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

Part 4:
Bulk current injection (BCI)

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

Partie 4: Méthodes d'injection de courant (BCI)

Reference number
ISO 11452-4:2005(E)

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Contents

Foreword

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

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11452-4 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This third edition cancels and replaces the second edition (ISO 11452-4:2001), which has been technically revised.

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: Bulk current injection (BCI)*
- *Part 5: Stripline*
- *Part 7: Direct radio frequency (RF) power injection*

The radiating loop method is to form the subject of a future part 8.

Introduction

Immunity measurements of complete road vehicles are generally able to be carried out only by the vehicle manufacturer, owing to, for example, high costs of absorber-lined shielded enclosures, the desire to preserve the secrecy of prototypes or a large number of different vehicle models.

For research, development and quality control, a laboratory measuring method can be used by both vehicle manufacturers and equipment suppliers to test electronic components.

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

Part 4:
Bulk current injection (BCI)

1 Scope

This part of ISO 11452 specifies bulk current injection (BCI) test methods for determining the immunity of electronic components of passenger cars and commercial vehicles regardless of the propulsion system (e.g. spark-ignition engine, diesel engine, electric motor). The electromagnetic disturbances considered in this part of ISO 11452 are limited to continuous narrowband electromagnetic fields. See ISO 11452-1 for general test conditions.

2 Normative references

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11452-1 apply.

4 Test conditions

The frequency range of the BCI test method is a direct function of the current probe characteristic. More than one type of current probe may be required.

For testing automotive electronic systems, the applicable frequency range of the BCI test method is 1 MHz to 400 MHz.

The user shall specify the test severity level(s) over the frequency range. Suggested test levels are included in Annex E.

Standard test conditions shall be according to ISO 11452-1 for the following:

- test temperature;
- supply voltage;

- modulation;
- dwell time;
- frequency step sizes;
- definition of test severity levels;
- test signal quality.

5 Test location

The tests shall be performed in a shielded enclosure.

6 Test apparatus and instrumentation

6.1 General

Bulk current injection (BCI) is a method of carrying out immunity tests by inducing disturbance signals directly into the wiring harness by means of a current injection probe. The injection probe is a current transformer through which the wiring harnesses of the device under test (DUT) are passed. Immunity tests are carried out by varying the test severity level and frequency of the induced disturbance.

6.2 Measuring equipment

6.2.1 Current injection probe or set of probes, capable of operating over the entire test frequency range, required to couple the test equipment to the DUT. The probe(s) shall be capable of withstanding a continuous input power over the test frequency range regardless of the system loading.

6.2.2 Current measurement probe or set of probes, capable of operating over the entire test frequency range.

6.2.3 Artificial network(s) (AN): see 7.2 and Annex C.

6.2.4 RF generator, with internal (or external) modulation capabilities.

6.2.5 Power amplifier

6.2.6 Powermeter (or equivalent measuring instrument), for measuring forward power and reflected power.

6.2.7 Current measuring equipment

6.3 Stimulation and monitoring of DUT

The DUT shall be operated as required in the test plan by actuators that have a minimum effect on the electromagnetic characteristics, e.g. plastic blocks on the push-buttons, pneumatic actuators with plastic tubes.

Connections to equipment monitoring electromagnetic interference reactions of the DUT may be accomplished by using fibre-optics, or high-resistance leads. Other types of lead may be used but require extreme care to minimize interactions. The orientation, length and location of such leads shall be carefully documented to ensure repeatability of test results.

Any electrical connection of monitoring equipment to the DUT may cause malfunctions of the DUT. Extreme care shall be taken to avoid such an effect.

7 Test set-up

7.1 Ground plane

The ground plane shall be made of 0,5 mm thick (minimum) copper, brass or galvanized steel.

The minimum width of the ground plane shall be 1 000 mm. The minimum length of the ground plane shall be 1 500 mm, or the length of the entire underneath of the equipment plus 200 mm, whichever is the larger.

The height of the ground plane (test bench) shall be (900 ± 100) mm above the floor.

The ground plane shall be bonded to the shielded enclosure such that the d.c. resistance shall not exceed 2,5 mΩ. In addition, the bond straps shall be placed at a distance no greater than 0,3 m apart.

7.2 Power supply and AN

Each DUT power supply lead shall be connected to the power supply through an AN.

Power supply is assumed to be negative ground. If the DUT utilizes a positive ground then the test set-ups shown in the figures need to be adapted accordingly. Power shall be applied to the DUT via a 5 µH/50 Ω AN (see Annex C for the schematic). The number of ANs required depends on the intended DUT installation in the vehicle.

- For a remotely grounded DUT (vehicle power return line longer than 200 mm), two ANs are required: one for the positive supply line and one for the power return line (see Annex D).
- For a locally grounded DUT (vehicle power return line 200 mm or shorter): one AN is required for the positive supply (see Annex D).

The AN(s) shall be mounted directly on the ground plane. The case or cases of the AN(s) shall be bonded to the ground plane.

The power supply return shall be connected to the ground plane — between the power supply and the AN(s).

The measuring port of each AN shall be terminated with a 50 Ω load.

7.3 Location of DUT

The DUT shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leqslant 1,4$), at (50 ± 5) mm above the ground plane.

The case of the DUT shall not be grounded to the ground plane unless it is intended to simulate the actual vehicle configuration.

The face of the DUT shall be located at least 100 mm from the edge of the ground plane.

There should be a distance at least 500 mm between the DUT and any metal part such as the walls of the shielded enclosure, with the exception of the ground plane on which the DUT is placed.

7.4 Location of test harness

The total length of the test harness between the DUT and the load simulator (or the RF boundary) shall be (1 000 ± 100) mm, unless otherwise specified in the test plan.

The wiring type is defined by the actual system application and requirement.

The test harness should be straight over its whole length and of fixed (position and number of wires) composition. It should pass through the current injection and current measurement probes. The length of the wires in the simulator should be short by comparison with the length of the harness. The wires within the simulator should be anchored.

The test harness shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leqslant 1{,}4$), at (50 ± 5) mm above the ground plane.

7.5 Location of load simulator

Preferably, the load simulator shall be placed directly on the ground plane. If the load simulator has a metallic case, this case shall be bonded to the ground plane.

Alternatively, the load simulator may be located adjacent to the ground plane (with the case of the load simulator bonded to the ground plane) or outside of the test chamber, provided the test harness from the DUT passes through an RF boundary bonded to the ground plane.

When the load simulator is located on the ground plane, the d.c. power supply lines of the load simulator shall be connected through the AN(s).

7.6 Location of current probe(s)

7.6.1 Substitution method

The injection probe shall be placed at the following distances, d, from the connector of the DUT:

- d = (150 ± 10) mm;
- d = (450 ± 10) mm;
- d = (750 ± 10) mm.

If a current measurement probe is used during the test it shall be placed at (50 ± 10) mm from the connector of the DUT.

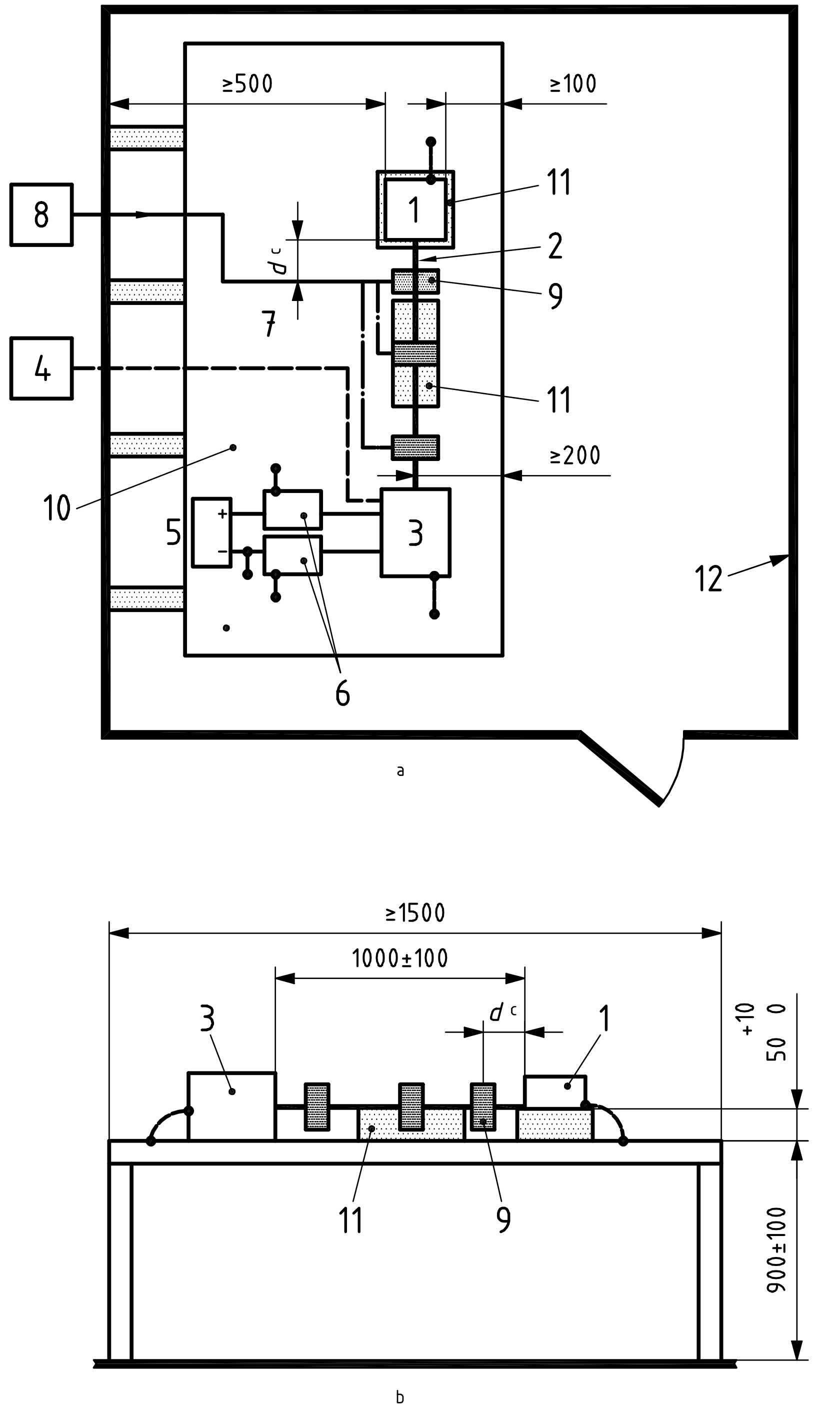
7.6.2 Closed-loop method with power limitation

The injection probe shall be placed at (900 ± 10) mm from the connector of the DUT.

The current measurement probe shall be placed at (50 ± 10) mm from the connector of the DUT.

Examples of test configurations are shown in Figure 1 for the substitution method (8.3.1) and Figure 2 for the closed-loop method with power limitation (8.3.2).

Dimensions in millimetres



Key

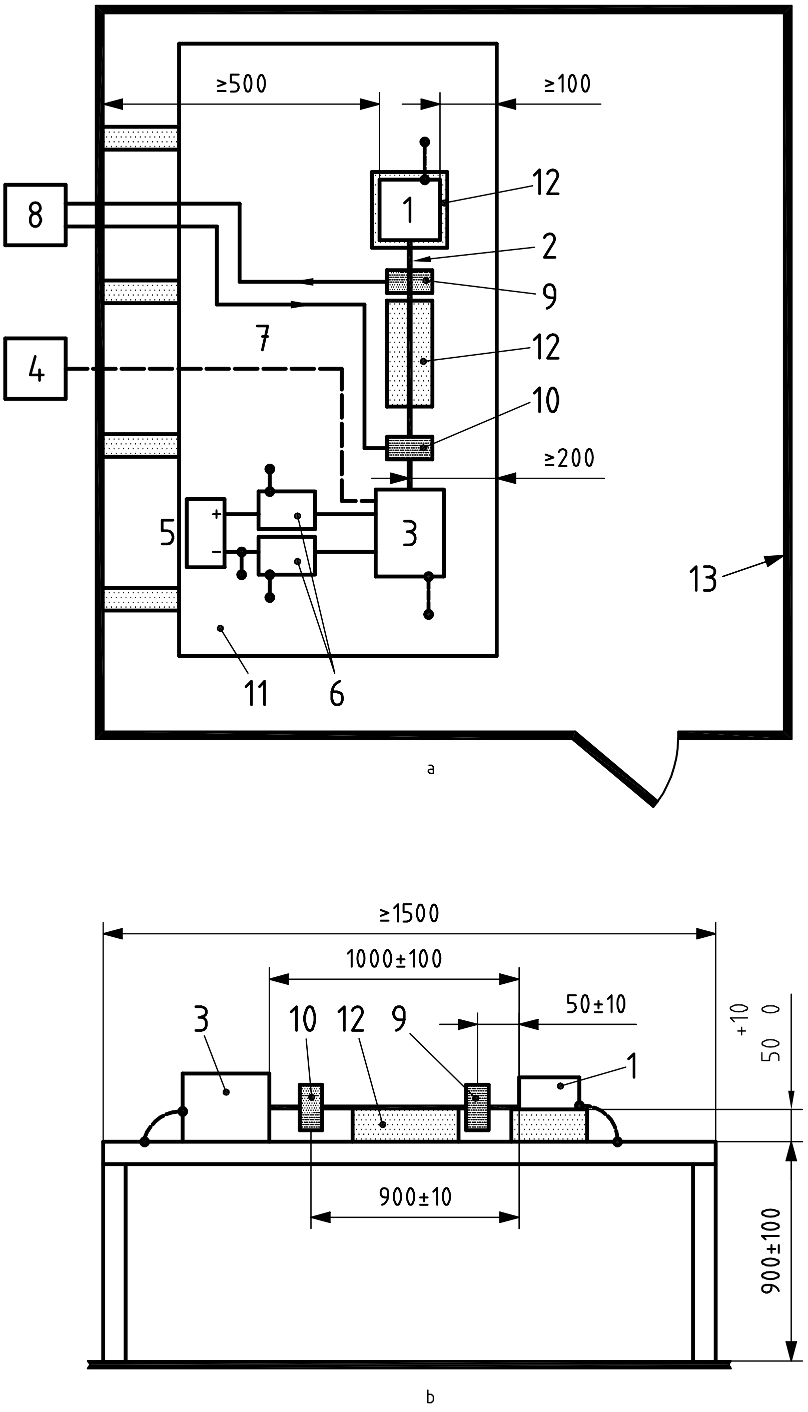
1	DUT (grounded if required in test plan)
2	test harness
3	load simulator (placement and ground: connection according to 7.5)
4	stimulation and monitoring system
5	power supply
6	artificial network (AN)
7	optical fibres
8	high-frequency equipment
9	injection probe
10	ground plane (bonded to shielded enclosure)
11	low relative permittivity support ($\varepsilon_r \leqslant 1,4$)
12	Shielded enclosure

NOTE The current measurement probe, optional-for this test, is not represented. See 8.3.1.3.

[a] Upper view. [b] Side view. [c] See 7.6.1.

Figure 1 — BCI test set-up — Substitution method

Dimensions in millimetres



Key

1 DUT (grounded if required in test plan)

2 test harness

3 load simulator (placement and ground: connection according to 7.5)

4 stimulation and monitoring system

5 power supply

6 artificial network (AN)

7 optical fibres

8 high-frequency equipment

9 current measurement probe

10 injection probe

11 ground plane (bonded to shielded enclosure)

12 low relative permittivity support ($\varepsilon_r \leqslant 1{,}4$)

13 Shielded enclosure

[a] Upper view.

[b] Side view.

Figure 2 — BCI configuration — Closed-loop method with power limitation

8 Test methods

8.1 General

The general arrangement of the disturbance source and connecting harnesses, etc. represents a standardized test condition. Any deviations from the standard test harness length, etc shall be agreed upon prior to testing and recorded in the test report.

The DUT shall be made to operate under typical loading and other conditions as in the vehicle. These operating conditions shall be clearly defined in the test plan to ensure that the supplier and customer are performing identical tests.

8.2 Test plan

Prior to performing the tests, a test plan shall be generated which shall include

- test set-up,
- test method,
- frequency range,
- DUT mode of operation,
- DUT acceptance criteria,
- test severity levels,
- DUT monitoring conditions,
- probe location,
- injection conditions for wiring with multiple connectors, and
- test report content,

as well as any special instructions and changes from the standard tests.

Every DUT shall be tested under the most significant conditions, i.e. at least in stand-by mode and in a mode where all the actuators can be excited.

8.3 Test procedure

CAUTION — Hazardous voltages and fields may exist within the test area. Care shall be taken to ensure that the requirements for limiting the exposure of humans to RF energy are met.

8.3.1 Substitution method

8.3.1.1 General

The substitution method is based upon the use of forward power as the reference parameter for calibration and testing.

The method is carried out in two phases:

a) calibration (on jig);

b) test of the DUT.

8.3.1.2 Calibration

The specific test level (current) shall be calibrated periodically by recording the forward power required to produce a specific current measured on a 50 Ω calibration jig (see Annex A) for each test frequency. This calibration shall be performed with an unmodulated sinusoidal wave.

Include, upon request, the values of forward and reverse power recorded in the calibration file in the test report.

The calibration jig should be terminated by a 50 Ω (high-power) load at one end and by a 50 Ω RF power meter at the other end, protected by a 50 Ω attenuator of adequate power rating (see Annex A).

8.3.1.3 DUT test

Install the DUT, harness and associated equipment on the test bench as shown in Figure 1.

Subject the DUT to the test signal based on the calibrated value as predetermined in the test plan.

A current measurement probe may be mounted between the current injection probe and the DUT. The use of a current measurement probe is optional; it can provide extra, useful information during investigative work on the cause of events and the variances in test conditions after system modifications. However, care should be taken, because the monitoring probe may affect the injected current.

8.3.2 Closed loop method with power limitation

8.3.2.1 General

The test method is based upon the use of the forward power as the reference parameter used for calibration and testing.

The method is carried out in two phases:

a) calibration (on jig);

b) test of the DUT.

The power limit is determined using a calibration jig.

The disturbance (I_{disturb}) applied to the DUT is determined using a limit curve versus frequency.

8.3.2.2 Calibration

This procedure determines the power limit applicable for the test with DUT.

The specific test level (current) shall be calibrated prior to the actual testing (see Annex A).

Prior to the actual test with DUT, the forward power required to produce a specific current measured on a 50 Ω calibration jig (see Annex A) shall be determined for each frequency.

This calibration shall be performed with an unmodulated sinusoidal wave.

Include, upon request, the values of forward and reverse power recorded in the calibration file in the test report.

The calibration jig should be terminated by a 50 Ω (high-power) load at one end and by a 50 Ω RF power meter at the other end, protected by a 50 Ω attenuator of adequate power rating (see Annex A).

Apply the current test signal level to the jig and record the corresponding forward power ($P_{\text{for cal}}$).

The power limit is calculated from:

$$P_{\text{CW limit}} = kP_{\text{for cal}}$$

where

$P_{\text{CW limit}}$ is the power limit;

$P_{\text{for cal}}$ is the forward power applied to reach the current test signal level in the jig.

The default value for k is 4, unless otherwise specified in the test plan.

8.3.2.3 DUT Test

Install the DUT, harness and associated equipment on the test bench as shown in Figure 2.

The test procedure uses a closed loop method with power limit (P_{limit}).

The procedure used at each frequency is described below.

Increase the forward power applied to the current injection probe and measure the injected current (I_{ref}) until either

— the measured current reaches the specified test level, or

— the forward power reaches the power limit $P_{\text{CW limit.}}$

In either case, record the achieved current (I_{ref}) and the applied forward power (P_{ref}).

When the DUT susceptibility threshold is found, the fault current (I_{fault}) and the forward power applied (P_{fault}) shall also be recorded.

When a harness containing several branches is used, repeat the test with the injection probe clamped around each branch, (900 ± 10) mm from the connector of the DUT. Under these test conditions, the current measurement probe, shall be left at its previous distance from the DUT.

8.4 Test report

As required in the test plan, a test report shall be submitted detailing information regarding the test equipment, test area, systems tested, frequencies, power levels, system interactions and any other relevant information regarding the test.

For the closed loop method with power limitation, the following additional information shall be included in the test report.

— The values I_{ref}, P_{ref}, I_{fault}, P_{fault}, and $P_{\text{CW limit}}$

— The test bench transfer impedance (the voltage injected at the plane of the current injection probe divided by the current measured by the current measurement probe). A precise description of test bench transfer impedance measurement or calculation methods is given in Annex B.

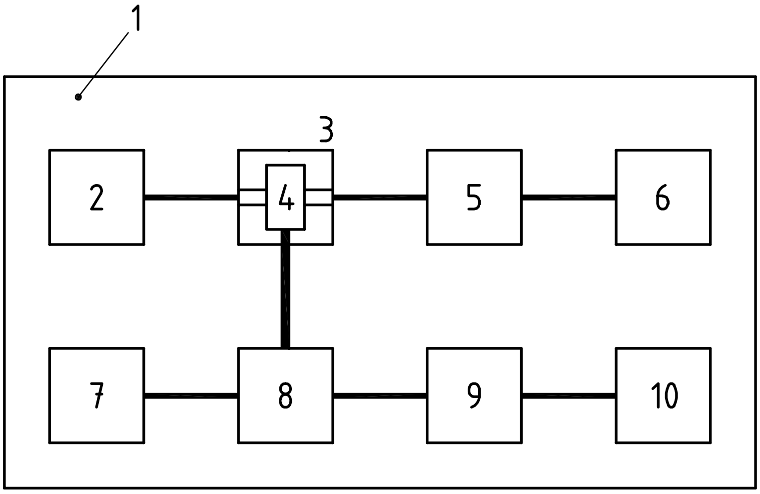
Annex A

(normative)

Calibration configuration (current injection probe calibration)

A calibration fixture is used to determine the injected current. Figure A.1 shows an example of a test equipment configuration for the current-injection probe calibration.

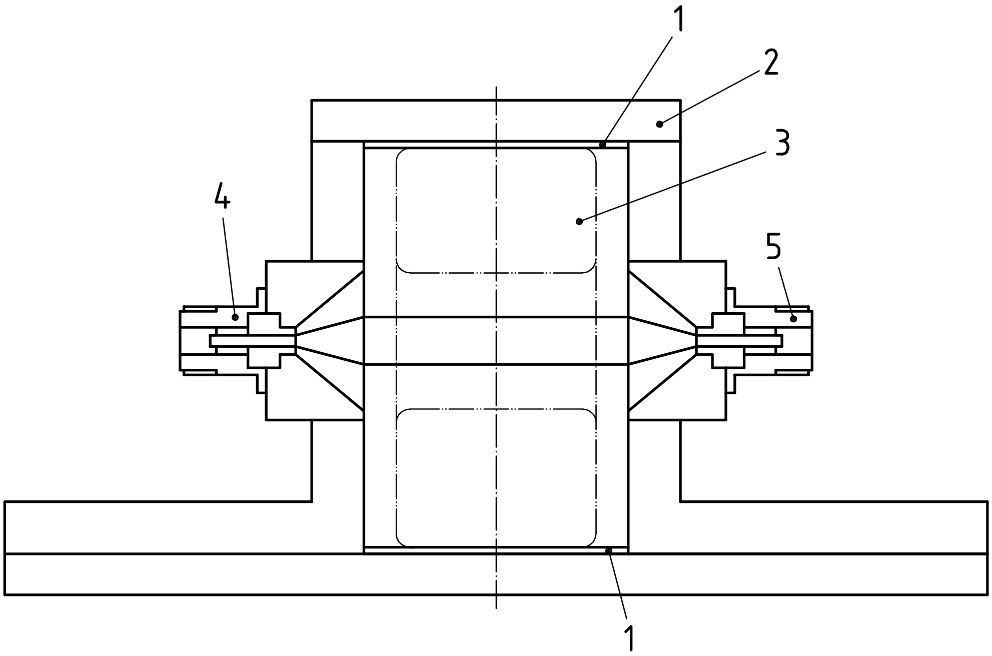
Mount the injection probe centred in the calibration fixture (see Figure A.2) and, while sweeping the test frequency range, measure the forward power required to achieve the current at which testing is to be conducted.



Key

1 shielded enclosure
2 50 Ω coaxial load, VSWR 1,2:1 max
3 calibration fixture
4 injection probe
5 50 Ω attenuator
6 spectrum analyser or equivalent
7 RF power level measuring device (two are required)
8 RF 50 Ω dual directional coupler (with 30 dB minimum decoupling coefficient)
9 broadband amplifier with 50 Ω output impedance
10 RF signal generator

Figure A.1 — Block diagram of calibration configuration



Key

1 insulation
2 removable metal cover
3 current injection probe
4 direct connection to 50 Ω measurement equipment
5 direct connection to 50 Ω load

NOTE The physical size of the calibration fixture shall be in accordance with the probe manufacturer's requirements.

Figure A.2 — Example of calibration fixture (jig)

Annex B
(normative)

Test set-up transfer impedance

B.1 General

The test set-up transfer impedance, Z_t, is defined as:

$$Z_t = \frac{U_{ind}}{I_{ind}} \qquad (B.1)$$

where

U_{ind} is the common-mode voltage induced in the wiring harness by the current injection probe;

I_{ind} is the common-mode current induced at the measurement point.

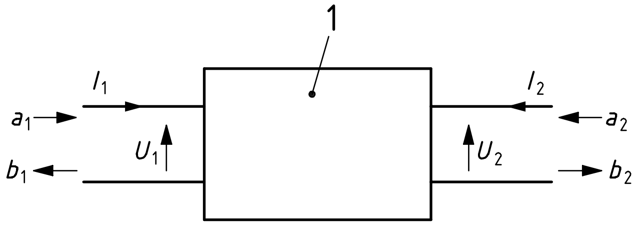
It is used to characterize the system comprising the wiring harness, the DUT and the loads, independent of the injection and current measurement probes, in order to make it easier to compare tests carried out in different laboratories or using different test wiring harnesses.

It can be measured using a network analyser as described in B.2 or deduced from the direct power and current measurements during calibration and testing as described in B.3.

B.2 Measuring transfer impedance using a network analyser

B.2.1 Defining the parameter relationships

See Figure B.1.



Key

1 S parameter quadripole

Figure B.1 — Measuring transfer impedance using network analyser

For a four-terminal network with given S parameters, the incident and reflected waves can be defined as follows.

- For port 1 of the network analyser:

$$a_1 = \frac{U_1 + Z_c I_1}{2\sqrt{Z_c}} \tag{B.2}$$

$$b_1 = \frac{U_1 - Z_c I_1}{2\sqrt{Z_c}} \tag{B.3}$$

where

a_1 is the incident wave;

b_1 is the reflected wave;

U_1 is the common-mode voltage induced in the wiring harness by the current injection probe;

I_1 is the common-mode current induced at the measurement point;

Z_c is the characteristic impedance (here, $Z_c = 50\ \Omega$).

- For port 2 of the network analyser:

$$a_2 = \frac{U_2 + Z_c I_2}{2\sqrt{Z_c}} \tag{B.4}$$

$$b_2 = \frac{U_2 - Z_c I_2}{2\sqrt{Z_c}} \tag{B.5}$$

where

a_2 is the incident wave;

b_2 is the reflected wave;

U_2 is the common-mode voltage induced in the wiring harness by the current injection probe;

I_2 is the common-mode current induced at the measurement point;

Z_c is the characteristic impedance (here, $Z_c = 50\ \Omega$).

In physical terms, the incident and reflected waves carry the input and output power to and from the four-terminal network.

The relationship between the incident and reflected waves is given by the S parameters:

$$b_1 = S_{11}\, a_1 + S_{12}\, a_2 \text{ and } b_2 = S_{21}\, a_1 + S_{22}\, a_2 \tag{B.6}$$

When the output of the network is loaded with 50 Ω:

$$a_2 = 0\text{, therefore, } b_1 = S_{11}\, a_1 \text{ and } b_2 = S_{21}\, a_1 \tag{B.7}$$

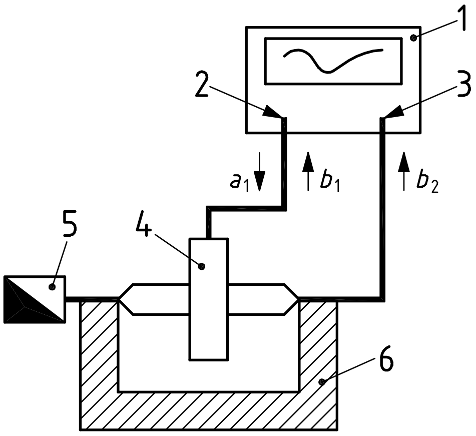
where

S_{11} is the coefficient of reflection;

S_{21} is the coefficient of transmission of the four terminal network.

B.2.2 Calibrating the current injection probe

See Figure B.2.



Key

1 network analyser
2 port 1
3 port 2
4 current injection probe
5 50 Ω load
6 calibration jig

Figure B.2 — Calibrating the current injection probe

By definition, the insertion loss, IL, of the current injection probe is given by the formula:

$$IL^2 = \frac{b_2^2}{a_1^2} = S_{21,\,\text{inject}}^2 \tag{B.8}$$

where

IL^2	is the power insertion loss of the current injection probe;
b_2^2	is the power induced on the calibration jig port;
a_1^2	is the power applied to the current injection probe;
$S_{21,\text{inject}}^2$	is the power transmission coefficient of the current injection probe.

i.e.

$$IL \quad (\text{dB}) = S_{21,\,\text{inject}} \quad (\text{dB}) \tag{B.9}$$

The current injection probe induces the voltage U_{ind} on the calibration jig, i.e. $U_{\text{ind}}/2$ on each of the 50 Ω loads on the jig, therefore:

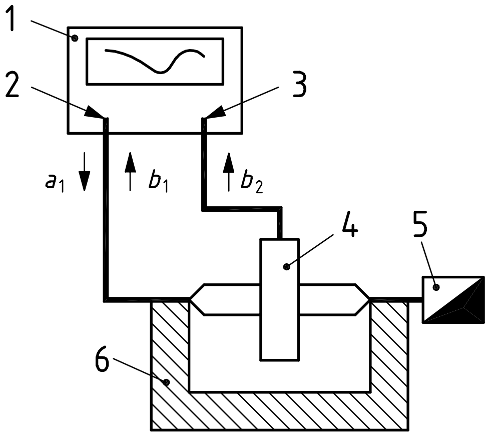
$$b_2^2 = \frac{1}{50}\left(\frac{U_{\text{ind}}}{2}\right)^2 \tag{B.10}$$

From Equations (B.8) and (B.10):

$$\frac{U_{\text{ind}}}{a_1} = 2\sqrt{50}\ IL \qquad \text{(B.11)}$$

B.2.3 Calibrating the current measurement probe

See Figure B.3.



Key

1 network analyser
2 port 1
3 port 2
4 current injection probe
5 50 Ω load
6 calibration jig

Figure B.3 — Calibrating the current measurement probe

The current measurement probe is characterized by its transfer impedance, Z_{t}, given by the following formula:

$$Z_{\text{t, probe}} = \frac{U_{\text{rtnd}}}{I_{\text{ind}}} \qquad \text{(B.12)}$$

where

U_{rtnd} is the voltage returned by the current measurement probe loaded by 50 Ω;

I_{ind} is the current to be measured.

$$b_2^2 = \frac{U_{\text{rtnd}}^2}{50} \qquad \text{(B.13)}$$

and

$$a_1^2 = 50\ I_{\text{ind}}^2 \qquad \text{(B.14)}$$

From Equations (B.12) and (B.13):

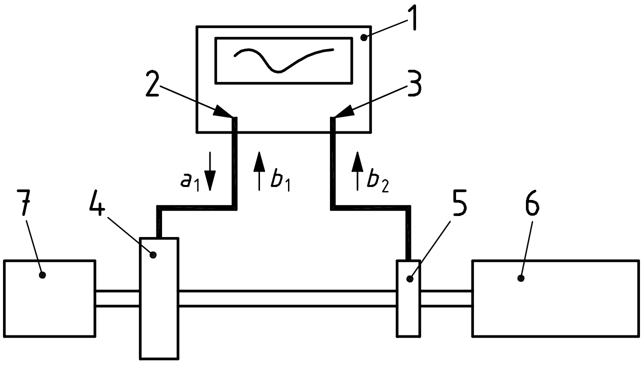
$$\frac{b_2}{I_{\text{ind}}} = \frac{Z_{\text{t, probe}}}{\sqrt{50}} \tag{B.15}$$

From Equations (B.14) and (B.15):

$$Z_{\text{t, probe}} = 50 \; \frac{b_2}{a_1} = 50 \;\; S_{21,\text{read}} \tag{B.16}$$

B.2.4 Measuring the transfer impedance

See Figure B.4.



Key

1 network analyser
2 port 1
3 port 2
4 current injection probe
5 current measurement probe
6 DUT
7 AN(s) under load

Figure B.4 — Measuring the transfer impedance

The transfer impedance, Z_t, is defined by the following formula:

$$Z_{\text{t}} = \frac{U_{\text{ind}}}{I_{\text{ind}}} = \frac{U_{\text{ind}}}{a_1} \times \frac{a_1}{b_2} \times \frac{b_2}{I_{\text{ind}}} \tag{B.17}$$

From Equations (B.11) and (B.16), the transfer impedance of the test bench can be calculated from the S_{21} parameter measurement for Figure B.4 and the characteristics of the probes as follows:

$$Z_{\text{t}} = \frac{2Z_{\text{t, probe}} \; IL}{S_{21}} \tag{B.18}$$

or

$$Z_{\text{t}} \; (\text{dB}_{\Omega}) = 6 \; + \; Z_{\text{t, probe}} \; (\text{dB}_{\Omega}) \; + \; IL \; (\text{dB}) \; - \; S_{21} \; (\text{dB}) \tag{B.19}$$

In Equation (B.19), IL (dB) is negative.

B.3 Calculating the transfer impedance

The transfer impedance, Z_t, can also be calculated from the measurements made during calibration and test, using the fact that the calibration jig transfer impedance is 100 Ω. By proportionality:

$$Z_{\mathrm{t}} = 100 \frac{I_{\mathrm{cal}}}{I_{\mathrm{ind}}} \sqrt{\frac{P_{\mathrm{dir}}}{P_{\mathrm{cal}}}} \tag{B.20}$$

where

I_{cal} is the calibration current;

I_{ind} is the current to be measured;

P_{cal} is the power applied to the current injection probe during calibration;

P_{dir} is the power applied to the calibration jig.

or

$$Z_{\mathrm{t}}\ (\mathrm{dB}_{\Omega}) = 40 + I_{\mathrm{cal}}\ (\mathrm{dB}_{\mathrm{mA}}) - I_{\mathrm{ind}}\ (\mathrm{dB}_{\mathrm{mA}}) + P_{\mathrm{dir}}\ (\mathrm{dB}_{\mathrm{m}}) - P_{\mathrm{cal}}\ (\mathrm{dB}_{\mathrm{m}}) \tag{B.21}$$

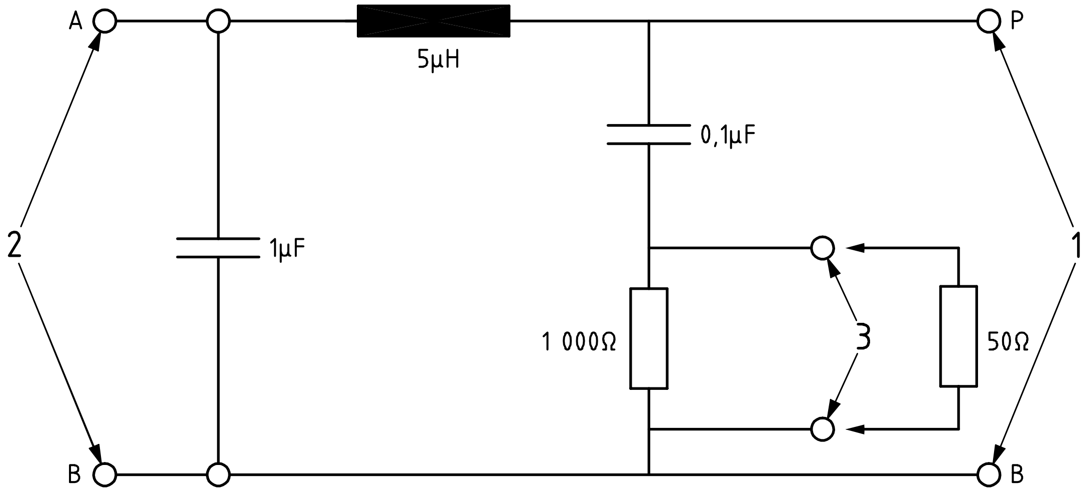
Annex C
(informative)

Artificial network (AN)

C.1 General

The AN is used as a reference standard in the laboratory in place of the impedance of the vehicle wiring harness in order to determine the behaviour of equipment and electrical and electronic devices. It shall be able to withstand a continuous load corresponding to the requirements of the DUT.

An example AN schematic is shown in Figure C.1 (see also C.2).



Key

1 port for the DUT

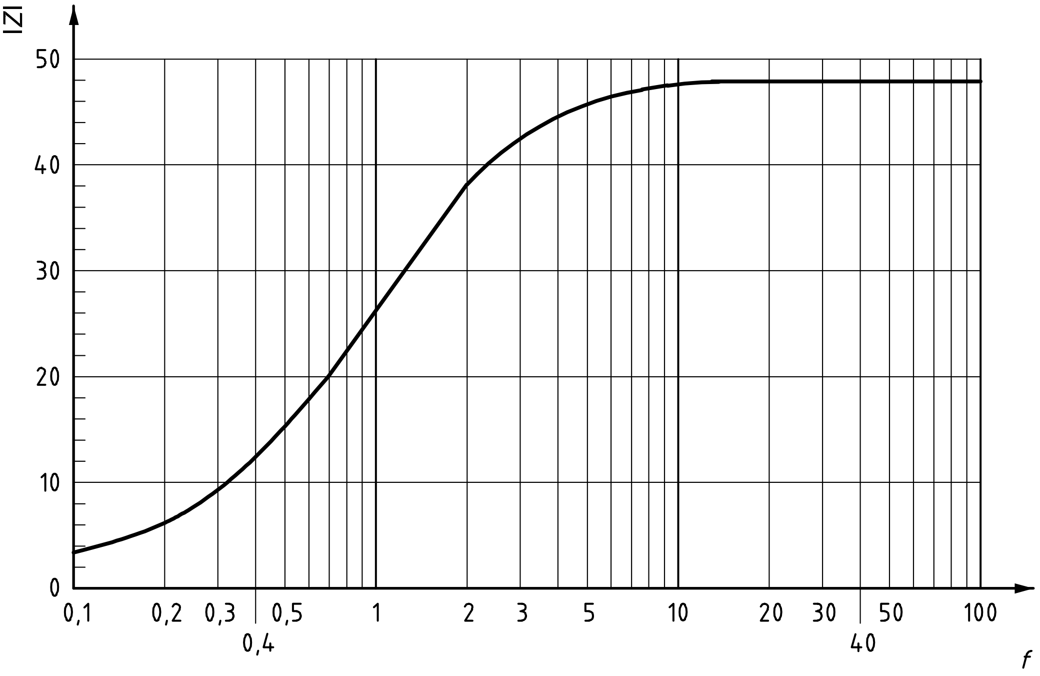
2 power supply port

3 measurement port

Figure C.1 — Example AN schematic

C.2 AN impedance

The AN impedance $|Z_{\mathrm{PB}}|$ in the measurement frequency range of 0,1 MHz to 100 MHz — assuming ideal electrical components — is shown in Figure C.2. In reality, a tolerance of ± 20 % is permitted. The impedance is measured between the terminals P and B (Item 1 of Figure C.1) with a 50 Ω load on the measurement port (Item 3 of Figure C.1) and with terminals A and B (Item 2 of Figure C.1) short-circuited.



Key

$|Z|$ impedance, Ω

f frequency, MHz

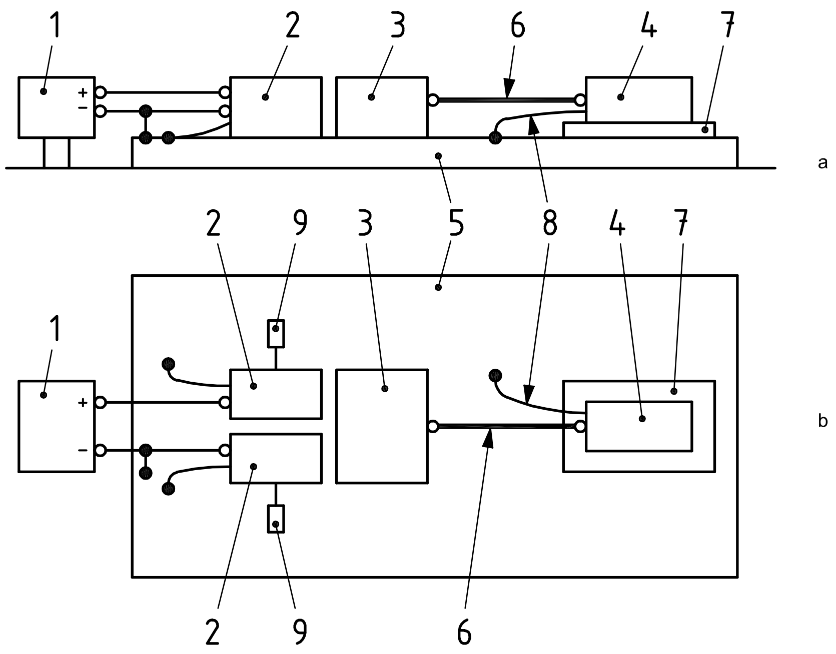
Figure C.2 — Characteristics of AN impedance $|Z_{\mathrm{PB}}|$ as function of frequency, f, 0,1 MHz to 100 MHz

Annex D
(informative)

Remote/local grounding

D.1 DUT remotely grounded

The principle for connecting a remotely grounded DUT is shown in Figure D.1.



Key

1	power supply
2	AN
3	simulator
4	DUT
5	ground plane
6	wiring harness (containing power supply and return line)
7	insulating support
8	housing of the DUT [c]
9	50 Ω load

[a] Side view.

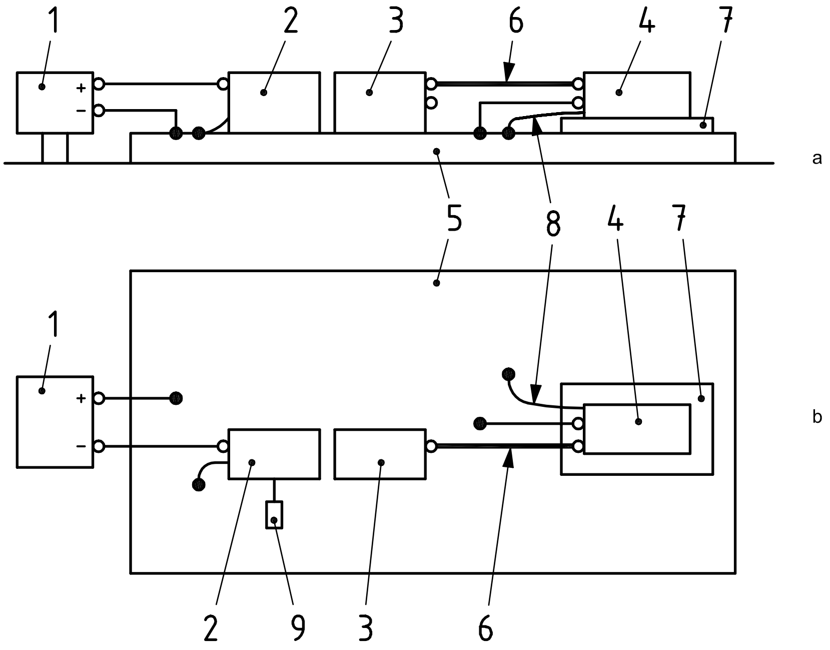
[b] Upper view.

[c] Not connected to the ground plane unless specified in the test plan (see 7.3).

Figure D.1 — DUT remotely grounded

D.2 DUT locally grounded

The principle for connecting a locally grounded DUT is shown in Figure D.2.



Key

1 power supply
2 AN
3 simulator
4 DUT
5 ground plane
6 wiring harness (not containing power return line)
7 insulating support
8 housing of the DUT [c]
9 50 Ω load
10 power return line (maximum length: 200 mm)

[a] Side view.
[b] Upper view.
[c] Not connected to the ground plane unless specified in the test plan (see 7.3).

Figure D.2 — DUT locally grounded

Annex E
(informative)

Function performance status classification (FPSC)

Suggested test severity levels and the frequency bands are given in Table E.1 and Table E.2, respectively.

NOTE See ISO 11452-1 for a detailed explanation of FPSC.

Table E.1 — Suggested test severity levels

Test severity level	Value mA
I	25
II	50
III	75
IV	100
V	Specific value agreed between the users of this part of ISO 11452, if necessary.

Table E.2 — Frequency bands

Frequency band	Frequency range MHz
F1	⩾ 1 to ⩽ 10
F2	> 10 to ⩽ 30
F3	> 30 to ⩽ 80
F4	> 80 to ⩽ 200
F5	> 200 to ⩽ 400

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