ECMA INTERNATIONAL

Technical Report

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# Guide for Assessment of Human Exposure to Electromagnetic Fields from Multimedia Products in accordance with IEC/EN 62311

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## Introduction

This Technical Report (TR) provides guidance for the assessment of electromagnetic field (EMF) exposure of the general public from multimedia equipment (MME) over the frequency range 0-300 GHz in accordance with the standard IEC 62311 and its European equivalent EN 62311. For convenience of the reader, in the remainder of this ECMA TR reference will be made to both standards as follows: IEC/EN 62311.

The standard IEC/EN 62311 is a generic standard that is applicable for all electrical and electronic equipment that are not covered by a specific EMF product standard. Several EMF standards exist for various categories of electronic products. However, specifically for MME, no product standard is currently available. Hence, the standard IEC/EN 62311 should be the applicable one for MME.

Due to its generic nature however, IEC/EN 62311 does not provide specific assessment methods for every particular technology. Therefore, it is the purpose of this TR to provide specific guidance on how to apply IEC/EN 62311 in case of MME.



This Ecma Technical Report has been adopted by the General Assembly of June 2009.

# Guide for Assessment of Human Exposure to Electromagnetic Fields from Multimedia Products in accordance with IEC/EN 62311

## 1 Scope

This Technical Report (TR) applies to multimedia equipment (MME) in the scope of IEC/EN 62311 for which no product standard is available.

MME may be powered by the mains power supply, by batteries or by any other electrical power source. The MME may also be connected to wired or wireless telecommunication networks. They may contain intentional radiators (like Wi-Fi or GSM) for wireless network connections. The MMEs are considered general public use. Hence, for the purpose of this technical report the EMF exposure limits for general public will be applied (see Annex B of this TR).

This document is not meant to provide new EMF exposure limits in addition to those referenced in IEC/EN 62311. This TR provides guidance on the application of IEC/EN 62311 with practical and specific methods to show compliance with the exposure limits for MME.

## 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.

CISPR 13: 2006-03, Sound and television broadcast receivers and associated equipment –radio disturbance characteristics – limits and methods of measurement

CISPR 22: 2006-03, Information technology equipment- radio disturbance characteristics – limits and methods of measurement

IEC 62209-1: 2005-02, Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)

IEC 62209-2, Human exposure to radio frequency fields from handheld and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for mobile wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz) (PT 62209-2, standard is under development: see 106/162/CDV).

IEC 62233: 2005-10, Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure

IEC 62311: 2007-08, Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)

EN 62311: 2008, Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)

EN 50371: 2002, 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

IEC 60950-1: 2005-12, Information technology equipment – Safety – Part 1: General Requirements, 2nd edition

IEC 61000-4-21, Electromagnetic compatibility (EMC) Part 4-21: Testing and measurement techniques - Reverberation chamber test methods (IEC 61000-4-21:2003).

## 3 Terms and definitions

For the purpose of this TR the following terms and definitions apply in addition to those already included in IEC/EN 62311. The internationally accepted SI-units are used throughout the TR.

**3.1**
**Assessment**
activity with the objective to demonstrate whether the MME, in a specified configuration and arrangement and in the relevant modes of operation, complies with the applicable EMF exposure limit at the agreed assessment positions near the MME.

**3.2**
**Arrangement**
physical layout of the all parts of the MME and the interfaces between the parts of the MME, the connecting cables and the interfaces to associated equipment which is preferably located outside the test area.

**3.3**
**Assessment distance**
distance from the MME at which the EMF assessment is performed.

**3.4**
**Assessment surface**
area, i.e. surfaces around the MME, at the assessment distance from the MME, where the EMF assessment is performed.

**3.5**
**Assessment position**
orientation of the person or phantom with respect to the MME, where the EMF assessment is performed.

**3.6**
**Configuration**
selection of functional units according to their nature, number, and chief characteristics.

**3.7**
**Mode of operation**
mode in which the MME operates during the EMF assessment.

**3.8**
**Multimedia equipment (MME)**
equipment that has the function of information technology equipment (ITE), audio, video, or broadcast receiving equipment, interaction and / or communication with the user of the product or combinations of these functions.

NOTE Examples of MME are: recorders, players and displays, televisions and radio receivers, wake-up alarm radio/players, DVD-players, CD-players, portable CD and MP3-players, monitors, personal computers, laptops and similar equipment.

## 4 Abbreviations

| | |
|---|---|
| A/V | Audio/Video |
| AC | Alternating Current |
| CENELEC | Comité Européen de Normalisation Electrotechnique (European Committee for Electrotechnical Standardization) |
| DC | Direct Current |
| DECT | Digital Enhanced Cordless Telecommunications |
| EIRP | Equivalent Isotropic Radiated Power |
| ELF | extreme low frequencies |
| EMC | electromagnetic compatibility |
| EMF | electromagnetic fields |
| EN | European norm |
| GHz | GigaHerz |
| GSM | Global System for Mobile communications |
| HF | high frequency |
| Hz | Hertz |
| ICNIRP | International Commission on Non-Ionizing Radiation Protection |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronics Engineers |
| ITE | Information Technology Equipment |
| LF | low frequency |
| MM | multimedia |
| MME | multimedia equipment |
| NF/FF | Near Field Far Field |
| PLT | Power Line Telecommunication |
| PRF | Pulse Repetition Frequency |
| RF | radio frequency |
| rms | root mean square |
| rss | root sum square |
| RVC | reverberation chamber |
| SA | Specific Absorption |
| SAR | Specific Absorption Rate |
| T | Tesla |
| TR | Technical Report |
| TRP | total radiated power |
| UHF | Ultra High Frequency |
| UMTS | Universal Mobile Telecommunications System |
| VHF | Very High Frequency |
| VLF | Very Low Frequency |

| | |
|---|---|
| WiFi | Wireless Fidelity |
| WIMAX | Worldwide Interoperability for Microwave Access |
| WLAN | Wireless Local Area Network |

## 5 Notation

| Quantity | Symbol | Unit | Dimension |
|---|---|---|---|
| Conductivity | σ | Siemens per meter | S/m |
| Current density | *J* | Ampere per square meter | $A/m^2$ |
| Electric field strength | *E* | Volt per meter | V/m |
| Frequency | *f* | Hertz | Hz |
| Magnetic field strength | *H* | Ampere per meter | A/m |
| Magnetic flux density | *B* | Tesla | T ($Wb/m^2$, $Vs/m^2$) |
| Power | *P* | Watt | W |
| Current | *I* | Ampere | A |

## 6 Consideration of the emissions generated by MME

MME may be the source of either intentional or non-intentional emissions through the space around the MME or through its interfaces.

Non-intentional emission may be 50 Hz harmonics through the mains, broadband noise through the mains and other interfaces, clock frequencies and their harmonics emitted though interfaces or through the free-space around the MME. Non-intentional emissions of MME are limited through EMC conducted and radiated emission requirements that are stated as limits for the various ports of a MME and specified as function of frequency together with specific measurement methods and measurement equipment.

Certain functions or technologies integrated in the MME may cause intentional emissions. One can think of e.g. a WLAN transmit module, Bluetooth or DECT.

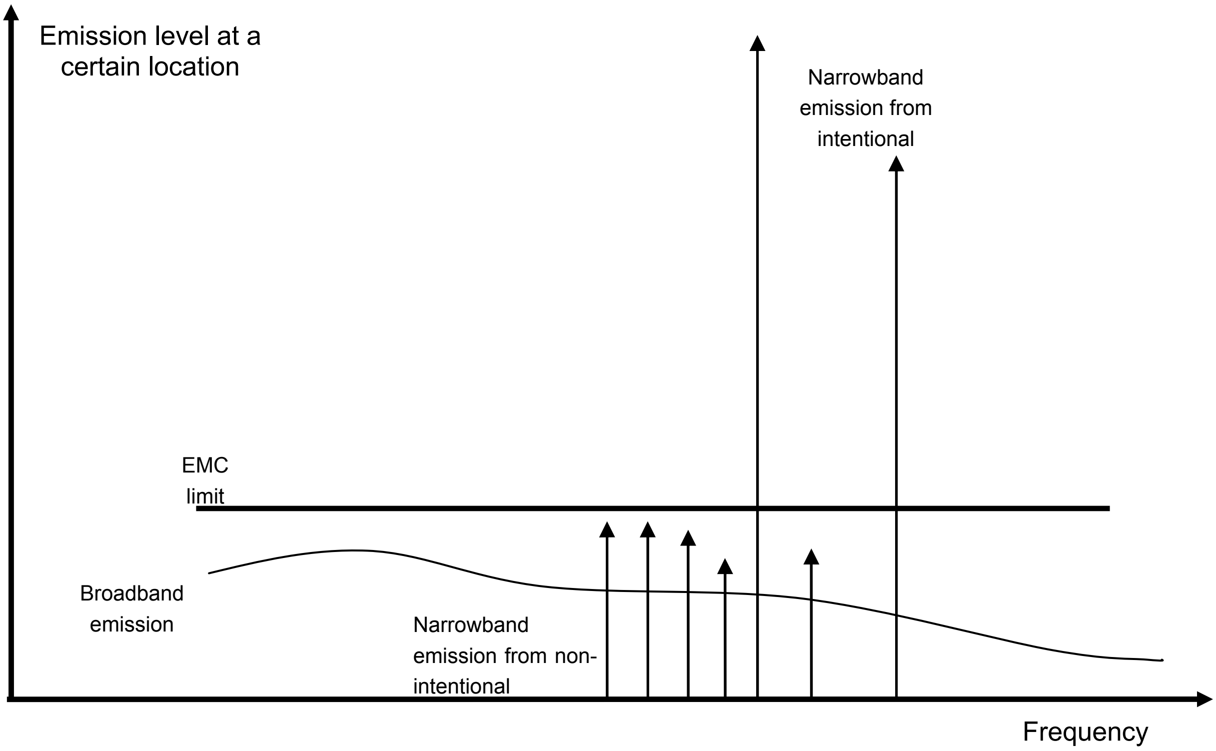


**Figure 1 — Illustration of a typical emission spectrum of a MME, including spurious broadband and narrowband emissions and narrowband intentional radiators**

EMF assessment does not only depend on the type of emission of certain MME but also on the exposure distance of a human being from such equipment. Therefore, the assessment distance and surface or position has to be selected for an MME before starting the actual assessment. Annex A is devoted to selection of the assessment distance, surface and position

Moreover, if multiple wireless technologies are implemented in an MME, the exposure assessment needs to consider the result of all intentional radiators together (see 7.3).

Summarizing, the following properties of an MME are key for an EMF assessment.

- The type of intentional emissions generated by the MME.
- The exposure distance of a human being from the MME.
- The number of intentional radiators implemented in the same MME.

Considering these properties, the standard IEC/EN 62311 allows the identification of the following four scenarios.

1. Equipment from which non-intentional emissions can be considered inherently compliant with the applicable EMF exposure limits. Examples of this equipment are given in clause 7.2 of IEC/EN 62311 (wrist watches, ADSL modems, computers, telecommunication equipment or hi-fi systems). Therefore, the great majority of MME can be considered as such. Clause 10 of this TR provides guidance for this kind of equipment.

   NOTE
   This consideration is also supported by ITU in recommendation ITU-T K.52 [10].

2. Equipment from which non-intentional emissions potentially need further assessment to show compliance with the applicable EMF exposure limits. Due to their technological nature, in general MME are not likely

 

to be considered under this kind of equipment. However, in cases where the nature of the MME is such that manufacturers know beforehand that relevant EMF emission might occur, this TR provides in Clause 11 guidance to perform the EMF assessment.

3. Equipment from which intentional emissions are below the low-power exclusion level. Clause 10 of this TR provides guidance for these “intentional radiators”.

4. Equipment from which intentional emissions are above the low-power exclusion level and therefore need further EMF assessment. Details on how to perform such assessment can be found in clause 11 of this TR.

# 7 Selection of compliance criteria

This clause provides guidance related to the selection of compliance criteria for the EMF assessment of MME as reflected in clause 4 of IEC/EN 62311.

## 7.1 General

Compliance with EMF basic restrictions and/or reference levels has to be proven by performing an exposure assessment over the MME. Compliance criteria (or the appropriate set of applicable exposure limits) must be selected for the MME under consideration. Annex B lists a number of exposure limits from different limit setting documents for information only.

## 7.2 Overview of physical quantities that can be used for exposure assessment

### 7.2.1 Basic restrictions

Limits on EMF exposure are named ‘basic restrictions’ and are based directly on established health effects and biological considerations. The physical quantities used in ICNIRP Guidelines [1], the EMF Recommendation [3], IEEE C95.1-2005 [4] and IEEE C95.6-2002 [5], reflect the different concepts of *dose* relevant to the lowest threshold for a health effect at different frequencies.

In the low frequency range (between 1 Hz and 10 MHz) the basic restriction is the current density ($J$, in $Am^{-2}$) for preventing effects in excitable tissues such as nerve and muscle cells; and in the high frequency range (between 100 kHz and 10 GHz), the basic restriction is the specific absorption rate (SAR, in W/kg) for prevention of whole-body heat stress and local heating.

In the intermediate frequency range (between 100 kHz and 10 MHz) restrictions are on both the current density and SAR, while in the very high frequency range (between 10 and 300 GHz) the basic restriction is the power density ($S$, in $Wm^{-2}$) for excessive tissue heating near or at the body surface.

### 7.2.2 Reference levels

Because basic restrictions are often specified as quantities that may be impractical to measure, other quantities are introduced for practical exposure assessment purposes to determine whether the basic restrictions are met. These are named ‘reference levels’.

Reference levels correspond to basic restrictions under worst case exposure conditions for one or more of the following physical quantities: electric field strength ($E$), magnetic field strength ($H$), magnetic flux density ($B$), power density ($S$), limb current ($IL$), contact current ($I_c$) and, for pulsed fields, specific energy absorption ($SA$). Hence, if the reference levels are met, then the basic restrictions will also be met, and the product complies with the applicable EMF exposure limits.

Exceeding the reference levels does not necessarily imply that the basic restrictions are also exceeded. However, in this case, it is necessary to assess compliance with the relevant basic restrictions and to determine whether additional protective measures are necessary.

#### 7.2.3 Derived compliance criteria

In some cases it may also be possible to derive compliance criteria that allow a simple measurement or calculation to demonstrate compliance with the basic restriction. Often these compliance criteria can be derived using realistic assumptions about conditions under which exposures from a device may occur, rather than the conservative assumptions that are the basis for the reference levels. An example of such an approach is the low power exclusion (20 mW) given in the low-power generic standard EN 50371 (or its successor IEC/EN 62479 [12], [13]).

### 7.3 Exposure to multiple transmitting sources

In case an MME is equipped with multiple intentional radiators, the EMF assessment might not be only reduced to the study of each one of the sources separately. The effect of multiple intentional radiators should be considered in the EMF exposure assessment.

Technical Report IEC 62630 [15] provides generic guidance on how to assess the exposure to multiple intentional radiators.

### 7.4 Criteria for selection of limits

In case the MME has to comply with EN 62311, the exposure limits of the Council Recommendation 1999/519/EC referred to in the common modification of EN 62311 shall be applied.

To comply with IEC 62311 the appropriate exposure limits established by the ICNIRP guidelines or IEEE standards may be applicable.

See Annex B for more detailed information on the actual exposure limit levels as a function of frequency.

## 8 Assessment procedure for MME

7.2 of IEC/EN 62311 provides a generic procedure together with a flowchart for performing the EMF assessment. This generic procedure and flowchart for the EMF assessment of MME will also be applied in this TR. For convenience the flowchart given in IEC/EN 62311 is repeated in this report as Figure 2. This figure indicates the steps to be taken and gives references to the clauses of this TR where each of the steps is explained from a MME perspective.

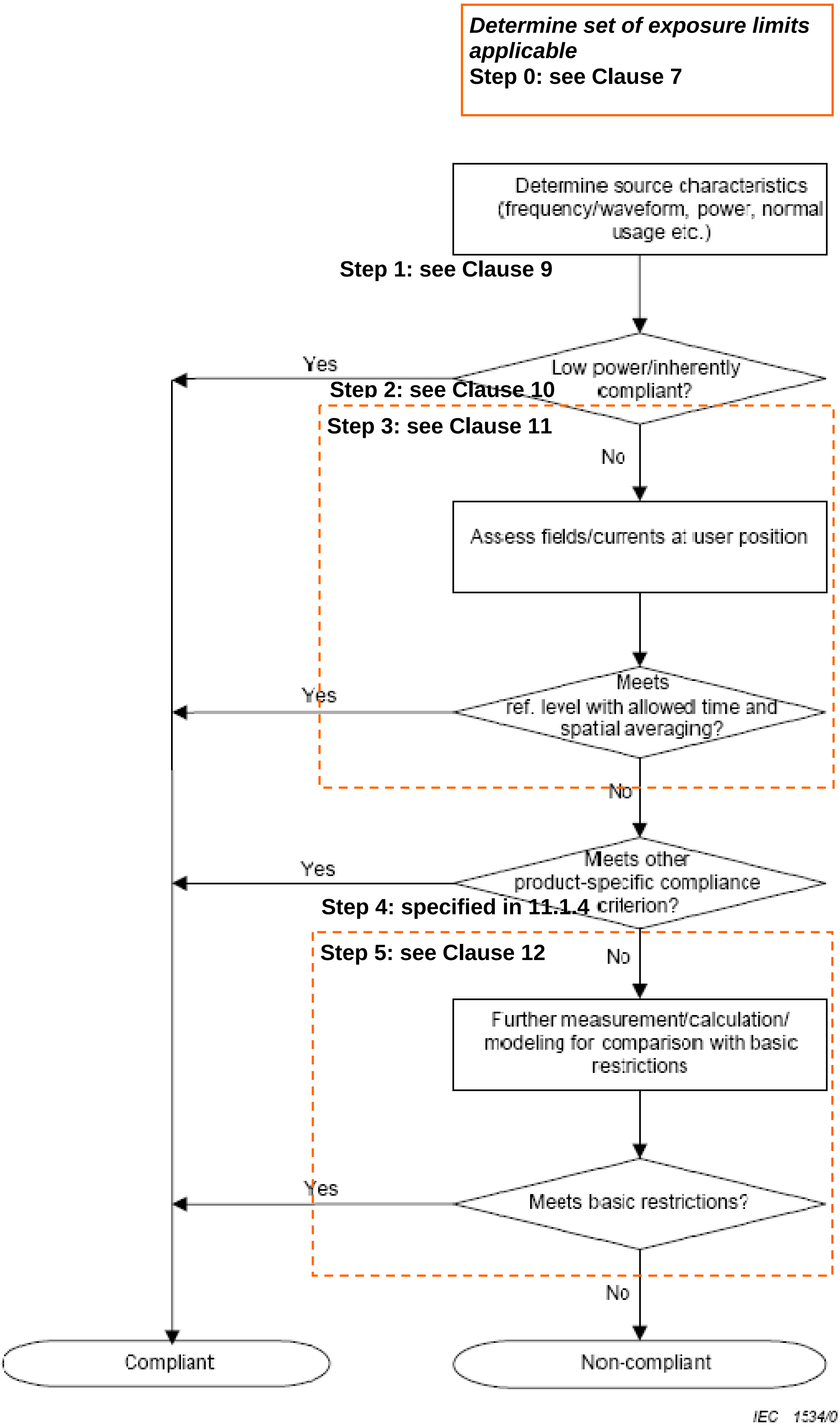


**Figure 2 — Assessment flowchart (black part equal to Figure 1 of IEC/EN 62311)**

# 9 Determine basic characteristics of the MME

This clause provides guidance related to Step 1 of the assessment flowchart given in Figure 2. A number of characteristics and data regarding the MME and its application may need to be gathered if the equipment can not be considered inherently compliant as specified in clause 6.

## 9.1 Introduction

Exposure levels in the neighbourhood of an actual MME in a real environment depend on various parameters, and are therefore a statistical parameter. In practice, an MME may have different configurations, numerous operating modes and different methods of powering can be applied. Also, various wired and wireless interconnections to other apparatus can be used. The MME may be set-up in different ways and the products may be located at different heights above the floor or at different positions from reflecting objects. Furthermore, environmental conditions such as temperature and humidity may affect the level of emission. Finally, persons may be at numerous distances and positions around the MME in question. Therefore, it is in general difficult to define one single exposure position or exposure distance for MME and while it is difficult to assess products against all possible configurations, conditions and positions, it is feasible to assess a representative configuration which can cover a broad range of implementations.

An EMF assessment of an MME should be feasible in practice from a time-consumption point of view. Furthermore, the assessment methods should be reproducible. Therefore, an EMF assessment should be carried out in a specific, simplified but relevant configuration using simplified but relevant operational and environmental conditions.

This clause explains the basic characteristics that have to be determined as a starting point for an EMF compliance assessment. Apart from the source characteristics (mentioned in Step 1 of Figure 2), also characteristics on the configuration, operating conditions, exposure positions and distances of MME should be determined.

## 9.2 Configuration of the MME

As a first step in the EMF assessment it is important to select a configuration of the MME which is representative for the MME in practical use and which can be used for the EMF assessment.

Often, configuration pertains to the choice of hardware, software, firmware, and documentation. The configuration affects system function and performance, and hence it affects the EMF characteristics. The operational conditions of the MME determine the set of hardware elements selected to make up the MME and the mode of operation used in exercising the MME during the assessment.

## 9.3 Reference environment of the MME

The assessment of the MME shall be performed in a simplified operational environment from an electromagnetic point of view. A first order approximation of actual electromagnetic environment is positioning the MME at a typical distance (height) above an electrically conducting ground plane.

For the EMF assessment of an MME, a semi free-space environment over the whole frequency range of 0 Hz to 300 GHz could be used. This simplified operational environment is called the reference environment:

- If the assessment is applied by using modelling, the MME-model could be put in a semi free-space modelling environment.
- If the assessment is done by measurements then the MME could be setup in a semi-anechoic test environment.

Such an environment can be implemented in different ways, depending on the frequency range in question:

 

- At low frequencies (quasi-static situation) the MME could be setup in a shielded room above a conducting ground plane.
- In the radiating frequency range (e.g. above 30 MHz) a semi-anechoic room could be used.
- At higher frequencies (i.e. above 1 GHz), the reference environment could be simulated by using a fully-anechoic room, provided that the exposure distance (assessment distance) is small with respect to the height above the conducting ground plane.

If results are obtained in an alternative assessment environment, e.g. a free-space environment in the frequency range between 30 MHz and 1 GHz, then the results could be transferred to values that are applicable in a semi-free space environment by taking the worst-case effect of a reflecting ground plane into account, e.g. multiplying the result with a factor of two.

Furthermore, the specific assessment methods described in basic EMF standards may provide more details about the setup of MME relevant for the method in question.

## 9.4 Arrangement of the MME

The MME should be setup in a normal use arrangement. The MME may consist of various units and various interconnections can be made between these units or the product may have various interconnections (ports) to external networks (mains, CATV etc).

The operating conditions outlined below are applicable in case of using any EMF measurement methods included in this TR

- The MME should be operated for a sufficient period of time to ensure that the conditions of operation are the typical ones during normal use.
- The MME should be supplied at the rated voltage and rated frequency, and operated as in normal use. MME having more than one rated voltage can be tested at one voltage only.
- A limited number (preferably one) of representative modes of operation should be selected for each function of the MME. The selected mode of operation shall produce the highest EMF exposure level during the assessment.
- Controls should be adjusted to the settings that likely provide the highest emission levels.
- Products having accessories and interconnections should be assessed with the accessory and interconnection that results in the highest emission.
- Products supplied by battery should be tested with the battery fully charged.

## 9.5 Assessment positions and distances

Several types of MME exist and the actual exposure distance and position is subject to many variations in practice. Assessment distances and positions for different categories of MME are specified in Annex A.

## 9.6 Power characteristics of the MME

MME is generally powered through batteries or through the mains AC power network. The means of powering of MME is important information for assessing the EMF parameters in the ELF frequency range since if the typical powering characteristics of an MME are known, then EMF effects can be predicted fairly well.

Therefore for the ELF frequency region the following characteristics should be known:

- Mains frequency
- Maximum operating mains voltage

- Maximum operating mains current
- Maximum internal power voltage and frequency
- Maximum internal power current and frequency

Since it is very unlikely that MME exceed the ELF limits, knowledge of these characteristics can be used to demonstrate EMF compliance in the low frequency region (see 11.1.2 and 11.1.4.2).

### 9.7 Intentional EM sources

The assessment should be performed in the frequency range of operation of the intentional radiator. In the frequency range above 18 GHz or below 50 Hz, MME in the scope of this TR are deemed to comply with the applicable EMF exposure limits without further assessment.

Annex D gives a non-exhaustive overview of possible technologies that might be part of MME.

As a first step of the assessment it is important to gather all relevant EMF information concerning these intentional EM sources. Important parameters are:

- Frequency range of operation
- Peak output power
- Duty cycle
- Waveform
- Gain of the antenna

These parameters are important information for assessing the EMF performance of a MME implementing intentional radiators.

## 10 Low power/Inherently compliant assessment methodologies

This clause provides guidance related to Step 2 of the assessment flowchart given in Figure 2 of this TR. This box deals with answering the question whether the MME is compliant with the applicable EMF exposure limits (see clause 7).

It is up to the user of this TR to choose one of the options presented below.

### 10.1 Inherently compliant statement

The inherently compliant statement is a fundamental concept that can be used to declare compliance of an MME with the applicable EMF exposure levels. This statement applies to non-intentional emissions and is explained in 7.2 of IEC/EN 62311 as follows. Some products use a technology or input powers that have the consequence that the emissions cannot exceed the basic restrictions. Subsequently a non-exhaustive list of some categories of non-transmitter products is given (wrist watches, ADSL modems, computers, telecommunication equipment and hi-fi systems).

The inherently compliant statement is based on the assessment of certain characteristics of the non-intentional emissions of the MME (physical nature, technologies or properties) by using inspection of design parameters.

According to what explained above, if the nature of the MME is such that can be considered inherently compliant, then the non-intentional emissions of this equipment comply with IEC/EN 62311 without further assessment.

## 10.2 The low-power exclusion

The standard IEC/EN 62311 considers that if equipment (both intentional and non-intentional emissions) can be shown as compliant with the generic low power standard EN 50371 (or IEC/EN 62479) then the EMF requirements of IEC/EN 62311 are considered to be met.

NOTE Measurements performed by ECMA TC20 members on a sample of MME using methods referenced in Annexes C and H show that all tested MME meet the applicable low power exclusion limits. Such a conclusion can reasonably be extended to all current MME without any intentional radiator.

### 10.2.1 Consideration for an alternative low-power exclusion levels

As explained in Annex E, it can be demonstrated that the 20 mW low-power limit specified in EN 50371 is very conservative in nature. For a body very close to the radiating source it is extremely unlikely that all the power would be absorbed in a single voxel of 10 gr tissue. This will be even more unlikely if the exposure distance is enlarged. Therefore a relaxation factor *R* can be used to for increasing the low-power threshold for larger exposure distances:

$$R = 2\pi r^2 \quad (1)$$

where *r* is the exposure distance.

The following table shows the effect of the relaxation factor as a function of the exposure distance in the frequency range 300MHz to 3GHz.

**Table 1 — Relaxation factors for the low-power exclusion**

| Distance r (m) | Relaxation factor R (dimensionless) | Low-power exclusion (mW) |
|---|---|---|
| <0.4 | 1.0 | 20 |
| 0.5 | 1.6 | 31 |
| 0.75 | 3.5 | 71 |
| 1.0 | 6.3 | 126 |
| 1.5 | 14.1 | 283 |
| 2.0 | 25.1 | 503 |
| 3.0 | 56.5 | 1131 |

It should be noted that even more relaxed low-power exclusion levels can be derived, also at distances below 0.4 m, if detailed simulations of the actual antenna configuration and exposed body are applied (refer to Annex E.3).

In conclusion, EMF compliance can be demonstrated for MME by applying the low-power exclusion level of 20 mW, and for exposure distances larger than 0.4 m or for specific exposure configurations in the frequency range 300MHz to 6GHz, much larger thresholds than 20 mW can be applied. This exclusion can be applied easily for assessment of intentional EM sources within the MME.

Example An internet radio which includes a WLAN link (IEEE 802.11 b & g) with a maximum RF output power of 100 mW will be EMF compliant for exposure distance larger than 1 m since at that distance the low-power exclusion level is 126 mW.

## 10.3 Extending EMF compliance to similar equipment

Certain categories, technologies or families of MME may be considered similar from an EMF point of view. Claiming similarity of MME is considered a valid approach for demonstrating compliance with the applicable EMF requirements.

The similarity-claim is based on the following steps:

1. an MME has been demonstrated compliant with the EMF requirements using this TR and will be considered as a reference;

2. a similar new MME is subject to EMF assessment. This assessment can be performed by focusing on the differences between the MME under assessment and a reference MME that has been demonstrated to be compliant with the applicable EMF exposure limits.

Methods to substantiate the similarity are for example:

- showing that a configuration difference does not affect the EM behavior (e.g. material of an enclosure);

- showing that a configuration will cause reduced exposure (e.g. by demonstrating that certain intentional radiators are not included in this MME configuration);

- showing that a configuration difference only partly affects the EMF assessment (e.g. if only a new mains power module is incorporated, then a repetition of the EMF assessment in the RF frequency range is not necessary);

- showing that a change in a EM-relevant module (e.g. a RF-transmitter module, an antenna or an antenna cable) has the same properties than its predecessor;

- showing that the same technology for which EMF compliance has been demonstrated has been used.

Hence, if a new type of MME is demonstrated similar to a reference MME, which is EMF compliant, then the new MME can be also considered EMF compliant.

# 11 Methods for assessment against reference levels

This chapter provides guidance related to Step 3 of the assessment flowchart given in Figure 2. Step 3 deals with the boxes related to whether the MME complies with the reference level requirements.

This chapter applies to:

- non-intentional emissions for which the inherently compliant statement (10.1) can not be applied, and/or

- equipment for which the low-power exclusion (10.2) does not apply.

NOTE Current MME without any intentional radiator are unlikely to require this Step 3 of the EMF assessment. Should future MME require such an assessment, the procedures detailed in this section would also apply.

## 11.1 Identification of EMF quantities that are compliant in certain frequency ranges

### 11.1.1 EMC compliance approach

All MME shall comply with EMC requirements for conducted and radiated emission in a certain frequency range. Although the measurands and conditions for EMF and EMC emission measurements are different from many perspectives, it has been demonstrated that MME that complies with the common EMC requirements of CISPR 13 and/or CISPR 22 is likely to also comply with EMF requirements in the associated frequency range [9] provided that:

i) the exposure distance is larger than 30 cm,

ii) the MME does not include intentional transmitters in the frequency range where EMC compliance has been demonstrated.

NOTE The 30 cm distance is a conservative value and it is highly likely that the conclusion is valid for closer distances.

Also IEC 62493 [14] product standard for lighting equipment demonstrates in its Annex D that lighting products inherently comply with the thermal-effect related EMF requirements (>100 kHz) provided that these products comply with the EMC emission limits of CISPR 15.

This rationale can be used to declare EMF compliance for MME (excluding the effect of intentional emissions), and for exposure distances larger than 30 cm, in the frequency range where the MME complies with EMC requirements. For MME with wired ports this frequency range is 150 kHz – 1 (6) GHz[1]. For battery-fed MME the frequency range of EMC compliance is 30 MHz – 1 (6) GHz[1].

Additionally, the ECMA TR/94 [11] also demonstrates that EMC compliance in the frequency range 10 MHz to 300 GHz, implies EMF compliance in that frequency range.

In summary, the following EMF compliance rationale can be concluded:

If an MME is EMC compliant, then in the associated frequency range, the EMF assessment can be limited to the intentional emission sources only. Hence, if no intentional EM emission sources are present, then in the EMC frequency range no additional EMF assessment needs to be performed.

11.2 of this TR provides guidance on how to assess EMF compliance in the frequency range different to the EMC one.

### 11.1.2 Low-frequency compliance of battery-fed MME

Battery-operated MME is compliant with the EMF requirements, and is deemed to comply without further assessment in the frequency range between 0 Hz and 150 kHz provided the following conditions are met:

a) exposure distance is larger than 20 cm,

b) levels of functional voltages applied within the MME are less than 10 V, in the frequency range below 150 kHz,

c) levels of functional currents within the MME are less than 1.5 A, in the frequency range below 150 kHz.

Conditions for compliance at some exposure distances are given in the following Table 2. For other exposure distances refer to Annex G.

**Table 2 — Conditions for maximum voltages and currents in battery-operated MM-products to be EMF compliant by design in the frequency range from 0 – 150 kHz**

| | E-field condition | H-field condition |
|---|---|---|
| Exposure distance (larger than) (cm) | Internal voltages (smaller than) (V) | Internal currents (smaller than) (A) |
| 1 | 10 | 0.15 |
| 20 | 10 | 1.5 |
| 100 | 1000 | 15 |

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[1] *6 GHz from 2010-10-01 according to EN 55022+A1*

Examples

1) An MME with an exposure distance of 20 cm should be assessed further against the E-field references if an internal operational voltage at a specific frequency below 150 kHz is above 10 V.

2) Table 2 explains why the inherently compliance of domestic appliances for E-fields applied in the product standard IEC 62233 is justified. For most of the mains-fed or battery-fed domestic appliances the applied or internal voltages are less than 1000 V. IEC 62233 goes even further, because this E-field condition is applied at any exposure distance.

The rationale for the possibility to demonstrate EMF compliance of battery-operated products by design in the frequency range below 150 kHz and above 30 MHz is given in Annex G.

11.2 of this TR provides guidance on how to assess EMF compliance in the frequency range between 150 kHz and 30 MHz.

#### 11.1.3 Compliance with contact current reference levels

Various EMF exposure limit setting documents provide limits for contact currents. These limits are set in the frequency range up to 110 MHz in terms of reference levels (see Annex B) to prevent that a metallic/conductive object that is charged by a nearby EM-source is discharged after being touched by a person.

Clause 4 of IEC/EN 62311 mentions contact currents as an exposure parameter that can be considered to be deemed to comply if the product does not have touchable conductive parts or if the conductive touchable parts are permanently connected to the ground. The latter is the case for many MME that have grounding or isolation provisions from a safety point of view.

The contact current leakage from electric/electrical equipment is already regulated to a very small level in safety standards, such as IEC 60950-1 (see references in clause **Error! Reference source not found.**). The effect of contact current is mainly in the frequency range below 100 kHz.

Subsequently, a duplication of contact current evaluation for EMF reasons can be avoided provided that the MME complies with current-leakage requirements given in the safety standard for information technology equipment. In this case the MME is deemed to comply also with the limits for the contact current given in the applicable EMF exposure limits without further assessment, and hence the MME is considered compliant with the contact current reference levels.

Annex C provides more details and substantiation on the compliance of MME for contact current requirements.

#### 11.1.4 Evaluation of product-specific or product-family specific criteria

Clause 5 and clause 7.2 of IEC/EN 62311 allows using certain properties or specification of products to limit the EMF compliance demonstration effort.

This practice can be considered as a method to declare a frequency band or a certain category of exposure parameter as EMF compliant.

This clause will identify the possibilities to apply this approach to MME.

##### 11.1.4.1 Limitation of the upper-frequency band

As explained in clause 5 of IEC/EN 62311 the upper frequency range may be limited by using the following criteria:

- if the highest internal frequency of the MME is less than 100 MHz, the assessments shall only be made up to 1 GHz;

- if the highest internal frequency of the MME is between 100 MHz and 400 MHz, the assessments shall only be made up to 2 GHz;

 

- if the highest internal frequency of the MME is between 400 MHz and 1 GHz, the assessments shall only be made up to 5 GHz;
- if the highest internal frequency of the MME is above 1 GHz, the assessment shall be made up to 5 times the highest frequency.

For the purpose of this TR the following practical interpretation will be given to 'highest internal frequency':

- highest clock frequencies (not its harmonics);
- in case of spread-spectrum technologies: the centre frequency of the associated frequency band.

Considering the EMC compliant approach given in 11.1.1, the assessment up to 1 (6) GHz[2] may be covered by compliance with EMC requirements.

For this TR we will assume an upper bound of the EMC frequency range of 1 (6) GHz[2]. These emissions also take into account the clock frequencies and its harmonics. Radiated emissions above 1 (6) GHz[2] are difficult to measure due to dynamic range problems of state-of-the-art EMC measurement methods. Therefore it is assumed that the radiated emissions of MME above the upper EMC-test frequency of 1 (6) GHz[2] are also irrelevant from an EMF point of view, provided that no intentional EM sources are present in this range.

Hence, for the frequency range above 1 (6) GHz[2], the non-intentional emissions of an MME are deemed to comply with the applicable EMF exposure limits without further assessment.

However, in case intentional emissions are present in this frequency range, these sources shall be also subject to an EMF assessment using methods provided in this TR (see clauses 11 and 12).

#### 11.1.4.2 Limitation of the lower-frequency bound

Generally for mains-fed MME, the mains frequency that is applied is 50 or 60 Hz and therefore no relevant EMF frequency components below 50 Hz are present. In case of battery-fed equipment the DC voltages and currents are very limited, while at the same time the DC exposure limits very high.

Hence, for the frequency range below 50 Hz, MME is deemed to comply with the applicable EMF exposure limits without further assessment.

NOTE For "power bricks" used to feed/charge MME, it can be assumed that no relevant EMF frequency components between DC and 50 Hz are present.

If sources with frequencies below 50 Hz are known to be present and able to produce relevant emissions, then these sources shall be also subject of an EMF assessment using methods provided in this TR (see clauses 11 and 12).

### 11.2 Overview of frequencies in which emissions can be identified as EMF compliant

Figure 3 provides an overview of which parameters and frequency ranges are left for further assessment after considering frequency ranges in which emissions can be identified as EMF compliant (11.1).

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[2] *6 GHz from 2010-10-01 according to EN 55022+A1*

[3] *6 GHz from 2010-10-01 according to EN 55022+A1*

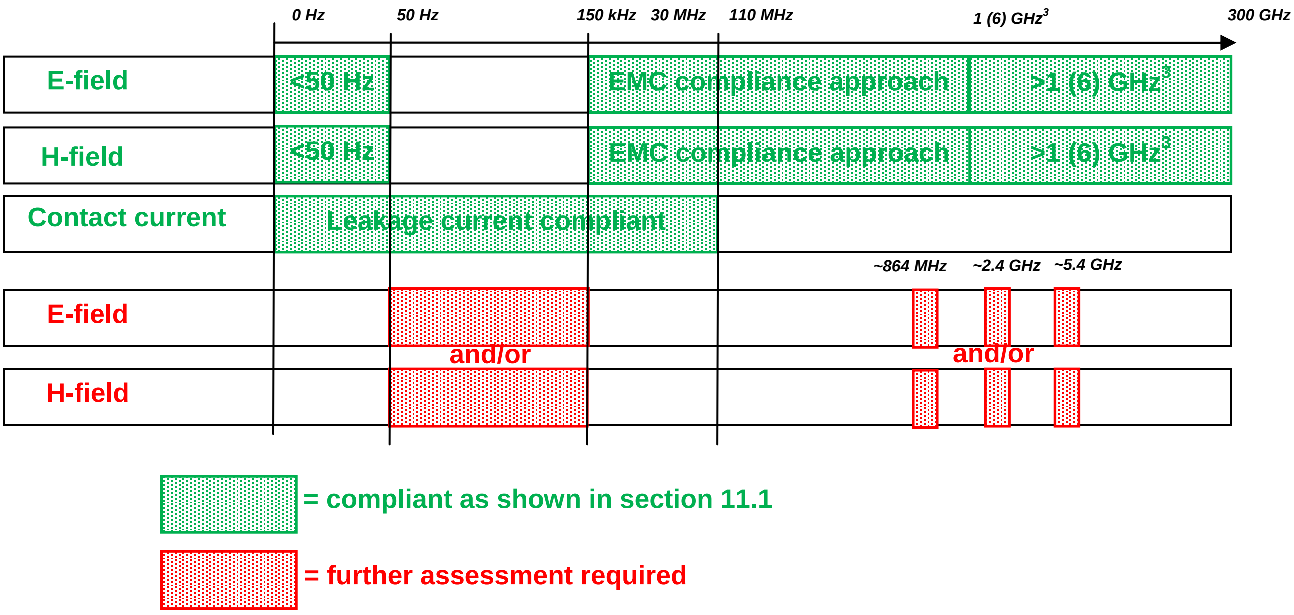



**Figure 3 — Illustration of the parameters left for assessment against the reference levels**

The green boxes in Figure 3 show the frequency ranges and parameters that may be covered by the compliance assessment methodologies given in 11.1. The remaining frequency ranges (red boxes) are to be assessed further.

These areas for further assessment concern the following:

- E-field and/or H-field assessment between 50 Hz and 150 kHz (or 30 MHz in case battery-operated MME) of the non-intentional emissions for which the inherently compliant statement can not be applied, and/or

- the frequency bands of intentional emissions (the three frequencies specified in red boxes in Figure 3 are just examples of possible intentional emissions)

The compliance assessment of E-fields and H-fields can be done in several ways using different methods. It is not necessary to establish the exact amount of emission if it can be shown that the equipment, because of other limitations e.g. maximum obtainable input power, cannot emit levels above the applicable.

Appropriate methods shall be selected for the exposure parameter, frequency range and exposure distance in question. Guidance for the selection of such parameters are presented in the following clauses.

## 11.3 Selection of exposure parameters to be assessed

The various applicable EMF exposure limits contain different types of exposure parameters as a function of frequency and as a function of the type of limit reference level.

The following conclusions can be taken in order to clarify which exposure parameters shall be considered when performing the EMF assessment:

- The magnetic field levels $H$ (in A/m) and the magnetic flux density levels $B$ (in µT) are to be evaluated in free space and have a fixed relationship in such condition. Therefore, in case of considering the magnetic field as a parameter of interest, then one may select either H or B.

- In the far-field region of a radiating structure the electric field $E$ (in V/m), the magnetic field $H$ (in A/m) and the power density $S$ (in W/m$^2$) have a fixed relationship. Therefore the evaluation of one of the parameters, E, or H, or B or S is sufficient due to these fixed relationships provided that the far-field condition is satisfied.

The far-field condition for a transmitter is satisfied if the assessment distance is larger than the far-field distance. The far-field distance of radiating structures ($R_{ff}$) depends on the dimension of the radiating structure ($D$) in relation to the wavelength of the radiated field ($\lambda$):

- For small structures with respect to the wavelength ($D \leq \lambda$) which are typically omni-directional (low directivity), the far-field region is reached at a distance of one-sixth of the wavelength (Rff =λ/2π).

- For a large radiating structure (D>>λ) with a localized small emission like e.g. a small dipole or monopole type of antenna integrated in a MME, relevant currents may flow in the region near the antenna 2λ. Therefore, a practical value of the near-field/far-field (NF/FF) transition region is Rff =8λ.

- Large radiating structures with respect to wavelength (D>>λ) have to satisfy the far-field distance criterion that is also applicable for high-gain antennas provided that the emission source is distributed over that large structure (this is explained in extent in Annex A of IEC/EN 62311).

These three different cases and their associated NF/FF criteria are summarized in Table 3.

**Table 3 — Far-field criteria for different types of radiating structures**

| Dimension *D* of radiating structure | Far-field criterion $r > R_{ff}$ | Exposure parameters to be evaluated |
|---|---|---|
| Small: low-gain antenna in free-space $D \leq \lambda$ | $R_{ff} = \lambda / 2\pi$ | *E* and (*H* or *B*) if $R < R_{ff}$ <br> *E* or *H* or *B* or *S* if $R > R_{ff}$ |
| Large: low-gain antenna installed on or near a large conducting ground plane with dimension $D >> \lambda$ | $R_{ff} = 8\lambda$ | |
| Large (high-gain antenna) with aperture diameter $D$: $D >> \lambda$ | $R_{ff} = 2D^2 / \lambda$ Rayleigh distance | |

NOTES:

1. For a large structure (e.g. a high gain antenna), sometimes also a radiating near-field region is distinguished. This region starts at $R_{ff} = D^2 / 2\lambda$. Beyond this range the power density obeys the free-space relation, but the value of the *E* or *H*-field cannot be estimated from the simple far-field formula.
2. Large structures with respect to wavelength have to satisfy the far-field distance criterion that is also applicable for high-gain antennas (Rayleigh distance criterion) provided that the emission source is distributed over that large structure. The far-field criterion for a large structure with a localized small emission source may be different.
3. Estimation of the maximum dimension *D* of the structure should include the dimension, interconnecting cables and the surroundings. It is not the dimension of units only that determine the dimension *D*. If the cables are long with respect to the wavelength, then it is sufficient to add one wavelength to the dimension of the MME. If the MME is above a floor or next to a wall that can be modeled as a conducting ground plane, then also the mirror image of the MME should be taken into account.

For MME, intentional radiators are integrated in such a way that their radiation pattern is almost omni-directional in order to enable good connection with wireless base stations or repeater. So, high gain radiating structures are unlikely to be part of an MME, and therefore the NF/FF-criterion for high-gain antennas is unlikely to be applicable for MME.

So for an MME, either one of the two ‘low-gain’ NF/FF-criteria ($R_{ff} = \lambda / 2\pi$ or $R_{ff} = 8\lambda$) applies, and hence the dimension of the MME becomes irrelevant.

Examples

A MME containing a 30 MHz radiating source behaves as a small dipole antenna, and the wavelength is 10 m. For exposure distances below 10/2π m (applying the NF/FF-criterion from the first row of Table 3) the exposed person can be considered in the near-field region, and hence both E- and H-field should be considered for assessment.

For a WiFi module with low-gain antenna is installed inside in a large conducting structure (e.g. a TV) operating at 2.4 GHz, the wavelength is 1/8 m. In this case the NF/FF-criterion in the second row of Table 3 applies and becomes 1 m. Therefore, for an exposure distance of 20 cm, the assessment should be done for both E- and H-field. For exposure distances >1 m it is sufficient to perform an E-field measurement only.

Considering the above, the assessment parameters to be selected for MME can be summarized as follows:

- In the induced current frequency (1 Hz - 10 MHz), MME can be considered small with respect to wavelength and both E- and H-field should be assessed separately for all exposure distances

- In the thermal frequency region (100 kHz – 300 GHz), the need to assess E and/or H-fields depends on the NF/FF criterion

These two aspects are reflected as red boxes in Figure 3.

### 11.4 Broadband measurement method

This method requires that the electric (*E*) and/or magnetic (*H*) field strengths are measured at the relevant assessment distance and positions using suitable isotropic broadband probes. The measurements results have to be compared with the applicable reference levels. This method provides the advantage of being a time-effective and conservative way of assessing the fields around an MME.

More details on the broadband measurement method are given Annex F.

### 11.5 Frequency selective measurement methods

A more accurate and conservative method compared to broadband measurements is performing narrowband frequency selective measurements.

Frequency selective measurements are however not straightforward. Apart from being a time consuming method, the right settings of spectrum analysers or measuring receivers are crucial to determine the right values. Annexes D and E of the basic standard EN 50492 provides more guidance on this method.

### 11.6 Test conditions

The operating conditions outlined in 9.4 are applicable in case of using any measurement method included in clause 11.

## 12 Methods for assessment against basic restrictions

This clause provides guidance related to Step 5 of the assessment flowchart given in Figure 2 of this TR. This box deals with answering the question whether the MME is compliant with the basic restriction requirements.

In the particular case of MME, the probability that this Step 5 is needed is rather low, especially in case of non-intentional emissions and/or the exposure distance is larger than 20 cm. However, it should be noted that Step 2 (low power/inherently compliant assessment methodologies) and Step 3 (methods for assessment against reference levels) are conservative in nature and hence the ultimate fall-back to assessment against the basic restrictions may be required (see 7.2).

## 12.1 General

After the steps 2, 3 and 4 (i.e. clauses 10 and 11 of this TR), there might be some remaining assessment effort still needed. In this case the assessment needs to be done using the parameters with respect to the basic restrictions, i.e.

- Induced current: 1 Hz – 10 MHz
- SAR: 100 kHz – 10 GHz

The EMF assessment against the basic restrictions is the last step possible, and it generally involves the most effort. The reason is that either numerical modeling or measurements of parameters inside the body are needed which requires validated models or phantoms.

An overview of the methods that may be applicable for EMF assessment of MME against the basic restrictions are summarized below:

Induced current assessment methods

- Modeling
- Measurement of body currents using a current clamp
- Measurement of body currents using a body phantom

SAR assessment methods:

- Modeling
- Application of the IEC 62209-2 for handheld and body mounted MME
- Actual measurement of total radiated power using a RVC

These methods will be explained in more detail in the next paragraphs.

## 12.2 Induced current assessment methods

### 12.2.1 General

Induced current assessment methods shall be considered in the frequency region from 50 Hz up to 150 kHz (or up to 30 MHz in case of battery-fed MME).

### 12.2.2 Modeling

Two main aspects shall be considered when performing Induced current modeling:

- Selection of the human body model
- Development of a valid source model

Development and validation of the source and human body models depends on various parameters like e.g. exposure distance and frequency.

Annex C of IEC/EN 62311 provides general guidance for modeling of induced current-levels inside a human body.

### 12.2.3 Induced current measurements

Direct measurement of induced currents by using phantoms is not feasible. Therefore, alternative derived measurands must be taken into account in order to assess the value of the actual induced currents inside a body.

The contact current, or the total current flowing from the body to the ground reference or through the limbs are measurands that can be used to demonstrate compliance with the induced current limits inside the body. The limits for induced currents and contact currents (Annex B) can be applied to judge compliance.

Annex D of IEC/EN 62311 provides general guidance for measurement of these body currents. Various types of current measurement devices are available in the frequency range of interest, like the clamp-on current probe or a stand-on parallel plate system. Disadvantage of these measuring systems is that actual human beings are needed to perform the measurements.

To prevent exposure of human beings to potentially hazardous currents and field and to reduce the uncertainty of such measurements it is preferred to apply a standardized phantom for induced current measurements.

In IEC 62493 (IEC 34/125/CDV), for the EMF assessment of lighting products, a “dummy person” (phantom) has been specified. This so-called ‘Van de Hoofden’ test-head is a conducting sphere on a support and represents a head and neck exposed by lighting products. The total current through the neck is measured through protection and impedance network.

## 12.3 SAR assessment methods

### 12.3.1 General

For MME it is sufficient to limit the SAR assessment to assessment of parts of the body, i.e. the head and the trunk. If compliance is demonstrated with these parts of the body then in most cases also the SAR requirements for limbs and for the whole body are met. The rationale for this assumption is that the total maximum rms power radiated by the MME is less than 12.5 times the whole body SAR-limit (see Annex B of IEC/EN 62311). For general public exposure this means that the total radiated power of the MME shall be less than 1 W, which is likely to be applicable for MME.

The measured or modeled SAR-values shall be averaged in time and over certain masses of tissue.

For MME, SAR assessments will be limited to assessment of narrowband or broadband intentional radiators (see Annex D to see typical technologies applied in MME). Hence the frequency range of interest for MME specified in this TR is limited to the range 30 MHz to 10 GHz.

### 12.3.2 SAR modeling

Two main aspects shall be considered when performing SAR modeling:

- Selection of the human body model
- Development of a valid source model

Development and validation of the source and human body models depends on various parameters like e.g. exposure distance and frequency.

Annex C of IEC/EN 62311 provides general guidance for modeling of SAR-levels inside a human body.

### 12.3.3 SAR measurement methods

This method allows the use of the actual MME under test (i.e. no need for source modeling). Furthermore, there are standardized body phantoms and measurement procedures currently available.

The product standard IEC 62209-2 is currently available and can be applied to MME as follows:

i) applies to handheld or body-mounted MME to demonstrate EMF compliance in case of exposure distances less than 20 cm;

ii) for exposure distances above 20 cm no specific product standard for SAR measurement is available. For the exceptional case that SAR assessments are needed for distances beyond 20 cm, it is advised to apply the flat-body phantom of same standard IEC 62209-2 at the larger exposure distance in question.

#### 12.3.4 Total radiated power evaluation

The application of the low-power exclusion (see 10.1) is generally done by inspection of design parameters of intentional radiators. However, sometimes these design parameters are not readily available like e.g. in case proprietary wireless standards are applied.

There might be also an issue on how the radiated power of multiple intentional radiators with complex modulations in a certain limited or even broad frequency band should be determined. Application of a spectrum analyzer may lead to different results depending on the type of detector and the resolution bandwidth.

For intentional radiators, the total radiated power often may be assessed easily by measuring the total output power of the transmit module by using a power meter, provided that the source can be connected directly. For certain modules this is however not always applicable.

Another option to measure the total radiated power is by sampling the field values (amplitude and phase) at a surface around the MME at all frequencies of interest. However this is a very time consuming method and requires a large economic investment.

A much more convenient way of measuring total radiated power (TRP) of an MME is by using the reverberation chamber (RVC) in combination with a thermal power meter. With this method many of the problems mentioned above can be overcome.

More details on the measurement of the TRP using a RVC are given in Annex H.

### 12.4 Test conditions

The operating conditions outlined in 9.4 are applicable in case of using any measurement method included in clause 12.

## 13 Evaluation of compliance to limits

This clause provides guidance related to the evaluation of compliance to the applicable EMF exposure limits taking into account the uncertainty of the assessment (clause 6 of IEC/EN 62311).

### 13.1 Determination of uncertainties

Measurement uncertainties should be treated in line with the ISO Guide to the expression of uncertainty in measurement (the GUM, see [6]) and with the IEC Guide 115 [7].

In general, the aim is to calculate the expanded uncertainty by using a confidence interval of 95 %. Often a k-factor of 1,96 is used to calculate the expanded uncertainty. However k=1,96 is applicable for judgement of a measurement value against an upper and a lower limit. For EMF emission measurements a single limit applies and therefore another k-factor (k=1,64) should be used.

The expanded uncertainty should be determined as a function of frequency using certain frequency ranges corresponding to the method applicable for that frequency range. If the uncertainty varies significantly over the frequency range, then it may be desirable to determine uncertainties in different subranges of the whole frequency range.

## 13.2 Compliance judgement

The compliance judgment is performed in accordance with procedure 1 given in 4.4.2 of the IEC Guide 115. In this procedure, the assessment result is directly compared to the defined limit. The result complies with the limit if the probability of being below the limit is at least 50 %.

# Annex A

## Assessment distances, positions and surfaces

### A.1 Introduction

Several types of MME exist and the actual exposure distance and position of the exposed person is subject to many variations in practice. For the reason of simplification and reproducibility, assessment distances, positions and surfaces have been specified for several types of MME. These distances, positions and surfaces are based on expected location of users of MME under typical and normal use. Hence, no worst-case distances are applied that are considered to be exceptional in normal practice.

The assessment distance to be selected is relevant for the setting up the MME configuration that will be used for the assessment of the EMF exposure parameter that is considered.

Only the assessment distance and surface are relevant in case the EMF assessment is performed against the reference levels.

In case of EMF assessment against the basic restrictions, only the assessment distance and position of the exposed (part of the) body with respect to the MME is relevant, because the actual level of the basic restriction parameter has to be evaluated inside the exposed body or within the model of the exposed body (phantom).

### A.2 Considerations for assessment distances, positions and surfaces

#### A.2.1 Assessment distances

Table A.1 contains the maximum assessment distances for different types of MME.

For actual evaluations a distance smaller than the assessment distance may be applied. Compliance demonstrated at a reduced assessment distance generally also implies compliance at the actual assessment distance.

#### A.2.2 Assessment positions

As mentioned above, the assessment position is only relevant in case of EMF assessment against the basic restrictions (SAR or current density inside the body). In these cases, the position of the body with respect to the MME shall be specified. Subsequently, the exposure levels to be compared with the basic restriction can be determined by using modelling or measurements (phantoms). The assessment position can be specified in terms of distance from the MME and relative orientation (angles, height, etc).

NOTE In general, basic restriction evaluations are not likely to be needed for exposure distances larger than 20 cm.

#### A.2.3 Assessment surfaces

Various types of assessment surfaces may be applied for the different types of MME. Basically, the following four basic types of assessment surfaces are defined (see Figure A.1):

- Cylindrical: assessment positions on a vertical cylindrical surface around the MME at a specified assessment distance measured from the surface of the MME.

- Top: assessment positions along a surface at the specified assessment distance from the top surface of the MME.
- Front: assessment positions along a surface at the specified assessment distance from the front surface of the MME.
- Around: assessment positions all around the MME along a surface at the specified assessment distance from the surface of the MME.

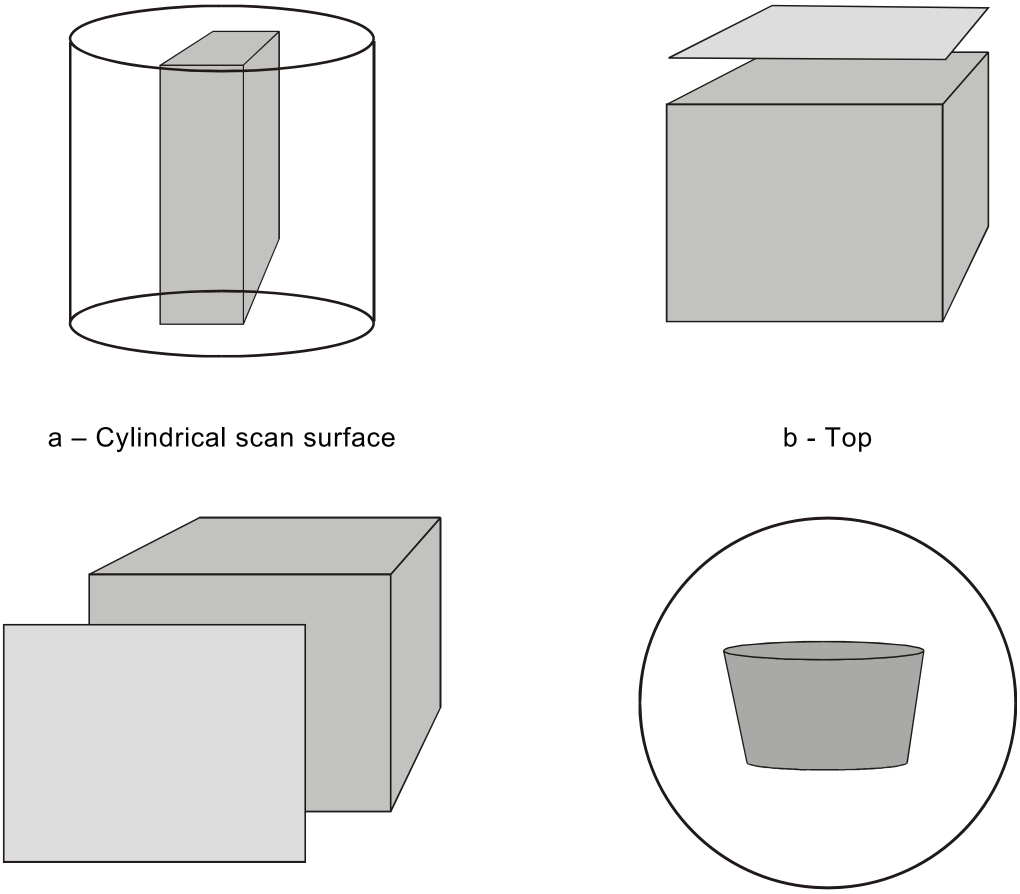
## A.3 Assessment distances, positions and surfaces for different types of MME

Depending on the type of MME, a certain assessment distance and a certain type of assessment position or surface shall be selected. Table A.1 gives an overview of assessment distances, positions and surfaces for various types of MME.

**Table A.1 — Assessment distances, positions and surfaces**

| **Type of MME** | **Assessment distance (cm)** (see A.2.1) | **Assessment position** (see A.2.2) | **Assessment surface** (see A.2.3 and Figure A.1) |
|---|---|---|---|
| Audio/video recorder/player (DVD/CD) | 30 | N/A | cylindrical |
| Television receiver | 100 | N/A | front |
| Radio receiver | 50 | N/A | cylindrical |
| Video display | 50 | N/A | front |
| Computer monitor | 50 | N/A | front |
| Desktop computer | 50 | N/A | cylindrical & top |
| Laptop/notebook computer | see IEC 62209-1 and -2 standards | | |
| Baby surveillance | 50 | | around |
| Headphone | see IEC 62209-1 and -2 standards | | |
| Portable, handheld or body mounted | see IEC 62209-1 and -2 standards | | |
| Other | typical normal use position | N/A | to be determined depending on the MME |

The assessment shall be performed over the assessment surface. The way of scanning (step size) depends on the frequency range, the type of field (E- or H-field) to be assessed and on the disturbance properties and size of the MME.



a – Cylindrical scan surface

b - Top

c – Front

d – Around

**Figure A.1 — Illustration of different types of surfaces for assessment of reference levels near an MME**

# Annex B

# Exposure limits

## B.1 Introduction

EMF exposure limits from different organisations and bodies are given in this annex. They are only for information and are not an exhaustive list. It is the responsibility of users of this TR to ensure that they use the applicable version of the limit sets as specified by the appropriate bodies or national authorities. The tables given below have been extracted from the original publications.

## B.2 ICNIRP guidelines

Tables B.2.1, B.2.2 and B.2.3 contain the exposure limits for the general public given by the ICNIRP guidelines [B.6.1].

**Table B.2.1 — Basic restrictions for general public exposure to time varying electric and magnetic fields for frequencies up to 10 GHz**

**Table 4.** Basic restrictions for time varying electric and magnetic fields for frequencies up to 10 GHz.[a]

| Exposure characteristics | Frequency range | Current density for head and trunk (mA m$^{-2}$) (rms) | Whole-body average SAR (W kg$^{-1}$) | Localized SAR (head and trunk) (W kg$^{-1}$) | Localized SAR (limbs) (W kg$^{-1}$) |
|---|---|---|---|---|---|
| Occupational exposure | up to 1 Hz | 40 | — | — | — |
| | 1–4 Hz | 40/*f* | — | — | — |
| | 4 Hz–1 kHz | 10 | — | — | — |
| | 1–100 kHz | *f*/100 | — | — | — |
| | 100 kHz–10 MHz | *f*/100 | 0.4 | 10 | 20 |
| | 10 MHz–10 GHz | — | 0.4 | 10 | 20 |
| General public exposure | up to 1 Hz | 8 | — | — | — |
| | 1–4 Hz | 8/*f* | — | — | — |
| | 4 Hz–1 kHz | 2 | — | — | — |
| | 1–100 kHz | *f*/500 | — | — | — |
| | 100 kHz–10 MHz | *f*/500 | 0.08 | 2 | 4 |
| | 10 MHz–10 GHz | — | 0.08 | 2 | 4 |

[a] Note:

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

## Table B.2.2 — Basic restrictions for general public exposure to time varying electric between 10 and 300 GHz

**Table 5.** Basic restrictions for power density for frequencies between 10 and 300 GHz.[a]

| Exposure characteristics | Power density ($W\ m^{-2}$) |
|---|---|
| Occupational exposure | 50 |
| General public | 10 |

[a] Note:

1. Power densities are to be averaged over any 20 $cm^2$ of exposed area and any $68/f^{1.05}$-min period (where $f$ is in GHz) to compensate for progressively shorter penetration depth as the frequency increases.
2. Spatial maximum power densities, averaged over 1 $cm^2$, should not exceed 20 times the values above.

## Table B.2.3 — Reference levels for general public exposure to time varying electric and magnetic fields

**Table 7.** Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed rms values).[a]

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

[a] Note:

1. $f$ as indicated in the frequency range column.
2. Provided that basic restrictions are met and adverse indirect effects can be excluded, field strength values can be exceeded.
3. For frequencies between 100 kHz and 10 GHz, $S_{eq}$, $E^2$, $H^2$, and $B^2$ are to averaged over any 6-min period.
4. For peak values at frequencies up to 100 kHz see Table 4, note 3.
5. For peak values at frequencies exceeding 100 kHz see Figs. 1 and 2. Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 kHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz it is suggested that the peak equivalent plane wave power density, as averaged over the pulse width does not exceed 1,000 times the $S_{eq}$ restrictions, or that the field strength does not exceed 32 times the field strength exposure levels given in the table.
6. For frequencies exceeding 10 GHz, $S_{eq}$, $E^2$, $H^2$, and $B^2$ are to be averaged over any $68/f^{1.05}$-min period ($f$ in GHz).
7. No E-field value is provided for frequencies $<1$ Hz, which are effectively static electric fields. perception of surface electric charges will not occur at field strengths less than 25 $kVm^{-1}$. Spark discharges causing stress or annoyance should be avoided.

## Table B.2.4 — Reference levels for contact currents from conductive objects

**Table 8.** Reference levels for time varying contact currents from conductive objects.[a]

| Exposure characteristics | Frequency range | Maximum contact current (mA) |
|---|---|---|
| Occupational exposure | up to 2.5 kHz | 1.0 |
| | 2.5–100 kHz | $0.4f$ |
| | 100 kHz–110 MHz | 40 |
| General public exposure | up to 2.5 kHz | 0.5 |
| | 2.5–100 kHz | $0.2f$ |
| | 100 kHz–110 MHz | 20 |

[a] $f$ is the frequency in kHz.

**Table B.2.5 — Reference levels for induced currents**

**Table 9.** Reference levels for current induced in any limb at frequencies between 10 and 110 MHz.[a]

| Exposure characteristics | Current (mA) |
|---|---|
| Occupational exposure | 100 |
| General public | 45 |

[a] Note:

1. The public reference level is equal to the occupational reference level divided by $\sqrt{5}$.
2. For compliance with the basic restriction on localized SAR, the square root of the time-averaged value of the square of the induced current over any 6-min period forms the basis of the reference levels.

## B.3 Council Recommendation

Tables B.3.1, B.3.2 and B.3.3 contain the exposure limits for the general public reflected in the Council Recommendation 1999/519/EC [B.6.2].

**Table B.3.1 — Basic restrictions for general public exposure to time varying electric and magnetic fields for frequencies up to 300 GHz**

*Table 1*

**Basic restrictions for electric, magnetic and electromagnetic fields (0 Hz to 300 GHz)**

| Frequency range | Magnetic flux density (mT) | Current density (mA/m²) (rms) | Whole body average SAR (W/kg) | Localised SAR (head and trunk) (W/kg) | Localised SAR (limbs) (W/kg) | Power density, S (W/m²) |
|---|---|---|---|---|---|---|
| 0 Hz | 40 | — | — | — | — | — |
| >0-1 Hz | — | 8 | — | — | — | — |
| 1-4 Hz | — | 8/f | — | — | — | — |
| 4-1 000 Hz | — | 2 | — | — | — | — |
| 1 000 Hz-100 kHz | — | f/500 | — | — | — | — |
| 100 kHz-10 MHz | — | f/500 | 0,08 | 2 | 4 | — |
| 10 MHz-10 GHz | — | — | 0,08 | 2 | 4 | — |
| 10-300 GHz | — | — | — | — | — | 10 |

**Notes:**

1. $f$ is the frequency in Hz.

2. The basic restriction on the current density is intended to protect against acute exposure effects on central nervous system tissues in the head and trunk of the body and includes a safety factor. The basic restrictions for ELF fields are based on established adverse effects on the central nervous system. Such acute effects are essentially instantaneous and there is no scientific justification to modify the basic restrictions for exposure of short duration. However, since the basic restriction refers to adverse effects on the central nervous system, this basic restriction may permit higher current densities in body tissues other than the central nervous system under the same exposure conditions.

3. Because of electrical inhomogeneity of the body, current densities should be averaged over a cross section of 1 cm² perpendicular to the current direction.

4. For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by √2 (~1,414). For pulses of duration $t_p$ the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$.

5. For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate basic restriction.

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

7. Localised SAR averaging mass is any 10g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure. These 10g of tissue are intended to be a mass of contiguous tissue with nearly homogeneous electrical properties. In specifying a contiguous mass of tissue, it is recognised that this concept can be used in computational dosimetry but may present difficulties for direct physical measurements. A simple geometry such as cubic tissue mass can be used provided that the calculated dosimetric quantities have conservative values relative to the exposure guidelines.

8. For pulses of duration $t_p$ the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$. Additionally, for pulsed exposures, in the frequency range 0,3 to 10 GHz and for localised exposure of the head, in order to limit and avoid auditory effects caused by thermoelastic expansion, an additional basic restriction is recommended. This is that the SA should not exceed 2mJ $kg^{-1}$ averaged over 10 g of tissue.

## Table B.3.2 — Reference levels for general public exposure to time varying electric and magnetic fields

*Table 2*

**Reference levels for electric, magnetic and electromagnetic fields (0 Hz to 300 GHz, unperturbed rms values)**

| Frequency range | E-field strength (V/m) | H-field strength (A/m) | B-field (μT) | Equivalent plane wave power density $S_{eq}$ (W/m²) |
|---|---|---|---|---|
| 0-1 Hz | — | $3{,}2 \times 10^4$ | $4 \times 10^4$ | — |
| 1-8 Hz | 10 000 | $3{,}2 \times 10^4/f^2$ | $4 \times 10^4/f^2$ | — |
| 8-25 Hz | 10 000 | 4 000/f | 5 000/f | — |
| 0,025-0,8 kHz | 250/f | 4/f | 5/f | — |
| 0,8-3 kHz | 250/f | 5 | 6,25 | — |
| 3-150 kHz | 87 | 5 | 6,25 | — |
| 0,15-1 MHz | 87 | 0,73/f | 0,92/f | — |
| 1-10 MHz | $87/f^{1/2}$ | 0,73/f | 0,92/f | — |
| 10-400 MHz | 28 | 0,073 | 0,092 | 2 |
| 400-2 000 MHz | $1{,}375\ f^{1/2}$ | $0{,}0037\ f^{1/2}$ | $0{,}0046\ f^{1/2}$ | f/200 |
| 2-300 GHz | 61 | 0,16 | 0,20 | 10 |

**Notes:**

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

### Table B.3.3 — Reference levels for contact currents from conductive objects

*Table 3*

**Reference levels for contact currents from conductive objects (f in kHz)**

| Frequency range | Maximum contact current (mA) |
|---|---|
| 0 Hz-2,5 kHz | 0,5 |
| 2,5 kHz-100 kHz | 0,2 f |
| 100 kHz-110 MHz | 20 |

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

## B.4 IEEE

Various tables with exposure limits that are given in the IEEE standards IEEE C95.6 and IEEE C95.1 [B6.3] [B.6.4] are given below.

### B.4.1 IEEE C95.6: 0 – 3 kHz

### Table B.4.1 — IEEE C95.6 Basic Restrictions

**Table 1—Basic restrictions applying to various regions of the body[a, b]**

| Exposed tissue | $f_e$ (Hz) | General public | Controlled environment |
|---|---|---|---|
| | | $E_0$ - rms (V/m) | $E_0$ - rms (V/m) |
| Brain | 20 | $5.89 \times 10^{-3}$ | $1.77 \times 10^{-2}$ |
| Heart | 167 | 0.943 | 0.943 |
| Hands, wrists, feet and ankles | 3350 | 2.10 | 2.10 |
| Other tissue | 3350 | 0.701 | 2.10 |

[a]Interpretation of table is as follows: $E_i = E_0$ for $f \leq f_e$; $E_i = E_0\,(f/f_e)$ for $f \geq f_e$.
[b]In addition to the listed restrictions, exposure of the head and torso to magnetic fields below 10 Hz shall be restricted to a peak value of 167 mT for the general public, and 500 mT in the controlled environment.

### Table B.4.2 — IEEE C95.6 MPEs: head and torso

**Table 2—Magnetic maximum permissible exposure (MPE) levels: exposure of head and torso[a, b]**

| Frequency range (Hz) | General public | | Controlled environment | |
|---|---|---|---|---|
| | *B* - rms (mT) | *H* - rms (A/m) | *B* - rms (mT) | *H* - rms (A/m) |
| < 0.153 | 118 | $9.39 \times 10^4$ | 353 | $2.81 \times 10^5$ |
| 0.153–20 | $18.1/f$ | $1.44 \times 10^4/f$ | $54.3/f$ | $4.32 \times 10^4/f$ |
| 20–759 | 0.904 | 719 | 2.71 | $2.16 \times 10^3$ |
| 759–3000 | $687/f$ | $5.47 \times 10^5/f$ | $2060/f$ | $1.64 \times 10^6/f$ |

[a] *f* is frequency in Hz.
[b] MPEs refer to spatial maximum.

### Table B.4.3 — IEEE C95.6 MPEs: arms or legs

**Table 3—Magnetic flux density maximum permissible exposure levels: exposure of arms or legs[a]**

| Frequency range (Hz) | General public *B* - rms (mT) | Controlled environment *B* - rms (mT) |
|---|---|---|
| < 10.7 | 353 | 353 |
| 10.7–3000 | $3790/f$ | $3790/f$ |

[a] *f* is frequency in Hz.

### Table B.4.4 — IEEE C95.6 MPEs: whole body exposure

**Table 4—Environmental electric field MPEs, whole body exposure**

| General public | | Controlled environment | |
|---|---|---|---|
| Frequency range (Hz) | *E* - rms (V/m) | Frequency range (Hz) | *E* - rms (V/m) |
| 1–368[c] | 5000[a,d] | 1–272[c] | 20 000[b,e] |
| 368–3000 | $1.84 \times 10^6/f$ | 272–3000 | $5.44 \times 10^6/f$ |
| 3000 | 614 | 3000 | 1813 |

[a] Within power line rights-of-way, the MPE for the general public is 10 kV/m under normal load conditions.
[b] Painful discharges are readily encountered at 20 kV/m and are possible at 5–10 kV/m without protective measures.
[c] Limits below 1 Hz are not less than those specified at 1 Hz.
[d] At 5 kV/m induced spark discharges will be painful to approximately 7% of adults (well-insulated individual touching ground).
[e] The limit of 20 000 V/m may be exceeded in the controlled environment when a worker is not within reach of a grounded conducting object. A specific limit is not provided in this standard.

### Table B.4.5 — IEEE C95.6 MPEs: induced and contact currents

**Table 5— Induced and contact current MPEs (mA-rms) for continuous sinusoidal waveforms, 0–3 kHz[a, b]**

| Condition | General public (mA, rms) | Controlled environment (mA, rms) |
|---|---|---|
| Both feet | 2.70 | 6.0 |
| Each foot | 1.35 | 3.0 |
| Contact, grasp | — | 3.0 |
| Contact, touch | 0.50 | 1.5 |

[a]Grasping contact limit pertains to controlled environments where personnel are trained to effect grasping contact and to avoid touch contacts with conductive objects that present the possibility of painful contact.
[b]Limits apply to current flowing between body and grounded object that may be contacted by the person.

### B.4.2 IEEE C95.1: 3 kHz – 300 GHz

**Table B.4.6 — IEEE C95.1 Basic Restrictions**

**Table 1—BRs applying to various regions of the body**

| | | Action level[a] | Persons in controlled environments |
|---|---|---|---|
| Exposed tissue | $f_e$ (Hz) | $E_0$ (rms) (V/m) | $E_0$ (rms) (V/m) |
| Brain | 20 | $5.89 \times 10^{-3}$ | $1.77 \times 10^{-2}$ |
| Heart | 167 | 0.943 | 0.943 |
| Extremities | 3350 | 2.10 | 2.10 |
| Other tissues | 3350 | 0.701 | 2.10 |

[a]Within this frequency range the term "action level" is equivalent to the term "general public" in IEEE Std C95.6-2002.

**Table B.4.7 — IEEE C95.1 MPEs for magnetic fields**

**Table 2—MPE for exposure of head and torso: $f$ = 3 kHz to 5 MHz**

| Frequency range (kHz) | Action level[a] | | Persons in controlled environments | |
|---|---|---|---|---|
| | $B_{rms}$ (mT) | $H_{rms}$ (A/m) | $B_{rms}$ (mT) | $H_{rms}$ (A/m) |
| 3.0–3.35 | $0.687/f$ | $547/f$ | $2.06/f$ | $1640/f$ |
| 3.35–5000 | 0.205 | 163 | 0.615 | 490 |

NOTE—$f$ is expressed in kHz.

[a]Within this frequency range the term "action level" is equivalent to the term "general public" in IEEE Std C95.6-2002.

## Table B.4.8 — IEEE C95.1 MPEs for magnetic fields

**Table 3—MPE for the limbs: *f* = 3 kHz to 5 MHz**

| Frequency range (kHz) | Action level[a] | | Persons in controlled environments | |
|---|---|---|---|---|
| | $B_{rms}$ (mT) | $H_{rms}$ (A/m) | $B_{rms}$ (mT) | $H_{rms}$ (A/m) |
| 3.0–3.35 | 3.79/*f* | 3016/*f* | 3.79/*f* | 3016/*f* |
| 3.35–5000 | 1.13 | 900 | 1.13 | 900 |
| NOTE—*f* is expressed in kHz. | | | | |
| [a]Within this frequency range the term “action level” is equivalent to the term “general public” in IEEE Std C95.6-2002. | | | | |

## Table B.4.9 — IEEE C95.1 MPEs for electric field

**Table 4—Electric field MPE–whole body exposure: *f* = 3 kHz to 100 kHz**

| | Action level[a] | Persons in controlled environments |
|---|---|---|
| **Frequency range (kHz)** | E (rms) (V/m) | E (rms) (V/m) |
| 3 kHz to 100 kHz | 614 | 1842 |
| [a]Within this frequency range the term “action level” is equivalent to the term “general public” in IEEE Std C95.6-2002. | | |

## Table B.4.10 — IEEE C95.1 Contact and induced current limits

**Table 5—RMS induced and contact current limits for continuous sinusoidal waveforms, *f* = 3 kHz to 100 kHz**

| Condition | Action level[a] (mA) | Persons in controlled environments (mA) |
|---|---|---|
| Both feet | 0.90*f* | 2.00 *f* |
| Each foot | 0.45*f* | 1.00 *f* |
| Contact, grasp[b] | — | 1.00 *f* |
| Contact, touch | 0.167*f* | 0.50 *f* |
| NOTE 1—f is expressed in kHz. | | |
| NOTE 2—Limits apply to current flowing between the body and a grounded object that may be contacted by the person. | | |
| NOTE 3—The averaging time for determination of compliance is 0.2 s. | | |
| [a]Within this frequency range the term “action level” is equivalent to the term “general public” in IEEE Std C95.6-2002. | | |
| [b]The grasping contact limit pertains to controlled environments where personnel are trained to make grasping contact and to avoid touch contacts with conductive objects that present the possibility of painful contact. | | |

### Table B.4.11 — BRs for frequencies between 100 kHz and 3 GHz

**Table 6—BRs for frequencies between 100 kHz and 3 GHz**

| | | Action level[a] SAR[b] (W/kg) | Persons in controlled environments SAR[c] (W/kg) |
|---|---|---|---|
| Whole-body exposure | Whole-Body Average (WBA) | 0.08 | 0.4 |
| Localized exposure | Localized (peak spatial-average) | 2[c] | 10[c] |
| Localized exposure | Extremities[d] and pinnae | 4[c] | 20[c] |

[a]BR for the general public when an RF safety program is unavailable.

[b]SAR is averaged over the appropriate averaging times as shown in Table 8 and Table 9.

[c]Averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube).*

[d]The extremities are the arms and legs distal from the elbows and knees, respectively.

*The volume of the cube is approximately 10 $cm^3$.

### Table B.4.12 — RMS induced and contact current limits for continuous sinusoidal waveforms, f = 100 kHz to 110 MHz

**Table 7—RMS induced and contact current limits for continuous sinusoidal waveforms, *f* = 100 kHz to 110 MHz**

| Condition | Action level[a] (mA) | Persons in controlled environments (mA) |
|---|---|---|
| Both feet | 90 | 200 |
| Each foot | 45 | 100 |
| Contact, grasp[b] | — | 100 |
| Contact, touch | 16.7 | 50 |

NOTE 1—Limits apply to current flowing between the body and a grounded object that may be contacted by the person.

NOTE 2—The averaging time for determination of compliance is 6 minutes.

[a]MPE for the general public in absence of an RF safety program.

[b]The grasping contact limit pertains to controlled environments where personnel are trained to make grasping contact and to avoid touch contacts with conductive objects that present the possibility of painful contact.

## Table B.4.13 — Action level (MPE for the general public when an RF safety program is unavailable)

**Table 9—Action level (MPE for the general public when an RF safety program is unavailable) (see Figure 4 for graphical representation)**

| Frequency range (MHz) | RMS electric field strength (E)[a] (V/m) | RMS magnetic field strength (H)[a] (A/m) | RMS power density (S) E-field, H-field (W/m$^2$) | Averaging time[b] $\lvert E\rvert^2$, $\lvert H\rvert^2$ or S (min) | |
|---|---|---|---|---|---|
| 0.1–1.34 | 614 | $16.3/f_M$ | $(1000, 100\,000/f_M^{2})$[c] | 6 | 6 |
| 1.34–3 | $823.8/f_M$ | $16.3/f_M$ | $(1800/f_M^{2}, 100\,000/f_M^{2})$ | $f_M^{2}/0.3$ | 6 |
| 3–30 | $823.8/f_M$ | $16.3/f_M$ | $(1800/f_M^{2}, 100\,000/f_M^{2})$ | 30 | 6 |
| 30–100 | 27.5 | $158.3/f_M^{1.668}$ | $(2, 9\,400\,000/f_M^{3.336})$ | 30 | $0.0636\, f_M^{1.337}$ |
| 100–400 | 27.5 | 0.0729 | 2 | 30 | 30 |
| 400–2000 | – | – | $f_M/200$ | 30 | |
| 2000–5000 | – | – | 10 | 30 | |
| 5000–30 000 | – | – | 10 | $150/f_G$ | |
| 30 000–100 000 | – | – | 10 | $25.24/f_G^{0.476}$ | |
| 100 000–300 000 | – | – | $(90f_G–7000)/200$ | $5048/[(9f_G–700)f_G^{0.476}]$ | |

NOTE—$f_M$ is the frequency in MHz, $f_G$ is the frequency in GHz.

[a]For exposures that are uniform over the dimensions of the body, such as certain far-field plane-wave exposures, the exposure field strengths and power densities are compared with the MPEs in the Table. For non-uniform exposures, the mean values of the exposure fields, as obtained by spatially averaging the squares of the field strengths or averaging the power densities over an area equivalent to the vertical cross section of the human body (projected area) or a smaller area depending on the frequency (see NOTES to Table 8 and Table 9 below), are compared with the MPEs in the Table.

[b]The left column is the averaging time for $\lvert E\rvert^2$, the right column is the averaging time for $\lvert H\rvert^2$. For frequencies greater than 400 MHz, the averaging time is for power density S

[c]These plane-wave equivalent power density values are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.

## B.5 Summation formulas

### Table B.5.1 — ICNIRP summation formulas for basic restrictions

For electrical stimulation, relevant for frequencies up to 10 MHz, induced current densities should be added according to

$$\sum_{i=1\ \mathrm{Hz}}^{10\ \mathrm{MHz}} \frac{J_i}{J_{L,i}} \leq 1. \qquad (5)$$

For thermal effects, relevant above 100 kHz, SAR and power density values should be added according to:

$$\sum_{i=100\ \mathrm{kHz}}^{10\ \mathrm{GHz}} \frac{SAR_i}{SAR_L} + \sum_{i>10\ \mathrm{GHz}}^{300\ \mathrm{GHz}} \frac{S_i}{S_L} \leq 1, \qquad (6)$$

where

$J_i$ = the current density induced at frequency $i$;
$J_{L,\,i}$ = the induced current density restriction at frequency $i$ as given in Table 4;
$SAR_i$ = the SAR caused by exposure at frequency $i$;
$SAR_L$ = the SAR limit given in Table 4;
$S_L$ = the power density limit given in Table 5; and
$S_i$ = the power density at frequency $i$.

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

### Table B.5.2 — ICNIRP summation formulas for reference levels 1 Hz – 10 MHz

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

$$\sum_{i=1\ \mathrm{Hz}}^{1\ \mathrm{MHz}} \frac{E_i}{E_{L,i}} + \sum_{i>1\ \mathrm{MHz}}^{10\ \mathrm{MHz}} \frac{E_i}{a} \leq 1, \qquad (7)$$

and

$$\sum_{j=1\ \mathrm{Hz}}^{65\ \mathrm{kHz}} \frac{H_j}{H_{L,j}} + \sum_{j>65\ \mathrm{kHz}}^{10\ \mathrm{MHz}} \frac{H_j}{b} \leq 1, \qquad (8)$$

where

$E_i$ = the electric field strength at frequency $i$;
$E_{L,\,i}$ = the electric field reference level from Tables 6 and 7;
$H_j$ = the magnetic field strength at frequency $j$;
$H_{L,\,j}$ = the magnetic field reference level from Tables 6 and 7;
$a$ = 610 V $m^{-1}$ for occupational exposure and 87 V $m^{-1}$ for general public exposure; and
$b$ = 24.4 A $m^{-1}$ (30.7 $\mu$T) for occupational exposure and 5 A $m^{-1}$ (6.25 $\mu$T) for general public exposure.

**Table B.5.3 — ICNIRP summation formulas for reference levels 100 kHz – 300 GHz**

$$\sum_{i=100\ \text{kHz}}^{1\ \text{MHz}} \left(\frac{E_i}{c}\right)^2 + \sum_{i>1\ \text{MHz}}^{300\ \text{GHz}} \left(\frac{E_i}{E_{L,i}}\right)^2 \leq 1, \qquad (9)$$

and

$$\sum_{j=100\ \text{kHz}}^{1\ \text{MHz}} \left(\frac{H_j}{d}\right)^2 + \sum_{j>1\ \text{MHz}}^{300\ \text{GHz}} \left(\frac{H_j}{H_{L,j}}\right)^2 \leq 1, \qquad (10)$$

where

$E_i$ = the electric field strength at frequency $i$;
$E_{L,\,i}$ = the electric field reference level from Tables 6 and 7;
$H_j$ = the magnetic field strength at frequency $j$;
$H_{L,\,i}$ = the magnetic field reference level from Tables 6 and 7;
$c$ = $610/f$ V $\text{m}^{-1}$ ($f$ in MHz) for occupational exposure and $87/f^{1/2}$ V $\text{m}^{-1}$ for general public exposure; and
$d$ = $1.6/f$ A $\text{m}^{-1}$ ($f$ in MHz) for occupational exposure and $0.73/f$ for general public exposure.

### Table B.5.4 — EC Recommendation summation formulas for basic restrictions

**Basic restrictions**

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

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

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

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

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

where

$J_i$ is the current density at frequency i;

$J_{L,\,i}$ is the current density basic restriction at frequency i as given in Table 1;

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

$SAR_L$ is the SAR basic restriction given in Table 1;

$S_i$ is the power density at frequency i;

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

### Table B.5.5 — EC Recommendation summation formulas for reference levels 1 Hz – 10 MHz

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

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

and

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

where

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

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

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

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

a is 87 V/m and b is 5 A/m (6,25 μT).

**Table B.5.6 — EC Recommendation summation formulas for reference levels 100 kHz – 300 GHz**

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

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

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

and where

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

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

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

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

## B.6 References

[B.6.1] ICNIRP Guidelines, Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz), Health Physics, vol. 47, no. 4, pp. 449-522, April 1998.

[B.6.2] European EMF Recommendation 1999/519/EC.

[B.6.3] IEEE Standard C95.1-2005, IEEE standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300 GHz, 19 April 2006.

[B.6.4] IEEE Standard C95.6-2002 (R2007), IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz", 23 October 2002 (reaffirmed 5 December 2007).

## Annex C

## Rationale for EMF compliance with contact current

### C.1 Introduction

This annex gives the substantiation for the fact that MME is EMF compliant with the contact current requirements.

Various EMF exposure limit setting documents provide limits for contact currents. These limits are set in the frequency range up to 110 MHz in terms of reference levels (see Annex B) to prevent that a metallic/conductive object that is charged by a external nearby EM-source is discharged after being touched by a person.

Clause 4 of IEC/EN 62311 mentions contact currents as an exposure parameter that can be considered to be deemed to comply if the product does not have touchable conductive parts or if the conductive touchable parts are permanently connected to the ground. The latter is the case for many MME that have grounding or isolation provisions from a safety point of view.

The contact current leakage from electric/electrical equipment is already regulated to a very small level in safety standards, such as IEC 60950-1 (see references in clause 2). The effect of contact current is mainly in the frequency range below 100 kHz.

Subsequently, a duplication of contact current evaluation for EMF reasons can be avoided provided that the MME complies with current-leakage requirements given in the safety standard for information technology equipment. In this case the MME is deemed to comply also with the limits for the contact current given in the applicable EMF exposure limits without further assessment, and hence the MME is considered compliant with the contact current reference levels.

### C.2 Rationale

As mentioned in the introduction, potential contact currents effect is not applicable to MME since in the majority of the cases the MME does not have touchable conductive parts or those conductive touchable parts are permanently connected to the ground. This is because in the frequency range where contact current limits apply these sources are located inside the MME.

MME has grounding (class I equipments) or isolation provisions (class II equipments) from a safety point of view.

The contact-current leakage from electric/electrical equipment including MME is already regulated to a very small level in safety standards, such as IEC 60950-1 (see references in clause 2). Table C.1 gives a comparison of the EMF contact current limits and the safety leakage current limits. It shows that the safety current limit (applicable for mains frequency signals) is similar (even lower) than the contact current limit. Compliance with the safety leakage current requirement is considered a sufficient condition for compliance with the EMF contact current requirements.

To support the above, contact current measurements were carried out on a range of multimedia and office equipment using a clamp-on current transformer Holaday HI-3702 that is clamped around the arm of a person. Details of the setup, measurement method and results are reported in [C.3.1]. Thirty two products have been assessed in this way. The measured values of the contact current lie far below the applicable reference levels. These results demonstrate that multimedia products in general, can be stated to be compliant against the requirements for contact currents.

**Table C.1 — Comparison of contact current limits for EMF and safety**

| EMF Contact current limit (mA) | | Safety leakage current limit (mA) |
|---|---|---|
| **Exposure Guideline ICNIRP Guideline(1998)** | | **Safety Standard IEC 60950-1** (see NOTE 1) |
| up to 2.5 kHz | 0.5 | 0.25(RMS) |
| 2.5 – 100 kHz | 0.2f f[kHz] | |
| 100kHz – 110MHz | 20 | |
| NOTE 1<br>The leakage current limit value in the safety standard applies to non-grounded equipment.<br>If the equipment is grounded, there is some relaxation on restriction. | | |

## C.3 Reference


[C.3.1] Ecma white paper Ecma/TC20/2009/021, Contact Current Measurement Results of Multimedia products and Office equipment, 2009-04-06.

# Annex D

## Overview of wired or wireless technologies that may be implemented in MME

Table D.1 provides EMF-relevant data of various wireless and wired technologies that typically may be implemented in MME.

**Table D.1 — Non-exhaustive list of wireless technologies that may be implemented in MME**

| Application/ Technology | Frequency range | Peak radiated power (mW) | EIRP power (mW) |
|---|---|---|---|
| Baby surveillance | 40.7 MHz | 10 | 10 |
| | 446 MHz | 500 | 500 |
| | 864 MHz | 10 | 10 |
| | 2450 MHz | | |
| Wireless headphone | 864 MHz | 10 | 10 |
| Cordless phone/DECT | 1880-1900 MHz | 250 | 250 |
| WLAN | 2400-2483 MHz | 100 | 100 |
| Bluetooth | 2400-2483 MHz | 100 | 100 |
| WLAN/IEEE 802.11x (USA) | 2400-2483.5 MHz | 100 | 400 |
| | 5150-5250 MHz | 17 dBm | 23 dBm |
| | 5250-5350 MHz | 24 dBm | 30 dBm |
| | 5470-5725 MHz | 24 dBm | 30 dBm |
| | 5725-5850 | 30 dBm | 36 dBm |
| WLAN/IEEE 802.11x (EU) | 2400-2483.5 MHz | n.a. | 400 |
| | 5150-5250 MHz | n.a. | 23 dBm |
| | 5250-5350 MHz | n.a. | 30 dBm |
| | 5470-5725 MHz | n.a. | 30 dBm |

# Annex E

# Alternative low-power exclusion levels

## E.1 Introduction

This annex describes a means to relax the 20 mW low-power exclusion levels to higher values. A study by M. Ali et. al. [E.4.1] demonstrates that the 20 mW low-power limit specified in EN 50371 is very conservative in nature.

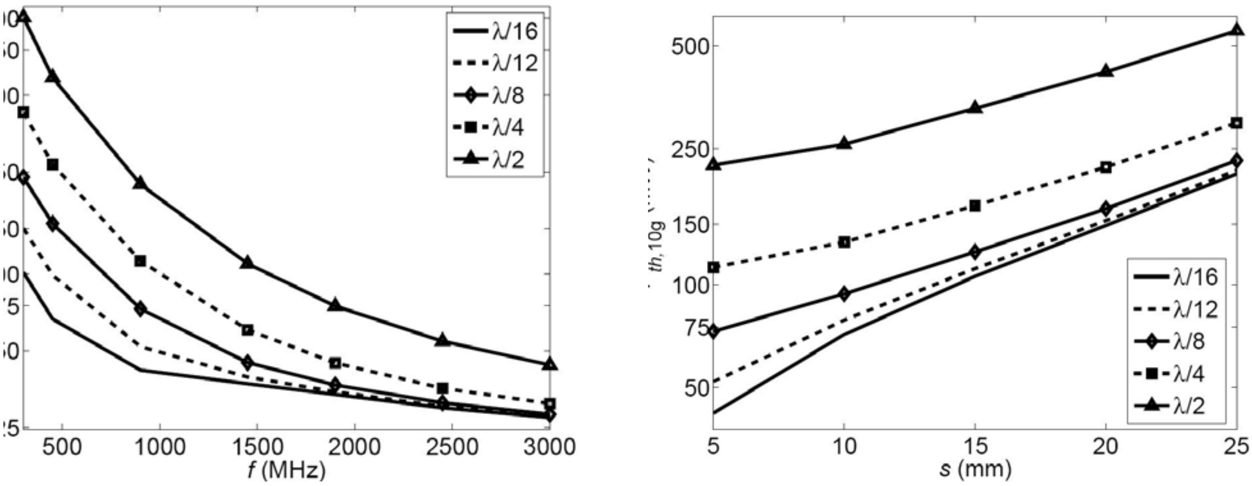
## E.2 Rationale for a relaxation of the low-power exclusion level

From the results in Figure E.1 more relaxed low-power exclusion limits can be derived.

For example, at 900 MHz, for different types of antennas, one can apply safely a relaxed criterion of 150 mW at a distance of 0.25 m. This is a relaxation of a factor 7.5.

A simple formula can be derived to calculate a relaxation coefficient for the low-power exclusion. Assume an isotropically radiating source where a human is exposed at a distance *r* from a radiating source. If the total radiated power is $P_{tot}$, then maximum power density *p*(d) at distance *r* equals (assuming far-field and free-space conditions):

$$p_d = \frac{P_{tot}}{4\pi r^2} \qquad \text{(Eq. E.1)}$$




(a)

(b)

**Figure E.1 — Relaxed threshold power levels for SAR $_{limit,10g}$ = 2 W/kg at**

**(a) s = 5 mm and f = 300 – 3000 MHz**

**(b) s = 5 – 25 mm and f = 900 MHz**

If one assumes that the typical surface of an exposed person is 1 m2, then the maximum power captured by that surface is 1 m2 times pd which is: $P_{cap} = P_{tot} / 4\pi r^2$. Now the ratio of total radiated power of the source and the maximum captured power by the exposed person is minimally:

$$p_d = \frac{P_{tot}}{4\pi r^2} \qquad \text{(Eq. E.2)}$$

At an exposure distance of 1 m, the relaxation is 4π. In other words, an intentional radiator may radiate 4π times 20 mW, and still complies with the basic restriction at an exposure distance of 1 m. This formula can be adopted for non-isotropical sources. Then the relaxation factor will be reduced by the amount of directivity D involved. The relaxation factor then becomes:

$$\frac{P_{tot}}{P_{cap}} = \frac{4\pi r^2}{D} \qquad \text{(Eq. E.3)}$$

It should be noted that the directivity of intentional radiators in MMEs is usually low, in the range 1 to 2.

Hence if we assume a maximum directivity of 2, the relaxation factor *R* becomes:

$$R = 2\pi r^2 \qquad \text{(Eq. E.4)}$$

Considering the above, it can be said that the low-power exclusion limit of 20 mW can be relaxed by a factor which can be estimated using equation Eq. E.3 or by simulating specific exposure configurations as done in E.3.

The following table shows the effect of the relaxation factor as a function of the exposure distance.

**Table E.1 — Relaxation factors for the low-power exclusion**

| Distance r (m) | Relaxation factor R (dimensionless) | Low-power exclusion (mW) |
|---|---|---|
| <0.4 | 1.0 | 20 |
| 0.5 | 1.6 | 31 |
| 0.75 | 3.5 | 71 |
| 1.0 | 6.3 | 126 |
| 1.5 | 14.1 | 283 |
| 2.0 | 25.1 | 503 |
| 3.0 | 56.5 | 1131 |

It should be noted that even more relaxed low-power exclusion levels can be derived, also at distances below 0.4 m, if detailed simulations of the actual antenna configuration and exposed body are applied (see E.3).

In conclusion, EMF compliance can be demonstrated for MME by applying the low-power exclusion level of 20 mW, and for exposure distances larger than 0.4 m or for specific exposure configurations in the frequency range 300MHz to 6GHz, much larger thresholds than 20 mW can be applied. This exclusion can be applied easily for assessment of intentional EM sources within the MME.

Example An internet radio which includes a WLAN link (IEEE 802.11 b & g) with a maximum RF output power of 100 mW will be EMF compliant for exposure distance larger than 1 m since at that distance the low-power exclusion level is 126 mW.

## E.3 Alternative low-power exclusion levels in the frequency range 300 MHz to 6 GHz

This clause describes a means to relax the 20 mW low-power exclusion levels in the frequency range 300 MHz to 6 GHz to higher values.

The algorithm presented in this clause is generally applicable to many popular wireless transmitters such as cellular telephones (GSM, CDMA, PCS, etc.), land mobile radios, and wireless local area network (WLAN) devices. The formulae have been shown to be conservative for a wide variety of antennas typically used on portable wireless devices, such as dipoles, monopoles, planar inverted-F antennas (PIFAs), and inverted-F antennas (IFAs). However, the formulae may not apply for wireless devices having antennas whose directivity is significantly greater than that of a half-wavelength dipole antenna (i.e., 2.1 dBi). The following description is based on the work in references [E.4.1] and [E.4.2], where further details are available.

NOTE The exact range of antenna directivity at which the formula applies is dependent on frequency and distance and is the subject of future work. In [E.4.2], a microstrip patch antenna with a directivity of 6 dBi was analyzed. The formula did not to provide a conservative Pmax' value at the highest frequency (6 GHz) and distance (20 mm) studied. However, the formula was found to be conservative at lower frequencies (2.45 and 3.7 GHz) and at a shorter distance (10 mm). The formula was also found to be conservative for all frequencies and distances when antennas with approximately 2 dBi directivity were analyzed. More information can be found in [E.4.2].

For a body very close to the radiating source it is extremely improbable that all the power would be absorbed in a single voxel of 10 gr tissue. This will be even more unlikely if the exposure distance is enlarged.

Based on a systematic study of canonical dipole antennas of different lengths and at different distances from a flat phantom, a simple equation was developed for predicting alternative higher values of the low-power exclusion levels ($P_{max'}$):

$$P_{max}' = \exp\left[As + Bs^2 + C\ln(BW) + D\right] \quad \text{(Eq. E.5)}$$

where s represents the nearest separation distance between the wireless device and the user's body, BW is the free-space antenna bandwidth, and A, B, C and D are third-order polynomials of frequency. The bandwidth corresponds to |S11| ≤ -7 dB, which is the reciprocal of the radiation quality factor, defined as the ratio between the stored and the radiated energies of an antenna. In Equation E.5, s is expressed in mm and BW is expressed in percent (e.g. enter 10 in the equation if the bandwidth is 10 %). The frequency dependent parameters A, B, C and D can be found from the following equations, where f is the frequency in GHz.

For compliance with the SAR limit of $SAR_{max}$ = 2 W/kg averaged over m = 10 g in ICNIRP Guidelines [1] and IEEE Std C95.1-2005 [4], use Equations (E.6) to (E9) in Equation (E.5):

$$A = \left(-0{,}4588\,f^3 + 4{,}407\,f^2 - 6{,}112\,f + 2{,}497\right)/\,100 \quad \text{(Eq. E 6)}$$

$$B = \left(0{,}1160\,f^3 - 1{,}402\,f^2 + 3{,}504\,f - 0{,}4367\right)/\,1000 \quad \text{(Eq. E 7)}$$

$$C = \left(-0{,}1333\,f^3 + 11{,}89\,f^2 - 110{,}8f + 301{,}4\right)/\,1000 \quad \text{(Eq. E 8)}$$

$$D = -0{,}03540\,f^3 + 0{,}5023\,f^2 - 2{,}297\,f + 6{,}104 \quad \text{(Eq. E 9)}$$

For other values of $SAR_{max}$ using an averaging mass of m = 10 g, multiply the final $P_{max'}$ value by $SAR_{max}$ / 2 W/kg.

For compliance with the SAR limit of $SAR_{max}$ = 1,6 W/kg averaged over m = 1 g in IEEE Std C95.1-1999 [5] for the uncontrolled environment, use Equations (E.10) to (E.13) in Equation (E.5):

$$A = \left(-0{,}4922\,f^3 + 4{,}831\,f^2 - 6{,}620\,f + 8{,}312\right)/\,100 \quad \text{(Eq. E 10)}$$

$$B = \left(0{,}1191\, f^{3} - 1{,}470\, f^{2} + 3{,}656\, f - 1{,}697\right) / 1000 \quad \text{(Eq. E 11)}$$

$$C = \left(-0{,}4228\, f^{3} + 13{,}24\, f^{2} - 108{,}1 f + 339{,}4\right) / 1000 \quad \text{(Eq. E 12)}$$

$$D = -0{,}02440\, f^{3} + 0{,}4075\, f^{2} - 2{,}330\, f + 4{,}730 \quad \text{(Eq. E 13)}$$

For the $SAR_{max}$ = 8 W/kg limit for the controlled environment, multiply the final $P_{max'}$ value by a factor of 5.

Table E.2 provides values of $P_{max'}$ calculated from Equations (E.5) through (E.13) for typical operating frequency bands used by portable wireless devices. The values of $P_{max'}$ were calculated at s = 5 mm and 25 mm assuming that the -7 dB free-space bandwidth of the antenna in free space is equal to the frequency band of the communication system. The values in Table E.2 may be used to get an impression of what kind of low-power exclusion levels could be expected in these frequency bands. For example, a GSM mobile telephone typically transmits at an average total radiated power less than or equal to 125 mW in a bandwidth centred at 1795 MHz (including the receive band). Table E.2 shows that if the -7 dB bandwidth of the antenna covers at least the 9,5 % bandwidth of the communication system, it cannot be exempted from SAR testing if it is held 5 mm from the body, but it could be exempted at 25 mm distance from the body (e.g. while held in a 25 mm thick carry accessory). Table E.2 is intended only as a guide. The reader should always use the correct values of s, BW, and f that apply to the specific portable wireless device under investigation.

**Table E.2 — Some typical frequency bands of portable wireless devices and corresponding low-power exclusion levels $P_{max}'$ predicted using equations (E.1) through (E.9)**

| *f* (GHz) | *BW* (%) | Example air interface | $P_{max}'$ (mW) | | | |
|---|---|---|---|---|---|---|
| | | | *s* = 5 mm | | *s* = 25 mm | |
| | | | *m* = 1 g | *m* = 10 g | *m* = 1 g | *m* = 10 g |
| 0,393 | 3,8 | TETRA | 97 | 292 | 265 | 526 |
| 0,420 | 4,8 | TETRA | 98 | 293 | 274 | 541 |
| 0,461 | 3,3 | GSM | 80 | 244 | 233 | 468 |
| 0,485 | 14,4 | APCO | 117 | 337 | 347 | 660 |
| 0,838 | 7,6 | iDEN | 48 | 148 | 198 | 399 |
| 0,859 | 8,1 | IS-136 | 47 | 145 | 198 | 398 |
| 0,884 | 16,7 | PDC | 54 | 162 | 233 | 456 |
| 0,896 | 5,7 | TETRA | 40 | 127 | 176 | 360 |
| 0,918 | 4,8 | iDEN | 37 | 118 | 165 | 342 |
| 0,925 | 7,6 | GSM | 41 | 129 | 185 | 375 |
| 1,465 | 4,9 | PDC | 17 | 60 | 128 | 281 |
| 1,795 | 9,5 | GSM | 13 | 50 | 139 | 308 |
| 1,920 | 7,3 | GSM | 11 | 44 | 132 | 302 |
| 2,045 | 12,2 | UMTS | 11 | 44 | 146 | 330 |
| 2,350 | 4,3 | WiBro | 7,9 | 34 | 130 | 323 |
| 2,442 | 3,4 | 802.11b | 7,3 | 32 | 130 | 328 |
| 3,550 | 14,1 | WiMAX | 6,7 | 37 | 244 | 657 |
| 5,250 | 3,8 | WiMAX | 6,8 | 53 | 258 | 845 |
| 5,788 | 1,3 | WiMAX | 6,2 | 52 | 164 | 564 |

## E.4 References


[E.4.1] M. Ali, M. G. Douglas, A. T. M. Sayem, A. Faraone, and C-K. Chou, Threshold Power of Canonical Antennas for Inducing SAR at Compliance Limits in the 300-3000 MHz Frequency Range, IEEE Trans. On Electromagnetic Compatibility, vol. 49, no. 1, February 2007.

[E.4.2] A.T.M. Sayem, M. G. Douglas, G. Schmid, B. Petric and M. Ali, “Correlating threshold power with free-space bandwidth for low directivity antennas,” IEEE Trans. Electromag. Compat., (accepted for publication), 2008.

# Annex F

# Broadband measurement method

## F.1 Introduction

The broadband measurement method can be used to demonstrate EMF compliance against the applicable reference levels in certain frequency range. Broadband measurements may be advantageous since it is a time-effective and conservative way of assessing the fields around an MME.

A few EMF standards specify broadband measurements as a valid means for compliance demonstration [F.1][F.2].

For this method the electric (*E*) or magnetic (*H*) field strengths are measured at the assessment distance around the MME using suitable isotropic broadband probes. Electric and magnetic fields may have to be measured separately depending on whether the far-field criterion is met or not. The measurements are to assess compliance with field strength reference values contained in the applicable exposure limits documents (Annex B).

The bandwidth of the measuring instruments shall be appropriate to the frequency range of the EM field being measured. Ideally, the operating range of the probe should cover the whole frequency range of the radiating MME. In this regard, in fact two frequency ranges may be distinguished, i.e. the frequency ranges associated with the basic restrictions current density and SAR:

| | | |
|---|---|---|
| Current density relevant frequency range | 1 Hz – 10 MHz | (f.1) |
| SAR-relevant frequency range | 100 kHz – 10 GHz | (f.2) |

For these two wide frequency ranges, generally more than one probe has to be used. The frequency ranges of these probes have to adjoin. For technical reasons the frequency ranges of the probes could be overlapping, and as a result of this overlapping, the total magnitude of exposure might be overestimated. The measurement time shall be sufficiently long to take effects from unstable signals.

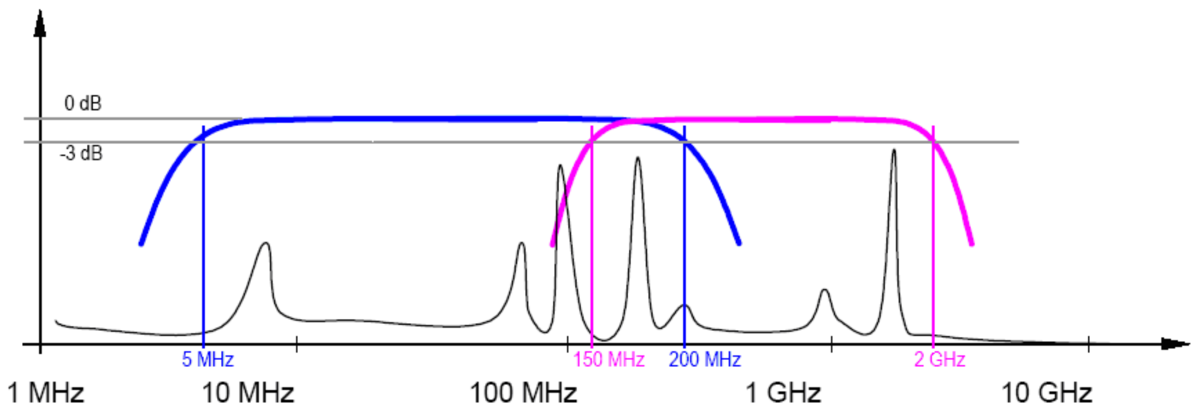



**Figure F.1 — Illustration of measurement with two broadband probes, the frequency ranges of which are overlapping**

The result of the measurement is the total field strength of all spectral components within the measurement bandwidth of the probe. This result has to be compared with the lowest reference level limit of corresponding frequency range. Subsequently, a summation of the various exposure results obtained in the different (overlapping) frequency ranges must be done. Examples of reference levels and the algorithm for summation can be found in Annex B. The summation must be performed separately for the effects of thermal and electrical stimulation (see frequency ranges f.1 and f.2 above).

This broadband measurement method may provide results above the applicable reference levels due to either overestimations because of the overlapping frequency ranges, or due to the fact that the lowest reference level in a certain frequency range is taken as the limit. In both cases, in case of exceeding the limits, selective (narrow band) measurements in certain frequency ranges may be applied (see 11.5).

If the measured value is still above the reference level limit then another assessment method must be chosen (see basic restriction evaluation in 12).

## F.2 Measurement setup

The presence of a human body may influence the electric field being measured. To prevent this, the person making the measurement and anyone else shall be sufficiently far from the meter and the measuring system or the probe shall be set up on a non-conductive stand or supported using a non-conductive pole. Annex G of EN 50492 provides guidance on the influence of the human body on probe measurements of the electric field strength.

## F.3 Measuring equipment

The measurement range of the instrumentation is required to be in accordance with the field strengths to be measured. The sensitivity should be sufficient to determine the lowest level to be measured within the level as stated by the instruments manufacturer. The frequency range of the measuring equipment should be sufficient to cover the frequencies of all relevant EM field sources.

Normally, broadband probes with a flat frequency response will be used. The measurement and assessment procedure given in the EMF product IEC 62233 for domestic appliances can also be used for broadband assessment of the H-field of MME. In this case a specific broadband measurement instrument of IEC 62233 is used, and the H-field is measured up to 400 kHz using a weighted (shaped) frequency response which takes the effect of the frequency dependent limits into account.

Broadband probes also apply a certain weighting methodology of the various frequency components. Generally, broadband probes apply an rms detector, and therefore the various frequency components are summed in an rms-way (sum of the power contributions). For the higher frequency range this appropriate (100 kHz – 300 GHz). For the lower frequency range a linear summation should be applied, which is more conservative than rms-summation. However, probes generally do not have a linear frequency weighting function. Hence, the broadband method is not suitable for the frequency range where linear summation is required.

The uncertainty of the measuring equipment shall be known and has to be considered in the final assessment.

## F.4 Measuring procedure

The following measurement procedure shall be applied for the broadband measurement method:

- To avoid influences of the environment the measurements should be performed in a shielded environment. In case this is not possible, then the effect of the environment should be taken into account.

- The MME should be set up in a typical configuration in accordance to clause 9.2 and 9.4. The operating conditions of the MME must be in accordance with 11.6 .

- A preliminary scan should be performed around the surfaces of the MME to determine the distribution of the field. For measurement distances and positions shall be selected in accordance with the requirements given in 9.5.

- The locations for a detailed scan should be chosen taking into account the preliminary scan results. To capture the maximum field level, the detailed scan should be performed in maximum hold function.

- In case of time varying emissions, time averaging of the results may be applied over a time period of 6 minutes in the frequency from 100 kHz up to 300 GHz (reference levels associated with the temperature-rise effect). If the repetition frequency of the time-varying signal is less than 6 minutes, a lower time-averaging time span may be applied. For the reference-levels related to the body-current effect (frequency range between 1 Hz and 10 MHz), no time averaging shall be applied.

- The measurements results have to be compared to the applicable exposure level limits (see Annex B). For each user position the summation of the measured field strengths should considered.

- The overall broadband exposure level should be determined by summing the results of the individual broadband measurement results obtained in the consecutive frequency ranges.

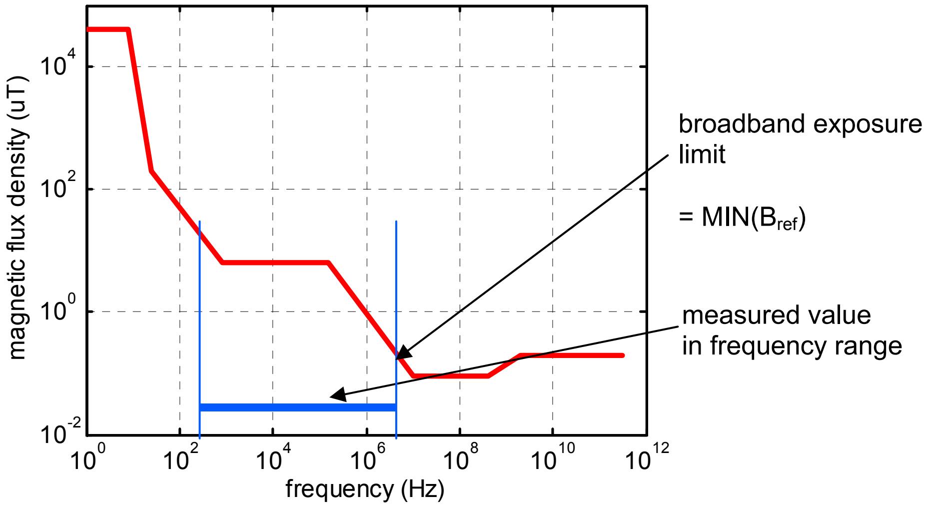
- The overall measurement uncertainty should be predicted and evaluated. All possible sources of uncertainty including the instrumentation uncertainties and the specific situation parameters shall be taken into account.

## F.5 Limits and summation formulas applicable to broadband testing

The exposure limits vary as a function of frequency and were originally applied for narrowband EM-source. Subsequently, summation can be applied to assess the exposure to multiple sources operating at the same or at different frequencies. These limits can then be applied for test results obtained with frequency-selective measurement equipment.

In case broadband measurement equipment is used then the response of the measurement equipment depends on the response characteristics of the equipment. In the general case, if multiple sources are present and emitting at different frequencies, the broadband equipment will weigh the contributions from the different sources. The weighting of different broadband measuring systems may be considered as a summation of the different individual spectral components. This ‘summation’ may be different from the summation formulas for the exposure limits given in Annex B.

As a basic principle, the result of a broadband measurement must be compared with the lowest value of the frequency-dependant limit in the corresponding frequency range. This will provide good results in case of a single source. An example of a broadband exposure limit is given in Figure B.1.




red line = reference level of the magnetic flux density (general public, ICNIRP)

blue line = level measured with broadband measuring equipment

**Figure F.2 — Illustrating the principle of determination of limits for broadband testing**

## F.6 References


[F.1] IEC 62233: 2005-10, Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure.

[F.2] EN 50492: 2008-11, Basic standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations.

# Annex G

# Rationale for exemption of battery-operated MME for EMF assessment

## G.1 Introduction

Battery-operated MME that does not include intentional radiators and that comply with EMC requirements are deemed to comply with the EMF requirements in a large part of the frequency range without further assessment, provided that certain conditions are met. This Annex provides the rationale and gives background on the conditions for this exemption.

This means that battery-operated MME which includes intentional radiators shall be assessed against the EMF requirements only at the frequency range of the intentional radiation.

## G.2 Frequency range below 150 kHz

The EMF-levels in the neighbourhood of battery operated-MME is intrinsically low due to the fact that the power supplied from the batteries to the electronics is limited and consequently also the voltages and currents applied within MME will be limited.

In general, battery operated products also may exhibit EMF-levels that are beyond the applicable reference levels, especially at small exposure distances.

For example, the EMF-standard for household appliances (IEC 62233) also applies to battery operated appliances. This EMF product standard for household appliances focuses on assessment of the *H*-field in the frequency range between 10 Hz and 400 kHz. Appliances that are working with internal voltage levels lower than 1000 V are deemed to comply with the *E*-field limits without further assessment.

In this G.2 the possible EMF-levels from battery-operated MME will be assessed and it will be identified the conditions that should be met to demonstrate EMF compliance without further assessment. This assessment will be limited to the frequency range between 0 Hz and 150 kHz where the assessment of *E*- and *H*-field parts will be done separately.

Basically, it will be assumed that the DC-power from the battery may be converted into a voltage and a current at a frequency between 0 Hz and 150 kHz.

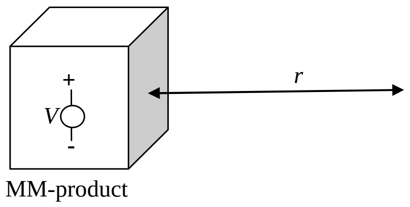
### G.2.1 E-field considerations

The open DC-voltage of a battery pack in a MME is typically maximally 9 V. From electrostatic modelling it can be readily seen that the maximum *E*-field at a certain distance from the product rapidly decreases with a $1/r^3$-rate, where *r* is the distance from the geometry where the differential voltage is applied.

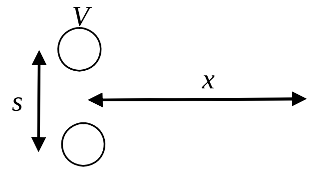
Figure G.1 gives an example of the quasi-static *E*-field modelling of a battery operated MME with an internal voltage source (Figure G.1.a). The MME is modelled by means of a dipole structure consisting of two small spheres separated at a distance of *d*, while a voltage source *V* is applied between these spheres (Figure G.1.b).

The lowest *E*-field reference-level in the frequency region between 0 Hz and 150 kHz is 87 V/m (see Figure G.1.c).

The E-field at a certain separation distance from the dipole is calculated for three separation distances 10 cm, 30 cm and 100 cm while a voltage of 1 V voltage is applied between the two spheres (results see Figure G.1.d). From this example it can be seen that the E-field decreases rapidly with distance from the centre of the dipole. By using this model, it can also be calculated the maximum voltage that can be applied between the two spheres such that the lowest limit level of 87 V/m is met.

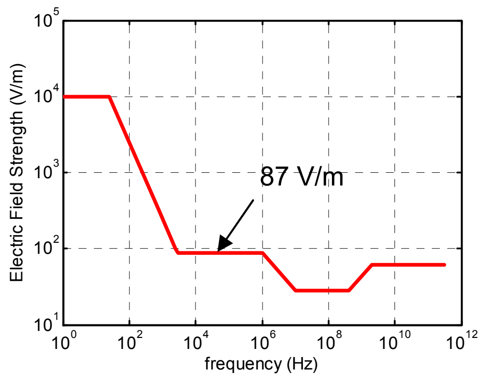



a – Exposure by a MME with an internal voltage source $V$

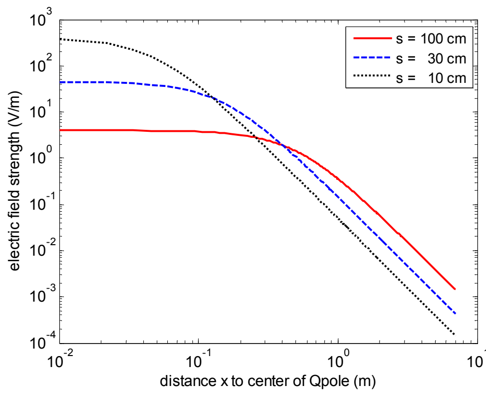



$$E = V \frac{s/2}{\left((s/2)^2 + x^2\right)^{3/2}}$$

b – Dipole model

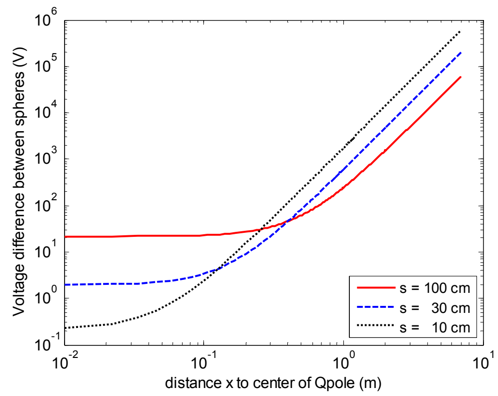



c – ICNIRP reference level *E*-field




d – Electric field as a function of distance for three distances *s* between the spheres

(1 V between the spheres)




e – Maximum voltage differences between the two spheres to enable compliance with the lowest limit level (87 V/m), for three distances *s* between the spheres

**Figure G.1 — Simplified quasi-static E-field model and results for an MME**

The results as a function of exposure distance for three distances between the spheres are given in Figure G.1.e. For instance, it can be seen that the maximum applied voltage over the spheres of the dipole may be approximately 20 V at a distance of 1 cm from the centre of the dipole. For a distance of 1 m, the maximum voltage difference is approximately 2000 V. Table G.1 provides a list of maximum internal voltages in battery operated MME for different exposure distances.

It should be noted that the validity of the results indicated in Figure G.1 is limited. It is assumed that this quasi-static model is valid up to approximately 1 MHz. The results above 1 MHz should be ignored.

Of course, this model is a simplification of many real situations which may occur (different configurations, distances between conductors, dielectric properties of materials in the neighbourhood of the conductors etc). For these modelling uncertainties, a margin has to be taken into account. Therefore, for assessment purposes, three internal voltage limits are selected for three different assessment distances (see 3rd column of Table G.1). These conditions are derived by using a safety factor of approximately 2. If all functionally applied internal voltages within the battery-operated MME are below the limit (for a certain assessment distance) then the product is deemed to comply with the electric field reference levels without further assessment.

**Table G.1 — Conditions for maximum internal voltages in battery-operated MME to be EMF compliant by design in the frequency range from 0 – 150 kHz**

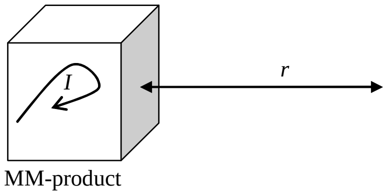
| Exposure distance (cm) | Voltage over the dipole sphere to comply with reference level of 87 V/m at the indicated exposure distance (V) | Condition for maximum applied voltage (less than) (V) |
|---|---|---|
| 1 | 22 | 10 |
| 10 | 23 | 10 |
| 20 | 27 | 10 |
| 50 | 220 | 100 |
| 100 | 1750 | 1000 |

### G.2.2 B/H-field considerations

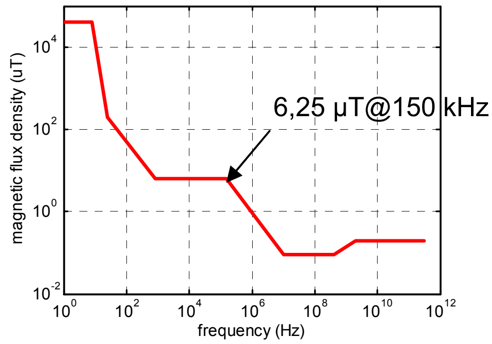
Various levels of internal functional currents within battery operated MME may be applied between 0 Hz and 150 kHz. A battery pack has a capacity of typically a few Ampere-hours. Hence, under the assumption that a battery-operated MME has an endurance of the standard duration of 20 hours, then typically currents of a few hundred milli-amperes may be expected. A current, beyond 1 A is unlikely. For battery operated MME different B-field models may be considered to calculate the B-field at different exposure distances, i.e. a current through a single straight wire, or a current through a straight wire pair, or a current through a wire loop. Figure G.2 gives these three different models that may apply to a certain current within a MME. For each of these models also the equation is given that relates the maximum current as a function of the B-field reference level and as a function of the exposure distance *r*. The B-field reference level decreases gradually between 0 Hz and 150 kHz. The limit is 6.25 μT at the highest frequency of 150 kHz. Figure G.2 gives various examples of the calculation of these maximum currents as a function of frequency. The current at 150 kHz always gives the worst-case value, because the B-field reference level is lowest.

For instance, a comparison between the results obtained at an exposure distance of 10 cm for the three different models can be done. For the straight wire model it can be seen that at a distance of 10 cm the B-field reference level is reached when the current is larger than approximately 3.1 A (see Figure G.2.d). However, for a wire pair separated *d* = 100 mm apart, the B-field reference level is exceeded if the current is above 6.2 A (Figure G.2.f). For the wire-loop model (diameter 14 cm = worst case) the reference level is exceeded if the current is larger than approximately 2.6 A. It should be noted that the validity of the results indicated in Figure G.2 is limited. It is assumed that these quasi-static models are valid up to approximately 1 MHz. Therefore the results above 1 MHz should be ignored.

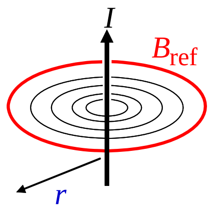
 




a – Exposure of a MME with an internal current *I*

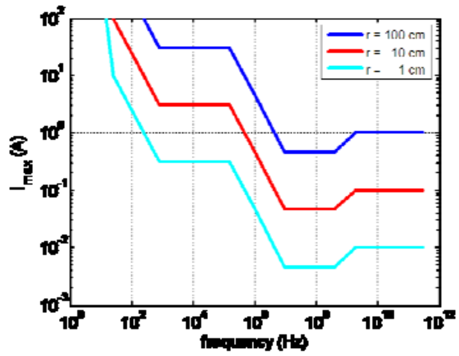



b – ICNIRP reference level B-field

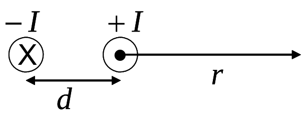



$$I_{max} = \frac{2\pi}{\mu_0} B_{ref} \cdot r$$

c – Straight wire model

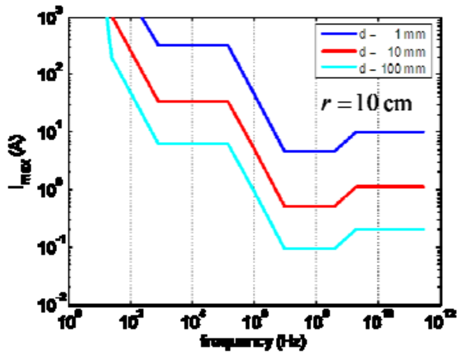



d – Maximum currents to comply with the B-field reference level: straight wire model

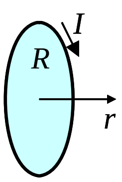



$$I_{max} = \frac{2\pi}{\mu_0} \frac{B_{ref}}{\frac{1}{r} - \frac{1}{r+d}}$$

e – Wire pair model

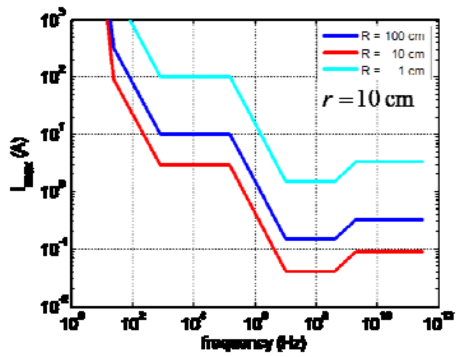



f – Maximum currents related to the B-field reference level: wire pair model




$$I_{max} = \frac{2B_{ref}}{\mu_0} \frac{\left(r^2 + R^2\right)^{3/2}}{R^2}$$

g – Wire loop model




h – Maximum currents related to the B-field reference level

**Figure G.2 — Quasi-static B-field models of a MME**

From the results it can be seen that the wire models and its parameters and the exposure distance determine the maximum current allowed in the battery-operated MME. It may also be identified the positive effect of exposure distance. Of course, these current models are also a simplification of many real situations that may occur (different configurations, distances between conductors, dielectric properties of materials in the neighbourhood of the conductors etc). The straight-wire model is the most conservative case (see second column of Table G.2). For these modelling uncertainties, a margin has to be taken into account. Therefore, for assessment purposes, internal current limits are selected for different assessment distances (see third column of Table G.2). If all functionally applied internal currents within the battery operated MME are below the limit (for a certain assessment distance) then the product is deemed to inherently comply with the magnetic field (*H*), or the magnetic flux density reference levels (*B*) without further assessment.

**Table G.2 — Conditions for maximum internal currents in battery-operated MME to be EMF compliant by design in the frequency range from 0 – 150 kHz**

| Exposure distance (cm) | Corresponding current using the straight-wire model (A) | Maximum applied internal current (less than) (A) |
|---|---|---|
| 1 | 0.3 | 0.15 |
| 10 | 3.1 | 1.5 |
| 20 | 6.3 | 3 |
| 50 | 15.6 | 7.5 |
| 100 | 31.3 | 15 |

## G.3 Frequency range above 30 MHz

EMC requirements exist for battery-operated MME in the frequency range above 30 MHz. In this frequency range CISPR 13 and/or CISPR 22 applies. If the MME complies with the applicable EMC-requirements (radiated emission), then no further EMF assessment is required above 30 MHz.

## G.4 Frequency range between 150 kHz and 30 MHz

For MME without mains and network cables no EMC requirements exist in the frequency range below 30 MHz.

Therefore, in the frequency range between 150 kHz and 30 MHz an additional EMF assessment is needed. The broadband measurement method given in this TR can be used in this frequency range.

## G.5 References


[G.5.1] IEC 62209-1, SAR testing mobile phones.

[G.5.2] IEC 62233, Measurement methods for EMFs of household appliances and similar apparatus with regard to human exposure, edition 1.0, 2005-10.

[G.5.3] CISPR 14-1, EMC emission requirements household appliances.

# Annex H

# Total radiated power measurements in a RVC

## H.1 Introduction

Another way of measuring total radiated power (TRP) of an MME is by using the reverberation chamber (RVC) in combination with a thermal power meter. The RVC and its applications are described in IEC 61000-21. The measurand (the physical parameter) provided by this method is total radiated power. Hence, no errors are introduced by conversion factors that may cause additional uncertainties. Furthermore, the RVC test method is time efficient.

Kildal and others also investigated the RVC method for total radiated power testing of wireless communication devices [H.4.1][H.4.2]. It has proven to be a method where one can assess easily the antenna efficiency or the absorbed power in tissue nearby an antenna.

The advantage of the RVC method is also the total power of signals having complex modulation schemes can be measured easily by connecting a true rms power meter to the chamber. Even if the signal has a relatively broadband signature (a few tens of MHz bandwidth), a broadband power meter will provide directly the total radiated power of the complex signal in question. The RVC method is also a quick means to determine the worst-case TRP associated with the non-intentional radiation of an MME. TRP measurement results of various MMEs in the frequency range between 80 MHz and 6 GHz have been reported in [H.4.3]. From these results, it can be concluded that the TRP associated with the unintentional radiation in the mentioned frequency range is much less (factor 100) than the low-power exclusion limit of 20 mW. In case the sources of radiation are at very different frequencies, then the frequency response characteristics of the RVC has to be taken into account in case a broadband power meter is used as sensor. Hence, the RVC in combination with a thermal power sensor is a convenient solution for summation of different sources of radiation in an rms way, which is very close to the way this would be summed in actual tissue (also rms).

Typically, state-of the-art RVCs have a lower frequency range of operation of approximately 100 MHz. For intentional radiators this is not so much a problem because most wireless technologies operate at frequency bands beyond 100 MHz.

## H.2 Setup and equipment

The setup for a total radiated power measurement in a RVC is given in Figure H.1.

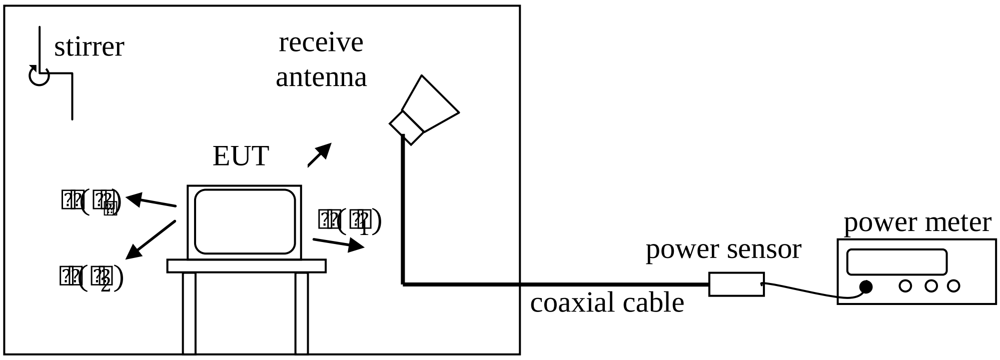



**Figure H.1 — Setup of a total radiated power measurement in a RVC**

The MME, or a known source of radiation is setup in the RVC on a foam setup table. The coaxial output of the RVC is connected to a broadband power sensor. This power meter contains a thermal sensor and measures average power of the incoming signal in the applicable frequency range. The dynamic range of such a power sensor may range from 1µW to 100 mW. The thermal power sensor performs RMS weighting of all signals in the full frequency range. The power sensor is subsequently connected to its associated readout device. The receive antenna used should be suitable for the frequency range under consideration.

The RVC is a facility suitable to measure total radiated power directly. The power transfer ratio of the RVC, which is the ratio of output power and total transmitted power inside the RVC, is frequency dependent.

$$Pout/Prad = c(f), \text{ where } 0<c(f)<1 \qquad \text{(H.1)}$$

This is due to the frequency dependent behaviour of the wall losses, cable losses and antenna involved.

The total radiated power of a narrowband frequency source inside the RVC can be determined by using equation H.1:

$$Prad=Pout/(c(f)=l(f).Pout \qquad \text{(H.2)}$$

where l(f) is the loss of the RVC.

The parameters defined above can be related to the performance parameters given in the RVC standard IEC 61000-4-21. The ACF (antenna calibration factor) and the IL (insertion loss) are two RVC performance parameters that are determined using the RVC calibration procedure using the tuned mode of operation. The ACF is the ratio of the average output power of the RVC and the average total radiated power of the MME. The IL relates the maximum total radiated power at the output of the RVC and transmitted from the MME. The power meter has an rms detector and determines the average power (in terms of RVC statistics). Therefore the loss indicated in equation H.2 is equivalent to the ACF.

## H.3 Response to multiple sources

If an MME is placed inside the RVC with multiple sources of radiation at different frequencies, then the total radiated power of the MME can be determined by summing the contributions from the different sources, provided that the sources can be switched on and off independently.

In case, all sources operate at the same time, then the summation should compensate for the frequency response of the RVC.

## H.4 References

[H.4.1] A. Wolfgang, C. Orlenius, P.-S Kildal, Measuring output power of Bluetooth devices in a reverberation chamber, Antennas & propagation society international symposium, 2003.

[H.4.2] S. Depienne, V. Monebhurrun, A. Azoulay, J-C. Bolomey, The reverberating chaber: a useful tool to characterize the radiated power of small size RF devices, IEEE EMC Symposium 2003.

[H.4.3] Ecma white paper Ecma/TC20/2009/019, Total Radiated Power Measurement Results of Multimedia products in Reverberation Chamber; Unintentional radiators, 2009-04-07.

# Bibliography


[1] ICNIRP Guidelines, Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz), Health Physics, vol. 47, no. 4, pp. 449-522, April 1998.

[2] ICNIRP statement on EMF-emitting new technologies, Health Physics, April 2008, Volume 94, no. 4, pp. 376 – 392 (also available through http://www.icnirp.de/documents/NewTech.pdf).

[3] European Council Recommendation 1999/519/EC, Council recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), (OJEC 30-07-199; L199/59) 12 July 1999.

[4] IEEE Standard C95.1-2005, IEEE standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300 GHz, 19 April 2006.

[5] IEEE Standard C95.6-2002, IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz", 23 October 2002.

[6] GUM, Guide to the expression of uncertainty in measurement (GUM), 1995.

[7] IEC Guide 115, Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector, Edition 1.0, 2007-09.

[8] CISPR 16-4-1, Specification for radiated disturbance and immunity measuring apparatus and methods – Part 4-1 Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests, edition 1.1, 2005-02.

[9] D.W. Harberts, 'On the use of EMC compliance test results to demonstrate EMF compliance', EMC Europe Workshop, 14-15 June 2007, Paris, France.

[10] ITU-T K.52, Guidance on Complying with Limits for Human Exposure to Electromagnetic Fields Series K: Protection Against Interference, 1 December 2004.

[11] ECMA TR/94, Assessment of the Human Exposure to Electromagnetic Fields for Low Power Electronic and Electrical Apparatus according to EN 50371:2002, December 2007.

[12] IEC 62479 (IEC 106/163/CDV), 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).

[13] EN 62479 (parallel vote IEC 106/163/CDV), 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).

[14] IEC 62493 (IEC 34/125/CDV, circulated 2008-09-05), Assessment of lighting equipment related to human exposure to electromagnetic fields – Product family standard.

[15] Technical Report IEC 62630 Ed.1 (106/173/DTR), Guidance for evaluating exposure from multiple EM sources.