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Earth-moving machinery — Electromagnetic compatibility

Engins de terrassement — Compatibilité électromagnétique

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 13766 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

This second edition cancels and replaces the first edition (ISO 13766:1999), which has been technically revised.

Introduction

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

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

Electrostatic discharges are relevant to earth-moving machinery because control elements can be positioned outside the operator's station and potential differences can emerge at contact points. Conducted transients in power supply wiring have to be taken into account because earth-moving machinery often represents open systems and several devices and/or components are combined with one another.

While there are many existing standards for a variety of products and systems, the test method presented in this International Standard provides for the specific test conditions of earth-moving machinery and the "electrical/electronic systems or electronic subassemblies" of earth-moving machines. The test method recognizes that because of the size and usage of earth-moving machinery, the arrangement of the machines in the test facility needs to be responsive to the operating characteristics of these types of machines. This International Standard provides test methods and criteria which are acceptable for earth-moving machinery, considering its unique characteristics and operating parameters.

Because earth-moving machines possess a number of systems that consist of components that can be used on a number of different types of machines, the approach of defining "electrical/electronic systems or electronic subassemblies" 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 systems or electronic subassembly tests are conducted, it is necessary to consider the effects of the wiring systems used to connect the subassemblies into the earth-moving machinery. The tests may also be conducted on the machines.

This International Standard is intended to provide the necessary technical specifications for evaluating the electromagnetic performance of earth-moving machinery with respect to government electromagnetic performance laws, directives, rules and/or regulations. Such an example is the European Directive 2004/108/EC.

Earth-moving machinery — Electromagnetic compatibility

1 Scope

This International Standard provides test methods and acceptance criteria for the evaluation of the electromagnetic compatibility of earth-moving machinery as defined in ISO 6165. The following electromagnetic phenomena are evaluated:

— broadband and narrowband electromagnetic interference;

— electromagnetic field immunity test;

— broadband and narrowband interference of electrical/electronic subassemblies;

— electromagnetic field immunity test of electrical/electronic subassemblies;

— electrostatic discharge;

— conducted transients.

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.

ISO 5353:1995, *Earth-moving machinery, and tractors and machinery for agriculture and forestry — Seat index point*

ISO 6165:2006, *Earth-moving machinery — Basic types — Vocabulary*

ISO 7637-1:2002, *Road vehicles — Electrical disturbance from conduction and coupling — Part 1: Definitions and general considerations*

ISO 7637-2:2004, *Road vehicles — Electrical disturbances from conduction and coupling — Part 2: Electrical transient conduction along supply lines only*

ISO 10605:2001, *Road vehicles — Test methods for electrical disturbances from electrostatic discharge*

ISO 11451-1:2005, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

ISO 11451-2:2005, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Off-vehicle radiation sources*

ISO 11452-1:2005, *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 11452-3:2001, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 3: Transverse electromagnetic (TEM) cell*

ISO 11452-4:2005, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Bulk current injection (BCI)*

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

IEC 60050-161:1998, *International Electrotechnical Vocabulary — Chapter 161: Electromagnetic compatibility*

CISPR 12:2004, *Vehicles, boats and internal combustion engine driven devices — Radio disturbance characteristics — Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices*

CISPR 16-1-1:2006, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-1: Radio disturbance and immunity measuring apparatus — Measuring apparatus*

CISPR 16-1-4:2004, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-4: Radio disturbance and immunity measuring apparatus — Ancillary equipment — Radiated disturbances*

CISPR 25:2002, *Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices — Limits and methods of measurement*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply

3.1
electromagnetic compatibility
EMC
ability of earth-moving machinery, component, electrical/electronic system or electronic subassembly to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

NOTE Adapted from IEC 60050:1998**,** 161-01-07.

3.2
electromagnetic disturbance
any electromagnetic phenomenon which may degrade the performance of earth-moving machinery, components, electrical/electronic systems or electronic subassemblies

EXAMPLE An electromagnetic disturbance may be electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

NOTE Adapted from IEC 60050:1998, 161-01-05.

3.3
electromagnetic immunity
ability of earth-moving machinery, components, electrical/electronic systems or electronic subassemblies to perform without degradation in the presence of specific electromagnetic disturbances

NOTE Adapted from IEC 60050:1998, 161-01-20.

3.4
electromagnetic environment
totality of electromagnetic phenomena existing at a given location

[IEC 60050:1998, 161-01-01]

3.5
reference limit
limit value with which the production is required to conform

3.6
reference antenna
designated measurement antenna having preferred measurement data that take precedence in the case of a discrepancy, such as between signal strength levels measured with the reference antenna and those measured with any other antenna

3.7
broadband emission
emission which has a bandwidth greater than that of a particular measuring apparatus or receiver

3.8
narrowband emission
emission which has a bandwidth less than that of a particular measuring apparatus or receiver

3.9
electrical/electronic system
electrical and/or electronic components or set of components intended to be part of an earth-moving machine, together with any electrical connections

3.10
electrical/electronic subassembly
ESA
electrical and/or electronic components or set of components intended to be part of an earth-moving machine, together with any associated electrical connections and wiring, which performs one or more specialized functions

3.11
machine type
earth-moving machinery which does not differ in such essential respects as

— structural shape,

— general arrangement of the electrical and/or electronic components and the general wiring arrangement, and

— the primary material of which its design consists (e.g. steel, aluminium or fibreglass covering parts)

3.12
ESA type
electrical/electronic subassemblies which do not differ in such essential respects as

— function performed,

— arrangement of the electrical and/or electronic components, if applicable, and

— the primary material of the casing

3.13
electrostatic discharge
ESD
transfer of electrostatic charge between bodies of different electrostatic potential in proximity or through direct contact

[IEC 60050:1998, 161-01-22]

3.14
conducted transients
transient voltage or current distributed in the power supply wiring of a machine via a conductor between the source of the transient and the receiver

4 Fulfilment of requirements

The requirements of this International Standard are to be met by earth-moving machinery and its electric/electronic subassemblies when the machinery operates in conformity with its final purpose. The user of this International Standard may chose either of the following alternatives to give evidence of conformity with this International Standard.

a) The performance requirements of this International Standard are met if the electrical/electronic systems or electronic subassemblies are in accordance with the applicable criteria of this International Standard and have been installed in accordance with the requirements given for the electronic subassembly.

b) The performance requirements of this International Standard are met for a complete machine when the criteria, as applicable to this International Standard, are fulfilled. In the case of a complete machine meeting the performance requirements of this International Standard, no measurement of the electrical/electronic systems or electronic subassemblies is required.

5 Requirements — General tests

5.1 Test specimen

The test specimen may be a machine type and/or an ESA type.

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

For a subsequent test on a like test specimen, conformity with the reference limits shall be accepted as fulfilment of the requirements of this International Standard.

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

5.2 Additional requirements for immunity tests

When a test specimen is subjected to the immunity levels specified in 5.5.2 and 5.8.2, no disturbance shall occur during testing which may affect the operator's control of the machine. The operator's control is exercised by means of, for example, steering, braking, or propulsion control. This also concerns movements of parts of the machine and modifications of the state of function, which may generate uncommanded, random or unresponsive machine operation (i.e. hazardous machine behaviour).

Use Annex F or similar evaluation methods to determine whether a potential for any significant changes made to the machine control system or the ESA exists that could require re-testing. This may include any revisions or modifications to the electrical/electronic system that would impact immunity or emission compliance with this International Standard.

ESA that are ancillary to machine operation and which do not alter machine control, such as monitors, alarms, gauges, lights, and wipers, may be tested according to the lesser immunity requirements of 5.5.3 and 5.8.3 or the higher levels of 5.5.2 and 5.8.2.

Traditional (without active semiconductor) control systems such as solenoids and relays need only comply with the reduced immunity requirements according to 5.5.3 and 5.8.3.

5.3 Broadband electromagnetic emission radiated from earth-moving machinery

5.3.1 Method of measurement

Measure the electromagnetic radiation in accordance with Annex B at either of the defined antenna distances. The choice shall be made by the user of this International Standard.

5.3.2 Broadband reference limits

When measurements are made using the method given in Annex B with an earth-moving machine-to-antenna spacing of 10 m $\pm$ 0,2 m, the emission reference limits shall be 34 dB(µV/m) (50 µV/m) in the 30 MHz to 75 MHz frequency band, and 34 dB(µV/m) to 45 dB(µV/m) (50 µV/m to 180 µV/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. In the 400 MHz to 1 000 MHz frequency band, the limit remains constant at 45 dB(µV/m) (180 µV/m).

When measurements are made using the method given in Annex B with an earth-moving machinery-to-antenna spacing of 3 m $\pm$ 0,05 m, the emission reference limits shall be 44 dB(µV/m) (160 µV/m) in the 30 MHz to 75 MHz frequency band, and 44 dB(µV/m) to 55 dB(µV/m) (160 µV/m to 562 µV/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. In the 400 MHz to 1 000 MHz frequency band, the limit remains constant at 55 dB(µV/m) (562 µV/m).

On the test specimen, the measured values, expressed in dB(µV/m) (µV/m), shall be at least 2 dB below the reference limits.

5.4 Narrowband electromagnetic emission radiated from earth-moving machinery

5.4.1 Method of measurement

Measure the electromagnetic emission in accordance with Annex C at either of the defined antenna distances. The choice shall be made by the user of this International Standard.

5.4.2 Narrowband reference limits

When measurements are made using the method given in Annex C with an earth-moving machinery-to-antenna spacing of 10 m $\pm$ 0,2 m, the emission reference limits shall be 24 dB(µV/m) (16 µV/m) in the 30 MHz to 75 MHz frequency band, and 24 dB(µV/m) to 35 dB(µV/m) (16 µV/m to 56 µV/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. In the 400 MHz to 1 000 MHz frequency band, the limit remains constant at 35 dB(µV/m) (56 µV/m).

When measurements are made using the method given in Annex C with an earth-moving machinery-to-antenna spacing of 3 m ± 0,05 m, the emission reference limits shall be 34 dB(μV/m) (50 μV/m) in the 30 MHz to 75 MHz frequency and 34 dB(μV/m) to 45 dB(μV/m) (50 μV/m to 180 μV/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. In the 400 MHz to 1 000 MHz frequency band, the limit remains constant at 45 dB(μV/m) (180 μV/m).

On the test specimen, the measured values, expressed in dB(μV/m) (μV/m), shall be at least 2 dB below the reference limits.

5.5 Immunity of earth-moving machinery to electromagnetic radiation

5.5.1 Test method

The immunity to electromagnetic radiation of the earth-moving machinery shall be tested in accordance with ISO 11451-1 and ISO 11451-2 with horizontal and vertical polarization. Immunity testing should be conducted according to ISO 11451-1, except that forward power may be used as the control regardless of the standing wave ratio of the system.

The testing may be conducted inside an absorber lined chamber or by another comparable method.

The determination of the reference point and relevant operating mode shall be machine-specific, as specified in this International Standard. The substitution method and the 80 % amplitude modulation (AM) with sinusoidal wave of 1 kHz (see ISO 11451-1) are determined as a test method. The testing shall be done in the frequency band of 20 MHz to 1 000 MHz using Table 1 criteria.

A minimum of two antenna locations shall be used. The locations shall be at approximately right angles to each other, with the antenna pointed at the locations of the machine where there are the greatest concentrations of electronic control components. At each location, the antenna shall be first polarized either horizontally or vertically, then rotated 90° to the other polarization and retested.

Table 1 — Maximum frequency step sizes

Frequency band MHz	Linear steps MHz	Logarithmic steps %
$> 20 \leqslant 200$	5	5
$> 200 \leqslant 400$	10	5
$> 400 \leqslant 1\,000$	20	2

5.5.2 Earth-moving machinery immunity reference limits for movement control

Reference limit 80 V/m (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. The immunity requirements are fulfilled by a field strength of 100 V/m (25 % above the reference limit). The general requirements for immunity testing given in 5.2 shall be fulfilled. Lower field strengths between 20 MHz and 60 MHz may be used, if appropriate antennas and testing equipment are not readily available. If the reduced field strength falls below 24 V/m (30 V/m for a single sample), other methods of ESA testing shall be used for those frequencies.

5.5.3 Earth-moving machinery immunity reference limits for functions other than movement control (and without active semiconductor-based controls)

Reference limit 24 V/m (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. The immunity requirements are fulfilled by a minimum field strength of 30 V/m (25 % above the reference limit). The general requirements for immunity testing given in 5.2 shall be fulfilled.

Testing at 24 V/m or 30 V/m is only required for frequencies where failures were first detected at 80 V/m or 100 V/m.

5.6 Broadband electromagnetic emissions radiated from ESA

5.6.1 Method of measurement

Measure the electromagnetic interference in accordance with Annex D.

5.6.2 ESA broadband reference limits

When measurements are made using the method given in Annex D, the emission reference limits shall be 64 dB(µV/m) to 54 dB(µV/m) (1 600 µV/m to 500 µV/m) in the 30 MHz to 75 MHz frequency band, this limit decreasing logarithmically (linearly) with frequencies above 30 MHz, and 54 dB(µV/m) to 65 dB(µV/m) (500 µV/m to 1 800 µV/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.5. In the 400 MHz to 1 000 MHz frequency band, the limits remains constant at 65 dB(µV/m) (1 800 µV/m).

On the test specimen, the measured values, expressed in dB(µV/m) (µV/m), shall be at least 2 dB below the reference limits.

5.7 Narrowband electromagnetic emissions radiated from ESA

5.7.1 Method of measurement

Measure the electromagnetic interference in accordance with Annex E.

5.7.2 ESA narrow band reference limit

When measurements are made using the method given in Annex E, the emission reference limits shall be 54 dB(µV/m) to 44 dB(µV/m) (500 µV/m to 160 µV/m) in the 30 MHz to 75 MHz frequency band, this limit decreasing logarithmically (linearly) with frequencies above 30 MHz, and 44 dB(µV/m) to 55 dB(µV/m) (160 µV/m to 562 µV/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(µV/m) (562 µV/m).

On the test specimen, the measured values, expressed in dB(µV/m) (µV/m) shall be at least 2 dB below the reference limits.

5.8 Immunity of ESA to electromagnetic radiation

5.8.1 Test method

For the testing of the immunity of ESA to electromagnetic fields, apply the test methods specified in ISO 11452-2, ISO 11452-3, ISO 11452-4 or ISO 11452-5. Immunity testing should be conducted in accordance with ISO 11452-1, except that forward power may be used as the control regardless of the standing wave ratio of the system. The chosen combination shall cover the 20 MHz to 1000 MHz band. The substitution method, with 80 % amplitude modulation (AM) with sinusoidal wave of 1 kHz (see ISO 11452-1), has been determined as a test methodology.

5.8.2 ESA immunity reference limits

The reference limits apply to the root mean square values of the unmodulated signal. The maximum value of the test signal with modulation shall comply with the maximum value of an unmodulated test signal. When tests are made in accordance with ISO 11452-1 to ISO 11452-5, the immunity reference limits are

— 80 V/m for the 150 mm stripline test method (ISO 11452-5),

— 80 V/m for the TEM cell test method (ISO 11452-3),

— 80 mA for the bulk current injection (BCI) test method (ISO 11452-4), and

— 80 V/m for the radiated field (absorber lined chamber) test method (ISO 11452-2).

Functional status class A applies to all tests. Reference limits increased by 25 % apply for the test specimen. The ESA shall not exhibit any operational change unacceptable for its application on the earth-moving machinery. See 5.2 for further specification of unacceptable operational change.

5.8.3 Reference limits for ESA or ESA functions that do not control machine movement

The reference limits apply to the root mean square values of the unmodulated signal. The maximum value of the test signal with modulation shall comply with the maximum value of an unmodulated test signal. If tests are made in accordance with ISO 11452-1 to ISO 11452-5, the immunity reference limits are

— 24 V/m for the 150 mm stripline test method (ISO 11452-5),

— 24 V/m for the TEM cell test method (ISO 11452-3),

— 24 mA for the bulk current injection (BCI) test method (ISO 11452-4), and

— 24 V/m for the radiated field (absorber lined chamber) test method (ISO 11452-2).

Testing at the reduced levels in this section is not required if the ESA passes at the higher levels in 5.8.2. Functional status class A applies to all tests. Reference limits increased by 25 % apply for the test specimen. The ESA shall not exhibit any operational change unacceptable for its application on the earth-moving machinery. See 5.2 for further specification of unacceptable operational change.

5.9 Electrostatic discharge (ESD)

5.9.1 Test method

Use the method given in ISO 10605 as the method of measurement of the earth-moving machinery or on the component in such areas where an ESD in standard use is possible (e.g. by means of touching by the operator).

5.9.2 Reference limits

Test level IV (8 kV contact discharge or 15 kV air discharge) according to ISO 10605:2001, Table B.1, applies.

5.10 Conducted transients

5.10.1 General

With remotely located ESA connected to the earth-moving machinery only 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 earth-moving machinery. Therefore, minimum values concerning emission and susceptibility for ESA and earthmoving machinery are required.

5.10.2 Test method

Use the method given in ISO 7637-1 and ISO 7637-2 as the test method. For the test of conducted transients, the ESA may be installed on the earth-moving machinery.

5.10.3 Reference limits

Test to level III according to ISO 7637-2:2004, Table A.1, for 12 volt systems, and according to ISO 7637-2:2004, Table A.2, for 24 volt systems.

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

6 Exceptions

For the requirements given in Clause 5, the following exceptions are valid.

a) Where earth-moving machinery or an electrical/electronic system or ESA does not include an electronic oscillator with an operating frequency greater than 9 kHz, it shall be deemed to comply with the requirements of 5.4 and 5.7.

b) Earth-moving machinery that utilizes electrical/electronic systems or ESA as described in 1) or 2), as follows, requires immunity testing; all other earth-moving machinery shall be deemed to comply with the requirements of 5.5, 5.8, 5.9 and 5.10:

   1) electrical/electronic systems or ESA in the direct control and modification of the state of function of the earth-moving machinery;

   2) electrical/electronic systems or ESA used to provide operator feedback which leads to a hazardous machine operation due to the influence of an electromagnetic disturbance.

c) ESA that only provide a convenience to the operator, such as radios and air conditioning, need not be tested for immunity, and shall be deemed to comply with the requirements of 5.5, 5.8, 5.9 and 5.10.

d) No specific tests need to be made regarding radio or telephone transmitters. Each earth-moving machinery manufacturer shall identify in the operator's manual those precautions, if any, which are applicable when installing and operating radio, telephone or other transmitters on the earth-moving machinery.

7 Test report

If a test report is made, the following information should be included:

a) description of the test specimen in accordance with 3.11 or 3.12 (machine model, or electric/electronic subassembly or separate technical unit identification);

b) description or classification of the test facilities or test site;

c) description of the instrumentation or the standards that the instrumentation meets;

d) level of broadband electromagnetic emissions in accordance with 5.3.2;

e) level of narrowband electromagnetic emissions in accordance with 5.4.2;

f) identification of any loss of functional control of the earth-moving machinery in accordance with 5.5.2 and 5.5.3;

g) level of broadband electromagnetic interference in accordance with 5.6.2;

h) level of narrowband electromagnetic interference in accordance with 5.7.2;

i) identification of any loss of functional control exhibited by the ESA which would affect the control of the earthmoving machinery in accordance with 5.8.2 and 5.8.3;

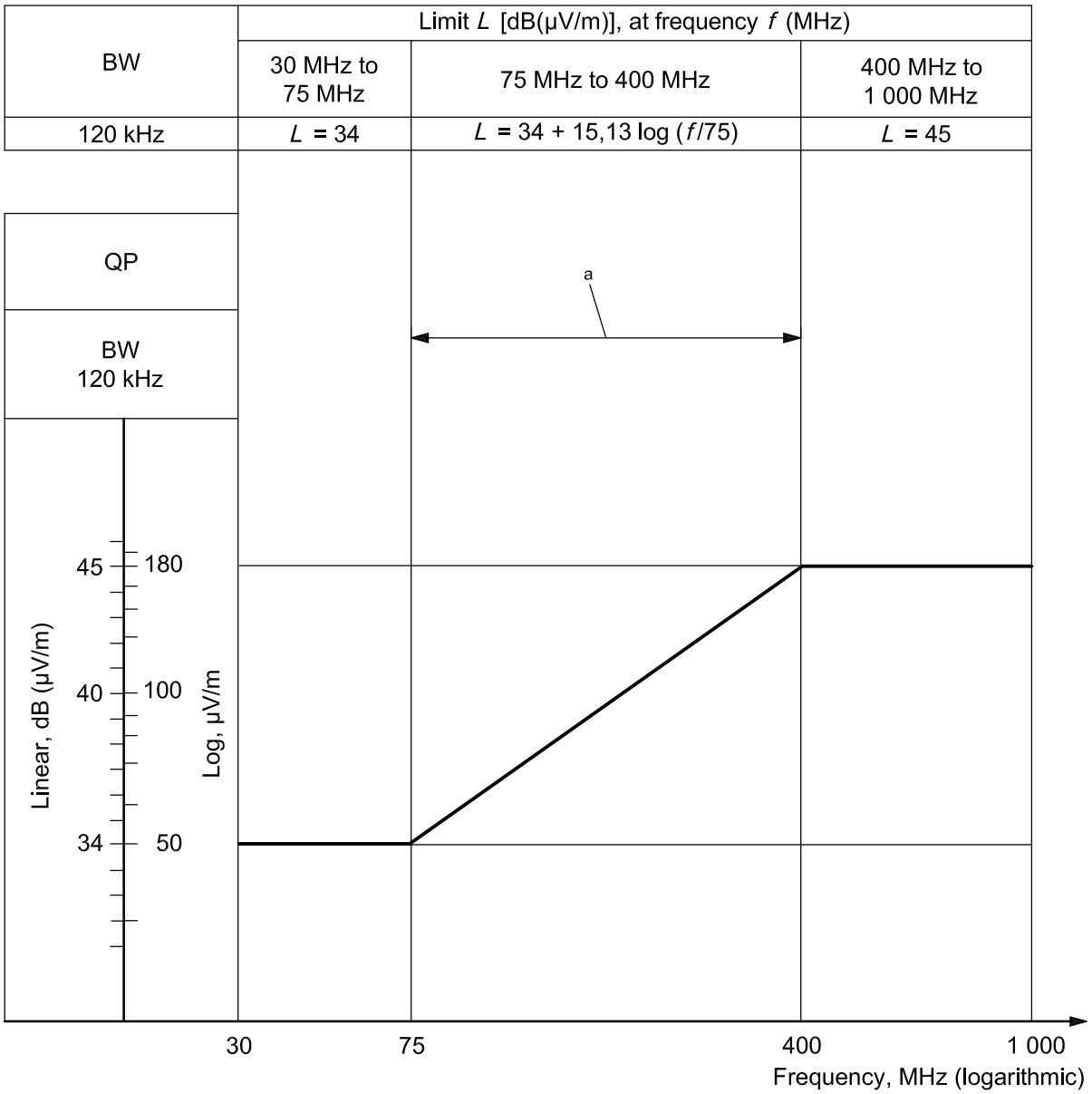
j) identification of components which are not in accordance with 5.9.2;

k) identification of components which are not in accordance with 5.10.2.

Annex A
(normative)

Reference limits

The reference limits are given in Figures A.1 to A.6.



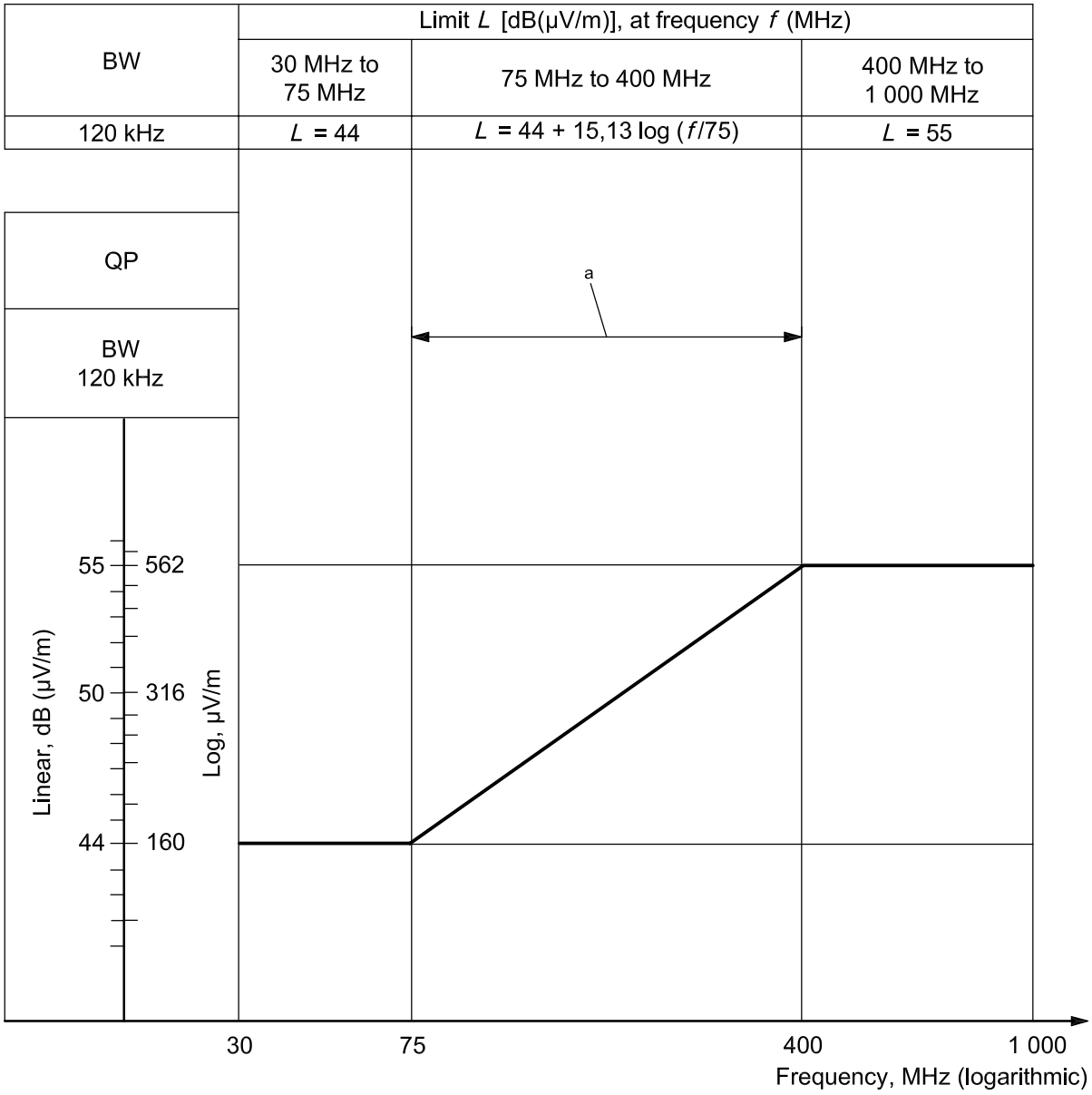
Key

BW bandwidth

QP quasi-peak

[a] Linear when plotted dB vs. log frequency.

Figure A.1 — Earth-moving machinery broadband reference limits by antenna — Machine distance 10 m



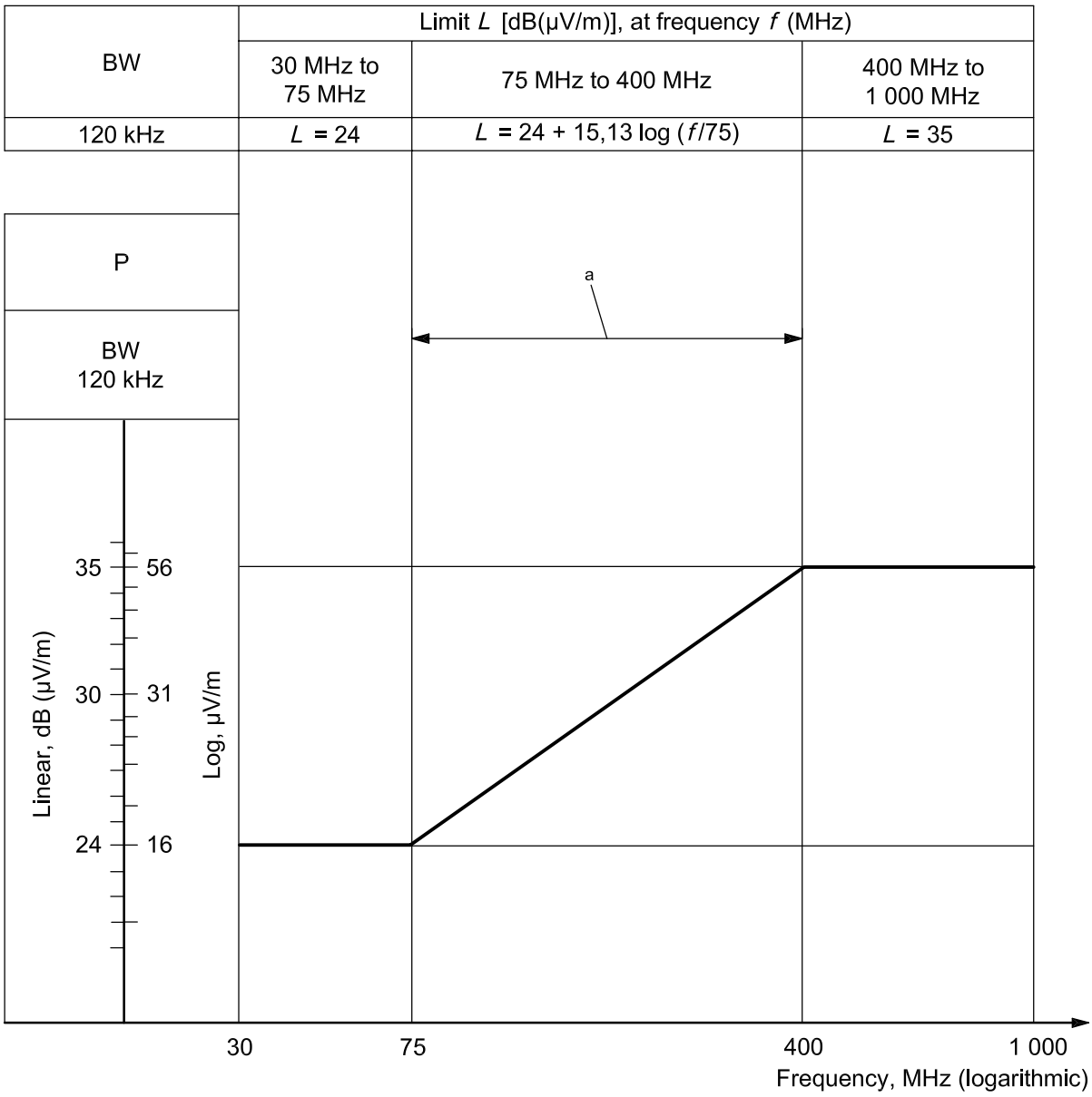
Key

BW bandwidth

QP quasi-peak

a Linear when plotted dB vs. log frequency.

Figure A.2 — Earth-moving machinery broadband reference limits by antenna — Machine distance 3 m



Key

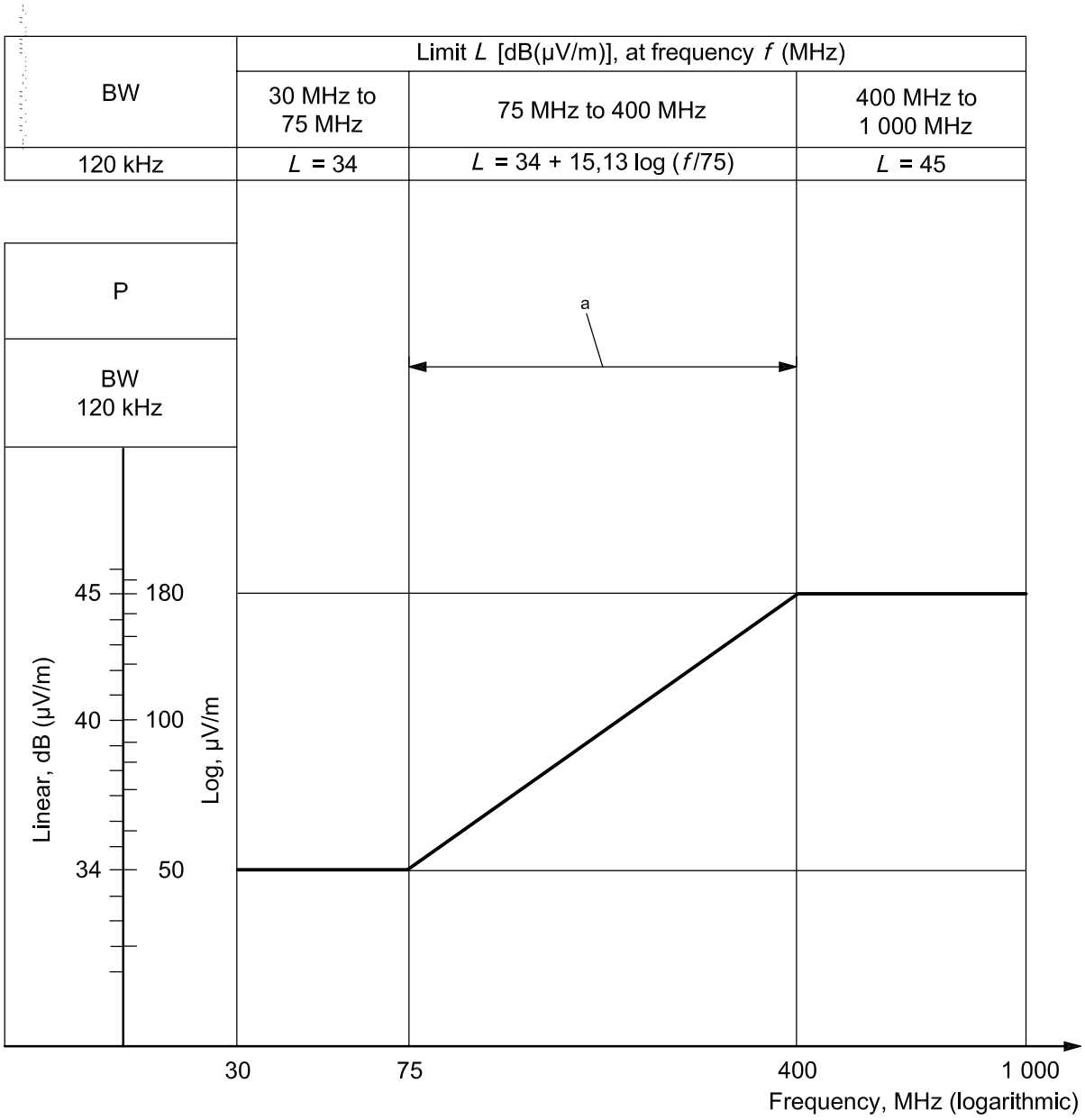
BW bandwidth

P peak

If measurements are made which pass the above emission reference limits, an analysis and evaluation of these peaks shall be made according to the method of determining conformance of radiated/conducted disturbance presented in CISPR 25:2002, Figure 1. An average detector can be used to determine the magnitude of any signals determined to be narrowband.

[a] Linear when plotted dB vs. log frequency.

Figure A.3 — Earth-moving machinery narrowband reference limits by antenna — Machine distance 10 m



Key

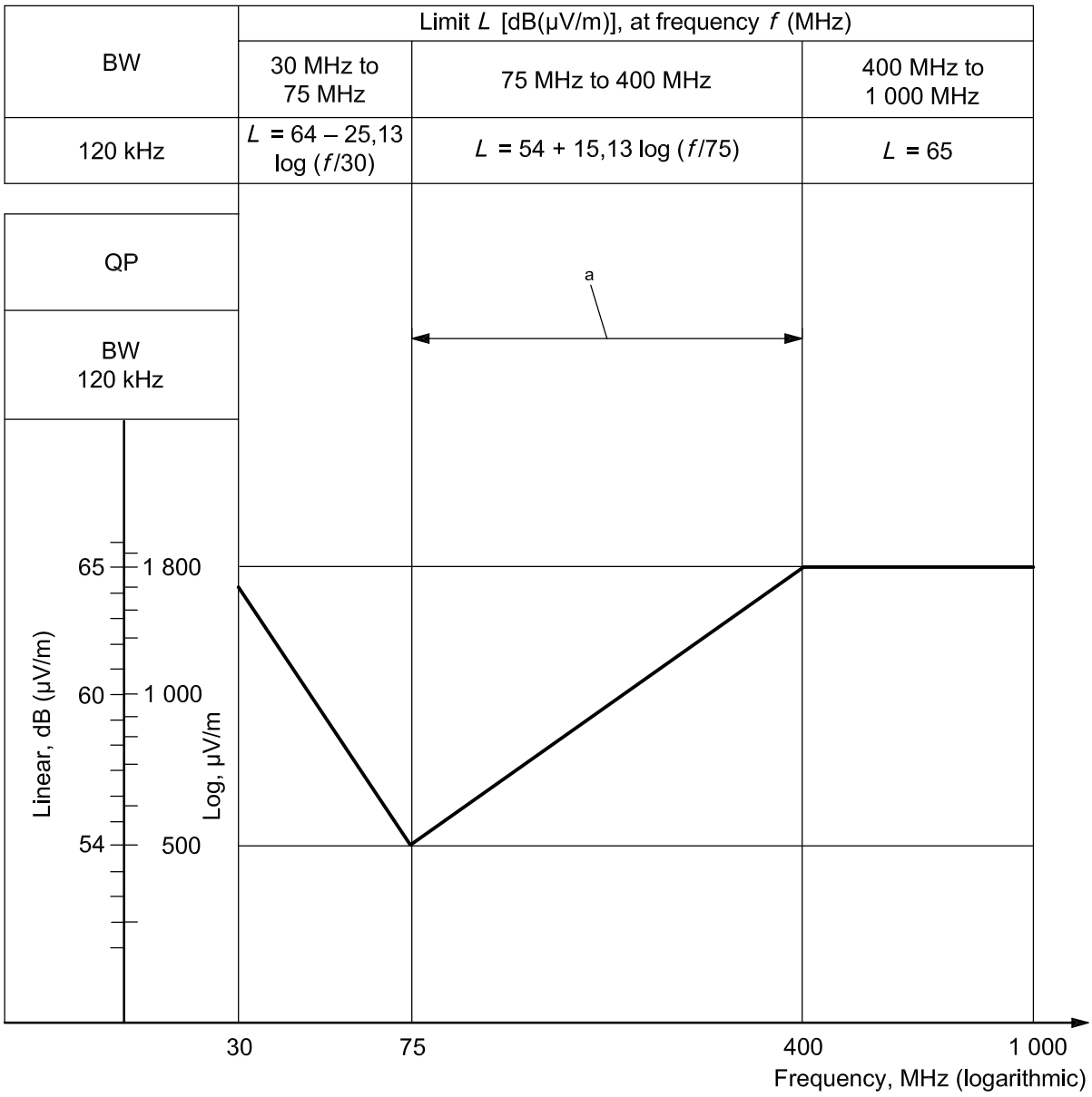
BW bandwidth

P peak

If measurements are made which pass the above emission reference limits, an analysis and evaluation of these peaks shall be made according to the method of determining conformance of radiated/conducted disturbance presented in CISPR 25:2002, Figure 1. An average detector can be used to determine the magnitude of any signals determined to be narrowband.

[a] Linear when plotted dB vs. log frequency.

Figure A.4 — Earth-moving machinery narrowband reference limits by antenna — Machine distance 3 m



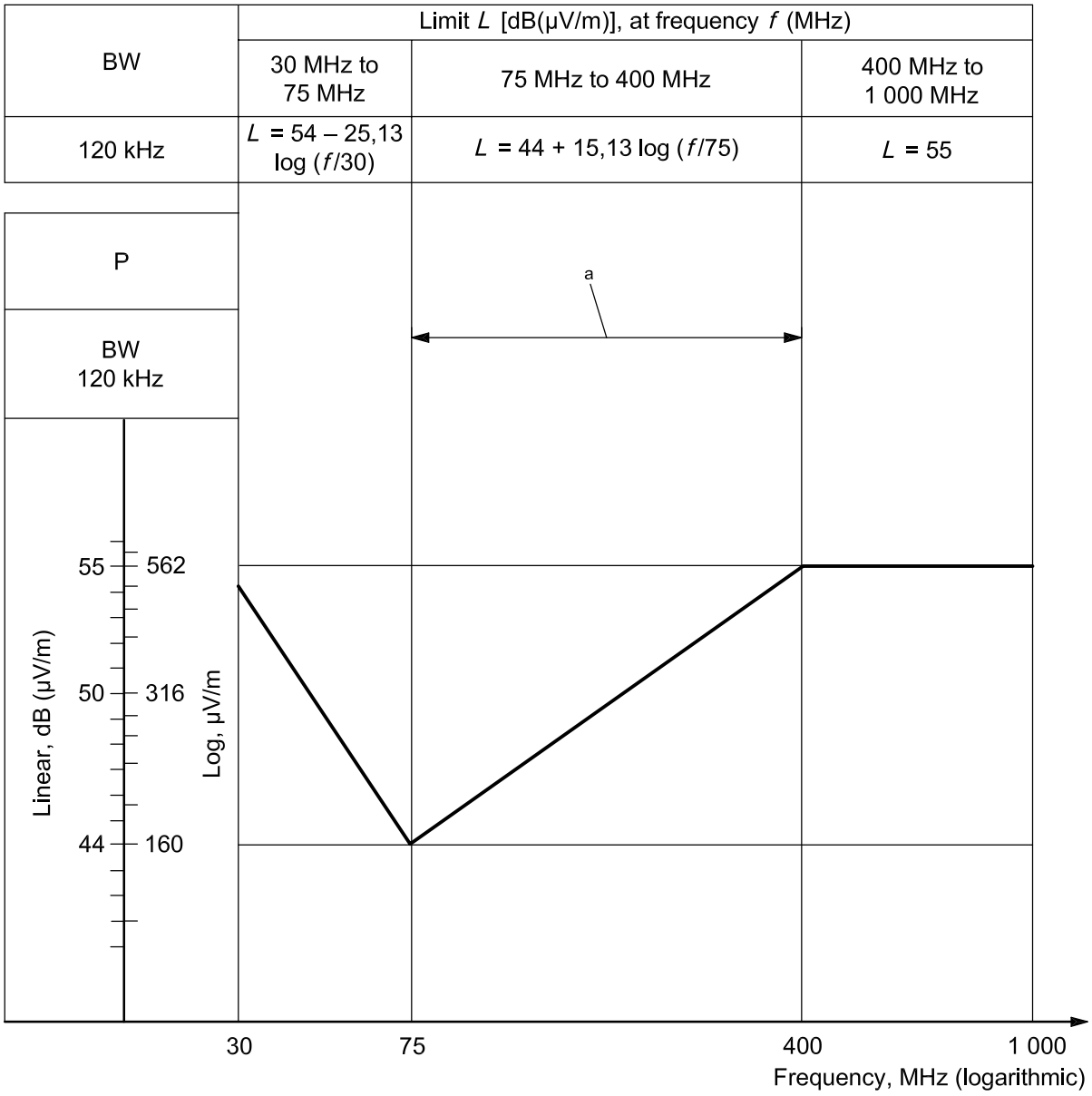
Key

BW bandwidth

QP quasi-peak

[a] Linear when plotted dB vs. log frequency.

Figure A.5 — ESA — Broadband reference limits



Key

BW bandwidth

P peak

If measurements are made which pass the above emission reference limits, an analysis and evaluation of these peaks shall be made according to the method of determining conformance of radiated/conducted disturbance presented in CISPR 25:2002, Figure 1. An average detector can be used to determine the magnitude of any signals determined to be narrowband.

[a] Linear when plotted dB vs. log frequency.

Figure A.6 — ESA — Narrowband reference limits

Annex B
(normative)

Method of measuring radiated broadband electromagnetic emissions from earth-moving machinery

B.1 General

B.1.1 Application

The test method described in this annex is applicable only to complete earth-moving machinery.

B.1.2 Measurement apparatus

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

A quasi-peak-detector shall be used for the measurement according to this annex of broadband electromagnetic emissions; or, if a peak-detector is used, an appropriate correction factor shall be used, depending on the pulse rate (see B.6 and CISPR 12).

B.1.3 Test method

This test is intended to measure the broadband emissions. Two alternative reference antenna distances are permissible: 10 m or 3 m from the earth-moving machinery. In either case, the requirements of B.2 shall be complied with.

B.1.4 Results of measurement

The results of the measurement shall be expressed in dB(μV/m) (μV/m) for a 120 kHz bandwidth.

B.2 Measuring location

B.2.1 Test site

The test site shall be a clear, level area, free from electromagnetic reflecting surfaces, within a circle of minimum radius of 30 m measured from a point midway between the earth-moving machinery and the antenna (see Figure B.1). All test sites shall comply with the relevant sections of CISPR 16-1-4.

B.2.2 Measurement facility

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

B.2.3 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 need not to meet the dimensional requirements of Figure B.1 other than distance from the antenna to the earth-moving machinery and height of the antenna. Ambient emissions need not be checked, either before or after the test according to B.2.4.

B.2.4 Ambient measurements

In order to ensure that there is no extraneous noise or signal of a magnitude sufficient to affect materially the measurement, measurements shall be taken before and after the main test. If the earth-moving machinery is present when ambient measurements are taken, it will be necessary to ensure that any emission from the earth-moving machinery does not affect significantly the ambient measurements, for example by removing the machine from the test area, removing the ignition key or disconnecting the battery. In both measurements, the extraneous noise or signal shall be at least 10 dB below the limits of interference given in 5.3.2 (except for intentional narrowband ambient transmissions).

B.3 Machine state during test

B.3.1 General

All sources of broadband emissions which are deemed to be continuously used should be switched on during the test. If the earth-moving 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 in accordance with Table B.1.

Table B.1 — Engine speed during test

Engine type		Method of measurement	
		Quasi-peak	Peak
		Engine speed r/min	
Spark ignition	one cylinder	2 500 ± 250	2 500 ± 250
	more than one cylinder	1 500 ± 150	1 500 ± 150
Diesel		Normal operation speed, with relative tolerance of ± 10 %	

B.3.2 Test site ambient conditions

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

B.4 Antenna

B.4.1 Antenna type

Any antenna may be used, provided it can be normalized to the reference antenna. The method according to CISPR 12:2004, Annex A, may be used to calibrate the antenna.

B.4.2 Height and measurement distance

B.4.2.1 Height

B.4.2.1.1 10 m test

The phase centre of the antenna shall be 3 m ± 0,05 m above the plane on which the earth-moving machinery rests.

B.4.2.1.2 3 m test

The phase centre of the antenna shall be 1,8 m ± 0,05 m above the plane on which the earth-moving machinery rests.

B.4.2.1.3 Antenna location

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

B.4.2.2 Distance of measurement

B.4.2.2.1 10 m test

The horizontal distance from the tip or other appropriate point of the antenna, defined during the normalization procedure given in B.4.1, to the outer body surface of the earth-moving machinery shall be 10 m ± 0,2 m.

B.4.2.2.2 3 m test

The horizontal distance from the tip or other appropriate point of the antenna, defined during the normalization procedure given in B.4.1, to the outer body surface of the earth-moving machinery shall be 3 m ± 0,05 m.

B.4.2.2.3 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 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 earth-moving machinery under test.

B.4.3 Antenna location relative to the earth-moving machinery

The antenna shall be located successively on the left- and right-hand sides of the earth-moving machinery, with the antenna parallel to the plane of the longitudinal symmetry of the earth-moving machinery and in line:

a) for diesel engines, at the SIP (see ISO 5353);

b) for spark ignition engines, at the engine mid-point.

See Figures B.2 and B.3.

B.4.4 Antenna position

At each of the measuring points, reading shall be taken both with the antenna in a horizontal and in a vertical polarization (see Figures B.2 and B.3).

B.5 Readings

The maximum of the four readings taken in accordance with B.4.3 and B.4.4 shall be taken as the characteristic reading at the frequency at which the measurements were made.

B.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.

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.

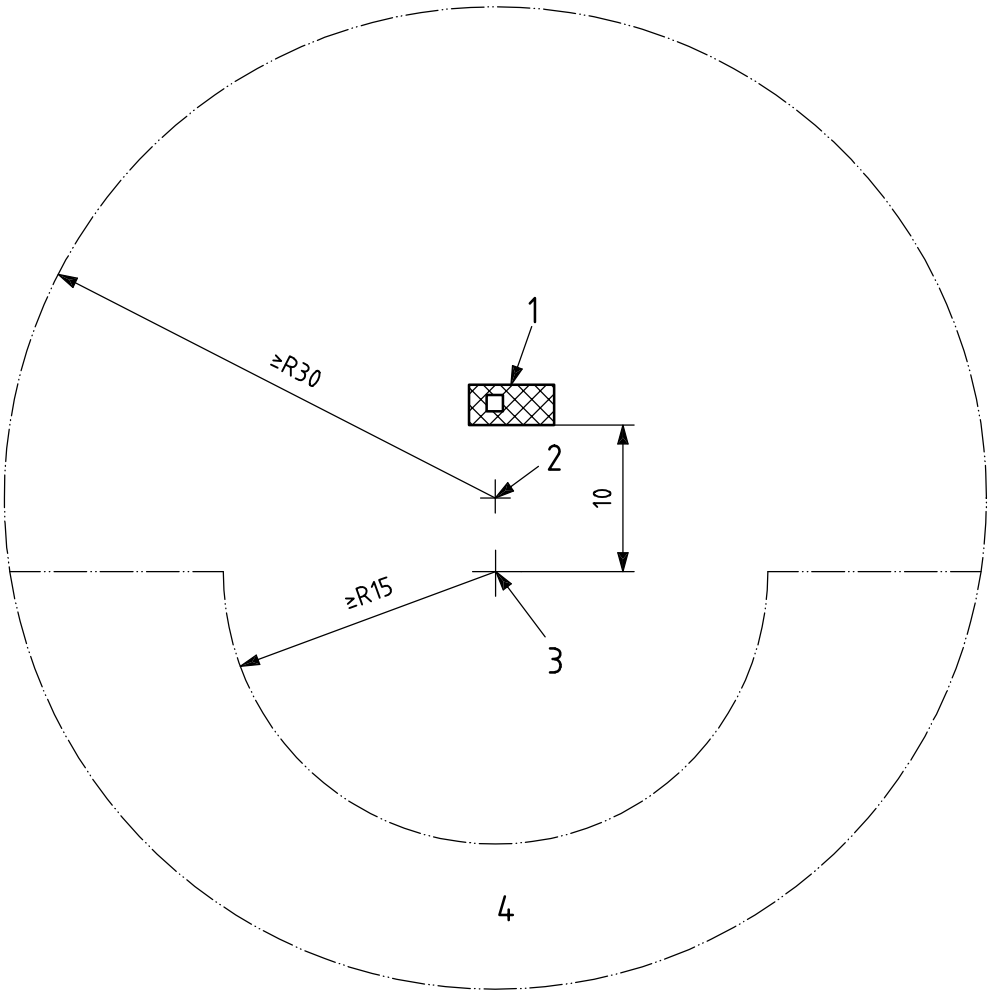
Measurements may be performed with either quasi-peak or peak detectors. The limits given in 5.3.2 are for quasi-peak. If a peak-detector is used, add 38 dB for a 1 MHz bandwidth or subtract 22 dB for a 1 kHz bandwidth, i.e.

— limit (peak, 1 MHz) = limit (quasi-peak, 120 kHz) + 38 dB, or

— limit (peak, 1 kHz) = limit (quasi-peak, 120 kHz) −22 dB.

NOTE In accordance with CISPR 12, the correlation factor between quasi-peak measurements is + 20 dB at 120 kHz bandwidth, and has been included in the above equations.

Dimensions in metres



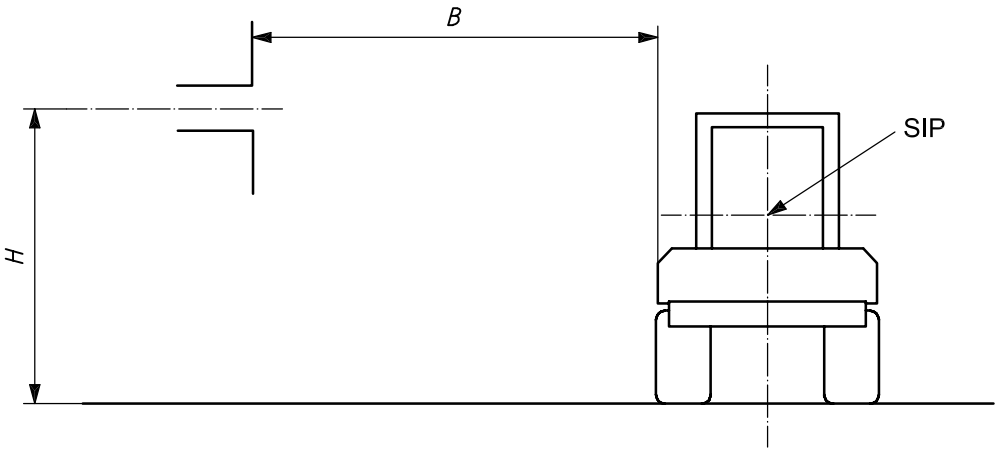
Key

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

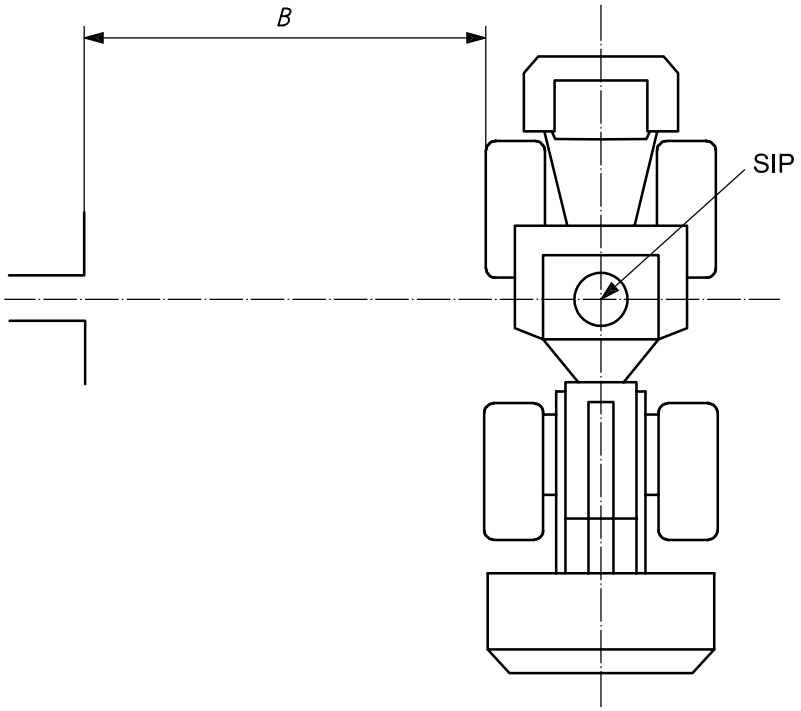
The area shall be clear, level and free from electromagnetic reflecting surfaces (see CISPR 12).

Figure B.1 — Earth-moving machinery — Test area

Dimensions in metres



a) Dipole antenna in position to measure vertical component of radiation



b) Dipole antenna in position to measure horizontal component of radiation

Key

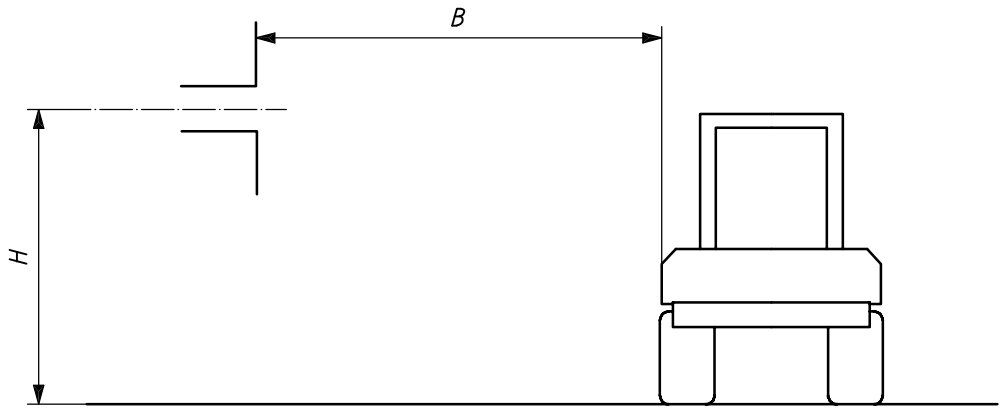
SIP seat index point (ISO 5353)

B 10 ± 0,2 (3 ± 0,05)

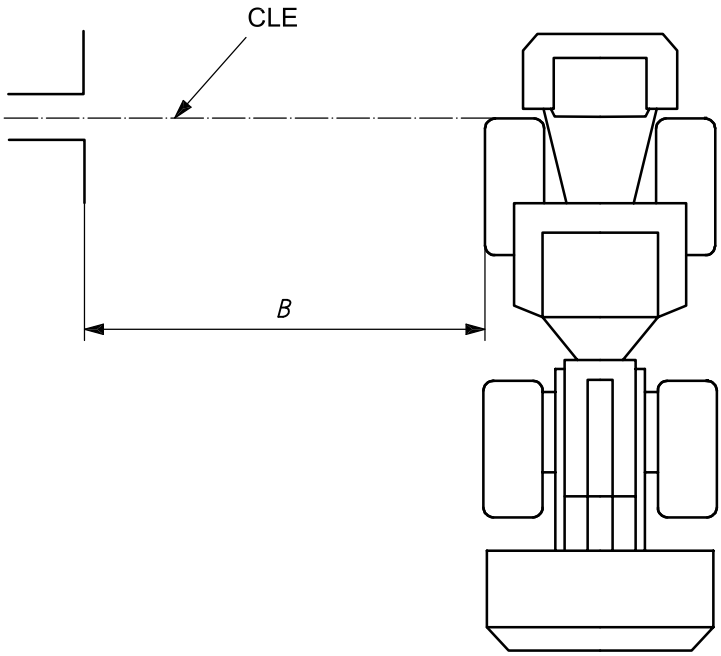
H 3 ± 0,05 (1,8 ± 0,05)

Figure B.2 — Position of antenna relative to earth-moving machinery with diesel engines

Dimensions in meters



a) Dipole antenna in position to measure vertical component of radiation



b) Dipole antenna in position to measure horizontal component of radiation

Key

CLE centreline of engine

B 10 ± 0,2 (3 ± 0,05)

H 3 ± 0,05 (1,8 ± 0,05)

Figure B.3 — Position of antenna relative to earth-moving machinery with spark ignition engine

Annex C
(normative)

Method of measuring radiated narrowband electromagnetic emissions from earth-moving machinery

C.1 General

C.1.1 Application

The test method specified in this annex is applicable only to complete earth-moving machinery.

C.1.2 Measuring apparatus

The measuring equipment shall comply with the requirements of CISPR 16-1-1. A peak or average detector shall be used for the measurement according to this annex of narrowband electromagnetic emissions.

C.1.3 Test method

This test is intended for measuring narrowband emissions such as those which might emanate from a microprocessing-based system or other narrowband source. In the test procedure, two alternative antenna distances are permissible: 10 m or 3 m from the earth-moving machinery. In either case, the requirements of C.2 shall be fulfilled.

C.1.4 Results of measurement

The results of the measurement shall be expressed in dB(μV/m) (μV/m).

C.2 Measuring location

C.2.1 Test site

The test site shall be a clear, level area, free from electromagnetic reflecting surfaces, within a circle of minimum radius 30 m measured from a point midway between the earth-moving machinery and the antenna (see Figure B.1). All test sites shall comply with the relevant sections of CISPR 16-1-4.

C.2.2 Measuring facility

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

C.2.3 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 earth-moving machinery and the height of the antenna. Neither do they need to have ambient emissions checked before or after the test as indicated in C.2.4.

C.2.4 Ambient measurements

In order to ensure that there is no extraneous noise or signal of a magnitude sufficient to affect materially the measurement, measurements shall be taken before and after the main test. If the earth-moving machinery is present when ambient measurements are taken, it will be necessary to ensure that any emission from the earth-moving machinery does not affect significantly the ambient measurements, for example by removing the machine from the test area, removing the ignition key or disconnecting the battery. In both measurements, the extraneous noise or signal shall be at least 10 dB below the limits of interference given in 5.4.2 (except for intentional narrowband ambient transmissions).

C.3 Machine state during test

C.3.1 Machine systems

Those of the earth-moving machinery's electronic systems which can generate narrowband emissions shall be operating during the measurement. If necessary, systems which can generate broadband emissions shall be cut off.

C.3.2 Machine controls

The ignition or the earth-moving machinery's engine run control shall be switched on. The engine shall not be operating.

C.3.3 Ambient conditions

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

C.4 Antenna

C.4.1 Antenna type

Any antenna may be used provided it can be normalized to the reference antenna. The method according to CISPR 12:2004, Annex A, may be used to calibrate the antenna.

C.4.2 Height and measurement distance

C.4.2.1 Height

C.4.2.1.1 10 m test

The phase centre of the antenna shall be 3 m $\pm$ 0,05 m above the plane on which the earth-moving machinery rests.

C.4.2.1.2 3 m test

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

C.4.2.1.3 Antenna location

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

C.4.2.2 Measurement distance

C.4.2.2.1 10 m test

The horizontal distance from the tip or other appropriate point of the antenna, defined during the normalization procedure given in C.4.1, to the outer body surface of the earth-moving machinery shall be 10 m ± 0,2 m.

C.4.2.2.2 3 m test

The horizontal distance from the tip or other appropriate point of the antenna, defined during the normalization procedure given in C.4.1, to the outer body surface of the earth-moving machinery shall be 3 m ± 0,05 m.

C.4.2.2.3 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 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 earth-moving machinery under test.

C.4.3 Antenna location relative to the earth-moving machinery

The antenna shall be located successively on the left- and right-hand sides of the earth-moving machinery, with the antenna parallel to the plane of longitudinal symmetry of the earth-moving machinery and in line with the seat index point (SIP) on the earth-moving machinery (see Figure B.1).

C.4.4 Antenna position

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

C.5 Readings

The maximum of the four readings taken in accordance with C.4.3 and C.4.4 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. 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.

Annex D
(normative)

Method of measuring radiated broadband electromagnetic emissions from ESA

D.1 General

D.1.1 Application

The test method according to this annex is applicable to ESA.

D.1.2 Measuring apparatus

The measuring equipment shall comply with the requirements of CISPR 16-1-1. A quasi-peak detector shall be used for the measurement, according to this annex, of broadband electromagnetic emissions; or, if using a peak detector, an appropriate correction factor shall be used (see D.6 and CISPR 12).

D.1.3 Test method

The test is intended for measuring the broadband electromagnetic emissions from ESA.

D.1.4 Results of measurement

The results of the measurement shall be expressed in dB(μV/m) (μV/m) for a 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 the 120 kHz bandwidth through multiplication by a factor of $120/B$.

NOTE This factor depends on the spectral distribution signal. For spark-like disturbance voltages the factor is as described. For harmonic disturbance signals the factor is $\sqrt{120/B}$.

D.2 Measuring location

D.2.1 Test site

The test site shall comply with the requirements of CISPR 16-1-4. See Figure D.1.

D.2.2 Measuring facility

The measuring set, test hut or earth-moving machinery in which the measurement set is located shall be outside the boundary shown in Figure D.1.

D.2.3 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 need not meet the dimensional requirements of Figure D.1, other than the distance from the antenna to the ESA under test and the height of the antenna (see Figures D.2 and D.3).

D.2.4 Ambient measurements

To ensure that there is no extraneous noise or signal of a magnitude sufficient to affect materially the measurement, measurements shall be taken before and after the main test. In both of the measurements, the extraneous noise or signal shall be at least 10 dB below the limits of interference given in 5.6.2, except for intentional narrowband ambient transmissions.

D.3 ESA state during test

D.3.1 Operational mode

The ESA under test shall be in normal operation mode. Measurements shall not be made while rain or other precipitation is falling on the ESA or within 10 min after precipitation has stopped.

D.3.2 ESA setup

The ESA under test and its wiring harnesses shall be spaced 50 mm ± 5 mm above a metallic ground plane by a wooden or equivalent non-conducting table. However, if any part of the ESA under test is intended to be electrically bonded to the earth-moving machinery's metal bodywork, that part shall be placed on a ground plane and shall be electrically bonded to the ground plane.

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 1 m ± 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 mm ± 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 are 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), shall be 1 m.

D.3.3 Power to ESA

Power shall be applied to the ESA under test via a 5 µH/50 Ω artificial network (AN), which shall be electrically bonded to the ground plane. The electrical supply voltage shall be maintained to ± 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.3.4 Multiple ESA

If the ESA under test consists of more than one unit, the interconnecting cables should ideally be the wiring harness as intended for use in the earth-moving machinery. If these are not available, the minimum length between the electronic control unit and the AN shall be 1,5 m. All cable trees should be terminated as realistically as possible, preferably with real loads and actuators. If extraneous equipment 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.4 Antenna

D.4.1 Antenna type

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

D.4.2 Height and distance of measurement

D.4.2.1 Height

The phase centre of the antenna shall be 150 mm ± 10 mm above the ground plane.

D.4.2.2 Distance of measurement

The horizontal distance from the phase centre or tip of the antenna, as appropriate, to the edge of the ground plane shall be 1 m ± 0,05 m. No part of the antenna shall be closer than 0,5 m to the ground plane.

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

D.4.2.3 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 0,5 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.4.3 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 Readings

The maximum of the two readings taken in accordance with D.4.3 at each spot 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 12.

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.

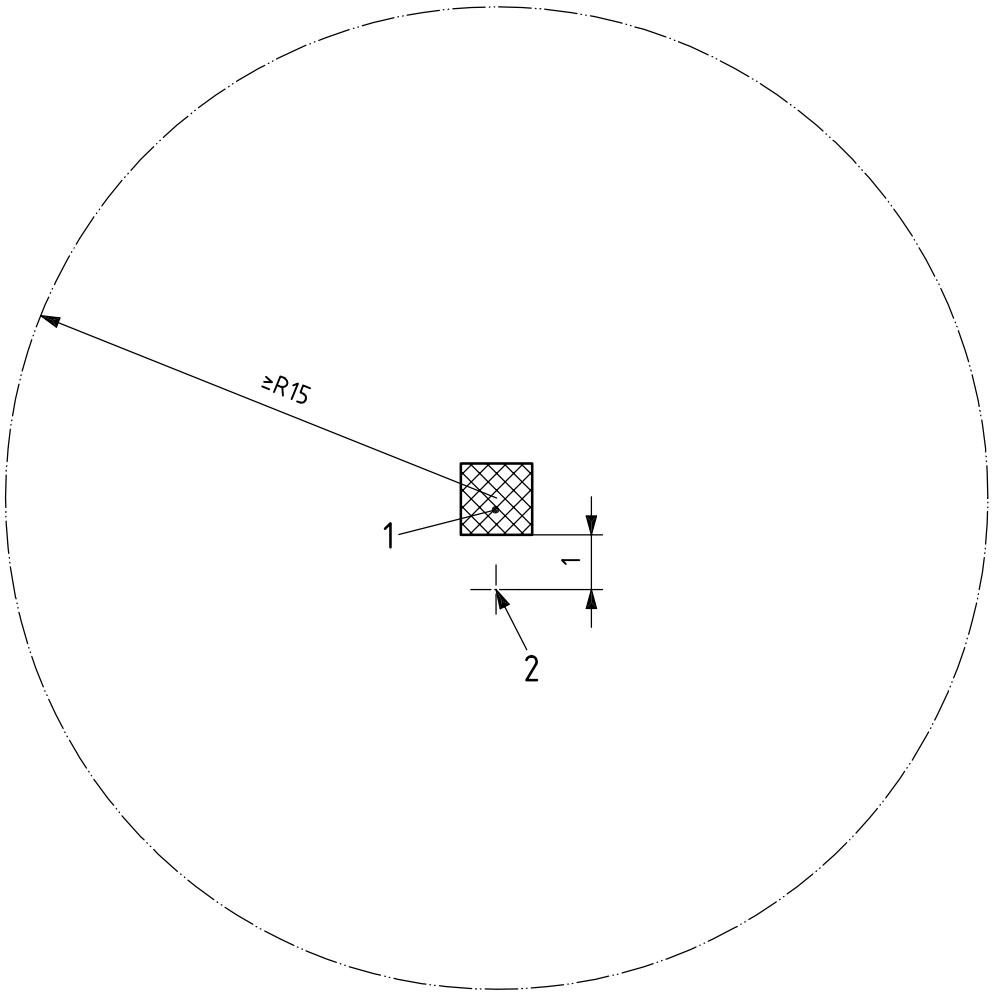
Measurements may be performed with either quasi-peak or peak detectors. The limits given in 5.6.2 are for quasi-peak. If a peak-detector is used, add 38 dB for a 1 MHz bandwidth or subtract 22 dB for a 1 kHz bandwidth, i.e.

— limit (peak, 1 MHz) = limit (quasi-peak, 120 kHz) + 38 dB;

— limit (peak, 1 kHz) = limit (quasi-peak, 120 kHz) − 22 dB.

NOTE In accordance with CISPR 12, the correlation factor between quasi-peak measurements is + 20 dB at 120 kHz bandwidth, and has been included in the above equations.

Dimensions in metres



Key

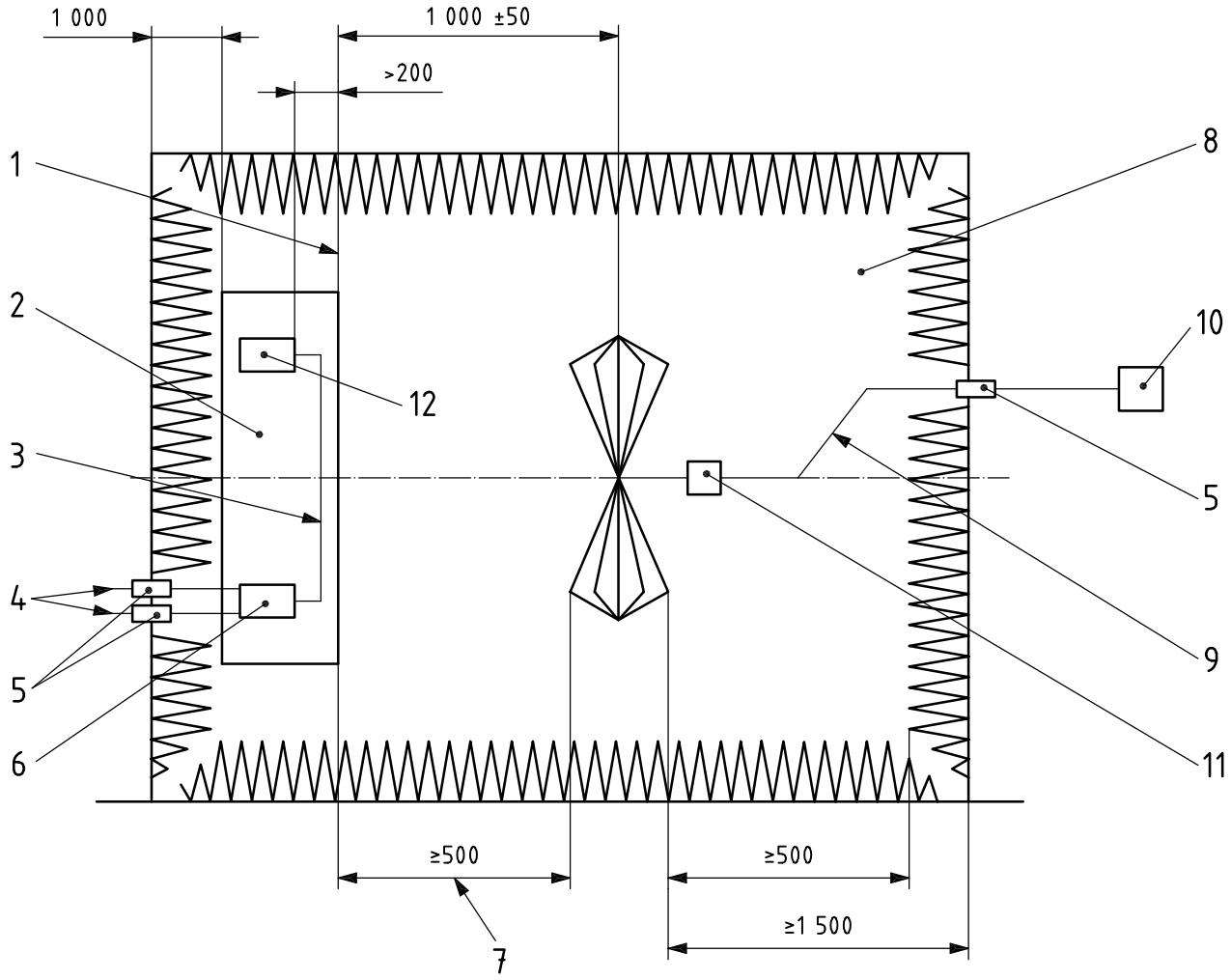
1 test sample on ground plane

2 antenna

The area shall be clear, level and free from electromagnetic reflecting surfaces (see CISPR 16-1-4).

Figure D.1 — ESA or component test area boundary

Dimensions in millimetres

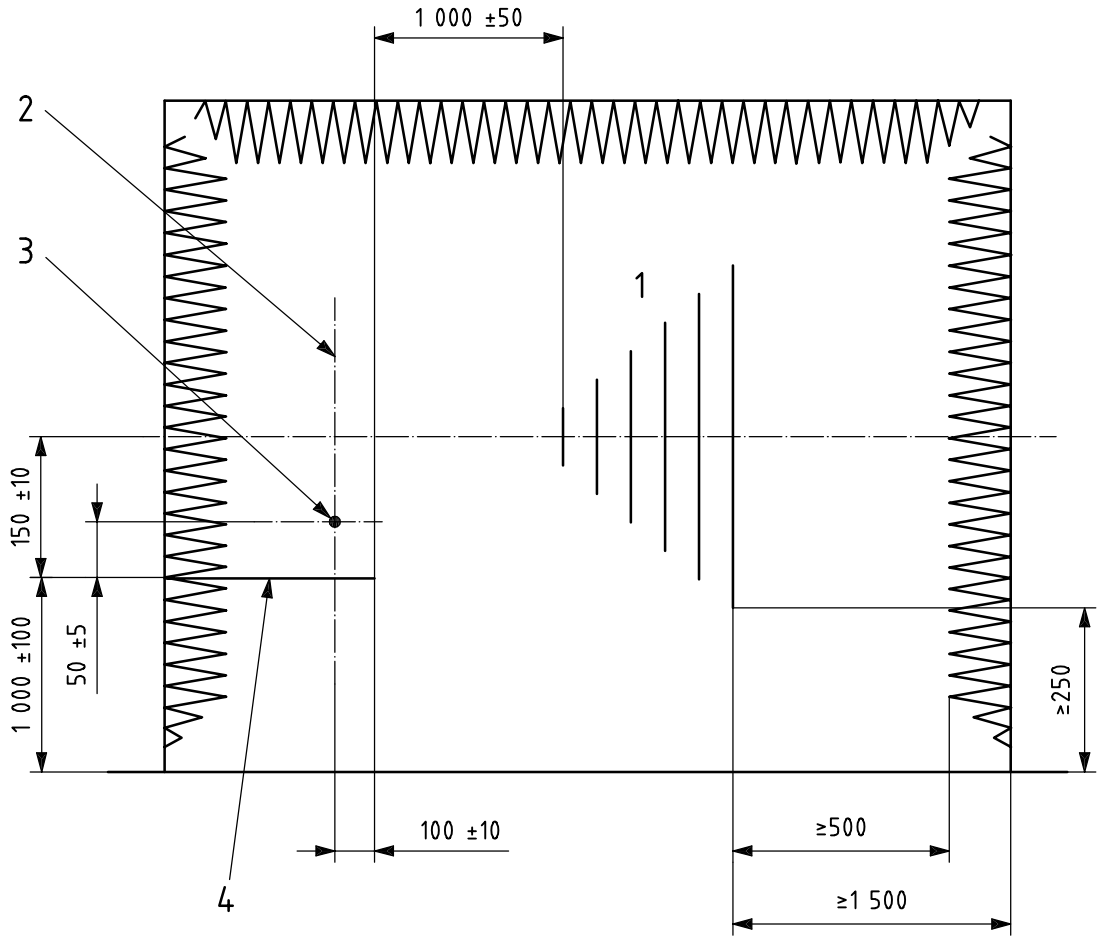


Key

1 to axis of antenna or closest element of log periodic array: 1 000 mm ± 50 mm
2 test bench with ground plane bonded to wall
3 test harness 1 500 mm ± 75 mm long and 50 mm ± 5 mm above ground plane
4 power supply to subject under test
5 feedthrough
6 connecting box including AN
7 closest radiating elements at least 500 mm from edge of ground plane
8 shielded enclosure
9 double shielded coaxial cable
10 measuring receiver
11 antenna matching unit (where necessary) in close proximity to antenna
12 ESA

Figure D.2 — Radiated broadband electromagnetic emissions from ESA — Test layout (general plan view)

Dimensions in millimetres



Key

1 antenna
2 plane in which lie the reference point and the main portion of the harness
3 reference point
4 base plate

Figure D.3 — Radiated broadband electromagnetic emissions from ESA — Side view on test bench plane of longitudinal symmetry

Annex E
(normative)

Method of measuring radiated narrowband electromagnetic emissions from ESA

E.1 General

E.1.1 ESA test method

The test method according to this annex is applicable to ESA.

E.1.2 Measuring apparatus

The measuring equipment shall comply with the requirements of CISPR 16-1-1. A peak or average detector shall be used for the measurement in accordance with this annex of narrowband electromagnetic emissions.

E.1.3 Test method

This test is intended to measure the narrowband electromagnetic radiation such as might emanate from a microprocessor-based system. As a short (2 min to 3 min) initial step, choosing one antenna polarization, it is permitted to make sweeps of the frequency range identified in E.6 using a spectrum analyzer to indicate the whereabouts of peak emissions. This may assist in the choice of frequencies to be tested (see E.6).

E.1.4 Results of measurement

The results of the measurement shall be expressed in dB(μV/m) (μV/m).

E.2 Measuring location

E.2.1 Test site specifications

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

E.2.2 Measuring facilities

The measuring set, test hut, or earth-moving machinery in which the measurement set is located shall be outside the boundary shown in Figure D.1.

E.2.3 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 need not meet the dimensional requirements of Figure D.1, other than the distance from the antenna to the ESA under test and the height of the antenna (see Figures D.2 and D.3).

E.2.4 Ambient measurements

To ensure that there is no extraneous noise or signal of a magnitude sufficient to affect materially the measurement, measurements shall be taken before and after the main test. In both measurements, the extraneous noise or signal shall be at least 10 dB below the limits of interference given in 5.7.2, except for intentional narrowband ambient transmissions.

E.3 ESA state during test

E.3.1 Operational mode

The ESA under test shall be in normal operation mode.

E.3.2 Test ambient conditions

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

E.3.3 ESA setup

The ESA under test and its wiring harnesses shall be spaced $50\ ^{+10}_{0}$ mm above a metallic ground plane by means of a wooden or equivalent non-conducting table. However, if any part of the ESA under test is intended to be electrically bonded to the earth-moving machinery's metal bodywork, that part shall be placed on a ground plane and shall be electrically bonded to the ground plane.

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 1 m $\pm$ 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 mm $\pm$ 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 are 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), shall be 1 m.

E.3.4 Power to ESA

Power shall be applied to the ESA under test via a 5 µH/50 W 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.

E.3.5 Multiple ESA

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

E.4 Antenna

E.4.1 Antenna type

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

E.4.2 Height and distance of measurement

E.4.2.1 Height

The phase centre of the antenna shall be 150 mm ± 10 mm above the ground plane.

E.4.2.2 Distance of measurement

The horizontal distance from the phase centre or tip of the antenna, as appropriate, to the edge of the ground plane shall be 1 m ± 0,05 m. No part of the antenna shall be closer than 0,5 m to the ground plane.

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

E.4.2.3 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 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.

E.4.3 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.

E.5 Readings

The maximum of the two readings taken in accordance with E.4.3 at each spot frequency shall be taken as the characteristic reading at the frequency at which the measurements were made.

E.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.

Annex F
(informative)

Guidelines for selecting test specimen configuration

F.1 General

Because of the many electrical/electronic variations which can be present on earth-moving machinery, the selection of the machine or ESA test specimen must be done based upon an evaluation of the conditions which are likely to present the most significant emissions and immunity impact to the earth-moving machinery and the environment in which it will be used. Thus to reduce the configurations of earth-moving machinery or ESA to be presented for testing, the information in this annex can be helpful to the users of this International Standard to make the best choices of what configurations to test.

F.2 Criteria for consideration

F.2.1 Narrowband emissions

No oscillator greater than 9 kHz (examples of oscillators that can be greater than 9 kHz are microprocessor clocks, and pulse width modulated signals).

F.2.2 Broadband emissions

No broadband source of emissions (examples of sources of broadband noise are wiper motors and spark gaps).

Not continuously operated.

F.2.3 Immunity

Degradation in system performance does not affect

— the operator's direct control of the earth-moving machinery,

— engine speed control,

— steering system,

— brake system,

— movement of equipment of the earth-moving machinery,

— any machine function which may generate a hazard,

— a display such that it indicates a faulty signal, thus generating a hazardous operation by the machine, or such that it gives feedback to the operator that might cause the performing of a hazardous operation.

The system does not include an active semiconductor device (examples of active semiconductor devices are transistors and microprocessors).

Power to the device is switched directly or via relay contacts.

Degradation of system performance is not perceptible to the operator. The manufacturer shall identify or demonstrate a mechanical limit such as the maximum rate of change.

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