
**Earth-moving and building
construction machinery —
Electromagnetic compatibility (EMC)
of machines with internal electrical
power supply —**

**Part 1:
General EMC requirements
under typical electromagnetic
environmental conditions**

*Engins de terrassement et machines pour la construction des
bâtiments — Compatibilité électromagnétique (CEM) des machines
équipées de réseaux électriques de distribution interne —*

*Partie 1: Exigences CEM générales dans des conditions
électromagnétiques environnementales typiques*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*.

This first edition of ISO 13766-1:2018, together with ISO 13766-2:2018, cancels and replaces ISO 13766:2006, of which it constitutes a technical revision and contains the following changes:

- the scope has been extended to specify building construction machinery as well as earth-moving machinery;
- the provisions have been brought up to date with technological change;
- normative references have been updated to the latest editions;

A list of all parts in the ISO 13766 series can be found on the ISO website.

Introduction

This document is a type-C standard as stated in ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

- machine manufacturers (small, medium and large enterprises);
- health and safety bodies (regulators, accident prevention organisations, market surveillance etc.)

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

- machine users/employers (small, medium and large enterprises);
- machine users/employees (e.g. trade unions, organizations for people with special needs);
- service providers, e.g. for maintenance (small, medium and large enterprises);
- consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

With the increasing use of electronic devices in areas where earth-moving and machinery operates, there is a need to ensure that the machinery is provided with adequate immunity to external electromagnetic fields. As more machinery is fitted with electrical and electronic devices, it is necessary to ensure that the emissions of electromagnetic fields from the machinery meet acceptable limits.

Electrical and high frequency disturbances emerge during the normal operation of many parts of machine devices and systems. They are generated within a large frequency range with different electrical characteristics and by conduction or radiation, which can be imparted to other electrical/electronic devices and systems by conduction or radiation. Narrowband signals generated by sources of interference inside or outside the machinery can also be coupled into electrical/electronic systems whereby they can influence the normal function of electrical/electronic devices.

Electrostatic discharges are relevant to the machinery because control elements can be positioned outside the operator station where potential differences could emerge at contact points. Conducted transients in power supply wiring must be considered because the machinery can contain open systems, in which several devices or components can be combined to complement machine functionality.

While there are many existing standards for a variety of products and systems, the test method presented by ISO 13766:2018 provides for the specific test conditions of the machinery within its scope as well as the electrical/electronic sub-assemblies (ESA) or ESA separate from the machinery. The test method recognizes that due to their size and usage, the arrangement of the machines in the test facility needs to be representative of their typical operating characteristics. This document provides test methods and criteria which are acceptable for the machine types it covers, considering their unique characteristics and operating parameters.

Because the machinery has a number of systems that consist of components that can be used on a variety of machine types, the approach of defining ESA or separate ESAs for these components is applied for the immunity and emissions test methods. This allows these components to be evaluated by

the test method in existing laboratory facilities consisting of specially equipped shielded rooms. When electrical/electronic sub-assembly tests are conducted, it is necessary to consider any additional effects imparted by wiring systems used to connect the sub-assemblies into the machinery. The tests can also be conducted on the machinery.

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Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply —

Part 1:

General EMC requirements under typical electromagnetic environmental conditions

1 Scope

This document provides test methods and acceptance criteria for the evaluation of the electromagnetic compatibility (EMC) of earth-moving machinery, as defined in ISO 6165:2012, and of the following building construction machinery as defined in ISO/TR 12603:2010:

- drilling and foundation equipment;
- equipment used for the preparation, conveyance and compaction of concrete, mortar and processing reinforcement;
- road construction and maintenance machinery and equipment.

It deals with general EMC requirements under typical electromagnetic environmental conditions. (ISO 13766-2:2018 deals with EMC requirements specifically related to functional safety).

Electrical/electronic subassemblies (ESA) and separate ESA intended to be fitted to the machinery are also dealt with. The following electromagnetic disturbance phenomena are evaluated:

- broadband and narrowband electromagnetic interference;
- electromagnetic field immunity;
- electrostatic discharge;
- conducted transients.

The machinery can have DC or AC or a combination of both as the internal electrical power supply system.

This document is not applicable to machines that are designed to be supplied by an external mains network or to phenomena caused by military applications.

NOTE 1 Grid-connected machines are covered by IEC 61000.

NOTE 2 *Hybrid* machines are covered in UN ECE R10-Rev. 5.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 6165:2012, *Earth-moving machinery — Basic types — Identification and terms and definitions*

ISO 7637-1:2015, *Road vehicles — Electrical disturbances from conduction and coupling — Part 1: Definitions and general considerations*

ISO 13766-1:2018(E)

ISO 7637-2:2011, *Road vehicles — Electrical disturbances from conduction and coupling — Part 2: Electrical transient conduction along supply lines only*

ISO 10605:2008, *Road vehicles — Test methods for electrical disturbances from electrostatic discharge*

ISO 11451-1:2015, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

ISO 11451-2:2015, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Off-vehicle radiation sources*

ISO 11451-4:2013, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Bulk current injection (BCI)*

ISO 11452-1:2015, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

ISO 11452-2:2004, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Absorber-lined shielded enclosure*

ISO 11452-3:2016, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 3: Transverse electromagnetic (TEM) cell*

ISO 11452-4:2011, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Harness excitation methods*

ISO 11452-5:2002, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 5: Stripline*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO/TR 12603:2010, *Building construction machinery and equipment — Classification*

ISO 16750-1:2006, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 1: General*

ISO 16750-2:2012, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

ISO 21848:2005, *Road vehicles — Electrical and electronic equipment for a supply voltage of 42 V - Electrical loads*

CISPR 12:2007+AMD1:2009, *Vehicles, boats and internal combustion engines — Radio disturbance characteristics — Limits and methods of measurement for the protection of off-board receivers*

CISPR 16-1-1:2014, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-1: Radio disturbance and immunity measuring apparatus — Measuring apparatus*

CISPR 16-1-4:2012, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-4: Radio disturbance and immunity measuring apparatus — Antennas and test sites for radiated disturbance measurements*

CISPR 25:2008, *Vehicles, boats and internal combustion engines — Radio disturbance characteristics — Limits and methods of measurement for the protection of on-board receivers*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6165:2012, ISO/TR 12603:2010 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <http://www.iso.org/obp>;
- IEC Electropedia: available at <http://www.electropedia.org/>.

3.1

internal electrical power supply

electrical power supply which is absolutely independent of outside sources (mains supply) and for which the connection to the mains is not intended during operation

3.2

electromagnetic compatibility

EMC

ability of the machinery or components or separate ESA to function satisfactorily in its *electromagnetic environment* (3.5), without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:1990, IEV ref. 161-01-07, modified — The machinery, components and ESA have been specified.]

3.3

electromagnetic disturbance

any electromagnetic phenomenon which can degrade the performance of machinery or components or separate ESA

Note 1 to entry: An electromagnetic disturbance can be electromagnetic noise, an unwanted signal or a change in the propagation medium itself (see IEC 60050-161:1990).

3.4

electromagnetic immunity

immunity

ability of the machinery or components or separate ESA to perform in the presence of specific *electromagnetic disturbances* (3.3) without degradation of performance

Note 1 to entry: See IEC 60050-161:1990.

3.5

electromagnetic environment

totality of electromagnetic phenomena existing at a given location

[SOURCE: IEC 60050-161:1990, IEV ref. 161-01-01, modified — The Note has been excluded.]

3.6

reference limit

limit value with which the production has to conform

3.7

reference antenna

<frequency range 30 MHz to 80 MHz> shortened balanced dipole which is a half-wave resonant dipole at 80 MHz

[SOURCE: CISPR 16-1-4:2012]

3.8

reference antenna

<frequency range above 80 MHz> balanced half wave resonant dipole tuned to the measurement frequency

[SOURCE: CISPR 16-1-4:2012]

3.9

broadband emission

emission which has a bandwidth greater than that of a particular measuring apparatus or receiver

Note 1 to entry: See IEC 60050-161:1990.

3.10

narrowband emission

emission which has a bandwidth less than that of a particular measuring apparatus or receiver

Note 1 to entry: See IEC 60050-161:1990.

3.11

out-of-band emissions

emission on a frequency or frequencies immediately outside the necessary bandwidth of radio frequency equipment which results from the modulation process, but excluding spurious emissions[SOURCE: [Article 1](#), No 1144 of the ITU Radio Regulations^[6].]

3.12

necessary bandwidth

for a given class of emission of radio-frequency-equipment, width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions[SOURCE: [Article 1](#), No 1152 of the ITU Radio Regulations^[6].]

3.13

spurious emission

emissions on a frequency or frequencies which are outside the necessary RF-bandwidth and the level of which can be reduced without affecting the corresponding transmission of information

Note 1 to entry: In every modulation process of radio-frequency-equipment additional undesired signals exist and are summarized under "spurious emissions". They include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude *out-of-band emissions* (3.11)

[SOURCE: [Article 1](#), No 1145 of the ITU Radio Regulations,^[6] modified — Subsidiary information has been transferred to the Note.]

3.14

electrical/electronic system

electrical and electronic components or set of components intended to be part of the machinery, together with any electrical connections

3.15

electrical/electronic sub-assembly

ESA

electrical and electronic components or set of components intended to be part of the machinery, together with any associated electrical connections and wiring, which perform one or more specialised functions

3.16

electrostatic discharge

ESD

transfer of electrostatic charge between bodies of different electrostatic potential in proximity or through direct contact

[SOURCE: IEC 60050-161:1990, IEV ref. 161-01-22, modified — The Note has been excluded.]

3.17

conducted transients

transient voltage or current distributed in the power supply wiring of the machinery or component or separate *ESA* (3.15) via a conductor between the source of the transient and the drain

3.18**machine type**

machinery which does not differ in such essential respects as

- the structural shape,
- the general arrangement of the electrical and electronic components and the general wiring arrangement, or
- the primary material of which the design of the machinery consists (for example, steel, aluminium or fibreglass covering parts)

3.19**ESA type**

ESA (3.15) which does not differ in such essential respects as

- the function performed by the ESA,
- the arrangement of the electrical and electronic components, if applicable, or
- the primary material of the casing

3.20**operator control**

control exercised by the operator by means of, for example, steering, braking, or propulsion control

Note 1 to entry: This also concerns movements of parts of the machine and modifications of the state of function, which can generate uncommanded, random or unresponsive machine operation (e.g. hazardous machine behaviour).

3.21**immunity-related functions**

functions related to *operator control* (3.20), and to the direct control or operation of the machine by affecting visibility, or which, when disturbed, cause confusion to the operator or others nearby or to machine statutory data, and functions related to machine data bus functionality

Note 1 to entry: Immunity-related functions affecting visibility include driving lights, windscreen wipers and demisting systems.

Note 2 to entry: Immunity-related functions which, when disturbed, cause confusion to the operator or others nearby include the following:

- optical disturbances from incorrect operation of, for example, direction indicators, stop lamps, end outline marker lamps, rear position lamp, light bars for emergency system, wrong information from warning indicators, lamps or displays related to the functions of *operator control* (3.20);
- acoustical disturbances from incorrect operation of, for example, anti-theft alarms, horns;
- “reverse/movement alarm” devices.

Note 3 to entry: Machine data bus immunity-related functions are those that can block data transmission on machine data bus-systems used to transmit data, and which are required to ensure the correct functioning of other immunity-related functions.

Note 4 to entry: Immunity-related functions which, when disturbed, affect machine statutory data include hour meters and odometers.

3.22**non-immunity related functions**

functions other than *immunity related functions* (3.21)

EXAMPLE Entertainment devices, air conditioning, fuel gauge.

4 Requirements

4.1 General requirements

4.1.1 Fulfilment of requirements

4.1.1.1 General

The user of this document shall prove compliance with the requirements by any one or a combination of

- testing the complete machine, as per [4.1.1.2](#), or
- testing ESA, as per [4.1.1.3](#), if the availability of an immunity test site proves restrictive due to machine size, regional environmental conditions or legal requirements.

Evaluations not restricted by the above may be made; however remaining gaps in the requirements should be evaluated at the ESA level.

NOTE In most regions of the world radiated immunity testing for large machines in open area test sites is legally prohibited. Below 1 GHz conducted testing methods are available as a substitute. Above 1 GHz there is no alternative to radiated immunity testing, and it is possible to perform the radiated immunity testing on ESA level in an anechoic chamber.

When testing ESA it is recommended that the integrity of the final system when combined at machine level be tested.

The requirements of this document are also deemed to be fulfilled when the machinery has no such equipment for which an immunity or emission test is required. In this case, no tests are necessary. For all exceptions, see [Clause 5](#).

4.1.1.2 Performance criteria for complete machines

The performance requirements are met if the machinery operates as intended and without unacceptable degradation when tested in accordance with the requirements of [4.2](#), [4.3](#), [4.4](#) and [4.8](#).

4.1.1.3 Performance criteria for ESA

The performance requirements of this document are met if the machine's ESA or separate ESA operate as intended and without unacceptable degradation for their application in machinery in accordance with the requirements of [4.5](#), [4.6](#), [4.7](#), [4.8](#) and [4.9](#).

4.1.2 Test specimen

The test specimen may be of a machine type or ESA type as defined in [3.18](#) and [3.19](#).

If a single test specimen is to be used to judge the performance of a population of like machinery, the reference limits for emissions and immunity shall be made more restrictive by a 20 % reduction for emissions limits and a 25 % increase for immunity limits so as to account for variability of emission and immunity due to any manufacturing variations of machine or ESA types and testing factors.

For a subsequent test on similarly configured machinery, conformity to the reference limits shall be accepted as fulfilment of the requirements of this document.

For electrostatic discharge and conducted transients, the reference limits are valid for all testing of any test specimen.

4.1.3 Additional requirements for immunity tests

When a test specimen is subjected to the immunity requirements, operator controls and any automatic controls for the machinery and any attachments or machinery shall remain functional so as to provide continued control of the machinery. This also applies to secondary or shut-down systems which are intended to be operated when the primary control has failed.

4.2 Specifications for broadband electromagnetic emission radiated from machinery

4.2.1 Method of measurement

The electromagnetic radiation shall be measured using the method specified in [Annex B](#) at either of the defined antenna distances. The choice of antenna distance is at the option of the user.

4.2.2 Broadband reference limits

For measurements made using the method specified in [Annex B](#) and a machinery-to-antenna spacing of $(10,0 \pm 0,2)$ m, the emission reference limit shall be

- 34 dB ($\mu\text{V}/\text{m}$) (50 $\mu\text{V}/\text{m}$) in the 30 MHz to 75 MHz frequency band,
- 34 dB ($\mu\text{V}/\text{m}$) to 45 dB ($\mu\text{V}/\text{m}$) (50 $\mu\text{V}/\text{m}$ to 180 $\mu\text{V}/\text{m}$) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz, as shown in [Figure A.1](#), and
- in the 400 MHz to 1 000 MHz frequency band, shall remain constant at 45 dB ($\mu\text{V}/\text{m}$) (180 $\mu\text{V}/\text{m}$).

For measurements made using the method specified in [Annex B](#) using a machinery-to-antenna spacing of $(3,0 \pm 0,05)$ m, the emission reference limit shall be

- 44 dB ($\mu\text{V}/\text{m}$) (160 $\mu\text{V}/\text{m}$) in the 30 MHz to 75 MHz frequency band,
- 44 dB ($\mu\text{V}/\text{m}$) to 55 dB ($\mu\text{V}/\text{m}$) (160 to 562 $\mu\text{V}/\text{m}$) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in [Figure A.2](#), and
- in the 400 MHz to 1 000 MHz frequency band, shall remain constant at 55 dB ($\mu\text{V}/\text{m}$) (562 $\mu\text{V}/\text{m}$).

On a single test specimen, the measured values, expressed in dB ($\mu\text{V}/\text{m}$) or ($\mu\text{V}/\text{m}$), shall be at least 2,0 dB or (20 %) below the reference limits.

NOTE The 20 % factor applies regardless of the use of CISPR 12:2007 or CISPR 12:2007+AMD1:2009.

4.3 Specifications concerning narrowband electromagnetic emission radiated from machinery

4.3.1 Method of measurement

The electromagnetic emission shall be measured using the method specified in [Annex C](#), at either of the defined antenna distances. The choice of antenna distance is at the option of the user.

4.3.2 Narrowband reference limits

For measurements made using the method specified in [Annex C](#) using a machinery-to-antenna spacing of $(10,0 \pm 0,2)$ m, the emission reference limit shall be

- 24 dB ($\mu\text{V}/\text{m}$) (16 $\mu\text{V}/\text{m}$) in the 30 MHz to 75 MHz frequency band,
- 24 dB ($\mu\text{V}/\text{m}$) to 35 dB ($\mu\text{V}/\text{m}$) (16 $\mu\text{V}/\text{m}$ to 56 $\mu\text{V}/\text{m}$) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in [Figure A.3](#), and
- in the 400 MHz to 1 000 MHz frequency band, shall remain constant at 35 dB ($\mu\text{V}/\text{m}$) (56 $\mu\text{V}/\text{m}$).

For measurements made using the method specified in [Annex C](#) using a machinery-to-antenna spacing of $(3,0 \pm 0,05)$ m, the emission reference limit shall be

- 34 dB ($\mu\text{V/m}$) ($50 \mu\text{V/m}$) in the 30 MHz to 75 MHz frequency,
- 34 to 45 dB ($\mu\text{V/m}$) ($50 \mu\text{V/m}$ to $180 \mu\text{V/m}$) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in [Figure A.4](#), and
- in the 400 MHz to 1 000 MHz frequency band, shall remain constant at 45 dB ($\mu\text{V/m}$) ($180 \mu\text{V/m}$).

On a single test specimen, the measured values, expressed in dB ($\mu\text{V/m}$) or ($\mu\text{V/m}$), shall be at least 2,0 dB or (20 %) below the reference limits.

NOTE The 20 % factor applies regardless of the use of CISPR 12:2007 or CISPR 12:2007+AMD1:2009.

4.4 Specifications concerning the immunity of machinery to electromagnetic radiation

4.4.1 Test method

The immunity to electromagnetic radiation of the machinery shall be tested according to ISO 11451-1:2015 and ISO 11451-2:2015 with both horizontal and vertical polarization. The determination of the reference points and the operating modes are machine-specific and shall be noted in the test report. Immunity testing shall be conducted according to ISO 11451-1:2015 except that forward power may be used as the control regardless of the standing wave ratio of the system, and machine reference points may be changed from the defined locations. The test report shall note which control method was used.

The substitution method and 80 % amplitude modulation (AM) with sinusoidal wave of 1 kHz is determined as a test method in the frequency band 20 MHz to 800 MHz (see ISO 11451-1:2015).

PM with $t_{\text{on}} 577 \mu\text{s}$, period $4 600 \mu\text{s}$ is determined as a test method in the frequency band 800 MHz to 2 000 MHz (see ISO 11451-1:2015).

Antenna may be moved further away from the machine to increase the area of RF illumination provided the field strength at the reference point of the machine is held at the required field strength.

The position of the machine reference points should take into account the diversity of the geometric arrangements of the machines that are addressed in this document.

4.4.1.1 Alternative test methods

If the machine is subject to BCI testing, this shall be carried out with an amplitude of 48 mA and only in the frequency range from 20 MHz to 800 MHz with AM, and from 800 MHz to 1 000 MHz with PM and in accordance with ISO 11451-4:2013. Above 1 GHz, radiated test methods shall be applied.

If the machine is subject to tubular wave coupling (TWC) testing, this shall be carried out with an amplitude of 22,5 dBm and only in the frequency range from 20 MHz to 800 MHz with AM, and from 800 MHz to 1 000 MHz with PM and in accordance with ISO 11451-4:2013. Above 1 GHz, radiated test methods shall be applied.

The manufacturer should consider the use of on-board RF-transmitters even if the machinery is not equipped with RF-transmitters at the time of delivery, e.g. by definition of frequency bands, power levels, antenna positions and installation provisions. For further information see ISO 11451-3:2015.

4.4.2 Machinery immunity reference limits

Reference limit 24 V/m referring to the root mean square value of the unmodulated signal applies. The maximum value of the test signal with modulation shall comply with the maximum value of an unmodulated test signal. On the test specimen, the immunity requirements are fulfilled by a field strength of 30 V/m (25 % above the reference limit). The general requirements for immunity testing

according to [4.1.3](#) shall be fulfilled by the machinery under test maintaining functional status A (see [Table 3](#)).

4.5 Specifications concerning broadband electromagnetic emissions radiated from ESA

4.5.1 Method of measurement

The electromagnetic interference shall be measured by the method specified in [Annex D](#).

4.5.2 ESA broadband reference limits

For measurements made using the method specified in [Annex D](#), the emission reference limits shall be

- 64 dB ($\mu\text{V/m}$) to 54 dB ($\mu\text{V/m}$) (1 600 $\mu\text{V/m}$ to 500 $\mu\text{V/m}$) in the 30 MHz to 75 MHz frequency band, this limit decreasing logarithmically (linearly) with frequencies above 30 MHz; and
- 54 dB ($\mu\text{V/m}$) to 65 dB ($\mu\text{V/m}$) (500 $\mu\text{V/m}$ to 1 800 $\mu\text{V/m}$) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in [Annex A](#) ([Figure A.5](#)).

In the 400 MHz to 1 000 MHz frequency band the limits remain constant at 65 dB ($\mu\text{V/m}$) (1 800 $\mu\text{V/m}$).

On a single test specimen, the measured values, expressed in dB ($\mu\text{V/m}$) or ($\mu\text{V/m}$), shall be at least 2,0 dB or (20 %) below the reference limits.

4.6 Specifications concerning narrowband electromagnetic emissions radiated from ESA

4.6.1 Method of measurement

The electromagnetic interference shall be measured by the method specified in [Annex E](#).

4.6.2 ESA narrowband reference limits

For measurements made using the method specified in [Annex E](#), the emission reference limits shall be

- 54 dB ($\mu\text{V/m}$) to 44 dB ($\mu\text{V/m}$) (500 $\mu\text{V/m}$ to 160 $\mu\text{V/m}$) in the 30 MHz to 75 MHz frequency band, this limit decreasing logarithmically (linearly) with frequencies above 30 MHz, and
- 44 dB ($\mu\text{V/m}$) to 55 dB ($\mu\text{V/m}$) (160 $\mu\text{V/m}$ to 562 $\mu\text{V/m}$) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in [Annex A](#) ([Figure A.6](#)).

In the 400 MHz to 1 000 MHz frequency band the limit remains constant at 55 dB ($\mu\text{V/m}$) (562 $\mu\text{V/m}$).

On a single test specimen, the measured values, expressed in dB ($\mu\text{V/m}$) or ($\mu\text{V/m}$), shall be at least 2,0 dB or (20 %) below the reference limits.

4.7 Specifications concerning the immunity of ESA to electromagnetic radiation

4.7.1 Method of testing

For the testing of the immunity of ESA to electromagnetic fields the test methods of ISO 11452-2:2004, ISO 11452-3:2016, ISO 11452-4:2011 or ISO 11452-5:2002 apply in the respective frequency ranges applicable for those International Standards.

The substitution method and 80 % AM with sinusoidal wave of 1 kHz (see ISO 11452-1:2015) is determined as a test method in the frequency band of 20 MHz to 800 MHz.

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PM with t_{on} 577 μ s, period 4 600 μ s is determined as a test method in the frequency band of 800 MHz to 2 000 MHz (see ISO 11452-1:2015).

If the substitution method is determined as the calibration method for the anechoic chamber test, the forward power may be used as the control regardless of the standing wave ratio of the system. In the case of ESA, the substitution method or the closed loop method may be used for the field calibration. The test report shall note which control method was used.

4.7.2 ESA immunity reference limits

For tests made according to ISO 11452-1:2015, ISO 11452-2:2004, ISO 11452-3:2016, ISO 11452-4:2011 or ISO 11452-5:2002, the immunity reference limits shall be

- 48 V/m for the 150 mm strip line test method (ISO 11452-5:2002),
- 60 V/m for the TEM cell test method (ISO 11452-3:2016),
- 48 mA for the BCI test method (ISO 11452-4:2011),
- 22,5 dBm for the TWC test method, (ISO 11452-4:2011), and
- 24 V/m for the radiated field (absorber lined chamber) test method (ISO 11452-2:2004 with horizontal and vertical polarization).

The reference limits shall apply to the root mean square value of the unmodulated signal. The maximum value of the test signal with modulation shall comply with the maximum value of an unmodulated test signal.

Functional status class A ([Table 3](#)) shall apply to all tests. The reference limits, increased by 25 %, shall apply for the single test specimen. The ESA shall not exhibit any operational change which is unacceptable for its application on the machinery. See [4.1.3](#) for a further definition of unacceptable operational change.

4.8 Electrostatic discharge (ESD)

4.8.1 Method of testing

The method specified in ISO 10605:2008 shall be used for measurement of the machinery or the component in such areas where an ESD in standard use is possible (e.g. by touching by the operator).

Choose

- a generator capacitance of 330 pF for areas that can easily be accessed from the inside of the machinery,
- a generator capacitance of 150 pF for areas that can easily be touched only from the outside of the machinery.

In either case, the resistance is 2 k Ω .

Packaging and handling tests according to ISO 10605:2008 are not required.

ESA should be evaluated for their intended location upon the machinery. If this is not known both test generator (150 pF and 330 pF) capacitance values shall be evaluated.

4.8.2 Reference limits

The following test levels apply for machinery and ESA:

- \pm 4,0 kV contact and air discharge at functional status class A (see [Table 3](#));

— ± 6,0 kV contact discharge and ± 8,0 kV air discharge at functional status class C (see [Table 3](#)).

4.9 Conducted transients

4.9.1 General

With remotely located ESA connected to the machinery through the wiring system, there is a possibility of a pulse generated in a remote ESA energizing the circuit and affecting other ESA or components on the machinery. Therefore, minimum values concerning emission and susceptibility for ESA fitted to machinery are required. It shall be considered that the emission value for an ESA shall be less than the susceptibility for all ESA of the system.

4.9.2 Method of testing

Testing of conducted transients is applicable for ESA configuration only.

The method specified in ISO 7637-1:2015, ISO 7637-2:2011 and ISO 16750-2:2012 shall be used as the method of testing.

4.9.3 Conducted emission — Reference limits

The user shall ensure that, for those devices likely to create higher pulses, such as solenoids, other highly inductive devices (including harnesses) and fast switching loads only create pulses that are less than the reference limits of the ESA testing as defined in [4.9.4](#).

4.9.4 Conducted immunity — Reference limits and functional status

The test levels at functional status class according to [Table 1](#) shall apply. The function performance status shall be specified before the testing of every different check pulse. [Table 2](#) shows the field of application of the different check pulses in the 12 V and 24 V on-board systems.

For each ESA, as applicable, instructions should be added to describe the correct installation and connections to the machinery or its devices to avoid malfunction of the ESA and the machinery.

Table 1 — Check pulse in 12 V and 24 V on-board systems

Test pulse	Standard reference	12 V on-board system Severity level ^a or Supply test level U_s V ^b	24 V on-board system Severity level ^a or Supply test level U_s V ^b	Functional status for systems
1	See ISO 7637-2:2011	III ^a	III ^a	C ^e / D ^h
2a	See ISO 7637-2:2011	III ^a	III ^a	B ^e / D ^h
2b	See ISO 7637-2:2011	III ^a	III ^a	C ^e / D ^h
3a	See ISO 7637-2:2011	III ^a	III ^a	A / D ^h
3b	See ISO 7637-2:2011	III ^a	III ^a	A / D ^h

^a Severity levels are based on recommendations from ISO 7367-2:2011 and ISO 16750-2:2012.

^b The calculation in ISO 16750-2:2012 should be used.

^c Functional status of ESA that are relevant for EUT (equipment under test) operation during cranking

^d Functional status of ESA other than for Footnote b.

^e Without uncommanded movement and without creating hazardous machine behaviour

^f In accordance with ISO 16750-2:2012, 4.6.3.

^g In accordance with ISO 21848:2005.

^h Functional status “D” is only allowed for devices only providing convenience

Table 1 (continued)

Test pulse	Standard reference	12 V on-board system Severity level ^a or Supply test level U_s V ^b	24 V on-board system Severity level ^a or Supply test level U_s V ^b	Functional status for systems
Starting profile ^f	See ISO 16750-2:2012	IV ^a	II ^a	A ^c / C ^d
Load dump ^g	See ISO 16750-2:2012 (unclamped)	See Table 5 ^b	See Table 5 ^b	C ^e
Load dump ^g	See ISO 16750-2:2012 (clamped)	See Table 6 ^b	See Table 6 ^b	C ^e

^a Severity levels are based on recommendations from ISO 7367-2:2011 and ISO 16750-2:2012.
^b The calculation in ISO 16750-2:2012 should be used.
^c Functional status of ESA that are relevant for EUT (equipment under test) operation during cranking
^d Functional status of ESA other than for Footnote b.
^e Without uncommanded movement and without creating hazardous machine behaviour
^f In accordance with ISO 16750-2:2012, 4.6.3.
^g In accordance with ISO 21848:2005.
^h Functional status "D" is only allowed for devices only providing convenience

Table 2 — Application of test pulses

Test pulse	Application
1	This test pulse is a simulation of transients due to supply disconnection from inductive loads; it applies to a device under test if, as used in the machinery, it remains connected directly in parallel with an inductive load.
2a	This test pulse is a simulation of transients due to the sudden interruption of current in an inductor (e.g. the wiring harness) connected in series with a device under test.
2b	This test pulse is a simulation of transients due to the castor of a DC motor when the ignition switch is opened and the motor is connected in parallel with a device under test.
3a, 3b	These test pulses are a simulation of transients, which occur as a result of the switching processes. The characteristics of these transients are influenced by distributed capacitance and inductance of wiring harness.
Starting profile	This pulse simulates supply voltage reduction caused by energizing the starter-motor circuits of internal combustion engines (excluding spikes associated with starting).
Load dump	This test pulse is a simulation of a load dump transient occurring in the event of a discharged battery being disconnected while the alternator is generating charging current at the moment of the battery being disconnected with other loads remaining on the alternator circuit at this moment. The load dump amplitude depends on the alternator speed and on the level of the alternator field excitation at the moment of the battery being disconnected. The load dump pulse duration depends essentially on the time constant of the field excitation circuit and on the pulse amplitude.

Table 3 — Functional status

Functional status	Description
A (I)	All functions of a device/system perform as designed during and after exposure to a disturbance.
B (II)	All functions of a device/system perform as designed during exposure; however, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after exposure is removed. Memory functions shall remain criterion A.
C (III)	One or more functions of a device/system do not perform as designed during exposure but returns automatically to normal operation after exposure is removed.
D (IV)	One or more functions of a device/system do not perform as designed during exposure and does not return to normal operation until exposure is removed and the device/system is reset by simple "operator/use" action.
E (V)	One or more functions of a device/system do not perform as designed during and after exposure and cannot be returned to proper operation without repairing or replacing the device/system.

NOTE Roman numerals refer to the system used in ISO 16750-1:2006.

5 Exceptions

For the requirements described in [Clause 4](#), the following exceptions are valid.

- a) Where machinery or an electrical/electronic system or ESA does not include an electronic oscillator with an operating frequency greater than 9 kHz or broadband sources as specified in [Annex B](#), it shall be deemed to comply with the requirements of [4.2](#), [4.3](#), [4.5](#), and [4.6](#).
- b) For ESA that only provide a non-immunity related function to the operator, the immunity tests according to [4.4](#) and [4.7](#) are optional.
- c) If the machinery does not possess an interface for the coupling of external electrical/electronic systems, a test of the conducted transients according to [4.9](#) is not necessary.
- d) The machinery manufacturer shall in the operator's manual identify the precautions in respect of electromagnetic compatibility, if any, are applicable when installing and operating radio, telephone or other transmitters which comply with the relevant EMC standards. For the application of this document, specific tests regarding radio or telephone transmitters are not necessary.
- e) Systems that only contain electromechanical parts are deemed to meet the requirements of this document if the immunity requirements are satisfied.
- f) Loss of function of RF receivers during the immunity test is acceptable within the receiver bandwidth (RF exclusion band), as long as the machinery maintains functional status A or shifts into the manufacturers predefined safe state. The RF exclusion band as specified for the specific radio service/product in the EMC International Standards shall be applied for this purpose.

Machine manufacturers shall provide evidence that machinery performance is not adversely affected by such transmitter installations (see ISO 13766-2:2018, 5.3.2).

Wanted emissions (e.g. from RF transmitting systems) within the necessary bandwidth and out-of-band emissions are disregarded.

NOTE Spurious emissions are within the scope of this document but might not need to be retested if the transmitter has already met equivalent regional requirements (e.g. it has a Declaration of Conformity according to Directive 2014/53/EU^[Z] using a harmonized standard for products sold in the European Union).

6 Test report

The test report shall include the following:

- a description of the test specimen (machine type or ESA type);
- a description or classification of the test facilities or test site;
- a description of the instrumentation or the standards that the instrumentation meets;
- the level of broadband electromagnetic emissions according to [4.2.2](#);
- the level of narrowband electromagnetic emissions according to [4.3.2](#);
- the identification of any loss of functional control of the machinery according to [4.4.2](#);
- the level of broadband electromagnetic interference according to [4.5.2](#);
- the level of narrowband electromagnetic interference according to [4.6.2](#);
- identification of any deviation from the specification of functional control exhibited by the ESA according to [4.7.2](#);
- identification of components not meeting the requirement of [4.8.2](#);
- identification of components not meeting the requirement of [4.9.3](#) and [4.9.4](#);
- the machine “configuration”, place and date, persons responsible, instruments and methods used;
- the instrument or calibration number;
- a justification of the test specimen configuration selected, as per [Annex F](#).

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Annex A (normative)

Reference limits

See [Figures A.1](#) to [A.6](#).

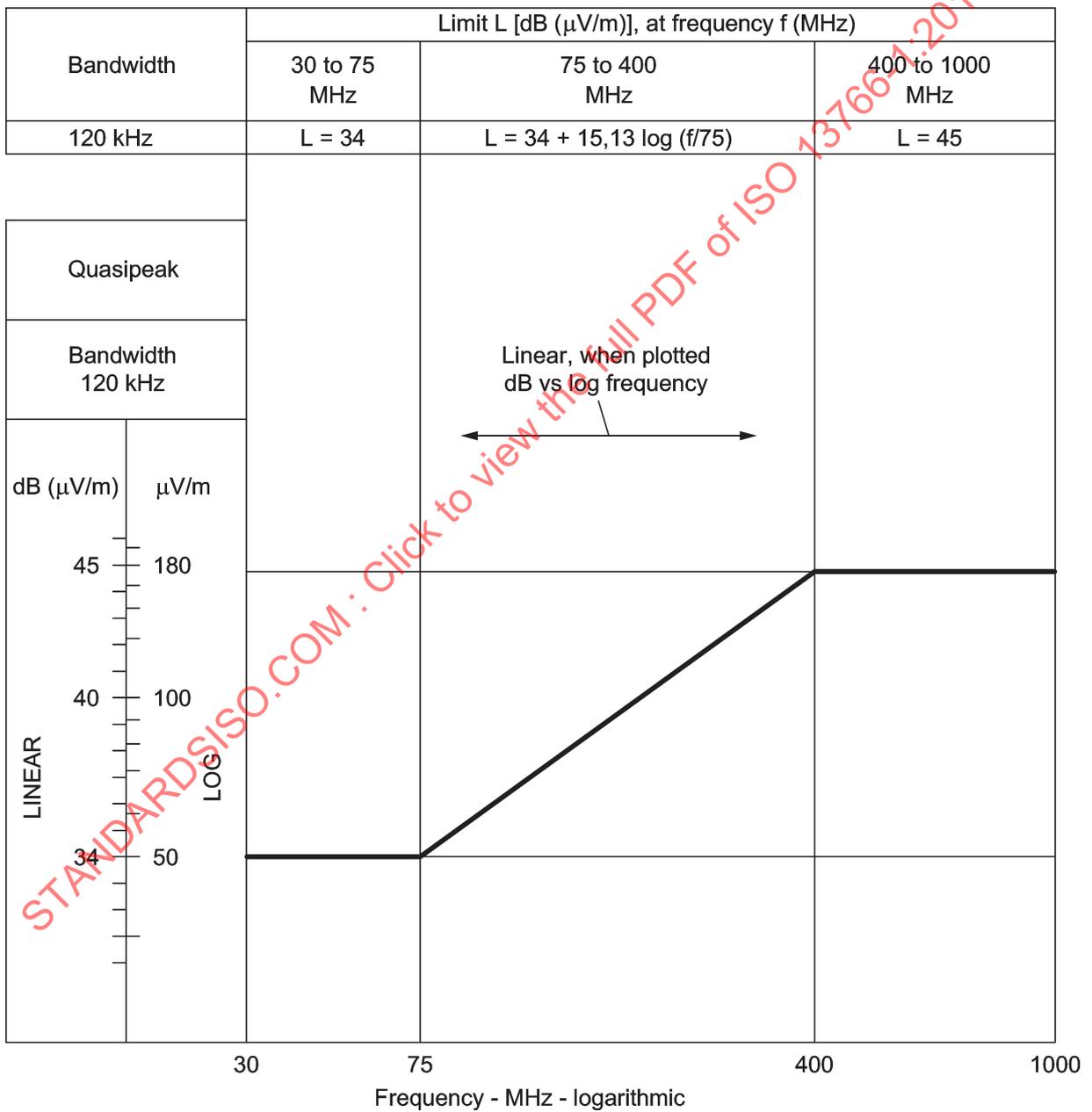


Figure A.1 — Machinery broadband reference limits for machinery-to-antenna distance of 10 m

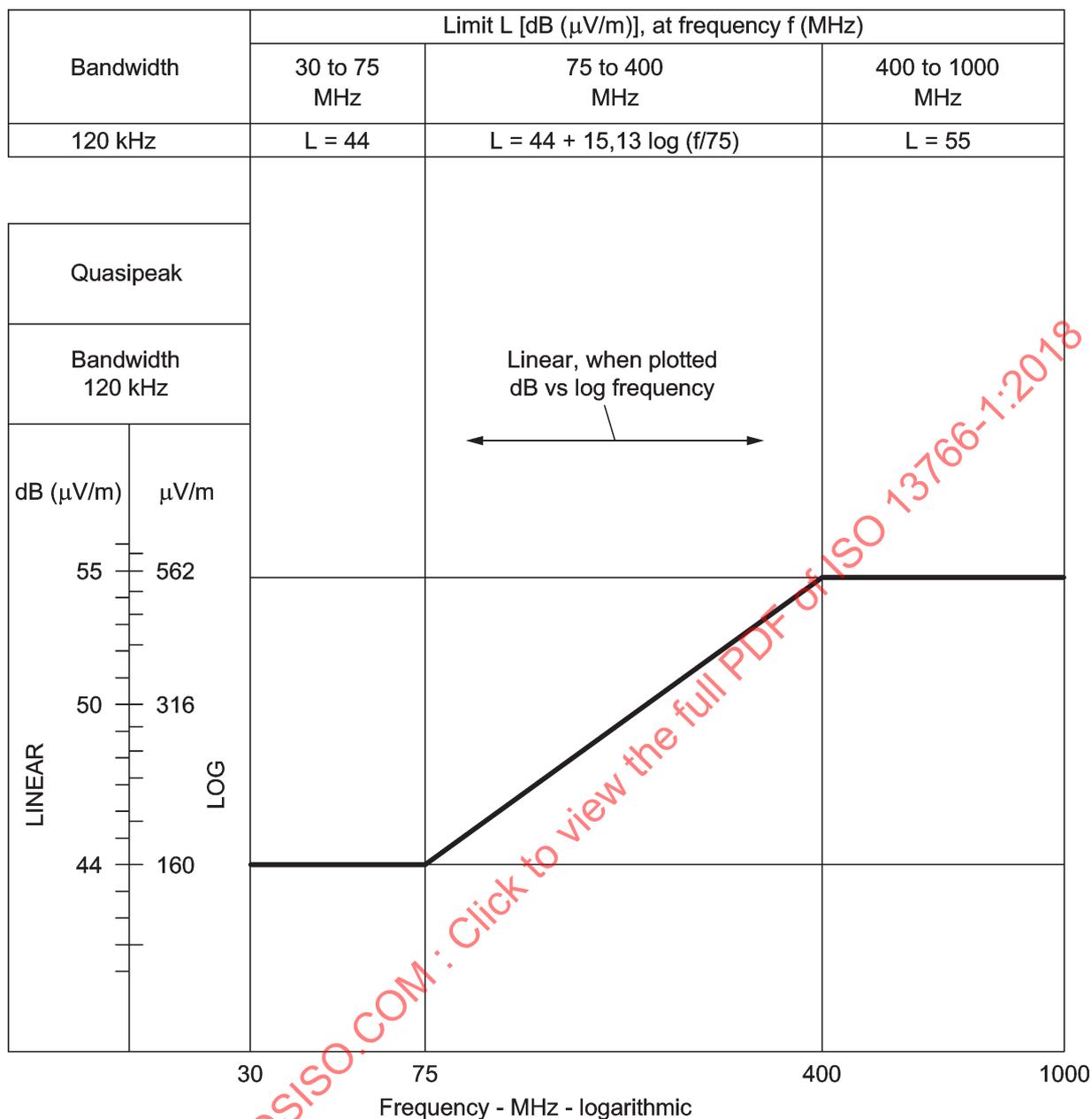
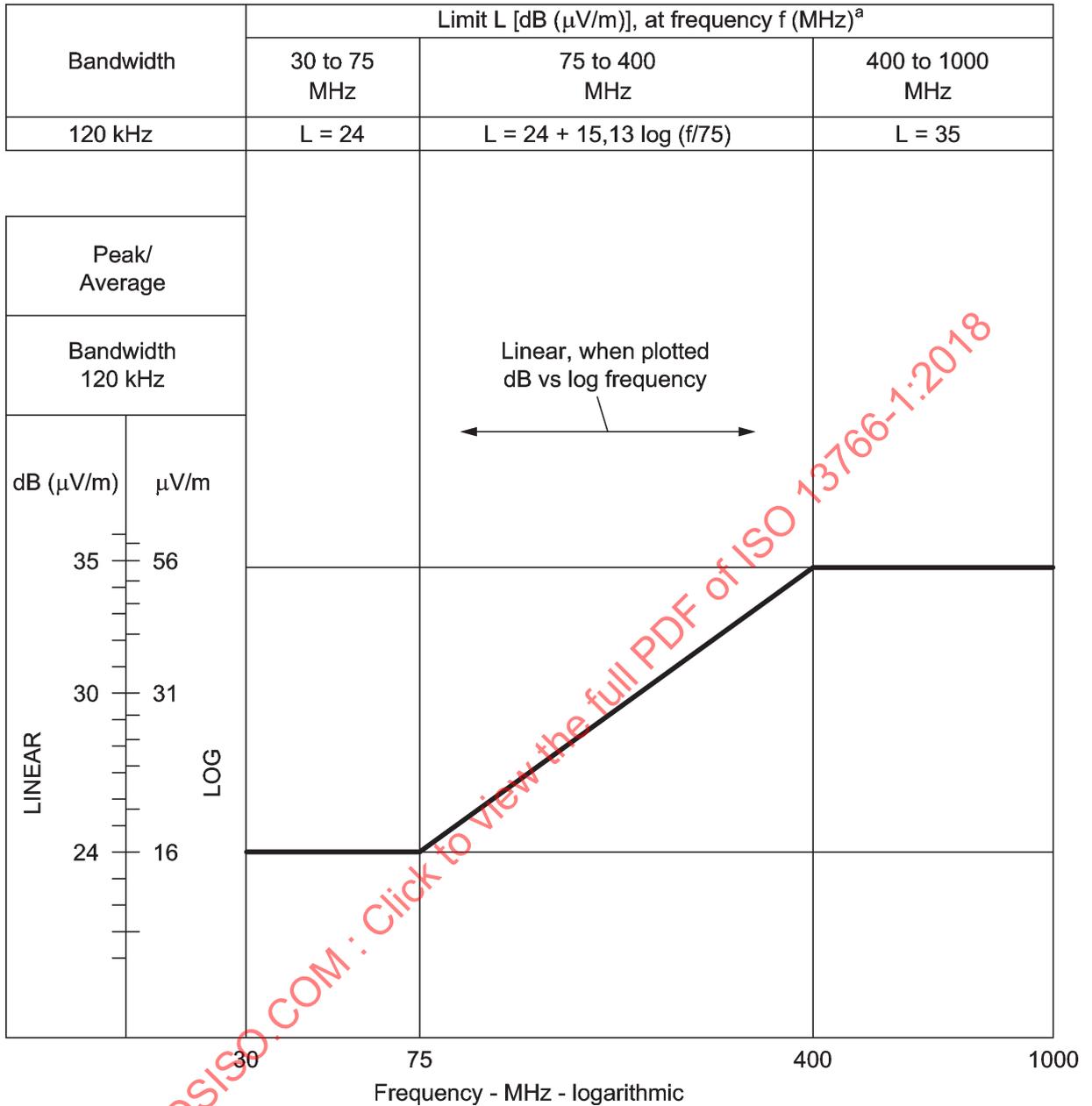
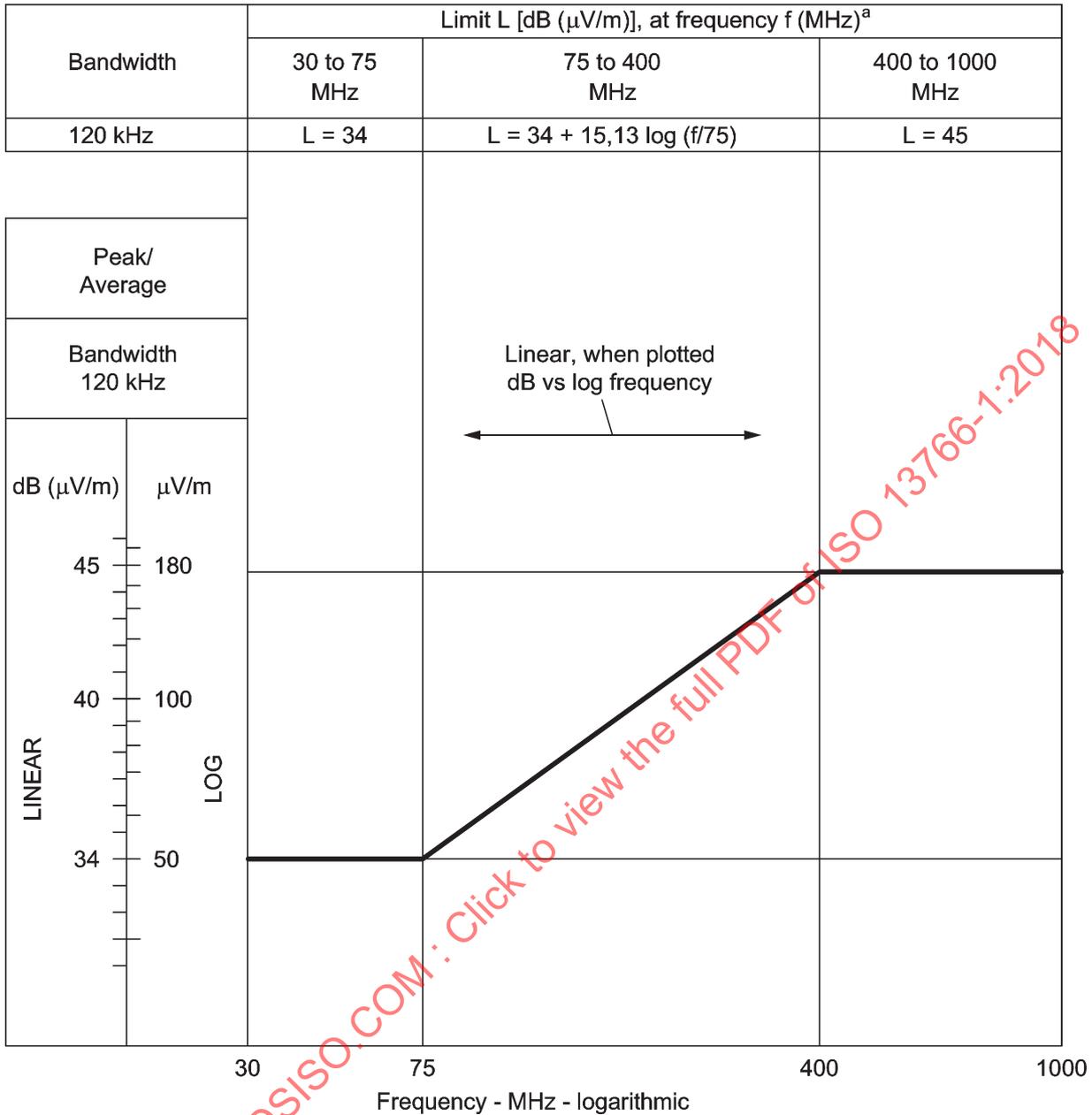


Figure A.2 — Machinery broadband reference limits for machinery-to-antenna distance of 3 m



^a If measurements are made which exceed the above emission reference limits, an analysis and evaluation of these peaks shall be made according to the method of determining conformance of radiated disturbance presented in CISPR 12:2007.

Figure A.3 — Machinery narrowband reference limits for machinery-to-antenna distance of 10 m



^a If measurements are made which exceed the above emission reference limits, an analysis and evaluation of these peaks shall be made according to the method of determining conformance of radiated disturbance presented in CISPR 12:2007.

Figure A.4 — Machinery narrowband reference limits for machinery-to-antenna distance of 3 m

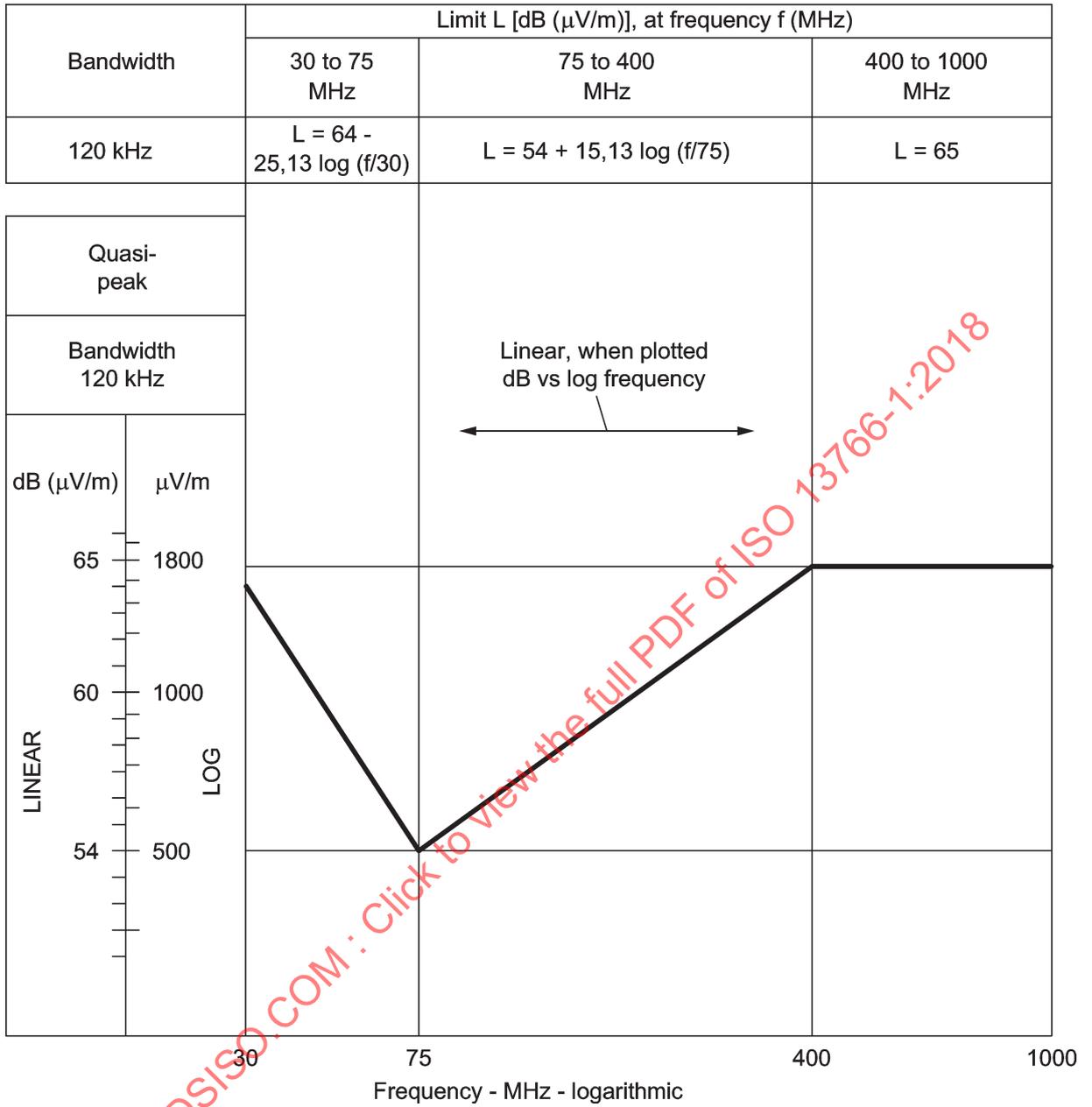
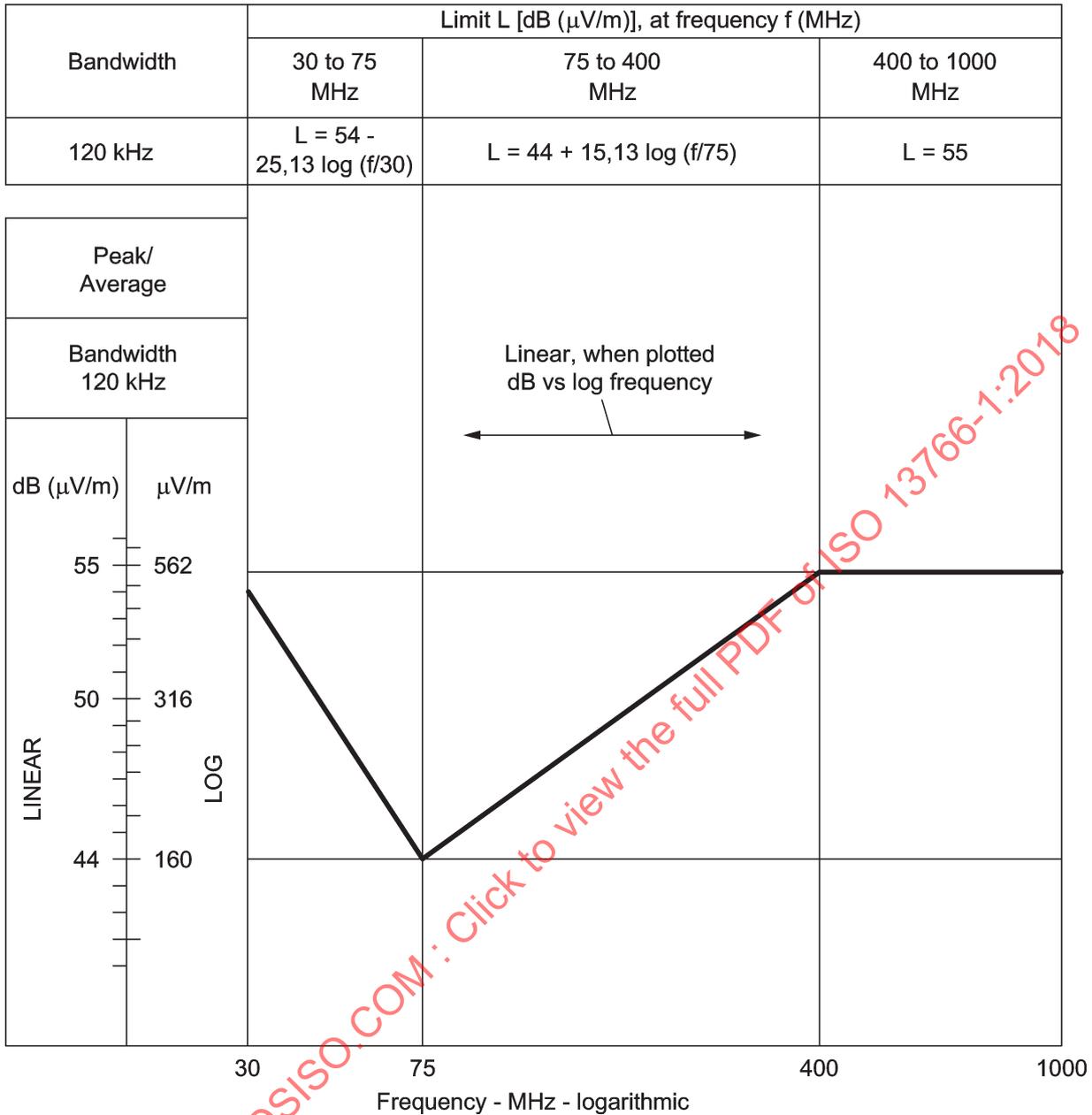


Figure A.5 — ESA broadband reference limits



^a If measurements are made which exceed the above emission reference limits, an analysis and evaluation of these peaks shall be made according to the method of determining conformance of radiated disturbance presented in CISPR 12:2007.

Figure A.6 — ESA narrowband reference limits

Annex B (normative)

Method of measurement of radiated broadband electromagnetic emissions from machinery — Complete machine only

B.1 General

B.1.1 Application

The test method of [Annex B](#) shall be applied to the complete machine.

Optional: The methodology described in CISPR 12:2007 can be applied by using the limit lines as specified in [Annex A](#).

On a single test specimen, the measured values, expressed in dB($\mu\text{V}/\text{m}$) or ($\mu\text{V}/\text{m}$), shall be at least 2,0 dB or (20 %) below the reference limits.

B.1.2 Measurement apparatus

The measuring equipment shall comply with the requirements of CISPR 16-1-1:2014.

A quasi-peak-detector shall be used for the measurement of broadband electromagnetic emissions or, if a peak-detector is used, an appropriate correction factor shall be applied which, depending on the pulse rate (see CISPR 12:2007).

B.1.3 Test method

This test is intended to measure the broadband emissions.

Two alternative reference antenna distances are permissible, with the reference antenna located either

- 10 m, or
- 3 m

from the machinery.

In either case, the requirements of [B.3](#) shall be complied with.

B.2 Results of measurement

The results of measurement shall be expressed in dB($\mu\text{V}/\text{m}$) or ($\mu\text{V}/\text{m}$) for a 120 kHz bandwidth. If the actual bandwidth B (expressed in kHz) of the measuring apparatus differs from 120 kHz, the readings, when given in dB($\mu\text{V}/\text{m}$), shall be converted through an addition of $20 \log(120/B)$ and, when given in $\mu\text{V}/\text{m}$, shall be converted through multiplication by $120/B$.

B.3 Measuring location

B.3.1 Test site

The test site shall be a clear, level area, free from electromagnetic reflecting surfaces within a circle of a minimum radius of 30 m measured from a point midway between the machinery and the antenna (for outdoor test sites — see [Figure B.1](#) and CISPR 12:2007+AMD1:2009, 5.2.1).

B.3.2 Measurement facility

The measuring set, test hut or machinery in which the measurement set is located may be within the test site, but only in the permitted region as shown in [Figure B.1](#). Other measuring antennae are allowed within the test area, at a minimum distance of 10 m both from the receiving antenna and the machinery under test, provided that it can be shown that the test results are not affected.

B.3.3 Enclosed test facilities

Enclosed test facilities may be used if correlation can be shown between the enclosed test facility and an outdoor site. Enclosed test facilities do not need to meet the dimensional requirements of [Figure B.1](#) other than the distance from the antenna to the machinery and the height of the antenna.

The requirements of [B.3.4](#) also apply for an enclosed facility.

B.3.4 Ambient

To ensure that there is no extraneous noise or signal of a magnitude sufficient to affect materially the measurement, ambient measurements shall be taken before and after the main test. If the machinery is present when ambient measurements are taken, it shall be ensured that any emission from the machinery does not affect significantly the ambient measurements — for example, by removing the machinery from the test area, or 1) removing the ignition key or 2) disconnecting the battery. In both measurements, the extraneous noise or signal shall be at least 6 dB below the limits of interference given in [4.2.2](#) (except for intentional narrowband and ambient transmissions).

Where 1) or 2) above is utilized, the manufacturer/tester should ensure that no machine telemetric device is communicating when the ambient is measured.

B.4 Machinery state during test

B.4.1 General

All sources of broadband emissions which are deemed to be continuously used should be switched on during the test. This could be any device which, when operated, is on for longer than 15 s. If the machinery is engine-driven, the engine shall be running at its normal operating temperature and the transmission shall be in neutral. Care shall be taken to ensure that the speed setting mechanism does not influence electromagnetic emissions. During each measurement, the engine shall be operated as follows:

Engine type	Method of measurement
	Quasi peak/peak
Spark ignition	Engine speed
One cylinder	2 500 rpm ± 10 %
More than one cylinder	1 500 rpm ± 10 %
Diesel	Nominal speed ± 10 %

B.4.2 Test site ambient

Testing shall not be conducted while rain or other precipitation is falling on the machinery or within 10 min after such precipitation has stopped.

B.5 Antenna type, position and orientation

B.5.1 Antenna type

Any antenna may be used provided it can be normalized to the reference antenna. The method given in CISPR 12:2007+AMD1:2009, Annex C, may be used to calibrate the antenna.

B.5.2 Height and distance of measurement

B.5.2.1 Height

B.5.2.1.1 10 m test

The phase centre of the antenna shall be $(3,00 \pm 0,05)$ m above the plane on which the machinery rests.

B.5.2.1.2 3 m test

The phase centre of the antenna shall be $(1,80 \pm 0,05)$ m above the plane on which the machinery rests.

B.5.2.1.3 Antenna location

No part of any antenna's receiving elements shall be closer than 0,25 m to the plane on which the machinery rests.

B.5.2.2 Distance of measurement

B.5.2.2.1 10 m test

The horizontal distance from the tip or other appropriate point of the antenna to the outer body surface of the machinery, as defined during the normalization procedure described in [B.5.1](#), shall be $(10,0 \pm 0,20)$ m.

B.5.2.2.2 3 m test

The horizontal distance from the tip or other appropriate point of the antenna to the outer body surface of the machinery, as defined during the normalization procedure described in [B.5.1](#), shall be $(3,0 \pm 0,05)$ m.

B.5.2.2.3 Antenna location

If the test is carried out in a facility enclosed for radio frequency electromagnetic screening purposes, the antenna's receiving elements shall be no closer than 1,0 m to any radio- absorbent material and no closer than 1,5 m to the wall of the enclosed facility. There shall be no absorbent material between the receiving antenna and machinery under test.

B.5.3 Antenna location relative to the machinery

The antenna shall be located successively on the left- and right-hand sides of the machinery, with the antenna parallel to the plane of the longitudinal symmetry of the machinery.

The determination of the reference points shall be machine-specific and related to the maximum concentration of emission, and shall be noted in the test report (for examples, see also [Figure B.2](#)).

The user shall ensure that the reception area of receiving antenna adequately covers all known broadband sources on the machinery.

NOTE Further guidance on the positioning of the antenna in relation to the machine can be found in CISPR 12:2007 and in respective type-C standards.

B.5.4 Antenna position

At each of the measuring points, a reading shall be taken both with the antenna in a horizontal and in a vertical polarization (see [Figure B.2](#)).

B.5.5 Readings

The maximum of the four readings taken in accordance with [B.5.3](#) and [B.5.4](#) at each frequency shall be taken as the characteristic reading at the frequency at which the measurements were made.

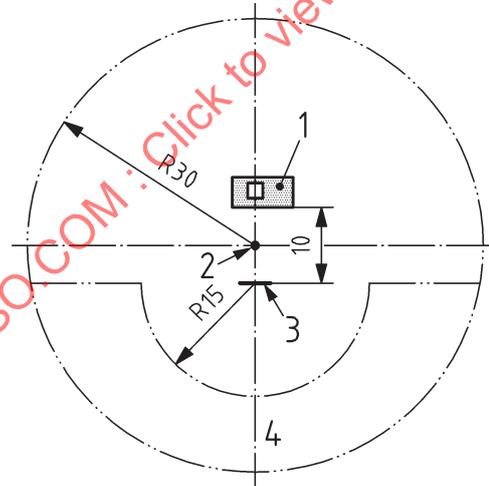
B.5.6 Frequencies

Measurements shall be made over the whole frequency range from 30 MHz to 1 000 MHz. The minimum scan time shall comply with the requirements of CISPR 12:2007.

In the event that the limit is exceeded during the test, investigations shall be made to ensure that this is due to the machine and not to background radiation.

Measurements can be performed with either quasi-peak or peak detectors. The limits given in [4.2](#) are for quasi-peak. If a peak-detector is used, add 38 dB for 1 MHz bandwidth or subtract 22 dB for 1 kHz bandwidth.

Dimensions in metres



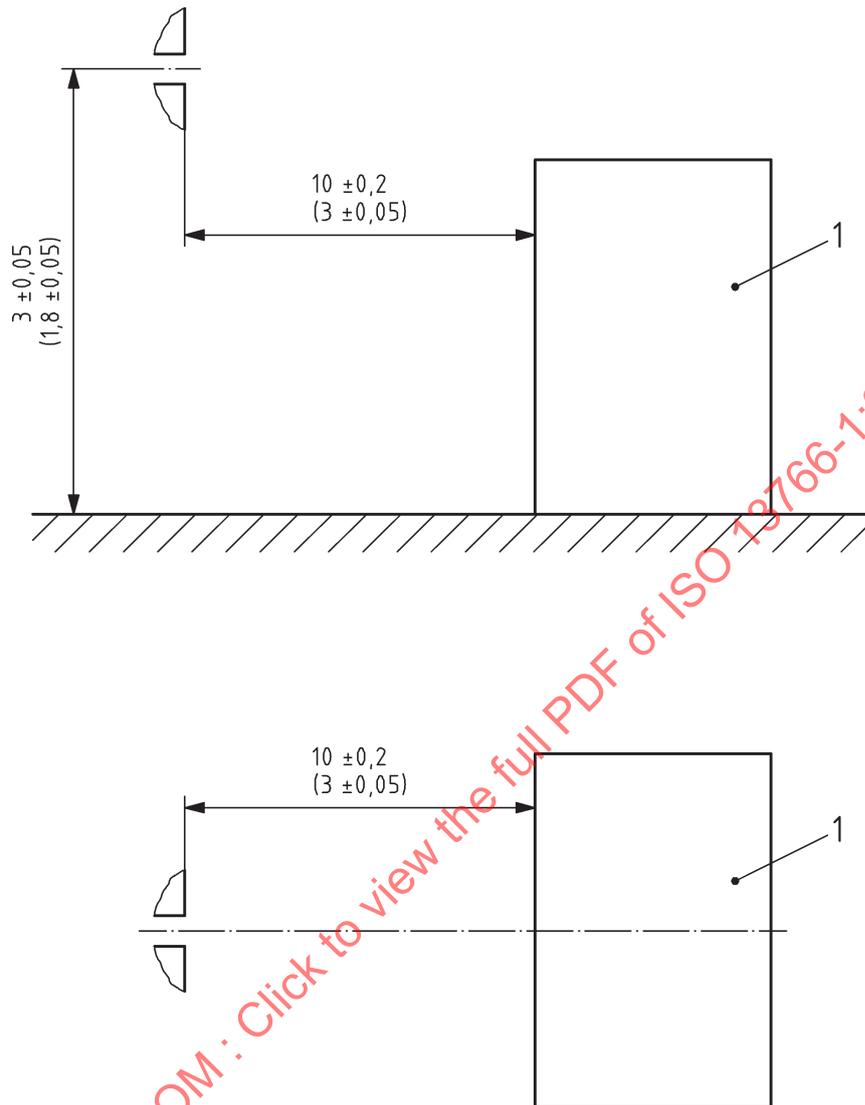
Clear level area, free from electromagnetic reflecting surfaces. Reference: CISPR 12:2007

Key

- 1 machine
- 2 centre of clear area midway between antenna and machine
- 3 antenna
- 4 permitted region for measuring set (in hut or vehicle)
- R radius

Figure B.1 — Machinery — Test area

Dimensions in metres



Dipole antenna in position to measure vertical and horizontal component of radiation

Key

- 1 machine (machine-specific reference point to be determined)

Figure B.2 — Position of antenna relative to machinery

Annex C (normative)

Method of measurement of radiated narrowband electromagnetic emissions from machinery — Complete machine only

C.1 General

C.1.1 Application

The test method of [Annex C](#) shall be applied to the complete machine.

Optional: The methodology described in CISPR 12:2007 can be applied by using the limit lines as specified in [Annex A](#).

On a single test specimen, the measured values, expressed in dB ($\mu\text{V}/\text{m}$) or ($\mu\text{V}/\text{m}$), shall be at least 2,0 dB or (20 %) below the reference limits.

C.1.2 Measuring apparatus

The measuring equipment shall comply with the requirements of CISPR 16-1-1:2014.

A peak or average detector shall be used for the measurement of narrowband electromagnetic emissions if the evaluation is carried out according to the procedure described in CISPR 25:2008.

Either detector may be used, since the pulse repetition rate for sources on board the machinery is above 10 Hz.

NOTE CISPR 16-2-3:2016, Annex D explains the differences between the CISPR AV detector and an AV detector complying with CISPR 16-1:1999.

C.1.3 Test method

This test is intended to measure the narrowband emissions such as might emanate from a micro-processing-based system or other narrowband source.

Two alternative reference antenna distances are permissible, with the reference antenna located either

- 10 m, or
- 3 m

from the machinery.

In either case, the requirements of [C.3](#) shall be complied with.

C.2 Results of measurement

The results of measurement shall be expressed in dB($\mu\text{V}/\text{m}$) or ($\mu\text{V}/\text{m}$).

C.3 Measuring location

C.3.1 Test site

The test site shall be a clear, level area free from electromagnetic reflecting surfaces within a circle of a minimum radius of 30 m measured from a point midway between the machinery and the antenna (see [Figure B.1](#)).

C.3.2 Measuring facility

The measuring set, test hut, or machinery in which the measurement set is located may be within the test site, but only in the permitted region as shown in [Figure B.1](#). Other measuring antennas are allowed within the test area, at a minimum distance of 10 m both from the receiving antenna and the machinery under test, provided that it can be shown that the test results are not affected.

C.3.3 Enclosed test facility

Enclosed test facilities may be used if correlation can be shown between the enclosed test facility and an outdoor site. Enclosed test facilities do not need to meet the dimensional requirements of [Figure B.1](#) other than the distance from the antenna to the machinery and the height of the antenna.

The requirements of [C 3.4](#) also apply for an enclosed facility.

C.3.4 Ambient

To ensure that there is no extraneous noise or signal of a magnitude sufficient to materially affect the measurement, ambient measurements shall be taken before and after the main test. If the machinery is present when ambient measurements are taken, it shall be ensured that any emission does not significantly affect the ambient measurements — for example, by removing the machinery from the test area, removing the ignition key or disconnecting the battery. In both measurements, the extraneous noise or signal shall be at least 6 dB below the limits of interference given in [4.3.2](#) (except for intentional narrowband ambient transmissions).

It shall be ensured that no emission significantly affects the ambient measurements.

C.4 Machinery state during test

C.4.1 Machinery systems

All the machinery's electronic systems shall be in normal operating mode with the machinery stationary.

C.4.2 Machinery controls

The ignition or the engine run control shall be switched on. The engine shall not be operating.

C.4.3 Ambient conditions

Measurements shall not be made while rain or other precipitation is falling on the machinery or within 10 min after such precipitation has stopped.

C.5 Antenna type, position and orientation

C.5.1 Antenna type

Any antenna may be used provided it can be normalized to the reference antenna. The method given in CISPR 12 ed. 6.1:2009, [Annex C](#) may be used to calibrate the antenna.

C.5.2 Height and distance measurement

C.5.2.1 Height

C.5.2.1.1 10 m test

The phase centre of the antenna shall be $(3,00 \pm 0,05)$ m above the plane on which the machinery rests.

C.5.2.1.2 3 m test

The phase centre of the antenna shall be $(1,8 \pm 0,05)$ m above the plane on which the machinery rests.

C.5.2.1.3 Antenna location

No part of any antenna's receiving elements shall be closer than 0,25 m to the plane on which the machinery rests.

C.5.2.2 Distance of measurement

C.5.2.2.1 10 m test

The horizontal distance from the tip or other appropriate point of the antenna to the outer body surface of the machinery, defined during the normalization procedure described in [C.5.1](#), shall be $(10,0 \pm 0,2)$ m.

C.5.2.2.2 3 m test

The horizontal distance from the tip or other appropriate point of the antenna to the outer body surface of the machinery, defined during the normalization procedure described in [C.5.1](#), shall be $(3,0 \pm 0,05)$ m.

C.5.2.2.3 Enclosed facility

If the test is carried out in a facility enclosed for radio frequency electromagnetic screening purposes, the antenna's receiving elements shall be no closer than 1,0 m to any radio absorbent material and no closer than 1,5 m to the wall of the enclosed facility. There shall be no absorbent material between the receiving antenna and the machinery under test.

C.5.3 Antenna location relative to the machinery

The antenna shall be located successively on the left- and right-hand sides of the machinery, with the antenna parallel to the plane of longitudinal symmetry of the machinery and in line with the reference point of the machinery (see [B.5.3](#)).

The user shall ensure that the reception area of receiving antenna adequately covers all known narrowband sources on the machinery.

C.5.4 Antenna position

At each of the measuring points, readings shall be taken with the antenna both in a horizontal and in a vertical polarization (see [Figure B.2](#)).

C.5.5 Readings

The maximum of the four readings taken in accordance with [C.5.3](#) and [C.5.4](#) at each frequency shall be taken as a characteristic reading at the frequency at which the measurements were made.

C.6 Frequencies

Measurements shall be made over the whole frequency range from 30 MHz to 1 000 MHz The minimum scan time shall comply with the requirements of CISPR 12:2007.

In the event that the limit is exceeded during the test, investigations shall be made to ensure that this is due to the machine and not to background radiation.

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Annex D (normative)

Method of measurement of radiated broadband electromagnetic emissions from electrical/electronic sub-assemblies (ESA)

D.1 General

D.1.1 Application

The test method of [Annex D](#) shall be applied to electrical/electronic sub-assemblies (ESA).

Optional: The methodology described in CISPR 25:2008 can be applied by using the limit lines as specified in [Annex A](#).

On a single test specimen, the measured values, expressed in dB ($\mu\text{V}/\text{m}$) or ($\mu\text{V}/\text{m}$), shall be at least 2,0 dB or (20 %) below the reference limits.

D.1.2 Measuring apparatus

The measuring instruments shall comply with the requirements of CISPR 16-1-1:2014.

A quasi-peak detector shall be used for the measurement of broadband electromagnetic emissions in this Annex, or if a peak detector is used an appropriate correction factor shall be used depending on the pulse rate (see CISPR 12:2007).

D.1.3 Test method

The test is intended to measure the broadband electromagnetic emissions from ESA.

D.2 Results of measurement

The results of measurement shall be expressed in dB($\mu\text{V}/\text{m}$) or ($\mu\text{V}/\text{m}$) for 120 kHz bandwidth. If the actual bandwidth B (expressed in kHz) of the measuring apparatus differs from 120 kHz, the reading shall be converted to 120 kHz bandwidth through multiplication by a factor 120/B.

D.3 Measuring location

D.3.1 Test site

The test site shall comply with the requirements of CISPR 16-1-4:2012 (see [Figure D.1](#)).

D.3.2 Measuring facility

The measuring set, test hut, or machinery in which the measurement set is located shall be outside the boundary in [Figure D.1](#).

D.3.3 Enclosed facility

Enclosed test facilities may be used if correlation can be shown between the enclosed test facility and an outdoor site. Enclosed test facilities do not need to meet the dimensional requirements of

Figure D.1, other than the distance from the antenna to ESA under test and the height of the antenna (see Figures D.2 and D.3).

D.3.4 Ambient

To ensure that there is no extraneous noise or signal of a magnitude sufficient to affect materially the measurement, ambient measurements shall be taken before and after the main test. In both of the measurements, the extraneous noise or signal shall be at least 6 dB below the limits of interference given in 4.5.2, except for intentional narrowband ambient transmissions.

D.4 ESA state during test

D.4.1 Operational mode

The ESA under test shall be in normal operation mode.

D.4.2 Test ambient

Testing shall not be conducted while rain or other precipitation is falling on the ESA or within 10 min after such precipitation has stopped.

D.4.3 ESA set-up

The ESA under test and its wiring harnesses shall be spaced 50^{+10}_0 mm above a metallic ground plane on a non-conductive, low relative permittivity material ($\epsilon_r \leq 1,4$). However, if any part of the ESA under test is intended to be electrically bonded to the machinery's metal bodywork, that part shall be placed on a ground plane and shall be electrically bonded to the ground plane.

The length of test harness parallel to the front of the ground plane shall be $(1\,500 \pm 75)$ mm.

The total length of the test harness between the ESA under test and the load simulator (or the RF boundary) shall not exceed 2 000 mm (or as defined in the test plan). The wiring type is defined by the actual system application and requirement.

The ground plane shall be a metallic sheet with a minimum thickness of 0,5 mm. The minimum size of the ground plane depends on the size of the ESA under test but shall allow for the distribution of the ESA wiring harness and components. The ground plane shall be connected to the protective conductor of the earthing system. The ground plane shall be situated at a height of $(0,9 \pm 0,1)$ m above the test facility floor and shall be parallel to it.

The ESA under test shall be arranged and connected according to its requirements. The power supply harness shall be positioned along and within (100 ± 10) mm of the edge of the ground plane/table closest to the antenna.

The ESA under test shall be connected to the grounding system according to the manufacturer's installation specification; no additional grounding connections shall be permitted.

The minimum distance between the ESA under the test and all other conductive structures, such as walls of a shielded area (with the exception of ground plane/table underneath the test object) or to the nearest surface of the absorber material shall be 1,0 m.

D.4.4 Power to ESA

Power shall be applied to the ESA under test via a $5\ \mu\text{H}/50\ \Omega$ artificial network (AN) which shall be electrically bonded to the ground plane. The electrical supply voltage shall be maintained to $\pm 10\%$ of its nominal system operating voltage. Any ripple voltage shall be less than $1,5\%$ of the nominal system operating voltage measured at the AN monitoring port.

D.4.5 Multiple ESA

If the ESA under test consists of more than one unit, the interconnecting cables should be the wiring harness as intended for use in the machinery. If these are not available, the minimum length between the ESA and the AN shall be 1,5 m. All cable trees should be terminated as realistically as possible and preferably with real loads and actuators. If extraneous machinery is required for the correct operation of the ESA under test, compensation shall be made for the contribution it makes to the emissions measured.

D.5 Antenna type, position and orientation

D.5.1 Antenna type

Any linearly polarized antenna may be used provided it can be normalized to the reference antenna.

D.5.2 Height and distance of measurement

D.5.2.1 Height

The phase centre of the antenna shall be (100 ± 10) mm above the ground plane.

D.5.2.2 Distance of measurement

The horizontal distance from the phase centre or tip of the antenna, as appropriate, to the longitudinal part of the wiring harness shall be $(1,0 \pm 0,01)$ m. No part of the antenna shall be closer than 0,25 m to the ground plane.

The antenna shall be placed parallel to a plane which is perpendicular to the ground plane and coincident with the edge of the ground plane along which the principal portion of the harness runs.

D.5.2.3 Enclosed facility

If the test is carried out in a facility enclosed for radio frequency electromagnetic screening purposes, the antenna's receiving elements shall be no closer than 1,0 m to any radio absorbent material and no closer than 1,5 m to the wall of the enclosed facility. There shall be no absorbent material between the receiving antenna and the ESA under test.

D.5.3 Antenna orientation and polarization

At each of the measuring points, readings shall be taken both with the antenna in a horizontal and in a vertical polarization.

D.5.4 Readings

The maximum of the two readings taken in accordance with [D.5.3](#) at each frequency shall be taken as the characteristic reading at the frequency at which the measurements were made.

D.6 Frequencies

Measurements shall be made over the whole frequency range from 30 MHz to 1 000 MHz. The minimum scan time shall comply with the requirements of CISPR 25:2008.

In the event that the limit is exceeded during the test, investigations shall be made to ensure that this is due to the ESA and not to background radiation.