

INTERNATIONAL STANDARD

NORME INTERNATIONALE

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

COMITÉ INTERNATIONAL SPÉCIAL DES PERTURBATIONS RADIOÉLECTRIQUES

Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of off-board receivers

Véhicules, bateaux et moteurs à combustion interne – Caractéristiques de perturbation radioélectrique – Limites et méthodes de mesure pour la protection des récepteurs extérieurs



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

**VEHICLES, BOATS AND INTERNAL COMBUSTION ENGINES –
RADIO DISTURBANCE CHARACTERISTICS –
LIMITS AND METHODS OF MEASUREMENT FOR THE PROTECTION
OF OFF-BOARD RECEIVERS**

FOREWORD

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International Standard CISPR 12 has been prepared by CISPR subcommittee D: Electromagnetic disturbances related to electric/electronic equipment on vehicles and internal combustion powered devices.

This consolidated version of CISPR 12 consists of the sixth edition (2007) [documents CISPR/D/322/CDV and CISPR/D/341/RVC] and its amendment 1 (2009) [documents CISPR/D/354/CDV and CISPR/D/361/RVC].

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 6.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

The following changes were made with respect to the previous edition:

- deletion of narrowband / broadband determination
- general improvement of wording

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

There is a specific need for standards to define acceptable radio frequency performance of all electrical/electronic products. CISPR 12 has been developed to serve the road vehicle and related industries with test methods and limits that provide satisfactory protection for radio reception.

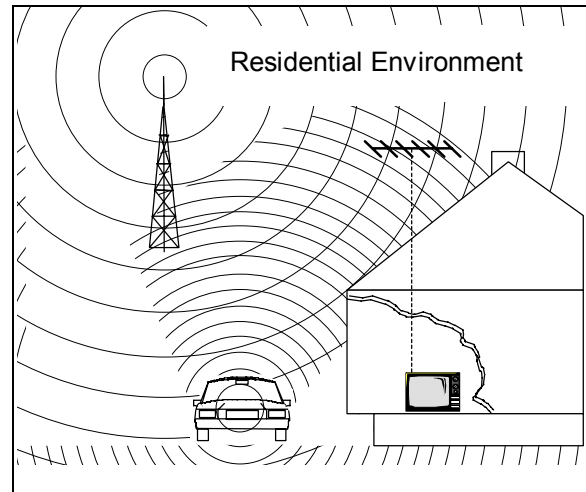
CISPR 12 has been used for many years as a regulatory requirement in numerous countries, to provide protection for radio receivers in the residential environment. It has been extremely effective in protecting the radio environment outside the vehicle.

VEHICLES, BOATS AND INTERNAL COMBUSTION ENGINES – RADIO DISTURBANCE CHARACTERISTICS – LIMITS AND METHODS OF MEASUREMENT FOR THE PROTECTION OF OFF-BOARD RECEIVERS

1 Scope

The limits in this International Standard are designed to provide protection for broadcast receivers in the frequency range of 30 MHz to 1 000 MHz when used in the residential environment. Compliance with this standard may not provide adequate protection for new types of radio transmissions or receivers used in the residential environment nearer than 10 m to the vehicle, boat or device.

NOTE 1 Experience has shown that compliance with this standard may provide satisfactory protection for receivers of other types of transmissions when used in the residential environment, including radio transmissions in frequency ranges other than that specified.



This standard applies to the emission of electromagnetic energy which may cause interference to radio reception and which is emitted from

- a) vehicles propelled by an internal combustion engine, electrical means or both (see 3.1);
- b) boats propelled by an internal combustion engine, electrical means or both (see 3.2). Boats are to be tested in the same manner as vehicles except where they have unique characteristics as explicitly stated in this standard;
- c) devices equipped with internal combustion engines or traction batteries (see 3.3).

See Annex G for a flow chart to help determine the applicability of CISPR 12.

This standard does not apply to aircrafts, household appliances, traction systems (railway, tramway and electric trolley bus), or to incomplete vehicles. In the case of a dual-mode trolley bus (e.g. propelled by power from either a.c./d.c. mains or an internal combustion engine), the internal combustion propulsion system shall be included, but the a.c./d.c. mains portion of the vehicle propulsion system shall be excluded from this standard.

NOTE 2 Protection of receivers used on board the same vehicle as the disturbance source(s) are covered by CISPR 25.

The measurement of electromagnetic disturbances while the vehicle is connected to power mains for charging is not covered in this standard. The user is referred to appropriate IEC and CISPR standards which define measurement techniques and limits for this condition.

Annex H lists work being considered for future revisions.

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.

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electro-magnetic compatibility*

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 16-1-3:2004, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-3: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Disturbance power*

CISPR 16-1-4:2007, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Radiated disturbances*

CISPR 16-2-3:2006, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements*

CISPR 25, *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 purpose of this document, the terms and definitions contained in IEC 60050-161 as well as the following apply.

3.1

vehicle

machine operating on land which is intended to carry persons or goods

NOTE Vehicles include, but are not limited to, cars, trucks, buses, mopeds, agricultural machinery, earth-moving machinery, material-handling equipment, mining equipment, floor treatment machines and snowmobiles.

3.2

boat

vessel intended to be used on the surface of water, its length being no greater than 15 m

3.3

device

machine driven by an internal combustion engine which is not primarily intended to carry persons or goods

NOTE Devices include, but are not limited to, chainsaws, irrigation pumps, snow blowers, air compressors, walk-behind floor treatment machines and landscaping equipment.

3.4

impulsive ignition noise

unwanted emission of electromagnetic energy, predominantly impulsive in content, arising from the ignition system within a vehicle, boat or device

3.5

ignition noise suppressor

that portion of a high-voltage ignition circuit intended to limit the emission of impulsive ignition noise

3.6

outdoor test site (OTS)

measurement site similar to an open area test site as specified in CISPR 16, however a ground plane is not required and there are dimensional changes

NOTE Specific requirements are defined in this document.

3.7

resistive distributor brush

resistive pick-up brush in an ignition distributor cap

3.8

frequency sub-band

segment of the frequency spectrum (30 MHz to 1 000 MHz) defined to enable statistical evaluation of the test data acquired by swept frequency testing

3.9

representative frequency

assigned frequency of a frequency sub-band to be used for comparison of the data to the limit

3.10

characteristic level

controlling (or dominant) emission level experienced in each frequency sub-band. The characteristic level is the maximum measurement obtained for both antenna polarizations and for all the specified measurement positions of the vehicle, boat or device. Known ambient signals are not considered part of the characteristic level.

3.11

tracking generator

test signal oscillator (continuous wave, cw) that is frequency locked to the receive frequency of a measuring instrument

3.12

RF disturbance power

RF power measured with a current transformer of an absorbing clamp and an RF measuring instrument. It may be measured – as the RF disturbance voltage – in a peak or quasi-peak mode

3.13

spark discharge

in this document, the discharge of energy stored in the ignition coil, in an arc across the electrodes of a measuring spark-plug

3.14

resistive high-voltage (HV) ignition cable

ignition cable whose conductor has a high resistance (attenuation)

3.15

residential environment

environment having a 10 m protection distance between the source and the point of radio reception and where the source uses the public low voltage power system or battery power

NOTE Examples of a residential environment include rooming houses, private dwellings, entertainment halls, theatres, schools, public streets, etc.

3.16**traction batteries**

high power batteries used for electric vehicle traction applications

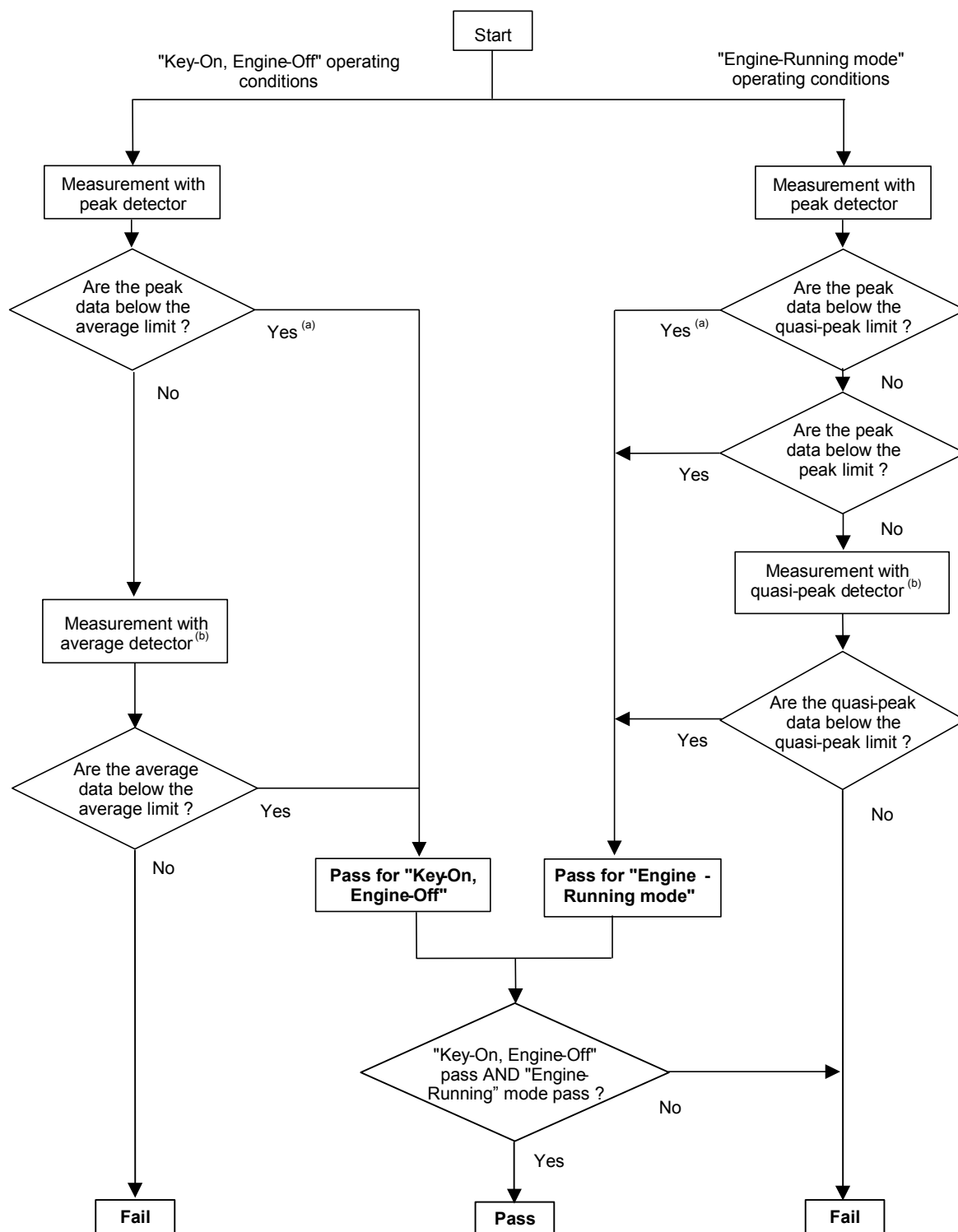
4 Limits of disturbance**4.1 Determination of conformance of vehicle/boat/device with limits**

In the 30 MHz – 1 GHz frequency range, the vehicle/boat/device shall comply with both:

- average limits when the vehicle/boat/device is in “Key-On, Engine-Off” mode (see 5.3.2.1), and
- peak or quasi-peak limits when the vehicle/boat/device is in “Engine-Running” mode (see 5.3.2.2)

The limits given in this standard take into account uncertainties.

Figure 1 defines the method for determination of conformance.



IEC 706/07

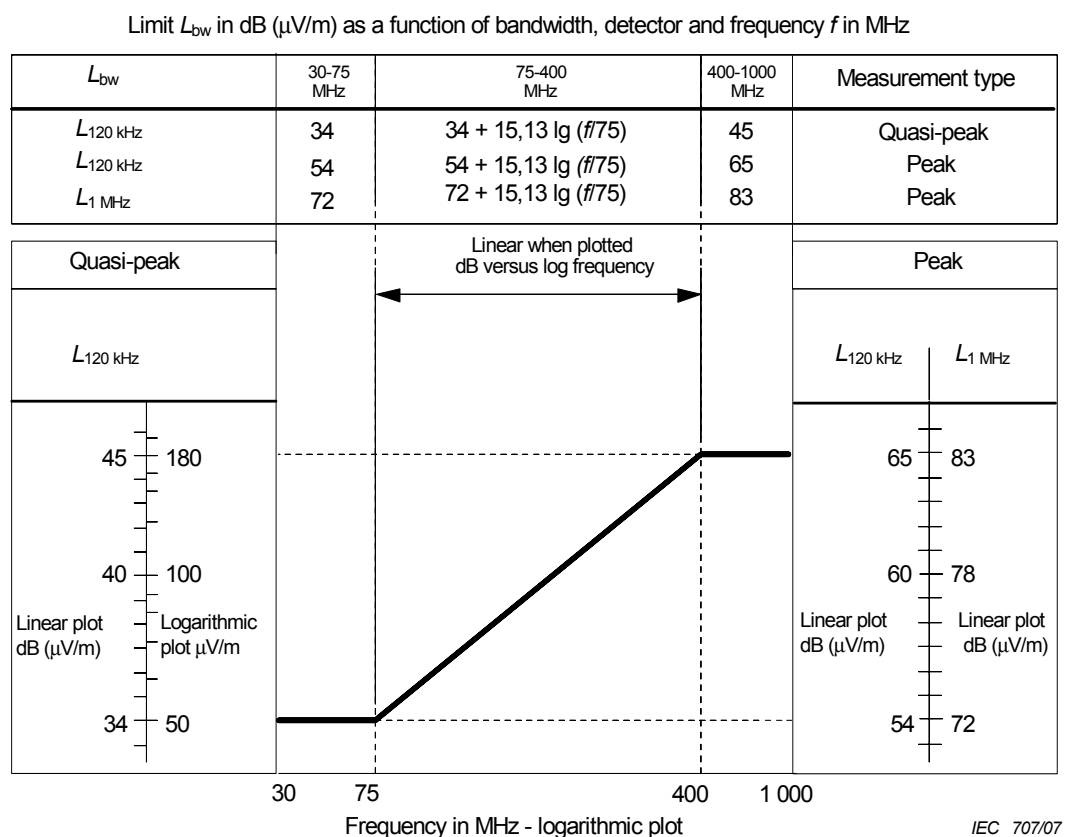
a Because measurement with peak detector is always higher than or equal to measurement with quasi-peak detector (and average detector respectively) and applicable peak limit is always higher than or equal to applicable quasi-peak limit (and average limit respectively), this single detector measurement can lead to a simplified and quicker conformance process.

b This flow-chart is applicable for each individual frequency, e.g only frequencies that are above the applicable limit need to be remeasured with quasi-peak detector (and average detector respectively).

Figure 1 – Method of determination of conformance

4.2 Peak and quasi-peak detector limits

The limit for emissions measured with peak or quasi-peak detector at 10 m antenna distance is given in the table of Figure 2 and is shown graphically in Figure 2. Only one of the bandwidths listed needs to be chosen for testing. For more accurate determination, the equations given in Figure 2 shall be used. For measurements at 3 m antenna distance, 10 dB shall be added to the limit.



NOTE 1 For vehicles equipped with electric propulsion motors, see 5.3.2.

NOTE 2 For peak measurements, see 5.5.

NOTE 3 The correlation factor between quasi-peak and peak measurements is +20 dB at 120 kHz bandwidth, based on experimental data accumulated in many countries.

**Figure 2 – Limit of disturbance (peak and quasi-peak detector)
at 10 m antenna distance**

4.3 Average detector limit

The limit for emissions measured with the average detector at 10 m antenna distance is shown in Figure 3. Vehicles/boats/devices not including electronic oscillators with an operating frequency greater than 9 kHz shall be deemed to be in compliance with the average requirements of this clause without performing tests for emissions with average detector. Vehicles/boats/devices which meet the average emissions requirements of CISPR 25, Clause 5 shall also be deemed to be in compliance with the average requirements of this subclause and no further testing is necessary.

For measurements at 3 m antenna distance, 10 dB shall be added to the limit.

Annex D of CISPR 16-2-3 explains the differences between the CISPR AV detector and an AV detector (complying with CISPR 16-1:1999). For the purpose of this standard either detector may be used, since the pulse repetition rate for internal combustion engines is above 10 Hz.

NOTE For type-approval testing per 6.4, use of an alternative test method based upon other regulatory standards is permitted as detailed herein. This alternate type-approval test applies to those vehicles/boats/devices for which on-board receivers can be installed. If, when measured in accordance with the vehicle test methodology of CISPR 25 for emissions using an average detector, the signal strength at the vehicle/boat/device broadcast radio antenna is less than 20 dB (μV) (10 μV) over the frequency range 76 MHz to 108 MHz, then the vehicle/boat/device can be deemed to comply with the limits for average emissions and no further testing must be required.

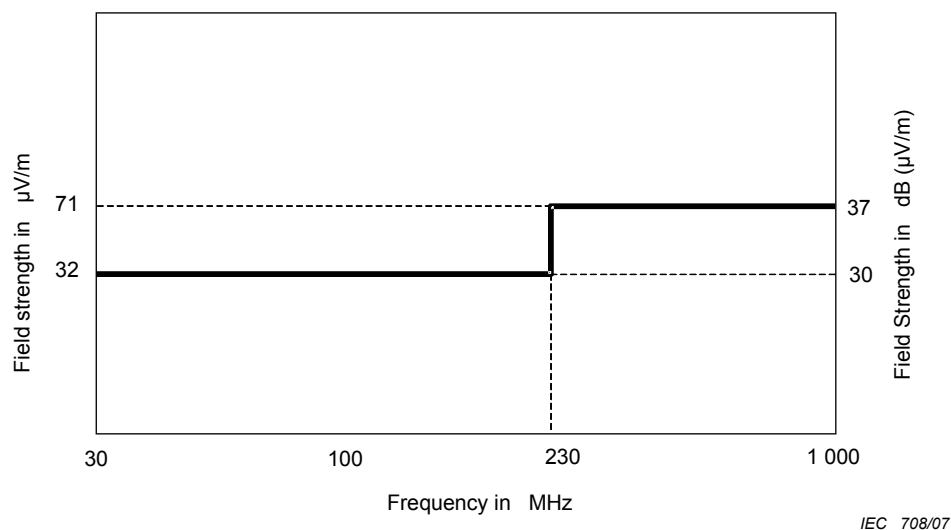


Figure 3 – Limits of disturbance (average detector) at 10 m antenna distance

5 Methods of measurement

5.1 Measuring instrument

The measuring instrument shall comply with the requirements of CISPR 16-1-1. Either manual or automatic frequency scanning may be used.

NOTE Spectrum analysers and scanning receivers are particularly useful for disturbance measurements. The peak detection mode of spectrum analysers and scanning receivers provides a display indication which is never less than the quasi-peak indication for the same bandwidth. It may be convenient to measure emissions using peak detection because of the faster scan possible than with quasi-peak detection.

When quasi-peak limits are being used, and a peak detector is used for time efficiency, any peak measurements with results at or above the test limit shall be re-measured using the quasi-peak detector.

5.1.1 Spectrum analyser parameters

The scan rate of the spectrum analyser shall be adjusted for the CISPR frequency band and detection mode used. The maximum scan rate shall comply with the requirements of CISPR 16-2-3.

The bandwidth of the spectrum analyser shall be chosen such that the noise floor is at least 6 dB lower than the limit curve.

NOTE A preamplifier may be used between the antenna and the spectrum analyser in order to achieve the 6 dB noise floor requirement.

The recommended scan time and bandwidth are listed in Table 1.

Table 1 – Spectrum analyser parameters

Frequency range MHz	Peak detector		Quasi-peak detector		Average detector	
	RBW ^{a)}	Scan time	BW ^{b)}	Scan time	RBW ^{a)}	Scan time
30 to 1 000	100 kHz / 120 kHz	100 ms / MHz	120 kHz	20 s / MHz	100 kHz / 120 kHz	100 ms / MHz
a) RBW is defined at –3 dB.						
b) BW is defined at –6 dB.						

If a spectrum analyser is used for peak measurements, the video bandwidth shall be at least three times the resolution bandwidth (RBW).

5.1.2 Scanning receiver parameters

The dwell time of the scanning receiver shall be adjusted for the CISPR frequency band and detection mode used. The minimum dwell time shall comply with the requirements of CISPR 16-2-3.

The bandwidth of the scanning receiver shall be chosen such that the noise floor is at least 6 dB lower than the limit curve.

NOTE A preamplifier may be used between the antenna and the scanning receiver in order to achieve the 6 dB noise floor requirement.

The recommended dwell time, maximum step size and bandwidth are listed in Table 2.

Table 2 – Scanning receiver parameters

Frequency range MHz	Peak detector			Quasi-peak detector			Average detector		
	Band-width	Step size ^a	Dwell time	Band-width	Step size ^a	Dwell time	Band-width	Step size ^a	Dwell time
30 to 1 000	120 kHz	50 kHz	5 ms	120 kHz	50 kHz	1 s	120 kHz	50 kHz	5 ms
^a For purely broadband disturbances, the maximum frequency step size may be increased up to a value not greater than the bandwidth value.									

5.1.3 Antenna types

5.1.3.1 Reference antenna

The antenna shall be a balanced dipole (see CISPR 16-1-4). Free-space antenna factors are to be used. For frequencies of 80 MHz or above, the antenna shall be resonant in length, and for frequencies below 80 MHz it shall be the length equal to the 80 MHz resonant length. It shall be matched to the feeder by a suitable symmetric-asymmetric transformer device.

5.1.3.2 Broadband antennas

Any linearly polarized receiving antenna is permitted, provided that it can be normalized to the reference antenna.

A broadband antenna shall be used when making measurements with an automated receiving system using a scanning measuring instrument. Such a broadband antenna is usable for measuring emission levels (over the frequency spectrum covered by this standard), provided that its output can be normalized to the output of the reference antenna in the actual test environment at the actual test site.

When broadband antennas are used, they shall meet the requirements for complex antennas given in CISPR 16-1-4. Examples of factors to be considered include:

- a) the effective aperture area of the antenna, including its polar response (horizontal and vertical planes);
- b) the effect of a phase centre which moves with frequency;
- c) the effect of ground reflection characteristics (including multiple ray reflections which may arise at specific frequencies at about 500 MHz vertical polarization and 900 MHz horizontal polarization).

See Annex C for alternate antenna characterization.

5.1.4 Accuracy

The measurement system consisting of the antenna, transmission line and the measuring instrument, but excluding the source and the measuring site, shall measure electric field strength over the frequency range of 30 MHz to 1 000 MHz with an accuracy of ± 3 dB. See Clause 4 of CISPR 16-1-4. The frequency accuracy shall be better than ± 1 %.

NOTE 1 To ensure that the measurements defined in this standard are within the stated tolerances, consideration should be given to all pertinent characteristics of measuring equipment (for example, frequency and amplitude stability, image rejection, cross-modulation, overload levels, selectivity, time constants, and signal/noise ratio), as well as those affecting the antenna and transmission line.

NOTE 2 It is reasonable to expect additional variations in measurements made of an electric field (see C.13) within the range of 30 MHz to 1 000 MHz. These are caused by variations in ground conductivity and other factors influencing repeatability.

5.2 Measuring location requirements

5.2.1 Outdoor test site (OTS) requirements

5.2.1.1 OTS for vehicles and devices

The test site shall be a clear area, free from electromagnetic reflecting surfaces within a circle of minimum radius 30 m measured from a point midway between the vehicle or device and the antenna. As an exception, the measuring equipment, and test hut or vehicle in which the measuring equipment is located (when used) may be within the test site, but only in the permitted region indicated by the crosshatched area of Figure 4.

NOTE The site requirements defined in 5.2.1.1 and Figure 4 are the application of CISPR 16-1-4 to large automotive objects.

Vehicles and devices smaller than 2 m in length and width may be tested on an OTS with dimensions corresponding to CISPR 16-1-4, Figures 2 or 3.

5.2.1.2 OTS for boats

The test site shall be a clear area free from electromagnetic reflecting surfaces within a circle of minimum radius 30 m measured from a point midway between the engine under test and the antenna. Exceptions for the measuring equipment are specified in 5.2.1.2.1 and also in 5.2.1.2.2. As an exception, the measuring equipment may be within the test site, but only in the permitted region indicated by the crosshatched area of Figure 5. The test hut or vehicle or non-metallic boat of test fixture in/on which the measuring equipment is located may be within the test site.

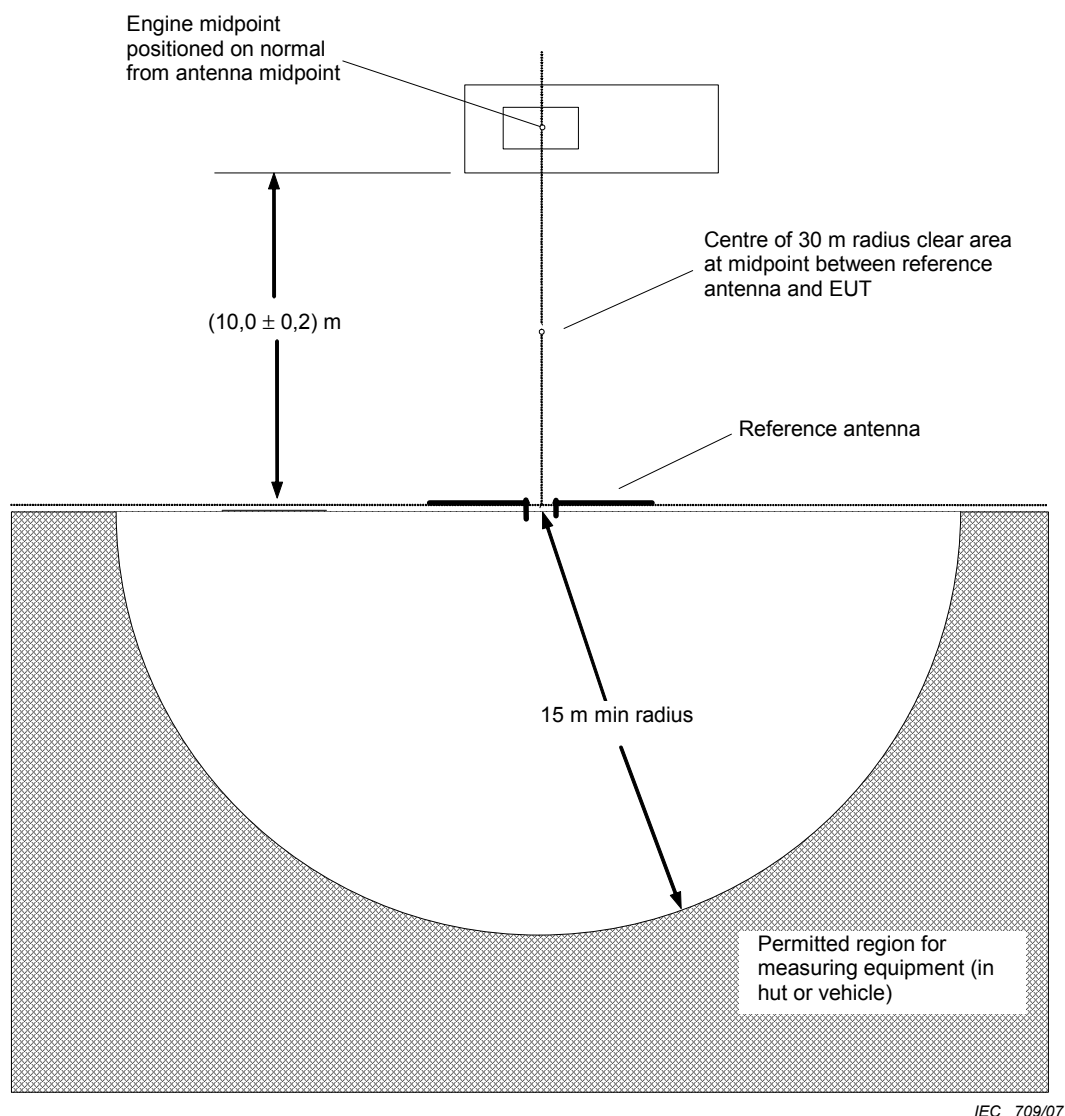
Boats or engines/motors for boats tested separately shall be tested in salt or fresh water at a measuring site as shown in Figure 5.

5.2.1.2.1 Land-based measuring equipment

When the measuring equipment is on land, the test hut or vehicle in which the measuring equipment is located may be within the test site, but only in the permitted region indicated by the cross-hatched area of Figure 5.

5.2.1.2.2 Water-based measuring equipment

The measuring equipment shall be installed in a non-metallic boat or non-metallic test fixture which may be within the test site, but only within the permitted region indicated by the cross-hatched area of Figure 5.



NOTE The 10,0 m ± 0,2 m dimension may be changed to 3,00 m ± 0,05 m in accordance with 5.2.3.2 and 5.2.3.4.

Figure 4 – Measuring site (OTS) for vehicles and devices

5.2.1.3 Ambient requirements

To ensure that there is no extraneous noise or signals of sufficient magnitude or density to affect materially the vehicle measurement, ambient measurements shall be taken before and after the main test, but without the vehicle/boat/device under test running. In both of these measurements, the ambient noise shall be at least 6 dB below the limits of disturbance given in Clause 4, excluding intentional radiators. When assessing compliance in accordance with Clause 6 any emission exceeding the limits shall require investigation to ensure that they are not attributable to the vehicle/boat/device in order to be excluded.

NOTE For further guidance, see 5.4 of CISPR 16-1-4.

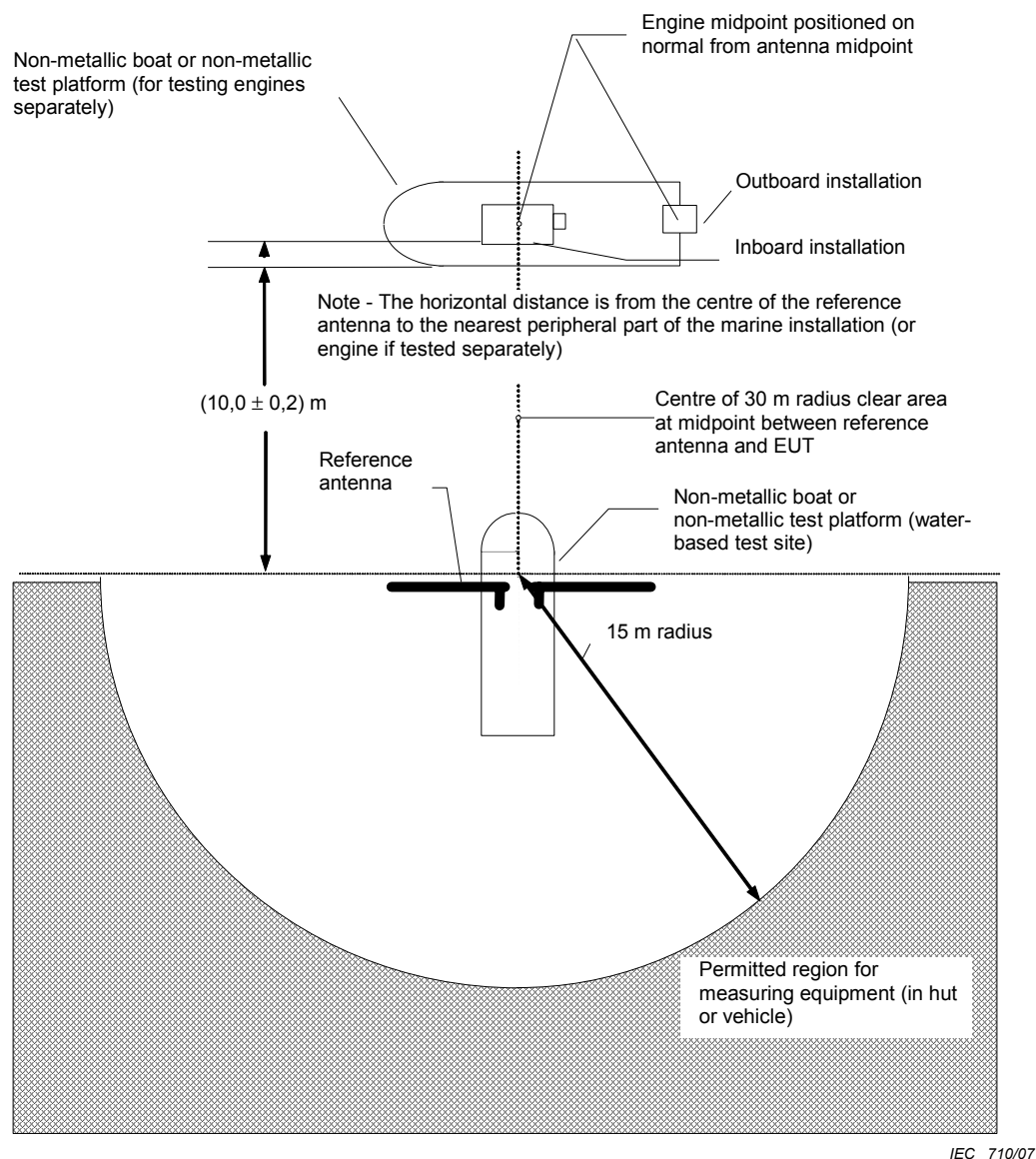


Figure 5 – Measuring site (OTS) for boats

5.2.2 Absorber lined shielded enclosure (ALSE) requirements

5.2.2.1 Correlation

Absorber lined shielded enclosures may be used provided that the results obtained can be correlated with those obtained using the OTS described in 5.2.1.

NOTE Such chambers have the advantages of all weather testing, controlled environment and improved repeatability because of stable chamber electrical characteristics.

5.2.2.2 Ambient requirements

The ambient noise level shall be at least 6 dB below the limits of disturbance given in Clause 4. The ambient level shall be verified periodically or when test results indicate the possibility of non-compliance.

5.2.3 Antenna requirements

At each measurement frequency (including the end frequencies), measurements shall be taken for horizontal and vertical polarization (see Figures 6 and 7).

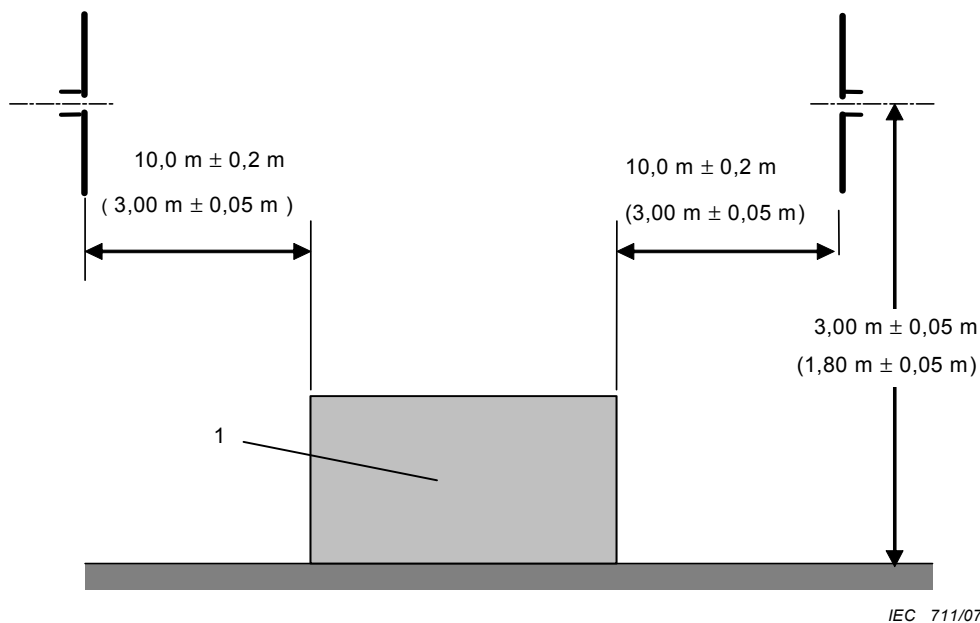
Electrical interaction between the antenna elements and the antenna support/guy system shall be avoided.

Theoretical considerations of antenna and transmission line geometry demand that the transmission line does not interact electrically with the antenna elements.

NOTE One acceptable transmission line geometry for a dipole antenna routes the transmission line horizontally rearward for a distance of 6 m at a height of 3 m (or 1,8 m for the 3 m antenna distance) before descending to ground level or below. Other geometries are acceptable if they can be shown not to affect the measurements, or if the effects can be included in equipment calibration.

5.2.3.1 Height

For an antenna distance of 10 m, the centre of the antenna shall be $3,00\text{ m} \pm 0,05\text{ m}$ above the ground/floor or water surface. For an antenna distance of 3 m, the height shall be $1,80\text{ m} \pm 0,05\text{ m}$.



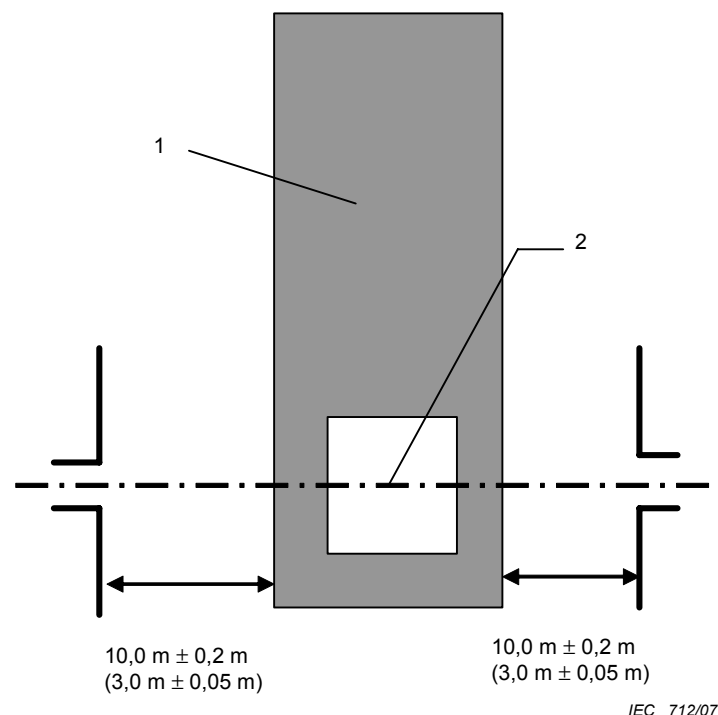
(Dimensions in brackets for 3 m antenna distance testing)

Drawing not to scale

Key

1 Equipment under test

Figure 6 – Antenna position to measure emissions – Vertical polarization



(Dimensions in brackets for 3 m antenna distance testing)

Drawing not to scale

Key

- 1 Equipment under test
- 2 Engine midpoint positioned on normal from antenna midpoint

Figure 7 – Antenna position to measure emissions – Horizontal polarization

5.2.3.2 Distance

The preferred horizontal distance between the reference point of the antenna and to the nearest metal part of the vehicle/boat/device shall be $10,0 \text{ m} \pm 0,2 \text{ m}$; as an alternative measurements may be made at a distance of $3,00 \text{ m} \pm 0,05 \text{ m}$, provided that the requirements of 5.2.3.4 are met.

5.2.3.3 Auxiliary (multiple) antennas

Auxiliary antennas are permitted, but if two antennas are facing each other, one shall be vertically polarized while the other is horizontally polarized.

The test site clear area requirement of 5.2.1.1 shall be applied also to the point midway between the vehicle/boat/device and the auxiliary antenna(s).

5.2.3.4 Multiple antenna positions (3 m antenna distance only)

Multiple antenna positions are required if the length of the vehicle or device is greater than the 3 dB beamwidth of the antenna. The same positions shall be used for both horizontal and vertical polarization measurements.

Multiple antenna positions can be avoided in the case where the measured emissions are lower than the original limit values minus a gain reduction calculated from the geometric dimensions of the test set-up and the antenna gain data (see Annex B).

NOTE A typical log periodic antenna has a 3 dB beamwidth of approximately 60°. This results in about 3,5 m of illumination at 3 m antenna distance, e.g. 1,75 m either side of the antenna centreline. Thus, a vehicle 8 m long requires three antenna positions on each side to quantify the radiation signature of that vehicle.

5.3 Test object conditions

5.3.1 General

Measurements made while the vehicle/boat/device is dry or made more than 10 min after precipitation has stopped falling are preferred. For outboard engines or propulsion motors and devices, all surfaces normally in contact with water while in use shall be exempt from the dryness criteria.

NOTE Dew or light moisture may seriously affect readings obtained on test objects having plastic enclosures.

For methods of evaluating compliance based on test object dryness see Clause 6.

5.3.2 Vehicles and boats

Measurements shall be made on the left and right sides of the vehicle or boat (see Figures 6 and 7).

All equipment which is automatically switched on together with the propulsion system shall be measured while operating in a manner which is as representative of normal operation as possible. The engine shall be at normal operating temperature.

For vehicles or boats with independent electric and internal combustion propulsion systems in the same vehicle or boat, the propulsion systems shall be tested separately.

Auxiliary engines shall be operated in their normal intended manner and tested separately from the main engine, if possible.

Depending upon the location of auxiliary engines, this requirement may dictate multiple tests of the vehicle or boat with the several engines successively positioned in front of the antenna during successive tests.

When tested separately, inboard, stern drive, and outboard engines or propulsion motors for boats shall be attached to a non-metallic board or non-metallic test fixture and tested in a way similar to that specified for boats with inboard engines/motors.

Measurements shall be made for two different operating conditions of vehicles and boats.

- "Key-On, Engine-Off" mode, and
- "Engine-Running" mode

These two operating conditions are applicable for vehicles/boats with an internal combustion engine and/or equipped with an electric propulsion motor (including hybrid propulsion systems)

5.3.2.1 "Key-On, Engine-Off" mode operating conditions

The "Key-On, Engine-Off" mode operating conditions are

- The ignition switch shall be switched on.
- The engine shall not be operating.
- The vehicle's electronic systems shall all be in their normal operating mode.

All equipment with internal oscillators >9 kHz or repetitive signals, which can be operated continuously, should be in normal operation.

5.3.2.2 "Engine-Running" mode operating conditions

Vehicles/boats with an internal combustion engine, shall be tested with the engine operated as shown in Table 3. The specified engine speed is the same for quasi-peak or peak measurements.

Table 3 – Internal combustion engine operating speeds

Number of cylinders	Engine speed min ⁻¹ ± 10 %
1	2 500 r/min
>1	1 500 r/min

Vehicles/boats equipped with an electric propulsion motor shall be tested with the vehicle driven on a dynamometer without a load, or on non-conductive axle stands, with a constant speed of 40 km/h, or the maximum speed, if this is less than 40 km/h

Vehicles with hybrid propulsion systems shall be tested with both the electrical and the internal combustion propulsion systems functioning to operate the vehicle at 40 km/h. If this is not possible, the vehicle shall be tested with the internal combustion engine operating at the speed defined in Table 3 and the electric propulsion system operating the vehicle at 40 km/h or the maximum speed if this is less than 40 km/h.

5.3.3 Devices

Measurements shall be made in normal operation position(s) and height(s), under normal full load and without load at idle speed, and in the direction of the maximum disturbance emission. Where practical, the device under test shall be measured in three orthogonal planes.

The operating conditions for devices ("Key-On, Engine-Off" mode and "Engine-Running" mode) shall be defined in the test plan.

Depending on the situation, the following conditions shall also be taken into account:

- if the operating position and height are variable, the device to be tested shall be so positioned that the spark-plug is 1,0 m ± 0,2 m above the ground;
- no operator shall be present, but, if necessary, a mechanical arrangement shall be made, using non-metallic material as far as possible, to keep the device in normal position(s) and at the specified engine speed.

5.4 Data collection

The entire required frequency range shall be measured. Spot frequency testing is only acceptable as used in 6.6, or for type approval purposes if the results of prior measurements covering the entire frequency range are available and prove compliance.

The results of average, quasi-peak and peak measurements shall be expressed in terms of dB ($\mu\text{V/m}$) for statistical evaluation.

The results of peak measurements shall be expressed in accordance with one of the bandwidths shown in Figure 2.

For peak detector measurements, the limits given in Figure 2 may be related to bandwidths other than 120 kHz or 1 MHz by adding a correction factor of $20 \lg [\text{bandwidth (kHz)}/120 \text{ kHz}]$ or $20 \lg [\text{bandwidth (MHz)}/1 \text{ MHz}]$.

6 Methods of checking for compliance with CISPR requirements

6.1 General

Some differences in the construction of vehicles/boats/devices are unlikely to have a significant effect on ignition noise emissions. For road vehicles, examples of such differences are given in Annex D.

6.2 Application of limit curves

6.2.1 Measurements under dry conditions

Certification measurements made while the vehicle/boat/device is dry (see 5.3.1), or made more than 10 min after the precipitation has stopped falling shall use the limit curves shown in Figures 2 and 3.

6.2.2 Measurements under wet conditions

If circumstances dictate that type approval measurements be made while precipitation is falling, or within 10 min after it has stopped, the vehicle/boat/device shall be deemed to comply with the requirements of this standard if the measured levels do not exceed a level of 10 dB below that shown in Figures 2 and 3.

In the event of any dispute concerning compliance, it shall be resolved by carrying out measurements under dry conditions.

Compliance based on good-faith wet measurements (and with the performance penalty mentioned above) shall remain valid until such time as it may be contested and dry measurements prove non-compliance. In such cases retrofitting of vehicles/boats/devices sold during the period when there was deemed compliance shall not be required.

When compliance is deemed on the basis of wet measurements, particular attention shall be paid to the surveillance of series production.

6.3 Evaluation (general)

For evaluation of a vehicle/boat/device the data from a complete scan shall be used.

For statistical analysis of multiple vehicles/boats/devices, the characteristic levels and calculation process of Annex A shall be used. The levels shall be compared to the limit at the representative frequency for the appropriate sub-band.

Statistical analysis of peak data from multiple vehicles/boats/devices shall be performed using data related to the same measurement bandwidth.

6.4 Type approval test

Compliance with the requirements given in Clause 4 shall be checked as follows:

6.4.1 Single sample

Measurements may be made on a prototype vehicle/boat/device of a later production series. The results shall be at least 2 dB below the limits specified in Clause 4.

6.4.2 Multiple samples (optional)

If optional multiple samples are tested, five or more additional vehicles/boats/devices shall be tested and the results combined with the data from the first test in 6.4.1. The result for each frequency sub-band shall be below the specified limits of Clause 4 at the representative frequency for that sub-band (see 6.3).

6.5 Surveillance (quality audit) of series production

6.5.1 Single sample

The results of the measurements on one vehicle/boat/device shall be a maximum of 2 dB above the specified limits of Clause 4.

6.5.2 Multiple samples (optional)

If optional multiple samples are tested, five or more additional vehicles/boats/devices shall be tested and the results combined with the data from the first test in 6.5.1. The results for each frequency sub-band shall be evaluated statistically, as described in Annex A; the result for each frequency sub-band shall be a maximum of 2 dB above the specified limit of Clause 4 at the representative frequency for that sub-band (see 6.3).

6.6 Quick prototype check for development testing (optional, quasi-peak detector emissions only)

An optional test using spot frequencies may be made to evaluate the approximate levels of emission of the vehicle/boat/device to determine whether the levels are likely to meet the limit of Clause 4. The spot frequencies to be used for specific measurements are the representative frequencies given in Annex A.

Annex A (normative)

Statistical analysis of the results of measurements

A.1 Number of vehicles/boats/devices

The following condition shall be fulfilled in order to ensure, with an 80 % degree of confidence, that 80 % of mass-produced vehicles/boats/devices conform to a specified limit L :

$$\bar{x} + kS_n \leq L \quad (\text{A.1})$$

where

$\bar{x}$ is the arithmetical mean of the results on n vehicles/boats/devices.

$$\bar{x} = \frac{1}{n} \left(\sum_{i=1}^n x_i \right) \quad (\text{A.2})$$

where

x_i is the individual result

k is the statistical factor dependent on n , as given by Table A.1

Table A.1 – Statistical factors

n	6	7	8	9	10	11	12
k	1,42	1,35	1,30	1,27	1,24	1,21	1,20

S_n is the standard deviation of results on n assembly line units.

$$S_n^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2 \quad (\text{A.3})$$

S_n , x_i , $\bar{x}$ and L are expressed in identical logarithmic units (e.g. dB (μV/m), dB (μV), etc.).

If a first sample of n vehicles/boats/devices does not meet the specifications, a second sample of N vehicles/boats/devices shall be tested and all results assessed as coming from a sample of $n + N$ vehicles/boats/devices.

NOTE See CISPR 16-3 for a more comprehensive discussion of statistical theory and application.

A.2 Frequency sub-bands for analysis

For analysis, the frequency range of 30 MHz to 1 000 MHz shall be divided into a minimum of 14 bands with approximately three bands in each octave (2:1 frequency ratio). For the regions where the limit is not constant (i.e. slopes), the ratio of the highest frequency to lowest frequency in each band shall be no greater than 1,34. See Table A.2 for an example of sub-bands.

A.3 Data collection

Each sub-band shall be scanned to determine its maximum emission level (i.e. the characteristic level). The characteristic levels for each sub-band shall be compared to the limit at the representative frequency for that sub-band, as determined by the methods of Clause 6.

Table A.2 – Example of frequency sub-bands

Frequency sub-band MHz	Representative frequency MHz
30 to 34	32
34 to 45	40
45 to 60	55
60 to 80	70
80 to 100	90
100 to 130	115
130 to 170	150
170 to 225	200
225 to 300	270
300 to 400	350
400 to 525	460
525 to 700	600
700 to 850	750
850 to 1 000	900

Annex B (normative)

Procedure to determine an alternative emission limit for measurements at 3 m antenna distance

B.1 Calculate the maximum antenna angle $\alpha_{\max.}$ = maximum (α_{right} ; α_{left}) from the vehicle dimensions, the antenna distance (vehicle surface – antenna reference point), and the antenna position (see Figure B.1).

Example: $d = 3$ m, vehicle length = 5 m, antenna centre line 1 m behind the front bumper, $\rightarrow$ $\alpha_{\max.} = 53^\circ$.

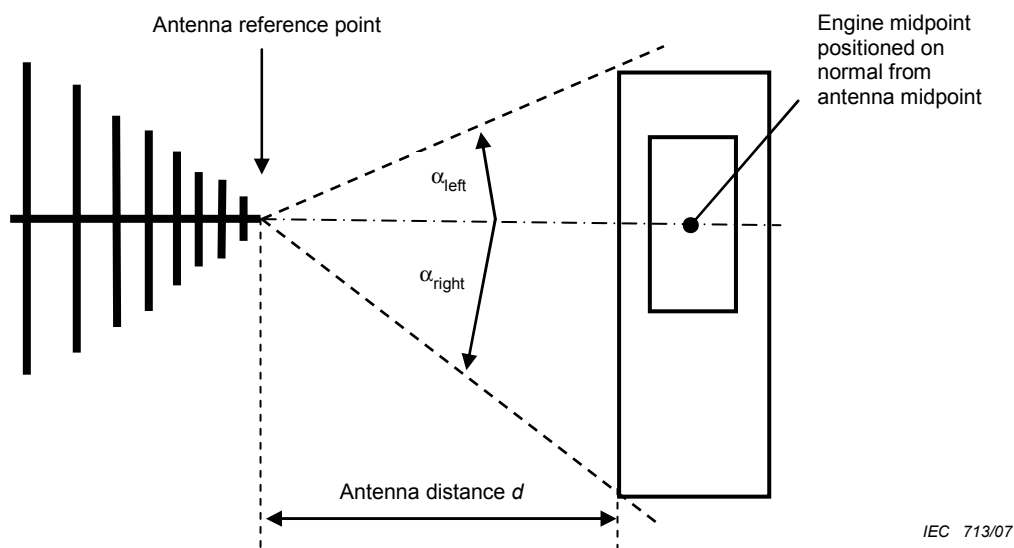


Figure B.1 – Determination of the maximum antenna angle

B.2 Read from the antenna directional pattern the gain reduction $a_{\max}$ at the maximum antenna angle $\alpha_{\max}$ (see Figure B.2).

Because antennas have a frequency dependent gain, either the maximum gain reduction over the whole frequency range (typically at the highest frequency) has to be used or the gain attenuation shall be determined for a number of frequency steps. In each of those frequency sub-bands the local maximum gain reduction shall be used.

Example: for a log-periodic antenna (80 MHz to 1 000 MHz) and $\alpha_{\max} = 53^\circ$ this leads to $a_{\max} = 7$ dB.

NOTE 1 Reference for the gain is the reference antenna (see 5.1.3.1)

NOTE 2 The radiation pattern provided from the manufacturer can be used unless visible damage of the antenna can be observed.

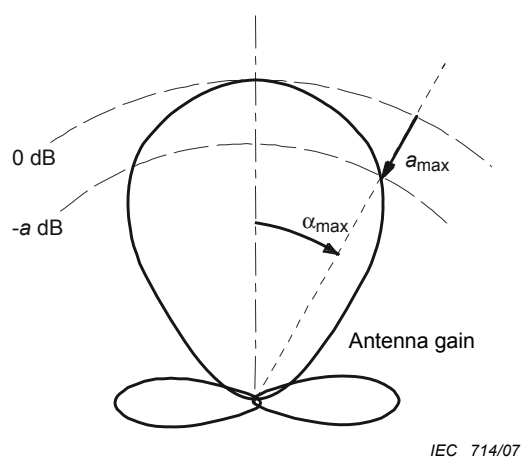


Figure B.2 – Calculation of the resulting gain reduction a

B.3 Calculate the alternative emission limit by subtracting from the original limit line the absolute value of the maximum gain reduction $a_{\max}$ calculated according to B.2.

Annex C (informative)

Antenna and transmission line maintenance and characterization

C.1 Introduction

This annex contains, for guidance, an example of an antenna and transmission line characterization procedure that complies with the intent of 5.1.2. Proper antenna and transmission line characterization is essential to account for transmission line loss and mismatch errors, and to define the antenna factor for a broadband antenna, if used. Because coaxial cables used for transmission lines are subject to much wear and possible abuse, a suggested procedure is included to be used when cables require replacement.

This report is intended to be tutorial in nature, as an aid for those who may not be familiar with antenna and transmission line characterization. Other methods, such as those using tracking generators, network analysers, or narrowband signal sources may be equally satisfactory and nothing in this annex should be interpreted as precluding their use.

C.2 Maintenance

Characterization of antennas and cables as a combination or individually is at the option of the user. It is highly recommended, however, that they be characterized separately because:

- frequently, antennas are supplied without cables;
- any cable may be used with any antenna without need for characterization of the combination;
- cables are easier to characterize than antennas and almost any test facility can characterize them. Some laboratories may not be able to characterize complex antennas with their associated transmission lines easily;
- either the antenna or cable can be modified or replaced without need to characterize the other.

C.2.1 Periodic checks required

C.2.1.1 Cables

Checks should be made monthly, contingent upon whether the cables are handled or flexed frequently, or if they are exposed to sun and weather for long periods.

NOTE Even cables in conduits can develop problems, if temperature and humidity are uncontrolled.

C.2.1.2 Antennas

Because they are subject to less wear than cables, antennas may be checked less frequently, possibly only once or twice per year.

C.2.1.3 Physical examination

C.2.1.3.1 Cables

Serious kinks (very sharp bends), flat spots, abrasions, stretched spots, damaged connectors/braid, contamination of the inner insulation, or ageing of the cable shall require replacement and characterization.

C.2.1.3.2 Antennas

Broken elements or other obvious mechanical problems shall be corrected or parts replaced. Characterization is required.

C.2.1.4 Electrical examination

Antennas and cables shall be checked for higher loss and other problems periodically. If a characteristic such as loss has changed, the antenna, the cable, or the combination shall be characterized. Severe changes in characteristics may require replacement and characterization.

C.2.2 Cable and antenna characterization

The following requirements apply when the transmission line cable or antenna is replaced:

C.2.2.1 If the antenna factor data contains the loss and other characteristics of a specific cable in combination with the antenna, they shall be considered a matched pair. If either is replaced, the combination shall be characterized.

C.2.2.2 If the antenna and cable have been characterized separately with separate losses, etc. replacement of either shall require characterization only of that portion replaced.

C.3 Antenna characterization

Electric field strength shall be expressed in units of dB ($\mu\text{V}/\text{m}$). The relationship expressing electric field strength to the measurement system is:

$$F = R + AF + T \quad (\text{C.1})$$

where

F is the electric field strength in dB ($\mu\text{V}/\text{m}$);

R is the instrument reading in dB (μV);

AF is the antenna factor in dB (1/m), defined in Clauses C.5 or C.6.;

T is the transmission line factor in dB, defined in Clause C.7.

For broadband measurements, F and R are a function of the measuring instrument bandwidth.

C.4 Reference antenna

See 5.1.3.1.

C.5 Antenna factor

The factor relating the field strength at the reference point of the antenna to the loaded antenna terminal voltage (see Note 1) is called the antenna factor, designated AF , expressed in dB (1/m). The antenna factor shall include the effects of baluns, impedance matching devices, any mismatch losses, and operation outside the resonant frequency of the antenna.

NOTE 1 As this is a voltage ratio, the calculations to convert to decibels should be made using the factor of 20 lg of the ratio of the parameters.

NOTE 2 This factor is a function of frequency and is usually provided by manufacturers of resonant dipoles. Knowledge of the antenna factor for free space operation for resonant dipoles is sufficiently accurate for purposes of this international standard. Greater accuracy can be obtained by knowing the antenna factor for the particular resonant dipole being used in the test environment. A method for determining antenna factor is described in ANSI C63.5 (see C.14).

C.6 Alternate antennas

The antenna factor for the alternate antenna is the antenna factor for the reference antenna (resonant dipole) minus the gain (dB) of the alternate antenna relative to the reference antenna.

C.7 Transmission line

The transmission line factor (loss) shall be measured over the test frequency range. The factor is designated T and is:

$$T = 20 \lg \left(\frac{\text{input voltage}}{\text{output voltage}} \right) \text{ dB} \quad (\text{C.2})$$

NOTE It is recommended that the transmission line be double braided or solid shielded coaxial cable to achieve proper shielding. It is permissible that transmission line loss and mismatch errors be accounted for by including the cable in the measuring instrument calibration. When this is done, T is dropped from equation (C.1) for F .

C.8 Alternate antenna characterization instrumentation

The prime function of the characterization instrumentation is to provide a repeatable RF field for the comparison of an alternate antenna to the reference dipole antenna.

C.8.1 Characterization signal generator

A measuring instrument with a built-in tracking generator or a network analyser or a signal generator together with a measuring instrument shall be used for alternate antenna characterization.

The output of the characterization signal generator shall be known to within $\pm 1,0$ dB. The characterization signal generator shall be capable of creating an electric field at least 6 dB above the least measurable field strength of the measuring instrument. A value of at least 10 dB is preferred.

A less accurate characterization signal generator is the impulse generator.

NOTE 1 If a broadband impulse generator is used, it should be capable of producing an uniform spectrum to within $\pm 3,0$ dB in the frequency range 30 MHz to 1 000 MHz.

NOTE 2 Experience indicates that an impulse generator that has a nominal 100 dB ($\mu\text{V}/\text{kHz}$) level can produce a field of approximately 10 dB ($\mu\text{V}/\text{m}/\text{kHz}$) at the receiving antenna when a 10 dB impedance matching attenuator is used at the output of the generator. This field strength varies depending on transmitting antenna losses and radiation characteristics and on propagation anomalies. This approximate value is provided so that the antenna factor determination can be performed. It is then possible to estimate the required sensitivities and the tolerable losses in the measuring system.

C.8.2 Transmitting antenna

For ease in measurement and to assure freedom from variation caused by antenna adjustment, it is recommended that broadband antennas be used. Typical antennas are the biconical for 30 MHz to 200 MHz, and the log periodic for 200 MHz to 1 000 MHz.

C.9 Alternate antenna factor determination

If an alternate antenna (see Clause C.6) is used, the antenna factor shall be determined by a substitution technique in the intended test environment. The reference shall be the dipole (see Clause C.4). The radiated field to be measured for the substitution technique is generated by the transmitting antenna and the characterization signal generator as specified in Clause C.8.

NOTE Error factors associated with this procedure include non-linearity of the measuring instrument, influence of the surroundings on the reference antenna and possible change in location of the alternate antenna phase centre relative to that of the reference antenna.

C.10 Test geometry

The alternate antenna shall be located at its intended test position. When substitution occurs, the dipole shall be placed so that its reference point is placed at the precise place that the reference point for the alternate antenna normally occupies. The reference point of the antenna is defined as:

- the phase centre (mid-point) for a dipole antenna,
- the phase centre (mid-point) for a biconical antenna,
- the tip or any specific point along the longitudinal axis for an antenna with log-periodic elements (including biconilog antennas).

C.10.1 The transmitting antenna shall be 10 m in horizontal distance from the alternate antenna reference point in Figure C.1 (taking the place of the nearest vehicle periphery) and shall be 1 m high.

C.10.2 For the 3 m antenna distance, the transmitting antenna shall be 3 m in horizontal distance from the alternate antenna, as in Figure C.1.

C.11 Test procedure

The procedure to be used is to measure the reference field with the reference antenna positioned as in Clause C.10 to obtain a meter reading (usually voltage). Then the alternate antenna is substituted and a second reading is taken.