancer for which risk is increased. The data are insufficient to provide a basis for ELF field exposure guidelines. In a large number of epidemiological studies, no consistent evidence of adverse reproductive effects have been provided.

Health effects of fields at frequencies between 100 kHz and 300 GHz

Available experimental evidence indicates that the exposure of resting humans for approximately 30 minutes to EMF producing a whole-body Specific Absorption Rate (SAR) of between 1 and 4 W/kg results in a body temperature increase of less than 1°C. Animal data indicate a threshold for behavioral responses in the same SAR range. Exposure to more intense fields, producing SAR values in excess of 4 W/kg, can overwhelm the thermoregulatory capacity of the body and produce harmful levels of tissue heating. Many laboratory studies with rodent and non-human primate models have demonstrated the broad range of tissue damage resulting from either partial-body or whole-body heating producing temperature rises in excess of 1–2 °C. The sensitivity of various types of tissue to thermal damage varies widely, but the threshold for irreversible effects in even the most sensitive tissues is greater than 4 W/kg under normal environmental conditions. These data form the basis for an occupational exposure restriction of 0.4 W/kg, which provides a large margin of safety for other limiting conditions such as high ambient temperature, humidity, or level of physical activity.

Both laboratory data and the results of limited human studies make it clear that thermally stressful environments and the use of drugs or alcohol can compromise the thermoregulatory capacity of the body. Under these conditions, safety factors should be introduced to provide adequate protection for exposed individuals.

Data on human responses to high-frequency EMFs that produce detectable heating have been obtained from controlled exposure of volunteers and from epidemiological studies on workers exposed to sources such as radar, medical diathermy equipment, and heat sealers. They are fully supportive of the conclusions drawn from laboratory work, that adverse biological effects can be caused by temperature rises in tissue that exceed 1°C. Epidemiological studies on exposed workers and the general public have shown no major health effects associated with typical exposure environments. Although there are deficiencies in the epidemiological work, such as poor exposure assessment, the studies have yielded no convincing evidence that typical exposure levels lead to adverse reproductive outcomes or an increased cancer risk in exposed individuals. This is consistent with the results of laboratory research on cellular and animal models, which have demonstrated neither teratogenic nor carcinogenic effects of exposure to athermal levels of high-frequency EMFs.

Exposure to pulsed EMFs of sufficient intensity leads to certain predictable effects such as the microwave hearing phenomenon and various behavioural responses. Epidemiological studies on exposed workers and the general public have provided limited information and

failed to demonstrate any health effects. Reports of severe retinal damage have been challenged following unsuccessful attempts to replicate their findings.

A large number of studies of the biological effects of amplitude-modulated EMFs, mostly conducted with low levels of exposure, have yielded both positive and negative results. Thorough analysis of these studies reveals that the effects of AM fields vary widely with the exposure parameters, the types of cells and tissues involved, and the biological endpoints that are examined. In general, the effects of exposure of biological systems to athermal levels of amplitude-modulated EMFs are small and very difficult to relate to potential health effects. There is no evidence of frequency and power density windows of response to these fields.

Shocks and burns can be the adverse indirect effects of high-frequency EMFs involving human contact with metallic objects in the field. At frequencies of 100 kHz – 110 MHz (the upper limit of the FM broadcast band), the threshold levels of contact current that produce effects ranging from perception to severe pain do not vary significantly as a function of the field frequency. The threshold for perception ranges from 25 to 40 mA in individuals of different sizes, and that for pain from approximately 30 to 55 mA; above 50 mA there may be severe burns at the site of tissue contact with a metallic conductor in the field.

Formulation of basic restrictions for the exposure of the general public

Based on previously summarized information on health effects, it can be concluded that:

- In a 200 mT static magnetic field, the calculated maximum induced current density (in the aorta) is 44 mA/m^2 , which is below that which would be expected to produce adverse haemodynamic or cardiovascular effects.
- Functions of the central nervous system may be adversely affected by current densities above 10 mA/m^2 at frequencies between approximately 5 Hz and 1 kHz, and by larger current densities at frequencies above and below this frequency range. This determines basic restrictions in terms of current density.
- For frequencies above about 100 kHz, adverse biological effects can result from temperature elevations in tissue that exceed 1°C . From this, basic restrictions in terms of the specific energy absorption rate (SAR) are derived, for whole body and for localised exposure. For frequencies above 10 GHz, energy absorption is restricted to the surface of the exposed body, and basic restrictions are accordingly expressed in terms of power density.
- The threshold levels of contact current are strongly frequency dependent between several Hz and 100 kHz. Over the frequency range from 100 kHz to 110 MHz (the upper limit of the FM broadcast band), the threshold levels of contact current that produce effects ranging from perception to severe pain do not vary significantly as a

function of the field frequency. Reference levels for both contact current and induced current are set in order to determine whether caution must be exercised to avoid shock and burn hazards.

The uncertainty in the scientific data, and the variations in terms of individual susceptibility as well as variations in actual exposure situations necessitate the use of safety factors when deriving restrictions to exposure.

OVERVIEW OF RELEVANT MEASURES TAKEN BY MEMBER STATES

Only a few Member States have promulgated comprehensive regulations and standards for the protection of the general public against electromagnetic radiation. In view of mounting public concern on this subject, however, several Member States and third countries are giving urgent consideration to adopting health protection measures. In this context some Member States indicated a need to obtain orientations as to the nature and extent of such health protection measures.

Some Member States have issued recommendations and some introduced compulsory provisions for either low and/or high frequency electromagnetic fields. A review of provisions and guidelines in this field was published by the Commission². In general, Member States make a distinction between health protection requirements of workers and members of the general public. One Member State, however, does not adhere to this rationale, but distinguishes between exposure of adults and children.

OVERVIEW OF COMMUNITY ACTS OF RELEVANCE

Public Health

The European Parliament adopted in 1994 a resolution on combating the harmful effects of non-ionizing radiation³ and called on the Commission to propose regulations and standards seeking to limit the exposure of workers and the public to non-ionizing electromagnetic radiation.

In the context of the framework for action in the field of public health⁴, the Commission adopted on 4 June 1997 a proposal for a programme of Community action 1999-2003 on pollution-related diseases⁵ which takes account of the fact that health risks including those associated with exposure to electromagnetic fields, are often perceived by the public very differently from what is established by scientific evidence; consequently, the Commission proposed to tackle this problem with actions targeted at improving capacity in the Member

² European Commission, Non-ionizing radiation: Sources, exposure and health effects, Office for Official Publications of the European Communities, 1996, ISBN 92-827-5492-8

³ OJ N° C 205, 25.7.94, p. 439

⁴ COM (93) 559 final, 24.11.1993

⁵ OJ N° C 214, 16.7.1997, p. 7-10

States to acquire a better understanding of public perceptions of environmental health risks, and better explain how they are assessed and managed.

Health and Safety at Work

Minimum requirements in respect of the protection of workers against certain exposure situations have been laid down pursuant to Article 118A of the EC Treaty.

Health and safety protection requirements for work with display screen equipment were laid down in Council Directive 90/270/EEC⁶. This obliges employers to take appropriate steps to ensure that workstations, i.e. an assembly of visual display units, keyboards, accessories and peripherals including telephone, modem and printer, meet certain minimum requirements. All radiation with the exception of the visible part of the electromagnetic spectrum must be reduced to negligible levels from the point of view of the protection of workers' safety and health.

Council Directive 92/85/EEC⁷ on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers stipulates that the employer has to assess all activities liable to involve a specific risk of exposure to agents, including non-ionizing radiation, processes or working conditions, and has to look into the nature, degree and duration of exposure, in order to decide what measures should be taken.

Moreover, the Commission presented in 1993 a proposal for a Council Directive on the minimum health and safety requirements regarding the exposure of workers arising from physical agents⁸. The physical agents to which the Directive would apply are noise, mechanical vibration, optical radiation and other electromagnetic fields and waves. The proposed directive, which was amended subsequent to the opinion of the European Parliament in a first reading⁹ refers to risks to the health and safety of workers due to the effects of electric fields and currents, as well as of absorption of energy, resulting from exposure to static and time-varying electric and magnetic fields with frequencies up to 300G Hz.

Product Safety

Essential requirements related to emission characteristics of machinery have been laid down at Community level in the context of the establishment of the Internal Market, in particular on the basis of Article 100A of the EC Treaty. Council Directive 73/23/EEC¹⁰ on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits and specially Annex 1 thereof establishes that electrical equipment may be placed onto the market only if it complies with certain

⁶ OJ N° L 156, 21.6.90, p. 14-18

⁷ OJ N° L 348, 28.11.92, p. 1-8

⁸ OJ N° C 77, 18.3.1993, p. 12-29

⁹ OJ N° C 230, 19.8.1994, p. 3-29

¹⁰ OJ N° L 077, 26.3.73, p. 29-33

essential requirements which include measures to ensure that temperatures, arcs or radiation which would cause danger are not produced.

Council Directive 89/336/EEC¹¹ on the approximation of the laws of the Member States relating to electromagnetic compatibility aims at avoiding electromagnetic disturbance in order to provide adequate protection to apparatus such as telecommunications networks, industrial and manufacturing equipment, medical and scientific apparatus, information technology equipment or domestic appliances and household electronic equipment. To this end, the apparatus covered by the Directive shall be constructed so that the electromagnetic disturbance generated does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended; and the apparatus has an adequate level of intrinsic immunity of electromagnetic disturbance to enable it to operate as intended.

Environmental Impact Assessment

Council Directive 85/337/EEC¹² on the assessment of the effects of certain public and private projects on the environment as amended by Council Directive 97/11/EC¹³ applies, amongst other projects, to the construction of overhead electrical power lines with a voltage of 220kV or more and a length of more than 15 km. This means that developers will have to provide information on the measures envisaged in order to avoid, reduce and, if possible, remedy significant adverse effects, as well as an outline of main alternatives studied by the developer and an indication of the main reasons for his choice.

In order to complement provisions of Directive 97/11/EC, the Commission proposed a Council Directive on the assessment of the effects of certain plans and programmes on the environment¹⁴. The proposal aims at plans and programmes which are part of a town and country planning decision-making process for the purpose of establishing the framework for subsequent development consent, including strategic plans and programmes adopted in the energy, transport and telecommunications sectors.

Research

Under the fourth framework programme of the European Community for research, technological development and demonstration (1994-98)¹⁵ a number of EMF-related research activities has been or is still carried out. In particular, Biomed 2, COST and the Standard, Measurement and Testing programmes have supported proposals, and some of them are still ongoing.

Potential adverse health effects from exposure to radiofrequencies were also addressed in the Commission's Green Paper on a common approach in the field of mobile and personal

¹¹ OJ N° L 139, 23.05.89, p. 19-26

¹² OJ N° L 175, 5.7.85, p. 40-48

¹³ OJ N° L 73, 14.3.97, p. 5-15

¹⁴ COM (96) 511 final, and OJ N° C 129, 25.4.97, p. 14

¹⁵ OJ N° L 126, 18.5.94, p. 1-33

communications¹⁶. As a result and in response to the European Parliaments Resolution on combating the harmful effects of non-ionising radiation, the Commission confirmed the need for further research in this area, and a working group of experts elaborated for the Commission pertinent recommendations for epidemiological, biophysical and biological research, and also for research on exposure systems and dosimetry. The proposed research agenda¹⁷ covers also effects on the immune system, nervous system-related effects, and genetic and cancer-related effects. These have been and still are of utmost concern to the public and the European Parliament.

The Commission took account of the experts' recommendations, and of the need for research with respect to health effects from exposure to other frequencies, when drawing up its proposal concerning the 5th framework programme of the European Community for research, technological development and demonstration activities (1998-2002)¹⁸. Moreover, the Commission recognises that risk communication is clearly important in this area because of the controversy over alleged long-term effects, and has proposed research on gaining a better understanding of the public's risk perception and on the assessment, communication and management of risks.

THE PROPOSED RECOMMENDATIONS

The ever-growing involvement of the Community in promoting activities in various industrial sectors likely to increase exposure of the population to electromagnetic fields, and the mounting concern over their effects of decision-makers, health professionals, interest groups, and members of the public, make it imperative to undertake efforts to establish commonly-agreed principles in this field at Community level.

Requirements that exist in some Member States result in varying regimes as regards the public's protection against electromagnetic fields. The existing variations and gaps in provisions and guidelines contribute to a sense of confusion and insecurity felt by many Community citizens and undermines confidence in health protection authorities. In keeping with the goal of making a contribution towards ensuring a high level of health protection to the citizens of the Community, and in view of the moves in this area undertaken by some Member States, the Commission considers it necessary to propose a common framework for protection of the general public to electromagnetic fields. Such a framework can be put in place by Council recommendations under Article 129 of the EC Treaty, and should deal with the general principles of limitation of exposures so that adverse health effects can be prevented.

The aim of the proposal for a Council Recommendation is, therefore, to provide for a commonly agreed framework concerning a high level of protection against exposure of the general public to electromagnetic fields (EMFs), based on a set of basic restrictions and

¹⁶ COM(94) 145 final

¹⁷ The document "studyhr.doc" can be downloaded from the internet site <http://www.ispo.cec.be/infosoc/telecompoliy/en>

¹⁸ COM (97) 142 final, and OJ N° C 173, 7.6.97, p. 10

reference levels developed internationally by the foremost experts in this field. The proposed recommendations on basic restriction and reference levels follow the advice of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and are based on the best available scientific data. They concern exposure of individual members of the public and not emissions from specific devices or equipment. The advice of ICNIRP has been endorsed by the Commission's Scientific Steering Committee.

The proposed recommendation is not intended to apply to occupational exposure and exposure of patients and volunteers during medical procedures. Problems of electromagnetic compatibility and interference with medical devices are not addressed in this proposal. Providing for a comprehensive system of protection in this area which includes detailed provisions and guidelines relevant not only to the exposure of individuals but also to the emissions from equipment and the burden from practices involving such exposures should be the task of the Member States, account taken of Community provisions in this field.

The recommended basic restrictions are directly based on established health effects only. The reference levels are recommended to be used for practical exposure assessment purposes.¹⁹ Respect of reference levels will ensure respect of the relevant basic restriction. If the measured value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded. Under such circumstances, however, there is a need to establish whether the basic restriction has indeed been respected.

It is recommended that when an exceedance of reference levels occurs, an assessment of the exposure situation should be carried out; it is up to the Member States to arrange for assessments and follow-up actions. The assessment of the actual exposure situation could take criteria such as the duration of the exposure, the exposed parts of the body, the number of exposed members of the public, their age and health status into account. Follow-up actions would have to be decided by the Member States with respect to the specific exposure situation which might call for measures such as the provision of information for the public exposed, the establishment of minimum distances to be kept to the source of exposure, changes in the installation or design of the specific source, or in the way the source is operated. Member States might decide to consider cost-benefit aspects when such action in respect of the exposure of members of the public is undertaken.

Finally, in order to take timely stock of the regulatory and actual exposure situation and of any scientific or technological developments that may require a prompt response, the Commission proposes that the Member States prepare reports on their measures and guidelines in the field covered by the proposed recommendation, and indicating how the latter has been taken into account, and that an overall report be presented by the Commission based on the reports of the Member States.

¹⁹ A similar system has been proposed for health and safety requirements for the protection of workers where a framework of threshold values and action values was presented.

**PROPOSAL FOR A
COUNCIL RECOMMENDATION**

**on the limitation of exposure of the general public
to electromagnetic fields
0 Hz – 300 GHz**

(presented by the Commission)

THE COUNCIL OF THE EUROPEAN UNION;

Having regard to the Treaty establishing the European Community, and in particular Article 129 thereof;

Having regard to the proposal from the Commission¹,

Having regard to the opinion of the European Parliament²;

1. Whereas in accordance with point (o) of Article 3 of the Treaty, Community action must include a contribution towards the attainment of a high level of health protection;
2. Whereas the European Parliament in its resolution on combating the harmful effects of non-ionizing radiation³ called on the Commission to propose measures seeking to limit the exposure of workers and the public to non-ionizing electromagnetic radiation;
3. Whereas Community minimum requirements for the protection of health and safety of workers in relation to electromagnetic fields exist for work with display screen equipment⁴; whereas Community measures were introduced to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding⁵ which oblige, inter alia, employers to assess activities which involve a specific risk of exposure to non-ionizing radiation; whereas minimum requirements have been proposed for the protection of workers from physical agents⁶ which include measures against non-ionizing radiation;
4. Whereas it is imperative to protect members of the general public in the Community against established adverse health effects that may result as a consequence of exposure to electromagnetic fields;
5. Whereas measures with regard to electromagnetic fields should afford all Community citizens a high level of protection; whereas provisions by Member

¹ OJ xxx

² O.J. xxx

³ O.J. N° C 205, 25.7.94, p. 439

⁴ O.J. N° L 156, 21.6.90, p. 14-18

⁵ O.J. N° L 348, 28.11.92, p. 1-8

⁶ O.J. N° C 77, 18.3.93, p. 12 and O.J. N° C 230, 19.8.94, p. 3-29

States in this area should be based on a commonly agreed framework, so as to ensure consistency of protection throughout the Community;

6. Whereas in accordance with the principle of subsidiarity, any new measure taken in an area which does not fall within the exclusive competence of the Community, such as non-ionizing radiation protection of the public, may be taken up by the Community only if, by reasons of the scale or effects of the proposed action, the objectives proposed can be better achieved by the Community than by Member States;
7. Whereas there is a need to establish a Community framework for the protection of the public with regard to electromagnetic fields by means of recommendations to Member States.
8. Whereas this framework must be based on the best available scientific data and advice in this area and should comprise basic restrictions and reference levels on exposure to electromagnetic fields; whereas advice on this matter has been given by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and has been endorsed by the Commission's Scientific Steering Committee.
9. Whereas such basic restrictions and reference levels should apply to all radiations emitted by electromagnetic fields with the exception of optical radiation and ionizing radiation; whereas for the former relevant scientific data and advice still requires additional consideration, and whereas for the latter Community provisions already exist;
10. Whereas adherence to the recommended restrictions and reference levels should provide a high level of protection in respect of established health effects that may result from exposure to electromagnetic fields, but may not necessarily avoid interference problems with, or effects on the functioning of, medical devices such as metallic prostheses, cardiac pacemakers and defibrillators, and cochlear implants; whereas interference problems with pacemakers may occur at levels below the recommended reference levels and should be the object of appropriate precautions which, however, are not within the scope of this recommendation;

11. Whereas, in accordance with the principle of proportionality, this recommendation must set general principles and methods of protection for members of the public while leaving it to the Member States to provide for detailed rules for sources and practices giving rise to exposure to electromagnetic fields and the classification of conditions of exposure of individuals as work-related or not, account taken of and in accordance with, Community provisions concerning the safety and health protection of workers;
12. Whereas Member States may provide for a higher level of health protection than that reflected in these recommendations;
13. Whereas measures by the Member States in this area, whether binding or non-binding and the way they have taken into account these recommendations should be the object of reports at national and Community level;
14. Whereas in order to increase awareness of risks and measures of protection against electromagnetic fields the Member States should promote the dissemination of information and rules of practice in this field, in particular with regard to the design, installation and use of equipment, so as to aim to obtain that levels of exposure will not exceed the recommended restrictions;
15. Whereas attention should be paid to appropriate understanding and communication on risks related to electromagnetic fields taking into account public perceptions of such risks;
16. Whereas the Member States should take note of progress made in scientific knowledge and technology with respect to non-ionising radiation protection; whereas these recommendations should be reviewed in particular in the light of guidance by competent international organisations such as the International Commission on Non-Ionizing Radiation Protection;

HEREBY RECOMMENDS THAT

- I. Member States assign for the purpose of this Recommendation to the physical quantities listed in Annex I.A the meaning given to them therein;
- II. Member States, in order to provide for a high level of health protection against exposure to electromagnetic fields:
 - a) adopt a framework of basic restrictions and reference levels using as a basis that given in Annex I.B;
 - b) implement measures in respect of sources or practices giving rise to exposure of the general public to electromagnetic fields on the basis of such a framework;
 - c) aim to achieve respect of the basic restrictions given in Annex II for public exposure;
- III. Member States, in order to facilitate and promote respect of the basic restrictions given in Annex II:
 - a) use the reference levels given in Annex III for exposure assessment purposes to determine whether the basic restrictions are likely to be exceeded;
 - b) evaluate situations involving sources of more than one frequency in accordance with the formulas set up in Annex IV, both in terms of basic restrictions and reference levels;
- IV. Member States, in order to increase understanding of risks and protection against exposure to electromagnetic fields:

provide in an appropriate format information to the public on the health impact of electromagnetic fields and the measures taken to address them;

- V. Member States, in order to enhance knowledge about the health effects of electromagnetic fields

promote and review research relevant to EMF and human health in the context of their national research programmes, taking into account Community and international research recommendations and efforts,

- VI. Member States, in order to contribute to the establishment of a consistent system of protection against risks of exposure to electromagnetic fields:

prepare reports on the adoption and implementation of measures that they take in the field covered by this Recommendation, and inform the Commission thereof after a period of three years following the adoption of this Recommendation, indicating how the latter has been taken into account in these measures,

INVITES

the Commission to prepare a report for the Community as a whole taking into account the reports of the Member States, and keep the matters covered in this recommendation under review, with a view to its revision and updating.

Done at Brussels,

For the Council

The President

ANNEX I

DEFINITIONS

In the context of this recommendation, the term electromagnetic fields include static fields, extremely low frequency (ELF) fields and radiofrequency (RF) fields, including microwaves, encompassing the frequency range of 0 Hz to 300 GHz.

A. Physical Quantities

In the context of EMF exposure, eight physical quantities are commonly used:

1. *Contact current* (I_c) between a person and an object is expressed in amperes (A). A conductive object in an electric field can be charged by the field.
2. *Current density* (\mathbf{J}) is defined as the current flowing through a unit cross section perpendicular to its direction in a volume conductor such as the human body or part of it, expressed in amperes per square metre (A/m^2).
3. *Electric field strength* is a vector quantity (\mathbf{E}) that corresponds to the force exerted on a charged particle regardless of its motion in space. It is expressed in volts per metre (V/m).
4. *Magnetic field strength* is a vector quantity (\mathbf{H}), which, together with the magnetic flux density, specifies a magnetic field at any point in space. It is expressed in amperes per metre (A/m).
5. *Magnetic flux density* is a vector quantity (\mathbf{B}), resulting in a force that acts on moving charges, it is expressed in teslas (T). In free space and in biological materials, magnetic flux density and magnetic field strength can be interchanged using the equivalence $1 A m^{-1} = 4\pi \cdot 10^{-7} T$.
6. *Power density* (\mathbf{S}) is the appropriate quantity used for very high frequencies, where the depth of penetration in the body is low. It is the radiant power incident perpendicular to a surface, divided by the area of the surface and is expressed in watts per square metre (W/m^2).
7. *Specific energy absorption* (SA) is defined as the energy absorbed per unit mass of biological tissue, expressed in joules per kilogram (J/kg). In these recommendations it is used for limiting non-thermal effects from pulsed microwave radiation.
8. *Specific energy absorption rate* (SAR) averaged over the whole body or over parts of the body, is defined as the rate at which energy is absorbed per unit mass of the body tissue and is expressed in watts per kilogram (W/kg). Whole body SAR is a widely accepted measure for relating adverse thermal effects to RF exposure. Besides the whole body average SAR, local SAR values are necessary to evaluate and limit excessive energy deposition in small parts of the body resulting from special exposure conditions. Examples of such conditions are: a grounded individual exposed to RF in the low MHz range and individuals exposed in the near field of an antenna.

Of these quantities, magnetic flux density, contact current, electric and magnetic field strengths and power density can be measured directly.

B. Basic restrictions and reference levels

For the application of restrictions based on the assessment of possible health effects of electromagnetic fields, differentiation should be made between basic restrictions and reference levels.

Basic restrictions. Restrictions on exposure to time-varying electric, magnetic, and electromagnetic fields that are based directly on established health effects and biological considerations are termed "basic restrictions". Depending upon the frequency of the field, the physical quantities used to specify these restrictions are magnetic flux density (**B**), current density (**J**), specific energy absorption rate (SAR), and power density (**S**). Magnetic flux density and power density can be readily measured in exposed individuals.

Reference levels. These levels are provided for practical exposure assessment purposes to determine if the basic restrictions are likely to be exceeded. Some reference levels are derived from relevant basic restrictions using measurements and/or computational techniques and some address perception and adverse indirect effects of exposure to EMFs. The derived quantities are electric field strength (**E**), magnetic field strength (**H**), magnetic flux density (**B**), power density (**S**), and limb current (I_l). Quantities that address perception and other indirect effects are (contact) current (I_c) and, for pulsed fields, specific energy absorption (SA). In any particular exposure situation, measured or calculated values of any of these quantities can be compared with the appropriate reference level. Respect of the reference level will ensure respect of the relevant basic restriction. If the measured value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded. Under such circumstances, however, there is a need to establish whether there is respect of the basic restriction.

Quantitative restrictions on static electric fields are not given in these recommendations. However, it is recommended that annoying perception of surface electric charges and spark discharges causing stress or annoyance should be avoided.

Some quantities such as the magnetic flux density (**B**) and the power density (**S**) serve both as basic restrictions and reference levels, at certain frequencies (see Annex II and III)

ANNEX II

BASIC RESTRICTIONS

Depending on frequency, the following physical quantities (dosimetric / exposimetric quantities) are used to specify the basic restrictions on electromagnetic fields:

Between 0 and 1 Hz basic restrictions are provided for magnetic flux density for static magnetic fields (0 Hz) and current density for time varying fields up to 1 Hz, in order to prevent effects on the cardiovascular and central nervous system.

Between 1 Hz and 10 MHz basic restrictions are provided for current density to prevent effects on nervous system functions.

Between 100 kHz and 10 GHz basic restrictions on SAR are provided to prevent whole-body heat stress and excessive localised heating of tissues. In the range 100 kHz to 10 MHz, restrictions on both current density and SAR are provided.

Between 10 GHz and 300 GHz basic restrictions on power density are provided to prevent heating in tissue at or near the body surface.

The basic restrictions, given in Table 1, are set so as to account for uncertainties related to individual sensitivities, environmental conditions, and for the fact that the age and health status of members of the public vary.

Table 1: Basic restrictions for electric, magnetic and electromagnetic fields (0 Hz - 300 GHz).

Frequency range	Magnetic flux density (mT)	Current density (mA/m ²) (rms)	Whole body average SAR (W/kg)	Localised SAR (head and trunk) (W/kg)	Localised SAR (limbs) (W/kg)	Power density, S (W/m ²)
0 Hz	40	--	--	--	--	--
>0-1 Hz	--	8	--	--	--	--
1-4 Hz	--	8/f	--	--	--	--
4 - 1000 Hz	--	2	--	--	--	--
1000 Hz -100 kHz	--	f/500	--	--	--	--
100 kHz – 10 MHz	--	f/500	0.08	2	4	--
10 MHz – 10 GHz	--	--	0.08	2	4	--
10 - 300GHz	--	--	--	--	--	10

Notes

1. f is the frequency in Hz.
2. The basic restriction on the current density is intended to protect against acute exposure effects on central nervous system tissues in the head and trunk of the body and includes a safety factor
3. Because of electrical inhomogeneity of the body, current densities should be averaged over a cross section of 1 cm² perpendicular to the current direction.
4. For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by $\sqrt{2}$ (~1.414). For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$.
5. For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate basic restriction.
6. All SAR values are to be averaged over any 6-minute period.
7. Localized SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.
8. For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$. Additionally, for pulsed exposures, in the frequency range 0.3 to 10 GHz and for localised exposure of the head, in order to limit and avoid auditory effects caused by thermoelastic expansion, an additional basic restriction is recommended. This is that the SA should not exceed 2mJ kg⁻¹ averaged over 10 g of tissue.

ANNEX III

Reference Levels

Reference levels of exposure are provided for the purpose of comparison with values of measured quantities. Respect of all recommended reference levels will ensure respect of basic restrictions.

If the quantities of measured values are greater than the reference levels, it does not necessarily follow that the basic restrictions have been exceeded. In this case, an assessment should be made as to whether exposure levels are below the basic restrictions.

The reference levels for limiting exposure are obtained from the basic restrictions for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection. A summary of the reference levels is given in Tables 2 and 3. The reference levels are generally intended to be spatially averaged values over the dimension of the body of the exposed individual, but with the important proviso that the localised basic restrictions on exposure are not exceeded.

In certain situations where the exposure is highly localised, such as with hand-held telephones and the human head, the use of reference levels is not appropriate. In such cases respect of the localised basic restriction should be assessed directly.

Field levels

Table 2: Reference levels for electric, magnetic and electromagnetic fields (0 Hz - 300 GHz, unperturbed rms values).

Frequency range	E-field strength (V/m)	H-field strength (A/m)	B-field (μT)	Equivalent plane wave power density S_{eq} (W/m^2)
0-1 Hz	-	3.2×10^4	4×10^4	-
1-8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	-
8 - 25 Hz	10,000	$4,000/f$	$5,000/f$	-
0.025 - 0.8 kHz	$250/f$	$4/f$	$5/f$	-
0.8 - 3 kHz	$250/f$	5	6.25	-
3 - 150 kHz	87	5	6.25	-
0.15 - 1 MHz	87	$0.73/f$	$0.92/f$	-
1-10 MHz	$87/f^{1.2}$	$0.73/f$	$0.92/f$	-
10 - 400 MHz	28	0.073	0.092	2
400 - 2000 MHz	$1.375 f^{1.2}$	$0.0037 f^{1.7}$	$0.0046 f^{1.2}$	$f/200$
2 - 300 GHz	61	0.16	0.20	10

Notes:

1. f as indicated in the frequency range column.
2. For frequencies between 100 kHz and 10 GHz, S_{eq} , E^2 , H^2 , and B^2 are to be averaged over any 6-minute period.
3. For frequencies exceeding 10 GHz, S_{eq} , E^2 , H^2 , and B^2 are to be averaged over any $68/f^{1.05}$ -minute period (f in GHz).
4. No E-field value is provided for frequencies < 1 Hz, which are effectively static electric fields. For most people the annoying perception of surface electric charges will not occur at field strengths less than 25 kV/m. Spark discharges causing stress or annoyance should be avoided.

For peak values, the following reference levels apply to the E-field strength (V/m), H-field strength (A/m) and the B-field (μT):

For frequencies up to 100 kHz, peak reference values are obtained by multiplying the corresponding rms values by $\sqrt{2}$ (1.414). For pulses of duration t_p , the equivalent frequency to apply should be calculated as $f_{\text{eq}} = 1/(2t_p)$.

- For frequencies between 100 kHz and 10 MHz peak reference values are obtained by multiplying the corresponding rms values by 10^α , where $\alpha = (0.665 \log(f/10^5) + 0.176)$, f in kHz.

- For frequencies between 10 MHz and 300 GHz peak reference values are obtained by multiplying the corresponding rms values by 32.

Although little information is available on the relation between biological effects and peak values of pulsed fields, it is suggested that, for frequencies exceeding 10 MHz, S_{eq} as averaged over the pulse width should not exceed 1000 times the reference levels or that field strengths should not exceed 32 times the fields strength reference levels. For frequencies between about 0.3 GHz and several GHz and for localised exposure of

the head, in order to limit or avoid auditory effects caused by thermoelastic expansion, the specific absorption from pulses must be limited. In this frequency range, the threshold SA of 4-16 mJ kg⁻¹ for producing this effect corresponds, for 30- μ s pulses, to peak SAR values of 130-520 W kg⁻¹ in the brain. Between 100 kHz and 10 MHz, peak values for the fields strengths are obtained by interpolation from the 1.5-fold peak at 100 kHz to the 32-fold peak at 10 MHz.

Contact currents and limb currents

For frequencies up to 110 MHz additional reference levels are recommended to avoid hazards due to contact currents. The contact current reference levels are presented in Table 3. The reference levels on contact current were set to account for the fact that the threshold contact currents that elicit biological responses in adult women and children are approximately two-thirds and one-half, respectively, of those for adult men.

Table 3: Reference levels for contact currents from conductive objects (f in kHz)

Frequency range	Maximum contact current (mA)
0 Hz - 2.5 kHz	0.5
2.5 kHz - 100 kHz	0.2 f
100 kHz - 110 MHz	20

For the frequency range 10 MHz to 110 MHz, a reference level of 45 mA in terms of current through any limb is recommended. This is intended to limit the localised SAR over any 6-minute period.

ANNEX IV

Exposure from sources with multiple frequencies

In situations where simultaneous exposure to fields of different frequencies occurs, the possibility that these exposures will be additive in their effects must be considered. Calculations based on such additivity should be performed separately for each effect; thus separate evaluations should be made for thermal and electrical stimulation effects on the body.

Basic restrictions

In the case of simultaneous exposure to fields of different frequencies, the following criteria should be satisfied in terms of the basic restrictions.

For electric stimulation, relevant for frequencies from 1 Hz up to 10 MHz, the induced current densities should be added according to:

$$\sum_{i=1\text{Hz}}^{10\text{MHz}} \frac{J_i}{J_{L,i}} \leq 1$$

For thermal effects, relevant from 100 kHz, specific energy absorption rates and power densities should be added according to:

$$\sum_{i=100\text{kHz}}^{10\text{GHz}} \frac{\text{SAR}_i}{\text{SAR}_L} + \sum_{i=10\text{GHz}}^{300\text{GHz}} \frac{S_i}{S_L} \leq 1$$

where

J_i is the current density at frequency i ;

$J_{L,i}$ is the current density basic restriction at frequency i as given in Table I;

SAR_i is the SAR caused by exposure at frequency i ;

SAR_L is the SAR basic restriction given in Table I;

S_i is the power density at frequency i ;

S_L is the power density basic restriction given in Table I.

Reference levels

For application of the basic restrictions, the following criteria regarding reference levels of field strengths should be applied.

For induced current densities and electrical stimulation effects, relevant up to 10 MHz, the following two requirements should be applied to the field levels:

$$\sum_{i=10\text{Hz}}^{1\text{MHz}} \frac{E_i}{E_{L,i}} + \sum_{i=1\text{MHz}}^{10\text{MHz}} \frac{E_i}{a} \leq 1$$

and

$$\sum_{j=10\text{Hz}}^{150\text{kHz}} \frac{H_j}{H_{L,j}} + \sum_{j=150\text{kHz}}^{10\text{MHz}} \frac{H_j}{b} \leq 1$$

where

E_i is the electric field strength at frequency i ;

$E_{L,i}$ is the electric field strength reference level from Table 2;

H_j is the magnetic field strength at frequency j ;

$H_{L,j}$ is the magnetic field strength reference level from Table 2;

a is 87 V/m and b is 5 A/m (6.25 μ T).

Compared to the ICNIRP guidelines¹ which deal with both occupational and general public exposure, cutoff points in the summations correspond to exposure conditions for members of the public.

The use of the constant values (a and b) above 1 MHz for the electric field and above 150 kHz for the magnetic field is due to the fact that the summation is based on induced current densities, and should not be mixed with thermal effect circumstances. The latter forms the basis for $E_{L,i}$ and $H_{L,j}$ above 1 MHz and 150 kHz respectively, found in Table 2.

¹ International Commission on Non-Ionizing Radiation Protection. Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz). Health Phys., in press

For thermal effect circumstances, relevant from 100 kHz, the following two requirements should be applied to the field levels:

$$\sum_{i=100\text{kHz}}^{1\text{MHz}} \left(\frac{E_i}{c} \right)^2 + \sum_{i=1\text{MHz}}^{300\text{GHz}} \left(\frac{E_i}{E_{L,i}} \right)^2 \leq 1$$

and

$$\sum_{j=100\text{kHz}}^{150\text{kHz}} \left(\frac{H_j}{d} \right)^2 + \sum_{j=150\text{kHz}}^{300\text{GHz}} \left(\frac{H_j}{H_{L,j}} \right)^2 \leq 1$$

where

E_i is the electric field strength at frequency i ,

$E_{L,i}$ is the electric field reference level from Table 2,

H_j is the magnetic field strength at frequency j ,

$H_{L,j}$ is the magnetic field reference level derived from Tables 2,

c is $87/\text{f}^{1/2}$ V/m and d $0.73/\text{f}$ A/m

Again, compared to the ICNIRP guidelines some cutoff points have been adjusted for public exposure only.

For limb current and contact current, respectively, the following requirements should be applied:

$$\sum_{k=10\text{MHz}}^{110\text{MHz}} \left(\frac{I_k}{I_{L,k}} \right)^2 \leq 1 \quad \sum_{n=1\text{Hz}}^{110\text{MHz}} \frac{I_n}{I_{C,n}} \leq 1$$

where

I_k is the limb current component at frequency k ,

$I_{L,k}$ is the reference level for limb current, 45 mA,

I_n is the contact current component at frequency n ,

$I_{C,n}$ is the reference level for contact current at frequency n (see Table 3).

The above summation formulae assume worst-case phase conditions among the fields from the multiple sources. As a result, typical exposure situations may in practice result in less restrictive exposure levels than indicated by the above formulae for the reference levels.

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