» Draft proposal for a Council Reccomendation »

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

(presented by the Commission) EXPLANATORY MEMORANDUM INTRODUCTION

Introduction

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 fields 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 possible adverse effects. Such concern 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 national and international regulations and guidelines. There is no convincing scientific evidence of EMFs causing cancer, and recommendations for limiting exposure are based solely on well-established acute effects.

The main aim of a Council Recommendation in this area of public health is to ensure an adequate level of protection against exposure of the general public to electromagnetic fields (EMFs) by providing a system of protection based on the set of basic restrictions and reference levels as published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)*). The recommended restrictions are based on robust scientific data, and currently available knowledge indicates that these restrictions provide an adequate level of protection. These restrictions are intended to limit the exposure of people and not the emissions from specific devices.

The recommendation is intended to apply to the general public; it excludes occupational exposure and exposure of patients and volunteers during medical procedures. Problems of electromagnetic compatibility are not addressed in this Council Recommendation

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 may involve exposure to static and slowly time varying fields. For instance, significant electric fields may exist close to visual display units (VDUs). People can be exposed to static fields also in some public transportation systems, e.g. in underground trains and tramways, which utilize DC supplies. Static magnetic fields ranging from 50 m T to 10 mT have been measured inside modern magnetic levitation (Maglev) trains.

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 m T 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 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 m T during acceleration of the train. The amount of traction current depends on the power consumption of the engine needed to accelerate any given type of train, with the result that magnetic fields 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. Dosimetric measurements or numerical calculations may be used to show that the basic restriction is not exceeded.

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 matter (UNEP/WHO/IRPA 1993):

- 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.

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/m^2. At higher levels of induced current density (10–100 mA/m^2), 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/m^2 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 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 end-points 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 these data, 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 excercised 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 the actual restrictions to exposure.

OVERVIEW OF RELEVANT MEASURES TAKEN BY MEMBER STATES

Only a few Member States have promulgated standards for the protection of the general public against electromagnetic radiation.

Some Member States established recommendations or compulsory provisions for either low or high frequency electromagnetic fields, or both. 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

By virtue of Articles 3(o) and 129 of the Treaty establishing the European Community, the protection of health has been made a priority. To this end, Community's role is to contribute towards ensuring a high level of health protection, directing actions towards the prevention of diseases.

The European Parliament adopted in 1994 a resolution on combating the harmful effects of non-ionizing radiation (OJ No C 205, 25.7.94) 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 light of its framework for action in the field of public health (COM (93) 559 final), the Commission adopted in 1997 a proposal for a programme of Community action 1999-2003 on pollution-related diseases (OJ No C 214, 16.7.97). The Commission, aware that risks perceived by the public sometimes widely differ from what is suggested by scientific evidence, proposed to tackle this problem with actions targeted to improve the collective capacity of the Member States to analyse public perceptions of environmental health risks, and better explain how they are assessed and managed. This is of particular importance to health risks associated with exposure to electromagnetic fields.

Health and Safety at Work

Community Minimum requirements designed to encourage improvements, especially in the working environment, to ensure the protection of workers' health and safety fall under the scope of Article 118a of the Treaty by which Member States are free to adopt more stringent health and safety requirements.

Health and safety protection requirements for work with display screen equipment were adopted in 1990. Council Directive 90/270/EEC (OJ L 156, 21.6.90) obliges employers take appropriate steps to ensure that workstations, i.e. an assembly of visual display units, keyboards, accessories and periphals including telephone, modem and printer, meet minimum requirements. All radiation with exception of the visible part of the electromagnetic spectrum shall be reduced to negligible levels from the point of view of the protection of workers' safety and health.

Council Directive 92/85/EEC on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers was adopted in order to protect particularly sensitive groups of workers against hazards which specifically affect them (OJ No L 348, 28.11.92). 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. He has to look into the nature, degree and duration of exposure, in order to decide what measures should be taken.

The Commission presented first in 1993 a proposal for a Council Directive on the minimum Health and Safety requirements regarding the exposure of workers arising from physical agents (OJ No C 77, 18.3.93). The physical agents to which the Directive would apply are noise, mechanical vibration, optical radiation, and fields and waves. The proposed Directive, which was amended subsequent to the opinion of the European Parliament in a first reading (OJ No C 230, 19.8.94) 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 300GHz.

Product Safety

A clear distinction between Directives setting out minimum requirements for health protection on the one hand, and Directives and standards setting out essential requirements which must be met by products, machinery and equipment, on the other hand, has to be made.

It is under Article 100a of the Treaty that the Commission may propose to harmonise national legislation as regards safety levels for equipment generating electric or magnetic fields. To this end, Member States cannot impose stricter safety levels than those set by the European authorities under Article 100a legislation, as this would constitute a breach of Article 30 that forbids Member States to create trade barriers. Stricter requirements may, however, be introduced in certain cases, if they are compatible with Article 36, the Treaty's safeguard clause.

Council Directive 73/23/EEC on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits (OJ No L 077, 26.3.73) and specially Annex 1 thereof establishes that electrical equipment may be placed onto the market only if it complies with certain essential requirements. Amongst these requirements, measures have to be prescribed in order to ensure that temperatures, arcs or radiation which would cause danger are not produced.

Council Directive 89/336/EEC on the approximation of the laws of the Member States relating to electromagnetic compatibility (OJ No L 139, 23.05.89) 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

Pursuant to Article 130r of the Treaty, Community policy on the environment is to contribute to the preservation, protection and improvement of the quality of the environment, the protection of human health and the prudent and rational utilisation of natural resources. It should be based on the precautionary principle, and the assessment of the environmental impact from certain projects has been made a fundamental instrument of Community policy in relation to the environment and sustainable development.

Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment (OJ No L 175, 5.7.85) as amended by Council Directive 97/11/EC (OJ No L 73, 14.3.97) now 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 environment (COM (96) 511 final). 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

In response to the European Parliament's resolution on combating the harmful effects of non-ionizing radiation (OJ No C 205, 25.7.94), a review document on sources, exposure and potential health effects of non-ionizing radiation was published (European Commission, DG V, Office for Official Publications of the European Communities, 1996, ISBN 92-827-5492-8).

Potential adverse health effects from exposure to radiofrequencies were, next to the importance and priority attached to the telecommunications sector, addressed in the Commission's Green Paper on a common approach in the field of mobile and personal communications (COM (94) 145 final). 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.

A working group of experts elaborated for the Commission a pertinent proposal with recommendations for epidemiological, biophysical and biological research, and also for research on exposure systems and dosimetry. The proposed research agenda covers also effects on the immune system, nervous system-related effects, and genetic and cancer-related effects. These have been and still are of highest concern to the public.

The Commission considered the experts' recommendations when drawing up its proposal concerning the 5th framework programme of the European Community for research, technological development and demonstration activities (1998-2002) (COM (97) 142 final). Moreover, the Commission recognises that risk communication is clearly as important in this area of uncertain risk and unestablished long-term effects as it is with other aspects of electromagnetic field exposures.

To this end, the Commission highlights the importance of both, gaining a better understanding of the public's risk perception, the assessment, communication and management of risks, and the need for further research on possible adverse health effects from exposure to electromagnetic fields.

CONCLUDING REMARKS

Requirements that exist in some Member States result in varying situations as regards the public's protection against electromagnetic fields in the Community. These existing variations among Member States contribute to a lack of 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 approaches taken by Member States, the Commission considers it important to provide Member States with a common framework of basic restrictions and reference levels for exposure limits of the general public to electromagnetic fields, and to be introduced by Member States based on agreed recommendations.

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.*)

D R A F T COMMISSION PROPOSAL FOR A COUNCIL RECOMMENDATION

on limits for exposure of the general public

to electromagnetic fields

THE COUNCIL OF THE EUROPEAN UNION;

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

of;

Having regard to the proposal from the Commission, Having regard to the opinion of the European Parliament; 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;

- Whereas the European Parliament in its resolution on combating the harmful effects of non-ionizing radiation called on the Commission to propose measures seeking to limit the exposure of workers and the public to non-ionizing electromagnetic radiation;
- Whereas Community minimum requirements for the protection of health and safety of workers in relation to electromagnetic fields exist for work with display screen equipment; 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 breastfeeding; whereas minimum requirements have been proposed for the protection of workers from physical agents;

- Whereas health protection of the general public in the Community is intended to prevent adverse health effects that have been well established as a consequence of exposure to electromagnetic fields;
- 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 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;
- Whereas the general public requires the same level of health protection against electromagnetic fields throughout the Community; whereas diverse health protection requirements in Member States would cause a loss of confidence amongst European citizens;
- Whereas agreement on recommendations for the protection of the general public against electromagnetic fields will help to ensure, throughout the Community, a consistent system of health protection which would bring benefit to the confidence of the public;
- Whereas such a system of protection should be based on a set of basic restrictions and reference levels;
- Whereas the basic restrictions and reference levels on exposure recommended should establish a framework of equivalent protection in the Community;
- Whereas adherence to the recommended reference levels may not necessarily preclude interference with, or effects on, medical devices such as metallic prostheses, cardiac pacemakers and defibrillators, and cochlear implants. Interference with pacemakers may occur at levels below the recommended reference levels. Advice on avoiding these problems is beyond the scope of this recommendation;
- Whereas in accordance with the principle of proportionality, the means to be deployed for implementing this recommendation must be in proportion to the objective pursued;
- Whereas the competent authorities in the Member States shall determine the details of the implementation of the recommended basic restrictions and reference levels on public exposure;
- Whereas potential sources of electromagnetic fields should be so designed, installed or used as to result in levels of exposure not exceeding basic restrictions;
- Whereas attention should be paid to an appropriate communication of risks related to electromagnetic fields taking into account the existing perceptions of the public;
- Whereas competent authorities should take notice of progress made in scientific knowledge and technology with respect to non-ionising radiation protection; whereas in the light of this progress the recommended system of health protection should be evaluated in cooperation with appropriate 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 to prevent the general public from exposure to electromagnetic fields on the basis of such a framework;

c) apply the basic restrictions given in Annex II for public exposure;

III. Member States, in order to facilitate and promote compliance with the basic restrictions given in Annex II:

a) use the reference levels given in Annex III for practical 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 research relevant to EMF and human health in the context of their national research programmes, taking into account Community and international research recommendations and research efforts of Community level;

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 implementation of measures that they take pursuant to this Recommendation and inform the Commission thereof after a period of three years following the adoption of this Recommendation;

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:

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.

Current density (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).

Electric field strength is a vector quantity (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).

Magnetic field strength is a vector quantity (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).

Magnetic flux density is a vector quantity (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 = 4p 10^{-7} T.

Power density (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).

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.

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 practical application of restrictions based on the assessment of possible health effects of electromagnetic fields, it is useful to differentiate 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 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 (IL). Quantities that address perception and other indirect effects are (contact) current (IC) 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. Compliance with the reference level will ensure compliance with 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 compliance with the basic restriction.

Quantitative restrictions on static electric fields are not provided 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

Restrictions on the effects of exposure are based on biological considerations and are termed 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 are set sufficiently below the levels of concern 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**	**Current density for head and trunk (mA/m^2) (rms)**	**Whole body average SAR (W/Kg)**	**Localised SAR (haed 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 - 300 GHz	-	-	-	-	-	10

Notes:

f is the frequency in Hz.

Because of electrical inhomogeneity of the body, current densities should be averaged over a cross section of 1 cm^2 perpendicular to the current direction.

For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by Ö2 (~1.414). For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$.

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.

All SAR values are to be averaged over any 6-minute period.

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.

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 hand, 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. To protect against adverse health effects, these basic restrictions should not be exceeded.

ANNEX III

Reference Levels

Reference levels of exposure are provided for the purpose of comparison with values of measured quantities. Compliance with all reference levels provided in this document will ensure compliance with basic restrictions.

Note: If the measured values are greater, it does not necessarily follow that the basic restrictions have been exceeded. In this case, an assessment should be made as to whether the exposure complies with 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 provision 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 compliance with 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 (mT)	Equivalent plane wave power density Seq (W/m^2)
0 - 1 Hz	-	$3.2x10^4$	$4x10^4$	-
1 -8 Hz	10,000	$3.2x10^4/f^2$	$4x10^4/f^2$	-
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	-
13 - 150 kHz	87	5	6.25	-
0.15 - 1 MHz	87	0.73/f	0.92/f	-
1 - 10 MHz	87/f1/2	0.73/f	0.92/f	-
10 - 400 MHz	28	0.073	0.092	-
400 - 2000 MHz	1.375 $f^{1/2}$	0.037 $f^{1/2}$	0.0046 $f^{1/2}$	f/200
2 - 300 GHz	61	0.16	0.20	10

Notes:

f as indicated in the frequency range column.

For frequencies between 100 kHz and 10 GHz, S_{eq}, E^2, H^2, and B^2 are to averaged over any 6-minute period.

For frequencies exceeding 10 GHz, Seq, E^2 , H^2 and B^2 are to be averaged over any $68/f^{1.05}$-minute period (f in GHz).

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 Ö2 (~1.414). For pulses of duration t_p the equivalent frequency to apply should be calculated as $f = 1/(2t_p)$.
- For frequencies between 100 kHz and 10 MHz peak reference values are obtained by multiplying the corresponding rms values by 10^a , where ^{a} = (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-µs 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 shall be met 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:

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

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

$$\sum_{i=100kHz}^{10GHz} \frac{SAR_i}{SAR_L} + \sum_{i>10GHz}^{300GHz} \frac{S_i}{S_L} \leq 1$$

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 1;

SAR_i is the SAR caused by exposure at frequency i;

SAR_L is the SAR basic restriction given in Table 1;

S_i is the power density at frequency i;

S_L is the power density basic restriction given in Table 1.

Reference levels

For practical 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:

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

and

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

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 µT).

Compared to the ICNIRP guidelines*) which deal with both occupational and general public exposure, Cutoff points in the summations correspond to exposure conditions for members of the public have been adjusted for public exposure only.

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. For thermal effect circumstances, relevant from 100 kHz, the following two requirements should be applied to the field levels: and where Ei is the electric field strength at frequency i; $E_{L, i}$ is the electric field reference level from Table 2;

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

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

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 $87/f^{1/2}$ V/m and d 0.73/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:

$$\sum_{k=10MHz}^{110MHz} \left(\frac{I_k}{I_{L,k}}\right)^2 \leq 1$$

$$\sum_{n>1Hz}^{110\,MHz} \left(\frac{I_n}{I_{cn}}\right)^2 \leq 1$$

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.