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Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy —

Part 1: **General principles and terminology**

Véhicules routiers — Méthodes d'essai d'un équipement soumis à des perturbations électriques par rayonnement d'énergie électromagnétique en bande étroite —

Partie 1: Principes généraux et terminologie

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Foreword

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

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

This fourth edition cancels and replaces the third edition (ISO 11452-1:2005) which has been technically revised. It also incorporates the Amendment ISO 11452-1:2005/Amd 1:2008.

ISO 11452 consists of the following parts, under the general title *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy*:

— *Part 1: General principles and terminology*

— *Part 2: Absorber-lined shielded enclosure*

— *Part 3: Transverse electromagnetic mode (TEM) cell*

— *Part 4: Harness excitation methods*

— *Part 5: Stripline*

— *Part 7: Direct radio frequency (RF) power injection*

— *Part 8: Immunity to magnetic fields*

— *Part 9: Portable transmitters*

— *Part 10: Immunity to conducted disturbances in the extended audio frequency range*

— *Part 11: Reverberation chamber*

Introduction

In recent years, an increasing number of electronic devices for controlling, monitoring, and displaying a variety of functions have been introduced into vehicle designs. It is necessary to consider the electrical and electromagnetic environment in which these devices operate.

Electrical and radio-frequency disturbances occur during normal operation of many items of motor vehicle equipment. They are generated over a wide frequency range with various electrical characteristics and can be distributed to on-board electronic devices and systems by conduction, radiation, or both. Narrowband signals generated from sources on or off the vehicle can also be coupled into the electrical or electronic system, affecting the normal performance of electronic devices. Such sources of narrowband electromagnetic disturbances include mobile radios and broadcast transmitters.

The characteristics of the immunity of components to radiated disturbances have to be established. The ISO 11452 series provides various test methods for the evaluation of component immunity characteristics. Not all test methods need be used for a given device under test (DUT). For example, stripline and transverse electromagnetic (TEM) cell test methods provide very similar exposure to the DUT. Only those tests necessary for replicating the use and mounting location of the DUT need to be included in the test plan. This will help to ensure a technically and economically optimized design for potentially susceptible components and systems.

The ISO 11452 series is not intended as a product specification and cannot function as one (see A.1). Therefore, no specific values for the test severity level are given.

Annex A of this part of ISO 11452 specifies a general method for functional performance status classification (FPSC), Annex B specifies Artificial Networks (AN), Artificial Mains Networks (AMN), and Asymmetric Artificial Networks (AAN), Annex C explains the principle of constant peak test level while Annex D describes an example for the design of a load simulator. Typical severity levels are included in an annex of each of the other parts of ISO 11452.

Protection from potential disturbances has to be considered as a part of total vehicle validation as described in ISO 11451, which covers vehicle test methods. Component test method described in the ISO 11452 series is to be performed prior to vehicle test. Due to the vehicle's shape, harness, and component location diversities, conformity to parts of ISO 11452 does not guarantee conformity to parts of ISO 11451. Nevertheless, the ISO 11452 series component tests are essential for giving a sufficient level of confidence before integration on vehicle(s).

Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy —

Part 1:
General principles and terminology

1 Scope

This part of ISO 11452 specifies general conditions, defines terms, gives practical guidelines, and establishes the basic principles of the component tests used in the other parts of ISO 11452 for determining the immunity of electronic components of passenger cars and commercial vehicles to electrical disturbances from narrowband radiated electromagnetic energy, regardless of the vehicle propulsion system (e.g. spark-ignition engine, diesel engine, electric motor).

The electromagnetic disturbances considered are limited to continuous narrowband electromagnetic fields. A wide frequency range (d.c. and 15 Hz to 18 GHz) is allowed for the immunity testing of the components in this and in the other parts of ISO 11452.

2 Normative references

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

CISPR 16-1-2; *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-2: Radio disturbance and immunity measuring apparatus — Ancillary equipment — Conducted disturbances; Edition 1.2*

3 Terms and definitions

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

3.1
absorber-lined shielded enclosure
shielded enclosure/screened room with radio-frequency-absorbing material on its internal ceiling and walls

Note 1 to entry: The common practice is for the room to have a metallic floor, but absorbing material may also be used on the floor.

3.2
amplitude modulation
AM
process by which the amplitude of a carrier wave is varied following a specified law, resulting in an AM signal

3.3
artificial mains network
AMN
network that provides a defined impedance to the EUT at radio frequencies, couples the disturbance voltage to the measuring receiver, and decouples the test circuit from the supply mains

Note 1 to entry: There are two basic types of AMN, the V-network (V-AMN) which couples the unsymmetrical voltages, and the delta-network which couples the symmetric and the asymmetric voltages separately. The terms line impedance stabilization network (LISN) and V-AMN are used.

Note 2 to entry: Network inserted in the power mains of the vehicle in charging mode and provides, in a given frequency range, a specified load impedance and which isolates the vehicle from the power mains in that frequency range.

3.4
artificial network
AN
network inserted in the supply lead or signal/load lead of apparatus to be tested which provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages and which can isolate the apparatus from the supply or signal sources/loads in that frequency range

Note 1 to entry: Network inserted in the d.c. power lines (low voltage and/or high voltage) of the DUT which provides, in a given frequency range, a specified load impedance and which isolates the DUT from the d.c. power supply in that frequency range.

3.5
asymmetric artificial network
AAN
network used to measure (or inject) asymmetric (common mode) voltages on unshielded symmetric signal (e.g. telecommunication) lines while rejecting the symmetric (differential mode) signal

Note 1 to entry: This network is inserted in the communication/signal lines of the vehicle in charging mode to provide a specific load impedance and/or a decoupling (e.g. between communication/signal lines and power mains).

3.6
bonded
grounded connection providing the lowest possible impedance (resistance and inductance) connection between two metallic parts with a d.c. resistance which shall not exceed 2,5 mΩ

Note 1 to entry: A low current (≤100 mA) 4-wire milliohm metre is recommended for this measurement.

3.7
broadband artificial network
BAN
device used in power, signal, and control lines that presents a controlled impedance to the DUT over a specified frequency range while allowing the DUT to be interfaced to its support system

3.8
bulk current
total amount of common mode current in a harness

3.9
compression point
input signal level at which the measurement system becomes non-linear, when the output value will deviate from the value given by an ideal linear system

3.10
coupling
means or device for transferring power between systems

[SOURCE: IEC 60050-726, modified]

3.11
current injection probe
device for injecting current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits

3.12
current (measuring) probe
device for measuring the current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits

[SOURCE: IEC 60050-161]

3.13
degradation (of performance)
undesired departure in the operational performance of any device, equipment, or system from its intended performance

Note 1 to entry: The term "degradation" also applies to temporary or permanent failure.

[SOURCE: IEC 60050-161]

3.14
dual directional coupler
four-port device consisting of two transmission lines coupled together in such a manner that a single travelling wave in any one transmission line will induce a single travelling wave in the other, the direction of propagation of the latter wave being dependent upon that of the former

[SOURCE: IEC 60050-726, modified]

3.15
electromagnetic compatibility
EMC
ability of equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbance to anything in that environment

[SOURCE: IEC 60050-161]

3.16
electromagnetic disturbance
any electromagnetic phenomenon which can degrade the performance of a device, equipment, or system, or adversely affect living or inert matter

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

[SOURCE: IEC 60050-161]

3.17
electromagnetic interference
EMI
degradation of the performance of equipment, transmission channel, or system caused by electromagnetic disturbance

Note 1 to entry: The English words "interference" and "disturbance" are often used indiscriminately.

[SOURCE: IEC 60050-161]

3.18
electromagnetic radiation
phenomenon by which energy in the form of electromagnetic waves emanates from a source into space; energy transferred through space in the form of electromagnetic waves

Note 1 to entry: By extension, the term “electromagnetic radiation” sometimes also covers induction phenomena.

[SOURCE: IEC 60050-161]

3.19
susceptibility
⟨electromagnetic⟩ inability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance

Note 1 to entry: Susceptibility is the lack of immunity.

[SOURCE: IEC 60050-161]

3.20
forward power
power supplied by the output of an amplifier or generator

3.21
function performance status
expected performance objectives for the function of the device under test subjected to the test conditions, agreed between the customer and the supplier which is specified in the test plan

3.22
ground (reference) plane
flat conductive surface whose potential is used as a common reference

[SOURCE: IEC 60050-161]

3.23
immunity (to a disturbance)
ability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161]

3.24
immunity level
maximum level of a given electromagnetic disturbance incident on a particular device, equipment, or system for which it remains capable of operating at a required degree of performance

[SOURCE: IEC 60050-161]

3.25
load simulator
physical device including real and/or simulated peripheral loads which are necessary to ensure DUT nominal and/or representative operation mode

3.26
narrowband emission
emission which has a bandwidth less than that of a particular measuring apparatus or receiver

[SOURCE: IEC 60050-161]

3.27
net power
forward power minus reflected power

3.28
polarization
property of sinusoidal electromagnetic wave or field vector defined at a fixed point in space by the direction of the electric field strength vector or of any specified field vector, when this direction varies with time

Note 1 to entry: The property may be characterized by the locus described by the extremity of the considered field vector.

[SOURCE: IEC 60050-726, modified]

3.29
portable transmitter
hand-held radio frequency communication device

Note 1 to entry: A portable transmitter could be a commercial device (e.g. cellular phone) or a simulated one.

3.30
pulse modulation
PM
process by which the amplitude of a carrier wave is varied following a specified law, resulting in a PM signal

3.31
reflected power
power reflected by the load due to impedance mismatch between RF source and the load

3.32
reverberation chamber
high quality factor shielded room (cavity) whose boundary conditions are changed via one or several stepped rotating tuners

Note 1 to entry: This results in a statistically uniform electromagnetic field.

3.33
shielded enclosure screened room
mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and external environment

[SOURCE: IEC 60050-161]

3.34
stripline
terminated transmission line consisting of two parallel plates between which a wave is propagated in the transverse electromagnetic mode to produce a specified field for testing purposes

3.35
transverse electromagnetic cell
TEM cell
enclosed system, often a rectangular coaxial line, in which a wave is propagated in the transverse electromagnetic mode to produce a specified field for testing purposes

[SOURCE: IEC 60050-161]

3.36
transverse electromagnetic mode
TEM mode
mode in which the longitudinal components of both the electric and magnetic field strength vectors are everywhere zero

[SOURCE: IEC 60050-726, modified]

3.37
tubular wave coupler
TWC
device to couple RF power to a harness or a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits

[SOURCE: IEC 60050-161]

3.38
voltage standing wave ratio
VSWR
ratio, along a transmission line, of a maximum to an adjacent minimum magnitude of a particular field component of a standing wave

Note 1 to entry: VSWR is expressed by the following formula:

$$\text{VSWR} = \frac{(1+r)}{(1-r)}$$

where r is the absolute value of the coefficient of reflection.

[SOURCE: IEC 60050-726]

4 General aim and practical use

The test methods, procedures, test instrumentation, and levels specified in the ISO 11452 series are intended to facilitate component specification for electrical disturbances by narrowband radiated electromagnetic energy. A basis is provided for mutual agreement between vehicle manufacturers and component suppliers intended to assist rather than restrict.

Certain devices are particularly susceptible to some characteristics of electromagnetic disturbance, such as frequency, severity level, type of coupling, or modulation.

Electronic devices are sometimes more susceptible to modulated, as opposed to unmodulated, radio-frequency (RF) signals. The reason is that high-frequency disturbances can be demodulated by semiconductors. In the case of unmodulated signals, this leads to a continuous shift of, for example, a voltage; in the case of amplitude-modulated signals, the resulting low-frequency fluctuations can be interpreted as intentional signals (e.g. speed information) and therefore disturb the function of the DUT more severely.

A single standard test might not reveal all the needed information about the DUT. It is thus necessary for users of ISO 11452 to anticipate the appropriate test conditions, select applicable parts of ISO 11452, and define function performance objectives. The main characteristics of each test method in ISO 11452-2 to ISO 11452-11 are presented in Table 1.

Table 1 — Main characteristics of test methods in ISO 11452

Part of ISO 11452 and subject	Applicable frequency range	Coupling to	Test severity parameter and unit	Provisions
ISO 11452-2 Absorber-lined shielded enclosure	80 MHz to 18 GHz	DUT and wiring harness	Electric field (V/m)	Absorber lined shielded enclosure required
ISO 11452-3 TEM cell	10 kHz to 200 MHz	DUT and wiring harness or DUT	Electric field (V/m)	DUT and/or wiring harness size limitation

Table 1 *(continued)*

Part of ISO 11452 and subject	Applicable frequency range	Coupling to	Test severity parameter and unit	Provisions
ISO 11452-4 Harness excitation methods	1 MHz to 3 GHz	Wiring harness	Current (mA) Power (W)	Shielded enclosure required
ISO 11452-5 Stripline	10 kHz to 400 MHz	Wiring harness and/or DUT	Electric field (V/m)	Shielded enclosure recommended: DUT size limitation
ISO 11452-7 Direct RF power injection	250 kHz to 400 MHz	Wiring harness	Power (W)	Influence of isolator on DUT sensor signals
ISO 11452-8 Immunity to magnetic fields	d.c. and 15 Hz to 150 kHz	DUT	Magnetic field (A/m)	
ISO 11452-9 Portable transmitters	26 MHz to 5,85 GHz	DUT and wiring harness	Power (W)	Absorber lined shielded enclosure recommended
ISO 11452-10 Immunity to conducted disturbances in the extended audio frequency range	15 Hz to 250 kHz	Wiring harness	Volt (peak to peak)	
ISO 11452-11 Reverberation chamber	LUF (lowest usable frequency) to 18 GHz	DUT and wiring harness	Electric field (V/m)	Shielded enclosure required

5 General test conditions

5.1 General

Unless otherwise specified, the following test conditions are common to all parts of ISO 11452:

— test temperature;

— supply voltage;

— modulation;

— dwell time;

— frequency step sizes;

— definition of test severity level;

— test signal quality.

Unless otherwise specified, the variables used shall have the following tolerances:

— ±10 % for durations and distances;

— ±10 % for resistances and impedances;

and the following magnitude accuracy:

— ±1 dB for power meter including power sensor;

— ±3 dB for field probe.

5.2 Test temperature

The ambient temperature during the test should be (23 ± 5) °C.

5.3 Supply voltage

5.3.1 Low Voltage (LV) power supply

LV is used for d.c. operating voltages below 60 V (e.g. 12 V, 24 V, 48 V). The supply voltage during the test shall be (13 ± 1) V for 12 V electrical systems and (26 ± 2) V for 24 V electrical systems.

5.3.2 HV d.c. power supply (excluding charger)

HV is used for operating voltages from 60 V to 1000 V d.c. The HV d.c. power supply voltage and tolerances shall be defined in the test plan.

5.3.3 Charger power supply (a.c. or d.c.) for HV battery

The d.c. power supply voltage during the test shall be nominal ±10%.

The a.c. power supply voltage during the test shall be nominal -15% +10%. The rated value of the frequency shall be nominal ±1%.

5.4 Modulation

The characteristics of the DUT determine the type and frequency of modulation to be used. If no values or specific modulation techniques are agreed between the users of the ISO 11452 series, the following modulations shall be used.

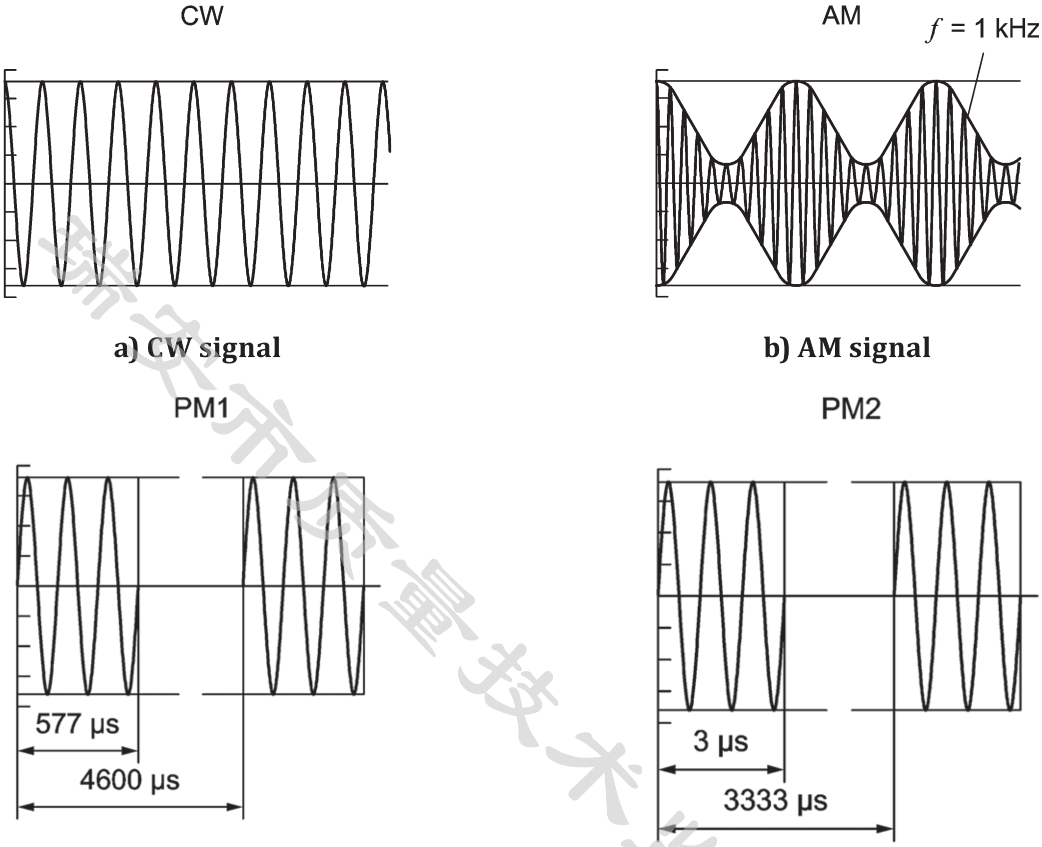
a) Unmodulated sine wave (CW): See Figure 1 a).

b) Sine wave amplitude modulated (AM) by 1 kHz sine wave at 80 % (modulation index m = 0,8): See Annex C and Figure 1 b).

c) Sine wave pulse modulated type 1 (PM, similar to GSM), with t_{on} = 577 µs and period = 4 600 µs: See Figure 1 c).

d) Sine wave pulse modulated type 2 (PM, similar to Radar), with t_{on} = 3 µs and period = 3333 µs: See Figure 1 d).

In practice, PM modulation should not be obtained using either the blanking of the amplifier or a 100 % (modulation index $m = 1$) AM modulation type.



a) CW signal

b) AM signal

c) PM type 1 signal

d) PM type 2 signal

Key

f frequency

Figure 1 — Modulation

The following modulations should be used for all applicable parts of ISO 11452:

— CW: 15 Hz to 18 GHz;

— AM: 10 kHz to 800 MHz;

— PM type 1: 800 MHz to 1,2 GHz and 1,4 GHz to 2,7 GHz;

— PM type 2: 1,2 GHz to 1,4 GHz and 2,7 GHz to 18 GHz.

5.5 Dwell time

At each frequency, the DUT shall be exposed to the test level for a time equal to the response time of the system. If a dwell time is not specified in the test plan, or system response time is not specified, then the dwell time shall be a minimum of 1 s.

5.6 Frequency step sizes

All tests in the ISO 11452 series shall be conducted with frequency step sizes (logarithmic or linear) not greater than those specified in Table 2. The step sizes agreed upon by the users of ISO 11452 shall be documented in the test report.

Table 2 — Maximum frequency steps sizes

Frequency band	Linear steps	Logarithmic steps
15 Hz to 100 Hz	10 Hz	10 %
> 100 Hz to 1 kHz	100 Hz	10 %
> 1 kHz to 10 kHz	1 kHz	10 %
> 10 kHz to 100 kHz	10 kHz	10 %
> 100 kHz to 1 MHz	100 kHz	10 %
> 1 MHz to 10 MHz	1 MHz	10 %
> 10 MHz to 200 MHz	5 MHz	5 %
> 200 MHz to 400 MHz	10 MHz	5 %
> 400 MHz to 1 GHz	20 MHz	2 %
> 1 GHz to 18 GHz	40 MHz	2 %

If it appears that the susceptibility thresholds of the DUT are very near to the chosen test level, these frequency step sizes should be reduced in the frequency range concerned in order to find the minimum susceptibility thresholds.

5.7 Definition of test severity levels

The user should specify the test severity level or levels over the frequency range. The concept of FPSC is detailed in Annex A. For both the substitution and closed loop levelling methods, and for tests with unmodulated and amplitude-modulated signals, the test severity levels of the ISO 11452 series (electric field, current, voltage, or power) are expressed in terms of the equivalent root-mean-square level value of the unmodulated wave.

Both these methods use a constant peak test level for tests with unmodulated and amplitude-modulated signals. The relationship between the mean power for the amplitude-modulated signal and the mean power for the unmodulated signal results from Formula (1) (see Annex C):

$$P_{AM} = \frac{\left(2+m^2\right)}{2\left(1+m\right)^2} P_{CW} \tag{1}$$

where

P_{AM} is the mean power for the amplitude-modulated signal;

P_{CW} is the mean power for the unmodulated signal;

m is the modulation index ($0 \le m \le 1$).

EXAMPLE A test severity level of 20 V/m means that the unmodulated and amplitude modulated tests will be conducted with a 28 V/m peak value.

5.8 Disturbance application

For disturbance application, see 7.2.4.

6 Instrumentation

6.1 Grounding and shielding

Establishing uniform measurement conditions at radio frequencies requires that specific grounding practices be followed.

The ground plane shall be made of copper, brass, or galvanized steel, and shall have a minimum thickness of 0,5 mm. The length and width shall be in accordance with the relevant part of ISO 11452.

No shielding shall be used other than that specified in the installation instructions.

6.2 AN, AMN, and AAN

The networks (AN, AMN, and AAN) to be used (when required by an individual test method) are defined in Annex B.

6.3 Power supply

6.3.1 LV power supply

The power supply shall have an internal resistance, R_S, of < 0,01 Ω dc and an internal impedance, Z_S, equal to R_S for frequencies ≤ 400 Hz. The output voltage shall not deviate more than 1 V from zero to maximum load (including inrush current) and shall recover 63 % of its maximum excursion within 100 μs. The superimposed ripple voltage, U_R, shall not exceed 0,2 V peak-to-peak and shall have a maximum frequency of 400 Hz.

If a standard power supply (with sufficient current capacity) is used in bench testing to simulate the battery, it is important that the low internal impedance of the battery also be simulated.

When a battery is used, a charging source is needed to achieve the specified reference levels.

Ensure that the charging source does not affect the test.

6.3.2 HV d.c. power supply (excluding charger)

The characteristics of the HV d.c. power supply shall be defined in the test plan.

6.3.3 Charger power supply (a.c. or d.c.)

The characteristics of the a.c. or d.c. power supply (excluding power mains) shall be defined in the test plan.

6.4 Load simulator

The design of the load simulator shall specifically take into consideration the following:

— load types (real or simulated) for I/O connected to the DUT;

— common mode impedance and/or differential mode impedance for each I/O connected to the DUT;

— internal wiring and layout.

All these parameters shall be chosen and agreed upon by the vehicle manufacturer and the equipment supplier.

NOTE An example of load simulator design and parameters is given in Annex D.

6.5 Test signal quality

In the frequency range limited by the bandwidth of both the amplifier and the antenna (transducer) in use, each amplifier output harmonic (up to the fifth harmonic) shall be limited to -12 dB (-6 dB for frequencies above 1 GHz) relative to the carrier wave, unless otherwise specified for a particular test method or in the test plan.

This characteristic shall be verified at least for the maximum used test level, with the amplifier output connected to the test transducer (antenna, TEM, injection probe, etc.).

NOTE When a specific part of ISO 11452 defines multiple polarizations test, the harmonics characteristics need only be verified for one polarization.

7 Test procedure

7.1 Test plan

Prior to performing the tests, a test plan shall be drawn up which shall include the following:

— DUT test severity levels;

— DUT monitoring conditions;

— frequency band(s);

— method(s) to be used;

— DUT mode of operation;

— DUT acceptance criteria;

— polarization;

— DUT orientation and grounding;

— antenna location;

— test report content;

— any special instructions and changes from the standard test.

NOTE Some of these items might not be applicable to all test methods.

7.2 Test methods

7.2.1 General

CAUTION — Hazardous voltages and fields can exist within the test area. Take care to ensure that the requirements for limiting the exposure of humans to RF energy are met.

The following two methodologies are used in certain parts of ISO 11452.

7.2.2 Substitution method

The substitution method is based upon the use of forward power as the reference parameter for calibration and testing. With this method, specific test level (electric field, current, voltage, or power) shall be calibrated prior to the actual testing of the DUT.

This method is carried out in two phases:

— calibration phase (without the DUT, wiring harness, and peripheral devices present);

— test of the DUT with wiring harness and peripheral devices connected.

During calibration both forward and reflected power shall be recorded.

7.2.2.1 Calibration

Calibration shall be performed in accordance with the requirements of each individual test method.

The specific test level shall be calibrated periodically by recording the forward power required to produce a specific test level, for each test frequency. This calibration shall be performed with an unmodulated sinusoidal wave.

The specific test level during calibration shall be within 0/+1 dB of the test severity level.

The method and results for each calibration shall also be documented in the test report.

7.2.2.2 DUT test

The test is conducted by subjecting the DUT to the test signals based on the calibrated values as predetermined in the test plan.

The test power required to achieve the test severity level shall be maintained at 0/+1 dB of P_{test} during the DUT test.

The test power (P_{test}) required to achieve the test severity level relative to the calibrated power (P_{cal}) can be determined 2 from Formula (2):

$$P_{test} = P_{cal} \left(\frac{L_{test}}{L_{cal}} \right)^{k} \tag{2}$$

where

P_{test} is the test power based on calibration (W);

P_{cal} is the calibrated power required to achieve test severity levels (W);

L_{test} is the test severity level;

L_{cal} is the calibrated test severity level;

k is a factor, equal to 1 for power test levels, and equal to 2 for electric field, current, or voltage test levels.

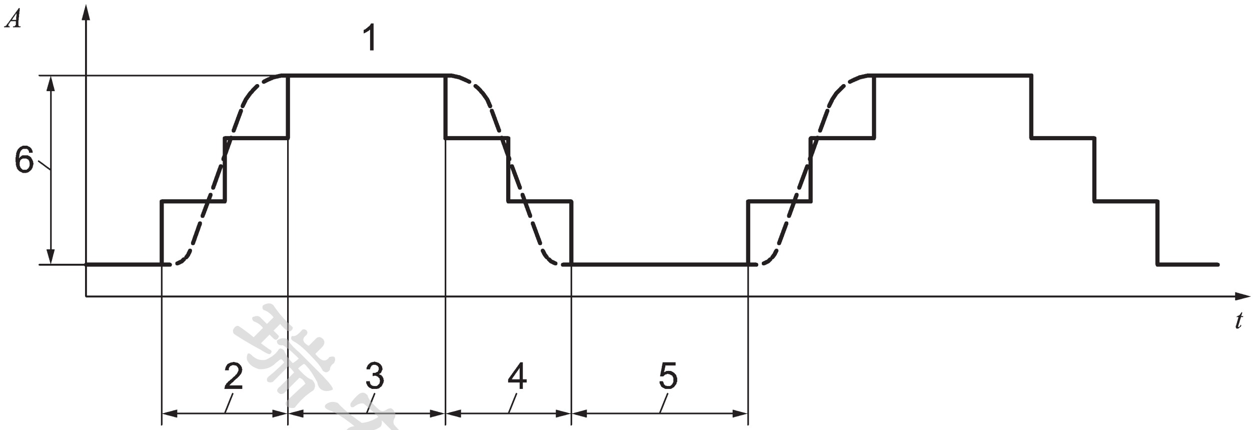
7.2.3 Closed loop levelling

During actual testing with the DUT, the test level (electric field, voltage, current, or power) is measured using a calibrated device and fed back to the signal generator in order to either increase or decrease the test level until the predetermined level is achieved.

The test level shall be within 0/+1 dB of the test severity level.

7.2.4 DUT immunity measurement

The disturbance signal may be maintained at the required test level during frequency transitions, provided the signal generation equipment is shown to be stable, or the disturbance signal level may be reduced before frequency transition using the procedure shown in Figure 2. The method chosen and the associated parameters shall be defined in the test plan.



Key

t time, seconds

1 specified signal level

2 signal rise time to be defined in test plan (levelling algorithm to avoid overshooting is test system-dependant)

3 dwell time (time of application ≥ 1 s)

4 signal fall time to be defined in the test plan

5 recovery time ≥ 0 s for DUT to be defined in test plan

6 reduction of test signal level for DUT recovery

Figure 2 — Example of disturbance application process

Users of ISO 11452 need to be aware of the following in order to ensure that the tests are carried out satisfactorily:

— systems could be susceptible only at intermediate interference levels;

— sudden application of interference could cause errors;

— generator switching transients could cause faults in the DUT.

The characteristics of the interference signal may be modified depending on the test level due to limitations in the signal generation procedure (depth of amplitude modulation, rejection of harmonics, etc.)

7.3 Test report

As required by the test plan, a test report shall be submitted detailing information regarding the DUT, temperature , test set-up, systems tested, supply voltage, frequencies, power levels, system interactions, and any other information relevant to the test.

Annex A
(normative)

Function Performance Status Classification (FPSC)

A.1 General

This Annex provides a general method for defining the acceptable performance of electrical/electronic functions of automotive electrical systems during and after components immunity test for electrical disturbances from narrowband radiated electromagnetic energy. This method is based on the following considerations.

a) DUT can include one or several functions (e.g. an electronic unit can manage front wiping, courtesy lighting, and low beam lighting).

b) Function can have one or several operating mode (e.g. low beam ON, low beam OFF, courtesy lighting ON, courtesy lighting OFF).

c) An operating mode can have several Status (I, II, III, IV) (e.g. in low beam ON operating mode, the Status II can be associated to low beam OFF during disturbance application with automatic recovery of low beam after disturbance suppression).

The functional performance status classification is applicable to each function.

A.2 FPSC approach

The approach is based on the following principles:

a) Functional performance status classification is applicable to each individual function. Hence, a DUT will likely include several functions (e.g. an electronic unit can manage front wiping, courtesy lighting, and low beam lighting)

b) A function can be a simple ON-OFF operation or be complex as data communication on a data bus.

It has to be emphasized that components or systems shall only be tested under the conditions, as described in the ISO 11452 series that represent the simulated automotive electromagnetic environments to which the devices would actually be subjected. This will help to ensure a technically and economically optimized design for potentially susceptible components and systems.

It should also be noted that this Annex is not intended to be a product specification and cannot function as one. It should be used in conjunction with a specific test procedure in the ISO 11452 series. Therefore, no specific values for the test signal severity level are included in this Annex since they should be determined by the vehicle manufacturers and component suppliers. Nevertheless, using the concepts described in this Annex and by careful application and agreement between manufacturer and supplier, this Annex can be used to describe the functional status requirements for a specific device. This can then, in fact, be a statement of how a particular device can be expected to perform under the influence of the specified test signals.

A.3 Essential elements of an FPSC

There are two elements, listed below, required to describe an FPSC.

A.3.1 Function performance status

This element defines the expected performance objectives for the function of the device under test subjected to the test conditions. The four function performance status of the function (expected behaviour of the function observed during test) are listed below.

NOTE This element is applicable to every single individual function of a DUT and describes the operational status of the defined function during and after a test.

The minimum functional status shall be given in each test. An additional test requirement may be agreed upon between supplier and vehicle manufacturer.

— **Status I**

The function performs as designed during and after the test.

— **Status II**

The function does not perform as designed during the test but returns automatically to normal operation after the test.

— **Status III**

The function does not perform as designed during the test and does not return to normal operation without a simple driver/passenger intervention such as turning off/on the DUT or cycling the ignition switch after the disturbance is removed.

— **Status IV**

The function does not perform as designed during and after the test and cannot be returned to proper operation without more extensive intervention such as disconnecting and reconnecting the battery or power feed. The function shall not have sustained any permanent damage as a result of the testing.

A.3.2 Test severity level

This element defines the specification of test severity level of essential signal parameters. The test severity level is the stress level applied to the device under test for any given test method. The test severity levels should be determined by the vehicle manufacturer and supplier depending on the required operational characteristics of the function.

A.4 FPSC approach example

A.4.1 General example of FPSC application

Figure A.1 demonstrates the relationship between the test signal severity levels (severity levels) and their corresponding function performance status classification.

Comments listed in Figure A.1 can be interpreted as follows:

— the function should be nominal event #1(Status I) up to severity level L1;

— unexpected events # 2 are allowed above test severity level L1;

— unexpected events # 3 are allowed above test severity level L2;

— unexpected events #4 are allowed above test severity level L3.

Users may group functions into categories to allow the use of different test levels.

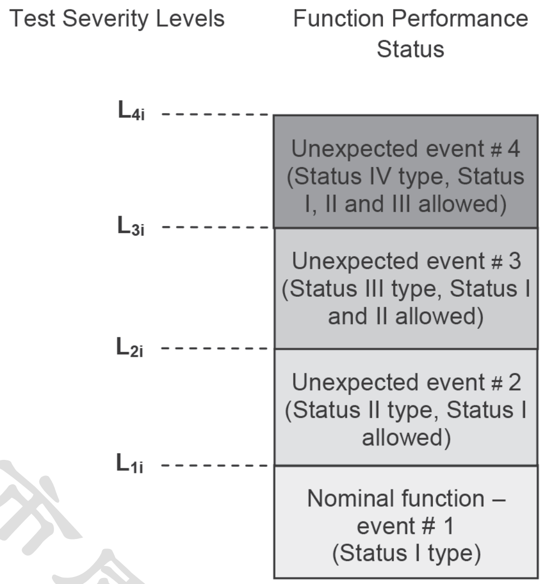


Figure A.1 — Illustration of Function Performance Status Classification

A.5 Classification of test severity levels

Examples of test severity levels are given in each part of ISO 11452.

Annex B
(normative)

Artificial networks (AN), artificial mains networks (AMN), and asymmetric artificial networks (AAN)

B.1 General

Currently, different types of power supplies and power supply cabling are used for a component powered by low voltage (LV) and/or high voltage (HV) and/or connected to the power grid (a.c. power mains, d.c. power supply). Therefore, it is necessary to use networks which provide specific load impedance and isolate the component from the power supply:

— artificial networks (AN): used for d.c. power supplies;

— artificial mains networks (AMN): used only for a.c. power mains;

— asymmetric artificial network (AAN): used only for communication lines.

B.2 Artificial networks (AN)

B.2.1 Component powered by LV

For a component powered by LV, a 5 µH/50 Ω-AN as defined in Figure B.1 shall be used.

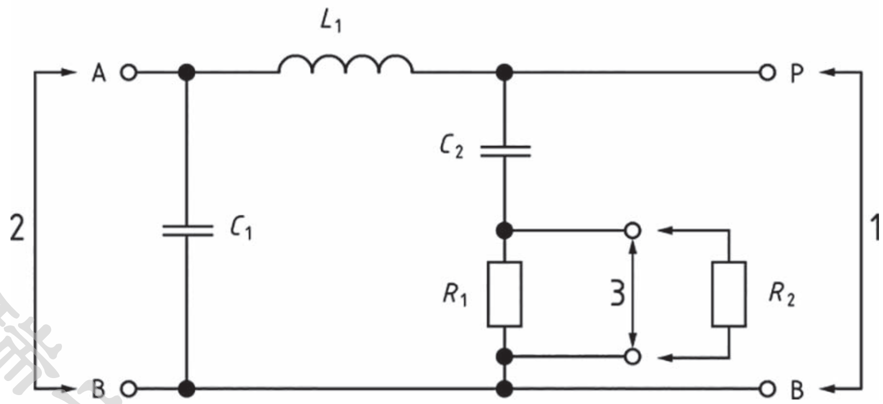
The AN(s) shall be mounted directly on the ground plane. The grounding connection of the AN(s) shall be bonded to the ground plane with a low inductivity connection.

Measurement ports of AN(s) shall be terminated with a 50 Ω load.

The AN magnitude impedance ZPB (tolerance ±20 %) in the measurement frequency range of 0,1 MHz to 100 MHz is shown in Figure B.2. It is measured between the terminals P and B (of Figure B.1) with a 50 Ω load on the measurement port with terminals A and B (of Figure B.1) short circuited.

NOTE 1 The AN phase impedance requirements are defined in CISPR 16-1-2, 4.4. If the phase requirement cannot be met, the measured phase angles can be taken into account in the uncertainty budget.

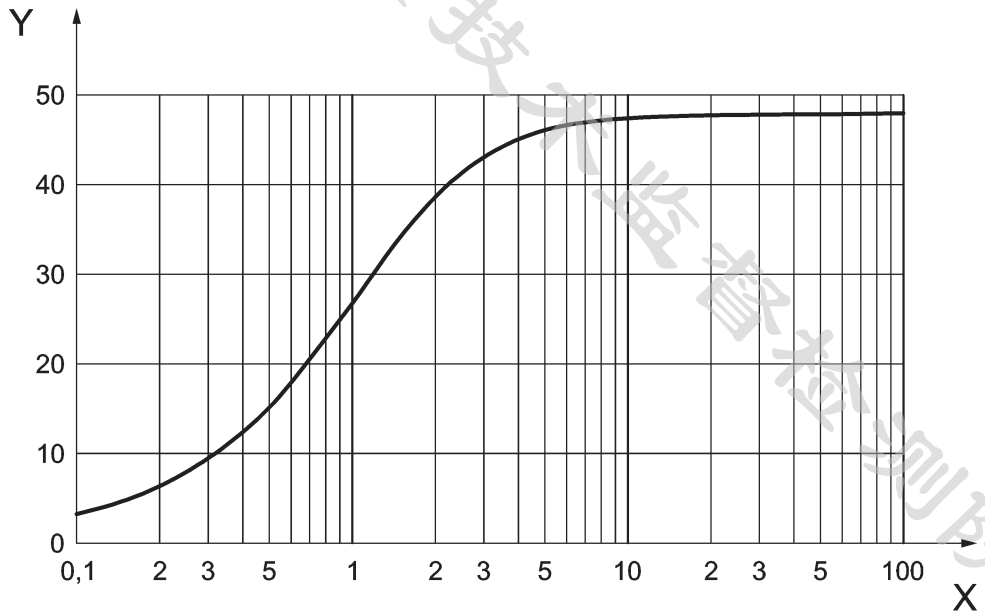
NOTE 2 The AN isolation (decoupling factor) requirements are defined in CISPR 16-1-2, 4.7.1.



Key

1	port for the DUT	C1	1 µF
2	power supply port	C2	0,1 µF
3	measurement port	R1	1 kΩ
L1	5 µH	R2	50 Ω

Figure B.1 — Example of 5 µH AN schematic



Key

X frequency (MHz)

Y impedance (Ohm)

Figure B.2 — Characteristics of the AN impedance

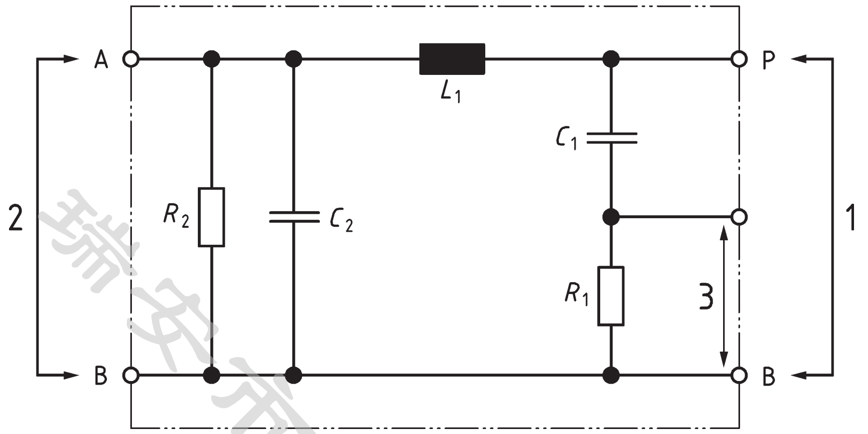
B.2.2 Component powered by HV

For a component powered by HV (e.g. 200 V to 1 500 V), a a 5µH/50Ω High Voltage Artificial Network (HV-AN) as defined in Figure B.3 shall be used.

The HV-AN(s) shall be mounted directly on the ground plane. The grounding connection of the HV-AN(s) shall be bonded to the ground plane with a low inductivity connection.

Measurement ports of HV-AN(s) shall be terminated with a 50 Ω load.

The HV-AN magnitude impedance ZPB (tolerance ±20 %) in the measurement frequency range of 0,1 MHz to 100 MHz is shown in Figure B.4. It is measured between the terminals P and B (of Figure B.3) with a 50 Ω load on the measurement port with terminals A and B (of Figure B.3) short circuited.



Key

1 port for the DUT

2 power supply port

3 measurement port

L_1 5 µH

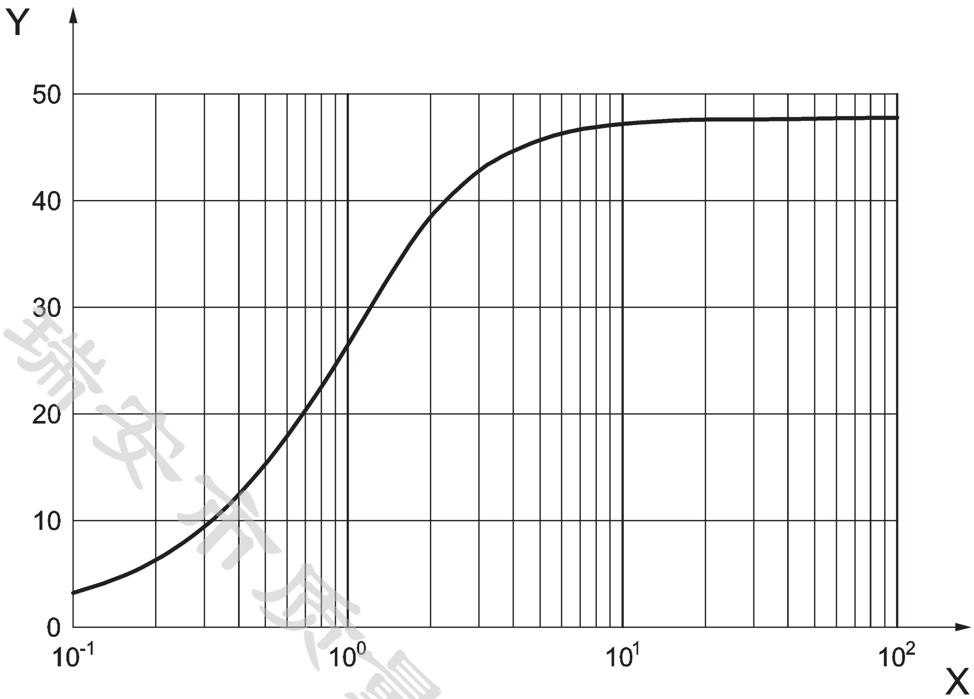
C_1 0,1 µF

C_2 0,1 µF

R_1 1 kΩ

R_2 1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

Figure B.3 — Example of 5 µH HV-AN schematic



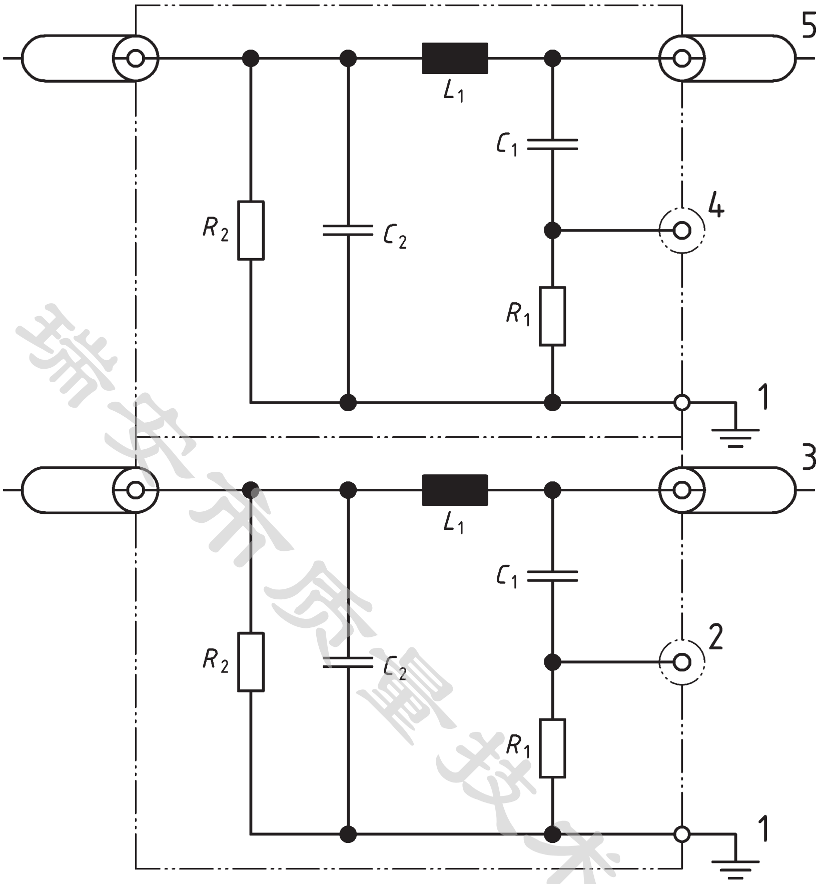
Key

X frequency (MHz)

Y impedance (Ohm)

Figure B.4 — Characteristics of the HV-AN impedance

If unshielded HV-ANs are used in a single shielded box, then there shall be an inner shield between the HV-ANs as described in Figure B.5.

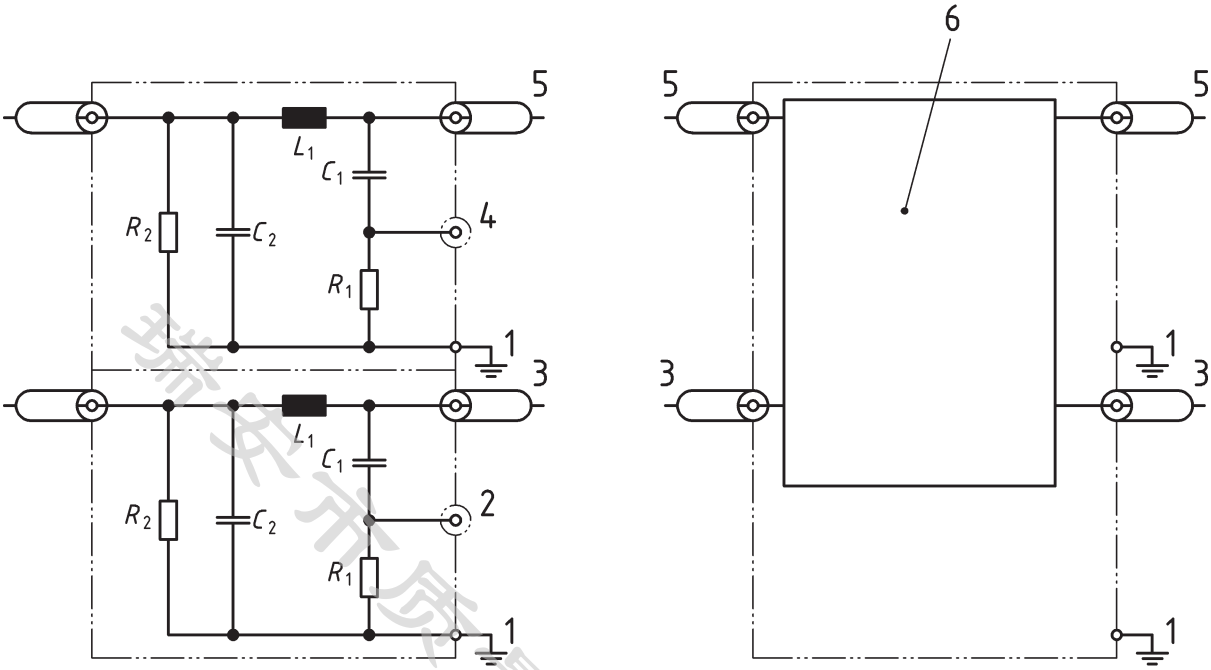


Key

1	ground	L_1	5 µH
2	measuring port HV-	C_1	0,1 µF
3	supply line HV-	C_2	0,1 µF
4	measuring port HV+	R_1	1 kΩ
5	supply line HV+	R_2	1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

Figure B.5 — Example of 5 µH HV-AN combination in a single shielded box

An optional impedance matching network may be used to simulate common mode/differential mode impedance seen by the DUT plugged on HV power supply (see Figure B.6). If used, this impedance matching network should be defined in the test plan.



Key

1	ground	L_1	5 µH
2	measuring port HV-	C_1	0,1 µF
3	supply line HV-	C_2	0,1 µF
4	measuring port HV+	R_1	1 kΩ
5	supply line HV+	R_2	1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)
6	differential & common mode impedance		

Figure B.6 — Impedance matching network attached between HV-ANs and DUT

B.2.3 Component involved in charging mode connected to d.c. power supply

For a component involved in charging mode (e.g. charger) connected to a d.c. power supply, a 5 µH/50 Ω-HV-AN as defined in B.2.2 shall be used.

B.3 Artificial mains networks (AMN)

For a component involved in charging mode (e.g. charger) connected to an a.c. power mains, a 50 µH/50 Ω-AMN as defined in CISPR 16-1-2, 4.3, edition 1.2 shall be used.

The AMN(s) shall be mounted directly on the ground plane. The grounding connection of the AMN(s) shall be bonded to the ground plane with a low inductivity connection.

Measurement ports of AMN(s) shall be terminated with a 50 Ω load.

B.4 Asymmetric artificial networks (AAN)

Currently, different types of communication system and communication cabling are used for the communication between charging station and component (e.g. charger). Therefore, a distinction between some specific cabling/operation types is necessary.

The AAN(s) shall be mounted directly on the ground plane. The grounding connection of the AAN(s) shall be bonded to the ground plane with a low inductivity connection.

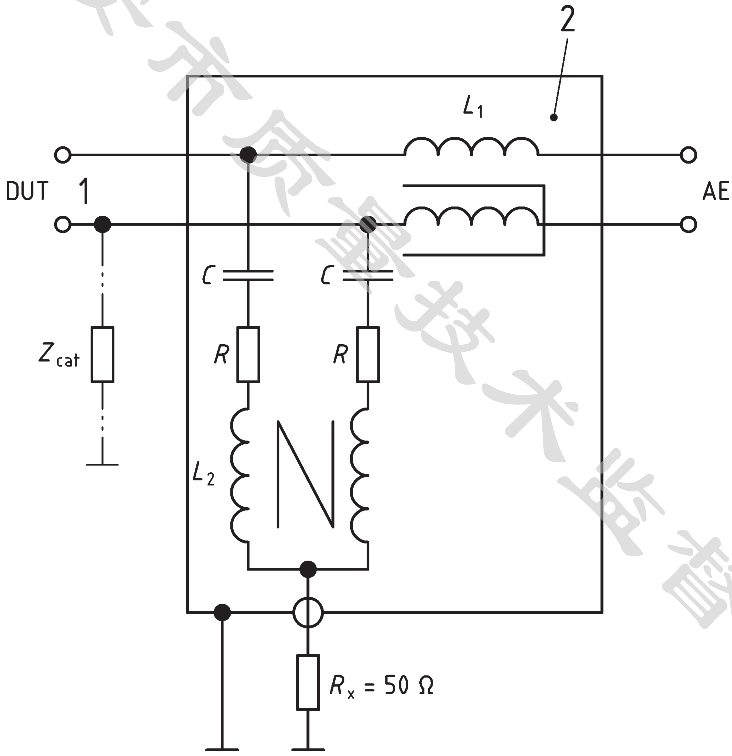
Measurement ports of AAN(s) shall be terminated with the corresponding load.

B.4.1 Symmetric communication lines

An asymmetric artificial network (AAN) to be connected between component (e.g. charger) or vehicle and charging station or any associated equipment (AE) used to simulate communication is defined in CISPR 16-1-2, Annex E, E.2 (T network circuit) (see example in Figure B.7).

The AAN has a common mode impedance of 150 Ω. The impedance Z_{cat} adjusts the symmetry of the cabling and attached periphery typically expressed as longitudinal conversion loss (LCL). The value of LCL should be predetermined by measurements or be defined by the manufacturer of the charging station/charging cable. The selected value for LCL and its origin shall be stated in the test report.

NOTE For some communications networks (e.g. CAN), this AAN cannot be used on these lines.



Key

1	balance pair	R	200 Ω
2	AAN metal case	AE	associated equipment
C	4,7 µF	DUT	device under test
L_1	2 x 38 mH	R_x	receiver input
L_2	2 x 38 mH	Z_{cat}	the unbalance network required to adjust the LCL (longitudinal conversion loss) of the AAN

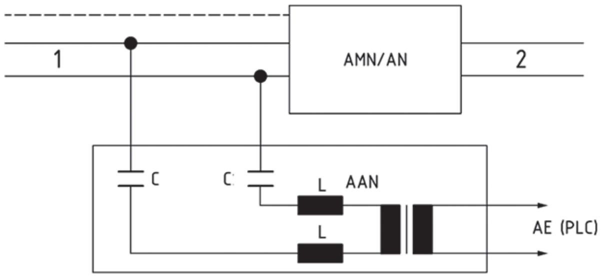
Figure B.7 — Example of an AAN for symmetric communication lines

B.4.2 PLC on power lines

If an original charging station can be used for the test, it might not be necessary to add any AAN for PLC communication.

If PLC communication cannot be ensured with original charging station and AMN, or shall be simulated with use of an associated equipment (AE) (e.g. as a PLC modem) instead of an original charging station, it is necessary to add an AAN for PLC communication between PLC modem and the AMN (component side) as defined in Figure B.8.

NOTE This AAN is intended to ensure adequate decoupling between PLC modem and power mains.



Key

1 DUT

2 mains/power supply

C 4,7 nF

L depends of the PLC modem (should be defined in the test plan); typical value of 100 μH

Figure B.8 — Example of AAN circuit of PLC on a.c. or d.c. powerlines

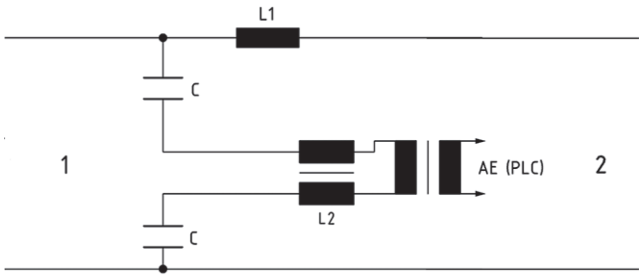
B.4.3 PLC (technology) on control pilot

Some communication systems use the control pilot line with a superimposed (high frequency) communication. Typically, the technology developed for powerline communication (PLC) is used for that purpose. On one hand, the communication lines are operated unsymmetrically, on the other hand, two different communication systems operate on the same line. Therefore, a special AAN shall be used as defined in Figure B.9.

It provides a common mode impedance of 150 Ω ± 20 Ω (150 kHz to 30 MHz) on the control pilot line (assuming a design impedance of the modem of 100 Ω). Both types of communications (control pilot, PLC) are separated by the network. Therefore, typically, a communication simulation is used in combination with this network.

The values of inductance and capacitance in the networks added for PLC on control pilot shown in Figure B.9 shall not induce any malfunction of communication between component (e.g. charger) and AE or charging station. It could therefore be necessary to adapt these values to ensure proper communication.

NOTE This AAN is intended to ensure a controlled impedance of the pilot line (and PLC) seen from the component side.



Key

1 DUT

2 mains/power supply

C 2,2 nF

L1 100 µH

L2 depends on the PLC modem (should be defined in the test plan); typical value of 100 µH

Figure B.9 — Example of AAN circuit for PLC on pilot line

Annex C
(informative)

Constant peak test level

C.1 General

This Annex explains the principle of constant peak test level and its implications for power levels.

C.2 Unmodulated signal

The electric field strength of an unmodulated sine wave signal E_{CW} can be written as Formula (C.1):

$$E_{CW} = E\cos(\omega t) \quad \text{(C.1)}$$

where

E is the peak value of E_{CW};

ω is the angular frequency of the unmodulated signal (CW) (e.g. RF carrier);

t is the time.

The mean power for the unmodulated signal, P_{CW}, is calculated using Formula (C.2)

$$P_{CW} = kE^2 \quad \text{(C.2)}$$

where k is a proportionality factor which is constant for a specific test set-up.

C.3 Modulated signal

The electric field strength energy of an amplitude-modulated signal E_{AM} can be written as Formula (C.3):

$$E_{AM} = E'(1+m)\cos(\theta t)\cos(\omega t) \quad \text{(C.3)}$$

where

E' is the peak amplitude of the unmodulated signal;

$E'(1 + m) = E_{AMpeak}$ is the peak value of the modulated signal E_{AM};

m is the modulation index ($0 \le m \le 1$);

θ is the angular frequency of modulating signal (i.e. voice, baseband, 1 kHz sine wave);

ω is the angular frequency of the unmodulated signal (CW) (e.g. RF carrier).

The total mean power for the amplitude-modulated signal (P_{AM}) is the sum of the power in the carrier component, $k\,E'^2$, and the total power in the sidebands component $\frac{k}{2}E'^2 m^2$.

The mean power for the amplitude-modulated signal P_{AM} is calculated using Formula (C.4)

$$P_{AM} = k\left(1+\frac{m^2}{2}\right)E'^2 \tag{C.4}$$

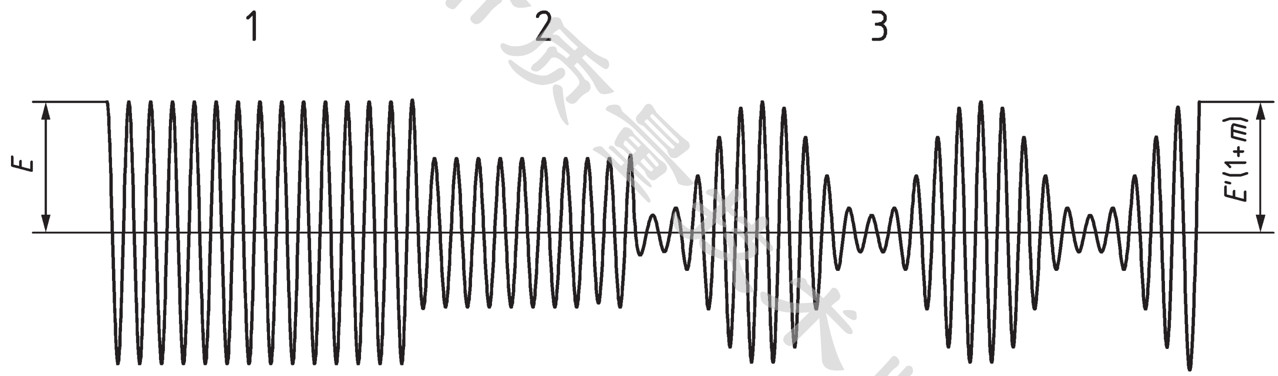
C.4 Peak conservation

C.4.1 General

For peak test level conservation, the peak amplitudes of the unmodulated and amplitude-modulated signals are defined to be identical as shown in Formula (C.5):

$$E_{CWpeak} = E_{AMpeak} \tag{C.5}$$

See Figure C.1.



Key

1 CW signal

2 reduced CW signal before applying modulation (see C.4.3)

3 AM signal

Figure C.1 — Peak conservation

There are two ways to adjust the signal to maintain peak conservation: by measuring the modulated power or by measuring the unmodulated power prior to modulation (see C.4.2 and C.4.3).

C.4.2 Measurement of modulated power

The relation between the mean power for the unmodulated signal, P_{CW}, and the mean power for the amplitude-modulated signal, P_{AM}, gives Formula (C.6):

$$\frac{P_{AM}}{P_{CW}} = \frac{k\left(1+m^2/2\right)E'^2}{kE^2} = \left(1+\frac{m^2}{2}\right)\left(\frac{E'}{E}\right)^2 = \frac{1+m^2/2}{(1+m)^2} \tag{C.6}$$

Therefore:

$$P_{AM} = P_{CW}\frac{2+m^2}{2(1+m)^2} \tag{C.7}$$

For m = 0,8 (AM 1 kHz 80 %), this relation gives Formula (C.8):

$$P_{AM} = 0{,}407 P_{CW} \tag{C.8}$$

C.4.3 Measurement of unmodulated power prior to applying modulation

The relation between the mean power for the unmodulated signal, P_{CW}, and the mean power for the non-amplitude-modulated signal before applying modulation, $P_{CW\ pm}$, gives Formula (C.10):

$$\frac{P_{CWpm}}{P_{CW}} = \left(\frac{1}{1+m}\right)^2 \tag{C.9}$$

Therefore:

$$P_{CWpm} = P_{CW}\left(\frac{1}{1+m}\right)^2 \tag{C.10}$$

For m = 0,8 (AM 1 kHz 80 %), this relation gives Formula (C.11)

$$P_{CWpm} = 0{,}309 P_{CW} \tag{C.11}$$

Annex D
(informative)

Example of load simulator design

D.1 General

This Annex is guidance for designing an easily made and low-cost load simulator. The intent is to propose a load simulator based on the use of a PCB and management of specific areas, so that this load simulator acts as a controlled “EMC DUT interface” in the test set-up.

D.2 Principle

For most DUTs, it is possible to use a simple PCB as a load simulator, with the following characteristics:

— double layers PCB with large ground plane on bottom side. A size of 350 mm × 210 mm is generally enough to achieve a sufficient value of the common mode capacitor of the ground plane;

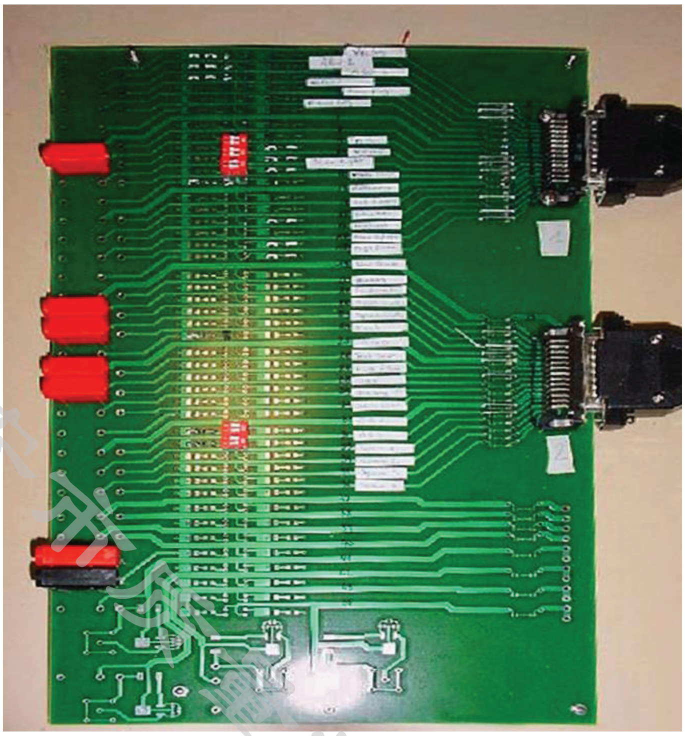
— a first area on the load simulator I/O to the DUT with discrete components (e.g. capacitor, PI-filter, etc.) may be placed in order to create, in combination with the load simulator ground plane, control common mode impedance. These impedances should be as close as possible to the ones of the real load. When real load impedance values are unknown, default values for some of these components may be chosen as defined in Table D.1;

— a second area in which, if necessary, some functional components (e.g. potentiometer, switches, etc.) may be added, in order to simulate simple functions like “sensors,” etc.

— a third area, on the other side of the board, with some standard connectors which may be used for connecting power supply, optical modules, real loads when needed, or any other required connection.

An example of such a “load simulator” is presented in Figure D.1.

NOTE An example of load simulator characteristics is represented in Table D.2.



Key

1 area 1 with discrete components (representative of real loads) and connectors to DUT harness

2 area 2 with “functional components” (potentiometer, switches, resistor, LEDs, etc.)

3 area 3 with “standard” connectors for power supply, real loads, optical modules, etc.

Figure D.1 — Example of PCB load simulator

Table D.1 — Recommended default value for discrete components (first area)

Connector pin n°	DUT function	Signal type	DUT side fixed impedance
-	**General digital output/input**	Output/input going to another DUT (with capacitive ESD protection)	1 nF to simulator ground
-	–	Output power (with real load used)	10 pF to simulator ground
-	**Power**	POWER supply	100 nF to simulator ground
-	–	Video input	10 pF to simulator ground
-	**Microphone**	Microphone input	100 nF to simulator ground
-	**CAN bus**	CAN signals	10 pF to simulator ground
-	**Speedometer**	Digital Input	10 pF to simulator ground

Table D.2 — Example of load simulator characteristics

Connector pin n°	Cluster function	Signal type	Functional components	Fixed impedance
1	Turn Signal Right	Input	SMD Switch to ground	10 pF to ground
2	Turn Signal Left	Input	SMD Switch to Power supply	10 pF to ground

Table D.2 *(continued)*

Connector pin n°	Cluster function	Signal type	Functional components	Fixed impedance
3			Nothing, and no wire on the harness	-
4	Ground		Connected to ground test bench	0 Ω to ground
5	Power supply		Connected to test bench Power supply	100 nF to ground
6	Speedometer	Digital input	SMD Switch to ground (mode3) and connected to an output of the test bench in order to connect a PWM via an optical module (external to test bench)	10 pF to ground
7	Ignition (+IGN)		SMD Switch to Power supply + connected to an output of the test bench in order switch to Power supply via an optical module (external to test bench)	10 nF to ground
8	Illumination		Switch in serial with a resistance fixed at 9 Ohms	
9	Temperature Gage	Sensor	SMD Switch to ground (mode3) and connected to an output of the test bench in order to connect a PWM via an optical module (external to test bench)	10 pF to ground
10	Service Vehicle Soon		SMD Switch to ground	10 pF to ground
11	Malfunction Indicator Light		Switch to ground or high impedance	10 pF to ground
12	RESERVED		Nothing, and no wire on the harness	-
13	Battery Charge		SMD Switch to ground	10 pF to ground
14	Oil Pressure	Input	SMD Switch to ground	10 pF to ground

Bibliography

[1] IEC 60050-161, *International electrotechnical vocabulary — Electromagnetic compatibility*

[2] IEC 60050-726, *International electrotechnical vocabulary — Transmission lines and waveguides*

ICS 43.040.10; 33.100.20

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