BS EN 50499:2008

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# Procedure for the assessment of the exposure of workers to electromagnetic fields

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## National foreword

This British Standard is the UK implementation of EN 50499:2008.

The UK participation in its preparation was entrusted to Technical Committee GEL/106, Human exposure to low frequency and high frequency electromagnetic radiation.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.



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**Compliance with a British Standard cannot confer immunity from legal obligations.**

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EUROPEAN STANDARD

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**EN 50499**

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English version

# Procedure for the assessment of the exposure of workers to electromagnetic fields

Procédure pour l'évaluation de l'exposition des travailleurs aux champs électromagnétiques

Verfahren für die Beurteilung der Exposition von Arbeitnehmern gegenüber elektromagnetischen Feldern

This European Standard was approved by CENELEC on 2008-10-21. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

**Central Secretariat: rue de Stassart 35, B - 1050 Brussels**



Ref. No. EN 50499:2008 E

## Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 106X, Electromagnetic fields in the human environment.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50499 on 2008-10-21.

The following dates were fixed:

| | | |
|---|---|---|
| – latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2009-11-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2011-11-01 |

This European Standard has been prepared under Mandate M/351 given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EC Directive 2004/40/EC.

This standard is intended to be a standard under which other standards related to the assessment of a work place can be used.

The approaches outlined in this standard, are intended to be simple, allowing most employers to make an assessment with the minimum of technical knowledge and effort.

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## 1 Scope

The scope of this European Standard is to provide a general procedure in order to assess workers' exposure to electric, magnetic and electromagnetic fields in a work place to demonstrate compliance with exposure limit values and action values as stated in the Council and European Parliament Directive 2004/40/EC.

The purpose of this European Standard is to

- specify how to perform an initial assessment of the levels of workers' exposure to electromagnetic fields (EMF), if necessary including specific exposure assessment of such levels by measurements and/or calculations,

- determine whether it is necessary to carry out a detailed risk assessment of EMF exposure.

This European Standard can be used by employers for the risk assessment and, where required, measurement and/or calculation of the exposure of workers. Based on specific workplace standards it can be determined whether preventive measures/actions must be taken to comply with the provisions of the Directive.

The frequencies covered are from 0 Hz to 300 GHz.

NOTE 1 This European Standard is written under Mandate M/351 and relates to the exposure limits as specified in the Directive 2004/40/EC. It is intended to protect workers from risks to their health and safety arising or likely to arise from exposure to electromagnetic fields (0 Hz to 300 GHz) during their work. However, this and other directives may include additional measures for the protection of specific groups of workers and/or specific work places for which the employer is required to investigate other protective measures as a part of the overall risk assessment. See Annex A.

NOTE 2 The Council and European Parliament Directive 2004/40/EC will be transposed into national legislation in all the EU member countries. It is recommended that users of this standard consult the national legislation related to this transposition in order to identify the national regulations and requirements. These national regulations and requirements may have additional requirements that are not covered by this standard.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 50371, *Generic standard to demonstrate the compliance of low power electronic and electrical apparatus with the basic restrictions related to human exposure to electromagnetic fields (10 MHz ± 300 GHz) ± General public*

EN 50400, *Basic standard to demonstrate the compliance of fixed equipment for radio transmission (110 MHz ± 40 GHz) intended for use in wireless telecommunication networks with the basic restrictions or the reference levels related to general public exposure to radio frequency electromagnetic fields, when put into service*

EN 50413, *Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz ± 300 GHz*)

EN 60335-2-29, *Household and similar electrical appliances ± Safety ± Part 2-29: Particular requirements for battery chargers* (IEC 60335-2-29)

EN 60335-2-45, *Household and similar electrical appliances ± Safety ± Part 2-45: Particular requirements for portable heating tools and similar appliances* (IEC 60335-2-45)

EN 60745-1, *Hand-held motor-operated electric tools ± Safety ± Part 1: General requirements* (IEC 60745-1, mod.)

EN 61029-1, *Safety of transportable motor-operated electric tools ± Part 1: General requirements* (IEC 61029-1, mod.)

EN 62226-1, *Exposure to electric or magnetic fields in the low and intermediate frequency range ± Methods for calculating the current density and internal electric field induced in the human body ± Part 1: General* (IEC 62226-1)

EN 62226-2-1, *Exposure to electric or magnetic fields in the low and intermediate frequency range ± Methods for calculating the current density and internal electric field induced in the human body ± Part 2-1: Exposure to magnetic fields ± 2D models* (IEC 62226-2-1)

EN 62226-3-1, *Exposure to electric or magnetic fields in the low and intermediate frequency range ± methods for calculating the current density and internal electric field induced in the human body ± Part 3-1: Exposure to electric fields ± Analytical and 2D numerical models* (IEC 62226-3-1)

EN 62311, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz ± 300 GHz)* (IEC 62311, mod.)

ETSI TR 101 870, *Fixed radio transmitter sites ± Exposure to non-ionising electromagnetic fields ± Guidelines for working conditions*

1999/519/EC, *Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)*

2004/40/EC, *Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)*

Further information on the scopes of these standards can be obtained from a national standardisation body who is a member of CENELEC or at the CENELEC web site www.cenelec.eu.

## 3 Terms and definitions

**3.1**
**action values**
magnitude of directly measurable parameters provided in terms of electric field strength (*E*), magnetic field strength (*H*), magnetic flux density (*B*) and power density (*S*), contact current and limb induced current at which one or more of the specified measures in this Directive must be undertaken. Compliance with these values will ensure compliance with the relevant exposure limit values (from 2004/40/EC)

**3.2**
**employer**
any natural or legal person who has an employment relationship with the worker and has responsibility for the undertaking and/or establishment (from 89/391/EEC)

**3.3**
**equipment**
for the purpose of this standard, the term equipment is understood in a broad sense covering all sources of electromagnetic emission, including devices, products, instrumentation, installations and prototypes under development

**3.4**
**exposure**
exposure occurs whenever and wherever a person is subjected to external electric, magnetic or electromagnetic fields or to contact current

**3.5**
**exposure limits**
guideline or restriction values on exposure that are given in international or national standards, guidelines or directives on human exposure to electromagnetic fields. For Directive 2004/40/EC the exposure limits are the action values and the exposure limit values and also the other specific requirements in that directive to avoid other risks related to workplace exposure to electromagnetic fields

**3.6**
**exposure limit values**
limits on exposure to electromagnetic fields which are based directly on established health effects and biological considerations. Compliance with these limits will ensure that workers exposed to electromagnetic fields are protected against all known adverse health effects (from 2004/40/EC)

**3.7**
**risk assessment**
process of determining compliance of a work place environment with the limits set in the Directive 2004/40/EC by performing the actions stated in Article 4 of the Directive 2004/40/EC

**3.8**
**work place**
location where workers have access as part of their duties

**3.9**
**worker**
any person employed by an employer, including trainees and apprentices but excluding domestic servants (from 89/391/EEC)

## 4 General considerations on assessment

### 4.1 Introduction

This clause describes the general concept of an initial assessment of a work place, how to compare assessment results with the action values and exposure limits, and further actions if needed.

The exposure to be assessed is at the work place(s) where a worker is permitted to be present. Work place exposure level is assessed at locations (“work spaces”) to which a worker would have access as part of their duties, and its contributors are emissions from equipment affecting that location.

Other health and safety issues covered by the Directive, in particular workers with active implanted medical devices (AIMDs), pregnant workers, and indirect effects shall be addressed, e.g. as outlined in Annex A.

Annex B offers two forms that may be used to document the result of the assessment.

### 4.2 Overview of risk assessment procedure

The flowchart presented in Figure 1 shows graphically the assessment process. Prior to commencing the assessment process, and in order to determine what level of work place assessment, if any, is necessary the work place must first be characterised. This requires the employer to establish what electrical equipment exists in the work place and is emitting electromagnetic fields into the work place.

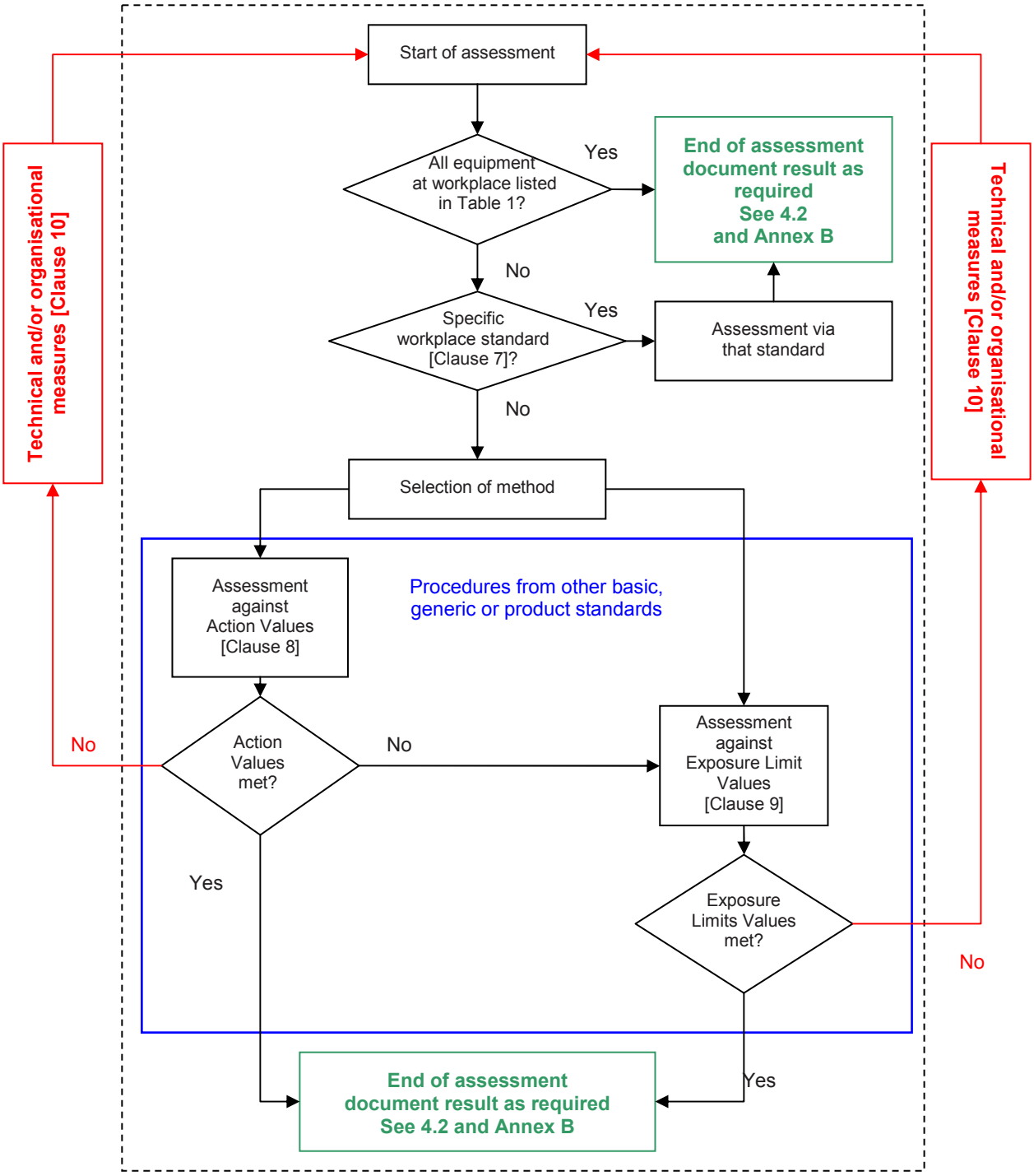
The first decision box of Figure 1 relates to compliant equipment. Most work places will contain only electrical equipment which either does not produce electromagnetic fields or produces them at levels below general public exposure limits. These work places will require no further assessment. Clause 5 defines which electrical equipment can be excluded from detailed exposure assessment. Table 1 defined in Clause 5 provides examples of such equipment. It includes in particular any equipment which has been placed on the European market in compliance with the relevant community directives. Examples of EMF related harmonised standards are listed in Annex C.

NOTE Zoning concepts defined when the compliance of the equipment was assessed can be implemented in agreement with Annex G.

Table 2 in Clause 6 gives a non-exhaustive list of equipment which is likely to require further assessment In preparation for this, the employer should identify the type of equipment in the work place, characteristics (e.g. frequency, emitted power, duty factor) and its normal conditions of use (e.g. normal position of operator, position of other workers than the operator, time spent at normal position, operations or maintenance or repair at distances from the emitting equipment closer than those recommended in the manufacturers instructions etc.). See Clause 6.

The term “normal” covers the intended use, the use as specified in the employers instructions to the workers, the installation(s) used, the instructions from the employer on how maintenance and repair shall be performed, situations of foreseeable incidents, and situations of foreseeable misuse.

Situations with simultaneous exposure to multiple sources and/or multiple frequencies shall be addressed. The employer can use the equations defined in Annex D, which provide a conservative way to demonstrate compliance with Directive 2004/40/EC. The employer may optionally use other appropriate methods e.g. time domain assessment procedures as provided in EN 62311 or the *TEQ* approach described in Annex E, which includes additional overestimation.




NOTE Optional measures to reduce exposure may be introduced at any point of the assessment in order to achieve compliance.

**Figure 1 ± Assessment process**

If a specific standard is applicable to the working environment or type of work place, then it is recommended to use that for the assessment. See Clause 7. If this standard contains other exposure limits than those stated in the Directive then the exposure limits from the Directive shall be applied.

If no such standard exists or if the employer considers it unsuitable then an exposure assessment shall be performed either against action values (see Clause 8) or directly against exposure limits (see Clause 9) using procedures from other basic, generic or product standards.

NOTE For some equipment considered in the assessment of the work place it may be appropriate to undertake an assessment against the exposure limits directly, and specific assessment standards for that equipment will indicate how that should be done. Other equipment in the same work place may be assessed by comparison with the action values.

When comparison is made between the measured exposure levels and the action values or exposure limits, then it may be appropriate to take into account the duration of exposure under normal working conditions, and also the duty cycle of the emission(s) from the equipment in the work place. In general time-averaging can be applied above 10 MHz, and cannot be applied below 100 kHz. Between these frequencies it may be permissible to apply time-averaging subject to constraints on maximum instantaneous exposure. For frequencies between 100 kHz and 10 MHz exposure limits based on *SAR* can be time averaged but exposure limits based on induced current in the central nervous system cannot. This is described more fully in generic or specific standards e.g. in EN 62311.

When measurements or calculations are used for a detailed exposure assessment, uncertainty analysis shall be performed according to the specific assessment method or standard applied.

If the assessment indicates that exposures in the work place do not meet the exposure limit values of the Directive, then measures must be taken to ensure that they do (see Clause 10) and the assessment process repeated until compliance is attained.

### 4.3 Indirect effects

The employer shall give particular attention, when carrying out the risk assessment, to any indirect effects as defined in Article 4, Clause 5(d) of the Directive 2004/40/EC. Information about the specific standards dealing with indirect effects can be found in Annex A.

### 4.4 Uncertainty for assessments using Clauses 7, 8 and 9

As a part of the assessment process measurements and/or calculations shall be associated with an uncertainty evaluation. Assessment uncertainty shall be reported (see Annex B) and it shall be taken into account when performing compliance evaluation according to national regulation in relation to the implementation of the directive.

## 5 Initial assessment

If the work place is affected only by equipment listed in Table 1 that work place is deemed to comply with this standard without further assessment. This is valid regardless of the number of pieces of electrical equipment present at the work place.

To be considered within this initial assessment the equipment must have been installed and must be used in accordance with the manufacturers´ instructions. Exposure situations for example during maintenance and production of equipment may be different from the exposure during normal usage of the equipment and should be assessed separately. In some situations a reassessment of exposure may be necessary after maintenance/repair/modification of an equipment.

Low power equipment that can be shown to comply with EN 50371, see note, is covered by Table 1 even if it is not CE-marked.

NOTE EN 50371 limits the frequency range to 10 MHz – 300 GHz and the transmitted power to 20 mW average and 20 W peak.

**Table 1 ± A priori compliant workplaces and equipment**

| Item | Designation of work place | Type of equipment | Remarks |
|---|---|---|---|
| T.1.1 | Work places open to the general public covered by 4.3 of Directive 2004/40/EC | | Work places open to the public and in compliance with the exposure limits given in the European Council recommendation 1999/519/EC are deemed to comply. |
| T.1.2 | All places | CE-marked equipment which have been assessed using the harmonised EMF standards see examples in Annex C. | Equipment must be installed and used in accordance with the manufacturers instructions. |
| T.1.3 | All places | Equipment placed on the European market in compliance with the European recommendation 1999/519/EC as required by the relevant directives in particular in compliance with their related harmonized standards listed in the OJEU. Examples are provided in Annex C. | Some equipment placed on the European market may also be compliant with the European recommendation 1999/519/EC although they have not received the CE marking, for example if it is part of an installation. |
| T.1.4 | All places | Lighting equipment | Excluding specialized RF energized lighting. |
| T.1.5 | All places | Computer and IT equipment | |
| T.1.6 | All places | Office equipment | Tape erasers may need further assessment. |
| T.1.7 | All places | Mobile phones, and cordless phones | |
| T.1.8 | All places | Two-way radios | Only types with time averaged emitted power less than 20 mW. |
| T.1.9 | All places | Base stations for DECT cordless phones and WLAN (e.g. Wi-Fi) | Limited to equipment intended for use by the general public. |
| T.1.10 | All places | Non - wireless communication equipment and networks | |
| T.1.11 | All places | Electric handheld and transportable tools | e.g. covered by the scope of EN 60745-1 and EN 61029-1 see Annex C. |

**Table 1 ± A priori compliant workplaces and equipment**
*(continued)*

| Item | Designation of work place | Type of equipment | Remarks |
|---|---|---|---|
| T.1.12 | All places | Portable heating tools | e.g. covered by the scope of EN 60335-2-45 (e.g. glue guns, heat guns)<br>See Annex C.<br><br>Induction heating tools and dielectric heating tools are excluded from Table 1. |
| T.1.13 | All places | Battery chargers | Covered by the scope of EN 60335-2-29. The scope covers chargers for normal household use and chargers intended for use in garages, shops, light industry and on farms<br>See Annex C. |
| T.1.14 | All places | Electric operated garden appliances | |
| T.1.15 | All places | Audio & video equipment | Special types using radio transmitters typically used by the broadcast industry may need further assessment. |
| T.1.16 | All places | Portable battery powered equipment not including radio frequency transmitters | |
| T.1.17 | All places | Electrical room heating equipment | Microwave heaters are excluded from this table. |
| T.1.18 | All places | All non-electrical equipment | |

**Table 1 ± A priori compliant workplaces and equipment**
*(continued)*

| Item | Designation of work place | Type of equipment | Remarks |
|---|---|---|---|
| T.1.19 | All places | Electricity supply networks (50 Hz) in the work place and electricity distribution and transmission circuits passing through or over the work place. The magnetic and electric field exposure are considered separately.<br><br>For magnetic field exposures the following are compliant:<br><br>• any electrical installation with a phase current rating of 100 A or less;<br>• any individual circuit within an installation, with a phase current rating of 100 A or less;<br>• any circuit where the conductors are close together and having a net current of 100 A or less;<br>• all components of the networks satisfying the criteria above are covered, (including the wiring, switchgear, transformers etc.);<br>• any overhead bare conductors.<br><br>For electric fields exposures the following are compliant:<br><br>• any underground or insulated cable circuit, rated at any voltage,<br>• any overhead bare circuit rated at a voltage up to 100 kV, or overhead line up to 125 kV, oversailing the work place, or at any voltage where the workplace is indoors. | The criteria given here for demonstrating compliance with work place exposure limits are based on demonstrating that the exposures are lower than the lower limits of the EC Recommendation (1999) of EMF exposures for the general public. These criteria are sufficient for demonstrating compliance in the majority of work places.<br><br>Assessment criteria, based directly on the work place exposure limits of the EC Directive, are given in Annex F. They use 500 A in place of 100 A, 200 kV instead of 100 kV and 250 kV instead of 125 kV. Thus the checklist in F.2.4 may be used for demonstrating compliance for magnetic fields, and F.3.1 may be used for demonstrating compliance for electric fields, in any work place. |
| T.1.20 | All places | Instrumentation, measurement and control equipment | |
| T.1.21 | All places | Household appliances | Professional appliances like cookers, laundry machines, microwave ovens etc. used in restaurants, shops etc. are also included in this table.<br><br>Professional inductive cooking equipment is excluded from this table and needs further assessment. |

**Table 1 ± A priori compliant workplaces and equipment**
*(continued)*

| Item | Designation of work place | Type of equipment | Remarks |
|---|---|---|---|
| T.1.22 | All places | Computer and IT terminal equipment having wireless communication | Examples are: WLAN (e.g. Wi-Fi), WMAN (e.g. WiMAX), Bluetooth and similar technologies.<br><br>Limited to equipment intended for use by the general public. |
| T.1.23 | All places | Battery driven transmitters | Limited to equipment intended for use by the general public. |
| T.1.24 | All places | Base stations antennas | Further assessment is only relevant if workers can get closer to the antenna than the defined safety distance in relation to the public exposure limits. |
| T.1.25 | Medical work places | All medical equipment not using intentional radiation with electromagnetic exposure or application of currents | |

If all the electrical devices in the work place are covered by Table 1, this can be recorded as the conclusion of the assessment, see Annex B.

## 6 Workplaces likely to require further assessment

Table 2 is a non-exhaustive list of equipment which is likely to produce exposures of workers requiring further assessment. If further assessment is required, all equipment listed in Table 1 can be excluded from this assessment.

**Table 2 ± Examples of equipment likely to require further assessment**

| Item | Equipment type | Remarks |
|---|---|---|
| T.2.1 | Industrial electrolysis | Both AC and DC types |
| T.2.2 | Electrical welding and melting | |
| T.2.3 | Induction heating | |
| T.2.4 | Dielectric heating | |
| T.2.5 | Dielectric welding | |
| T.2.6 | Industrial magnetizer/demagnetizers | Including bulk tape erasers. |
| T.2.7 | Specialized RF energized lighting | |
| T.2.8 | RF plasma devices | Includes vacuum deposition and sputtering. |
| T.2.9 | Diathermy | All medical treatment equipment using time averaged emitted high power (> 100 mW) RF sources. |
| T.2.10 | Electric crack detector system | |
| T.2.11 | Radars | Typically air traffic control, military, weather radars and long range radars.<br><br>Typically more than 100 mW RMS (> 20 W peak). |
| T.2.12 | Electrically driven transport: trains and trams | |
| T.2.13 | All medical equipment using intentional radiation with electromagnetic exposure or application of currents | |
| T.2.14 | Industrial microwave heating and drying | |
| T.2.15 | Base station antennas | Further assessment is only relevant if workers can get closer to the antenna than the defined safety distance in relation to the public exposure limits. |
| T.2.16 | Electricity supply networks in the work place and electricity distribution and transmission circuits passing over the work place that does not satisfy the criteria given in Table 1 | Assessment criteria are given in Annex F. |

## 7 Standards for specific work places

If a specific standard is applicable to the working environment or type of work place, then it is recommended to use that for the assessment. If this standard contains other exposure limits than those stated in the Directive then the exposure limits from the Directive shall be applied.

If no such standard exists or if the employer considers it unsuitable then an exposure assessment shall be performed either against action values (see Clause 8) or directly against exposure limit values (see Clause 9) using procedures from other basic, generic or product standards.

NOTE This list of candidates (standards) is meant as separate documents to be used under this standard.

**Candidates:**

EN 50496, *Determination of workers' exposure to electromagnetic fields and assessment of risk at a broadcast site*

EN 60601-2-33, *Medical electrical equipment ± Part 2-33: Particular requirements for the safety of magnetic resonance equipment for medical diagnosis* (IEC 60601-2-33)

Others under consideration such as:

*Power generating stations, Power substations and distribution, Trains and transport* (EN 50500 – CLC/TC 9X) *and Electrolysis*

## 8 Methodology for assessing work place exposure by comparison with the action values

The assessment can be performed either by measurements or calculations.

This assessment can be based on the methods given in the generic standards e.g. EN 50371 or EN 62311, and/or basic standards e.g. EN 50413 and/or corresponding data derived from manufacturers' information. If there exists another EMF assessment standard for the technology used in the equipment in the work place this may be used. If the standard is to be used to assess compliance with the action values, then this can be done using only the parts of the standard that apply to such an assessment.

If the exposure at the assessed work place is below the action values the work place is compliant and this can be recorded as the conclusion of the assessment, see Annex B. If the action values are exceeded, then the employer can choose either to apply exposure reduction measures (see Clause 10) or to assess compliance with the exposure limit values. See Clause 9.

NOTE Annex B is provided for information only and the forms it contains are not mandatory.

## 9 Methodology for assessing work place exposure by comparison with the exposure limit values

The assessment can be performed either by measurements or calculations.

Comparison with exposure limit values can be based on the methods given in the generic standards e.g. EN 50371 or EN 62311 and/or basic standards e.g. EN 50413 and/or corresponding data derived from manufacturers' information.

If the result of the exposure assessment of the work place is below the exposure limit values the work place is compliant and this can be recorded as the conclusion of the assessment, see Annex B. Otherwise the employer shall take further measures (see Clause 10) until the exposure is below the exposure limits.

NOTE Annex B is provided for information only and the forms it contains are not mandatory.

## 10 Methodology for taking measures

See Directive 2004/40/EC, Article 5 (partly quoted):

“comprising technical and/or organisational measures intended to prevent exposure exceeding the exposure limit values, taking into account in particular:

(a) other working methods that entail less exposure to electromagnetic fields;

(b) the choice of equipment emitting less electromagnetic fields, taking account of the work to be done;

(c) technical measures to reduce the emission of electromagnetic fields including, where necessary, the use of interlocks, shielding or similar health protection mechanisms;

(d) appropriate maintenance programmes for work equipment, work places and workstation systems;

(e) the design and layout of work places and workstations;

(f) limitation of the duration and intensity of the exposure;

(g) the availability of adequate personal protection equipment.”

If a specific standard for a work place is used and this standard gives guidance on measures then this may supplement the measures described in this clause.

Furthermore, see Annex G – Zoning. This annex describes a simple administrative procedure that employers may wish to consider in order to define different areas in their work place including areas where the relevant exposure limits may be exceeded.

# Annex A
(normative)

# Other health and safety issues: indirect effects of fields and workers at particular risk

## A.1 Introduction

Directive 2004/40/EC, in addition to specifying action values and exposure limit values, requires that, in making their risk assessment, employers shall give particular attention to a number of other possible effects of the fields. These include: indirect effects of fields on workers, indirect effects of fields on materials and equipment, effects of fields concerning the health and safety of workers at particular risk, particularly workers with active and passive implanted medical devices and pregnant workers. These four areas are considered in the following sections.

## A.2 Indirect effects of fields on workers

When assessing exposures it is necessary to consider not only the direct effect of the interaction of electric and magnetic fields with the body, but also any indirect effects of the fields on the body, and in particular contact currents. Currents and voltages are induced by fields in people and in objects, and when people touch objects in electric and magnetic fields, contact currents can flow.

The assessment process in this standard for the direct effects of fields, as illustrated in Figure 1, allows several routes to be used to show compliance with Directive 2004/40/EC. Whichever method of assessment is used for the direct effects of fields it is necessary to assess the risk of shock and/or burn. The method that involves the use of Table 1 to ascertain that the workplace contains only equipment that is compliant already takes account of both direct and indirect effects. To facilitate this, action values for contact current (for 0 Hz to 110 MHz) and for limb induced current (for 10 MHz to 110 MHz) are given in Table 2 of the annex to the Directive.

For fields at lower frequencies, including those associated with the electricity system, these indirect effects of the fields can be avoided by adopting the correct earthing practice (see F.5).

## A.3 Indirect effects on workers with implanted medical devices

Where the work place has workers with active implanted medical devices (AIMDs) or passive metallic implants, then the employer shall consider the specific risk arising from the effect on these devices or implants of the electric and magnetic fields in the work place. The particular risks for workers with AIMDs are effects on device operation whilst the risks for passive metallic implants arise from self-heating of the implant. The employer should consider whether any restrictions on access to particular processes or locations may be required for these workers, with reference to relevant European Standards or, where these are not available, national standards or accepted best practice.

## A.4 Indirect effects on equipment and materials

The Directive also requires that the employer consider risks from indirect effects of electromagnetic fields such as interference with non-implanted medical electronic equipment and devices, the projectile risk from ferromagnetic objects in static magnetic fields with a magnetic flux density greater than 3 mT, initiation of electro-explosive devices (detonators), and the risk of fires and explosions resulting from ignition of flammable materials by sparks caused by induced fields, contact currents or spark discharges. The employer shall give particular attention, when carrying out the risk assessment, to any indirect effects.

For other possible risks and in some identified cases, CENELEC European Standards or Technical Reports exist on the subject and apply or give information to deal with it:

- EN 60601-1-2, Medical electrical equipment – Part 1-2: General requirements for basic safety and essential performance – Collateral standard: Electromagnetic compatibility – Requirements and tests (IEC 60601-1-2, mod.)

- CLC/TR 50426, Assessment of inadvertent initiation of bridge wire electro-explosive devices by radio-frequency radiation – Guide

- CLC/TR 50427, Assessment of inadvertent ignition of flammable atmospheres by radio-frequency radiation – Guide

NOTE It is important that equipment is installed and used as described by the manufacturer because EU Directives e.g. the Machinery Directive, 98/37/EC, have requirements related to the functional safety of equipment. In some cases it may be necessary to verify that the equipment will have an adequate level of immunity to the electromagnetic disturbance to be expected in its intended location.

## A.5 Pregnant workers

The requirement and extent of any specific measures to protect pregnant workers is not within the scope of this standard. Directive 2004/40/EC does require that an employer considers workers who may be at particular risk and this may include pregnant workers. Under Directive 92/85/EEC, an employer is anyway obliged to assess in detail any specific risk of exposure of pregnant workers and in particular the exposure to non-ionizing radiation [which includes electromagnetic fields] in order to decide what measures should be taken, including the moving of the worker concerned or the granting of leave.

NOTE The following information has been provided by the EU Commission, Directorate General for Employment and Social Affairs.

Letter from the Head of Unit DG EMPL/D/4 to the technical director of CENELEC
Reference: Empl/D/4/TM/adg/D(2004)22661 – dated 12.10.2004

*"CEN, CENELEC and ETSI shall take into account the limit values and action values laid down in Directive 2004/40/EC. This directive does not foresee specific limit values or action values for pregnant workers. Therefore, the only binding occupational limit and action values are those laid down in Directive 2004/40/EC.*

*Of course, under Directive 92/85/EEC (on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding (tenth individual directive within the meaning of Article 16 (1) of Directive 89/391/EEC)), the employer is obliged to assess in detail any specific risk of exposure of pregnant workers, in particular the exposure to non-ionizing radiation in order to decide what measures should be taken, including the moving of the worker concerned or the granting of a leave (Articles 4, 5 and 6 and Annexes I and II of Directive 92/85/EEC).*

*In order to help employers to perform their risk assessments the Commission adopted Guidelines on "Communication from the Commission on the Guidelines on the assessment of the chemical, physical and biological agents and industrial processes considered hazardous for the safety or health of pregnant workers and workers who have recently given birth or are breastfeeding (Council Directive 92/85/EEC) (COM(2000)466 final).*"

## A.6 Zoning

Annex G describes a simple administrative procedure that employers may wish to consider in order to define different areas in their work place where general public and occupational exposure may be met. In the absence of any more specific national or international guidance, this zoning framework may be useful for the implementation of specific measure to protect against indirect effects of fields and control access for workers of particular risk.

# Annex B
(informative)

## Documenting the risk assessment

This annex offers two forms that help to document the risk assessment process.

In cases where the work place only contains equipment mentioned in Table 1, form 1 can be used.

Form 2 may be used when a detailed risk assessment has been done. The information suggested in form 2 would only provide an overview, and further documentation might be needed in a measurement report. The full contents of such a report is not within the scope of this annex but the essential information i.e. the measurement results and the uncertainty, are pointed to in form 2.

For some types of work places the EMF risk assessment is covered by a specific work place standard. If such a standard is used for risk assessment then the presentation of the result should normally be done in accordance with this standard. Otherwise a slightly customised version of form 2 could also be used. In a more complex situation such as when more equipment has emissions on more than one frequency, a more detailed form may be necessary.

Special considerations are often needed when it comes to the assessment of work that takes place outside the employer's premises. It is generally advised that the employer train employees to be aware of particular risks that they might encounter during their work. This could typically be in situations where craftsmen like bricklayers, plumbers and carpenters do maintenance work on chimneys, rooftops etc. where radio transmission or other transmitting antennas could be installed.

Employees should be instructed on how to deal with such equipment in a safe manner. Generally this means that employees are informed about the safety distances of such equipment. If the safety information is not provided in a sign at the site, it can be requested from the owner of the equipment. However, it is the employer's responsibility that the employee has the right information on every work place that they visit.

## B.1 Form 1: Work place containing only equipment in Table 1

**General information**

- Name and address of the company
- Date of assessment
- Assessment group (name of participants taking part in the assessment)
- Address or location of the work place (i.e. of different company locations, room number ...)
- Short description of work place and equipment

**Assessment**

**Work place contains only equipment in Table 1** ❑

Specify (e.g. office equipment): _____

**Conclusion**

**Work place compliant** ❑

**Signatures of assessment group**

## B.2 Form 2: Work place requiring detailed risk assessment

**General information**

- Name and address of the company
- Date of assessment
- Assessment group (names of participants taking part in the assessment)
- Address or location of the work place (i.e. different company locations, room number ...)

**Assessment**

- Detailed description of work place/equipment (type, manufacturer ...)
- Detailed description of working conditions (working process and time of exposure, equipment settings, location of worker to equipment, e.g. with drawing ...)
- Standards related to the equipment (list of used standards _____)
- Compliance demonstration:
    - Reference to the report of calculation and/or measurement (containing type of measurement equipment, calculation program, measurement condition, e.g. with drawings)
    - Result of measurement or calculation: _____
    - Uncertainty: _____
    - Exposure action values or exposure limit values used :_____
    - The measured exposure levels of workers: _____
    - Detailed description of measures taken in order to obtain compliance, if any:

      _____

      _____
    - Are there special protective measures necessary for worker with medical implants?

      _____

**Conclusion**

**Work place compliant** ❑

**Signatures of assessment group**

# Annex C
(informative)

# CE-marked equipment

## C.1 CE-marked equipment

CE-marked equipment may have been assessed against a harmonised EMF standard or relevant safety standards and consequently be in compliance with the requirements of this standard. However, not all CE-marked equipment have been assessed and it may be necessary to gather information e.g. from the manufacturer or supplier on the assessment of the equipment.

NOTE 1 Not all CE-marked equipment is required to be assessed against EMF emission standards. Furthermore, some equipment and installations are not required to be CE-marked.

A list of harmonised EMF standards and relevant safety standards for products can be found in Table C.1. The list in the annex may not always include all the valid standards and it is recommended to check frequently for changes.

If the equipment in the work place is compliant with one or more of the standards listed in this annex, the work place is consequently compliant with requirements of this standard.

If the equipment has not been assessed in accordance with a harmonised EMF standard, or if the compliance is unknown further assessment may be necessary.

NOTE 2 Some equipment placed on the European market may also be compliant with this recommendation although they have not received the CE-marking, for example if it is part of an installation.

Table C.1 lists the harmonized EMF standards at the time this standard was finalized.

**Table C.1 ± List of EMF product standards**

| EMF product standards | Title |
|---|---|
| EN 50360 | Product standard to demonstrate the compliance of mobile phones with the basic restrictions related to human exposure to electromagnetic fields (300 MHz – 3 GHz) |
| EN 50364 | Limitation of human exposure to electromagnetic fields from devices operating in the frequency range 0 Hz to 10 GHz, used in Electronic Article Surveillance (EAS), Radio Frequency Identification (RFID) and similar applications |
| EN 50366 | Household and similar electrical appliances – Electromagnetic fields – Methods for evaluation and measurement |
| EN 50371 | Generic standard to demonstrate the compliance of low power electronic and electrical apparatus with the basic restrictions related to human exposure to electromagnetic fields (10 MHz – 300 GHz) – General public |
| EN 50385 | Product standard to demonstrate the compliance of radio base stations and fixed terminal stations for wireless telecommunication systems with the basic restrictions or the reference levels related to human exposure to radio frequency electromagnetic fields (110 MHz – 40 GHz) – General public |
| EN 50401 | Product standard to demonstrate the compliance of fixed equipment for radio transmission (110 MHz — 40 GHz) intended for use in wireless telecommunication networks with the basic restrictions or the reference levels related to general public exposure to radio frequency electromagnetic fields, when put into service |
| EN 60335-2-25 | Household and similar electrical appliances — Safety — Part 2-25: Particular requirements for microwave ovens, including combination microwave ovens (IEC 60335-2-25:2002) – EN 60335-2-25:1996 + A1:2000<br>Note 2.1 Date expired (1.10.2005) - Amendment A1:2005 to EN 60335-2-25:2002 (IEC 60335-2-25:2002/A1:2005) |
| EN 60335-2-90 | Household and similar electrical appliances — Safety — Part 2-90: Particular requirements for commercial microwave ovens (IEC 60335-2-90:2002) – EN 60335-2-90:1997<br>Note 2.1 Date expired (1.10.2005) - Amendment A1:2003 to EN 60335-2-90:2002 (IEC 60335-2-90:2002/A1:2003) |

Information on the list of harmonized standards can be obtained by contacting your national member of CENELEC. Contact points can be found in the members list at www.cenelec.eu.

It is recommended to check for an updated list of harmonised standards.

## C.2 Identifying equipment that has been assessed

This information may be stated in the documentation supplied with the equipment. If that is not stated in the documentation it is recommended to contact the supplier or manufacturer in order to gather information on whether or not the equipment has been assessed.

# Annex D
(informative)

# Simultaneous exposure to multiple frequencies: general process

## D.1 Introduction

The action values and exposure limit values defined in the Directive 2004/40/EC are derived from the ICNIRP Guidelines of 1998 [1] and use the same frequency dependence principles. However, the EMF Directive does not itself give information on how to combine simultaneous exposures from multiple sources, exposures from electromagnetic fields with high harmonic contents and exposures to non-sinusoidal fields.

The equations defined in this annex provide a conservative way to demonstrate compliance with Directive 2004/40/EC for simultaneous exposure to multiple frequencies. They are consistent with the equations adopted in the ICNIRP Guidelines and the European Council Recommendation 1999/519/EC.

## D.2 General process

According to ICNIRP, there are two separate frequency dependent summation regimes: 1 Hz - 10 MHz and 100 kHz - 300 GHz. The ICNIRP equations for these frequency regimes are further developed in D.2.1 and D.2.2 respectively. Further information can be found in [1].

Exposures to fields with frequencies below 100 kHz should never be added to exposures to fields with frequencies above 10 MHz. Neither should exposures for the different summation regimes be combined between 100 kHz and 10 MHz. Subclause D.2.3 provides the equation for contact currents in the frequency range 1 Hz – 110 MHz. For radio frequencies, exposure assessment can be performed using the Total Exposure Ratio evaluation process defined in EN 50400.

If the action values according to the equations are not exceeded, then the exposure limit values will not be exceeded. If the action values according to the equations are exceeded, this does not necessarily mean that the exposure limit values are exceeded. In such a case further evaluation may be necessary to check compliance against the exposure limit values using the relevant summation form.

If the sources are independent (phase non-coherent source) the possibility that these exposures might be additive in their effects should be considered.

To take effects from unstable signals into account, the measurement time shall be sufficiently long.

In situations where sources are not independent (phase coherent sources) or the frequencies are harmonics of only one source the phase information should be considered. EN 62311 gives further guidance for these cases.

NOTE Although this chapter has some similarities with EN 62311, the text is not, and is not meant to be, identical to these standards to fit with the EMF Directive and Mandate M/351. In particular, these standards address emissions from products, not exposure of people.

### D.2.1 Frequency range from 1 Hz - 10 MHz

#### D.2.1.1 Frequency domain assessment

For investigation in the frequency domain, it is most realistic to include relative phase. This can be achieved by using a waveform capture approach with *post hoc* Fourier analysis.

The pure (no phase information) summation almost always results in an overestimation of the exposure for broadband fields consisting of higher frequency harmonic components or noise. The limitation based on equation is very conservative because the components do not necessarily have the same phase. The default neglecting of phase is equivalent to assuming that they do have the same phase.

In this frequency range the underlying exposure limit value is induced current density. The induced current-density-based summations may or may not include consideration of phase. The most conservative is to neglect phase altogether. Therefore, as a worst case assumption multiple current densities at different frequencies should be undertaken according to the following equation:

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

where

$J_i$ is the current density at frequency $i$;

$J_{\mathrm{L},i}$ is the current density exposure limit value at frequency $i$ as given in Table 1 of Directive 2004/40/EC.

When action values are used, the exposures should be summed according to these equations:

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

and

$$\sum_{j=1\,Hz}^{65\,kHz} \frac{H_j}{H_{\mathrm{L,j}}} + \sum_{j>65\,kHz}^{10\,MHz} \frac{H_j}{b} \leq 1$$

where

$E_i$ is the electric field strength at frequency $i$;

$E_{\mathrm{L},i}$ is the electric field strength action value at frequency $i$;

$H_j$ is the magnetic field strength at frequency $j$;

$H_{\mathrm{L},j}$ is the magnetic field strength action value at frequency $j$;

a is 610 V/m;

b is 24,4 A/m (30,7 µT).

#### D.2.1.2 Time domain assessment

In general for all kinds of signals (e.g., broadband, non-sinusoidal) a measurement system (time domain assessment), which incorporates a "weighting filter", is applicable. The measurement will be done in the time domain, but the measured signal will be weighted in the frequency-domain. This procedure can also be computationally applied, once the measured time signal is available.

The ICNIRP Guidelines [1] and the ICNIRP Statement [2] present such an approach for specific pulsed complex exposure situations.

This time domain approach is based on the restriction of the weighted peak value of a broadband field. The weighting function has been derived from the action values as a function of frequency. The weighted peak restriction can be applied for periodic non-sinusoidal waveforms where the mutual phases of harmonic components do not vary significantly. If the mutual phases vary significantly the measurement time must be long enough to detect the worst peak value with a reasonable probability.

For comparison with the given exposure levels, the weighting filter should have a frequency response (transfer function $W$), which matches the frequency response of the exposure standard (function $V$) so that the weighting happens in the time-domain.

More detailed information can be found in EN 50413 and EN 62311.

### D.2.2 Frequency range from 100 kHz - 300 GHz

In this frequency range, the exposure restrictions in Directive 2004/40/EC are based on the avoidance of thermal effects. The exposure limit values are on *SAR* and power density, and summation of these quantities should follow the equation

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

where

$SAR_i$ is the *SAR* caused by exposure at frequency *i*;

$SAR_L$ is the *SAR* exposure limit value;

$S_i$ is the power density at frequency *i*;

$S_L$ is the power density exposure limit value.

$SAR_s$ can be for the whole body or part of body. Partial body *SAR*s that arise in the same averaging volume of 10 g of tissue as each other should be summed together; whole body *SAR*s should be summed together. Partial body *SAR*s should not be summed with total body *SAR*s. Partial body *SAR*s that occur in different volumes of tissue should not be summed.

Exposure field strengths can be compared to the action values on a field strength squared basis:

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

and

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

where

$E_i$ is the electric field strength at frequency $i$;

$E_{\mathrm{L},i}$ is the electric field action value from Table 2 of Directive 2004/40/EC;

$H_j$ is the magnetic field strength at frequency $j$;

$H_{\mathrm{L},j}$ is the magnetic field action value derived from Table 2 of Directive 2004/40/EC;

c is 610/$f$ V/m ($f$ in MHz);

d is 1,6/$f$ A/m ($f$ in MHz).

The equation for limb current is:

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

where

$I_k$ is the limb current component at frequency $k$;

$I_{\mathrm{L},k}$ is the action value for limb current, 100 mA.

Under this thermal summation regime, the relative phases of the spectral components can be neglected.

### D.2.3 Contact currents in the frequency range 1 Hz ± 110 MHz

For contact current in the frequency range 1 Hz – 110 MHz, the following requirements should be applied:

$$\sum_{n=1\mathrm{Hz}}^{110\mathrm{MHz}} \frac{I_n}{I_{\mathrm{C},n}} \leq 1$$

where

$I_n$ is the contact current component at frequency $n$;

$I_{\mathrm{C},n}$ is the action value for contact current at frequency $n$.

# Annex E
(informative)

# Simultaneous exposure to multiple frequencies: The Total Exposure Quotient (*TEQ*) approach

## E.1 Terms and definitions

### E.1.1
**Exposure Quotient (*EQ* or *EQ* %)**
proportion of the available allowed contribution to exposure from multiple sources. This can be expressed in terms of a proportion of the action values or of the exposure limit values over the frequency range. It may be expressed as a fraction (*EQ*) or as a percentage (*EQ* % = *EQ**100 %)

### E.1.2
**Total Exposure Quotient (*TEQ* or *TEQ* %)**
result of the summation of the exposure quotients, including those based on action values and those based on exposure limits, from the equipment causing exposure in any specific place. It may be expressed as a fraction (*TEQ*) or as a percentage (*TEQ* %)

## E.2 The *TEQ* approach

### E.2.1 Explanation

This is a simplified approach to assist employers in summing contributions from multiple sources:

– it can only be used to demonstrate compliance of the exposure situation, but never to prove non-compliance. A *TEQ* of greater than 1 indicates that further investigation is necessary, for example using the procedures outlined in Annex D or other more appropriate assessment methods;

– the *TEQ* allows an employer to roughly sum contributions from different equipment, even if the individual equipment assessments have been carried out on different bases (action values, reference levels or exposure limit values) or with regard to different safety standards (general public, occupational exposure), which prevents using the equations defined in Annex D;

– use of the *TEQ* or *EQ* is not mandatory – they are only provided as a simple tool to demonstrate compliance – but not non-compliance - with the exposure limit values of Directive 2004/40/EC. An employer always has the option to use other appropriate assessment procedures e.g. those provided in EN 50413 or EN 62311, the equations in Annex D or other more appropriate assessment methods.

The *TEQ* approach is intended for adding exposures from multiple fixed EMF sources not listed in Table 1, such as in an industrial work place. For this reason a *TEQ* summation should not include any Table 1 devices.

The *TEQ* approach can be carried out with different levels of complexity:

– calculate the total *TEQ* across the whole frequency band (0 Hz – 300 GHz) neglecting the different physiological bases of exposure to EM Fields;

– calculating separate *EQ*'s for the low frequency range (e.g. for stimulation effects) and the high frequency range (e.g. for thermal effects).

The benefit of a single *TEQ* is that it makes the combination of contributions from different sources very simple, and can be used to rapidly demonstrate compliance with the requirements of the directive if all exposure levels are very much below the action values or exposure limit values.

The benefits of using separate low and high frequency *EQ*s are that this represents a slightly better approximation of the exposure situation.

### E.2.2 *EQ* for a single piece of equipment

#### E.2.2.1 Obtaining or calculating the *EQ* for a single piece of equipment

The *EQ* or specific exposure level information may be obtainable directly from the equipment suppliers. This is likely to be specified at a particular distance, or distances, representing the normal use of the equipment concerned, or use as defined in the relevant operating instructions. The contributions of cabling and other aspects of an installation also should be considered, and it may be necessary to define separate *EQ*s for these also.

There may also be publicly available information for common types of equipment. Care should be taken to ensure that public information is obtained from a reputable source such as a peer-reviewed publication, or provided by a national or international authority, or from a source whose use can be otherwise justified by the employer.

If the only information that can be obtained is that the equipment in question meets the worker EMF exposure limits (as specified in the Directive 2004/40/EC), then the *EQ* shall be assumed to be 1, representing the worst case condition. Similarly if the only available information is that the equipment in question meets the guidelines for the general public as provided in Council Recommendation 1999/519/EC, then it would be included in Table 1 and the *EQ* should be assumed to be 0.

If no information on the *EQ* for a particular piece of equipment is available, then it can be calculated from its measured emission levels.

#### E.2.2.2 Calculating single equipment *EQ* from measured emission or exposure levels

The *EQ* for a particular piece of equipment can be calculated from one or more of the following equations.

$$EQ(lf) = \sum_{f} \frac{F_f}{A_f}$$

$$EQ(j) = \sum_{f} \frac{J_f}{J_{Lf}}$$ For frequencies less than 10 MHz

$$EQ(hf) = \sum_{f} \left( \left( \frac{F_f}{A_f} \right)^2 or \left( \frac{S_f}{A_f} \right) \right)$$ For frequencies greater than 100 kHz

$$EQ(th) = \sum_{f=100kHz}^{f=10GHz} \frac{SAR_f}{SAR_{Lf}} + \sum_{f=10GHz}^{f=300GHz} \frac{S_f}{S_{Lf}}$$

where

$F_f$ is the field strength (electric and/or magnetic) at any emission frequency;

$A_f$ is the relevant action value at that frequency;

$J_f$ is the induced body current density at any emission frequency;

$J_{L,f}$ is the relevant current density exposure limit value at that frequency;

$SAR_f$ is the *SAR* at any emission frequency;

$SAR_{L,f}$ is the relevant *SAR* exposure limit value at that frequency;

$S_f$ is the power density at any emission frequency;

$S_{L,f}$ is the relevant power density exposure limit value at that frequency.

*EQ(lf)* is a low frequency exposure quotient based on the action values of Directive 2004/40/EC.

*EQ(j)* is a low frequency exposure quotient based on the current density exposure limit values of Directive 2004/40/EC.

*EQ(hf)* is a high frequency exposure quotient based on the action values of Directive 2004/40/EC.

*EQ(th)* is a high frequency exposure quotient based on the thermal (*SAR* and power density) exposure limit values of Directive 2004/40/EC.

Any frequencies at which the provided value is less than 5 % of the relevant limit at that frequency do not need to be included as the methodology is inherently conservative.

### E.2.3 Combining the separate equipment *EQ*s into a *TEQ*

#### E.2.3.1 Simple assessment of the *TEQ*

In its simplest, most conservative, form the assessment of the *TEQ* is made by adding the individual *EQ*s for each of the items of equipment that contribute to the exposure. The equation for this is given below:

$$TEQ = \sum_{n=1}^{N} EQ_n$$

where

*N* is the total items of equipment;

*n* is the item of equipment;

$EQ_n$ is the *EQ* of equipment *n*, converted to a decimal fraction, based on any assessment method.

As an example, consider a situation where a worker is exposed by four pieces of equipment, the *EQ* obtained for each is 25 %, 0,1, 1/20 and 1/25 respectively. Converting these to decimal fractions and making the calculation would give *TEQ* = 0,25 + 0,1 + 0,05 + 0,04 = 0,44. Alternatively, converting these to percentages and making the calculation would give *TEQ* % = 25 % + 10 % + 5 % + 4 % = 44 %, and thus *TEQ* = 44 % / 100 % = 0,44 as before.

As a second example, consider a situation where a worker is exposed by four pieces of equipment, the *EQ* from each is 0,6, 0,3, 0,2 and 0,1 respectively. The *TEQ* in this case would be 1,2.

The simple equation for *TEQ* assessment provided above gives a very conservative result. It is provided to make easy assessments of simple exposure situations. If the *TEQ* is found to be above 1 using this equation, it does not necessarily mean that the exposure is above the limits. It only means that a more complex assessment must be undertaken.

For a more realistic determination of *TEQ* it is not appropriate to add together exposures at frequencies where the limits are thermally based and those at frequencies where the limits are stimulation based. These should be evaluated separately. The results are still conservative.

If an employer wishes to, and is able to, evaluate the *TEQ* on a more realistic basis then this is encouraged. There is no requirement to perform the simple assessment first.

#### E.2.3.2 Assessment of low frequency (electrical) effects

This applies for exposure source frequencies up to 10 MHz

$$TEQ(j) = \sum_{n=1}^{N} EQ(lf)_n + \sum_{m=1}^{M} EQ(j)_m$$

where

| | |
|---|---|
| *M* | is the number of items of equipment assessed against electrical effects; |
| *N* | is the number of items of equipment assessed against field levels; |
| $EQ(j)_m$ | is the *EQ* proportion of equipment *m*, as a decimal fraction, based on electrical effects; |
| $EQ(lf)_n$ | is the *EQ* proportion of equipment *n*, as a decimal fraction, based on field measurements. |

*TEQ*(*j*) must be less than 1.

The same equipment should not be included both as an *EQ*(*lf*) and an *EQ*(*j*) if the *EQ*(*lf*) and the *EQ*(*j*) are different ways of measuring the same emission.

#### E.2.3.3 Assessment of high frequency (thermal or *SAR*) effects

This applies for exposure source frequencies above 100 kHz

$$TEQ(th) = \sum_{n=1}^{N} EQ(hf)_n^2 + \sum_{m=1}^{M} EQ(th)_m$$

where

| | |
|---|---|
| *M* | is the number of items of equipment assessed against thermal effects; |
| *N* | is the number of items of equipment assessed against field levels; |
| $EQ(th)_m$ | is the *EQ* proportion of equipment *m*, as a decimal fraction, based on thermal effects; |
| $EQ(hf)_n$ | is the *EQ* proportion of equipment *n*, as a decimal fraction, based on field measurements. |

*TEQ*(*th*) must be less than 1.

The same equipment should not be included both as an *EQ*(*th*) and an *EQ*(*hf*) if the *EQ*(*th*) and the *EQ*(*hf*) are different ways of measuring the same emission.

#### E.2.3.4 Assessment of intermediate frequencies 100 kHz to 10 MHz, or if the applicable frequency of measurement assessments covers both the electrical effects and thermal effects, or is unknown

In this case, both electrical and thermal effects are present. Both of the previous assessments must be made. For individual *EQ* evaluations made against field measurements, *EQ*(*f*), they must be included in both assessments on the basis of the following equation:

$$EQ(f) = EQ(lf) = EQ(hf)$$

This equation applies only for this intermediate frequency range.

The results of each assessment, *TEQ*(*j*) and *TEQ*(*th*), remain independent and do not have to be added together. Each, however, must be less than 1.

#### E.2.3.5 Example of multiple exposure using separate *TEQ* assessments

In this example a worker is exposed to EMF from four different pieces of equipment simultaneously.

Equipment A is an industrial machine emitting only low frequency EMF with an *EQ* of 0,4. Thus *EQ(j)* = 0,4 and there is no *EQ(th)*.

Equipment B is a high frequency communications system with an *EQ* of 0,35, which was calculated from the *SAR* value. Thus *EQ(th)* = 0,35 and there is no *EQ(j)*.

Equipment C is a small monitoring transponder emitting only high frequency fields at a low level corresponding to an *EQ* of 0,1, based on the action values. Thus *EQ(hf)* = 0,1.

Equipment D also has no details or frequency information but has a declared *EQ* % of 25 % based on the action values. Thus *EQ(lf)* = *EQ(hf)* = 0,25.

$$TEQ(j) = 0{,}25 + 0{,}4 = 0{,}65$$

and

$$TEQ(th) = 0{,}1^2 + 0{,}25^2 + 0{,}35 = 0{,}01 + 0{,}063 + 0{,}35 = 0{,}423$$

# Annex F
(informative)

# AC electricity supplies

This annex provides a method for assessing whether electricity supplies comply with the exposure limit values. It covers the electricity wiring services within the work place as well as overhead and underground electricity transmission and distribution services passing through or close to a work place. The information in this annex applies to both normal operation of and maintenance of these services.

This annex is not intended to cover fields from equipment associated with the use of electricity. Neither is this annex intended to cover exposures from the fields from all equipment associated with electricity production and supply such as high-power generators. These shall be the subject of separate assessments (see Clause 7).

## F.1 Field values to use for checking compliance

An assessment of electric and magnetic field exposure may be either against action values (see Clause 8) or against exposure limit values (see Clause 9). In addition it is necessary to assess exposure to indirect effects (see Annex A and F.5).

The action values to be used are given in Table 2 of the annex to the EC Directive (2004/40/EC) and are given here for 50 Hz in Table F.1.

**Table F.1 ± Electric and magnetic field action values for 50 Hz**

| | **Magnetic field** | **Electric field (unperturbed)** |
|---|---|---|
| Action value field | 500 µT | 10 kV/m |

The exposure limit value, in the frequency range 1 Hz to 1 000 Hz, is an induced current density in the central nervous system of 10 mA/m$^2$. To carry out an exposure assessment against the exposure limit value requires an assessment of the fields that correspond with the exposure limit value. This is not dealt with in this annex, but may be done by reference to numerical dosimetry using detailed numerical models of the body such as has been carried out by Dimbylow (2005) or by reference to EN 62226-2-1 and EN 62226-3-1. It may be noted that the field corresponding to the exposure limit can be shown to be considerably greater than the action value. For example, for magnetic field, Dimbylow (2005) demonstrates that the field corresponding with the exposure limit value is a factor of at least 3,6 times greater (for the most the onerous field orientation) than uniform field and is even higher for other exposure conditions, such as non-uniform fields.

This annex gives only details for demonstrating compliance with the action value. This is sufficient for nearly all work places.

Exposure situations where the action value is exceeded are rare but may occur in localised parts of workplaces where high-current or high-voltage equipment is operated, such as within the electricity supply industry. Exposure assessment for such workplaces is beyond the scope of this annex. Instead see Clause 7.

The values given in this annex are for a system frequency of 50 Hz since this is the frequency used for electricity supply systems throughout Europe. For an AC power system operating at a different frequency, *f*, multiply the field values by 50/*f*, or if the frequency of the system lies outside the range 8 Hz to 820 Hz, refer to the source references given.

Waveforms of electric and magnetic fields at 50 Hz are not necessarily purely sinusoidal but may contain harmonic components which may have an effect on the exposure. See Annex D for further information.

## F.2 Magnetic field sources

There are many sources of power frequency magnetic field in the work place. However for the field to be large enough to exceed either the action value or the field that corresponds to the exposure limit, it is necessary to be very close to conductors which are carrying very large currents.

### F.2.1 Currents in single conductors

Compliance with exposure limits can be demonstrated by showing that personnel are always at a distance larger than a given minimum distance from conductors that carry high currents. For a current $I$ (in amperes) flowing in a single conductor the magnetic field magnitude $B$ (in μT) is proportional to the current and inversely proportional to the distance $D$ (in m) to the centre of the conductor (Ampere's law).

$$B = 0{,}2\ I / D\ \mu T$$

The minimum distance $D_{min}$ is therefore a function of the current and the magnetic field, $B_{lim,}$ which is the exposure limit being used.

$$D_{min} = 0{,}2\ I / B_{lim}$$

This is valid where the person is close to the conductor relative to its length. (At greater distances this is conservative as it overestimates the field and overestimates the minimum distance.)

Table F.2 gives the minimum distance to the centre of an individual conductor carrying a particular current (between 100 A and 2 500 A) necessary to demonstrate compliance with the action value.

**Table F.2 ± Minimum distance of approach, in metres, to the centre of individual insulated conductors, based on the action value alone**

| **Current in conductor** A | **Distance corresponding to the action value** m |
|---|---|
| 100 | 0,04 |
| 200 | 0,08 |
| 500 | 0,20 |
| 1 000 | 0,40 |
| 1 500 | 0,60 |
| 2 000 | 0,80 |
| 2 500 | 1,00 |

A current of 500 A produces a magnetic field that corresponds with the action value at a distance of 0,2 m between the surface of the body and the centre of the conductor. Closer to the conductor, considerations relating to the non-uniformity of the field (see EN 62226-1), the diameter of conductor necessary to carry the current and numerical computation of induced current density in the body for uniform field (Dimbylow, 2005), have the consequence that for currents up to 500 A the exposure limit will always be complied with however close together the body and conductor are.

Therefore exposure associated with any conductor carrying up to 500 A complies with the exposure limit at any distance from the conductor, however small. For conductors carrying currents of different phases in bundles it is the net current in the bundle of conductors that is applicable, but this is generally much lower than the largest individual current.

Where there are separate conductors carrying currents greater than 500 A then a separation should be maintained between the surface of the person and the centre of the conductor. The separation distance to be maintained is given by the equation above and illustrated in Table F.2, and depends only on the maximum current. This distance results from consideration of the action value field. In many situations there are already physical constraints in place, such as for a high voltage cable, the insulation surrounding the conductor. Smaller minimum separations than are given by the above equation and illustrated in Table F.2 can also be justified, based on considerations of non-uniformity of the field and numerical dosimetry, but this is beyond the scope of this annex.

### F.2.2 Currents in circuits

The conductors carrying electric current from its source to its destination and back again are referred to as an electrical circuit. Electrical circuits always use two or more conductors.

For an idealised single-phase circuit there are two conductors which carry equal currents flowing in opposite directions. Because the currents are equal and opposite and are close together, the fields largely cancel out, where the degree of cancellation depends on how close together they are. When the two conductors carrying current $I$ are a distance $S$ apart (in m, where $S << D$) the field is:

$$B = (0{,}2\ I / D) \times (S / D)\ \mu T$$

Similarly an idealised three-phase circuit comprises three currents phased approximately 120° apart. Either these three currents are balanced so that they sum to zero or there is a fourth conductor (the neutral) and the four currents sum to zero. In either case if the conductors are close together the fields largely cancel.

In the real situations the currents are not exactly balanced, or the conductors of the circuit may not be close together.

The current unbalance will occur where there are alternative return paths for the currents such as when the neutral of a circuit is grounded in more than one place or where there are parallel circuits supplying a particular load.

The conductors of a circuit will usually be bundled together as part of the same cable. In these situations very low magnetic fields are produced even very close to the cable. Situations where the separate conductors are not close together include overhead lines, where the conductor separation increases with the voltage of the circuit. There are also more specialised situations where phases and/or neutral conductors of a circuit follow different routes. This is most likely to occur only within a substation containing transformers and/or distribution switching equipment.

The information described above is applied using the method presented in F.2.3 for assessing exposures from electrical circuits. There are very conservative and cover most situations that arise in practice.

### F.2.3 Assessing magnetic fields exposures

The methodology for assessing exposures from the three types of magnetic field source, insulated conductors, bare conductors and other sources, is considered here and a check list for applying is given in F.2.4.

#### F.2.3.1 Insulated cables

For insulated conductors the simplest assessment is to use the current rating of the circuit and to assess the minimum distance using Table F.2. The current rating of a circuit can be found from the steady-state rating of the fuses or circuit breaker protecting the circuit. This is a highly conservative approach because it considers the field produced by the current from only one of the conductors of the circuit, and it does not take account of the almost complete cancellation of this field by the field from the currents in the other conductors.

Following on from the information in F.2.1 for single conductors, it follows that all circuits rated at less than 500 A (per phase) can be regarded as being compliant with the action value without any further consideration. The majority of circuits fall easily within this category.

This assessment does not require consideration of whether or not the conductors of a circuit are bundled or follow different routes and because this approach is very conservative it is not necessary to make additional provision for multiple circuits running close together.

Similarly any work place where the rating of the electricity intake supplying the work place is less than 500 A will be compliant with the action value. Where there are more than one electricity intakes, each one may be considered separately. Where the supplies are taken from a step down transformer within the work place, each circuit on low voltage side of the transformer may be considered separately.

Exceptionally, where a circuits is rated at more than 500 A and where the separation of the conductors is small, an assessment of the maximum possible net current in the cable may be made and this value compared with 500 A.

Where a circuits is rated at more than 500 A and the spacing between conductors is large compared with the distance to where people may be, then the minimum distance of approach to each conductor shall be assessed separately for each conductor for the rated phase current of the conductor.

#### F.2.3.2 Overhead bare conductors

For overhead bare conductors minimum safety clearances are specified (EN 50423-1 and EN 50341) to prevent flashover to objects or people. These distances are all greater than the minimum distances derived using Table F.2, so all overhead circuits with bare conductors are compliant with magnetic field exposure limits without further consideration.

#### F.2.3.3 Other magnetic field sources

While certain items of equipment are capable of producing fields greater than the action value at their surface, there are very few where the field can exceed the action value at a distance of 0,2 m or more from their surface. Items where this is likely to happen will need to be subject to further investigation involving the determining the magnetic fields values in the vicinity of the equipment, by either calculation or measurement, and comparing them with the action value.

Equipment requiring this further investigation are those with high currents (hundreds of amperes) flowing in multiple adjacent turns of a winding, such as those of air cored power transformers, air cored reactors (used for voltage control of power systems), and the end windings of high-power generators.

By contrast, conventional iron-cored devices are designed in a way that results in low external leakage fields. The fields associated with motors and transformers, particularly where they are enclosed in a ferromagnetic or conducting case will not normally be large enough to exceed the action value.

However, whether iron or air cored, where the current rating is high consideration need to be given to the currents in the connections to generators, motors and transformers at both the phase and neutral end of the windings.

Where there is doubt about whether or not the fields in places where workers have access surrounding a particular equipment are below the action values then the further investigation is required.

### F.2.4 Check list for assessing compliance for magnetic fields

For magnetic field exposure the following are compliant with the action value for magnetic field. This list may be used for a Clause 8 magnetic field exposure assessment:

- any overhead bare conductors of any voltage or current rating;
- any electricity installation in the work place with a phase-current rating of 500 A or less;
- any individual circuit within an installation with a phase-current rating of 500 A or less;
- any circuit where the spacing of the conductors is small compared with the distance to places where workers have access, and where the net current is 500 A or less;
- any conductor rated at 500 A or more where the minimum distance between the centre of the conductor to where workers have access is less than the distances given in Table F.2 for the action value field;
- any iron-cored transformer, motors, generator or power-driven system, with a steel casing, excluding the connections to them and end-windings of high power generators, which shall be assessed separately (as above);
- switchgear and any other circuit components associated with the above circuits apart from the exceptions listed below.

Situations where the action value for magnetic field may be exceeded, and which therefore require further investigation, include the following:

- high-power transformers without metallic casing;
- high-current air-cored reactors;
- in the vicinity of the end-windings of high-power generators.

Exposure assessment for these is beyond the scope of this annex.

## F.3 Electric field sources

Insulated cables for installation underground or whose voltage is greater than about 1 kV have a protective sheath which is conducting and screens the electric field. There therefore is no external electric field associated with these cables.

Power and lighting circuits within buildings operating at 230 V can be unshielded in which case they produce localised electric fields around them. These fields are compliant with the EU EMF exposure Recommendations for the general public and therefore they are also compliant with occupational exposure limits.

Unshielded busbars and conductors produce electric fields that increase with the operating voltage and the conductor separation. Overhead lines operating at up to 250 kV or busbars operating up to 200 kV will not produce electric fields at ground level which are large enough to exceed the action value.

Where there are overhead lines or busbars operating at voltages greater than those values directly above locations in the work place which are not accessible to the general public, such as in electricity switching stations, there is the possibility that there are electric fields which exceed the action value. This possibility should be investigated further, for example, by referring to the operator of the high-voltage equipment.

### F.3.1 Check list for assessing compliance with electric fields

For electric field exposure the following are compliant with the action value for unperturbed electric field. This list may be used for a Clause 8 electric field exposure assessment:

- any wiring at 230/400 V and associated components;
- any cabling with a conducting sheaths at any voltage (conducting sheaths are normal on insulated cables for use at 1 kV or more);
- at ground level, with any overhead line rated at a voltage of up to 250 kV, or any busbar operating at up to 200 kV.

Situations where the action value for electric field may be exceeded and which therefore require further investigation include the following:

- any overhead bare conductors within or oversailing the work place which are rated at a voltage of more than 200 kV, or 250 kV for overhead lines, may be able to produce electric fields that exceed the action value, depending on the circumstances.

Exposure assessment for these is beyond the scope of this annex.

## F.4 Exposure assessment using public exposure limits

Table 1 of this standard is a list of items which are compliant, not only with the requirements of the directive for worker exposures, but also with the lower levels recommended by the EC Recommendation (1999/519/EC) for public exposure to EMFs.

Instead of action values and exposure limit values the Recommendation specifies reference levels (magnetic and electric field values) and basic restrictions (induced current density). The basic restriction for the general public exposure is one fifth of the exposure limit value for worker exposure.

Table F.3 gives the electric and magnetic field reference levels, for use in assessing exposures in relation to the EU Recommendation for the general public.

**Table F.3 ± Electric and magnetic field reference levels for 50 Hz**

| | **Magnetic field** | **Electric field (unperturbed)** |
|---|---|---|
| Reference level field | 100 μT | 5 kV/m |

Thus for the purposes of Table 1 the relevant field values are given in Table F.3 instead of Table F.1.

### F.4.1 Simplified checklist for assessing compliance using public exposure limits

The advice given in Table 1 is as follows. It is based on the information contained in F.2.4 (for magnetic field) and F.3.1 (for electric field) but using the field values in Table F.3.

Electricity supply networks in the work place and electricity distribution and transmission circuits passing through or over the work place:

For magnetic field exposures the following are compliant:

- any electrical installation with a phase-current rating of 100 A or less;
- any individual circuit within an installation, with a phase-current rating of 100 A or less;
- any circuit where the conductors are close together and having a net current of 100 A or less;
- all components of the networks satisfying the criteria above are covered (including the wiring, switchgear, transformers etc.);
- any overhead bare conductors of any voltage or current rating.

For electric field exposures the following are compliant:

- any underground or insulated cable circuit, rated at any voltage;
- any overhead bare circuit rated at a voltage up to 100 kV, oversailing the work place.

## F.5 Indirect effects of power-frequency fields on workers

As explained in Annex A, when assessing exposures it is necessary to consider not only the direct effect of the interaction of electric and magnetic fields with the body, but also any indirect effects of the fields on the body, and in particular contact currents. Currents and voltages are induced by fields in people and in objects, and when people touch objects in electric and magnetic fields, contact currents can flow which can occur when the body comes into contact with conducting objects in which currents and voltages are induced by the fields, causing contact currents to flow, which can occur when the body contacts an object at a different electric potential, resulting from the effect of the electric and/or magnetic fields impinging on the body.

One source of contact currents is the electric and magnetic field associated with the supply and use of electricity. Contact current is most commonly induced when there is both an electric fields and an unearthed object which can be touched by a person. The contact current that flows increases with the magnitude and frequency of the electric field, and with the size of the object. The electric field action value was designed to protect against both the direct effects and the indirect effects of the field. This means that with electric fields which are less than the action value, it is unlikely that the contact current action value will be exceeded. Nevertheless whenever there is an electric field, care should be taken to ensure conducting objects that workers can come into contact with, are adequately earthed. If the electric field exceeds the action value but is shown to be lower than the exposure limit value for direct effects (as in a Clause 9 exposure assessment) then it is important to ensure that conducting objects are adequately earthed. A non-exhaustive list of examples of conducting objects that must be considered is: tools, equipment, fences, ladders, scaffolding, storage tanks and vehicles.

Contact current can also be induced by magnetic fields where there are large loops of conductor where there is a source of magnetic field. This is less common but may occur where maintenance takes place on an out-of-service electrical circuit which runs parallel with another circuit that is carrying currents, or where an unearthed fence is running parallel with electrical circuit.

## F.6 Bibliography

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89/391/EEC, *Council Directive 89/391/EEC of 12th June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work*

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2004/40/EC*, Directive of the European Parliament and of the Council of 29th April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual directive within the meaning of Article 16(1) of Directive 89/391/EEC*)

EN 50341-1, *Overhead electrical lines exceeding AC 45 kV - Part 1: General requirements - Common specifications*

EN 50423-1, *Overhead electrical lines exceeding AC 1 kV up to and including AC 45 kV - Part 1: General requirements - Common specifications*

# Annex G
(informative)

# Zoning

## G.1 Introduction

This annex describes a simple administrative procedure that employers may wish to consider in order to define different areas in their work place.

These are not intended to be strict or “hard” boundaries corresponding to the exact locations that different exposure levels might be exceeded. Instead they might correspond to, for example, existing areas of a work place. For example, a particular building or area might contain equipment that gives rise to exposures greater then public levels, even though those levels are not exceeded in most of the building or area. The employer may choose, for reasons of convenience, that access to that whole building or area should be restricted to certain people (e.g. excludes visiting members of the public) or that access is associated with information about likely EMF levels.

Various zones (as described in G.2) are defined, but whether and where the exact zone boundaries are decided is a matter for the individual employer. What actions (if any) are to be taken at zone boundaries also is a matter for the employer.

## G.2 Work place zones

- A Zone 0 work place is one in which exposure levels are in accordance with national limit values for public exposures or all the equipment in the work place is included in Table 1.

- In Zone 1, exposures may be greater than national limit values for public exposures but will be compliant with the occupational exposure limit.

- In Zone 2, exposures may be greater than the occupational exposure limit. If access is possible to Zone 2, then remedial measures to reduce exposure or to restrict or limit access should be taken.

## G.3 Implementation of zoning

Figure G.1 illustrates the process by which such zoning can be implemented by an employer. It is parallel to, and coherent with, the overall assessment procedure described in Clauses 8 and 9. The exposure in a zone would be assessed under normal working conditions.

A work place which contains only equipment listed in Table 1, including equipment as described in Annex C, is normally a Zone 0 work place.

The zone definition process is illustrated by the shaded area of Figure G.1. This assessment is used to establish the Zone 1 and (if relevant) Zone 2 boundaries.

Determination of the Zone 2 boundary should be in accordance with the assessment procedures of Clause 5. The Zone 1 boundary can be determined similarly, although an employer may wish to take a simple administrative approach and, for example, set a Zone 1 boundary at the entrance to a work place or location if it contains equipment likely to, or shown to, exceed the relevant general public exposure limit at a closer distance than the entrance, even though parts of it are Zone 0. In this way, zoning of a work place could be achieved solely on the basis of information from a manufacturer or supplier. The Zone 1 boundary need not be a "hard" boundary and could just be a subject for worker training or information based on identifiable areas of the work place.

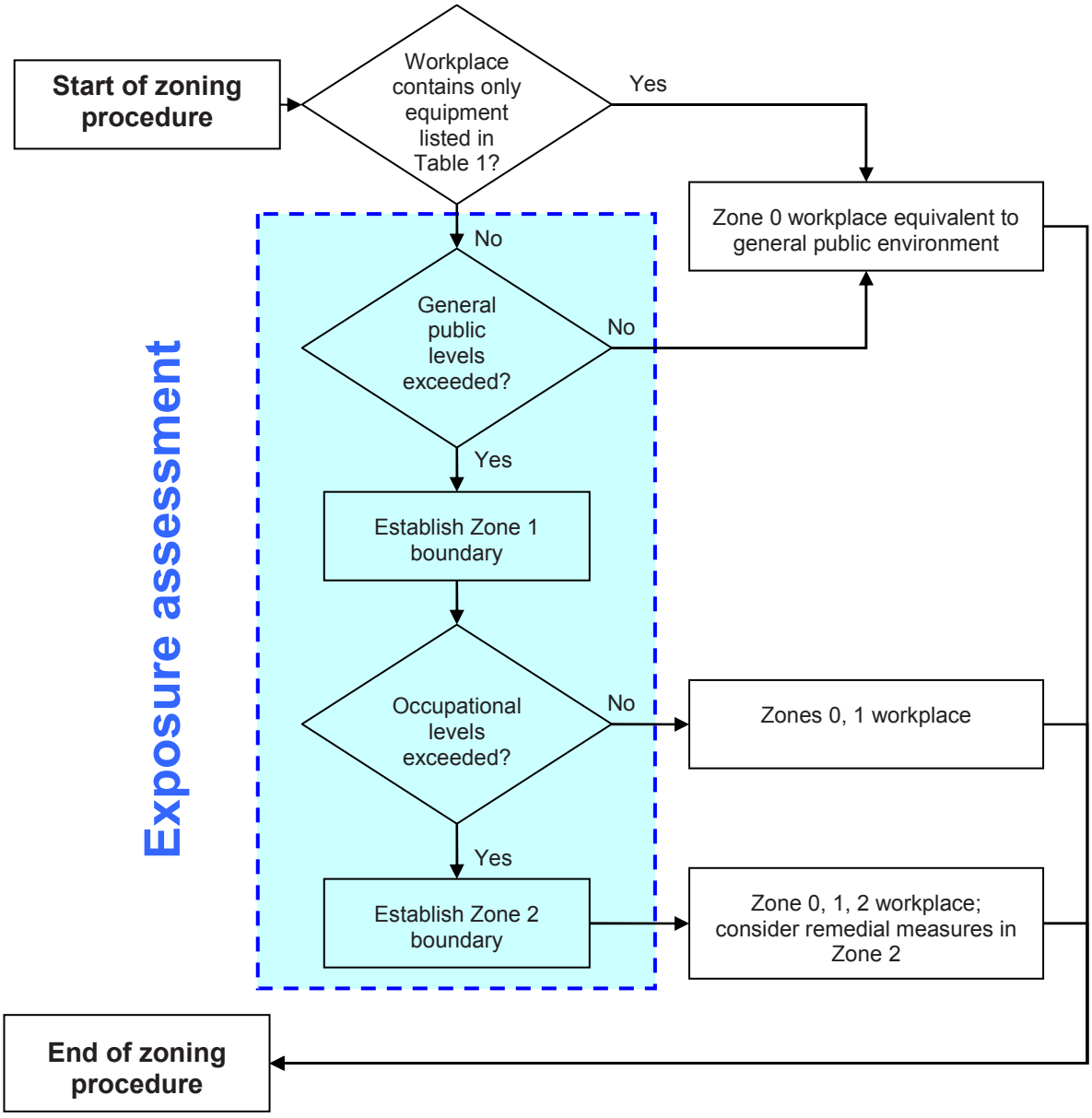


**Figure G.1 ± Zoning process**

More information related to principles of zoning can be found in ETSI/TR 101 870.

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EN 50505, *Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for resistance welding and allied processes*

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